JOURNAL of the TRANSPORTATION RESEARCH FORUM

Volume 51, Number 1

Spring 2012

Transportation Research Forum
NDSU Dept. 2880
PO Box 6050
Fargo, ND 58108-6050
www.trforum.org

Journal of the Transportation Research Forum

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The Journal of the Transportation Research Forum (JTRF) is distributed to members of the Transportation Research Forum and subscribers.

Currently, the JTRF is published three times per year. Annual subscriptions are available to the general public for $150 and must be purchased for a calendar year.

An electronic version (PDF format) is available for $50 per Journal or single Journal articles for $10 each.

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ISSN 1046-1469

Published and Distributed by
Transportation Research Forum
NDSU Dept. 2880
P.O. Box 6050
Fargo, ND 58108-6050
P: (701) 231-7766 • F: (701) 231-1945

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Table of Contents

On the cover: In "Electrified Vehicle Technology Trends, Infrastructure Implications, and Cost Comparisons," David Tuttle and Kara Kockelman explore the market potential of electrified vehicles including the effect of fuel and battery replacement costs on the purchase price competitiveness of electrified vehicles compared to their gasoline powered counterparts. *(photo credit: Toyota.com)*

BOOK REVIEWS

A Message from the JTRF Co-General Editors

The Spring 2012 issue of *JTRF* contains the usual wide variety of contemporary transportation topics that is the distinguishing characteristic of JTRF. Topics in this issue include the following:

- Airline stock performance
- Electronic appraisal for right-of-way acquisition
- Electrified vehicle cost comparisons
- Private railcars in North America
- Impact on air travel due to decreased wealth
- Cross docking and freight distribution
- Rural road closure methodology

In "Baggage Fees and Airline Stock Performance: A Case of Initial Investor Misperception," Barone et al. use an event study methodology to examine the impact of baggage fee announcements on airline stock prices. The authors found evidence of large, negative abnormal returns on the date on which the airline announced an initial baggage fee on passengers' first checked bag. The results further showed that investors learned of the revenue generation caused by the baggage fees, and reacted differently to announced increases in baggage fees. They noted that subsequent announcements of baggage fee increases are correlated with positive abnormal returns on the announcing airline's stock price.

Carlos H. Caldas et al. developed an electronic appraisal method to improve the appraisal process of highway right-of-way acquisition in "Electronic Appraisal Methodology for Right-of-Way Acquisition in Highway Projects." The main objective of the research was to develop the conceptual framework and technical requirements of a new Electronic Appraisal System (EAS), which could effectively support the transmission, analysis, and storage of appraisal information. The authors also constructed a prototype of the proposed EAS to demonstrate its capabilities. The authors found that an EAS solves many of the current practices of right-of-way valuation and acquisition. The authors state that their prototype EAS offers a secure, well organized platform for the appraisers to submit their appraisal reports.

In "Electrified Vehicle Technology Trends, Infrastructure Implications, and Cost Comparisons," David Tuttle and Kara Kockelman describe various types of plug-in electric (PEV) vehicles. They discuss market availability, technologies and trends, practical driving ranges, battery replacement and power costs, and implications for electric grid operations. They utilize manufacturers' recently announced prices for PEVs and EPA standardized test data to increase the accuracy of cost comparisons for competing vehicles. The authors found that in relatively low fuel-cost regions, such as the U.S., PEVs have a positive discounted net present value due to tax credits, assuming the original battery does not need replacement by the owner. They noted that even without the tax credits, PEVs have financial payback for drivers in higher fuel-cost regions, as long as their batteries last the vehicle's lifetime or are replaced by manufacturers under warranty. The authors also concluded that without the federal tax credit, the net present values for PEVs are negative at current U.S. gas prices.

Thomas Corsi, Ken Casavant, and Tim Graciano analyze the economic conditions of a dramatic change in railcar ownership over the past 10 years in "A Preliminary Investigation of Private Railcars in North America." They point out that private railcar ownership has increased to the point where they now account for 54% of the ton-miles and 56% of the total tonnage of all railroads.

The objective of the paper is to investigate, identify, and document changes in railcar ownership and offer some implications on the future of the rail industry. The authors review current car-hire practices, car rules, and interchange rules that may restrain investment in the private railcar fleet. The authors concluded that the financial returns to private car owners are barely compensatory. They found that the rate of return on investment is at least 30% below the lowest risk-free Treasury Bill. They note that a large decline in private railcar investment could pose a serious threat to the railroad industry, rail shippers, and the U.S. economy.

In "Disappearance of American Wealth and Its Impact on Air Travel: An Empirical Investigation," Dipasis Bhadra measures the impact of the Great Recession (2008-2010) on U.S. wealth and air travel. The objectives of the paper are to answer two questions: (1) Does wealth have any quantifiable impact on U.S. air travel? and (2) What has been the quantitative impact of wealth loss on air travel? To answer these questions Bhadra specifies a model in which the demand for air travel is a function of current income, household wealth, average fare, credit accessibility, a one-period lag of air passengers, and the interest rate. The equation was estimated for the 1990:Q1–2010:Q4 period. The author concluded that the household wealth loss of $17 trillion resulted in a loss of air travel demand of 730,000 passengers and a loss of $244 million. He points out that some of the lost passenger demand has been recouped (435,000) but a complete wealth-induced recovery seems far off.

Jesus Gonzalez-Feliu presents the main concepts of multi-echelon transportation with cross docking through a multidisciplinary analysis in "Freight Distribution Systems with Cross Docking: A Multidisciplinary Analysis." He explains that in a multi-echelon transportation system, the cross docking operation consists of trans-shipment of one or more freight units from an incoming vehicle into an outbound vehicle with little or no storage in between. The author's analysis includes an optimization study and an interview-based analysis. The optimization analysis uses both a geographic approach based on the concept of accessibility, and a scenario simulation analysis for collaborative freight transportation. The interview-based analysis includes a conceptual framework for logistics and transport pooling systems, and a simulation method for strategic planning optimization. The author concluded that multi-echelon transport has potential and can be accepted by practitioners and public authorities.

In "Methodology to Measure the Benefits and Costs of Rural Road Closure: A Kansas Case Study," Michael W. Babcock and Abhinav Alakshendra present a methodology that can be used to evaluate rural road investment and disinvestment proposals. The main objective of the paper is to estimate the economic impact on selected county road systems from reducing the size of the system. The objective is achieved using the transportation network model TransCAD, which calculates the minimum travel costs for all rural resident trips assuming the county network as it currently exists. Then selected low traffic volume road segments are removed from the network and TransCAD recalculates total minimum travel costs for rural resident trips. The difference between the two travel cost simulations is the cost of the assumed closed roads. The benefit of road closure is the avoided maintenance costs of the closed road segments. The authors' main conclusion is that rural counties will be able to save money by closing some relatively low traffic volume roads and redirecting the saving toward increasing the quality of other county roads.

Michael W. Babcock
Co-General Editor

Kofi Obeng
Co-General Editor

Baggage Fees and Airline Stock Performance: A Case of Initial Investor Misperception

by Gerhard J. Barone, Kevin E. Henrickson, and Annie Voy

In response to increasing fuel costs, airlines began introducing baggage fees as a new source of revenue, fees which have since been increased. In this study, an event study methodology is used to examine the impact of these announcements on airline stock prices. The results indicate that the initial announcements led to negative abnormal returns for the announcing firm and other competing airlines, as they were interpreted as a sign of industry weakness. However, the results also show that subsequent increases in baggage fees, which had been shown to positively impact the airline's financial performance, are associated with positive abnormal returns.

INTRODUCTION

Rapidly rising oil prices over the past several years have had a dramatic and sustained impact on airline profitability. In response to declining profits, airlines have increased their dependence on revenue from service fees to counterbalance rising expenses.[1] In 2008, a number of airlines announced the introduction of baggage fees for passengers' first and second checked bags.[2] Ex ante, it is not immediately clear how introducing new baggage fees should affect the financial performance of an airline. On one hand, the new baggage fees could cause consumers to switch to competing airlines that don't require baggage fees, potentially causing a drop in the total revenues of the announcing airline. Alternatively, fees on checked baggage could be a means to increasing revenue, as passengers might not consider the additional cost associated with checking baggage at the time of their ticket purchase. Further, revenue generated from baggage fees might allow the airline to maintain competitive ticket pricing in spite of rising fuel costs. Indeed, Henrickson and Scott (2011) find that airlines implementing baggage fees often lower ticket prices to maintain competitiveness, with each $1 increase in baggage fees causing firms to lower ticket prices by an average of $0.24.

In this study, a traditional event study methodology is used to estimate the impact of these announcements of baggage fees on airlines' stock prices. Results suggest that announcements of the introduction of baggage fees on passengers' first checked bags are correlated with large negative and statistically significant abnormal returns for both the announcing airline and, to a lesser extent, competing airlines. These results are interpreted as investors viewing these additional baggage fees as a sign of competitive weakness for not only the announcing airline, but for the airline industry as a whole.

Despite these initial market reactions, however, it became apparent that baggage fees held significant revenue potential for cash-strapped airlines. In a July 2008 press release, United Airlines (2008) stated that "…a $773 million or 54.1% increase in consolidated fuel expense caused the company's net, pre-tax and operating results to be significantly lower year-over-year." Just a month prior, United, following a precedent established by American Airlines, announced they would begin charging passengers for checked baggage, which they allude to as a way of establishing "new revenue streams by charging for a la carte service" (United Airlines 2008). By the end of 2008, the majority of the legacy air carriers in the U.S. had also announced new service fees charging passengers for checked baggage. These fees, according to the U.S. Department of Transportation, generated $1.15 billion in revenue for U.S. airlines in what amounted to half of 2008 (Smith 2009).

By mid-2009, approximately one year after American Airlines became the first U.S. airline to charge passengers for their first checked bag, airlines began increasing fees over and above the initial fee for the first and second checked bags.

In light of these new announcements, the event study methodology was extended to estimate the effect of announcements increasing existing baggage fees on airlines' stock prices. Interestingly, the market responded differently to firms' announcements of fee increases, with subsequent baggage fee increases being associated with small, but statistically significant, positive abnormal returns for the announcing airline. This result stems from the fact that investors had several quarters of financial data from the airlines with which to learn about the revenue potential of these baggage fees, causing them to view these increases as positive events rather than a sign of weakness.

As such, these results illustrate one part of the response to airlines' changes in the components of their airfares, something that impacts the airlines, their potential use of similar ancillary fees, their ability to raise capital, and their passengers who pay these higher fees. In addition, the results are important for both stock analysts and individuals who hold the stock of airlines, as the abnormal returns associated with these announcements dramatically impact the market valuation of these stocks. Finally, the results of this analysis shed light on the way in which the market and investors perceive the level of competition between large legacy carriers and lower-cost carriers, as the initial announcements are perceived by the market as a signal of weakness by the announcing airlines, and to a lesser extent, the competing legacy carriers. Yet, the impact of these announcements does not negatively impact their lower cost counterparts.

This paper proceeds as follows. The second section presents a review of related literature. The third section presents the empirical methodology and describes the data used herein. The fourth section presents the findings and the last section concludes.

LITERATURE REVIEW

The existing stock market event study literature has made an important contribution to understanding how firms providing transportation-related services are impacted by various events. For example, Chance and Ferris (1987) examine the impact of air crashes on the return of the airline's stock, arguing that the best measure of the true impact of a catastrophic event is the airline's stock return, since the stock market will quickly incorporate this information into its assessment of a firm's valuation. Using data on air crashes between 1962 and 1985, it is shown that the impact of an air crash is immediately incorporated into the valuation of the airline's stock through a negative abnormal return on the date of the crash, with no subsequent impact on the days following the crash. In addition, Chance and Ferris (1987) find that crashes do not impact other airlines or aircraft manufacturers, a result related to the results presented in this paper, whereby the market reaction to an announced baggage fee or a baggage fee increase impacts low-cost carriers and large legacy carriers differently.

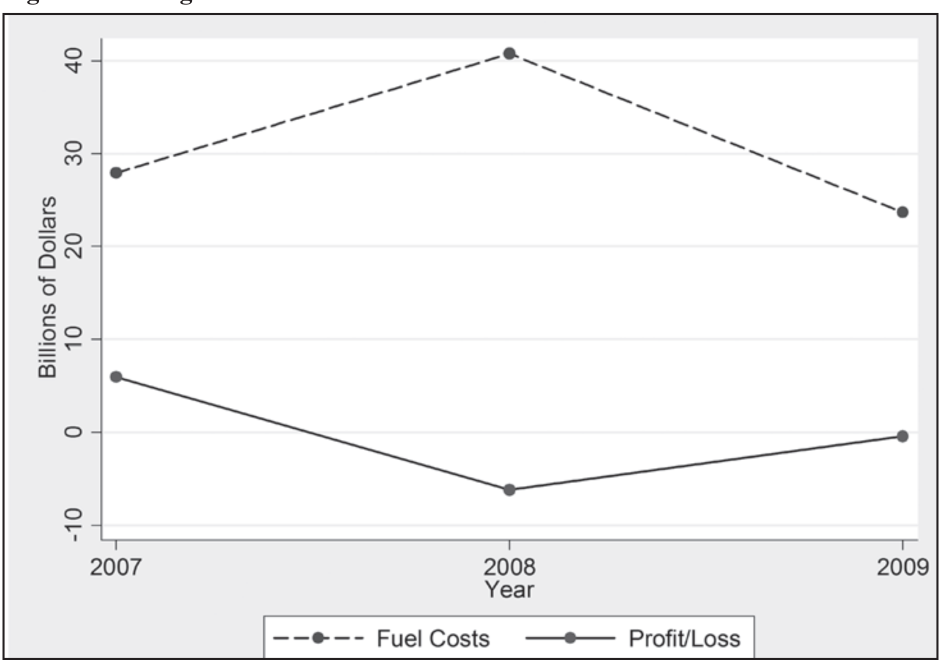
Similar to the findings of Chance and Ferris (1987), Davidson, Chandy, and Cross (1987) use stock market returns for airlines between 1965 and 1984 to examine the impact of air crashes. The results of this analysis show that on the day of a crash there is a large negative return for the airline, similar to the findings of Chance and Ferris (1987), but that these losses are recovered within five days of the crash. One reason provided for this result is that air crashes are not necessarily unexpected events in the airline industry, even if they are rare, and that the airlines carry insurance for such events, potentially limiting their liability.

Walker, Pukthuanthong, and Barabanov (2006) follow the methodology set forth by the aforementioned studies examining the stock market reaction to air crashes, but instead focus on the reaction to railroad accidents. Analyzing the impact of accidents that occurred between 1993 and 2003, the results of this analysis show that the stock market reaction to such events may not be efficient. Indeed, the findings indicate that there was an initial negative return in the railroad stock price, which was followed by negative returns over the days immediately following the accident, but that these negative returns are reversed within a short period of time. The Davidson, Chandy, and Cross (1987) and Walker, Pukthuanthong, and Barabanov (2006) results are of importance to this study, as both show that the market may initially respond to an event in one direction and then reverse course over time, a result consistent with the effect of initial baggage fee announcements having a different impact than subsequent baggage fee increases.

More recently, the impact of the 9/11 terrorist attacks, which used airplanes as weapons, has attracted a great deal of attention in the event study literature. Drakos (2004) focuses on the impact of 9/11 on both the systematic risk and idiosyncratic risk for airlines, finding a structural break in systematic risk for airline stocks and illustrating the importance of portfolio diversification for investors. Carter and Simkins (2004) focus instead on the potential for the market to differentiate between different firms, finding that the impact of 9/11 differed from airline to airline based on their cash reserves, a proxy for the firm's ability to survive the aftermath of 9/11. In addition, Carter and Simkins (2004) find that the market believed that the subsequent Air Transportation Safety and System Stabilization Act would benefit the major airlines over small airlines. Finally, Flouris and Walker (2005) look at the stock market returns of Southwest Airlines, Northwest Airlines, and Continental Airlines to differentiate the impact of 9/11 on legacy carriers versus low-cost carriers, concluding that the market had more faith in Southwest and low-cost carriers than in their legacy competitors, and that 9/11 had a smaller impact on these firms. The results of Carter and Simkins (2004) and Flouris and Walker (2005) are particularly important for this study, as they both illustrate the propensity for the market to react to information differently based on whether the air carrier is a low-cost carrier or a legacy carrier.

Within a decade of 9/11, airlines were faced with another challenge in the form of dramatically increasing jet fuel costs. Figure 1 illustrates this impact by showing the spike in the average airline's jet fuel costs in 2008 along with the related decrease in firm profitability.[3] Carter, Rogers and Simkins (2006) show that the impact of fuel costs can be reduced through the use of jet fuel price hedging, and that the stock market values companies using such hedging strategies at a premium. However, as Figure 1 shows, this hedging strategy cannot fully protect airlines from increases in jet fuel costs.

Figure 1: Average Airline Jet Fuel Costs and Profits/Losses Between 2007 and 2009



In addition to increasing firm costs, these jet fuel price increases also exacerbate the competitive pressure low-cost airlines place on their full service counterparts. Indeed, Dresner, Lin and Windle (1996) find that the entrance of a low-cost carrier reduces prices on the route in which the competition increased as well as other competitive routes, implying a spillover competitive effect of the low cost carrier's entry. Likewise, Goolsbee and Syverson (2008) find that the presence of a low cost carrier at two airports reduces the prices on flights between the two airports even if the airline doesn't offer service between the two locations. Rather, the mere threat of competition from a low-cost carrier causes the existing carriers to strategically lower their prices. Whinston and Collins (1992) use an event study methodology similar to that employed in this study to examine the entrance of a low-cost carrier on the stock market returns of existing firms, finding that the increased competition has a negative impact on the incumbent's returns. Similarly, Hergott (1997) uses an event study methodology to show that mergers in the airline industry leading to increased concentration result in increased market power within the industry. Finally, Windle and Dresner (1999) find that the entrance of low-cost carriers cause existing firms to lower their prices on competing routes, but that these firms do not raise their price on non-contested routes to make up for the revenue lost due to the increased competition.

This paper adds to the event study literature by examining the stock market's response to the introduction of new revenue streams. In particular, following 9/11 and increases in fuel costs, airlines introduced baggage fees as a method of increasing their revenues. Table 1 shows the dates and amounts of these fees by airline, with most of the fees being introduced in 2008 at a level of $15 for a first checked bag. These fees were subsequently increased in 2009 and 2010 as shown in Table 2. Also notice that, as shown in Table 2, many airlines first increased their baggage fees only for customers checking their baggage at the airport in an attempt to get more customers to check their baggage online, saving costs associated with the time needed to check customers in at the airport. The results of this analysis indicate that the stock market initially viewed these fees as a signal of weakness by the announcing firm and other legacy carriers, but not for low cost carriers. However, the results also indicate that the market learned of the revenue potential of these fees over the first year, and reacted differently to the announced increases in baggage fees, with the announcing firm's stock receiving a positive abnormal return on the announcement date.

Table 1: Chronology of Initial Baggage Fees, by Date of Announcement

Announcement Date	Airline	Effective Date	Initial 1st Bag Fee
May 21, 2008	American	June 15, 2008	$15
June 12, 2008	United	June 13, 2008	$15
June 12, 2008	US Airways	July 9, 2008	$15
July 9, 2008	Northwest	July 10, 2008	$15
September 5, 2008	Continental	October 7, 2008	$15
September 12, 2008	Frontier	September 13, 2008	$15
November 5, 2008	Delta	November 5, 2008	$15
November 12, 2008	AirTran	November 12, 2008	$15
April 23, 2009	Alaska Air	May 1, 2009	$15

Southwest Airlines and Jet Blue Airlines did not institute mandatory baggage fees.

Table 2: Chronology of Subsequent Baggage Fee Increases, by Date of Announcement

Announcement Date	Airline	Effective Date	New 1st Bag Fee (online)	New 1st Bag Fee (airport)
April 23, 2009	US Airways	April 23, 2009	$15	$20
May 13, 2009	United	May 14, 2009	$15	$20
July 15, 2009	Delta	July 16, 2009	$15	$20
July 21, 2009	Continental	July 21, 2009	$15	$20
July 24, 2009	American	August 15, 2009	$20	$20
August 26, 2009	US Airways	August 27, 2009	$20	$25
October 2, 2009	Continental	October 2, 2009	$18	$20
January 5, 2010	Delta	January 5, 2010	$23	$25
January 8, 2010	Continental	January 9, 2010	$23	$25
January 13, 2010	United	January 14, 2010	$23	$25
January 15, 2010	US Airways	January 18, 2010	$23	$25
January 19, 2010	American	February 1, 2010	$25	$25
April 22, 2010	Alaska Air	May 1, 2010	$20	$20
August 17, 2010	AirTran	September 1, 2010	$20	$20

Southwest Airlines and Jet Blue Airlines did not institute mandatory baggage fees.

METHODOLOGY

The dates of the market's reaction to baggage fee announcements are identified by first searching on the websites of the major U.S. airlines for information about the baggage fees that they are currently charging, including the date these fees were put into effect.[4] This information is used to search backwards in time on Google News to identify the actual date and time of the press release associated with either the introduction of a baggage fee or the increase to an existing baggage fee. Finally, the press releases are used to choose the date on which to investigate the market's reaction to the announcement. In particular, if the press release indicated that a particular airline made a baggage fee announcement "in the morning" on a particular date, the actual announcement date was identified as the date on which to investigate the market's reaction to the announcement. Alternatively, if the press release indicated that a particular airline made a baggage fee announcement "in the afternoon" or "in the evening" on a particular date, then the day following the announcement date was used as the date on which to investigate the market's reaction to the announcement.

This process of identifying announcement dates yielded nine announcements introducing the initial implementation of baggage fees, and 14 announcements increasing existing baggage fees.[5] The first of these fees on checked bags was announced by American Airlines in May 2008, with most of the other major airlines following suit later that same year.[6] These fees were introduced at the level of $15 for the first checked bag, which was then followed up by baggage fee increases beginning in mid-2009 and continuing through January 2010, when baggage fees were increased to $20–$25 for the first checked bag. While 23 baggage fee announcements over a three-year period is a significant amount of information dissemination, it is also noted that this results in a fairly small sample size, especially when treating initial announcements and subsequent announcements separately; however, this limitation is unavoidable given the small number of airlines and the short amount of time since the initial introduction of these fees. In addition, three of these announcements were excluded from the analysis. One of these, Frontier's September 12, 2008, announcement was excluded because the company's stock was delisted. Two other announcements needed to be excluded because the announcement was made at the same time as the company's quarterly report (U.S.

Airway's April 23, 2009, announcement and Continental Airline's July 21, 2009, announcement). Because of the simultaneous announcement of accounting information and the baggage fee increase, it is not possible to determine what portion of the stock's daily return is attributable to the baggage fee announcement rather than the quarterly report.[7]

The Model

The market's perception of the valuation effects of both types of baggage fee announcements, initial and fee increase, are investigated by using traditional event study methodologies. Specifically, a modified market model is used to establish an estimate of what an airline's stock return would have been without considering the effects of the announcement related to baggage fees. In calculating this estimate, the market model is modified by including the change in the daily spot-price of jet fuel as an additional predictor, along with the return on the market portfolio, according to the Standard and Poors 500. Note that the change in jet fuel prices is included in the model because jet fuel is one of the largest costs for airlines, and therefore is highly correlated with firm value and the daily returns to airlines' stocks. The market model is estimated via ordinary least squares (OLS) as:

$$(1) \qquad R_{it} = \alpha_i + \beta_{1i} R_{mt} + \beta_{2i} Jet\ Fuel_t + \varepsilon_{it}$$

where R_{it} and R_{mt} are the period t returns for security i and the market portfolio, m, $Jet\ Fuel_t$ is the period t percentage change in jet fuel costs, and ε_{it} is the zero-mean error term.

In order to estimate equation (1) above, closing stock prices were collected from Yahoo! Finance for each of the airlines announcing baggage fees from July 2007 through December 2010. An airline's stock return, R_{it}, is then calculated as the percentage change in the closing price of the stock from one trading day to the next. As with the firm's return, the market return, R_{mt}, is calculated as the percentage change in the closing price of the Standard & Poor's 500 from one trading day to the next.[8] To estimate the percentage change in the daily price of jet fuel, the Daily U.S. Gulf Coast Kerosene-Type Jet Fuel Spot Price was collected as reported by the U.S. Energy Information Administration (1990–2011), and then the percentage change in these prices was calculated from one day to the next.

Event study methodology requires specifying the length of an event window. To determine the length of the event window, airline stock returns were examined on the seven trading days before and after a baggage fee announcement. Figure 2 shows the average daily returns surrounding the announcement for firms introducting a baggage fee on the first checked bag. This figure illustrates a large negative average return on the announcement day, day 0, with relatively smaller average returns on the seven days before and after the announcement. This indicates that, on average, these airlines saw dramatic changes in their valuations on the exact day that they made their initial baggage fee announcements (without, however, taking into account the overall return on the market or the change in the daily spot price of jet fuel on those days.) Similarly, Figure 3 shows the average daily returns for the seven days before and after announced increases to baggage fees. As was shown in Figure 2, Figure 3 indicates that when announcing increases to baggage fees, the announcing airline saw dramatic changes in their valuations on the exact day that they made their announcement. Based on these two figures, an event window of one day is specified, in particular, the exact day on which the baggage fee announcements were made. Additionally, Figures 2 and 3 highlight the aforementioned difference in the market's reaction to the different types of baggage fee announcements. As such, these announcements were treated as two separate events, first examining the impact of the initial announcements, and then later examining the impact of announced increases in baggage fees.

Figure 2: Average Stock Returns of Announcing Companies One Week Before and One Week After Announcement of Initial Baggage Fees

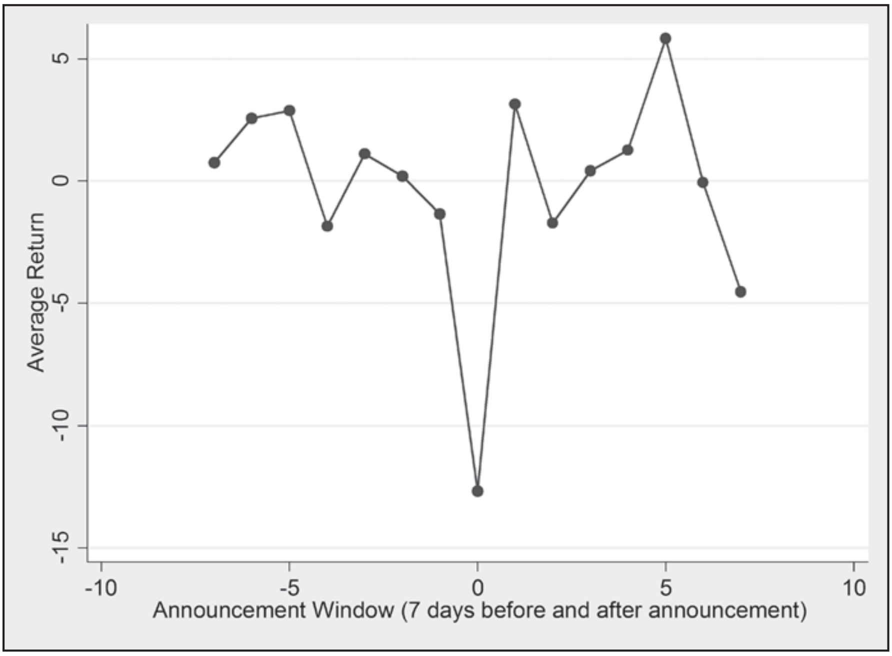
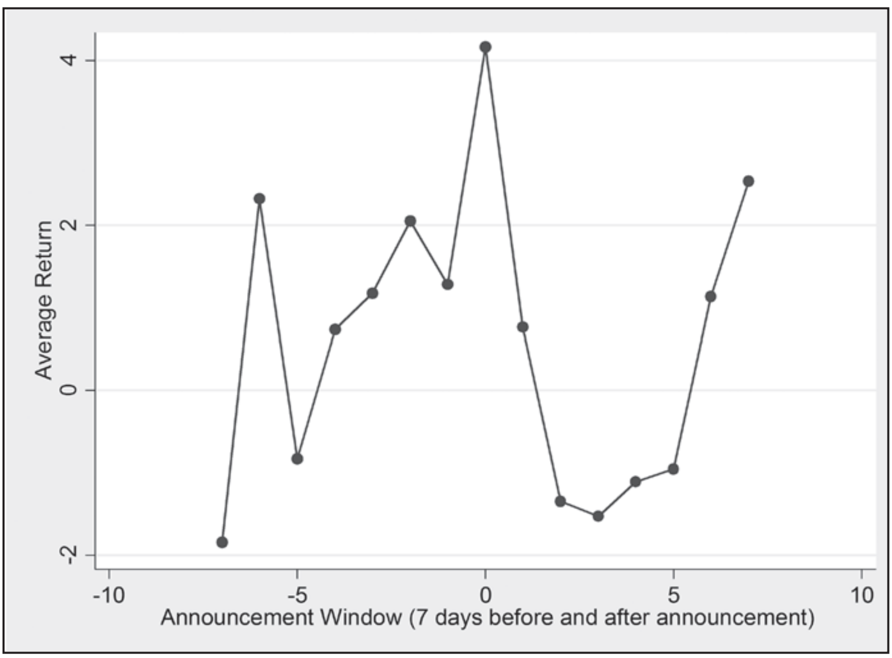


Figure 3: Average Stock Returns of Announcing Companies One Week Before and One Week After Announcement of Baggage Fee Increases



To quantify the impact of each baggage fee announcement, equation (1) is estimated for each announcing airline over the 120 trading days prior to the announcement date.[9] The firm's expected return on the date of the announcement was then calculated based on the estimated coefficients from equation (1), and the actual values of the market return, R_{mt}, and jet fuel, $Jet\ Fuel_t$, variables on the announcement date. Any difference between the airline's expected return and actual return on the announcement date is attributed to the information content delivered to the market in the baggage fee announcement, and is referred to as the airline's abnormal return:

$$(2) \qquad Abnormal\ Return_{it} = R_{it} - (\alpha_i + \beta_{1i} R_{mt} + \beta_{2i} Jet\ Fuel_t)$$

This process is done separately for each type of baggage fee announcement (initial fee introduction and subsequent fee increase), and the abnormal returns are then tested for statistical significance to determine the impact of the type of announcement on the market price of the announcing airline's stock.

RESULTS

The results are presented in three sections. The first section examines the impact of the announcements of initial baggage fees, which were shown in Figure 2, to cause a large negative return to the announcing firm. The impact of an announced increase in baggage fees is then analyzed as the market had time to absorb several quarters' worth of financial reports prior to these announcements, which gave investors more information regarding how to interpret baggage fees. Finally, it should be noted that these announcements may impact competing airlines, so in the third section the impact of announcements on the returns of non-announcing airlines is examined.

Initial Announcements of Baggage Fees

Table 3 presents the results of estimating equation (1) via OLS for each of the announcing airlines. These results, while not the focus of this paper, show that the firms' stock returns are positively correlated with the market return, and negatively correlated with increases in jet fuel prices.

Using the estimates presented in Table 3 to calculate the expected return on the announcement date, along with the actual market return and the percentage change in jet fuel spot prices on the announcement dates for each airline, the abnormal return associated with each announcement of an initial baggage fee is calculated. The results, presented in Table 4, indicate that there is a -10.1% mean abnormal return associated with these announcements, which is statistically significant at 1%. Thus, in 2008, with oil prices at record highs, the announcements by these airlines of charges associated with a first checked bag were interpreted by the market as a signal of weakness, as these firms were searching for any additional source of revenue to survive, causing a -10.1% mean abnormal return to the announcing firms' stock prices.

Subsequent Increases in Baggage Fees

Table 5 presents the OLS estimates of equation (1) for each airline's announcement of baggage fee increases. Comparing the results in Table 5 with those in Table 3, it is worth noting that the impact of jet fuel prices is much smaller and in many cases statistically insignificant in the second set of regressions. This is largely due to the decrease in jet fuel prices between 2008, when the baggage fees were introduced, and 2009, when most of these fees were increased, as shown in Figure 1. Table 6 shows that subsequent announcements of increases in an airline's baggage fee are associated with a statistically significant 2.5% mean abnormal return. This result shows that while the market initially interpreted these baggage fees as a signal of weakness on the part of the firm or industry, once it was

Table 3: OLS Estimates of the Daily Stock Return for Announcing Firms 120 Days Prior to Announcement

	AirTran Airways	Alaska Airlines	American Airlines	Continental Airlines	Delta Airlines	Northwest Airlines	United Airlines	U.S. Airways
S & P 500 Daily Return	1.369*** (0.248)	1.068*** (0.172)	1.999*** (0.282)	2.882*** (0.474)	1.577*** (0.254)	1.608*** (0.446)	2.231*** (0.418)	1.918*** (0.364)
Daily Change in Jet Fuel Prices	-0.366*** (0.133)	-0.126 (0.122)	-0.945*** (0.197)	-1.438*** (0.266)	-0.397*** (0.133)	-1.163*** (0.268)	-0.907*** (0.263)	-1.019*** (0.229)
Intercept	0.008 (0.007)	0.001 (0.005)	-0.003 (0.004)	0.003 (0.006)	0.009 (0.007)	0.008 (0.006)	-0.005 (0.006)	-0.005 (0.005)
R2	.21	.27	.40	.45	.25	.26	.28	.32
Observations	120	120	120	120	120	120	120	120

Standard errors in parentheses. *** significant at 1%.

Table 4: Abnormal Performance of Airlines on Announcement of Initial Baggage Fees

Abnormal Return on Day of Announcement	Two Tail t-Test of Abnormal Return = 0 (p-value)	One Tail t-Test of Abnormal Return < 0 (p-value)
-10.01%	0.009	0.004

Table 5: Estimates of the Daily Stock Return for Announcing Firms 120 Days Prior to Announcement of Baggage Fee Increase

Initial Increase in Baggage Fees

	AirTran	Alaska	American	Delta	United
S & P 500 Daily Return	1.217*** (0.196)	1.571*** (0.263)	1.936*** (0.274)	1.975*** (0.260)	2.083*** (0.244)
Daily Change in Jet Fuel Prices	-0.109 (0.143)	-0.059 (0.135)	-0.147 (0.181)	-0.038 (0.170)	-0.234 (0.165)
Intercept	-0.0001 (0.002)	0.002 (0.002)	-0.004 (0.005)	-0.004 (0.005)	-0.004 (0.006)
R2	.34	.29	.36	.41	.40
Observations	120	120	120	120	120

Subsequent Increases in Baggage Fees

	American	Continental (2nd increase)	Continental (3rd increase)	Delta (2nd increase)	United	U.S. Airways (2nd increase)	U.S. Airways (3rd increase)
S & P 500 Daily Return	2.397*** (0.046)	2.192*** (0.360)	2.209*** (0.361)	1.875*** (0.304)	2.700*** (0.513)	2.947*** (0.348)	2.86*** (0.506)
Daily Change in Jet Fuel Prices	-0.380** (0.187)	-0.259 (0.199)	-0.494*** (0.168)	-0.310** (0.133)	-0.429* (0.239)	-0.513** (0.222)	-0.387* (0.231)
Intercept	0.003 (0.004)	-0.001 (0.004)	0.005 (0.003)	0.003 (0.003)	0.009 (0.005)	-0.001 (0.005)	0.005 (0.005)
R2	.23	.27	.24	.25	.19	.40	.15
Observations	120	120	120	120	120	120	120

Standard errors in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%.

learned that these fees produced large revenues for the firms, the increases were then interpreted as positive events. This is not to say that the market's initial reaction was wrong (particularly given that the introduction of these fees was likely a sign of weakness), but rather that the market's view of these fees evolved as it learned, through company financial statements, that these fees were generating new revenues for the firms. Evidence of this learning can also be anecdotally seen in looking at the size of the abnormal returns over time, where the first several announcements of the introduction of baggage fees were received with negative abnormal returns greater than 10%, while firms announcing the introduction of baggage fees later tended to have smaller abnormal returns. For example, American Airlines, the first airline to announce baggage fees on the first checked bag, had an estimated -16.6% abnormal return, while Delta, one of the later legacy carriers to announce baggage fees on the first checked bag, had only a -0.4% abnormal return.

Table 6: Abnormal Performance of Airlines on Announcement of Baggage Fee Increases

Abnormal Return on Day of Announcement	Two Tail t-Test of Abnormal Return = 0 (p-value)	One Tail t-Test of Abnormal Return > 0 (p-value)
2.5%	0.074	0.037

Impact of Announcements on Non-Announcing Firms

In addition to the impact on the announcing firm, it is possible that an announcement of an initial baggage fee and/or increase in baggage fees could impact the return of competing airlines. Further, the literature indicates that within the airline industry, low-cost carriers and large, legacy carriers are often differentiated by the market (e.g., Carter and Simkins [2004] and Flouris and Walker [2005]).[10] As such, the abnormal returns were calculated for all non-announcing airlines as shown in equation (2) above, and then these abnormal returns were separated by carrier type: low-cost carrier or legacy carrier.[11] These returns are shown in Table 7 by type of airline and type of announcement (initial or subsequent increase in baggage fees).

The results presented in Table 7 show that an announcement of changes in baggage fees, of any type, caused a marginally significant -1.1% mean abnormal return for legacy carriers, and had no statistically significant impact on the average return of low-cost carriers. However, it's been established that the market learned about the positive revenue impact of these baggage fees between the initial announcements and the subsequent announcements of increases; therefore, there is no reason to focus specifically on the impact of an announcement without differentiating between the type of announcement.

Indeed, if the market viewed the initial announcements as a signal of weakness, it is likely that all similar stocks would be viewed by the market as weak. Thus, the second set of results in Table 7 presents the impact of the initial announcements of baggage fees on the stocks of competing legacy carriers and low-cost carriers. The results indicate that competing legacy carriers had a -3.4% mean abnormal return when baggage fees were announced by their competitors since they would also be perceived to be vulnerable. However, the low-cost carriers experienced a marginally significant 0.9% mean abnormal return as the market would have viewed these firms as being in stronger positions than their legacy carrier competitors.

Finally, as noted in Table 7, subsequent announcements of baggage fee increases had no statistically significant impact on the stock prices of competing airlines. This result makes intuitive sense since the market had learned that baggage fees actually serve as a new revenue stream for the announcing firm, which will not impact the revenues of competitors, hence their stocks experienced no impact from such an announcement.

Table 7: Abnormal Performance of Competing Airlines

	Abnormal Return on Day of Announcement	Two Tail t-Test of Abnormal Return = 0 (p-value)	One Tail t-Test of Abnormal Return > or < 0 (p-value)
On Announcement of Baggage Fee Changes (Initial or Increase)			
Legacy Carriers	-1.1%	0.053	0.027
Low Cost Carriers	-0.5%	0.242	0.121
On Announcement of Initial Baggage Fees			
Legacy Carriers	-3.4%	0.003	0.002
Low Cost Carriers	0.9%	0.172	0.086
On Announcement of Baggage Fee Increases			
Legacy Carriers	-0.2%	0.691	0.345
Low Cost Carriers	-1.0%	0.232	0.116

CONCLUSION

Using traditional event study methodologies, this paper analyzes the impact of airlines' baggage fee announcements on firms' stock market returns. There is evidence of large negative abnormal returns on the date on which the airline announced an initial baggage fee on passengers' first checked bag. It was also found that these announcements impacted competing airlines' stock prices, but that, as previous literature has shown, the market differentiated between large legacy, carriers and low-cost carriers in its reaction. The results further show that investors learned of the revenue generation caused by these baggage fees, and reacted differently to announced increases in baggage fees. Specifically, subsequent announcements of baggage fee increases are correlated with positive abnormal returns on the announcing airline's stock price, with no impact on competing airlines' stock prices. As such, this research highlights both the effects that these types of announcements had on airline's stock prices, as well as the learning curve faced by market participants when presented with these types of announcements.

Endnotes

1. In 2010, U.S. airlines collected roughly $5.7 billion in service fees charged to passengers for checked baggage and reservation change fees (U.S. Department of Transportation 2011).

2. Prior to the implementation of these new fees, virtually all airlines charged fees for passengers checking more than two bags. Thus baggage fees weren't new, in and of themselves, but the practice of charging customers for a first checked bag was a new strategy.

3. Jet fuel costs and carrier profitability were obtained from the U.S. Department of Transportation's Form 41 Financial Data (2008 – 2010).

4. Airlines included are: AirTran Airways, Alaska Airlines, American Airlines, Continental Airlines, Delta Air Lines, JetBlue Airways, Northwest Airlines, Southwest Airlines, United Airlines, and US Airways.

5. The term 'initial baggage fees' refers to airlines implementing fees on each passenger's first checked bag. Oftentimes these airlines had fees on second and subsequent checked bags prior to the dates examined here, but the focus of this analysis is on the impact of implementing fees on first checked bags as this, potentially, has a greater impact on travelers.

6. All of the "legacy" carriers introduced baggage fees by spring 2009, but several "low cost carriers" have differentiated themselves by not charging for baggage.

7. However, inclusion of these two observations does not qualitatively change our results.

8. Other measures of the market return were examined, and the estimates presented here are robust to these different measures.

9. Note that various window sizes were examined, and the results presented here do not qualitatively differ from those associated with these different window sizes.

10. Low-cost carriers included in this analysis include Southwest Airlines, JetBlue Airlines and AirTran Airways.

11. Note that the most prominent low cost carrier, Southwest Airlines, focused their advertising campaign on "Bags Fly Free" following the introduction of baggage fees by the legacy carriers.

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Electronic Appraisal Methodology for Right-of-Way Acquisition in Highway Projects

by Carlos H. Caldas, Zhanmin Zhang, Ragheb Al Halabi, and Elizabeth Kincaid

When right-of-way is acquired for highway projects, state departments of transportation (DOTs) must ensure property owners receive a fair market value for their land by delivering high-quality appraisals. Despite recent technological advances, the highly complicated appraisal process often results in similar properties being assessed differently. Several DOTs sponsored a study to develop an electronic appraisal method to improve the appraisal process and to reduce the likelihood of inconsistent appraisal values by capturing, transmitting, storing, managing, and analyzing the appraisal data. The proposed method's framework is discussed and a prototype of the system has been developed to demonstrate its features.

INTRODUCTION

One of the primary functions of the state departments of transportation (DOTs) is to provide safe and reliable transportation facilities to the public. To meet this demand, construction of new infrastructure facilities, such as highways, is imperative. The construction effort usually requires a significant amount of right-of-way (R/W) acquisition, which can be a complicated process in that it involves multiple stages and various participants with diverse and differing interests. Therefore, it is not surprising that the acquisition of R/W has become a significant part of the total project cost and duration.

One significant component of the R/W acquisition process is the determination of the monetary value to be paid to the property owner by a state DOT. The valuation must completely compensate the loss suffered by the owner in terms of the value of the land acquired, the improvements acquired, and any other financial damages resulting from the acquisition of the property. This process can be extremely complex, depending on the type and location of the property being acquired, and commonly causes variations in the valuation of similar or same properties appraised by different individuals. According to the National Cooperative Highway Research Program (NCHRP) Report 126 (1971), "the most important basic reason for divergence in estimates of value is the nature of the value itself. Value is a subjective phenomenon. Real estate valuation is an art that calls for the exercise of experienced judgment based on a logical and justifiable approach; it is an observational process—by no means an exact science" (NCHRP 1971). The report also found that approximately 21 % of R/W valuation divergence occur as an outcome of the lack of proper or insufficient data, and many incongruities result from misguided information on the part of the appraiser (NCHRP 1971). The occurrence of this problem is primarily because of varying degrees of experience, knowledge, and background of the individuals employed to perform the valuation of the property being acquired.

There are three methods for determining property values: the cost approach, the sales comparison approach, and the income approach. The cost approach is based on the premise that a potential buyer should not pay more for a property than the cost of building an equivalent one. The sales comparison approach uses the price of recently sold properties that are comparable to the subject property in order to determine the value. The income approach is common on commercial and investment properties. It uses methods such as discounted cash flow, direct capitalization, and gross income multiplier to model the behavior of market participants. Since these methods are based on fundamentally different approaches and assumptions, the appraised property value may vary. It is usually up to the appraiser to choose the best method for a given property, and justify the selection and final appraisal.

There are many motivations that triggered the research study discussed in this paper. First, as discussed above, the problem of property valuation is complex in nature and there is no consistent process used to determine it, resulting in dissimilar price valuations for properties that are alike in nature. Hence, it is essential to determine the data that are required to arrive at the just compensation for the property. Moreover, the inconsistencies in the appraised values are extremely difficult to detect and can often go unnoticed by the reviewer. It is necessary to develop a mechanism to identify these abnormalities in property values in order to make the process more efficient. In addition, the traditional R/W acquisition system is a paper-based system. With the developments in the field of information technology, there is a substantial scope to employ the emerging as well as the established technologies in the field of R/W acquisition to make the system more proficient and organized. Last, there is a substantial delay in the transfer of appraisals from the appraisers to the reviewers and from the reviewers to the R/W administrators. A system that reduces the time required for the entire appraisal submission and evaluation would be beneficial.

The objectives of the research are, first, to establish the list of data required by the appraiser so as to arrive at the just compensation for a property. It also aims to develop a statistical mechanism to reduce the likelihood of inconsistent appraisals by warning the reviewer of variations deemed to be conflicting with the expected values. Exploring emerging technologies for use in the R/W acquisition process and building a system that can efficiently organize, manage, and store the appraisal data would be very beneficial. Last, developing an effective communication mechanism would minimize the idle time spent during an appraisal acquisition process. Thus, the ultimate objectives of this research project are to develop the conceptual framework and technical requirements of a new electronic appraisal system (EAS), which could effectively support the transmission, analysis, and storage of the appraisal information, and also to construct a prototype of the proposed EAS to demonstrate its capabilities.

To ascertain the above objectives, a staged development process for the new EAS was conducted. This process included an overview of the current practices followed in R/W acquisition and the recent advances made in this field. Secondly, a conceptual framework of the EAS describing the data flow structure was developed. The results of a survey conducted at 13 DOTs were used as an input for the framework. The Statistical Process Control (SPC) mechanism that was used as a validation tool for the appraisal results was created and tested by comparing similar parcel appraisals. The SPC implementation was done through the use of data clustering; thus a suitable data clustering technique was selected for incorporation in the tool. Finally, a prototype of the EAS was designed and developed to prove its applicability. The prototype is briefly discussed in this paper.

LITERATURE REVIEW AND CURRENT PRACTICES

In order to develop an effective understanding of the principles and practices followed in the appraisal community, a literature review has been conducted that explains the traditional R/W acquisition procedure followed by the various state DOTs as well as the recent advances made in this field by public and private bodies.

Under the U.S. Constitution and state constitutions, states have the right to acquire either the entire amount of a privately-owned property (whole-taking) or a part of the property (partial-taking) depending upon the needs of the transportation project. Since the property owner must be properly compensated for his/her losses, states enlist the services of an independent fee appraiser, who must follow the framework specified by the respective state transportation agency to determine the appropriate value of the property being acquired (FHWA 2000; 2001; 2002a; 2002b), as well as follow the rules developed by the U.S. Appraisal Institute as a licensed professional.

Conventionally, the appraisal process begins with an evaluation of the physical land, improvements, and the area and neighborhood characteristics that might increase the value of the property. The various data elements that are generally collected as part of the property valuation process are listed in Table 1 (FHWA 2000; 2001; 2002a; 2002b).

Table 1: Examples of Data Elements Collected During the Valuation Process

Land Characteristics	Improvements	Local Services	Property Use
Size	Structures	Educational facilities	Arts and entertainment
Shape	Paving	Health care facilities	Retail and shopping centers
Topography	Landscaping	Religious facilities	Amount of business and industry
Soil type	Curbs and sidewalks	Public services	
Geographical location	Signage	Utilities	
Land-use type	Transportation facilities		
Access to property	Improvements to surrounding property		
Surrounding land characteristics	Fencing		

Once this information is collected, the subject property, comparable sales, and the neighboring area are inspected by the appraiser. The appraiser analyzes these data and the data listed in Table 1 in a systematic procedure known as the valuation process, from which the *best use* of the land is determined. Based on this best use, a monetary value is assigned to the property and submitted to the DOT for review. The state makes an offer to the property owner based on the fee appraiser's recommendation. If the land owner declines the offer, he/she may make a counteroffer to the state. If the terms of the counteroffer are not acceptable to both parties, the state will institute eminent domain as a last resort. Eminent domain is the power given to a state by the constitution to confiscate private property without the owner's consent, either for its own use or on behalf of a third party. The property's final value is decided by an impartial third party, such as a jury (FHWA 2000; 2001; 2002a; 2002b).

In the appraisal process, an enormous amount of data and information is collected. The information is mostly recorded by hand and stored in a hard-copy format. This system of data recording, storage, and analysis is not only time consuming, but is also open to error, miscalculation, and misplacement of information. According to a study conducted by Adkins and Buffington (1967), poor documentation of appraisals was a leading cause of discrepancies in more than half of the districts in Texas. As mentioned earlier, the valuation of properties and a host of different issues also lead to complications in the appraisal process.

Thus, a reliable computer-based system that can be used to store, transmit, and analyze this appraisal information would prevent the aforementioned problems and improve the appraisal process significantly. A few electronic R/W appraisal systems have been developed for use at state DOTs and other institutions to help organize appraisal and R/W information so that it may be analyzed, queried, and retrieved to aid in decision making. In Virginia, a Right-of-Way and

Utility Management System (RUMS) tool was developed to help upper-level managers track construction projects, R/W acquisitions, displaced/relocated persons, and the installation of utilities within R/W land (FHWA 2005). This system provides managers with an excellent tool to monitor key project dates to ensure that resources can be shifted for on-time completion. The RUMS tool allows a multitude of information, including that from appraisals, to be entered into a database. It also permits detailed querying and reporting of database information via Cizer reporting software, a Microsoft server-based query reporting tool that utilizes Report Definition Language (RDL). Minnesota DOT has purchased the rights to the RUMS software (FHWA 2005). A few other DOTs are also considering purchasing the rights.

The Florida DOT has also ventured into the development of electronic R/W management tools by developing two systems: an appraisal document storage database that stores the R/W appraisal reports, and an R/W management system (FHWA 2004). The storage document can only store the information from the appraisals. Statistical analysis cannot be performed using the database. Attempts have been made by the Florida DOT to implement an SPC mechanism. The system was created using MS Excel and Visual Basic. These efforts met with little success. They seemed to work well with vacant lands, but they failed to give the desired results for complicated properties.

Bentley developed "Projectwise" to help organize appraisal and R/W information so that it may be analyzed, queried, and retrieved to aid in decision making (AEC 2004). Projectwise organizes the information for each piece of property into a single electronic folder. It offers the professionals from various stages of the R/W process an option to retrieve information from the folder using a standard web browser to create summary reports, such as the R/W costs associated with highway projects (AEC 2004). Component indexing allows users to search, query, and navigate all data-base entries. Thus, project-wide reports and statistics can be generated by the users, providing them with timely information. Projectwise has been incorporated into the Massachusetts Highway R/W management system.

Another advanced R/W management system is the Right-of-Way Suite, designed and developed by Quorum. It integrates R/W management obligations, such as payment, with highway design aspects like alignment information (Quorum Right-of-Way Management 2004). It comprises various technologies like web viewing, Geographical Information System (GIS), query and reporting, and site assessment. Web viewing allows the personnel to access the information online and also generate reports using the query and reporting tools. GIS produces integrated maps and site assessment captures and manages field data surveys and associated documents. It also validates the data and ensures accuracy and consistency (Quorum Right-of-Way Management 2004). Micro Solve (2006) developed a suite of software applications to manage appraisals. They are collectively referred to as Computer Assisted Mass Appraisal Solutions or CAMA 2000. The system helps in the actual valuation process by offering three types of valuation approaches: the cost approach, the market approach, and the income approach. The software package includes SPSS, which is used for carrying out the linear and non-linear regression required for the market approach. The software also has a data storage system to securely save the appraisals (MicroSolve 2006).

FRAMEWORK AND REQUIREMENTS OF THE ELECTRONIC APPRAISAL SYSTEM

This research study on developing an EAS for R/W acquisition was funded by several state DOTs. All state DOTs have been invited to participate, but only 13 states DOTs agreed to fund this study: Alabama, Alaska, Florida, Idaho, Illinois, Louisiana, Mississippi, Montana, New York, North Carolina, Texas, Washington, and Wisconsin.

The main advantages of the proposed method over the existing approaches described above are: the method is based on the needs and the requirements of the participating state DOTs, supports the three types of appraisal methods, provides controlled access to different user types, contains a statistical process control component, supports appraisal reviews, enables version control, and provides access to different users via the Internet.

In formulating the various requirements of the EAS, the research team worked extensively with consultants from the appraisal industry. Also, the participating state DOTs were requested to provide information and advice on critical issues concerning the entire development of the EAS. Various technical memorandums were prepared, and these documents were sent to the participating state DOTs as a survey for input on the conceptual framework, the user functional needs, and the data requirements for the EAS. With the help of the Texas Department of Transportation's (TxDOT) Right-of-Way Division as the contact point, the research team sent the survey documents to the 13 state DOTs that funded the study. The reviewers and the appraisers from the respective states were requested to assign a score on a scale of 1 to 5, with 5 being the highest, about the usefulness and applicability of the various components of the conceptual framework, functional needs, and the data requirements.

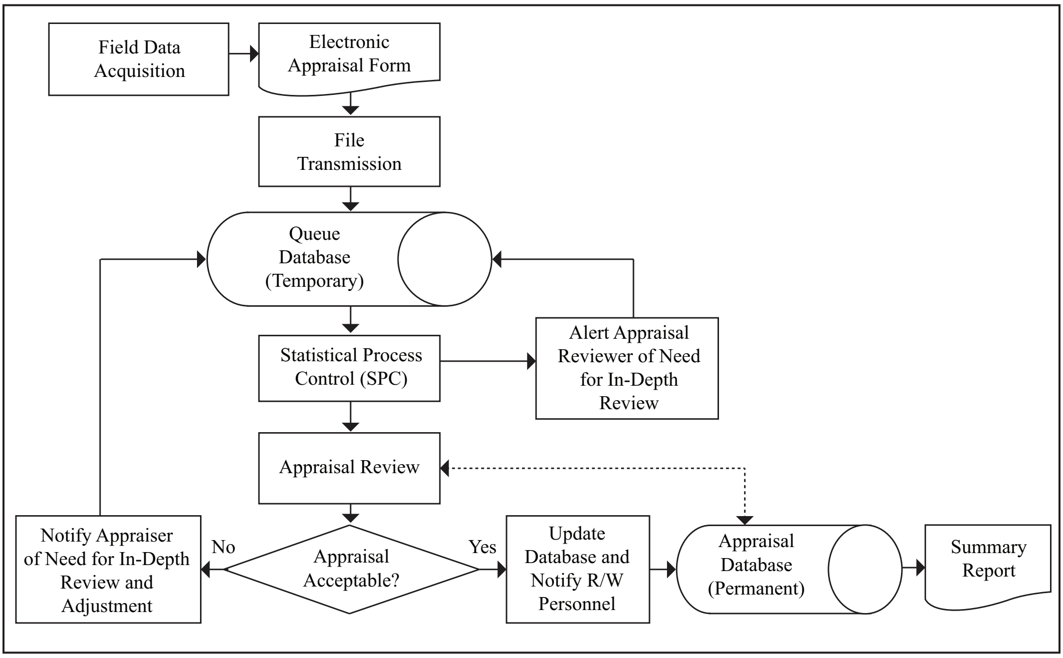
The responses received from the participating state DOTs were then analyzed using the Delphi Technique. This technique involves having the state DOT employees answer surveys and questionnaires, which are then grouped with the other comments and returned to all respondents. This process is repeated multiple times until a consensus about a particular opinion is reached. The idea is that by seeing the replies of other panel members, experts will rethink their prior responses. It replaces direct debate and committee activity with a carefully designed program, thereby reducing the influence of certain psychological factors such as the bandwagon effect. The responses, in general, were very encouraging. In fact, the rankings received for the User Needs and Data Requirements were very high for almost all the sections. Most of the comments were positive and were in agreement with the philosophy of the research team.

Based on the comments from the DOTs, the decision was made to develop a web-based system, as opposed to a File Transfer Protocol (FTP) system, which is a standard network protocol to transfer files across a network. Also, the survey influenced the decision that an appraisal can be changed only by the appraiser of the original appraisal. One of the most important outcomes of the survey was to clear misunderstandings surrounding the use of the SPC. Many participating DOTs had suspicions about the SPC and the part it would play in the appraisal process. It was explained to the DOTs that the SPC mechanism was only for guidance to support the reviewer during the review process. The reviewer would be the final judge regarding the acceptability of an appraisal report submitted by the appraiser. The DOTs also requested clarifications and provided their suggestions about allowing flexibility in the appraisal form to cater to complicated situations that could not be predicted. The researchers agreed with the DOTs and decided to provide comment boxes wherever possible to accommodate that situation. The DOTs were very positive about the provision to automatically send the reviewer's comments to the appraiser and the appraiser's response to the reviewer electronically.

The design of the conceptual framework lied in the core of the EAS. It helped elucidate the entire process envisioned in the proposed system. The framework for the EAS was prepared by the research team based on the literature review and fine-tuned with comments provided by the participating state DOTs. Figure 1 gives a schematic representation of the conceptual framework of the EAS.

The first component of the EAS, Field Data Acquisition, involves gathering basic information vital to making a value estimate. Data pertaining to site characteristics, such as physical features and dimensions, are collected onsite by the appraiser and recorded in either paper or electronic format. Afterwards, all data, including the appraisal, background information pertaining to the appraiser, the property owner, and other interested parties, are loaded onto the standardized EAS. This process is accomplished by uploading the necessary information into the appropriate data fields through a web-based user interface, accessible with a personal computer and completed by the appraiser. The electronic appraisal form is then transmitted from the office of the appraiser to a centrally located Temporary Queue Database via a secured web-based interface. Upon file transmission,

Figure 1: Electronic Appraisal System Process



the electronic appraisal form will receive an electronic signature, verifying its authenticity. The function of the temporary queue database is short-term storage of the appraisal while it is being reviewed by appraisal reviewers. Meanwhile, queued appraisals are protected from unauthorized persons tampering with them by providing authorization only to the appraiser, appraisal reviewers (including contract reviewers), and a limited number of DOT R/W personnel to view, modify, or suspend the appraisal as necessary.

The SPC, if initiated by the user, would examine and check all critical values on the electronic appraisal form against historical appraisal information currently stored in the permanent electronic appraisal database. The purpose of the SPC is to identify and flag any information contained within an appraisal that falls outside of historical and/or known levels of acceptability. The SPC will only guide the reviewer, who is the final judge about the acceptability of an appraisal.

The appraisal reviewer then performs the review and decides if any of the flagged data need correction, verification, or analysis by the appraiser. If the information contained in the appraisal in its current form is deemed acceptable and approved by the appraisal review process, the appraisal is transmitted to the permanent electronic appraisal database for storage. Only those appraisals accepted by the appraisal review process are uploaded to the permanent electronic appraisal database. Appraisals stored in the database may be accessed only by personnel authorized by the DOT for later use. At all times, all appraisals stored in the permanent database are available to authorized R/W personnel to perform various analyses and to generate summary information. This summary information may be viewed on personal computers and printed.

After the conception of the framework for the EAS, it was necessary to generate the functional needs and capabilities that are required by the users of the proposed EAS. The users of the system comprise the appraisers, the reviewers, and the R/W administrators. As can be imagined, each user type has a specific requirement and performs various functions. The Appraisal Form is the first component of the user functional needs. It should be expandable and include all of the primary sections (such as neighborhood analysis and value of the property). A cover page with essential information, such as the certification of the appraiser and executive summary, should be included in addition to the identification and justification of the valuation approaches used during the appraisal process. For security purposes, the electronic appraisal form must contain a mechanism for applying an electronic signature via login IDs and passwords. Navigation and control mechanisms should be provided to ensure that all of the required data fields are completely filled with valid data. Error handling can be done at the frontend (on the user page) using Java Script, or on the backend (on the server) using computer programming technologies such as PHP, Perl, ASP, JSP, and ColdFusion. Every time the user clicks on the "Next Page" button, the system will check the mandatory data fields before proceeding to the next page. Data/file transmission comes second in the user functional needs. The system should have a mechanism to retain a copy of the original acceptable appraisal in the database, and be able to automatically send reviewers' comments back to the appraiser and corresponding district R/W office. Also, a quality control mechanism for the appraiser must be provided to review the submittals to ensure that all data fields are completely and accurately filled. As discussed earlier, the queue database should be accessible to the appraisers, the reviewer, and corresponding R/W personnel with controlled privileges, with only the appraiser having the capacity to edit an appraisal. The reviewer will be provided with the feature to send his/her comments to the appraiser and relevant DOT personnel. In the approval process, the system must have the capability to approve the appraisal online with the support of the electronic appraisal review form. E-mail notification of the approval should be sent to the appraiser, the reviewer, and R/W acquisition consultant(s). Access to the permanent appraisal database should be restricted to personnel authorized by DOT. The permanent database should provide a mechanism to conduct the various queries based on attribute information (appraisal number, property address, owner name, appraiser name, or combined keywords). This will help DOT personnel to quickly get the relevant information about a specific appraisal or a group of appraisals along a corridor.

The User Functional Needs as discussed above cannot be fulfilled without the appropriate support of adequate data. Hence, it was necessary to produce a list of data requirements that were required to be collected by the appraiser in order to use the proposed EAS to support making a sound and a judicious decision about the value of the property. To meet that objective, a detailed list of the data requirements was prepared. The list also contained the format in which the data would be provided in the appraisal (e.g., categorical, text). The primary reason for this fixed format of data collection was to standardize the entire process. By standardizing the data, it was now possible to use the data for statistical analysis. As mentioned earlier, this list of data requirements was sent to the DOTs as a part of the survey for their ratings. Only the data elements which received an average rating of 3 or more were retained in the final version of the list of data requirements. An excerpt from the final version of the Data Requirements is provided in Table 2.

Table 2: Excerpt From the Data Requirements of the EAS

5.7 Adjustment Explanation				
5.7.1	Financing Terms	Text	Text Box	4.66
5.7.2	Conditions of Sale	Text		4.77
5.7.3	Date of Sale (Market Conditions)	Text		4.77
5.7.4	Location	Text		4.77
5.7.5	Physical Characteristics	Text		4.77
5.7.6	Size	Text		4.77
5.7.7	Utilities	Text		4.77
5.7.8	Zoning	Text		4.77
5.7.9	Others	Text		4.77
5.7.10	Concluding Remarks	Text	Comment Box	4.88
5.7.11	Maps	Maps	Box	4.55

MECHANISM OF STATISTICAL PROCESS CONTROL

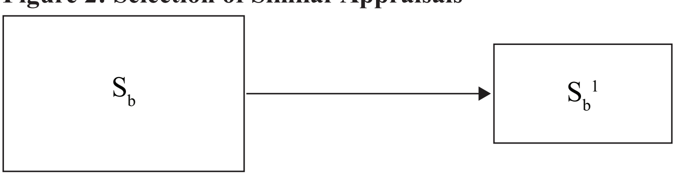
SPC is a methodology that is widely used in manufacturing and financial industries and is making inroads in the appraisal industry. It is a method that allows users to separate random variations,in their data from nonrandom variations and then to analyze the nonrandom variations to improve the quality and reduce the cost of products. SPC is a control philosophy concerned with continuous process improvements using a collection of tools for data and process analysis and making inferences about process behavior. SPC is a key component of total quality initiatives. In the appraisal industry, there are several different interpretations of this technology. Therefore, the development of an SPC mechanism for the EAS proposed in this project is a complex task.

There are several techniques that could be used to implement an SPC mechanism for the proposed EAS. The statistical analysis method was chosen because it is one of the most widely used. One example of an SPC mechanism for this project is a very simple process in which the data entered by the appraiser are compared with the range of values that are possible for that data entry. Simple statistical analysis is carried out to determine the mean of the values that are available from similar appraisals. The lower limit (LL) and the upper limit (UL) for the expected property value are found using an acceptable range based on historical data (Berger 1986). When an appraiser submits his/her data, the SPC mechanism compares the value entered by the appraiser with the range of values that are generated based on other similar appraisals. If the observed value, i.e., the value entered by the appraiser in dollars per square foot ($/SF), is within the acceptable range, this value is considered "consistent" and is not flagged by the SPC. Conversely, if the value entered by the appraiser is outside this limit, then the value is deemed "inconsistent." Such a data entry will be flagged by the SPC mechanism to alert the appraisal reviewer about possible inconsistencies in the appraisal.

The SPC mechanism as envisioned for the EAS is described as follows:

Let S_b be the group of appraisals in the database. $S_b = \{B_1, B_2, B_3 \ldots\ldots\ldots B_n\}$ where B_1, B_2, B_3 are the appraisals. Also, the appraisals consist of various attribute data, such as property type and size, among others. The appraisal value is a function of these attributes. Consider the appraisal under review. Let it be B_x. Now, $B_x = f(a_1, a_2, a_3 \ldots\ldots a_n)$. For the SPC mechanism, the procedure would be to identify appraisals from S_b that have attributes very similar to B_x. As Figure 2 illustrates, S_b^1 is the sub-group of S_b consisting of appraisals that are a function of similar attributes. Thus a good measure for comparison can be obtained.

Figure 2: Selection of Similar Appraisals



To identify similar appraisals, the process of data clustering is used. Data clustering is an unsupervised classification of data items into groups based on some measure of similarity (Jain and Dubes 1988). There are various available algorithms to cluster the data. One of the most commonly used algorithms is the K-Means method (MacQueen 1967). The K-means method is also one of the most efficient methods for data clustering. Although other more complicated and advanced clustering methods were investigated during this study, K-means was deemed as better suited for the purposes of this research.

K-means clustering is an iterative method. It is a type of partitional clustering method where the data are clustered into "K" clusters specified by the user (Webb 2002). It assigns each object to the cluster whose centroid is the nearest. The centroid is the average of all the objects of the cluster.

It is usually based on the squared error algorithm. The basic steps of the algorithm are to randomly generate k cluster centroids, assign each object in the dataset to the centroid that is nearest to it, recalculate the centroid of the clusters, and then repeat until the assignment remains unchanged. The main advantage of this clustering method is that it is very straightforward. It is fast and can be used with acceptable levels of accuracy on large datasets. The major disadvantage of this method is that the resulting clusters depend on the initial choice cluster centroids. This leads to the generation of different results on repeated running of the algorithm.

The clustering technique was incorporated into the EAS. Before starting the process, the key was to identify the attributes that would be used to cluster the data. The attributes selected to cluster the data came from diverse fields based on experts' opinions. These include the attributes dealing with the property compensation, attributes of area and neighborhood, and the highest and best use of the property. The list of attributes selected for data clustering are presented in Table 3.

Table 3: List of Selected Attributes for Data Clustering

S. No	Attribute	Data Type
I.	***Compensation***	
1	Market value of the whole property	Continuous
2	Market value of the part to be acquired	Continuous
3	Land value	Continuous
4	Net damages	Continuous
5	Net enhancements	Continuous
II.	***Area, Neighborhood and Whole-Site Analysis***	
1	Total acre	Continuous
2	Acquired acre	Continuous
3	Improvement age	Continuous
4	Setting	Categorical
5	Shape	Categorical
6	Access	Categorical
7	Distance from Central Business District (CBD)	Continuous
8	Frontage	Categorical
9	Topography	Categorical
10	Corner plot	Categorical
11	Soil conditions	Categorical
III.	***Highest and Best Use***	
1	Property type	Categorical
2	Highest and best use as "vacant"	Categorical
3	Highest and best use as "improved"	Categorical

Before clustering the data into their respective clusters, some data preparation is required. In view of the fact that some of the attributes selected for data clustering are categorical in nature, dummy variables are created for each of the individual categories. Also, because the scales of the various attributes are significantly different, the standardized scores (z-scores) for the attribute data are computed to avoid bias towards the attributes with large values. The z-scores are calculated using the following equation:

$z = (X-\mu)/\sigma$

where

z - Standardized score

X - Raw data value

μ - Mean of the population

σ - Standard deviation of the population

As part of the data preparation, appraisals will be represented as points in a multi-dimensional space. Therefore, distances between these points can be calculated. Once the data preparation stage is complete, clustering can be undertaken. For the SPC, a variation of K means clustering has been developed. The procedure is diagrammed in Figure 3 and presented as follows:

Step 1: Initialize the mechanism.

Step 2: Select the first appraisal and let it be the centroid of the first cluster.

Step 3: Select another appraisal.

Step 4: Calculate the distance between the point representing the latest appraisal and all the other cluster centroids.

Step 5: If the distance is greater than the threshold distance, make the second appraisal as the centroid of the next cluster, or add the appraisal to cluster nearest to the appraisal and recalculate the centroid (mean) of the cluster.

Step 6: Repeat step 3 through step 5 till no appraisal remains.

Step 7: End.

To protect the integrity of the mechanism, the clusters obtained during the initial run of the mechanism are stored. Henceforth, whenever the SPC process is initialized, the mean values for these clusters serve as centroids for the clustering iterations. This method has the added advantage of reducing the number of data points to be clustered, thus making the process less time consuming. Once the clusters are obtained, statistical information for the appraisals that belong to the cluster to which the appraisal under consideration belongs can be calculated. These values are provided to the reviewer to assist him/her in the appraisal review process. A sample result obtained from the SPC mechanism is shown in Figure 4. As can be seen from the figure, the circle-shaped dot on the graph represents the subject property. The upper and the lower limits are calculated as the second standard deviations of the distribution curve. This curve is generated under the assumption that the appraisal values in the clusters are normally distributed.

Analyzing the sample result, it can be seen that the land value provided by the appraiser for the subject property is $2 per square ft (SF). The upper limit is $14/SF and the lower limit is $0/SF. Hence, the appraised value lies within the range of recommended values and is thus deemed "consistent." The reviewer is also provided graphs for the Market Value for the Whole Property and Total Compensation in order to support the reviewing process.

PROTOTYPE OF THE ELECTRONIC APPRAISAL SYSTEM

After the framework and the requirements of the proposed EAS have been discussed, the next step was proving the applicability of the proposed EAS and demonstrating its capabilities by developing an EAS prototype. The steps were to come up with a development plan specifying the various components and features of the prototype, the design of the prototype, and the prototype testing underlying the tests carried out to ascertain the proper working of the prototype.

The prototype of the EAS is a web-based system. It essentially has the following components: a login system, an appraisal form, a temporary queue database, a permanent database, and an

Figure 3: Flow Chart of Clustering Mechanism

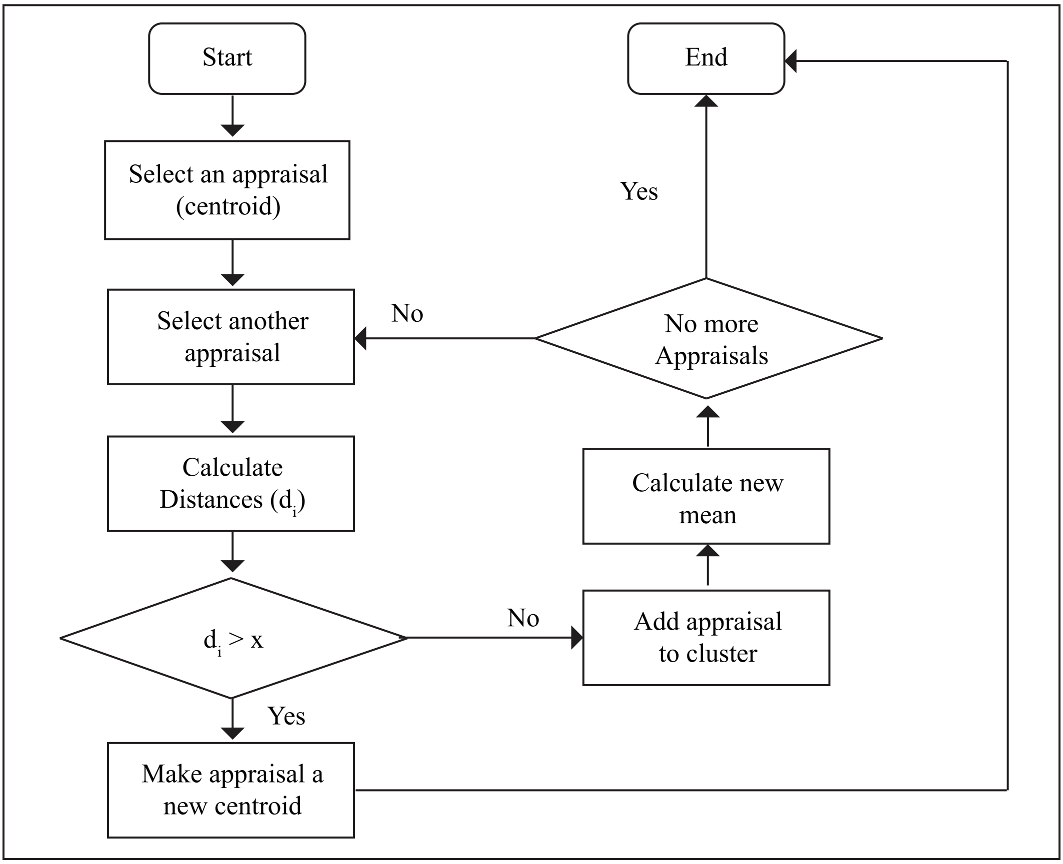
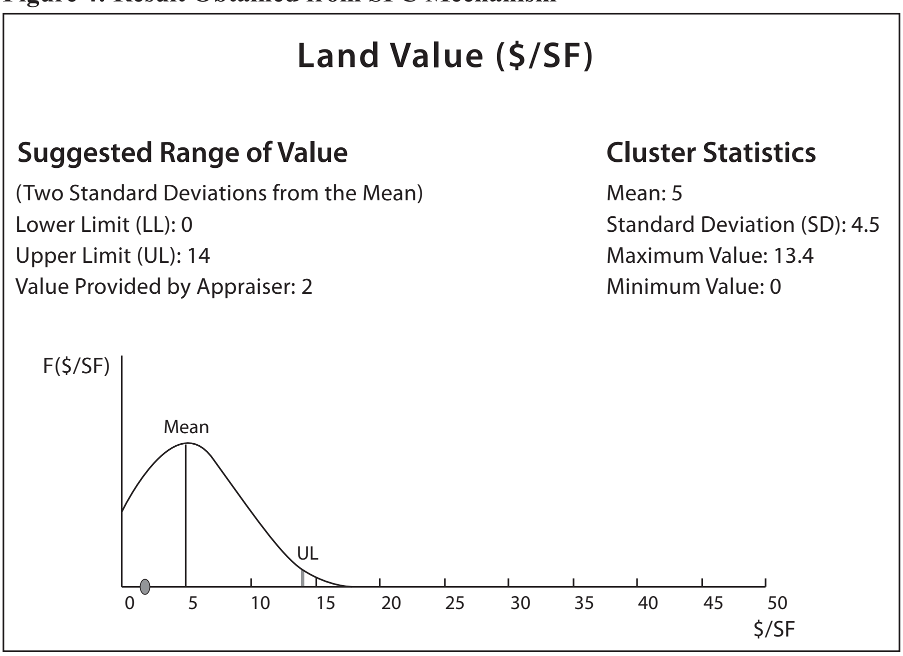


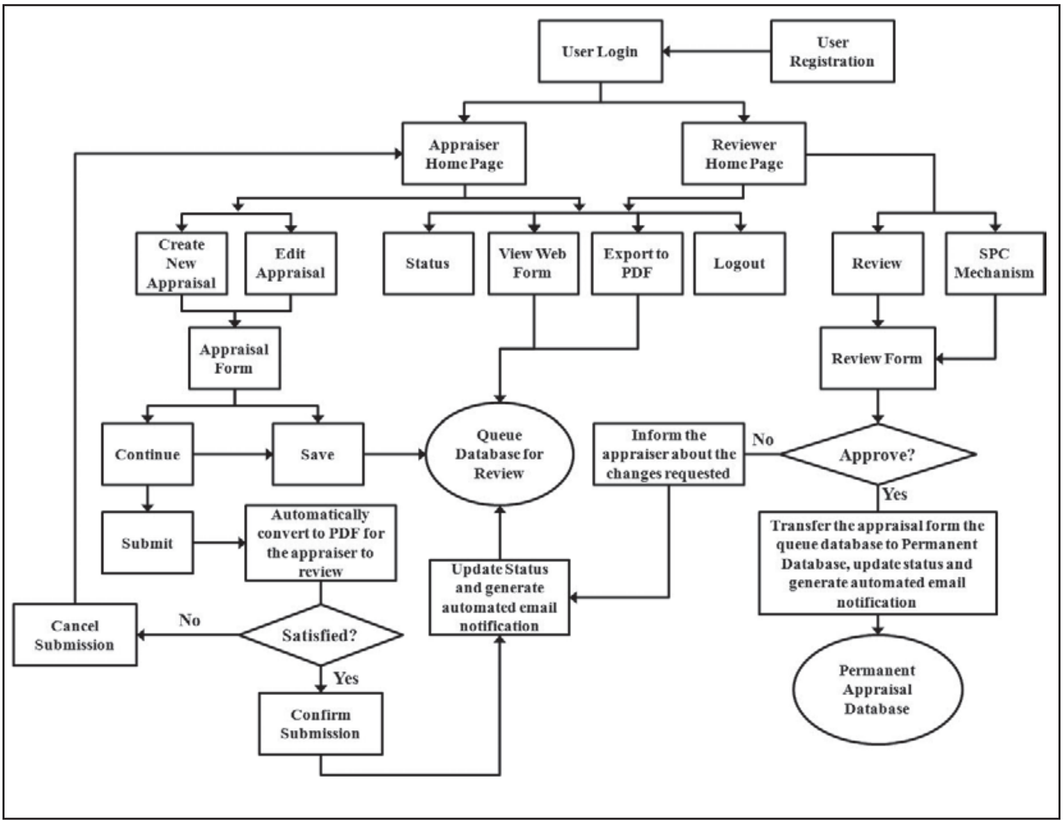
Figure 4: Result Obtained from SPC Mechanism



SPC mechanism. PHP, a programming language that is commonly used for developing web-based applications, was used for the backend generation (server side) of the appraisal form and for submitting the data to the database. It was also used for creating a secure login system and to run queries on the database. Java script was used for the frontend (client side) development of the dynamic electronic forms. The databases were developed using MySQL (W3Schools 2004). The SPC mechanism was established through statistical analysis and database queries.

The design of the structure and relationships were built on a close interaction among the various components of the prototype. Figure 5 shows the interaction and relationship between components. When the user first accesses the system, he/she is requested to register. The user will be directed to the login page to login into a system. Upon successful login, based on the user type, the appraiser home page or the reviewer home page will be loaded.

Figure 5: Relationship and Interaction Among Components



The appraiser home page and the reviewer home page have some common links. Both the appraiser and the reviewer are provided with the option of checking the status of a particular appraisal. The appraisal appears on the reviewer's home page only when the appraiser formally submits the appraisal report. Another common feature is the ability to view the appraisal report in PDF format or as a web page. Apart from these shared features, the appraiser also has links that enable him/her to create a new appraisal and to edit an existing appraisal. To accomplish this feature, the user is provided access to the electronic appraisal form. The appraisal form provides the appraiser the opportunity to complete the appraisal in stages. When the appraiser submits the appraisal form, a PDF version of the appraisal is automatically generated, providing the appraiser with an opportunity to completely go through the appraisal report and verify its contents. If the appraiser is satisfied, he/she can formally submit the appraisal report. If not, he/she can cancel the submission and edit the appraisal before resubmitting the same. If the appraisal is submitted, it will be saved in the queue database and an email will be sent to all parties involved in the appraisal informing them of the submission. The appraisal now appears on the reviewer home page as well.

The reviewer's home page has the additional options of reviewing the appraisal and initializing the SPC mechanism apart from the options that are common to the reviewer and the appraiser. In the review process, the reviewer will have the ability to comment on the appraisal report and finally approve/request changes/not approve the appraisal. The SPC mechanism can be initialized by the reviewer. If the reviewer approves the appraisal, the appraisal is transferred from the queue database to the permanent appraisal database and an automated e-mail is generated informing all the parties involved about the approval. If the appraisal is not approved or if changes are requested, the concerned appraiser will be sent an e-mail informing him/her about the changes requested and the appraisal will be retained in the queue database. In either case, the status of the appraisal is updated, which will be reflected on the user home page.

Once the architectural design and the module design were completed, the prototype development was undertaken. The development of the prototype was per the designs made in the earlier steps. During the development process, close communications with the state DOTs was maintained for their feedback, and this information was suitably integrated into the prototype development. After the prototype was developed, it was tested internally and evaluated with typical R/W appraisals to ensure that it had the robustness to demonstrate the requirements. The tests were carefully planned and executed to ascertain a good quality product.

One of the tests ensured that the logging system differentiated between the privileges being offered to the appraisers, reviewers, and system administrators. After successfully logging into the system, the appraisal form was next tested to ascertain if its length was consistent with the appraisal type selected by the appraiser, to ensure that data could be saved at any time, and to make certain that the visuals and plats could be included in the appraisal as pictures. Since this appraisal information provided by the appraiser is in HTML, its conversion to a PDF format was then verified. Next, the system was tested to validate the submission mechanism by confirming that after successfully submitting the appraisal, a message was received by the appraiser and all concerned parties. Subsequent messages concerning notifications of appraisal status were also verified. Then, in order to check the effectiveness of the SPC mechanism, it was run on a control dataset with a known number of clusters. To test the transferal of approved reports from the temporary to a permanent database, a report was accepted online and verified that it was moved. The final test involved conducting queries from the permanent database to generate summary information of importance to DOT R/W personnel.

After successfully conducting the aforementioned tests internally, the prototype was demonstrated to representatives of several DOTs where it was determined that the final prototype of the EAS is user-friendly. The features provided are easy to comprehend, navigate, and use. Moreover, the prototype developed is both realistic and sensible. It has the features that are required and useful for producing quality appraisals. Maintainability is assured by easy and straightforward means and mechanisms for system maintenance. The prototype is also flexible, such that it can be used for different types of appraisals and for future modifications as needed. The system is agile enough to accommodate any future needs.

IMPLEMENTATION RECOMMENDATIONS

The demonstrations to the DOTs, however, indicated further steps that should be taken in order to move from the prototype version of the EAS to an operational version. After all, since the prototype was built to demonstrate the key features of the proposed EAS, it was designed with limited functionalities. In order to move the system beyond the prototype, various components of the EAS must be refined, such as improving the PDF conversion mechanism and the quality control mechanism for data entry. Also, allowing an appraiser to specify the number of non-photograph visuals (such as maps and plats) that he/she might provide, and to use an existing appraisal as a template while creating an appraisal for a similar property, are beneficial features not included in the prototype. Thus, the development of an operational EAS can be accomplished by first fine-tuning the system and then through the following additional work: customize the system to meet the specific needs of the individual DOTs, improve the system's security, populate the system with real appraisals to test key functions, implement a pilot study for the system, and finally transfer the technology to the DOT. By following these recommendations, an operational version of the EAS can be developed for states that are interested in implementing an electronic appraisal system.

RECOMMENDATIONS FOR FUTURE ADVANCEMENTS

Although the EAS developed as part of this research is an advanced system, opportunities for further enhancements to the EAS still exist. There are several recommendations for future advancements to the EAS. There is an enormous scope for the introduction of GIS applications in the EAS. GIS can be used to map the parcels along the corridor. Moreover, the SPC mechanism provided in the prototype of the EAS is a sophisticated system, but scope for further improvements remains. Finally, the EAS can be made more robust and user-friendly by introducing a host of other features. A distance calculation tool can be provided, particularly in cases of urban cities, which could automatically calculate the distance from the parcel to the central business district, or the nearest freeway. Also, the same logic could be used to locate the zoning for the area, the school district, or the FEMA map number. This information could then be automatically filled into the appraisal forms. The appraiser should still have the flexibility of providing this information manually.

CONCLUSIONS

Most of the state DOTs currently use a paper-based property appraisal system. These processes are arguably ineffective and laborious and provide ample opportunities for divergence in appraised values. In order to overcome some of the deficiencies of the traditional methods of R/W acquisition, there has been a widespread desire to move towards an electronic appraisal process. An earnest endeavor has been made through this research towards the development of an EAS.

This research study makes significant contributions in solving many problems that are associated with the current practices of R/W valuation and acquisition. First, the data required for a complete and competent appraisal were specified, thus offering a solution to one of the primary causes for divergence in R/W valuation. The list of data requirements prepared as part of the research is based on a consensus among experts from several DOTs, which was formed using the Delphi Approach. Moreover, a conceptual framework and a list of user requirements were developed. In addition, this project has developed an SPC mechanism, which helps the reviewer in recognizing inconsistent appraised values. The developed system reduces the likelihood of condemnation hearings for acquiring the properties. It also improves the purchasing power of the state DOTs. The EAS minimizes the time delay in conveying messages from the reviewer to the appraiser, as well as the R/W administrators. Afterwards, a prototype of the EAS was developed to demonstrate the salient features and attributes of the proposed EAS. Because the EAS is a web-based system, it offers flexibility to the system users. The prototype exhibits the qualities that are desirable in any appraisal system. It offers a secure, professional, and well-organized platform for the appraisers to submit their appraisal reports and for the DOT staff to review and accept the reports while maintaining proper communication among them.

Acknowledgements

The authors would like to thank TxDOT and the other state departments of transportation that provided financial support for this project. Thanks to all right-of-way experts that contributed to this study. A special thanks to Nadeem Moulvi, Zach Piepmeyer, and Liang Liang for their work on this project while pursuing their degrees at The University of Texas at Austin.

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Electrified Vehicle Technology Trends, Infrastructure Implications and Cost Comparisons

by David P. Tuttle and Kara M. Kockelman

Alternatives to petroleum-based fuels for transportation are sought to address concerns over climate change and energy security. Key semiconductor, software, and battery technologies have sufficiently progressed over the past few decades to enable a mass-market-viable plug-in electric vehicle (PEV) alternative. In this paper, the various PEV architectures are described, including market availability, technologies and trends, practical ranges, battery replacement and power costs, implications for grid operations, and other developments. Manufacturers' recently announced prices and EPA standardized test data are used (where available) to increase the accuracy of cost comparisons for competing vehicles. Results indicate that in relatively low fuel-cost regions, like the U.S., PEVs enjoy a positive discounted net present value, thanks to tax credits and assuming that the original battery does not need replacement by the owner. Even without the tax credits, PEVs offer financial payback for those residing in higher fuel-cost regions, as long as their batteries last the vehicle's lifetime or are replaced by manufacturers (under warranty).

BACKGROUND

The motivations for developing alternative energy sources and associated vehicle powertrains[1] is to reduce a widespread dependence on oil (particularly foreign oil), imported oil-driven trade deficits (with oil imbalances constituting close to half of the U.S.'s trade deficit, [U.S. BEA 2008]), oil-related costs (Greene 2010), and environmental concerns (including climate change and oil spills) while improving energy security and air quality (Siosanshi and Denholm 2008, Thompson et al. 2009, EPRI and NRDC 2007).

Vehicle manufacturers have an interest in developing emerging technologies to demonstrate leadership (and improve brand image), while ensuring long-range capabilities in key alternative fuel/powertrain technologies critical for success in global vehicle markets. These alternative powertrains may, in the end, be more pervasively deployed in non-U.S. markets even after being pioneered and/or first sold in the U.S. Long-term average U.S. gasoline prices have generally stayed under $3 per gallon, and do not reflect external damages (Delucchi and McCubbin 2010). While oil prices are likely to rise over the long term (ECB 2008, Deffeyes 2002), low fuel prices (both in the past and currently) have not encouraged consumer demand for highly fuel efficient or alternative-fuel vehicles, which then would encourage active investment by manufacturers. In fact, hybrid-electric vehicles (HEVs) have enjoyed less than 3% of new U.S vehicle sales (Green Car Congress 2010).

During the last few decades, advanced technology was deployed to increase power, performance, and vehicle size instead of fuel economy. A combination of relatively recent events has contributed to new investments in alternative fuel and efficient powertrain technologies. These include spot fuel shortages in 2005 from Hurricane Katrina, substantial oil and gasoline price spikes in 2008, the passing of more stringent corporate average fuel economy (CAFE) and emissions regulations, and Tesla Motors' demonstration of a high-performance long-range full-function battery electric vehicle (BEV). Several new vehicle options are emerging in the U.S. market, as described below. Moreover, several foreign markets have substantially higher gasoline and diesel prices, and thereby offer strong near-term (and long-term) incentives for alternative vehicle technologies to reduce the near- and long-term private and social costs of personal mobility.

The following section describes new and emerging vehicle options. It is followed by a cost comparison for U.S. and non-U.S. consumer choice settings, to highlight differences in financial paybacks across competing vehicle pairs. Various vehicle designs' strengths and limitations and power grid impacts are also discussed, followed by the paper's conclusions.

NEW VEHICLE OPTIONS

In 2010, mass-market-viable PEVs became available from several global vehicle manufacturers. A variety of PEV models are emerging, and it is useful to define these, while assessing their strengths and weaknesses. Essentially, grid-enabled or plug-in electric vehicles (PEVs) can be categorized as BEVs, extended-range electric vehicles (eREVs), and plug-in hybrid electric vehicles (PHEVs).

BEVs incorporate a large on-board battery, charged while parked via a cord to the power grid. This battery then wholly provides the energy for the electric traction motor to propel the vehicle. eREVs are BEV-derived vehicles with an on-board internal combustion engine (ICE) generator that provides electrical energy to the motor once the initial battery charge is exhausted. This configuration solves the classic "range anxiety" problem of a BEV (Markel 2010) by providing an overall range on par with a traditional gas or diesel vehicle. Once its initial charge from the grid is depleted, or if the vehicle is never plugged into the grid, the eREV should operate like a conventional HEV. PHEVs effectively are HEVs with larger batteries and a charging cord to access grid power. PHEVs typically operate in a "blended" mode, using the gas engine and electric motor together, to substantially reduce gasoline consumption while operating in battery charge depletion (CD) mode (Vyas et al. 2009). PHEVs also solve the range anxiety problem and should operate similarly to a traditional HEV if never plugged into the grid.

Range-extended (eREV and PHEV) architectures leverage the energy density of petroleum to solve the problem of range anxiety at the cost of incorporating a hybrid electric-gasoline powertrain. Along with the energy density advantage of petroleum, a pervasive refueling infrastructure is available when longer trips are taken. Range-extension capabilities enable the eREVs and PHEVs to serve as a U.S. household's primary or sole vehicle. This petroleum-based backup allows downsizing of the most expensive PEV component, the battery (as compared to a BEV), while providing a range on par with those of conventional and hybrid-electric vehicles.

Since most models are still emerging, there is not yet full public disclosure (and third-party testing) of technical details to definitively compare their differences. Nevertheless, recent EPA test results for the Chevrolet Volt and Nissan Leaf (used for their respective window stickers) are now available and used in these comparisons. Meaningful differences in design and operation of eREV and PHEV powertrain technologies exist (Tate et al. 2008), even if, from a user's perspective, they appear to operate the same. For example, eREVs are fully functional in electric mode across the entire operating range — from being stationary at a stop light to operating at maximum speed without any dependence on gasoline. This architecture may provide a marketing advantage by creating a product which satisfies drivers who desire to drive "petroleum free," even with a modest all-electric range (AER) while still having a gasoline backup generator (which comes online after the initial charge is depleted). An eREV owner could conceivably never put gas in the tank and simply use the vehicle as a BEV.[2]

PHEVs operating in blended or mostly electric mode have the potential to achieve impressive liquid fuel economy (over 100 mpg) for some travel distances while the battery is in CD mode (Vyas et al. 2009). Since the gas engine and electric motor work cooperatively to propel the vehicle, the motor may be smaller than that of a comparable eREV design. Blended-mode designs also enjoy a wide array of design strategies, to optimize the balance of battery size, weight, and cost, engine size, and overall efficiency. Such design options may reduce vehicle price, thereby encouraging sales volumes and economies of scale in production.

Without the gasoline engine running, the smaller PHEV motor size and reduced motor or battery-cooling capacity may limit top speeds below 62 mph and AER values to about 13 miles (Toyota 2010), depending on battery design and size, powertrain control algorithms, and other parameters. However, drivers with low-speed needs and short daily commutes may still find a PHEV can fulfill their desire to drive without consuming any petroleum and at a lower purchase price. Many will continue to refer to both eREVs and PHEVs simply as PHEVs, since the differences are likely to be subtle for many owners. Nevertheless, in an analysis of driving pattern data from a Southern California regional travel survey, Tate and Savagian (2009) concluded that PHEVs may rarely operate in EV mode over a full day's driving, while a majority of eREV drivers will experience a full day of driving without consuming gasoline.

BEVs have a relatively simple all-electric powertrain, which can reduce non-battery-related costs. Manufacturers also avoid the costs of emissions testing, certification, and warranties, since the vehicle has no tailpipe emissions. However, range limitations, greater battery weights, and longer charge times can be problematic in BEV vehicles. Without a range-extending back-up, BEVs also force a greater dependence upon public charging infrastructure, better trip planning by the driver, access to a conventional second car, or regular and modest-length commuting needs.

The advertised electric range for PEVs will be based upon a particular objective test cycle, such as the U.S. EPA's LA4/UDDS drive cycle (EPA 2010) for conventional vehicles. While these test cycles are useful for purchase comparisons, the effective ranges experienced in practice typically will differ from estimates stated on a new vehicle's required window sticker or on the U.S. government's official website (www.fueleconomy.gov). The actual electric range achieved by BEVs, in particular, will likely affect their adoption rate. The U.S. test procedures were updated in 2008 to reflect more realistic driving conditions, so official estimates have become more representative of owner-experienced fuel economies (EPA 2010). Over the short term it is expected that future advances in battery cost, capacity, and durability will result in the installation of smaller and, hence, less expensive batteries, to allow PEVs to reduce their initial cost disadvantage (as compared with conventional vehicles).

NEW VEHICLE DESIGNS

The Chevrolet Volt eREV, the Nissan Leaf BEV, and the $109,000 Tesla Roadster are the most popular PEVs available today. Tesla has created compelling performance BEVs with its Roadster and future Model S sports sedan. With the upcoming Ford Focus BEV, Ford CMAX Energi PHEV (a crossover utility vehicle), Mitsubishi iMIEV,and Toyota Prius PHEV, vehicle manufacturers appear to be targeting drivers seeking compact vehicles that dramatically improve fuel economy (while potentially permitting petrol-free travel). Plug-In America's evolving list of emerging (worldwide) vehicle models (http://www.pluginamerica.org/vehicles) notes whether a vehicle is available for purchase, under development, or a concept vehicle (with no committed production date).

A summary of the vehicles most likely to be available for near-term purchase in the U.S. — and with the greatest potential for market impact — can be divided into range-extended and non-range extended PEVs (i.e., BEVs). Table 1 describes key features of these various models (including estimates of the manufacturer's suggested retail price [MSRP] and state of charge [SOC] window, where SOC refers to the percentage of battery capacity that can be used to power the vehicle while maintaining long-term battery durability).

Table 1: PEV Details for Near-Term U.S. Sales

Make & Model	Release Date	Estimated Retail Price (after rebate)	Body Type	Battery Size (kWh)	Estimated State of Charge Window	All Electric Range (miles)
Range-Extended PEVs						
Chevy Volt eREV	2010	$33,500	4-door sedan	16	65%	25-50
Ford CMAX Energi PHEV	2012	TBA	4-door CUV	10	TBA	Est 30
Toyota Prius PHEV	2012	$29,500	4-door sedan	5.3	Est 70%	15 (at limited speeds)
Non-Range-Extended (BEVs)						
Tesla Roadster	2009	$101,500	2-door sports car	53	80%+	240
Nissan Leaf	2010	$25,250	4-door sedan	24	90%+	100
Ford Focus	2012	$31,700	4-door sedan	23	TBA	100
Tesla Model S	2012	$49,900 base	4-door sedan	42 (also 65 & 85kWh options)	80%+	160 (also 230 & 300 options)
Mitsubishi iMiEV	2011	$21,625	4-door sedan	16	TBA	100
Mercedes Smart Car ED	2012	TBA	2-door sedan	TBA	TBA	90

Note: All details shown here have been found at the manufacturer's websites: chevrolet.com, toyota.com, tesla.com, nissanusa.com, ford.com, mitsu-motors.com, and smartusa.com. Volt, Leaf, Focus, and iMiEV prices are after a federal $7,500 tax credit and the Prius-PHEV reflects a $2,500 tax credit (for the first 200,000 such vehicles sold in the U.S. by each manufacturer). All range-extended PEVs evaluated here are gasoline fueled (in order to meet strict U.S. particulate matter emissions standards).

THE MARKET FOR PEVS

An area of considerable debate is the projected PEV adoption rate (e.g., Vyas et al. 2009 and KEMA 2010). For example, KEMA's (2010) aggressive forecast meets the goal of one million U.S. PEV sales by 2015, and its slow case hits the one-million-units target in 2019. The KEMA penetration curves are based on the Prius experience, with an increase due to fleet introductions after initial market entry in 2012.

The PHEV adoption rate could be less than the HEV adoption rate over the past 10 years (dominated by the Toyota Prius), due to additional complexities involving grid charging, higher purchase costs (though lower operation costs), less certain technologies (e.g., battery life), and more uncertainty regarding long-term maintenance costs and support. Conversely, the adoption rate could be far greater than that of the Prius HEV, given gas price jumps, rising fuel economy requirements, climate change legislation, and other factors.

Since range-extended PEVs operate similarly to conventional HEVs — even if never plugged into the grid, they are a natural successor to advanced HEVs. Additionally, the potential of driving "petroleum free" is alluring to some, and perhaps many. Avoiding the risks of oil supply disruptions and price spikes, and helping mitigate concerns over oil-related environmental, security, and economic concerns, may outweigh the effort required for almost-daily charging for many potential owners. Some may also prefer the convenience or safety of home refueling instead of stopping at the gas station. Such factors may well lead to a U.S. PEV adoption rate that matches or exceeds that of the Prius HEV over the past decade. Concerns over the actual range achieved by drivers in different climates on different highway types, under different topographical conditions and speeds, may also impact adoption.

Total U.S. year 2020 PEV market share projections similar to HEV sales — with approximately 2.5% market share (Vyas et al. 2009) — may well be achieved if manufacturers avoid serious early technology safety and quality problems. Battery thermal management and durability are a clear risk, especially for the deep cycled and conductive-cooled battery packs that Nissan will be incorporating into its aggressively priced Leaf. PEV sales may increase more rapidly if manufacturers expand their product offerings over the next decade to include a greater diversity of PEV platforms, such as minivans and sport utility vehicles, or performance PEVs — ideally all with targeted marketing to highlight the positive social externalities (and personal benefits) or attractive driving experience of PEV ownership.

When PEVs use their electric motors to save petroleum consumption costs, they are obviously consuming electricity. The average retail residential price for electricity is \$0.1175 per kWh in the U.S. (EIA 2001). The cost of the electrically driven miles traveled will vary by vehicle, driver, location and season. To gain a rough estimate of the cost, the Chevrolet Volt will nominally consume 10.9 kWh to travel 30 miles, with a resulting electricity cost of \$0.0423 per mile (GM 2010). Assuming a comparable conventional vehicle achieves 28 mpg, a gasoline price of \$3.00 per gallon yields a cost of \$0.107 per mile (or two and a half times higher than electrically driven miles).

According to a recent Pacific Northwest National Laboratory study (Kintner-Meyer et al. 2007), with only modestly well-behaved charging (i.e., mostly off-peak times of day), the existing U.S. grid can support a 70% shift in light duty vehicle design, to PHEV status. Avoidance of extreme-peak charging of PEVs (during, for example, late afternoon on a hot summer day) can be met with relatively simple driver-programmed charge window settings and by lower night-time energy prices to encourage off-peak charging. Some local distribution transformers may need to be upgraded when stressed by PEV clustering (KEMA 2010), similar to upgrades following advances in home appliances 60 years ago, introduction of air conditioning systems 40 years ago, and rising electronics loads 20 years ago.

FINANCIAL ANALYSIS OF COMPETING PEVs AND COMPARABLE CONVENTIONAL VEHICLES

As U.S. and other consumers now enjoy the choice of a BEV and eREV, full-cost accounting becomes a factor in new-technology adoption rates. There are many factors to consider beyond base price and fuel costs. The durability of PEVs' advanced lithium batteries is a justifiable concern, given the technology's relative immaturity. A total-cost-of-ownership analysis should also include likely maintenance or repair costs and potential battery replacement costs.

A key assumption for asset payback comparisons is lifetime use, or vehicle miles traveled in the case of PEVs. A National Highway Traffic Safety Administration report (Lu 2006) finds average U.S. personal-vehicle lifetimes of 156,000 miles. This average lifetime is skewed high by pickups and SUVs, which tend to be used over more time and for greater distances (and thus average closer to 180,000 lifetime miles). Mid-size and compact cars, such as these PEVs and their conventional twins, typically are used less. To reconcile such statistics, the following calculations assume consumers evaluate range-extended PEVs (like the Volt eREV and the Prius PHEV) over a 15-year, 150,000-mile horizon (typical of the average U.S. light-duty vehicle). Given their shorter range and longer charge times, BEVs are likely to achieve higher adoption rate among households with lower-distance needs. The BEV analysis thus assumes a 15-year, 100,000-mile life. Included in the cash flow are estimates of expected maintenance costs from interviews with Chevrolet, Nissan, and Toyota service managers. While informal, such data provide insight and fairly accurate estimates on the differences in relevant costs. For example, HEV experience suggests that vehicles with regenerative braking exhibit substantially less brake wear than their conventional counterparts. Many Prius owners never experience the need for expensive brake service. This analysis assumes that the front and rear brakes are replaced at 40,000- and 60,000-mile intervals, respectively, on conventional vehicles. These assumptions imply that the comparable conventional vehicle will require three sets of front brakes and two sets of rear brakes over the 150,000-mile lifetime. For the BEV comparison, the Nissan Versa was assumed to have two front brake replacements and one rear brake replacement over its 100,000-mile lifetime.

Chevrolet and Nissan have both announced eight-year/100,000-mile battery warranties on their respective PEVs. For this analysis, if a battery is replaced, it is expected to occur during the ninth year, immediately after the warranty expires, which is a conservative assumption (in favor of conventional vehicles). Given the likelihood of second-use applications for such batteries (e.g., grid power and computer backup power storage devices) and falling battery costs (thanks to scale economies in production and accelerating competition), net replacement costs may lie close to Argonne National Laboratory's recent higher volume projection of $150/kWh (Santini et al. 2010). Continued improvements in battery energy density are expected over time. These improvements can be applied to achieving greater range or reducing ownership costs. If customers indicate a satisfaction with 73 to 100 miles of AER, future battery packs may be smaller with fewer cells, and therefore less expensive.

This paper provides the net present values (NPVs) of the differences that will emerge in cash flows for a PEV relative to its conventionally fueled counterpart. A positive NPV should be interpreted as follows: the higher initial PEV purchase price is fully offset by the future savings from lower operating and maintenance costs. A negative NPV implies that the future savings do not offset the higher PEV purchase price. NPV calculations involve standard accounting equations to find the present-day value of a series of current and (discounted) future costs (and revenues or other benefits, when those exist). Since future gasoline and lithium battery prices are unknown, NPV values were computed for each PEV/conventional vehicle comparison over a wide range of price assumptions, as shown in Tables 2 through 5. Table values illuminate the impact of higher or lower fuel prices and battery replacement costs on the net, long-term monetary benefits of buying a PEV over a conventional vehicle. As one would expect, higher gasoline prices and lower battery replacement costs result in a higher NPV of a PEV over its conventional counterpart.

Table 2's values assume a 5% discount rate and 100,000-mile vehicle lifetime for the Nissan Leaf BEV over its comparably equipped conventional twin, the Nissan Versa. With the $7,500 federal tax credit included and no battery replacement required, the NPV remains positive for gasoline priced as low as $2.75/gallon. The BEV Leaf avoids not only brake replacement costs but also regular oil and filter changes, which should generate greater savings for its owners. By looking at NPV entries in Table 2 close to $7,500 (the assumed tax credit), it can be deduced that without a tax credit, the Leaf is estimated to offer cost savings (i.e., have a positive NPV) at gasoline prices between $5.50 and $6/gallon (again assuming no battery replacement). If battery replacement is required post warranty, the break-even gasoline price (where the Leaf offers no long-term owner savings or cost over the Versa) is estimated to increase by approximately $0.66/gallon for each $100/kWh increase in battery replacement cost, as implied by pairs of similar values in Table 2, including the two values that are underlined. For example, the paired values of $1,969 and $1,927 suggest that for a $100/kWh increase in battery replacement cost, the gasoline price must rise approximately $0.66/gallon ($3/4.5) to maintain the same NPV.

Similar calculations (not shown here, due to space limitations) with a discount rate of 10% (common among relatively myopic consumers) reduces the benefit of the BEV's future fuel and maintenance savings (but also battery replacement cost implications) such that the NPV becomes slightly negative (-$932) with the tax credit in place and gasoline at $3.00/gallon. When discounting at 10%, a gas price of about $8 per gallon (still below that in many EU countries) is required for the Leaf to break even with the Versa (i.e., zero NPV) without any tax credit and with a relatively low lifetime VMT (100,000 miles, as stated earlier and noted in the table).

Given its lower travel-distance assumptions, the Leaf's fuel and maintenance cost savings are reduced; 100,000 miles over 15 years averages to less than 19 miles per day, well below the 100-mile nominal range (and below its worst-case harsh-weather range). If this short range does represent the typical driving pattern, then this very low reliance on the battery's capacity could lead to far lower stresses and failures and contribute to greater durability and battery life. If the miles driven are increased, the fuel and maintenance costs savings over the conventional Versa also increase, improving the NPV for the Leaf (Table 3). A lowest-cost scenario would maximize miles driven while avoiding battery replacement. Noting that the eight-year/100,000-mile battery warranty expired from age (not mileage) after eight years, one may expect the battery to last the 15-year/100,000-mile life of the vehicle (since the battery is lightly stressed).

Table 2: Net Present Values of Nissan Leaf Over Nissan Versa (100,000-mile lifetime)

	Replacement Battery Price (per kWh)				
Gasoline Price ($/Gallon)	$0 No Battery Replacement	$150	$250	$350	$450
$7.00	$10,042	$7,721	$6,174	$4,627	$3,080
$6.50	$8,889	$6,568	$5,021	$3,474	<u>$1,927</u>
$6.00	$7,735	$5,415	$3,868	$2,321	$774
$5.50	$6,582	$4,262	$2,715	$1,167	($380)
$5.00	$5,429	$3,108	$1,561	$14	($1,533)
$4.50	$4,276	$1,955	$408	($1,139)	($2,686)
$4.00	$3,122	$802	($745)	($2,292)	($3,840)
$3.50	<u>$1,969</u>	($352)	($1,899)	($3,446)	($4,993)
$3.00	$816	($1,505)	($3,052)	($4,599)	($6,146)
$2.50	($338)	($2,658)	($4,205)	($5,752)	($7,299)

Note: The underlined, similar values of $1,927 and $1,969 are used to estimate a value for the increase (or decrease) in gas prices needed to maintain a similar NPV given a higher (or lower) battery replacement cost. Assumptions: 5-% (real) discount rate; 100,000 miles over 15 years; Versa: 30 miles/gallon; Leaf: 73-100 miles AER, 2.94 miles/kWh (electric); 6,667 miles/year; electricity cost: $0.1175/kWh; battery replacement in year nine (after eight year warranty's expiration); 2011 Leaf price of $25,280 (after $7,500 U.S. federal tax credit); 2011 Versa at $19,840 (comparably equipped to Leaf); Terminal values of both vehicles assumed equal.

Table 3: Net Present Values of Nissan Leaf Over Nissan Versa (150,000-mile lifetime)

	Replacement Battery Price (per kWh)				
Gasoline Price ($/Gallon)	$0 No Battery Replacement	$150	$250	$350	$450
$7.00	$18,128	$15,807	$14260	$12,713	$11,166
$6.50	$16,398	$14,077	$12,530	$10,983	$9,436
$6.00	$14,668	$12,347	$10,800	$9.253	$7,706
$5.50	$12,938	$10.617	$9,070	$7,523	$5,976
$5.00	$11,208	$8,888	$7,340	$5,793	<u>$4,246</u>
$4.50	$9,478	$7,158	$5,611	$4,063	$2,516
$4.00	$7,748	$5.428	$3,881	$2,333	$786
$3.50	$6,018	$3,698	$2,151	$604	($944)
$3.00	<u>$4,288</u>	$1,968	$421	($1,126)	($2,673)
$2.50	$2,558	$238	($1,309)	($2,856)	($4,403)

Note: The underlined, similar values of $4,246 and $4,288 are used to estimate a value for the increase (or decrease) in gas prices needed to maintain a similar NPV given a higher (or lower) battery replacement cost. Assumptions: 5% (real) discount rate; 150,000 miles over 15 years; Versa: 30 miles/gallon; Leaf: 73-100 miles AER, 2.94 miles/kWh (electric); 6,667 miles/year; electricity cost: $0.1175/kWh; battery replacement in year nine (after eight year warranty's expiration); 2011 Leaf price of $25,280 (after $7,500 U.S. federal tax credit); 2011 Versa at $19,840 (comparably equipped to Leaf); Terminal values of both vehicles assumed equal.

Table 4 contains the NPVs calculated using a 5% discount factor for the Chevrolet Volt over its comparably equipped conventional twin, the Chevrolet Cruze. With the $7,500 tax credit included and no battery replacement required, its NPV becomes positive when gas costs $3.00/gallon or more and reaches a maximum at $7.00/gallon (the highest gas price assumed here, and relatively common abroad). As with other PEVs and hybrids, the Volt should avoid brake replacement costs but will still require oil and filter changes at least every two years, according to the Volt owner's manual (compared to the Cruze's twice-a-year or every 5,000-8,000 miles recommendation). The table's NPV entries will hit $7,500 at slightly more than $5.00/gallon (without battery replacement), suggesting that, without the tax credit, the Volt enjoys a positive NPV advantage at gas prices below that. Interpolating from Table 4's underlined values, if battery replacement is required post warranty, the gasoline price must increase approximately $0.29/gallon ($1/3.5) for each $100/kWh increase in battery replacement cost to maintain the same NPV difference between the two competing vehicles. The implied break-even ratio of gas price to battery storage price is less than half that computed for the Leaf-Versa comparison, because the Volt's battery is 33% smaller than the Leaf's and fewer annual miles were assumed for the range-limited Leaf. As discussed earlier, discounting at 10%[3] reduces the benefit of future fuel and maintenance savings (but also the cost of the battery replacement in the outyears) such that the NPV is a negative $928 with the federal tax credit, no battery replacement, and gasoline at $3.50/gallon. A gas price of about $6.60/gallon is required for zero NPV (where the Volt and Cruze have equal long-term costs) without any tax credit.

The fuel and maintenance costs savings for the Volt extend to 150,000 miles. This total vehicle life yields an average daily usage of less than 29 miles per day — and thereby well within the Volt's 40-mile all-electric range. Hence, all 10,000 yearly miles traveled are assumed to be electrically driven. GM has indicated that the battery failure mode may be a degradation of storage capacity instead of a sudden total failure. If all 10,000 miles traveled are electrically driven, the battery may last the entire 15-year/150,000-mile life of the vehicle and still meet the 29-mile average daily driving need.

Table 4: Net Present Values of Chevrolet Volt (eREV) Over Chevrolet Cruze

	Replacement Battery Price (per kWh)				
Gasoline Price ($/Gallon)	$0 No Battery Replacement	$150	$250	$350	$450
$7.00	$14,869	$13,322	$12,291	$11,259	$10,228
$6.50	$13,205	$11,468	$10,437	$9,406	$8,374
$6.00	$11,162	$9,615	$8,584	$7,552	$6,521
$5.50	$9,308	$7,761	$6,730	$5,699	$4,667
$5.00	$7,455	$5,908	$4,877	$3,845	$2,814
$4.50	$5,601	$4,054	$3,023	$1,992	$960
$4.00	$3,748	$2,201	$1,170	$138	($893)
$3.50	$1,894	$347	($684)	($1,715)	($2,747)
$3.00	$41	($1,506)	($2,538)	($3,569)	($4,600)
$2.50	($1,813)	($3,360)	($4,391)	($5,422)	($6,454)

Note: The underlined, similar values of $5,601 and $5,699 are used to estimate a value for the increase (or decrease) in gas prices needed to maintain a similar NPV given a higher (or lower) battery replacement cost. Assumptions: 5% (real) discount rate; 150,000 miles over 15 years; Cruze: 28 miles/gallon; Volt: 40 miles AER, 2.78 miles/kWh (electric); cost of electricity: $0.1175/kWh; Battery replacement in ninth year (after eight-year warranty's expiration); 2011 Volt price of $33,500 (after $7,500 Federal Tax Credit) vs. 2011 Cruze at $25,100 (comparably equipped to Volt); Terminal values of both vehicles assumed equal.

Table 5 contains the net present values calculated using a 5% discount factor for the Toyota Prius-PHEV over its comparably equipped conventional twin, the Toyota Corolla. With the $2,500 tax credit included and no battery replacement required, the NPV is positive for gasoline values nearing $3.75/gallon. As with other PEVs and HEVs, the Prius-PHEV should avoid brake replacement costs but will likely still require yearly oil and filter changes (compared to the Corolla's recommended twice yearly per 5,000-8,000 mile interval). The lower-cost benefit of the relatively small 5.3kWh battery is apparent, since NPVs become positive — even without this PHEV's $2,500 tax credit — at gas prices of slightly less than $3.75/gallon (again assuming no battery replacement). From Table 5, given lower battery replacement costs overall (due to smaller battery size) and the difficulty in determining the exact price decline rate over time for batteries, for each $100 higher price in potential Prius PHEV replacement battery costs, the gasoline price must increase by only $0.14/gallon ($0.50/3.5) to maintain the same NPV (versus $0.66/gallon for the Leaf and $0.29/gallon for the Volt). As before, annual discounting at 10% (for more risk-averse or myopic buyers) will reduce the benefit of future fuel and maintenance savings (but also the present value of battery replacement) such that the NPV of the Prius PHEV (over a Corolla) begins being positive at about $3.10 per gallon, with a tax credit and assuming no battery replacement. A gas price of about $5.90/gallon is required for a break-even condition, without any tax credit (and no battery replacement).

The fuel and maintenance costs savings for the Prius-PHEV extend to 150,000 miles. As noted earlier, this assumption implies an average daily usage of 29 miles per day. Given Toyota's AER intent of 15 miles, just 15 miles are assumed to be driven electrically, and the remainder uses gasoline to provide a reasonable approximation of fuel consumption. It is interesting to note the lower gasoline-price break-even points without tax credits given the Prius-PHEV's smaller battery and modest AER, but lower purchase price premium. These results are consistent with prior PEV architecture cost studies (Vyas, et al. 2009). In addition, if a replacement battery is required, it should be considerably less expensive, given the smaller size.

Table 5: Net Present Value of Toyota Prius-PHEV Over Toyota Corolla

	Replacement Battery Price (per kWh)				
Gasoline Price ($/Gallon)	$0 No Battery Replacement	$150	$250	$350	$450
$7.00	$8,548	$8,035	$7,693	$7,352	$7,010
$6.50	$7,237	$6,725	$6,383	$6,041	$5,700
$6.00	$5,927	$5,414	$5,073	$4,731	$4,390
$5.50	$4,617	$4,104	$3,762	$3,421	$3,079
$5.00	$3,306	$2,794	$2,452	$2,110	$1,769
$4.50	$1,996	$1,483	$1,142	$800	$459
$4.00	$686	$173	($169)	($510)	($852)
$3.50	($625)	($1,137)	($1,479)	($1,820)	($2,162)
$3.00	($1,935)	($2,448)	(2,789)	($3,131)	($3,472)
$2.50	($3,245)	($3,758)	($4,100)	($4,441)	($4,783)

Note: The underlined, similar values of $3,421 and $3,306 are used to estimate a value for the increase (or decrease) in gas prices needed to maintain a similar NPV given a higher (or lower) battery replacement cost. Assumptions: 5% (real) discount rate; 150,000 miles over 15 years; Corolla: 29 miles/gallon; Prius-PHEV: 15 miles AER, 49 mpg (gas), 3.8miles/kWh (estimated electric); 5,475miles/year (electric) + 4,525miles/year (gas); cost of electricity: $0.1175/kWh; Battery replacement in ninth year (after eight-year warranty expiration); 2012 Prius-PHEV announced price at $29,500 ($32,000 MSRP - $2,500 federal tax credit), vs. 2011 Corolla: $19,244 (comparably equipped but Navigation not available on Corolla); Terminal values of both vehicles assumed equal.

Interestingly (but perhaps not by accident, given manufacturer and government sales aspirations), for all three vehicles, the U.S. battery-size-based tax credit results in positive (though slight) NPVs at fuel costs of under $3.75, if the owner does not face battery replacement costs. Of course, as driving distances, future-cost discounting, recharge frequencies, gasoline prices, battery prices, power prices, and other attributes or assumptions change, the NPVs can go either way. A sensitivity analysis was performed to estimate the price of fuel required for breaking even between each PEV and its comparable conventional vehicle. Assuming no battery replacement and no credits, the NPV would also be positive with gas prices above approximately $5.90, $5.00, and $4.70 per gallon for the Leaf (assuming a 100,000-mile life), Volt (150,000 lifetime), and Prius-PHEV (150,000 lifetime), respectively.

The relative cost analysis was repeated to observe the effect of increasing the Leaf's lifetime miles to that of the other PEVs (150,000 miles). If the Leaf is driven an average of 29 miles per day (150,000 over its 15-year vehicle life, instead of 100,000 miles), the break-even fuel price (without tax credit and without battery replacement) drops to less than $4.00 per gallon. This 29 miles-per-day distance lies well within the range of a BEV, such as the Leaf (and well within the round-trip commute of most workers), even in harsh weather conditions with reduced range. If vehicle manufacturers succeed in engineering and manufacturing PEVs with batteries to last the vehicle's lifetime, their financial attractiveness, particularly in higher fuel cost regions (including China), seems very solid, especially at moderate discount rates. If one were to price the social costs of the various vehicles, the comparisons should land more heavily in favor of PEVs (Lemp and Kockelman 2008).

Analysis was also performed to compare the payback for the 2010 Prius HEV to the 2010 Toyota Corolla, and then to the Prius PHEV described earlier. Given its higher purchase price, but slightly lower maintenance costs and much lower fuel costs, the NPV of a Prius HEV over a Corolla is positive at gas prices below $2.50 per gallon (assuming no battery replacement, 150,000-mile life, 5% real discount rate and no tax credits). Using a 10% discount rate, the HEV Prius enjoys a positive payback over a Corolla at gas prices below $3.10 per gallon. Given the recently announced pricing of the Prius PHEV at only $2,205 over a comparably equipped Prius III HEV, gas price estimates must reach only $3.50/gallon to generate a positive return on the Prius PHEV, over the Prius III HEV, but nearly $4.75 per gallon without its $2,500 federal tax credit.

These results rely on actual retail prices and EPA efficiency data. Some observations can be made that are consistent with previous studies that used bottom-up component cost and efficiency estimates (Kromer and Heywood 2007, Vyas 2009, and Shaiu et al. 2009) in that the most attractive purchase conditions without tax credits are typically achieved when the expensive battery's size is as small as possible to provide no spare electric drive range capacity and the electric driving range is somewhat less than the driver's average driving needs.

KEY TRENDS

The rate of PEV adoption and use, as well as their environmental and other implications, will depend on a variety of trends that are expected, but with uncertain rates. These include grid management and feedstock use, battery technology advances, charging infrastructure, and energy pricing, and they are discussed briefly in turn here.

Evolution of Grid Power Generation

Emissions levels from electricity generation are specific to the region, technologies, and feed stocks used. Some sources, including wind, solar, nuclear, and hydro, create little or no emissions (though their construction and maintenance certainly imply some embodied energy). Other sources, such as coal and natural gas have become less polluting as environmental regulations have tightened over time and newer technologies have improved efficiencies. It is reasonable to expect further improvement is possible given the eventual retirement of older, less efficient coal plants with less effective grandfathered emissions control systems. The technology exists today to make grid generation emissions-free; however, doing so would substantially raise electricity prices. The issue is economic deployment of zero/low emitting generation resources.

Given that the grid has no electron-based energy storage, to maintain system stability grid operators must fine-tune total output to precisely match real-time loads every second of every day. The unique nature of PEV charging offers the new opportunity for grid operators to fine-tune the charging load to match intermittent renewable generation sources such as wind and solar. PEV owners do not care about the precise power charging levels of their vehicles at any particular time. Drivers simply care that the vehicle is charged sufficiently by the time of their next departure, such as leaving for work in the morning. Hence, while the electric industry has lowered relative emissions in the U.S. to meet progressively more stringent regulatory standards over time, the mass deployment of intelligently charging PEVs presents the opportunity to further improve overall emissions by improving the economics and hence deployment of renewable zero-emissions generation.

Automotive-Grade Battery Trends

A number of factors lead to the expectation that battery costs will decline over time. Automotive-grade lithium batteries have no meaningful global sales at this time. Increased volumes typically introduce manufacturing or scale efficiencies and encourage new manufacturers to enter the market, increasing competition and reducing prices.

Engineers are expected to enhance control algorithms, which will improve efficiency and enable downsizing as more is learned about battery wear mechanisms from field experience. Electrical energy required for cabin heating and cooling directly reduces PEV range, so weather conditions become relevant. It is reasonable to expect efficiency improvements in electrically driven PEV heating and air conditioning systems and cabin insulation to further reduce demands on the battery.

Also, increased energy recapture through advances in regenerative braking are likely, through innovations like ultracapacitor/battery combinations. PEV batteries appear to have substantial potential for cost reductions as production volumes increase (Santini et al. 2010), perhaps to $150/ kWh with large volumes. The overall incremental price of a PEV driven by the battery cost is likely to decline from a combination of lower battery prices and an ability to use smaller batteries while maintaining range and other capabilities through design innovations.

Public and Multifamily Charging Infrastructure

Homes are expected to be the predominant charging location (PUCT 2010). More charging points (and smart plugs) are expected to be installed over time to support potential PEV buyers who do not have a home garage. Work, apartment building, and public charging options are far more important for BEVs than for eREVs and PHEVs. It is likely that PEV drivers without garages will favor eREVs/PHEVs, have reasonable charging options at work, and/or live in a community with strong commitment to (and investment in) public charging. With more pervasive deployment, shorter daily commuting distances, and better mass-transit systems, European and Japanese markets may experience much greater shares of BEVs (as compared to eREVs/PHEVs) than in the U.S. and much greater PEV adoption rates overall.

Residential Energy Pricing

Electricity is an essential good and, hence, typically served by utilities with oversight from public utility commissions, self-owned co-operatives, and/or other forms of democratically elected oversight bodies (in the case of municipally owned utilities). For the foreseeable future, retail energy prices (and customers) are unlikely to be subjected to real-time price fluctuations (with a market clearing price determined every five to 15 minutes, for example) as wholesale power prices are today. Time-of-use (TOU) rates presently differ from real-time rates in that they typically offer just two rates per day: peak and off-peak. TOU rates also may have different peak/off-peak rates for summer and winter seasons, to provide incentives for efficiency during the most stressful, seasonal peaks, and to encourage loadshifting (to off-peak periods).

It is important to note that a significant portion of the grid's value to customers for the past century has been providing as much energy as a homeowner desires, whenever they want it, at an attractively low cost (relative to other energy options) and delivered with great simplicity. Customers simply plug their devices into the wall. The ability to improve incentives for energy efficiency has been moderated in the past by the relatively low price of energy, and an inability to precisely estimate the benefits of energy-saving behaviors and investments given that the only data available are monthly total-energy bills. TOU rates are expected to continue to provide attractive energy costs during the expected dominant nighttime PEV's charging period. Regulating entities are highly unlikely to support substantially raising off-peak retail rates as a policy as they are typically resistant to allowing any rate increase. Experience has shown that even in the highest electricity cost regions, nighttime rates are still relatively low.

Utilities face an inherent dilemma: lower CO_2 emissions imply lower energy sales and hence lower revenues. PEV energy sales provide a means for utilities to offset their residential energy sales lost to structure energy efficiency improvements while improving overall (vehicle plus generation) CO_2 emissions.

Potential Implications for Travel Patterns

While both PHEVs and BEVs are grid connected, BEVs will likely foster a greater variety of behavioral changes. Even with a 100-mile claimed AER, more planning for the day's travel will be required. This overhead will be driver specific and may not be meaningful if daily travel distances (e.g., the work commute) do not vary greatly. When the daily drive is less predictable, rental or ownership (and use) of a second conventional vehicle may be needed, and/or searching for available public charging stations. BEV owners may be much more "interconnected" through the use of their vehicle telematics (communications plus navigation) systems, which can guide them to pre-reserved public charging stations. It is possible that this overhead may decrease (or vacillate) over time, with improvements in the availability of public charging stations but then worsen with more PEVs on the road competing for these stations.

The range anxiety of a BEV might also be solved via non-technological solutions. For example, manufacturers may sell BEVs with attractive car rental arrangements at their dealerships for longer range and/or less conventional vehicle types. Rental options are very likely to include SUVs, pickup trucks and minivans, for example, to accommodate less regular — but important — tripmaking, including weekend camping trips or furniture moving days. Such strategies can help a variety of U.S. households — and others around the globe — "downsize," offering a potentially dramatic long-term gasoline savings, by moving household ownership trends away from the light-duty-truck fleet. This strategy may also provide less risk of remote repair (if an accident or breakdown occurs, the renter simply and quickly gets another vehicle to continue the trip without the need to search for a reputable repair shop or wait for the repair) and the advantage of bringing the PEV owner into the dealer for service, enhancing the dealer- and manufacturer-consumer relationships.

SUMMARY AND CONCLUSIONS

PEV-related technologies have progressed sufficiently to enable the introduction of mass-market-viable vehicles by mainstream global manufacturers. With the advent of the Chevrolet Volt and Nissan Leaf PEVs, the industry has been set in motion and consumers have some serious choices to make.

Assuming a discount rate of 5%, the estimated net gains for owners of these early PEV models (compared to comparably-equipped conventional vehicles) is small in low-gas-price regions like the U.S., but still positive, when U.S. tax credits are included, assuming no battery replacement is required by owners. Without such credits, the relative NPVs are negative at current U.S. gas prices. Nevertheless, cost savings may be substantial for longer-distance drivers who electrify their miles and is estimated to be strongly positive for those in higher-fuel-cost regions (e.g., Germany at $7 to $8 per gallon). Gas prices above approximately $5.90, $5.00, and $4.70 per gallon are estimated to make the Leaf, Volt, and Prius-PHEV attractive from a purely financial standpoint, respectively, than their conventional counterparts, without any credits and with today's PEV component and retail prices, using a 5% discount rate. Gas prices above approximately $8.00, $6.60, and $6.50 per gallon are required when using a discount rate of 10% for a positive NPV without tax credits.

PEVs are expected to sell well to innovators and early adopters despite potentially higher overall costs in low-fuel-cost regions, just as HEVs have enjoyed some niche-market success. Early purchase opportunities, greater personal wealth, and pent-up demand for such innovative vehicles may trigger the greatest markets for PEVs initially in the U.S., with long-term total sales highest abroad, thanks to higher fuel prices settings elsewhere, higher base-level charging voltages, shorter commutes, and/or a greater focus on transportation environmental impacts (and potentially stronger government incentive programs relative to the U.S.).

The higher component costs (such as lithium batteries), which lead to higher purchase prices for PEVs, are likely to decline over time, as they have for HEV-related components and past automotive innovations (such as fuel injection, electronic engine management, and air bags). Continued component price declines and fuel cost increases will lead to higher NPVs for PEVs, relative to comparable conventional vehicles. Even in relatively low-fuel-cost countries, such as the U.S., the HEV Prius has a positive NPV over a similar conventional vehicle. The experience with the HEV

Prius over the past decade demonstrates the trends and factors that may lead to PEV cost parity with conventional vehicles over the coming decade.

Charging infrastructure build-out also may also proceed more rapidly in the U.S. over the short term, but then accelerate relatively rapidly in regions with higher fuel prices (such as Europe and Japan). Over time, the share of BEVs in European and Japanese markets may become much greater than in the U.S., due to shorter daily commuting distances, the presence of better mass-transit systems, and potentially more pervasive charging infrastructure deployment.

The U.S. grid is expected to continue to become more "green" over time (EIA 2001), and the deployment of larger numbers of PEVs has the potential to accelerate grid-emissions reductions, through the synergistic coordination of PEV charging with renewable generation sources (such as wind and solar). More meaningful PEV architectures and battery-technology competition are expected, with many viable combinations that offer a variety of optimization opportunities, reducing battery costs and PEV prices over time.

Interestingly, the introduction of PEVs may stimulate a competitive response which may accelerate advances in conventional powertrain efficiency, biofuels, or hydrogen fuel-cell vehicles as well. As long as issues like energy security, air quality, trade deficits, and other concerns continue, all such innovations bode well for the world at large.

Endnotes

1. A vehicle powertrain includes the components associated with the source of propulsion (such as a gasoline engine or electric motor), transmission, driveshaft(s), differential(s), and axles.

2. While eREV/PHEV owners can drive in a fashion to avoid gasoline use and maximize electric drive, manufacturers will likely advise that owners need to keep a few gallons of gasoline in the tank to let the engine occasionally operate to lubricate the ICE's bearings and seals. Blended-mode-PHEV manufacturers will likely require that drivers have gas in the tank to ensure full functionality for safe operation (e.g., over 15 miles range, above 60 mph, or freeway merging acceleration). While the ability to replace liquid fuel consumption with electric drive substantially depends on the nature of the driver's commuting pattern, it is reasonable to assume that PEVs with a wider range of electric operation (either distance, load, and/or speed) have the potential for greater degrees of reduction in the amount of liquid fuel consumed.

3. The break-even gas prices and 10% discounting calculations are not shown here, due to paper length limitations.

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Acknowledgements

We would like to thank Southwest University Transportation Center for financially supporting a couple months of student work, and Ms. Annette Perrone for facilitating administrative features of this work.

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A Preliminary Investigation of Private Railcars in North America

by Thomas M. Corsi, Ken Casavant, and Tim A. Graciano

This paper analyzes the economic conditions of a dramatic change in railcar ownership over the last 10 years. Private railcar ownership has increased to the point where they now carry 54% of ton-miles and 56% of tonnage for all railroads. Despite the increasing reliance on private railcars, returns to railcar ownership are decreasing, with current rates of return falling below those necessary to fund future investment. The problem is further exacerbated by shifting costs from railroad to shipper. A large drop in private investment could pose a serious threat to the railroad industry, shippers, and the economy as a whole.

INTRODUCTION

The role of private ownership of the freight car fleet has been one of steady evolution, with railroad investment in and ownership of freight cars progressively declining over the past decades. William E. O'Connell, Jr[1] (1970) documented the increasing role of the private fleet and offered some suggestions as to the initial and continuing cause, noting:

> *"After initial widespread use of private cars under the "common road" concept of early railways, railroad-owned freight cars predominated from the 1840's through the 1860's, except for a short-lived boom in cars owned by "fast freight" lines. From this time on, however, the percentage of private cars has increased as railroads refused to build specialized freight cars because of high initial costs, rapid technological obsolescence, outside pressure, and managerial shortsightedness."* (O'Connell 1970)

This trend has continued unabated. Currently, over 50% of the tons shipped on the North American railroads are moved in cars owned by non-railroad leasing companies and shippers (Surface Transportation Board 2008). Concurrent with this change in car ownership, there has been an apparent shift of costs from the railroads to private car owners (Prater et al. 2010). The purpose of this research paper is to investigate, identify, and document these changes and offer some implications on the future of the rail industry. Producers who rely on railcars as a link in their supply chain stand to be greatly impacted by such changes in the structure of the industry. The growing reliance on a single source of railcars exposes sectors that depend on a steady supply of cars to increased risk, either through declining investment in railcars, increased costs, or both. This paper reviews current car-hire practices, car rules, and interchange rules that may inhibit sustained investment in the private car fleet.

Between 2000 and 2008, there was a dramatic increase in the share of freight cars owned by non-railroad leasing companies and shippers in order to compensate for the decreased investment in these cars by railroads (Surface Transportation Board 2008). Not only have private cars increased in numbers but also in the share of tons carried and in revenue generated (Surface Transportation Board 2008). Our national economy, as well as the overall financial health of the entire railroad industry, has benefited from this heavy reliance on the continuing investment in freight cars by leasing companies and shippers; however, current investment rates are not large enough to replace an aging North American fleet. This analysis suggests that future private investment levels could be dramatically below those required given the increased system dependence on private railcars.

LITERATURE REVIEW

This paper adds to the literature on the railcar composition of the North American fleet. Previous work has focused on both the concern about track infrastructure and rolling stock, especially looking at the particular categories of cars. Here particular attention has been paid to the impacts of the heavier rail grain hopper on local infrastructure.

Norton and Klindworth (1989) also highlight potential fleet shortages, however, their focus is on a single commodity (i.e., grain) rather than ownership structure. Another closely related paper is Bitzan and Tolliver (2003), who also use return on investment analysis on railroad equipment. Bitzan and Tolliver (2003) model the railroad's decision to abandon track due to 286,000-pound railcars, while this paper is concerned with returns to the cars themselves.

A large literature that analyses particular car types exists. Resor et al. (2000) look at 286,000-pound cars, as does Martens (1999) and Casavant and Tolliver (2001). This literature is primarily concerned with the impact of a particular type of car (heavy-axle) regardless of who owns the cars in question. The main contribution of this paper is to analyze the rate of return for cars based not on type, but ownership category.

This paper is not the first to investigate investment in railcars. For example, Bortko, Babcock, and Barkley (1995) examine a sharp decline in jumbo covered hopper car investment. The authors estimate a model of investment in jumbo covered hopper cars to explain why investment fell sharply in the 1980s. They find that deregulation, combined with falling prices for commodities primarily moved in jumbo covered hopper cars, explain most of the fall in investment. In response to the fall in investment identified by Bortko, Babcock, and Barkley (1995), Norton and Klindworth (1989) examine whether the jumbo covered hopper fleet will be able to meet future demand. Like these authors, this paper attempts to identify one potential cause of falling investment, but only for private railcars.

To study the impact of changes in the ownership structure of railcars this paper uses rate of return on investment analysis, similar to Babcock and Sanderson (2006), who use return on investment analysis to determine the likelihood of shortline railroad owners upgrading their tracks and bridges to handle 286,000-pound cars. The authors calculate the internal rate of return for shortline investment and conclude that needed upgrades are unlikely to attract private investment due to negative rates of return. The main contribution of this paper is to identify the changing trends in railcar ownership, and show that this trend is unsustainable at current rates of returns to private car owners. Lastly, the paper identifies some possible economic implications if returns, which could come from the competitive workings of the railcar market, do not improve.

SHIFT IN RAILCAR OWNERSHIP

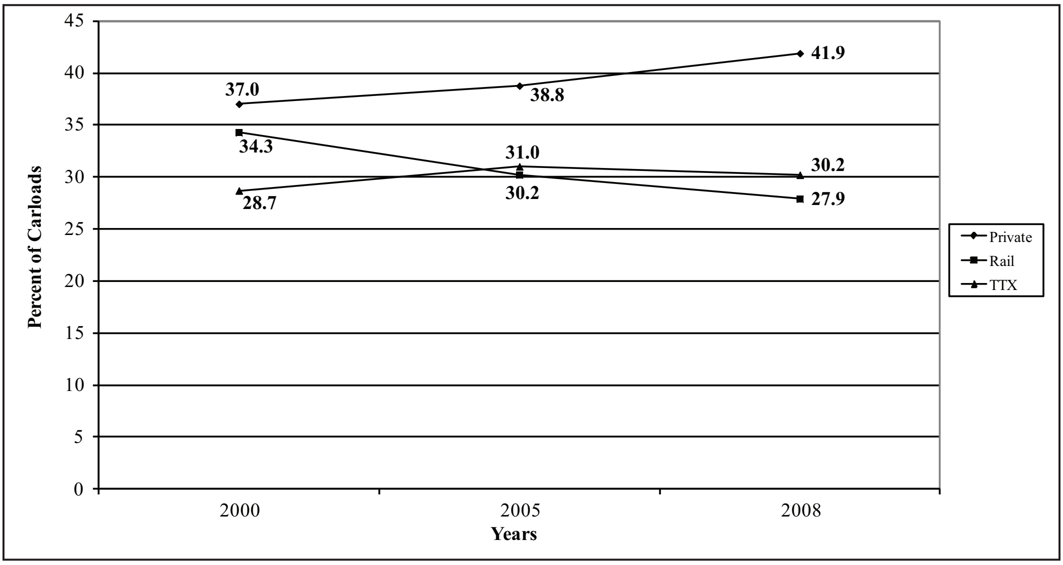
The analysis in this paper documents the shift to a fleet of railcars dominated by non-railroad leasing companies and shippers. The primary data sources used to illustrate these trends are the Railroad Carload Waybill Public Use data files from 2000, 2005, and 2008. The Railroad Waybill database, available from the Surface Transportation Board, Washington, D.C.,[2] is a stratified 1% sample of carload waybills for all U.S. rail traffic of U.S., Canadian, and Mexican origin submitted by those U.S. railcarriers terminating 4,500 or more revenue carloads annually (Surface Transportation Board 2008). It forms the basis for an estimation of the annual railroad carloads, tons, ton-miles, and revenues associated with U.S. railroad traffic. The Railroad Waybill database allows identification of the ownership of each freight car as well as the type of freight car involved in each shipment.

There are three freight car ownership categories identified in the waybill data. The first category is the private ownership category, which represents non-railroad leasing companies and shippers. The second category is the railroad ownership category which represents freight cars owned by individual railroads. The third category of freight cars is labeled as TTX cars, [3] which are owned by North America's leading railroads through the railroad-owned and controlled leasing company, TTX. TTX cars are leased to individual railroads on an as-needed basis.

Growth in Private Cars 2000-2008: Carloads, Tons, Ton-Miles, and Revenue

Figure 1 shows that private cars' share of total carloads increased 4.9% from 37% of total carloads in 2000 to 41.9% in 2008.[4] The increase in private car ownership share came from declines in the rail ownership category. The ownership share of TTX cars remained relatively stable over the study period. Clearly, private cars have become the dominant ownership category on a carload basis.

Figure 1: Distribution of Total Carloads by Ownership Category, 2000-2008



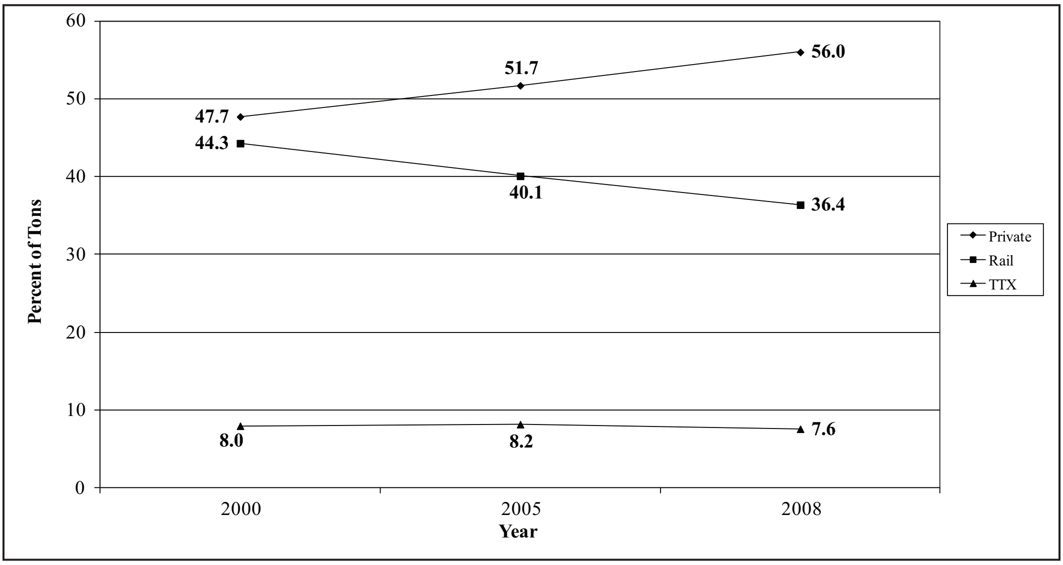
Source: Railroad Carload Waybill Data, Surface Transportation Board, Washington, D.C., Public Use File, 2000, 2005, and 2008.

Figure 2 reflects total tons moved on the railroad system by ownership category. The growth in the share of tons moved in private cars is very significant. In 2000, private cars accounted for 47.7% of total rail tonnage. By 2008, private cars accounted for 56% of the total rail tonnage, even as total rail tonnage was increasing. In contrast, rail-owned cars were responsible for 44.3% of total tonnage in 2000, but only 36.4% in 2008. The share of total tonnage in TTX-owned cars has been relatively stable.

In 2008, private cars moved 1.2 billion tons of freight on the railroad system, rail-owned cars moved 770 million tons, and TTX cars moved 160 million tons (Corsi and Casavant 2010). TTX cars handle a much smaller share of total tonnage carried on the railroads versus the percentage of carloads on the system. This is due to TTX cars' heavy participation in the intermodal market, which involves merchandise traffic with lower car weights than many of the bulk commodities (Corsi and Casavant 2011).

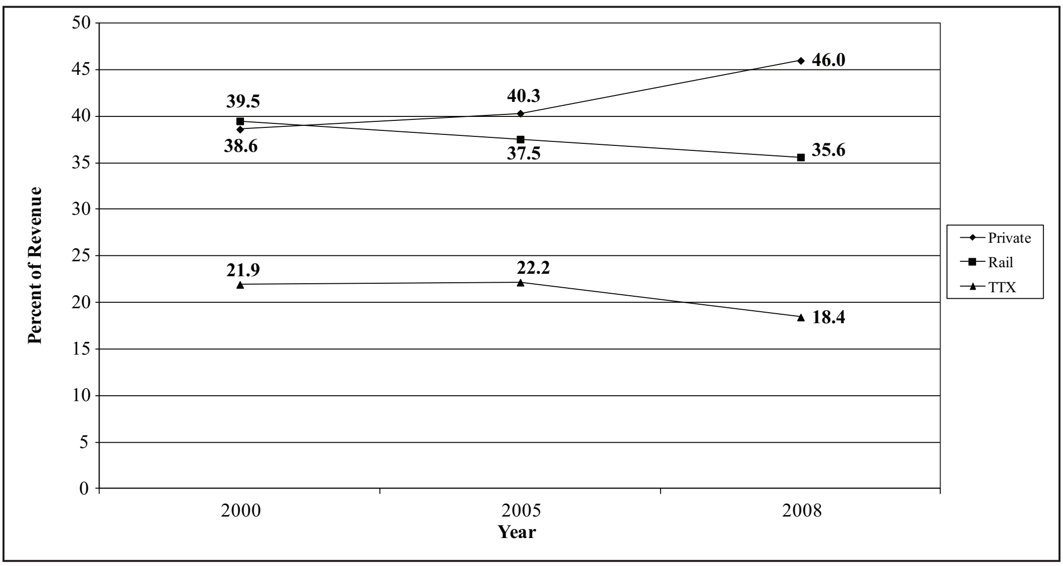
The distribution of total railroad revenue by ownership category is provided in Figure 3. Once again, participation of private cars increased throughout the study period. In 2000, 39.6% of railroad revenue was generated by private cars, increasing to 46% in 2008. In contrast, rail-owned cars accounted for 39.5% of the revenue in 2000, decreasing to only 35.6% in 2008. TTX cars accounted for 21.9% of total railroad revenue in 2000, dropping to only 18.4% of the revenue in 2008. In 2008, the railroads generated $72.6 billion in revenues; $33.4 billion was derived from private cars, $25.9 billion from rail-owned cars, and $13.4 billion from TTX cars.

Figure 2: Distribution of Total Tons by Ownership Category, 2000-2008



Source: Railroad Carload Waybill Data, Surface Transportation Board, Washington, D.C., Public Use File, 2000, 2005, and 2008.

Figure 3: Distribution of Total Railroad Revenues by Ownership Category, 2000-2008



Source: Railroad Carload Waybill Data, Surface Transportation Board, Washington, D.C., Public Use File, 2000, 2005, and 2008.

TTX cars, which represent a significant portion of the railroads' investment in railcars, accounted for 27.9% of all carloads in 2008, but represented only 7.6% of all tons, 12.3% of all ton-miles on the system, and 18.4% of their revenue (Surface Transportation Board 2008). This is a reflection of the TOFC/COFC movements in TTX cars, which more often than not consist typically of lighter weight-manufactured goods in contrast to movements in other car types, which focus on heavier bulk commodities, (e.g. private cars account for 41.9% of all carloads, but 56% of all tons and 54.3% of all ton-miles due to the heavier weight bulk commodities they carry).

Private Car Usage by Car Type, 2000-2008

This section investigates the significance of private railcars in a number of different car type segments, as well as the growing reliance on private railcars in these segments. Table 1 shows total rail system revenues in 2008 by car type and ownership category. Rail shipments are listed in 15 car type categories in accordance with Surface Transportation Board definitions.

Of the 15 car type categories, private cars account for the majority of railroad system revenue in six of the categories. The highest category of private car revenue generation is in the two tank car categories (under 22,000 gallons and 22,000 gallons and over); where over 99% of revenue is generated in private cars. There are virtually no railroad or TTX-owned tank cars even though tank car categories account for 11.7% of total railroad revenues in 2008. The second highest category of private car revenue generation involves open top hopper cars (special service). Private cars in this category contributed 75.2% of all railroad system revenues derived from this type of car and 9.1% of all railroad revenues.

Not only do private cars generate the majority of revenue for specific categories of cars but they also create the majority of revenues for the entire rail system. Private cars in three car type categories — plain box cars (50 feet and above), plain gondola cars, and covered hopper cars — accounted for over 50% of total railroad revenues in all three car types in 2008. In these three categories, private cars were responsible for 53.1%, 60.4%, and 59.0%, respectively, of the total revenues by these types of cars across all types of ownership. The covered hopper car category generated 20.6% of total rail system revenues in 2008, 59% of which was derived from privately owned cars.

TTX, which represents a significant railroad investment in railcars, did not participate in any of these six car type categories, although 53.81% of total railroad system revenues are generated by these six car types.[5] The TTX cars do, however, account for a majority of total railroad system revenues for TOFC/COFC intermodal movements.

Types of Products and Commodities Predominately Moved in Private Cars

Numerous industries in the U.S. economy are dependent on the availability of private railcars. The private rail fleet is singularly responsible for tank car movements, which primarily contain food products, chemical or allied products, and petroleum or coal products. The food product category includes primarily corn syrup, soybean oils, tropical oils and nut or vegetable oils. The chemical or allied product category consists predominately of alcohol, sulfuric acid, and fertilizers. Lastly, the petroleum or coal products category consists of liquefied gases, coal, or petroleum (Corsi and Casavant 2011). It is these industries that are so dependent on the continued availability of private tank cars.

Privately owned plain box cars are used to move the following commodities and products: paper waste, scrap, fiberboard, paperboard, pulp board, and beer. (Corsi and Casavant 2011). Coal is the primary commodity moving in privately owned open hopper cars and in plain gondolas (Surface Transportation Board 2010). Additionally, privately owned open hopper cars are used extensively to transport crushed stone, pulpwood, and other wood chips, while iron and steel scrap are the

Table 1: Railroad Revenue Distributed by Car Type and Ownership Category, 2008

Category	Private Revenue	% Private	Rail Revenue	% Rail	TTX Revenue	% TTX	Total Revenue	% of Total
All Cars	$33,391,590	45.98	$25,858,581,660	35.60	$13,378,665,046	18.42	$72,628,586,296	100.00
Plain Box Cars 50 ft. and Above	$248,461,061	53.15	$219,045,719	46.85	$0	0.00	$467,506,781	0.64
Equipped Box Cars	$542,362,011	10.51	$4,617,999,750	89.46	$1,841,080	0.04	$5,162,202,841	7.11
Plain Gondola Cars	$5,153,671,811	60.40	$3,379,570,732	39.60	$0	0.00	$8,533,242,543	11.75
Equipped Gondola Cars	$419,035,251	13.18i	$2,757,733,896	86.76	$1,741,200	0.05	$3,178,510,347	4.38
Covered Hopper Cars	$8,825,517,576	59.04	$6,121,275,268	40.95	$794,120	0.01	$14,947,586,964	20.58
Open Top Hopper Cars-- General Service	$996,167,748	29.11	$2,426,052,239	70.89	$0	0.00	$3,422,219,987	4.71
Open Top Hopper Cars--Special Service	$4,973,123,429	75.20	$1,640,271,651	24.80	$0	0.00	$6,613,395,080	9.11
Refrigerator Cars--Mechanical	$135,808,776	22.46	$468,933,643	77.54	$0	0.00	$604,742,419	0.83
Refrigerator Cars--Non-Mechanical	$18,048,440	4.96	$345,840,566	95.04	$0	0.00	$363,889,006	0.50
Flat Cars TOFC/COFC	$3,209,449,172	24.00	$1,470,997,537	11.00	$8,692,258,174	65.00	$13,372,704,883	18.41
Flat Cars--Multi-Level	$6,530,520	0.15	$583,326,737	13.55	$3,716,447,748	86.30	$4,306,305,005	5.93
FlatCats--General Service	$5,009,211	36.09	$7,128,600	51.36	$1,742,560	12.55	$13,880,371	0.02
Flat Cars--Other	$187,952,486	6.49	$1,745,894,119	60.28	$962,222,780	33.23	$2,896,069,385	3.99
Tank Cars-- Under 22,000 Gallons	$3,128,769,194	99.90	$3,251,084	0.10	$0	0.00	$3,132,020,278	4.31
Tank Cars-- 22,000 Gallons and Over	$5,389,617,640	99.99	$371,760	0.01	$0	0.00	$5,389,989,400	7.42

Source: Railroad Carload Waybill Data, Surface Transportation Board, Washington, D.C., Public Use File, 2008.

Table 2: Railroad Ton-Miles Distributed by Car Type and Ownership Category, 2008

Category	Private Ton-Miles	% Private	Rail Ton-Miles	% Rail	TTX Ton-Miles	% TTX	Total Ton-Mles	% of Total
All Cars	941386	54.26	580989	33.49	212670	12.26	1735045	100.00
Plain Box Cars 50 ft. and Above	3967	51.76	397	48.24	0	0.00	7664	0.44
Equipped Box Cars	11135	13.54	71096	86.43	32	0.04	82263	4.75
Plain Gondola Cars	285407	72.83	106458	27.17	0	0.00	391865	22.59
Equipped Gondola Cars	8105	16.62	40624	83.30	38	0.08	48766	2.81
Covered Hopper Cars	191741	52.65	172440	47.35	8	0.00	364189	20.99
Open Top Hopper Cars-- General Service	28593	35.30	52416	64.70	0	0.00	81009	4.67
Open Top Hopper Cars--Special Service	184695	79.27	48312	20.73	0	0.00	233007	13.43
Refrigerator Cars--Mechanical	2517	24.80	7629	75.20	0	0.00	10146	0.58
Refrigerator Cars--Non-Mechanical	393	5.68	6524	94.32	0	0.00	6917	0.40
Flat Cars TOFC/COFC	63732	24.00	292.10	11.00	172606	65.00	265548	15.30
Flat Cars--Multi-Level	73	0.25	3849	13.33	24961	86.42	28882	1.66
FlatCats--General Service	44	20.79	137	65.46	29	13.75	210	0.01
Flat Cars--Other	1723	3.19	37313	69.09	14972	27.72	54008	3.11
Tank Cars-- Under 22,000 Gallons	59805	99.91	53	0.09	0	0.00	59859	3.45
Tank Cars-- 22,000 Gallons and Over	97201	100.00	4	0.00	0	0.00	97205	5.60

Source: Railroad Carload Waybill Data, Surface Transportation Board, Washington, D.C., Public Use File, 2008 commodities that move predominately in privately owned plain gondolas. The importance of these industries in the U.S. economy is far reaching.

Finally, the major shippers of privately owned covered hopper cars transport bulk grains (including corn, soybeans, wheat, barley, sorghum), prepared feed, soybean meal and pellets, feed ingredients, flour, corn products, and grits; dry fertilizers, salt, clay, plastic materials, or synthetic resins; sodium compounds; and hydraulic cement (Surface Transportation Board 2000). Both the privately owned and TTX-owned TOFC/COFC flat cars handle miscellaneous mixed shipments.

Table 2 portrays the distribution of total rail system ton-miles in 2008 by car type and ownership category. Of the 15 car type categories listed in Table 2, private cars account for the majority of railroad ton-miles in six of the categories, identical to the ones in which they provided a majority of the total railroad revenues. The tank car categories accounted for 9.1% of total railroad system ton-miles in 2008. Private open top hopper cars (special service) transport 79.3% of all system ton-miles transported in this type car and generated 13.4% of all railroad system ton-miles. Privately owned plain gondola cars transport 72.8% of all system ton-miles transported in these gondola cars and generated 22.6% of total railroad system ton-miles. Plain box cars (50 feet and above) and covered hopper cars were responsible for 51.8% and 52.7% of the total ton-miles generated in these car types, respectively.

REPLACEMENT COST OF PRIVATE RAILCARS

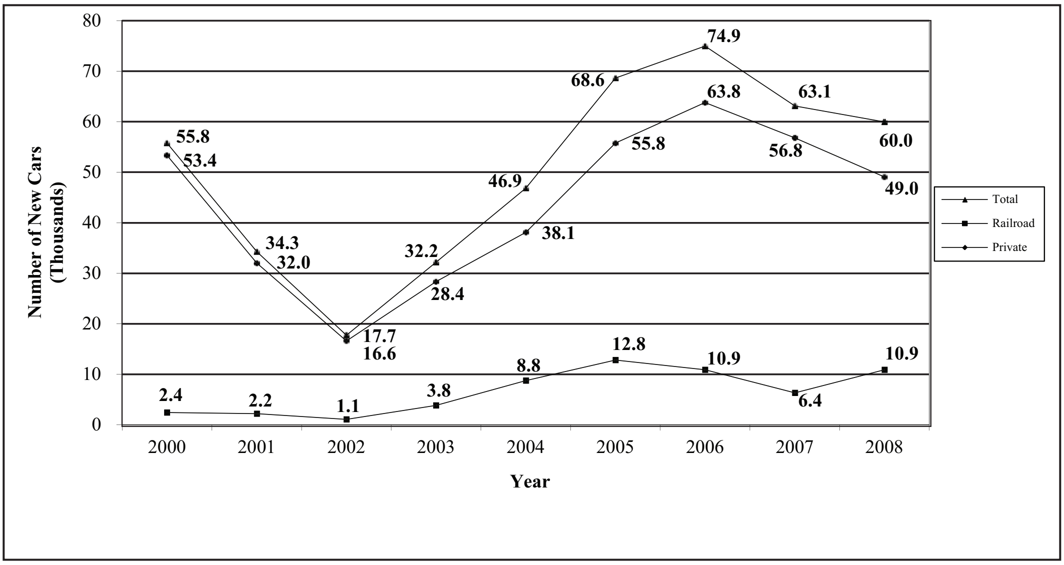
The total investment in the private fleet of railcars is highly significant and reflects investment that the railroads have not had to make. Railroads could not replace the investment made in the private fleet with their own equipment. Service disruptions would almost certainly result if private investment declined significantly. This would represent a significant challenge for distressed industries and an already strained national economy. Table 3 provides estimates of the magnitude of the investment costs associated with replacing the entire fleet of private railcars by identifying the current number of private railcars by category.[6] Investment in railcars represents a long term commitment since railcars are assets that typically have 40- to 50-year lives.

Table 3: Replacement Cost of Fleet of Private Railcars by Car Type

Equipment Category	Number of Private-Owned Cars	Replacement Costs Per Car	Total Replacement Costs
Plain Box Cars 50 ft and above	68,784	$107,000	$7,359,888,000
Plain Gondola Cars	154,593	$72,000	$11,130,696,000
Covered Hopper Cars	393,545	$74,500	$29,319,102,500
Open Top Hopper Cars	103,062	$80,000	$8,244,960,000
Flat Cars TOFC/COFC	15,524	$196,000	$3,042,704,000
Flat-Cars-General Service	37,133	$70,000	$2,599,310,000
Tank Cars-Under 22,000 Gallons	315,926	$86,000	$27,169,636,000
All Cars	1,088,567	--	$88,866,296,500

Source: Private railcar fleet size by car type from industry sources; Estimates of private railcar replacement costs by car type averaged from manufacturers, owners, and lessors. Costs are retail costs based on typical car in each car type category. Number of private-owned car data from UMLER (Equipment Management Information System 2010).

Figure 4: New Railcar Installations by Ownership Category, 2000-2008



Source: Progressive Railroading, June 2009.

If all 1.088 million private railcars were to be replaced, the total investment cost would be \$88.9 billion. The car type category generating the largest portion of the total replacement cost is the private covered hopper category – the 393,545 covered hopper cars in the private fleet have an estimated replacement cost of \$29.3 billion. The replacement cost for the second largest car type – tank cars – would be \$ 27.2 billion for 315,926 tank cars.

To further analyze the importance of the investment in private cars to the railroad industry, we examined investments in freight cars brought into the fleet during the 2000-2008 time period. Figure 4 shows the number of new railcars by ownership category during this time period. There were 453,495 new railcars built, with non-railroad, private cars representing 87%, and only 13% being provided by the railroads.

During 2006-2008, the 169,644 new private railcars added to the fleet – at an average replacement cost of a new railcar at \$87,056– represented a non-railroad investment in private railcars of \$14.8 billion, minus the scrap value of any older cars retired. This compares with the approximately \$10 billion in total annual expenditures for capital improvements by the railroads themselves.

A decline in the rate of return to private owners has coincided with a decrease in the number of new railcar installations. Even though new railcars continue to enter service, the numbers have fallen in recent years. The number of new installations is not enough to meet the replacement rate of old cars. As a result, the railcar fleet in North America is aging. The average car age has increased to over 25 years in the last 10 years (FTA Associates 2005). Low rates of return may cause problems in the future as the system ages and private investment drops off.

Overall, the rail industry, both railroads and shippers alike, have become almost completely reliant upon private car owners for investment capital in railcars. The railroads provide the locomotive power and physical infrastructure, while the overwhelming share of railcars comes from private, non-railroad investment dollars.

ADEQUACY OF RETURNS FROM INVESTMENTS IN PRIVATE CARS

The continued viability of the private fleet of freight-carrying railcars is dependent upon private fleet owners' returns on their investments. The options available to private railcar owners to obtain revenues for their cars include leasing their cars to shippers and railroads directly on both short- and long-term leases and arranging car-hire-based leases with individual railroads to compensate them for the use of their equipment, and selling cars to shippers.[7]

The following section provides an analysis of rates of returns in those cases in which data were available, and a summary of shippers' evaluation of their individual experiences with compensatory or non-compensatory rates. The analysis is based on a survey of all members of the North American Freight Car Association. Members of the association account for approximately 70% all privately owned railcars in North America (North American Freight Car Association 2011). Members were sent electronic surveys in which they filled in their answers to specific questions, including some with open-ended text-based answers. The response rate for the survey was near 100%, but with some item nonresponses.[8]

Questions in the national survey were focused on evaluating the extent of recent interchange rules and standards, the distribution of benefits and costs associated with these changes, and the perceived or documented impact of those changes on the cost structure of private car owners. Specific questions dealt with the changes in car maintenance costs, the causes of those changes, and the distribution of new costs between railroads and car owners. For a full description see Corsi and Casavant 2010.

Rates for Shipper Owned and Leased Cars

The majority of cars in the rail fleet are private cars either owned or leased by the shippers and provided to the railroads. Generally, private car owners negotiate a lease contract with a shipper, commonly a three-to five-year term tenure, at a given lease rate that provides expectations of a return over time to the lessor. Under this scenario, private car owners and shippers (lessees) assume the risk of market fluctuations, decreased demand, and other factors that affect the capital value of the car. Shippers pay the lease cost for the equipment and run the additional risk of reduced or inadequate compensation from the railroad, and any accessorial charges and other costs that arise from use of the equipment. While the shipper does obtain some benefit from providing cars, such as relief from demurrage if the cars are on industry track, the principal benefit is derived from ensuring the availability of cars at times when the market or the supply-chain needs require capacity and service.

The Interstate Commerce Act provides that shippers who furnish their own cars are entitled to reasonable compensation from the railroads. The Interstate Commerce Commission (ICC) has determined that private covered hopper cars operated by shippers are not entitled to fixed compensation from the railroads, but instead to a "market-level compensation," which was not defined by the ICC. A similar standard applies to privately financed cars furnished to (small) railroads by private sources. Indeed, market-level compensation is not easily identifiable or quantifiable in all cases. Of the survey respondents, 90% indicated that the costs they bore for routine running maintenance expenses, and the newly imposed accessorial charges assessed by the railroads, were, in some fashion, not being covered by the compensation paid by the railroads (Corsi and Casavant 2010).

As railroads worked with shippers to encourage them to provide car capacity, the method of compensation to shippers initially agreed upon for equipment other than tank cars was per mile allowances. Later, an alternative was adopted; a "differential" in rates between tariffs for railroad-provided cars and shipper-provided cars. Other early incentives for shipper investment in cars included initial mileage allowances of 35 cents to 50 cents, to as high as 60 cents per loaded mile for some commodities and movements (Corsi and Casavant 2010). Approximately 40% of survey respondents noted how over time these allowances have been substantially reduced, resulting in the current mileage allowances in the 18-21 cents per loaded mile range, a range identified by shippers as being non-compensatory. In some cases these allowances are not provided at all. Regardless of the method of compensation, shippers currently face a "silent investment loss" wherein allowances do not generate a return on leasing and accessorial charges sufficient to encourage future and continuing investment by shippers in the car fleet (Corsi and Casavant 2011).

The initial mileage allowances, resulting from statutory requirements, were designed to compensate shippers for their investment or the lease charges they paid, and served as an incentive for shipper-provided capacity. Currently, however, mileage charges at the existing level are only offered to and used by shippers for about 5%-10% of the railcar fleet, and these are offered only by select railroads (Corsi and Casavant 2010).

The common alternative is to use a spread rate for a given movement. The spread is the difference between the rates for a shipper-provided car versus a carrier-provided car. In this case, shippers are private car owners who negotiate directly with railroads.

This spread, or reduced tariff rate for the shipper-provided car, was originally calculated by using the basic mileage allowance of 24 cents per loaded mile times the estimated "turns" per month. A turn is a car's round trip to and from the originating market. Increased number of turns per time period means increased revenue. Over 50% of the responding shippers in the survey reported that the original 24 cents per loaded mile was not a compensatory rate, so any differential based on that rate was flawed.

This is even truer today where the current purchase price of cars is double what it was 20 or 30 years ago. The rate spread methodology was accepted, and, in most cases, welcomed by both carriers and shippers only because of the significant decrease in administrative activities of tracking mileage and determining costs. Today many carriers do not even offer spreads. For many of their rates they simply offer a rate in private cars for which car compensation is invisible.

In the mid to late 1990s, the shortage of cars, particularly covered hopper cars, resulted in shippers struggling to find adequate supply. To ensure a guaranteed car supply, shippers leased many cars and in numerous cases subleased them to railroads, which guaranteed shippers a minimum monthly supply of cars in return. In addition to the benefit of an increased supply of shipper-provided cars, sublease rates were compensatory. These sublease programs have since been discontinued by the railroads.

Additionally, more and more railroad rates have abandoned spreads and allowances altogether, with railroads claiming that their freight rates would have to increase if they paid private car compensation of any sort. Some private car movements today are entirely without discernable compensation to the car owner, according to 60% of the survey respondents that answered this question (Corsi and Casavant 2010). The main cost categories identified in survey responses were: lease costs, maintenance, repair, and new accessorial costs. These are costs that are covered by the shipper/private car owner and not the railroad.

Rate differentials are the difference in rates for railroad-owned or non-railroad-owned railcar shipments. Goods shipped in railroad-owned cars are typically charged more than if the shipper provides their own car. However, most rate differentials do not cover the lease or ownership costs due to additional costs imposed by railroads that were previously covered by the differential rates, such as routine maintenance costs as well as new accessorial costs, according to 90% of the survey respondents that answered this question. Private car owners identified operating, maintenance, and running repair costs at anywhere from $800 annually per car for a low-mileage general purpose freight car to over $10,000 per car for a high-mileage multi-platform intermodal car (Corsi and Casavant 2010). Furthermore, recent unilateral decisions by the railroads have put shippers in a position of paying additional costs in varying forms.

Significant rail line abandonments have severely shrunk the branch tracks available for storage and positioning of cars. For the past 10 years, shippers have had to move empty private cars off railroads' lines after being returned to a loading point or pay storage charges, or lease or rent track. The carrier-compelled need for storage of private cars has resulted in some shippers building new rail yards and facilities encompassing multiple private tracks that shippers have to maintain. Thus, in addition to providing their own fleets, shippers now find they are required to provide infrastructure and locomotive power. Railroads historically made these investments, but now shippers are forced to make up for the inadequacy of the railroad investment in cars. When normal maintenance costs along with storage charges are considered, then the rates of return outlined below fall significantly, making the overall investment in private railcars less justifiable from a rate-of-return perspective.

Finally, for railroad car types in which the railroads have no investments, e.g., tank cars, the railroads usually quote only a single rate to the shipper, which they assert is lower than it would be if they were providing the car. In this case, the shipper may also own railcars or have to contract with a third party to provide them. However, 50% of the survey respondents emphasized that they were left with no real way to verify these railroad claims. As indicated above, the railroads do pay mileage compensation on about 10% of tank car movements.

Car-Hire-Based Leases/Deprescription Rates

Private car owners may also act as leasers through formal agreements with producers who ultimately are the shippers. While some large producers, e.g., coal companies, have their own railcars, private shippers, e.g., grain elevators, who are separate from the railroad often handle the exchange from agricultural producer to destination. Car-hire-based leases compensate railcar owners who lease their cars to railroads who use their equipment in revenue-generating services. These types of arrangements generally involve small railroads with limited ability to make capital investments in cars. Through these leases, the leasing companies and railcar owners provide cars to railroads and receive payments based on hourly and mileage revenues that the car lessee receives from the railroads using their equipment as cars are interchanged.

Car-hire rates were initially determined through the use of a formula, developed by the ICC, to compensate car owners for the cost of equipment ownership along with a fair return on the investment. In an order effective on January 1, 1993, the ICC repealed the existing formulas for car-hire rates and adopted a then called market-based approach for setting car-hire rates, except for tank cars, which remained subject to prescribed car-hire rates (Corsi and Casavant 2011). The ICC's deprescription order was phased in over a 10-year period with full implementation becoming effective on January 1, 2003.

Deprescription rates are negotiated rates departing from the published rates. In theory, these rates are designed to reflect the market conditions of supply and demand. Deprescription is designed to result in negotiated rates between equipment owners and users to reflect market conditions. If, however, negotiations between the parties fail to reach an agreement, either party may request binding best and final offer arbitration, somewhat similar to the process employed by Major League Baseball to resolve player salary disputes. In the established Surface Transportation Board rules, the arbitration process is mandatory and legally binding. The associated arbitration fees are shared by both parties, up to a total of $2,000. Fees beyond this ceiling, however, are borne by the losing party in the arbitration process. Each party bears its own costs and legal fees.

Of overriding significance for the owners of railcars, however, is the extent to which market-based deprescribed rates provides the owners with a revenue stream that compensates them for the costs of ownership, plus a return on their original investment. In the case of railcars operating under deprescription rules, returns to private car owners have declined to the point of being marginally compensatory or nonexistent; such cars in many cases offer an average return of 3%, which is substantially below the railroad revenue adequacy standard of 10% defined by the STB (Corsi and Casavant 2011). In order to investigate this question, an empirical analysis was conducted of the adequacy of return rates associated with market-based deprescribed rates for the five most common different types of railroad cars: A405 Boxcars (50 ft. in length); A606 Boxcars (60 ft. or above in length); E530 Gondola cars; C112 Hopper Cars (3,000-4,000 cubic ft.); and C114 Hopper Cars (5,000 cubic ft.).

Estimating Rates of Return

Market deprescription rates were obtained from the Association of American Railroad (AAR) website, from which all records were selected where the Car-Hire Accounting Rate Master (CHARM) rate type code is equal to M (market rate) or S (spot market rate).[9] These rates are collected by railroads themselves. For each railroad car type, the average hourly market rate was calculated for each month of 2009 to get an annual average hourly rate.

It was assumed that the equipment would have a 70% utilization rate or 511 revenue hours per month (an industry average performance). Annual revenue was estimated on the basis of the hourly market rates and the assumed utilization factor. It is assumed that the mileage revenue received by the equipment owner would offset any maintenance expenses associated with the equipment.

Thirty-year rates of return were calculated for each type of equipment under the following set of assumptions: (1) annual revenue based on 730 revenue hours per month times 12 months times the average annual hourly market rate; (2) industry estimated car replacement costs based on current equipment retail prices; (3) a $5,000 residual equipment value at age 30; and (4) gross rail load of 286,000 lbs. for each railcar. The use of average annual rates is appropriate since railcar leases are typically a year or longer. Very few leases are signed for less than a calendar year.

Table 4 provides the implied 30-year rates of return under 2009 market-based deprescription rates for each of the five railroad car types. The return rates vary from a low of 2.19% for the A405 Boxcars to 3.84% for the C112 Hopper Cars and the E530 Gondola Cars. In all cases, these rates of return are below the 20-year risk-free treasury rate of 4.27% (as of May 4, 2010) and dramatically below the STB revenue adequacy return of around 10%.

Table 4: Market Deprescription Rates: Adequacy of Returns

Equipment Type	Average Hourly Rate	Equipment Replacement	Implied 30 Yr Return Rate	Risk Free 20 Yr. T-Rate
Boxcar A405	$0.78	$107,000	2.19%	4.27%
Boxcar A606	$0.8	$120,000	2.33%	4.27%
Gondola E530	$0.65	$72,000	3.84%	4.27%
Hopper C112	$0.63	$74,500	3.84%	4.27%
Hopper C114	$0.64	$80,000	2.95%	4.27%

Source: Equipment Management Information System, 2010 (286 GRL assumed); average hourly rate: 2009 average market rate; equipment cost: industry estimates; 30-year return rate: assumes 70% utilization, 511 revenue hours per month $5,000 residual value at age 30; risk-free 20-year T-Rate as of May 4, 2010.

The market-based deprescribed rates appear to have not yielded car owners a return rate that compensates them for their investments compared with available alternatives. In part because the difference in price charged by railroads based on whether cars are private or owned by the railroad has been declining (Corsi and Casavant 2011).

Indeed, the 30-year rates of return are substantially below the risk-free Treasury bill rates. It is safe to assume that unless rates of return are increased, investors will find more appropriate uses for their capital investments, and the railroad industry will find itself in an unsustainable position going forward absent a substantial investment in railcars. This analysis is limited to the monetary returns of railcar ownership. Surely, owners benefit from car ownership in other ways, for example, faster and more reliable service, increased certainty in car capacity availability, and improved ability to forecast their own movements for their internal needs.

Note too that the comparison on return rates of the risk-free Treasury bill does not even compare with a more appropriate point of reference—the internal rate of return used by the railroads themselves in making investments. Indeed, the railroads seek a 10% return rate on their own investments—significantly above the Treasury bill return rate. The data show that deprescribed rates have failed to deliver compensatory rates of return for equipment owners. If rates of return remain at low levels, future private investments will decrease. The next section details some of the costs that have been shifting to car owners; however, a full investigation into all sources of low returns is beyond the scope of this paper and left to future work.

Continued Shifting of Costs

The previous section covered economic conditions that affect revenue generation from private car ownership. This section analyzes factors that impact the cost of car ownership. Many costs that were traditionally paid by railroad companies are now being paid by car owners. Such shifts amplify pressures on the revenue side.

Railroads are in charge of fitting cars with wheel sets. A wheel set consists of a single axle and two wheel plates which roll along the track. An issue has arisen regarding the allocation of new versus used wheel sets. Some survey responses indicated that some railroads are applying the higher priced new wheel sets to privately owned freight cars and retaining the lower priced turned wheel sets for their own fleet of freight cars (Corsi and Casavant 2010). Another issue is the Single Car Air Brake Test. The AAR chargeable price for a car that is past due is higher than the cost of a car not overdue. While not well documented in the survey, the understanding is that the added charge is for the cost to move the car to a repair track. However, that cost is also included in the AAR Labor Rate Overhead under "Switching."

When car parts are found missing from cars in railroad possession, the railroads historically paid for the missing parts. Now, railroads accept responsibility only when railroad documentation of their removal is produced. Car parts lost or stolen while a car is in a railroad's possession are left for the car owner to pay, even though the car owner has no control of the car in the train. Looking into the future, the advent of electronic brakes and positive train control has both safety and efficiency benefits. The Federal Railroad Administration has already identified the benefits of electronic brakes as accruing to railroads primarily as a result of increased railroad operating efficiency and fuel cost reductions. Concerns about the future allocation of the estimated $6 billion cost of this innovation are self-evident.

The industry survey found numerous instances of new rules shifting costs or increasing costs to car owners when car owners do not share in the benefits resulting from implementation of those rules. Most changes in the AAR Interchange Rules are related to safety or efficiency improvements on the part of the railroads and the private car owners (who may also be shippers). Two major changes, the Wheel Impact Load Detectors (WILD) rule and the Long Travel Constant Contact Side Bearings (LTCCSB) rule, have been shown to produce substantial efficiency benefits to the railroads and minor public safety benefits.

From an economic efficiency and welfare perspective, benefit/cost ratios should be calculated both for the industry as a whole, and the distribution of benefits between railroads and car owners. The results should form the basis for distributing costs among affected parties. For the market to work for car investment there needs to be an equitable, non-discriminatory, and transparent interchange rule process.

CONCLUSION

The dependence of the railroad industry, the shippers using that industry, and the United States economy on the private car rail fleet is dramatic and growing. Private car owner equipment now carries 54% of total ton miles and 56% of total tonnage moved by railroads, and 87% of new investment in railroad cars has been made by private car owners.

Returns to the private car owners are considered barely compensatory. Under the deprescription rules, the ROI of the revenue streams is at least 30% below the lowest risk-free Treasury Bill (an average of 3%, compared with 4.27%, both substantially below the railroad revenue adequacy standard of 10%). While there are other benefits to private car ownership, such as more responsive service, car capacity availability, and ability to forecast their own movements, the monetary returns remain low. The required investment to replace the current private car numbers is staggering, about $90 billion would be required to replace the current private car fleet at current replacement values. The overall adequate supply of railcars is a critical component of the freight rail supply chain, including the efficient delivery of products to the nation's producers and consumers.

The results presented here are based on readily available data, and are a good starting point for documenting the low rates of return to railcar ownership. A more formal statistical investigation into exact causes of low returns is a promising question that is left for future work. This paper suggests that more work is needed to understand why rates are low, and if the driving force is market driven, regulatory driven, or both. It is possible that market forces would resolve the returns issue over time if no significant market imperfections exist. Otherwise, regulatory action may be needed.

This tenuous situation is further exacerbated by continual cost shifting from railroads to shippers or owners. Changes in regulations have forced significant increased costs, such as those for WILD, LTCCSB, among others, to be borne by the car owner, even though the benefits of these improvements are received in most cases by the railroads. Other shifts have forced car owners to build new rail yards and facilities encompassing multiple private tracks. They now have to maintain investments they were forced to make to achieve what the railroads used to provide. The loss or lessening of these private car investments would create dramatic economic impacts.

Endnotes

1. William E. O'Connell is the retired Chessie Professor of Business at the College of William & Mary, Williamsburg, Virginia.

2. Surface Transportation Board. "2008 Public Use Waybill. Washington DC,. 2008 Accessed August 2, 2011 http://stb.dot.gov/stb/industry/econ_waybill.html.

3. Although the 1990 Railroad Carload Waybill Public Use data files are available, the 1990 data file does not identify the TTX ownership category, instead including the TTX data in the private car ownership category. In order to portray an accurate picture of the dynamic redistribution of traffic among the three categories, this paper focuses on the years for which the three ownership categories were identified.

4. Data for all figures come from the Railroad Carload Waybill Data, Surface Transportation Board, Washington, D.C., Public Use File, 2000, 2005, and 2008.

5. The six car types are: plain box cars 50 ft. and above, plain gondola cars, covered hopper cars, tank cars under 22,000 gallons, tank cars 22,000 gallons and over, and open top hopper cars-special service.

6. While it is unlikely the entire private fleet would be replaced with new railroad-owned cars, if low returns resulted in all private car owners leaving the business, the actual investment decisions in these circumstances are difficult to predict, as it would involve railroad choices between keeping older, smaller, and more maintenance-intensive cars and replacing them with newer, larger cars.

7. All private cars must obtain OT-5 operating authority to originate loads. We found some private car owners noting that certain railroads have been denying OT-5 operating authority on the grounds that they have too many cars. This is against STB rules stating that OT-5 operating authority may not be denied except for safety or mechanical reasons or a lack of adequate storage space for the cars. Such denials may, indeed, impact the revenue opportunities for private car owners.

8. The North American Freight Car Association has approximately 31 members, so a 100% response rate is not unexpected.

9. Accessed May 10, 2011. http://www.aar.org/StatisticsAndPublications.aspx.

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Acknowledgements

This research is based on work funded by the North American Freight Car Association. We thank the editor and two anonymous referees whose comments greatly improved the paper. The views presented in this article represent those of the authors and not those of the United States Department of Agriculture or the Economic Research Service.

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Disappearance of American Wealth and Its Impact on Air Travel: An Empirical Investigation

by Dipasis Bhadra

Recently, the Federal Reserve reported that U.S. households net worth dropped by $17 trillion, a stunning 26% loss from the peak of the cycle to the bottom. The precipitous drop in home and stock prices that continued through the first quarter of 2009 accelerated the drop in household wealth. Meanwhile, U.S. air travel suffered tremendously. While the economy contracted by around 1% in 2008 and the first part of 2009, total domestic enplanement dropped more than 4% over its 2007 level. Gross domestic product (GDP) or some other measure of current income has been a good predictor of air travel in the past. While current income is considered to be a good proxy for current discretionary spending, of which air travel is only one small part, recent destruction of wealth has significantly reduced the average consumer's traditional appetite for expenditure, including air travel. Interestingly, there is very little empirical analysis that establishes a link between wealth and air travel. The paper seeks to address this gap by asking and investigating two empirical questions: (a) Does wealth have any quantifiable impact on U.S. air travel, controlling for all other relevant variables such as current income, past wealth, fare, and credit availability? (b) What has been the quantitative impact of wealth loss on air travel? The paper finds that the household wealth loss of U.S. $17 trillion yielded a loss of air travel demand of 730,000 passengers; or a loss of revenue of $244 million. As household wealth improved during the last two years, air travel recovered. Some of the lost passenger demand has been recouped (435,000) but a complete wealth-induced recovery still seems to be far off. Results of this analysis are important for both understanding future transitions in U.S. air travel, and hence forecasting, and formulating policy responses that may be designed more narrowly and effectively.

INTRODUCTION

Much has been written on the meltdown of U.S. financial markets and the impact on household's net wealth or net worth.[1] At the height of the financial debacle, the average wealth of American families plunged over 26%, or by almost $17 trillion. This was the largest loss since the Federal Reserve began keeping track of U.S. household wealth since World War II. Virtually every economic indicator went down, thus creating the longest and deepest economic recession since the Great Depression. The reverberations of the Great Recession of 2007-2009 are still being felt in almost all sectors of the U.S. economy.

Interestingly, very little research has been done to understand how this massive change in household's portfolio of assets and wealth impacted the way households consume goods and services. While the drop in overall personal consumption expenditure (PCE) in response to the Great Recession has been noted, there has been very little research investigating the effect of wealth loss on the composition of PCE. In particular, there does not exist any theoretical or empirical research integrating wealth and its impact on U.S. domestic air travel.

Empirical relationships postulate positive relationship between current income and components of current consumption. Using the estimated relationships and assuming them constant over time, forecasters derive components of PCE given the forecasts of current income. A similar methodology is also employed in generating forecasts of air travel. Despite the empirical (Gournichas and Parker 2002) and theoretical (Ghez and Becker 1974) existence of life cycle consumption hypotheses, the influence of asset portfolios is generally ignored. Very little is known as to how wealth is used to smooth out fissures in current consumption as nominal income drops due to a contracting economy; or alternatively, current consumption is boosted due to the expansion of wealth-enhancing consumer confidence and providing relatively easy access to liquidity. In other words, asset holding has a significant influence on consumption patterns and overall standards of living. This point was captured succinctly by Alan Greenspan as following: "Ultimately, we are interested in the question of relative standards of living and economic well-being. We need to examine trends in the distribution of wealth, which, more fundamentally than earnings or income, represents a measure of the ability of households to consume." Former Chairman of the Federal Reserve Bank, 2008 (see http://www.federalreserve.gov/boarddocs/Speeches/1998/19980828.htm).

There appears to be two reasons for ignoring this relationship: First, asset portfolios have traditionally remained illiquid and have had relatively little impact on changes in consumption as a whole and air travel in particular; only in recent times, has part of the massive wealth expansion been made available for current consumption via easy liquidity. Second, it is difficult to forecast movements in asset portfolios, far more difficult than forecasting growth in current or nominal income over time. Thus, *apriori* knowledge of the empirical relationship between wealth and consumption as a whole and air travel in particular is not really useful because of the forecasters' restricted ability to predict movements in wealth.

This paper is designed to fill the void with respect to the former issue; that is, the relationship between assets and air travel is explored at some length in this paper. This paper seeks to demonstrate that the asset portfolio has become important as people began to take advantage of the liquidity of the asset portfolio, and increasingly more people retire over time. Second and more importantly, volatility in asset portfolios has had considerable influence over air travelers' behavior. Examining size and relative change in magnitude of wealth and its impact on air travel is the key empirical issue underlying this paper. The paper acknowledges the difficulty in forecasting wealth. Nevertheless, an alternative is sketched out toward the end of this paper strengthening the forecasting of air travel that incorporates both nominal income and movements in assets. By offering a somewhat simple and tractable empirical framework, the paper sheds some new light on the issues relating to forecasting, i.e., movements in assets and impact on air travel in the future.

The paper is organized as follows. The second section provides a brief discussion of the magnitude of losses (and more recently, gain) of total wealth and its impact on overall PCE and air travel. This section also reviews the available empirical literature on related issues. Borrowing from the macroeconomic literature, the third section provides an analytical framework linking wealth, current income, and air travel. This section lays out the key empirical hypotheses and introduces data and empirical structure. The next section provides the key empirical findings, and discusses the implications of these findings including forecasting. The last section explores future research, and policy implications and provides some concluding thoughts.

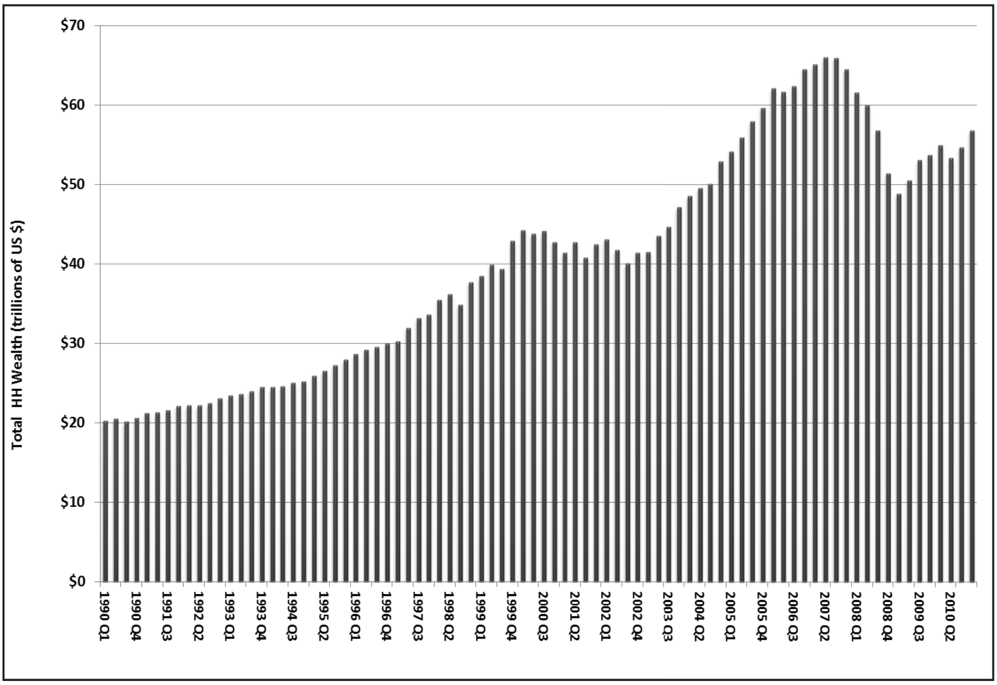
BACKGROUND

U.S. households experienced an extraordinary expansion in wealth (see Figure 1) over the last two decades. Not accounting for inflation, the value of U.S. households' wealth doubled in the decade of 1990s; from a total of $20 trillion in 1990 to over $43 trillion in 1999:Q4 (Figure 1).

Following an average growth rate of around 5% in the earlier part of the decade of 1990s (1990-1994), wealth began to expand rapidly in 1995 fueled by the tech boom that lasted until 2000:Q3. During this period, i.e., 1995:Q1 – 2000:Q3, the average rate of growth doubled to an annual return of 10% (see Figure 2).

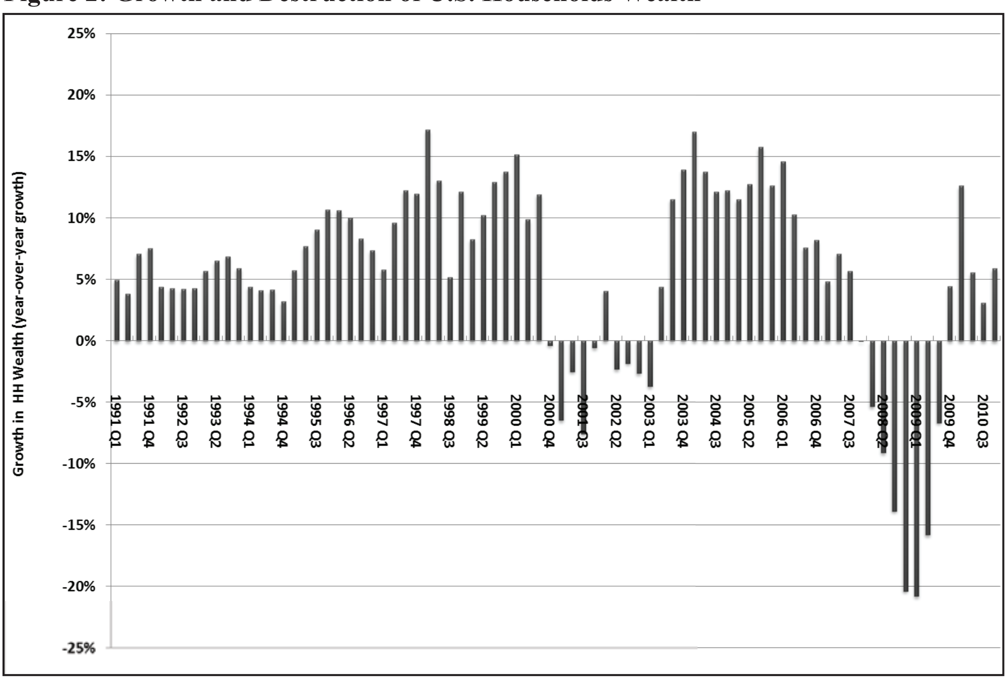
As the tech bubble burst, the wealth portfolio began to shrink at an annual average rate of -2% that lasted 10 quarters from 2000:Q4 to 2003:Q1 (see Figure 2). Interestingly, however, the economic recession during this period lasted only eight months from March, 2001 to November,

Figure 1: Trends in U.S. Households Total Wealth (Trillions of U.S. $)



Source: Based on data available at http://www.bea.gov/national/index.htm#gdp; and http://www.federalreserve.gov/releases/z1/Current/

Figure 2: Growth and Destruction of U.S. Households Wealth



Source: Based on data available at http://www.bea.gov/national/index.htm#gdp; and http://www.federalreserve.gov/releases/z1/Current/

2001. Nonetheless, the economic recession lasting a shorter period than the average duration has had a significant impact on the duration of wealth contraction.

The next phase in family wealth expansion began to take place as early as 2003:Q2. Rapid expansion in the housing market fueled the next round of wealth expansion that lasted 17 quarters during 2003:Q2–2007:Q3, generating over $22 trillion additional value and yielding an annual average rate of 11%. Like the prior period, additional wealth generated during this period found its way to liquidity via numerous types of secured and unsecured loans. Consumers responded to this additional liquidity by consuming more.

The financial crisis that accompanied the housing market crash continued during 2007:Q4–2009:Q3 and was extraordinary in both severity and effect. Over half of the earlier gains, $15 trillion (out of $22 trillion) at the bottom in 2009:Q2, was lost, recording an all-time average decline of 11% annually and was unprecedented compared to earlier declines, particularly to the one that was followed by the tech bubble deflation (i.e., -2%). This extraordinary contraction was possible due to an overall decline in home prices, which is still continuing in many major metro areas, and a decline in stock prices. However, despite the overall continuing fall in market price and thus, declining value of real estate, households' wealth portfolio began to expand again in 2009:Q4 and continues at an average rate of 6% annually. This was possible primarily due to the superior performance of the stock market. The stock market has had an extra ordinary performance run for almost six quarters; the performance has halted only recently following a devastating natural disaster in Japan in March 2011 and the European debt crisis.

The rise and fall in asset holdings demonstrate that while, in the long run, wealth tends to expand at around 5%-6% annually, the interim pace of returns appears to have become increasingly volatile, particularly during contraction. Second, and most importantly, the volatility may have behavioral consequences on the way households allocate finances and consume goods and services. These changes may have long-term implications on transitions of the economy.

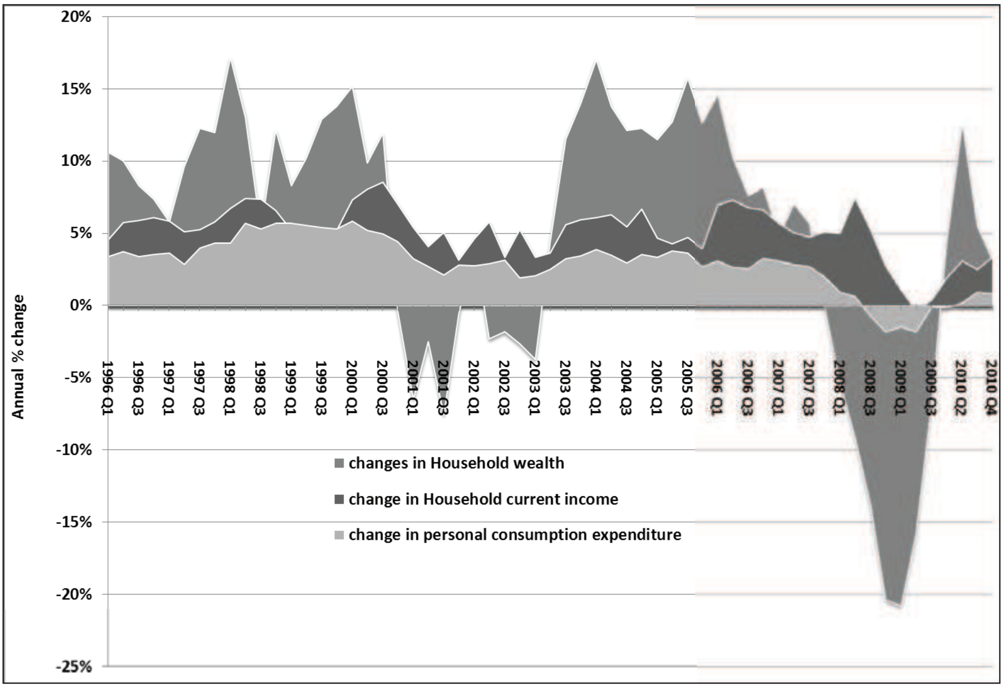
At the end of 2010, PCE in current dollars stood at around $10.35 trillion, or around 70% of gross domestic product (GDP) of $14.66 trillion in current dollars and $13.25 trillion in chained or constant dollars (see http://www.bea.gov/national/index.htm#gdp). In addition to a severe decline in returns to wealth holding, the severity of the Great Recession resulted in a contraction of PCE; the U.S. households' PCE shrank an annual average rate of 1% during 2008:Q3–2009:Q4 (see Figure 3).

Interestingly, PCE grew despite the earlier recession (2001) although the rate of growth slowed considerably to an average rate of 3% during the earlier part of the decade of 2000. The PCE grew at an average annual rate of 4.6% during the latter 1990s. Following the deep recession, PCE growth has turned positive only recently (2010:Q1) and now shows a little over 1% annual growth. It is worthwhile to note that, other than during the period of the Great Recession, the relationship between PCE and net worth is not easily evident.

This relationship is somewhat clearer as components of the PCE are considered. Not including expenditure on durable and non-durable goods (around $3.43 trillion), PCE for services stood at $6.7 trillion (or 64% of total PCE) in 2010. Households spent around 28% on housing/utility related expenditure ($1.69 trillion); a little over 25% on health care ($1.46 trillion); a little over 9% on food services ($626 billion); 4.5% on transportation services ($300 billion); 5.7% on recreation services ($381 billion); 12.3% on financial services and insurance ($821 billion); and 14% on other services ($942 billion).

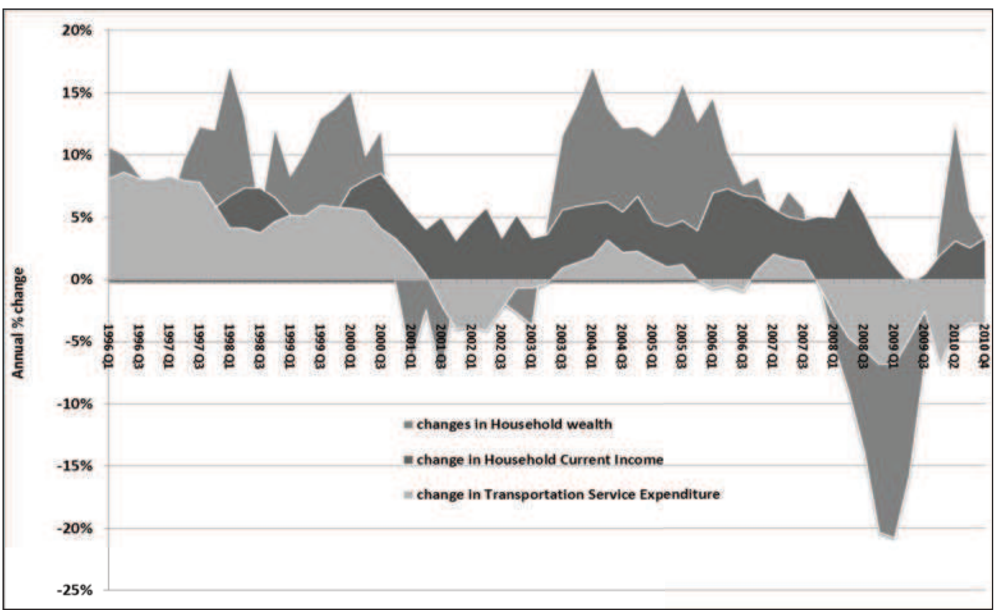
Aggregate household expenditure account does not identify air travel; instead, the expenditure can be indirectly calculated using expenditures on transportation and recreation services. Expenditure on air travel and related services is estimated[2] to be 2.1% of total PCE services, or $190 billion/year and assumed to be originated in expenditure on transportation and recreational services. Figure 4 illustrates the trends in expenditure on transportation services with respect to changes in household wealth and net income. As the figure shows, expenditure on transportation services has

Figure 3: Trends in U.S. Households Income, Net Wealth and PCE



Source: Based on data available at http://www.bea.gov/national/index.htm#gdp; and http://www.federalreserve.gov/releases/z1/Current/

Figure 4: Trends in Income, Wealth and Transportation Service Expenditure

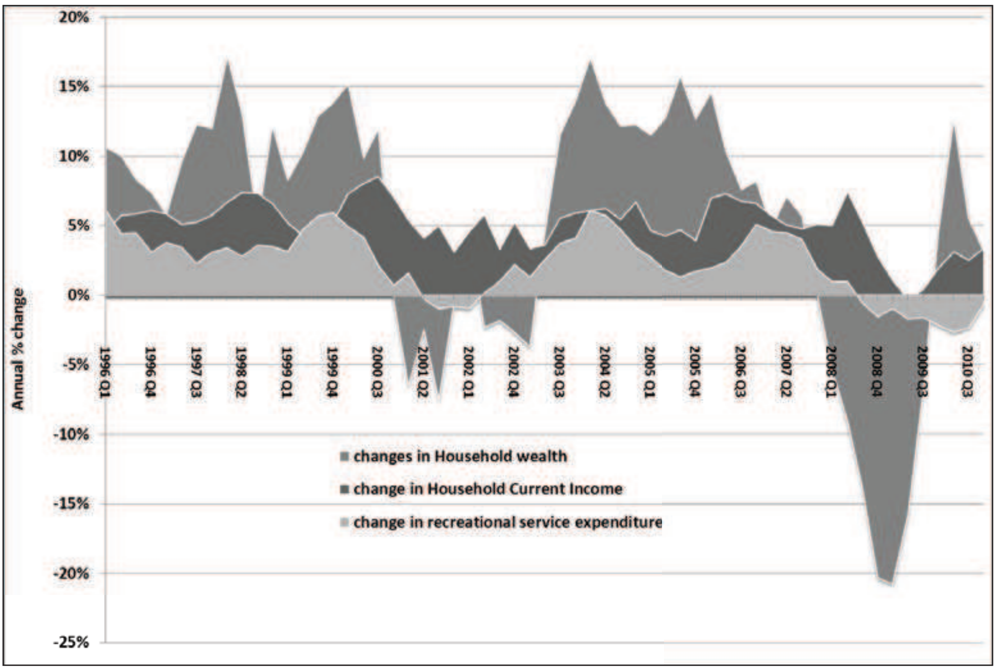


Source: Based on data available at http://www.bea.gov/national/index.htm#gdp; and http://www.federalreserve.gov/releases/z1/Current/

been relatively responsive to changes in economic conditions; as income and wealth contracted, households adjusted their spending by cutting down on transportation services and vice versa (see Figure 4).

In comparison, spending on recreational services adjusted downwards rather slowly as income and wealth went down but adjusted upward faster during the period of economic expansion, i.e., the decade of 2000 following 9/11 (see Figure 5).[3] An evaluation of the expenditure patterns reveals that expenditure contraction has been rather disproportionate for transportation and recreational services during the Great Recession: -5.6% (Figure 4) and -1.44% (Figure 5) respectively although PCE services declined "only" by 1% during the period 2008:Q3–2009:Q4. In other words, of the total unspent expenditure on PCE-Services of around $92 billion for a year (-1%), a combined total of $20 billion (or, 22%) had not been spent on transportation and recreational services in aggregate. Notice that this knowledge in aggregate does not allow us to decipher the amount lost in air travel during this period. The analysis presented later attempts to shed some lights on identifying this value.

Figure 5: Trends in Income, Wealth and Recreational Service Expenditure

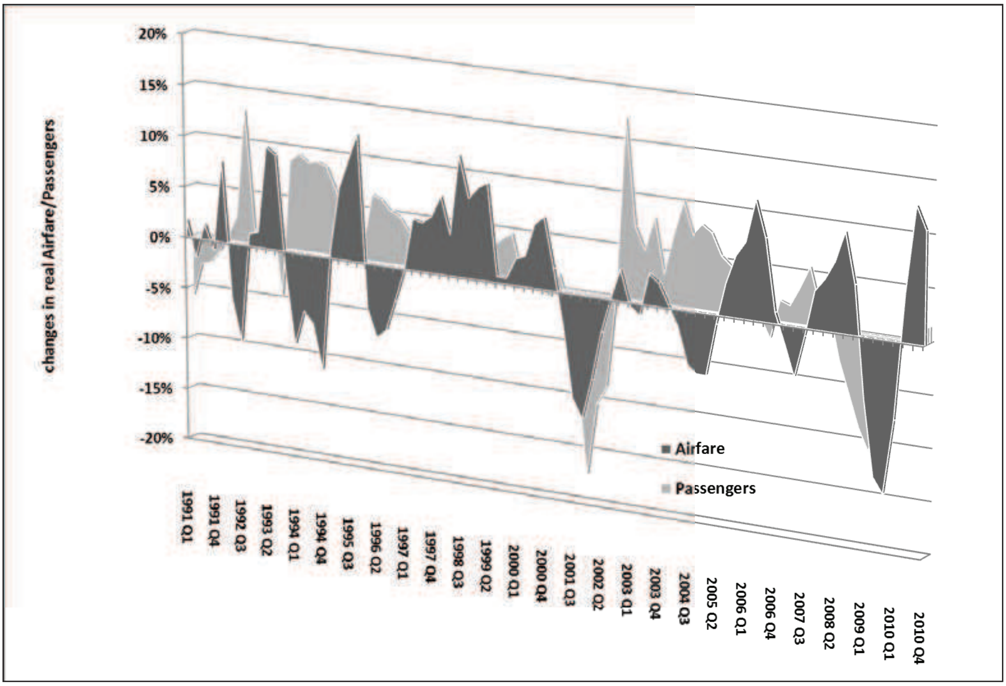


Source: Based on data available at http://www.bea.gov/national/index.htm#gdp; and http://www.federalreserve.gov/releases/z1/Current/

The above discussion appears to indicate that there may be a relationship between household wealth and spending on different components of consumption expenditures, particularly air travel given the focus of this paper. However, the causality of that relationship is not clearly evident, nor is it quantified and established in the empirical literature. Most empirical studies of domestic air travel do not take into account wealth (or any measure of permanent income) in estimation and/or forecasting. Most of the existing studies and forecasting framework employ some form of gravity framework (Bhadra 2003; Bhadra and Kee 2008) specified in terms of fare, economic activities (i.e., mostly, current income), demographics, distance, and seasonal variations. At the core of these empirical studies sits the negative relationship – observed and/or estimated - between fare and passenger demand. Figure 6 demonstrates this basic relationship: as airfare drops, generally speaking, passenger demand increases and vice versa. Positive co-movements, on the other hand, capture the essential responsiveness of passenger demand to changes in economic growth, such as GDP and/or personal income (Bhadra 2003 and Bhadra and Kee 2008).

However, when this negative relationship does not hold, e.g., periods of 1991, 2001–2002, and 2009–2010 in Figure 6, econometric modelers often use dummy or qualitative variables to capture the major structural shifts in the quantitative relationship (i.e., periods of economic recessions, 9/11, financial calamities). Interestingly, very little attention has been given to capture the underlying dynamics beyond the flow mechanics of price/fare, current income, and role of dummy variables to capture the movement in demand for air travel.

Figure 6: Trends in Air Fare and Passengers



Source: Based on data available at http://www.transtats.bts.gov/

LITERATURE REVIEW

In representative spirit of earlier empirical studies, Bhadra and Kee (2008) provided an analysis of the fundamental structures and dynamics of the origin-destination (O&D) or core air travel markets in the U.S. using quarterly data covering 1995–2006. Despite all the adversities, e.g., the industry gradually consolidating its network, SARS, internet pricing and availability of videoconferencing, jet fuel price hikes of summer 2008, and sustained capital drain via losses in the last decade - just to name a few, passenger flows between O&D markets have exhibited strong growth in recent years. When segmented by types of markets, Bhadra and Kee (2008) found that while super-thin markets (10 passengers or less a day) lost service, other market segments gained service over time. For example, a majority of passengers flying in the thick markets (more than 100 passengers a day) accounted for only a small portion of the markets, but demand continued to grow in those markets over time. Using fare and income elasticities (both origin and destination), Bhadra and Kee (2008) demonstrated that thick markets were structurally different than other types of markets.

Reviewing 23 key empirical studies covering the last quarter century, InterVistas (2007) concluded that the changes in air fares was the key factor in determining demand responses. The exact magnitude of the demand responses depended upon types of passengers (i.e., business vs. leisure passengers), distance of travel (short-haul vs. long-haul travel), carrier vs. market vs. national level responsiveness in demand changes (i.e., differentiated responses in traffic with respect to fares), and income elasticities. Using this review in the background, InterVistas (2007) modeled passenger demand employing domestic O&D data (or 10% sample data as it is commonly known) for the top 1,000 city pair routes, IATA's Billing and Settlement Plan (BSP) data, and UK outbound international passenger survey data.

One of the most comprehensive analyses of elasticities in air travel has been reported in Gillen, Morrison, and Stewart (2003). The authors reviewed 21 studies and categorized them in terms of travel characteristics (i.e., business and leisure travel, long-haul vs. short-haul travel), market and route characteristics (i.e., connecting vs. O-D passengers, hub-and-spoke airports, route-specific estimates), model specification and aggregate statistics (i.e., inclusion of income coefficient, inclusion of intermodal substitution, adjusted R-squared values) and data characteristics (i.e. panel vs. time series vs. cross section, country focus, age of the study). Using arbitrary values on these characteristics, Gillen et al. (2003) scored the studies and reported a range of own-price elasticities or fare elasticities based on 254 estimates in the range of -3.20 to 2.5. The midpoint of these estimates was found to be -1.122 with the third quantile reported to be around -0.633 with the first quartile to be -1.418. Skewness (-0.37) of the data distribution was found to be significantly different than the median (-1.122), indicating that estimated fare elasticities were not normally distributed, i.e., there were significant variations in the characteristics of the estimates. Interestingly, none of the studies they reported consisted of discussion on wealth or impact of permanent income on air travel. Due to this omission, Alperovich and Machnes (1994) earlier argued that many existing empirical models may have been mis-specified and thus, estimated elasticity coefficients are exaggerated.

Earlier, Brons, Pels, Nijkamp, and Rietveld (2002) reviewed 37 empirical studies. Using estimates from these studies, Brons et al. (2002) developed a meta model deciphering the key characteristics of air travel. Authors concluded that time series data, inclusion of business passengers, short-haul elasticities and inclusion of an income variable led to smaller fare elasticities. Using this meta model, the authors found that air travelers have become less fare sensitive over time. Again, no consideration was given to wealth or permanent income as opposed to or in addition to current income determining air travel.

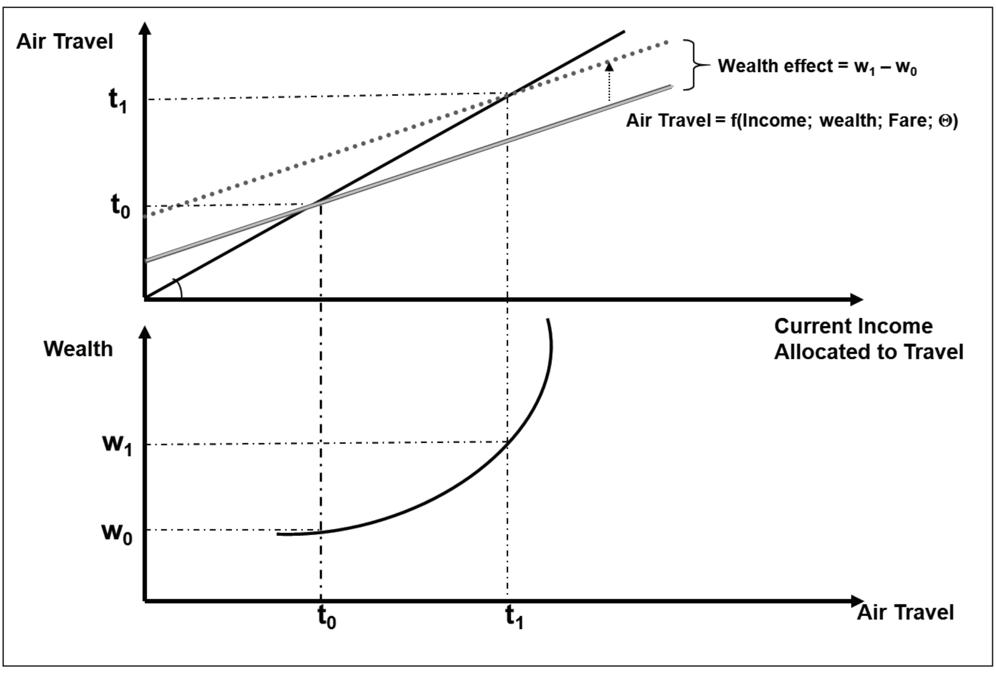
Interestingly, studies determining international air travel tend to use wealth (or some proxy) in addition to other variables. Unlike the determinants of domestic air travel, selective studies used wealth as an explanatory variable for determining international air travel. For example, trends in dwelling prices (as representative of household wealth), consumer expenditure and GDP were found to have strong contemporaneous cyclical correlations, i.e., troughs and peaks tend to go up and down together; however, there is very little trend or secular correlations among these variables. Examining co-movement data for the period 1970-2002, CAA (2005) concluded that "(correlations) suggest that household wealth may be an important predictor of demand for air travel over the *short term*. This may in part be explained by the fact that changes in consumer confidence are closely related to wealth since consumers are known to use asset, and in particular house prices as an indication of the state of the economy.[4] At the same time, however, the preliminary evidence suggests that wealth may add very little, if anything, to *long-term* predictions of demand, over and above the information already contained in the GDP variable" (p. 19; CAA 2005). CAA thus used house prices, in addition to consumer expenditure, air fares, and effective price of tourism, to model and forecast international air passenger traffic for a given market in a particular year.

Noting the lack of some measures of wealth in determining air travel demand in present empirical studies, Alperovich and Machnes (1994) used per-capita non-financial assets (i.e., housing, machinery and equipment, durable goods, and stocks of physical inputs) and per-capita financial assets (i.e., retirement funds, long-term saving deposits, bonds, shares, other deposits, and cash) to represent consumers' wealth. These measures of wealth essentially differ in terms of the degrees of liquidity and are generally implicit in demand models. Using time-series aggregate annual data (1970-1989) from Israel on number of travelers, population, full price of travel, income, financial assets, non-financial assets, and CPI, Alperovich and Machnes (1994) found: (a) air travel from Israel to all foreign destinations is highly elastic in income and inelastic in price; and (b) there was no difference in demand elasticity between financial and non-financial assets and both are shown to be inelastic. The results provided solid support for the central empirical hypothesis that demand for international air travel is determined, other things being equal, by consumers' wealth. Despite these findings, it is interesting to note that none of the later empirical studies reviewed in Brons et al. (2002) and Gillen et al. (2003) incorporated any measure of consumers' wealth in determining demand.

EMPIRICAL FRAMEWORK AND DATA

This section lays out a simple analytical framework where the basic relationship between nominal or current wealth and air travel is investigated together with the standard relationship involving current or nominal income (Figure 7) and air travel. The discussion in the preceding section indicates that wealth has an impact on current consumption and particularly on air travel. The figure below provides one postulated linkage[5] drawing on the literature discussed above. The top part of the panel in Figure 7 depicts the standard relationship between current income allotted to travel and air travel; as current income increases (and allocation of income on travel), so does the air travel. Along with the current income, air travel is also dependent on wealth, air fare, and a host of other factors captured by Θ.

Figure 7: Determinants of Air Travel: Current Income and Household Worth



Following the standard demonstration of the Keynesian cross in determining macroeconomic equilibrium, an intersection between the 45-degree line and air travel function above determines the equilibrium air travel of t_0 corresponding to a given level of allotted current income on travel, holding all other variables constant (upper panel of Figure 7). As nominal or current level of wealth increases, the air travel function shifts upward (dotted line) thus, determining a higher level of equilibrium air travel (t_1) given the same level of allotted current income on travel and all other variables. This establishes the relationship between wealth and air travel as captured in the lower panel of Figure 7, increasing exponentially at first and then leveling out at higher levels of wealth.

The slope of the air travel function or the marginal propensity of air travel, i.e., changes in air travel in response to changes in allotted current income on travel, measures the "pure"[6] elasticity of air travel. As current income allotted on travel goes down, air travel goes down and vice versa, yielding a positive slope that is constant at all income levels.[7]

Air travel is also a function of air fare; so as air fare increases, it is expected that air travel will go down through a downward shift in the air travel function and vice versa. Traditionally, this is captured by fare elasticity and generally estimated to be negative.

Finally, as nominal or current wealth goes up, households feel wealthier and their confidence enhances leading to an increase in air travel causing an upward shift in air travel function (Figure 7: upper panel) and vice versa. However, the sense of being wealthy and its impact on air travel is not constant at all levels of wealth, giving rise to a non-linear relationship between wealth and air travel (lower panel). Increase in air travel due to increase in wealth is faster at lower levels of wealth, i.e., a "novelty" aspect; while at higher levels of wealth, increases in air travel corresponding to increases in wealth slows down, i.e., a "normal" aspect. This leads to the shape of the curve in the lower panel, an empirical hypothesis that will be tested in this study.[8] Earlier empirical studies (see InterVistas 2008 and Brons, 2002) tend to lend some credence to this assertion.

The above relationships underlying the extended passenger demand function can be generally stipulated as follows:

(1) PaxD = f (Current Income, Household wealth, average fare, Θ)

where PaxD denotes the demand for air travel at a particular time t. All variables are denoted at the corresponding time t.

For the empirical analysis presented in this paper, cross section data of current income, household wealth, average fare, and other variables have been assembled for the period 1990:Q1–2010:Q4 or 84 observations in total. Passenger demand is represented by total enplanement (i.e., domestic and international) and come from the U.S. Department of Transportation (see http://www.transtats.bts.gov/Data_Elements.aspx?Data=1). Average fare series is calculated using data from the USDOT and Air Transport Association (see http://www.airlines.org/economics/finance/PaPricesYield.htm). Current income, household wealth, interest income, and all other related data come from U.S. Flow of Funds Accounts (see http://www.federalreserve.gov/releases/z1/).

The above specification is similar to earlier estimation framework from the empirical literature in the sense that it takes into account both current income and average fare. Using the estimated parameters, the standard fare and income responsiveness or elasticities can be easily calculated. However, it differs from most of the earlier studies in two important aspects: (a) the specification in (1) applies a generalized framework involving aggregate current income and wealth to determine and explain passenger air travel, and not a subset of it (e.g., CAA 2005 and Alperovich and Machnes 1994); and (b) it hypothesizes interdependencies determining both passenger demand and household wealth. Unlike the studies that incorporated wealth as an exogenous driver of passenger demand, the present study postulates that wealth can be determined within the empirical system and there are interdependencies within different variables and thus, demand and wealth should be determined as a system of equations as opposed to a single equation for air travel demand.

Estimation, Discussion of Results and Implications for Forecasting

The empirical framework thus hypothesizes that household wealth is determined alongside the passenger demand and there are interdependencies that need to be estimated. Two equations that capture the essence of the empirical relationships and interdependencies are stipulated as a system as follows:

$$\text{(2)} \quad PaxD = a_0 + a_1 * average\_fare + a_2 * Hh\_Wealth + a_3 * HH\_worthiness + a_4 * (HH\_Wealth\ squared) + a_5 * lag(1)passengers + g_{pax}$$

$$\text{(3)} \quad Hh\_Wealth = b_0 + b_1 * Income + b_2 * Interest\_rate + b3 * lag(1)HHwealth + \psi_{wealth}$$

Equation (2) is an empirical re-specification of (1) with a few modifications. For example, HH_worthiness, defined as the ratio of household wealth over current income, has been added to the estimating equation. As indicated earlier, the massive expansion of household wealth facilitated household's financial or credit worthiness via increased access to liquidity;[9] conversely, financial worthiness dropped significantly as wealth contracted. This variable is thus considered to be a proxy for credit accessibility and is hypothesized to have a positive impact on passenger air travel. Household wealth (HH_wealth) is hypothesized to have a positive impact on air travel; the more the accumulated wealth, it is likely that households will be able to afford more air travel. HH_wealth squared has been incorporated to test the empirical hypothesis underlying the shape of the air travel function (lower panel) in Figure 7. Average fare has the standard impact; higher the air fares, less the air travel. Finally, given the time series nature of the proposed estimation, a one-period lag of passengers (lag(1)passengers) has been incorporated, as the stationarity test indicated such inclusions to improve the model structure. Results of these tests will be reported and discussed later.

Equation (3) accounts for household wealth (HH_Wealth) that has been hypothesized to depend on current income (Income), interest rate (Interest_rate) and lagged household wealth (lag(1) HHwealth). Current income accounts for household's present contribution to wealth; while the interest rate accounts for interest earnings from the accumulated wealth. Unlike these two flow variables, the biggest determinant of present household wealth is past accumulation of wealth - a stock variable - as captured by one-period lag of household wealth. The endogeniety of household wealth (HH_Wealth) via the third equation and its entry into the second equation as an exogenous variable determine the interdependency in the system consisting of (2) and (3).

Given the hypothesized interdependencies within the two equations above and the nature of the variables, it is likely that the error structures of the equations may be linked to one another. Although each equation seemingly appears to be independent and unrelated, each might actually be linked to one another through errors. Thus, this type of system is called "disturbance-related" or "error-related" regression equations.

Under this circumstance, econometricians often use a seemingly unrelated regression (SUR) or via iteration (ITSUR) technique for estimation. The SUR/ITSUR is applicable when the system consists of two or more equations whose errors may be correlated across equations. The SUR/ITSUR is considered to be appropriate when all the regressors are assumed to be truly exogenous and whose errors satisfy the following conditions:

i. ε_{pax} (error in equation (2)) and ψ_{wealth} (error in equation (3)) have zero means and finite variances;
ii. the variances of errors may differ; and,
iii. there is a presumed correlation between ε_{pax} and ψ_{worth}.

As noted elsewhere (Pindyck and Rubenfeld 1996), ordinary least squares (OLS) methodology, under the conditions of (i) to (iii), suffers from simultaneity bias, i.e., endogenous variables may depend on errors. Given the assumptions that (i) to (iii) are true for the data for reasons stated above, iterative SUR methodology was used for estimation. The ITSUR estimation begins with OLS parameter estimates and improves the estimation in subsequent steps resulting in efficient estimates of the specified parameters.

The summary statistics of key variables are reported in Table 1.

Table 1: Summary of Household Wealth and Air Travel Characteristics

Variable	N	Mean	Median	Maximum	Minimum	Std Dev	Skewness	Kurtosis
Passengers (quarterly)	84	141,820,000	142,480,000	178,430,000	99,845,289	20,054,666	-0.28	-0.74
Household Wealth (in millions)	84	$40,392,584	$41,380,936	$66,007,422	$20,124,360	$14,173,501	0.17	-1.20
Household Income (in millions)	84	$ 7,493,783	$ 7,340,529	$11,509,100	$ 4,163,997	$ 2,307,613	0.25	-1.26
Average airfare (one way)	84	$154	$154	$180	$128	$12	-0.06	-0.58
Interest Rate (%)	84	3.87	4.48	8.25	0.12	2.16	-0.21	-0.83

Source: Based on data available at http://www.transtats.bts.gov/Data_Elements.aspx?Data=1; and http://www.federalreserve.gov/releases/z1/Current/

Average quarterly passengers in the dataset are around 142 million with median value nearby to the mean. With maximum passengers observed during 2007:Q3 while minimum was observed during 1991:Q1 and a standard deviation of 20 million passengers. Skewness value indicates that most of the observations are concentrated on the right of the calculated mean with extreme values located mostly to the left; while Kurtosis indicates that the underlying distribution of data is somewhat flatter than the normal distribution with wider peak and spread around the mean. Household wealth and income averages have been calculated to be around $40 trillion and $7 trillion, respectively; with medians found nearby. Highest wealth was observed during 2007:Q2 while highest income was observed during 2008:Q2, right before the Great Recession began. On average, passengers paid around $154 for one-way fare with a standard deviation of around $12. During the period of the sample, 1990:Q1–2010:Q4, U.S. households, on average, faced an interest rate of 3.9% with wide variations of over two percentage points.

Before the model is described and results discussed, it is important to discuss time series properties of the system. Although the proposed model is not used for forecasting purposes, it is nevertheless important to explore the stationarity properties of the system. Earlier econometric studies (Dickey 2002) established that time series used in econometric applications must be stationary. Generally speaking, stationarity implies that means underlying the series in question (i.e., passengers and household wealth) are constant. While visual examination of data series may be used to accomplish this, econometricians have developed robust tests for examining stationarity. Stationarity of a time series ensures that standard properties of econometric estimation, for example, t-test statistics have approximately normal distribution, are valid. Natural log of the two series, passenger and household wealth, are used together with four lags (i.e., 1 year) in order to test the stationarity property. Dickey (2002) describes two tests for stationarity: unit root test[10] (captured by tau below) and normalized bias test (captured by rho below) and they have been reported in Table 2.

Table 2: Stationarity Tests for Passengers and Household Wealth Series

Augmented Dickey-Fuller Unit Root Tests: In Pax					
Type	**Lags**	**Rho**	**Pr < Rho**	**Tau**	**Pr < Tau**
Single Mean	**0**	-12.84	0.0585	-2.79	0.0639
	1	-12.6	0.0623	-2.57	0.1026
	2	-2.468	0.7169	-1.36	0.5995
	3	-1.939	0.7819	-1.59	0.483
	4	-4.413	0.4847	-2.04	0.2711
Augmented Dickey-Fuller Unit Root Tests: In Wealth					
Type	**Lags**	**Rho**	**Pr < Rho**	**Tau**	**Pr < Tau**
Single Mean	**0**	-1.12	0.8723	01.5	0.5285
	1	-1.319	0.8521	-1.33	0.6145
	2	-1.69	0.8113	-1.5	0.5305
	3	-1.775	0.8014	-1.39	0.5857
	4	-1.684	0.8118	-1.26	0.6459

Estimated tau indicates that there is evidence to accept unit roots, that is, both series are shown to be stationary; i.e., estimated taus are shown to be not statistically significant (5% or less) in any lags. On the other hand, estimated rhos shows inclusion of first lag, particularly in the case of passengers, may improve the estimated time series properties. Inclusion of one-period lag may also address the issues relating to auto-correlations in the errors, if any. Thus, in addition to the exogenous variables discussed above, one period lags for both passengers and household wealth have been incorporated in respective estimating equations.

The system of the equations has been specified in terms of natural log (ln). The advantage of log-transformed specification is that the estimated parameters can be easily interpreted as elasticity quotients for those that are meaningful. The results of the estimation are reported in Table 3. Aggregate statistics show that the specifications of the system and individual equations are quite robust and statistically significant.

Table 3: Air Travel and Household Wealth: Summary of Residual Errors

Nonlinear ITSUR Summary of Residual Errors									
Equation	**DF Model**	**DF Error**	**SSE**	**MSE**	**RootMSE**	**R-Square**	**Adj R-Sq**	**Durbin Watson**	**Label**
lnpax	6	77	0.2858	0.00371	0.0609	0.8331	0.8223	1.6208	log of quarterly passengers
lnHHwealth	4	79	0.074	0.00094	0.0306	0.9933	0.9931	1.4398	log of household wealth

For example, over 82% of variation in passenger demand (equation (2)) is explained by the variables specified in the above equation; while over 99% of variation in wealth equation (equation (3)) is captured by simple specifications of current income, interest rate, and lagged impact of logged wealth. Both equations have reasonable Durbin-Watson (DW) statistic. The value of DW lies between zero and four. As a general rule, if the DW statistic is equal to two, then, it is expected that the errors are not serially correlated. However, if DW statistic is substantially less than two, there is evidence of positive serial correlation; a value less than 1.0, for example, is certain to ensure positive correlation; i.e., successive errors are correlated. If DW > 2, on the other hand, successive error terms are much different in value to one another on average, i.e., negatively correlated. Estimated DW statistic for equation (1) has been found to be 1.62 while it is 1.44 for equation (2). These values indicate no correlation or slight hints of positive correlations among errors and believed to be unlikely to influence results in any meaningful way. Furthermore, such DW values are often observed in long time series and may not have any material impact since they are not used for forecasting, a task that is not the focus of this paper.

In Table 4, results of the estimation are reported. Some parameters, except those marked with '*', have been found to be statistically significant at the 99% level of significance including fare elasticity, wealth elasticity of passengers, and lagged wealth. Log of one-period lagged passengers is significant at 95% and exponential growth of wealth (i.e., wealth squared) at 90% significance (t-values). It is important to note that all other variables in the wealth equation turn out to be statistically insignificant once lagged wealth effect was incorporated.[11] Finally, all estimated parameters have the "right" signs; i.e., estimated signs conform with those stipulated by the analytical framework, and their magnitudes appear to agree with those reported in the literature.

Table 4: Air Travel and Household Wealth: Estimation Results

Nonlinear ITSUR Parameter Estimates					
Parameter	**Estimate**	**Approx Std Err**	**t Value**	**Approx Pr > |t|**	**Label**
a_1	-0.45519	0.1274	-3.57	0.0006	fare elasticity of passenger
a_2	0.423482	0.0838	5.06	<.0001	wealth elasticity of passenger
a_3	0.123928*	0.0888	1.39	0.167	household worthiness (pax)
a_4	-3.34^{E}-17	1.94^{E}-17	-1.72	0.0888	household wealth squared
a_5	0.217269	0.1047	2.08	0.0412	log of lagged (one-period) passengers
a_0	9.441766	1.5949	5.92	<.0001	pax equation intercept
b_1	0.033001*	0.1286	0.26	0.7982	income elasticity of wealth
b_2	0.002803*	0.00943	0.3	0.7671	interest impact on wealth
b_3	0.0962979	0.0948	10.16	<.0001	lagged impact of log wealth
b_0	0.13441*	0.4322	0.31	0.7566	Wealth equation intercept

* Not statistically significant.

For example, for a 10% sustained increase in average fare (i.e., $17 for one-way average for 2010 based on DOT data), passenger demand has been estimated to decline (estimated a1) by 4.56% or 6.45 million passengers per quarter (i.e., a_1 or fare elasticity of passenger) or almost 29 million passengers[12] for the year at the 2010 average value (see http://www.transtats.bts.gov/Data_Elements.aspx?Data=1 for data), controlling all other variables. That is, the estimated fare effect (-0.45) is found to be relatively unresponsive (or inelastic) on passenger demand. Although the estimated magnitude conforms well with some of the reported results from earlier empirical studies (Gillen et al. 2003 and Brons et al. 2002), it is on the lower side. A fully-specified model incorporating wealth is expected to yield lower fare elasticity, as argued by Alperovich and Machnes (1994).

Second, for each 1% increase in wealth, passenger demand (estimated a_2) would increase by 0.42% (i.e., a_2 or wealth elasticity on passenger); or wealth effect on passengers was found to be relatively inelastic. U.S. net aggregate household wealth stood at around $55 trillion (see http://www.federalreserve.gov/releases/z1/) and total annual passengers stood at a little over 629 million in 2010 (see http://www.transtats.bts.gov/Data_Elements.aspx?Data=1). Thus, for an increase of U.S. $550 billion (1% of $55 trillion), there would be 2.67 million (0.42% of 629.41 million; see http://www.transtats.bts.gov/Data_Elements.aspx?Data=1) additional passengers, holding all else constant. Passenger responsiveness to changes in wealth was found to be relatively inelastic. This finding is consistent with Alperovich and Machnes (1994), where international passenger demand was found to be impacted in the magnitude of 0.38% with respect to financial assets and 0.56% with respect to non-financial assets. Furthermore, the empirical test underlying the postulated shape of the air travel demand function in the lower panel of Figure 7 is captured by using the estimated parameters a_2 and a_4. Combined with a positive a_2 (i.e., first derivative) and negative a_4 (i.e., second derivative) demonstrate that air travel function increases at a diminishing rate as wealth grows.

Third, for a sustained 1% increase in household worthiness (i.e., proportionately larger expansion in wealth in relation to current income), passenger air travel (estimated a3) is expected to increase by 0.12% (a3 or household worthiness impact on passenger), holding all else constant. Although statistically insignificant, passenger demand is relatively inelastic with respect to household worthiness as measured by the ratio of wealth over current income. This is not surprising given the fact that travel as a whole consists of such a small percentage of total PCE services (3% in 2010) and air travel accounts for only a fraction of that expenditure (see http://www.federalreserve.gov/releases/z1/ for more details).

Fourth, one-period lag of passengers appears to influence present air travel (estimated a5). For a 1% increase in last quarter's passengers appears to lead to, controlling for all other variables, almost a 0.22% increase in passengers in the current quarter. Despite the fact that passenger flows are influenced by many factors, including fare, current income and wealth, past passenger flow provides a good indicator of the present passenger flow and estimated a5 confirms this empirically.

Fifth, lagged wealth is strongly influential in determining the present wealth, i.e., estimated b3. A one-period lag demonstrates that there is almost a one-to-one correspondence between last year's wealth and this year's. For example, a 1% increase in last quarter's wealth would have a little over 0.96% increase in the present quarter's wealth. Other effects are captured by flow variables such as income and interest earnings. Although not statistically significant, they appear to have the right signs. For a 10% sustained increase in income, for example, wealth is estimated to increase by 3.3% (i.e., b1 or income elasticity of wealth). That is, wealth is relatively inelastic with respect to changes in income (i.e., income elasticity effect of wealth). Current income for households mostly consists of wage income and other non-wage benefit/income and in many ways is an indicator of the overall economy. Income increase is generally associated with productivity enhancement, tightening labor market conditions leading to an increase in wage income and other resource prices, and overall economic expansion. Thus, as current income increases, it is highly likely that all components of household wealth, i.e., value of real estate, corporate and non-corporate equities, other financial assets including mutual fund shares, and other assets including life insurance, pension fund reserves and miscellaneous assets, would increase as well.

Finally, it is well known that interest rates,[13] as the most potent monetary policy tool, move cyclically with a lag; thus, as the economy goes into recession, interest rates fall and as the economy recovers, interest rates go up. For the overall sample, the estimated coefficient (b2) indicates that if interest rates go up by 1%, household wealth will go up by 0.003%. This finding has a similar interpretation as impact of current income on wealth; as interest rates go up representing overall economic expansion leading to comprehensive improvement in overall wealth.

Equipped with the estimated parameters, an attempt is now made to isolate and calculate the annual passenger loss (i.e., lost demand) due to the decline in household wealth, holding all else constant. From the last peak (2007:Q2) to the trough (2009:Q1), total household wealth loss was calculated to be a little over $17 trillion (i.e., from the peak of $66 trillion to the bottom at $49 trillion); or a loss of around 26%. During this period overall, average total household wealth stood at around $59 trillion (see http://www.federalreserve.gov/releases/z1/ for these numbers and calculations). Corresponding total number of passengers averaged around 659 million per year during these periods[14] (see http://www.transtats.bts.gov/Data_Elements.aspx?Data=1). Given the estimated wealth elasticity of 0.42% and the decline in wealth of 26%, this implies that around 730,000 (i.e., 0.423482% X -26.08% X 657.922 million[15]) passengers did not travel. A comparison of the two years (2008 and 2007) reveals that over 27 million people altogether did not fly; i.e., 679 million in 2007 vs. 652 million in 2008, from the peak of the cycle to trough of the cycle or a decline of little over 4% annually (see http://www.transtats.bts.gov/Data_Elements.aspx?Data=1). Thus, decline in wealth induced lost air travel demand of around 2.6% (i.e., 730,000 /27 million). Furthermore, using the observed average round trip fare during this period ($335), calculated loss due explicitly to the loss in household wealth turned out to be over $244 million.[16]

During 2010, total household wealth expanded by $8 trillion in comparison to the last trough (2009:Q1) despite the fact that average total household wealth is still considerably less than those observed during peak years. For example, household wealth expanded by $8 trillion (or 16%) in 2010:Q4, the last quarter for which data were available, in comparison to the most recent bottom observed in 2009:Q1 ($48 trillion). Although recent expansion recouped some of the losses and average annual wealth now stands at $53 trillion, it is still less than 10% ($6 trillion) of the average size observed during the last peak and trough cycle ($59 trillion) (see http://www.federalreserve.gov/releases/z1/ for more details). During this last period of expansion (i.e., 2009:Q1–2010:Q4), corresponding average total passengers is calculated to be around 624 million (see http://www.transtats.bts.gov/Data_Elements.aspx?Data=1). Using the method used earlier, additional passenger travel induced by the wealth expansion is calculated to be around 435,000 (i.e., 0.423482% X 16.45% X 623.695 million). Notice, however, during these two periods (2009 vs. 2010), total passengers increased by 11.43 million (617.98 million and 629.41 million in 2009 and 2010, respectively), or around 1.90% annually. Wealth-induced increase in passenger travel (435,000) thus accounted for around 3.8% (i.e., 435,000/11.43 million) of the total increase in passengers. A comparison of air travel lost and induced by wealth loss vs. wealth gain, respectively, shows an asymmetry; air travel appears to bounce back more with the increases in wealth gain compared to the air travel lost due to wealth losses (i.e., 2.6% for wealth loss vs. 3.8% for wealth gain).

Given the possibility that a structural model such as proposed above may be used for limited forecasting and/or scenario planning, it is important that the residuals of the estimated models are understood in order to validate the assumptions underlying the estimation technique. In specification and estimation, it is assumed that errors of the equations (2) amd (3) are normally distributed. Table 5 provides the results of normality tests.

As evident that normal distribution for the estimated passenger equation residual cannot be rejected; while that of residuals for household wealth equation cannot be accepted. Two of the three normality tests for the system, as a whole, indicate that normal distribution assumption for the residuals cannot be rejected.

The financial calamity that started off in 2007:Q3 setting off the most severe recession[17] since the Great Depression has had multifarious impacts on all sectors of the economy. While the housing, labor, and credit markets have been the primary focus of policymakers, this analysis demonstrated that the impact had been felt in air travel as well. Decoupling air travel from the cycles of the economy is unlikely in the U.S.; however, their impact may be minimized by conscious business and policy choices. For example, tightening credit environment, along with other cost pressures (i.e., sudden increase in jet fuel price in summer 2008), has disciplined the U.S. domestic airline industry in managing capacity well. Consequently, there had been much less idle capacity and thus, much less downward pressure on fares during the last cycle than earlier ones. The subsequent recovery in demand has brought a healthy improvement in airline financials, yielding overall industry profit for 2010; and the same is expected for 2011 as well.

Table 5: Normality Tests of Residuals

Normality Test			
Equation	**Test Statistic**	**Value**	**Prob**
lnpax	Shapiro-Wilk W	0.96	0.0256
lnHHwealth	Shapiro-Wilk W	0.97	0.2714
System	Mardia Skewness	10.71	0.03
	Mardia Kurtosis	1.3	0.1937
	Henze-Zirkler T	1.85	0.0638

Forecasting challenges from a model that is offered here are no different than those employed in standard econometric estimation and forecasting. In the simple framework presented above, true exogenous variables are average fare, interest rate, and current income. Projecting these variables are no more challenging than projecting, for example, GDP (for current income), interest rate for inflation (inversely related), and inflation for average fare (i.e., adjusted downward due to the fact that overall CPI-U increases faster than the average fare). In comparison to standard specification, however, the proposed model incorporates household wealth, an important variable in determining the long-term or life cycle induced consumption and air travel. Furthermore, varying these three variables, a relatively manageable task, to account for different economic realities or scenarios may also provide corresponding simulated or projected air travel, thus meeting important strategic needs as well.

CONCLUSIONS

This paper is an attempt to bridge an important empirical void between household wealth and its impact on air travel. Examining trends of household wealth and air travel and other related variables over the last two decades, the paper establishes an empirical causality. Despite this linkage and the presence of a theoretical construct, existing empirical literature, interestingly enough, does not incorporate the wealth effect in determining air travel for most of the studies. Consequently, present forecasting does not go beyond incorporating current or nominal income.

Following the guidance of standard macroeconomic literature, the paper builds a simple analytical framework where current income is linked to air travel together with households' accumulation of wealth or permanent income. This framework was then applied to determine passenger air travel together with household wealth in a simultaneous equation system. The empirical results suggest that the framework is highly robust in specification, aggregate statistics, and parameter estimates. Household wealth has been found to be important in determining passenger air travel, together with average fare and past travel. Furthermore, household wealth has been determined to be a function of stock of past wealth accumulations.

The estimated parameters helped to determine the magnitude of lost demand due to the massive wealth loss during the last financial crisis and Great Recession, an area of research that has been generally overlooked. The household wealth loss of U.S. $17 trillion yielded a loss of air travel demand of 730,000, or a loss of revenue of $244 million. As household wealth improved during the last two years, air travel recovered. Some of the lost passenger demand has been recouped (435,000) but a complete wealth-induced recovery still seems far off. Furthermore, wealth expansion tends to increase air travel proportionately more, holding all else constant, than wealth contraction does to reduce air travel.

This model can be used for forecasting macroeconomic air travel trends in the country or in scenario planning. Due to the simplicity of the proposed framework, it holds great promises to generate air travel scenarios corresponding to different projected economic realities (or scenarios), thus meeting strategic needs of air transportation planning. Due to the simplicity and its tractability, the model lacks comprehensibility. For example, future research may separate out the financial assets from non-financial assets and examine the impact of degrees of liquidity on air travel. In a similar vein, household distributions of assets have not been considered in the macro framework presented above; households holding higher wealth may have different spending patterns and air travel than those holding less – an issue that should be addressed in a future empirical framework. These are some of the tasks for future research.

Endnotes

1. See http://online.wsj.com/article/; published on March 11, 2011; and http://www.bloomberg.com/news/; published on March 25, 2011, among many others. Wealth and worth is used interchangeably in this paper. Household's net wealth consists of (a) real estate; (b) corporate and non-corporate equities; (c) other financial assets including mutual fund shares; and (d) other assets including life insurance, pension fund reserves and miscellaneous assets (see http://www.federalreserve.gov/releases/z1/Current/z1.pdf for more details).

2. This is estimated using the following steps; first, operating revenue of US commercial air travel for the system (i.e., domestic and international) as a whole has been accounted for and is estimated to be around $165 billion for the year 2010 (see http://www.transtats.bts.gov/Data_Elements.aspx?Data=1). Second, $30 billion a year has been added towards general aviation revenue (see Commission on the Future of the US Industry 2002, thus totaling over $190 billion as the aggregate value of the sector, using this expenditure accounting method for the year 2010.

3. A relatively slow decline of expenditure on recreational services accompanied with moderately large decline on transportation services during the Great Recession led to spending on vacation without traveling, or *staycation,* i.e., stay home vacation, an altogether new term to characterize this phenomenon (http://en.wikipedia.org/wiki/Staycation).

4. Interestingly, rationalizing quantitative easing-2 (QE2) current Federal Reserve Chairman Ben Bernanke wrote on November 5, 2010: "The FOMC intends to buy an additional $600 billion of longer-term Treasury securities by mid-2011 and will continue to reinvest repayments of principal on its holdings of securities, as it has been doing since August…This approach eased financial conditions in the past and, so far, looks to be effective again. *Stock prices rose* and long-term interest rates fell when investors began to anticipate this additional action. Easier financial conditions will promote economic growth. For example, lower mortgage rates will make housing more affordable and allow more homeowners to refinance. Lower corporate bond rates will encourage investment. And *higher stock prices will boost consumer wealth and help increase confidence, which can also spur spending. Increased spending will lead to higher incomes and profits that, in a virtuous circle, will further support economic expansion*" (author's added italics; published in The Washington Post, op. ed., see http://www.federalreserve.gov/newsevents/other/o_bernanke20101105a.htm).

5. This is a modified version of famous Keynesian cross diagram in the present context. Instead of deriving the demand for air travel from the standard behavioral relationship (i.e., utility-maximization subject to income and wealth), the postulation below derives the relationship using the macro structural relationship between air travel and income allotted to travel and wealth. Using either framework is appropriate; however, the macro relationship has been chosen due to the casting of the central empirical hypothesis in an aggregate macroeconomic context in the paper.

6. In the standard empirical literature, income elasticity is defined as changes in air travel as the result of changes in current or nominal income, a definition that is applied in the empirical framework of the paper as well. However, in demonstrating the relationship between air travel, wealth, and current income (Figure 7), a distinction is made where air travel is related to current income allotted to travel in order to draw the equilibrium in the upper panel. Since the relationship calls for air travel and income allotted to travel (and not total current or nominal income), therefore, it is defined as "true" income elasticity of air travel defined as changes in air travel due to changes in nominal travel budget. Presumably, the "true" elasticity will be much higher compared to observed income elasticity measured on nominal total income.

7. This is an over simplification. It is likely that at higher levels of income, air travel becomes a "normal" good thus losing the novelty (or luxury) characteristics. Income distribution-adjusted absolute values of income (and fare) elasticities have been found to be declining over time (see Schafer 2011). There is indirect evidence which prove this assertion. For example, income elasticities for business travelers are often found to be smaller (in absolute terms) than those observed for the leisure travelers. In other words, leisure travelers, i.e., presumably with relatively lower income, are found to be far more price-sensitive than their counterparts in business, i.e., presumably with higher incomes.

8. After all, how much can one travel by air even if you are the richest person in the world! However, this is an empirical issue, as correctly pointed out by an anonymous referee, which will be tested in this study.

9. Generally speaking, this ratio is calculated to be around five for average household; i.e., household's financial portfolio is five times the current annual income. As wealth expanded, vis-à-vis current income, worthiness of households increased to almost 6.4 (2006:Q1). This facilitated credit worthiness of households making it possible for increased borrowing to finance many components of consumption, including air travel. This is accounted for by inclusion of financial worthiness of household in the second equation.

10. Unit root is a feature of the data process that evolves through time and may lead to problems for statistical inference. Finding a unit root is equivalent to finding that mean and variance of the series (a) evolves over time; (b) departs from a constant value as time goes on; and (c) exhibits that a trend if the movement is predominantly in one direction. Rejection of unit root of a series thus ensures that the time series is stationary.

11. In an earlier version of the paper, wealth accumulated in a past period was not incorporated in determining the wealth equation; i.e., it was defined only in terms of flow variables (income and interest) and both were found to be statistically significant (99%). Once lagged wealth was incorporated, those flow variables lost their statistical significance thus indicating the importance of past wealth in determining current wealth and minimal roles current flows of

income and interest earning can actually make. Given these implications and despite their statistical insignificance, we decided to include the results in the paper.

12. This is calculated as follows: in 2010, total number of passengers was 629.413 million. Multiplying 4.56% to this annual total gives a value of 28.65 or rounded to 29 million passengers. Due to quarterly variations, annualized average total will be different than multiplying 6.45 million passengers by four quarters.

13. Federal fund rates at long-term constant maturity have been used for the estimation. For description and data, see http://www.federalreserve.gov/econresdata/releases/statisticsdata.htm

14. Although both the estimation and discussion refer to passenger enplanement in this paper, the real metric for consideration should be the origin and destination (OD) of passengers. Total passenger enplanement is an artifact of OD passengers (i.e., true demand) and existing airline network (i.e., connections). Since connection passengers result from airline network and passengers' true demand, OD passengers would be less than total passenger enplanement; e.g., corresponding to 659 million total enplanement, OD passenger stood around 431 million (65%). Nevertheless, the central point of this discussion still remains valid, irrespective of passenger metric.

15. Since the first two numbers are in percentages, the multiplication would be: 0.00423482 x -0.26076 x 657.922 million = -726,513 or rounded up to -730,000. This calculation and numerous others involve rounding off involving detailed actual numbers, and thus, may not equal to quick calculations.

16. This is a lower approximation of the total loss because likely lost demand due to wealth contraction would be disproportionately those of business travels. Since wealth is concentrated in higher income households (Schäfer 2011) who are likely to travel more for business than the average household, the loss in revenue is likely to be a lower approximation. In addition, business travelers, on average, pay higher fares. Thus, the lost value is likely to be a few fold higher than what is calculated here as a first approximation.

17. National Bureau of Economic Research (NBER), the national recession dating committee, identified December 2007 as the official start of this recession (see http://www.nber.org/cycles.html). Although the NBER has not dated the official end, the recession ended in June–July 2009 by all accounts.

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Freight Distribution Systems with Cross-Docking: A Multicisciplinary Analysis

by Jesus Gonzalez-Feliu

Freight transport assures a vital link between suppliers and customers and it represents a major source of employment. Multi-echelon distribution is one of the most common strategies in this field. This paper presents the main concepts of multi-echelon distribution with cross-docking through a multidisciplinary analysis that includes an optimization study and an interview-based analysis. The optimization analysis uses both a geographic approach based on the concept of accessibility and a scenario simulation analysis for collaborative freight transportation. The interview-based analysis includes a conceptual framework for logistics and transport pooling systems and a simulation method for strategic planning optimization.

INTRODUCTION

The freight transport industry is a major source of employment and supports the economic development of a country. However, freight transport has many adverse effects including congestion and environmental disturbances that affect quality of life (Brewer et al. 2001). In recent years, companies have adapted their logistics strategies to changing demand leading to the development of multi-echelon transport schemes in which two or more connected transportation schemes are linked by one or more transshipment operations (Gonzalez-Feliu 2011). A wide variety of fields have developed multi-echelon transportation approaches with cross-docking; for example, the press (newspapers and magazines), spare parts supply, postal and urban freight distribution systems, intermodal transportation, and grocery distribution (Gonzalez-Feliu 2008). A cross-docking operation is a form of consolidation (Beuthe and Kreutzberger 2001) of specific road and railroad freight transportation. In a multi-echelon transportation system, cross-docking operation consists of transshipment of one or more freight units from an incoming vehicle into an outbound vehicle with little or no storage in between (Gonzalez-Feliu 2008).

According to Brewer et al. (2001), cross-docking and warehousing are used in multi-echelon systems. However, multi-echelon transportation with cross-docking differs from that with warehousing in that there is no stocking on intermediary platforms though consolidation and transshipment operations are allowed (Beuthe and Kreutzberger 2001). Because these two concepts are studied separately by different disciplines, the relationships between them are less understood. This paper contributes to understanding this relationship. It uses a multidisciplinary framework to conceptualize and study multi-echelon transport systems with cross-docking by focusing not only on their theoretical and technical aspects but also on their applicability and general feasibility.

The paper is organized as follows. First, a review of the relevant literature on multi-echelon systems with cross-docking is presented. It is followed by mathematical models that conceptualize multi-echelon transportation cost optimization with cross-docking, and assess a two-echelon transport system for a single carrier, and three collaborative freight transportation scenarios to assess the potentials of collaboration among carriers to optimize transportation costs. In both models the practical implications of the results are examined rather than computational effectiveness. Next is a section on interview-based analysis that identifies the benefits and limitations of multi-echelon transportation systems, followed by a conclusion section.

LITERATURE REVIEW

In freight transport, decisions on transport networks have a direct impact on service quality and costs. Consequently, it is important to adapt transport networks to economic, geographic, organizational, and quality constraints. In the past, several strategies and logistics models have been developed to increase the effectiveness of freight transport systems (Beuthe and Kreutzberger 2001). Multi-echelon systems with cross-docking are among the most popular because they reduce logistics costs by avoiding inventories (Lambert 2008). Moreover, they are the base of most collaborative transportation systems (Gonzalez-Feliu and Morana 2011). In the scientific literature, several disciplines and researches deal with multi-echelon transportation with cross-docking including operations research, business, management, economics, and transport engineering.

In transport engineering, the main research related to multi-echelon distribution is vehicle management at terminals (Wang and Regan 2008) and infrastructure management and not transportation itself. Also in operations research, such works relate to terminal management (Soltani and Sadjadi 2010, Larbi et al. 2011) and infrastructure (Klose and Drexl 2005). These categories of research will not be detailed here because they are technical and unrelated to multi-echelon transportation management.

In the past, tactical and operational issues in multi-echelon transportation were the focus in major research. For example most operations research works in freight transport management derived from the vehicle routing problem and sought to minimize the total transportation cost of delivering to a number of customers with a fleet of vehicles that are based at one or more depots (Toth and Vigo 2002). In comparison, multi-echelon vehicle routing aims to minimize the costs of both locating intermediate facilities and delivering to several final destinations using cross-docking platforms. According to Jacobsen and Madsen (1980), there are four phases in multi-echelon vehicle routing. First, customers are grouped and assigned to vehicles using cross-docking platforms. Second, one transshipment location for each vehicle is determined. In the third and last stages, all routes are determined by heuristics methods that assign each destination to a suitable route.

Besides the heuristics approach, Semet and Taillard (1993) develop an algorithm which initially solves the route selection problem using a procedure similar to those above, and improves the solution by reallocating customers onto routes. Gerdessen (1996) used an algorithm that finds an initial solution by a combination of heuristics like those of Jacobsen and Madsen (1980), and improves it by reallocating the destinations using iterative local search heuristics (Toth and Vigo 2002). Nguyen et al. (2011) used a constructive heuristics approach that builds each echelon's routes separately and a post-optimization algorithm based on route reallocation. These route selection studies have been complemented by studies focusing on managerial issues in multi-echelon distribution related to interactions between transportation and supply chain management. Most of these works, however, deal with multi-echelon system optimization in the general contexts of supply chains defined as an integrated set of processes related to product manufacturing and distribution. These supply chains cover all the operations from raw material collection to final product delivery to customers and product returns. According to Brewer et al. (2001), a supply chain consists of three integrated parts, which are raw material collection and production supply, production planning and inventory, and distribution to the final destination. To this must be added transportation, information, and financial flow activities, which are important aspects of supply chain management. In global supply chain works, decisions on supply, production, and inventory are internal to the company, whereas, distribution and transportation are usually externalized using third-party companies. Therefore, many works in supply chain management focus on factors internal to the company and include transportation as additional costs without taking into account transport management and optimization analysis (Lambert 2008)

In distribution logistics, most works deal with multi-echelon distribution systems with warehousing, focusing on inventory management rather than on transportation planning (Lambert

2008). Regarding multi-echelon distribution with cross-docking, most works focus on production-distribution coordination (Galbreth et al. 2008). In these works, distribution costs are mainly associated with transport demand and cross-docking platform management costs, and not to traveled distances or chosen transport strategies. In addition, there are qualitative studies that deal with supply chain management and can be related to multi-echelon transportation with cross-docking. Yang et al. (2010) analyze the factors affecting cross-docking in a terminal management perspective, including the impacts on other supply chain echelons such as delays in production and distribution. Concerning relational aspects of collaboration, Newbourne (1997) defines the main principles of a logistics partnership and the differences between other forms of inter-enterprise relationships, while Lambert (2008) presents a model to analyze the feasibility of collaboration from a management viewpoint. These works are mainly related to production and warehousing and in general involve multiple participants.

While these studies continue, there is very little done in terms of the acceptability and limits of multi-echelon transportation with cross-docking. Beuthe and Kreutzberger (2001) analyze different multi-echelon schemes and estimate the changes in their costs. Simonot and Roure (2007) examine the typologies of transport networks regarding their constitution, objectives, and organizational behavior. From their results they suggest that transport management and modal split are less used in multi-echelon transportation because of several limitations in terms of relationships between stakeholders and transportation carriers. Gonzalez-Feliu and Morana (2011) make a case study for press (newspaper and magazine) distribution to examine the limits to possible changes in their distribution schemes.

To summarize, several works deal with multi-echelon transportation with cross-docking in related disciplines and can be broken into two streams: (1) optimization methods related to computer science and applied mathematics, and (2) works from economics, business, and management focusing on business relationships and not on transportation management. These disciplines seldom collaborate to provide multidisciplinary analyses. In an applied research subject like multi-echelon transportation, it is essential to deal with realistic and applicable methods and analysis. To deal with this question, an optimization analysis focusing on practical and applicability aspects of multi-echelon transportation with cross-docking is presented below followed by a socio-economic feasibility study.

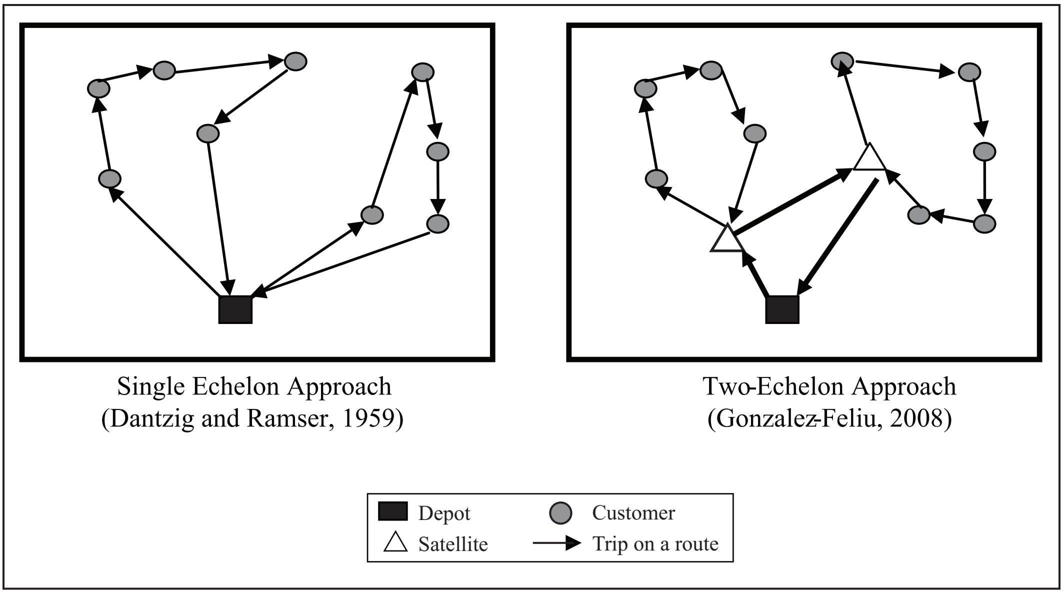
OPTIMIZATION ANALYSIS

Two analyses are used to show the potentials of multi-echelon distribution systems. These analyses are based on transportation cost optimization and are mainly related to travel distances (Gonzalez-Feliu 2011). The first is an analysis from the viewpoint of a single carrier, and the second is the possibility of collaboration among various operators.

Issues for a Single-Carrier Transportation System.

The first considers the viewpoint of a single transportation operator who has both possibilities of delivering freight directly using less-than-truck load routes without cross-docking, or using intermediate platforms to develop a two-echelon transportation system. In this context, one-echelon distribution results in direct routes from the depot to a set of customers, and a two-echelon transportation uses intermediary cross-docking platforms (see Figure 1). The details of the mathematical formulations of this problem and a solution are in Appendix A.

Figure 1: Single-Echelon and Two-echelon Vehicle Routing Schemes



Accessibility is used to study the impacts of multi-echelon transportation with cross-docking compared to one-echelon transportation systems. Following Geurs and van Wee's (2004) accessibility is the extent to which transport systems enable individuals to reach their destinations. According to them there are four categories of accessibility indicators. The first consists of infrastructure-based indicators, largely used in transport planning studies. These measures deal with service levels of transport infrastructure, for example, congestion or average travel speed (Ewing 1993). The second includes location-based measures, which analyze accessibility on a macroscopic scale and describe access to spatially distributed activities, and are used largely in urban planning and geography. Two main groups of indicators in this category are distance-based and potential accessibility measures. The distance-based measures (Pirie 1979) represent the degree to which two locations are connected. Several distance measures can be defined, for example, the linear distance between two points and travel time or transport cost to access a number of opportunities (Geurs and van Wee 2004). Potential accessibility, also called gravity-based measures of accessibility, estimates access to opportunities in zone *i* by all other zones. These measures take into account both the number of opportunities and the transportation costs to reach them (Hansen 1959) and can be generalized as follows:

$$(1) \quad A_i = \sum_j D_j . f(c_{ij})$$

where A_i is the potential accessibility of zone *i*, D_j are the opportunities at each destination zone *j*, and $f(c_{ij})$ a function of c_{ij}, the transportation cost between zone *i* and zone *j*.

The third category defines accessibility at the individual level (Burns 1979). This measure is based on space-time geography following Hägerstrand (1970) and measures limitations on an individual's freedom of action in the environment. The main measures are related to travel budgets and are difficult to define precisely with standard survey techniques (Geurs and van Wee 2004). The fourth includes utility-based measures derived from the benefits of having access to spatially distributed activities. For example, utility-based accessibility can show benefits in terms of travel time for users of a transport system or network. This type of measure has its origin in economics and considers accessibility as the outcome of a set of transportation choices. Two main types of measures are used for this accessibility. One is a log-sum indicator (Ben-Akiva and Lerman 1979), which is a summary measure of the desirability of a full choice set. This indicator is included in the multinomial logit models of discrete choice commonly used in the four-step transportation models. The other is derived from Williams' (1976) integral transport-use benefit measure defined as an integral function of cost and transport demand. For more details about the four types of accessibility, see Geurs and van Wee (2004).

In the context of the proposed analysis, personal indicators do not seem useful because carrier-oriented transportation planning often refers to facility location and fleet management. Moreover, in multi-echelon freight transportation systems the main cost optimization issues are total traveled distances related to the geographic configuration of the transportation network. For these reasons, location-based indicators seem the most reasonable to use in this study since they take geographic contexts of networks into account and can use both costs and access opportunities as their main variables.

A two-echelon transportation system is defined by two connected transportation systems, each assigned to an echelon. For the first echelon, the freight is not pre-assigned to each intermediary facility. Although capacity and other operational data of these facilities are available, demand is strongly dependent on each final destination and on the second echelon. Therefore, two indicators are defined. First, a gravity model-based accessibility measure is defined for the second echelon following the general definition presented above. This accessibility is related to both customer demand and distance to a chosen satellite. Thus, a freight transportation trip is more attractive when large freight can be delivered to a customer's location, and a customer is less accessible when the distance from the customer's location to the starting point of the route increases. An exponential cost function is used to accentuate the role of increasing distances. To compare test cases of different sizes and scales, a normalized accessibility indicator whose value range is independent of its size (number of satellites and customers) and distance is used (Gonzalez-Feliu 2008). This measure is defined as follows:

(2) $$A_k = \sum_{i \in V_c} \frac{q_i}{q_{\max}} \exp\left(-\beta \left[\frac{c_{ki} - c_{\min}}{c_{\max} - c_{\min}} \right] \right)$$

Where q_i is customer *i's* demand, q_{max} the maximum overall demand for customers, c_{ki} is transport cost between satellite *k*, and the customer *i*, c_{min} and c_{max} the minimum and maximum values of the second-echelon transport costs, respectively, and β is a given parameter representing traveling impedance. Following Bertuglia et al. (1987), it is assumed that β is 0.1 in Eq. (2). Concerning transportation cost, c_{ki} accounts for travel distance between *k* and *i*. This distance can be Euclidean or not and it is not always symmetric, i.e., c_{ki} can be different from c_{ik}.

A second measure of accessibility derived from average distance ratios is used to complement the accessibility indicator in Eq. (2). More precisely, it is desired to measure how long it takes to deliver to a customer by passing through a satellite and using a direct transportation path from the depot to the customer. This indicator is denoted as first-echelon distance ratio and it is defined for each satellite *k*, as follows:

(3) $$r_k = \frac{\sum_{i \in V_c} \frac{c_{0k} + c_{ki}}{c_{0i}}}{n_c}$$

Where c_{0i} is the distance between a depot and customer *i*, c_{0k} the distance between a depot and satellite *k*, c_{ki} transport cost between the satellite *k* and customer *i*, and n_c the total number of customers.

The accessibility analysis is carried out for 80 test cases for which a global optimum was found by solving the combinatorial optimization problem in the appendix. This optimization considers four sets consisting of 66 test cases with 12 customers, six test cases with 21 customers and a central depot, another six with 21 customers and a peripheral depot, and two with 32 customers. Each set is from Christophides and Eilon (1965) and it is compared to basic one-echelon cases. Note that the original single-echelon test cases with 12 customers have non-Euclidean distances, whereas all the others have Euclidean distances (Christofides and Eilon 1965).

Overall transportation cost is calculated for each two-echelon test case and compared to the corresponding single-echelon benchmark case. Then, the quartiles (first quartile, median, third quartile, fourth quartile) are calculated respectively for the second echelon accessibility and the first echelon cost ratio. This division of the data leads to 16 homogeneous classes, each containing five values. Table 1 shows for each class the number of test cases where a two-echelon system results in a lower travel cost compared to a single-echelon scheme.

Table 1: Impacts of Accessibility and Transportation Cost Ratio

Quartile		Transportation Cost Ratio				
		First quartile	Second quartile	Third quartile	Fourth quartile	**Total**
Mean 2nd-echelon accessibility	First quartile	3	4	3	0	**10**
	Second quartile	4	3	3	0	**10**
	Third quartile	5	5	2	3	**15**
	Fourth quartile	5	4	3	3	**15**
	Total	**17**	**16**	**11**	**6**	**50**

This table can be read as follows. For example, for the third quartile of the transport cost ratio and the second quartile of accessibility, three test cases result in a cost reduction. Although the sizes of the test cases in terms of the number of customers are small, the comparison is between exact optima and as such it provides information about the travel costs impacts of multi-echelon distribution with cross-docking. Indeed, the table shows that multi-echelon distribution leads to a cost reduction in 50 (63%) of the test cases. On the average, the range of the decrease/increase is -23% to 21% of the transport cost of a single-echelon system resulting in an average cost decrease of 5% as shown in Table 2.

Table 2: Average Percent Gain/Loss Compared to the Single-Echelon Optimum

Quartile		Transportation Cost Ratio				
		First quartile	Second quartile	Third quartile	Fourth quartile	**Average**
Mean 2nd-echelon accessibility	First quartile	-23%	-13%	-1%	14%	**-6%**
	Second quartile	-20%	-13%	-7%	11%	**-7%**
	Third quartile	-11%	-12%	-4%	9%	**-5%**
	Fourth quartile	-9%	-15%	-4%	21%	**-2%**
	Average	**-16%**	**-13%**	**-4%**	**14%**	**-5%**

Examining these results further, Table 2 shows the average cost increases or decreases compared to the single-echelon approach. This table considers only the cases where two-echelon distribution leads to a cost reduction. It is observed from the second echelon accessibility mean value that when it increases, two-echelon systems are less costly than one-echelon schemes. This, however, is not the case for average cost decreases. For example, when the second-echelon accessibility is in the fourth quartile (i.e., when it reaches its highest values), 75% of the two-echelon cases result in cost reductions in Table 1 but the average cost reduction is only 2% in Table 2. Focusing on the fourth quartile of accessibility, when the transport cost ratio is low (the two first quartiles), nine test cases result in cost reductions in Table 1, ranging from 9% -15% in Table 2. Each of the third and fourth quartiles has three cases resulting in cost reductions. However, the third quartile has an average cost reduction of 4%, and the fourth, an average cost increase of 21%. To summarize, cost reductions are found for the first three quartiles of transport cost ratio in Table 2. However, the effect of accessibility is less evident. Indeed, only for the first quartile of the transport cost ratio is it observed that the number of cases resulting in cost reductions increases with accessibility. This result is not confirmed in terms of average cost reduction (Table 2).

From this analysis, accessibility and cost ratio can be used to study the potential of two-echelon transportation systems with cross-docking. In this analysis, only transportation cost directly related to travelling distances has been taken into account to produce a homogeneous comparison between single- and two-echelon transportation schemes. However, no investment costs have been taken into account, especially those related to the financing of infrastructures and vehicles needed in two echelon schemes. Therefore, issues concerning investments and financing will be considered in the socioeconomic analysis further presented.

Comparison of Single-Echelon and Collaborative Multi-echelon Systems

A scenario analysis is used to compare single-echelon and multi-echelon strategies with data from Fisher (1994), who proposed three real-life test cases. Each test case can be seen as an optimization problem for a transport company. Complementary information is assigned to each test case to allow the company to use a single- or a two-echelon transportation system. Each company's characteristics are summarized in Table 3.

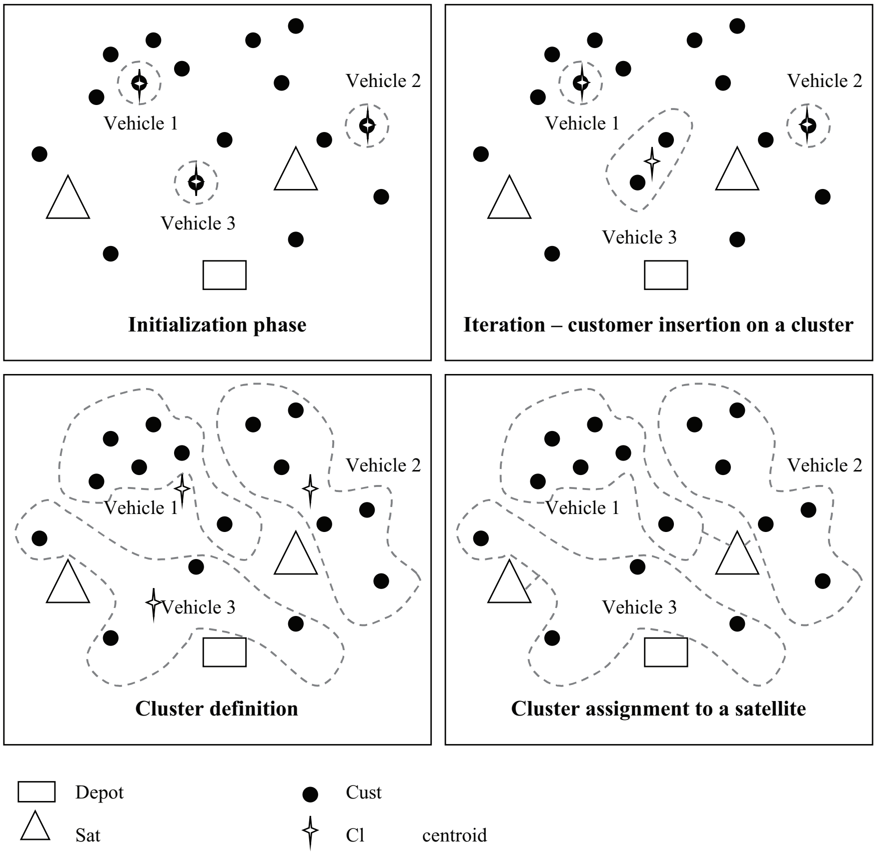
Table 3: Main Characteristics of Each Carrier (Adapted from Fisher 1995)

Transport Carrier Number	Number of Customers	n_s	n_c	m_1	m_2	C_1	C_2
1	71	2	71	2	6	7800	3000
2	44	2	44	2	6	6500	2500
3	136	3	136	3	10	6500	2500

n_s: Number of cross-docking platforms (also known as satellites); n_c: Number of customers; m_1: Number of first-echelon vehicles; m_2: Number of second-echelon vehicles; C_1: Maximum capacity of first-echelon vehicles (in kg); C_2: Maximum capacity of second-echelon vehicles (in kg)

From the test cases, four scenarios are defined. The first is where each company has a single-echelon transportation system. In the second, each carrier develops its own two-echelon distribution strategies. The third assumes a form of collaboration involving companies sharing cross-docking platforms. The fourth assumes complete collaboration among partners involving sharing both vehicles and facilities. Because it is of interest to present realistic situations and solve the optimization problem quickly, each carrier's route is simulated using a two-step algorithm (Jacobsen and Madsen 1980, Nguyen et al. 2011). The first is clustering, where customers are assigned to each second-echelon vehicle, then to a satellite using an adapted Forgy and Random Partition method (Hamerly and Elkan 2002). To initialize this algorithm, m_2 observations are chosen randomly from the data set (i.e., a number of customers equal to the number of second-echelon vehicles). Each customer becomes the centroid of a cluster. Then, each customer is assigned to a cluster using a k-means algorithm. This algorithm is an iterative procedure that assigns each customer to a cluster to minimize the mean distance among customers in that cluster. Here, the mean distance to minimize is the Euclidean distance between each customer and the cluster's centroid. Each cluster contains customers whose overall demand does not exceed the capacity of the second echelon vehicle to which the cluster is associated. In order to take into account the two-echelon nature of the problem, once the clusters are defined, each is assigned to a satellite using the same principle as shown in Figure 2.

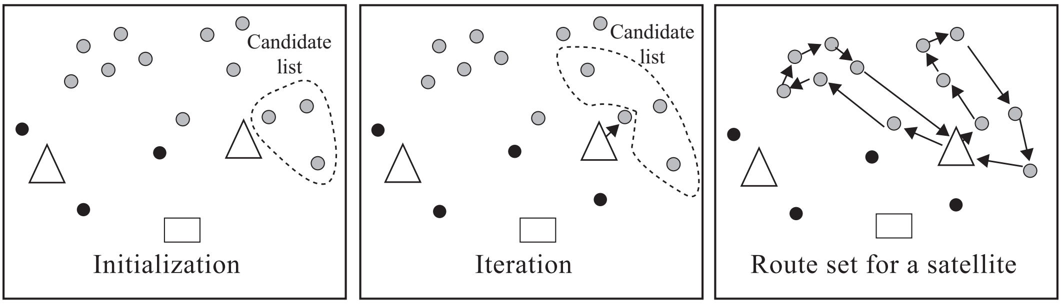
Figure 2: An Example of the Clustering Phase



The second phase is route construction. Given the satellite clusters defined in the first phase, a semi-greedy algorithm (Toth and Vigo 2002) is used. In the initialization phase of the algorithm each customer is assigned to a satellite following the results of the clustering phase. Then, for each satellite, account is taken of the maximum number of routes, which is equal to the number of clusters assigned to it in the clustering phase. Routes are generated following an iterative procedure that adds each customer to a route in the following manner. Given each iteration and incomplete route, a list of candidates is defined by taking the n closest customers to the last point on the route as shown in Figure 3. This is done by defining a distance threshold δ. Customers whose distances to the last point of the route are less than δ are included in this list, which will be called Restricted Candidate List (RCL). Then, the customer to be added to the route is chosen at random from the RCL customers. Finally, the first-echelon routes are built following the same principle and knowing the load that will transit in each satellite from the second-echelon routes. Since the number of intermediary facilities is small, all feasible first-echelon routes can be easily identified, and the optimal solution obtained by combining the routes iteratively until all the satellites are served by at least one echelon route, and the vehicles have adequate capacity to deliver the required freight. The algorithm solves optimization problems of more than 200 destinations and five satellites in less than one second.

To adapt the algorithm to a single-echelon system, this scheme is represented by a two-echelon system with one satellite whose distance to the depot is equal to zero. The different scenarios have been tested by programming the simulation in Python. This analysis identified the main cost sources,

Figure 3: Schema of the Semi-Greedy Algorithm for the Second-Echelon Routes



traveled distances, the number of open cross-docking platforms, and the number of vehicles used. A generalized cost function is not used but the method analyzes these three variables and deduces their main implications taking into account that each affects a carrier differently.

It is observed that all scenarios result in decreases in distances and a larger number of vehicles. In Table 4, scenario one gives a small reduction of about 5% in total travel distance and uses a larger number of vehicles. In this scenario, each carrier needs to almost double its number of vehicles and all available vehicles are used. This is due to the algorithm and the assumptions assigning vehicles to each satellite and not using the same vehicle on more than one route. The number of open platforms is seven, i.e., each carrier uses all the satellites it has and employees to perform different operations related to consolidation and transshipment.

Table 4: Scenario Simulation Results

	First-echelon vehicles	Second-echelon vehicles	Used satellites	First-echelon vehicle variation	Second-echelon vehicle variation	Distance variation
0	0	15	0	-	-	-
1	7	22	7	+7	+7	-5%
2	7	21	7	+7	+6	-10%
3	5	14	4	+7	-1	-22%

A similar situation is observed in scenario two. If only platforms are shared, transportation costs can only be improved by using more platforms, which is not the best for the number of satellites and vehicles used. Indeed, the number of open satellites is also seven (see the fourth column of Table 4) but they are used by all three carriers. This leads to a small reduction in the number of second-echelon vehicles because one carrier can, by using a satellite not belonging to it, group a set of customers to gain one vehicle. The overall transportation costs in the last column of Table 4 in terms of travel distances are reduced about 10% compared to scenario zero or one-echelon schemes for each company.

Finally, the third scenario which involves collaboration among all the carriers to share vehicles leads to a reduction of about 22% in travel distance and a better usage of vehicles. In this scenario Table 4 shows 19 vehicles are used (five for the first and 14 for the second echelon), which is the best taking capacity constraints into account. Note that in these simulations, account is taken of the fact that one route is served by only one vehicle. The cost reduction in terms of distance traveled by the vehicles remains however small if it is considered that other costs mostly related to consolidation and vehicle driving have not been considered in this study. To complete the study, an interview-based analysis on major limitations to transport sharing and collaboration is presented in next section.

Interview-Based Analysis

From the simulation multi-echelon transport can be useful in reducing transport cost. However, these cost reductions do not ensure the successes of these schemes because they are a part of a socio-economic system and are influenced by it. To study the limitations to multi-echelon transportation with cross-docking, 25 companies and their contact persons were randomly identified to be surveyed about their experiences with multi-echelon distribution. The number of interviews was limited to 25 for the following reasons. First is the nature of the analysis. A qualitative analysis needs long interviews, and data processing times are significant. Second, it is important to use many companies to show diverse use of multi-echelon transportation. Third, the 25 interviews are more than the 20 Raux et al. (2007) consider appropriate for a qualitative exploratory analysis. Questions for the survey came from existing literature on multi-echelon transportation and several professional documents containing the experiences of companies regarding multi-echelon distribution. Then, a face-to-face interview was conducted with each contact person following the approach in Gonzalez-Feliu and Morana (2011). Missing information was collected by phone interviews.

Each interview was organized in three parts. First, a questionnaire that identified the main logistics schemes and flows of the company was completed by company contacts. In many cases, the questionnaire was sent prior to the interview to decrease interview time. Next, a set of questions about how the company should change its logistics systems in relation to different external factors was developed. Third, an open-phase interview was conducted that consisted of making the contact person identify the main advantages and disadvantages of managing multi-echelon transportation systems with cross-docking. More precisely, the respondent was asked to define a list of factors that help or work against multi-echelon transportation systems. For confidentiality reasons, the companies' identities are kept anonymous. The interviews were done with six grocery distribution companies, four automotive and spare part industry companies, three press distribution companies, three urban consolidation centers, four parcel and postal distribution companies, and five transport operators. Except the urban consolidation centers the interviewed stakeholders work for global companies or operate on different continents (Europe, North America, or East Asia).

The interview questions sought information on different socio-economic and legislative factors that could affect multi-echelon transportation with cross-docking. Three types of factors derived from the model were identified in each interview, and then synthesized to generalize the findings of Lambert (2008) and Gonzalez-Feliu and Morana (2011) about multi-echelon transportation with cross-docking. The first factor is that of motivators, defined as the factors that contribute to the development of a transportation system with cross-docking. The interviewed stakeholders indicate that these motivators derive from the socio-economic and legislative contexts of their practices and can be grouped into the following sub-categories. First, are the economic, environmental, and value motivators, which from the interviews can be defined as the factors related to economic efficiency, prestige of partners, and image. For example, the need for just-in-time deliveries to deal with service quality targets is one of the main factors that defines the press and spare parts distribution systems, and which leads to a network of consolidation platforms connecting different transportation networks. In addition are logistics performance-related to the optimal use of resources in terms of costs and revenues mentioned by all stakeholders, and sustainable performance in terms of the minimization of environmental impacts. The latter was mentioned by 76% of the company representatives interviewed who believe that environmental factors can motivate the use of multi-echelon systems. The existence of social policies as motivators was mentioned by 24% of those interviewed. Also mentioned are legislation and jurisprudence aspects of transport collaboration, which seem to affect transport management. Transportation carriers, postal and parcel delivery operators, and urban consolidation centers state that existing legislation compels them to develop new forms of organizations, including multi-echelon transportation. The most important aspects of this latter category are different local laws that help develop multi-echelon transportation systems in urban and regional freight transportation.

Relationship motivators are closely related to habits and interpersonal relations, and are the most difficult to identify. Those interviewed were not always forthcoming about their relationships with direct competitors. But when they have collaborated in such schemes, which as was found is common in the automotive and spare parts industry, collaboration is taken into account more naturally than when there is no such prior experience. Last, there are financial motivators, which according to those interviewed, are related to subsidies and financial help that can come from public, private, or mixed companies. However, of note is that multi-echelon distribution is seen by transport carriers and parcel distribution operators as resulting in direct cost increases. As well, changing their logistics systems to accommodate multi-echelon transportation is seen by 84% of those interviewed as costly and slow. Therefore, financial support is seen by those interviewed as a factor that can make them develop new organizational concepts.

The second category of factors is that of facilitators, which are the conditions and situations that have positive impacts on the daily operations of multi-echelon transportation schemes. They are similar to collaboration and logistics partnerships (Lambert 2008) and will not be analyzed indepth. These factors are not only related to the logistics organization but also to the evolution of strategic relationships between partners. A history of relationships can facilitate a durable partnership, as shown by the urban consolidation centers that persist in the automotive industry. The boundary between motivators and facilitators is not always clear, as revealed by the interviews. Indeed, several companies did not see clearly the difference between these two categories of factors. For this reason, it is important to explain here the main differences between them. The motivators have an impact on strategic decisions before a project's experimentation and deployment, i.e., in strategic planning, and the facilitators have impacts that are observed at tactical and operational levels.

Closely related to the facilitators, the study identified limitations and obstacles which consist of the factors that can become impediments to the successful development of strategies concerning multi-echelon transportation with cross-docking. These factors constitute a third category and are seldom studied in the logistics literature (Lambert 2008). For this reason, they are the focus of the analyses. From the experiences and feedbacks, several types of limitations and obstacles have been identified and are synthesized as follows.

First, there are commercial strategies. Each enterprise has its own commercial interests, which are not the same for loaders and transport operators. In general, producers aim to sell products and transport is seen as a cost and/or a constraint but seldom as an opportunity to improve performance. This derives from the fact that transport is carried out by third parties. Transport carriers see transport management as a leverage to improve their performance, as stated by all considered urban consolidation centers and transportation companies, as well as four of the six grocery distribution companies. However, each sector has its specific characteristics and constraints. For example, transport demand for press distribution is fixed by publishers and the benefits of the distribution company depend on sales. Also, for the press companies whose representatives were interviewed, distribution by transport and route selection are planned six months ahead and this makes it difficult to optimize. Aggressive strategies and disregard of transport plans to favor "friends" or customers were identified by many transport operators as a problem in the development of collaborative multi-echelon networks. Since multi-echelon transportation affects the transportation field directly, producers and distribution companies that subcontract transportation are less concerned about it.

Another limitation identified in the interviews concerns the financial aspects of implementation of a multi-echelon system, more precisely, investment costs of construction or adaptation of cross-docking platforms, depots or other infrastructures. This is an important limitation to the development of urban consolidation centers and is one of the main factors that define grocery distribution supply chains. Yet another limitation, especially for parcel distribution companies and transportation carriers, is the ownership of these infrastructures or managerial issues related to them once they are operational. Also, the logistics strategies of each stakeholder as well as the potential or real changes that a multi-echelon system would introduce are a source of obstacles to their development. Most transport carriers, postal and parcel delivery companies, and urban consolidation centers state that the physical and organizational conditions for freight compatibility such as dimensions, type of freight, type of packaging, loading unit, and loading requirements are important and are not only related to legislation but also to organizational type, equipment, and habit. Another limitation identified by 92% of those interviewed is acceptability of organizational changes.

Two other important limitations identified by those interviewed are responsibility transfer and confidentiality. Although the main transactions in freight transportation are regulated by several commercial contracts, the responsibilities of sub-contractors are not always well defined (Simonot and Roure 2007). Moreover, not all transport operators use subcontractors if responsibility issues are not well defined. And as found, none of the transportation and parcel distribution carriers would give freight to another operator without well defined responsibility transfer rules. In cases of conflicts, the responsibility transfer clause of a contract plays an important role because it defines liability. For this reason, transportation carriers are reticent to organizational changes that imply collaboration with other carriers. Moreover, confidentiality was mentioned as an obstacle to multi-echelon systems when two competing companies decide to collaborate to reduce their transport costs. Since information flow is the basis of good collaboration, if one or more partners manage confidential information that they do not want to share for competitive reasons, the efficiency of multi-echelon approaches can decrease considerably. These issues come to light in most of the initiatives involving competing enterprises that are not supported by public entities.

CONCLUSION

This paper presents a multidisciplinary analysis to study multi-echelon transport with cross-docking using both engineering and social science approaches. Two optimization analyses were undertaken to study the potentials of these systems as well as their main limits. The first, based on the notion of accessibility, shows that the physical and geographical characteristics of a network have important impacts on the development of transportation systems with cross-docking. Such systems are useful if they group delivery points to use small vehicles to make short distance deliveries, but are disadvantageous if the distances to reach cross-docking platforms are long. The second analysis explores the possibility of collaboration between transport carriers to optimize vehicle loads. This analysis leads to two main conclusions. The first is that significant cost reductions can be obtained only by sharing vehicles. However, other costs will appear mainly related to the introduction of new vehicles and the use of cross-docking facilities. This leads to the second conclusion, which is that it is important to have enough freight to put on the vehicles feeding the satellites. In this respect, collaboration seems a good way to increase vehicle load.

To complete these analyses, an interview-based analysis of 25 companies was undertaken. Several factors that can be considered incentives and limitations to multi-echelon transportation with cross-docking were identified. These factors are related to commercial strategies, financing, organization, and legislation. Since transport is used by humans, the social aspects of human interactions are important and can be its keys to success. For these reasons, optimization methods are useful but have to meet operational needs and limits, most of them related to habits that are often difficult to change.

In conclusion, multi-echelon transport has potential and can be well accepted by practitioners and public authorities, but structural changes have to be implemented in a medium term perspective, after identifying and analyzing the potential obstacles to its development to ensure its continuity from an economic point of view. Finally, some future extensions to this study can be done in two complementary directions. One is to provide more realistic simulation tools, by adding a cost function that takes into account not only traveled distances but other costs related to vehicle usage, crew scheduling, platform management, and maintenance issues, among others. The other is to include qualitative variables in the simulation approaches to develop integrated decision support systems to help planners and practitioners in their strategic or tactical decisions related to multi-echelon transportation with cross-docking.

APPENDIX: The two-echelon vehicle routing problem

Consider a transportation carrier that has to deliver to a set of N_C destinations, called customers (Fisher 1994). To each customer i is associated a quantity of freight q_i to be delivered, called demand. The carrier has one depot and N_S intermediate facilities, or satellites (Nguyen et al., 2011) where cross-docking operations can take place. The company has two fleets of homogeneous vehicles, m_1 and m_2, assigned respectively to the first and the second echelon. These vehicles have a maximum capacity of C^1 and C^2 respectively. Two types of routes are then defined, one for each echelon. A first echelon route starts and finishes in a depot and visits the satellites. At the satellites, the freight is transshipped into the second echelon vehicles. Each of them makes a round trip to deliver to one or more customers.

Define three sets of nodes: V_0 includes the depot, V_S the satellite nodes and V_C the customers. Then define an arc (i,j) to link node i and node j. Cost c_{ij} is defined as the travel distance associated with arc (i,j). The decision variables are the following: x_{ij} is an integer that represents the number of first echelon vehicles traveling on arc (i,j); y_{ij}^k is a binary variable equal to one if a second echelon route starting from satellite k travels on arc (i,j) otherwise it is zero. Also define z_{kj} as a binary variable equal to one if the freight to be delivered to customer j is transshipped at satellite k, otherwise it is zero. Finally define a set of variables that represents the quantity of freight loaded into a vehicle passing through each arc. These variables are real and can be noted as Q_{ij}^1, Q_{ij}^{2k} respectively, for each subset, k representing the satellite where the second echelon route starts. The corresponding optimization problem can be written as follows (Gonzalez-Feliu 2008):

$$(A.1) \quad \min \sum_{i,j \in V_0 \cup V_S} c_{ij} x_{ij} + \sum_{k \in V_S} \sum_{i,j \in V_S \cup V_C} c_{ij} y_{ij}^k$$

Subject to

$$(A.2) \quad \sum_{i \in V_S} x_{0i} \leq m_1$$

$$(A.3) \quad \sum_{j \in V_S} x_{j0} = \sum_{i \in V_S} x_{0i}$$

$$(A.4) \quad \sum_{k \in V_S} \sum_{i,j \in V_c} y_{ij}^k \leq m_2$$

$$(A.5) \quad \sum_{i,j \in V_C} y_{ji}^k = \sum_{i,j \in V_C} y_{ij}^k \ \forall k \in V_S$$

$$(A.6) \quad \sum_{i \in V_S} Q^1_{ij} - \sum_{k \in V_S} Q^1_{jk} = \begin{cases} \sum_{h \in V_C} q_h z_{jh} & \text{if } j \text{ is not the depot} \\ \sum_{i \in V_c} -q_i & \text{if } j \text{ is the depot} \end{cases}$$

$$\forall j \in V_0 \cup V_S, k \neq i, k \neq j$$

$$(A.7) \quad \sum_{i \in V_c} Q^{2k}_{ij} - \sum_{l \in V_c} Q^{2k}_{jl} = \begin{cases} z_{kj} q_j & \text{if } j \text{ is not a satellite} \\ -\sum_{h \in V_C} q_h z_{jh} & \text{if } j \text{ is a satellite} \end{cases}$$

$$\forall j \in V_S \cup V_C, \forall k \in V_{S,} \; l \neq i, k \neq j$$

$$(A.8) \quad \sum_{i \in V_S} Q^1_{i0} = 0;$$

$$(A.9) \quad \sum_{i \in V_C} Q^{2k}_{ik} = 0 \qquad \forall k \in V_S$$

$$(A.10) \quad Q^1_{ij} \leq C^1 x_{ij} \quad \forall i, j \in V_S \cup V_0, i \neq j$$

$$(A.11) \quad Q^{2k}_{ij} \leq C^2 y^k_{ij} \quad \forall i, j \in V_S \cup V_0, \forall k \in V_S, i \neq j$$

$$(A.12) \quad y^k_{ij} \leq z_{kj} \quad \forall i, j \in V_S \cup V_C, \forall k \in V_S$$

$$(A.13) \quad y^k_{ij} \leq \sum_{h \in V_{S \cup \{0\}}} x_{hk} \quad \forall i \in V_S, \forall j \in V_C, \forall k \in V_S$$

$$(A.14) \quad \sum_{k \in V_S} z_{kj} = 1 \quad \forall j \in V_C$$

Where x_{ij} is integer; y^k_{ij} and z_{lk} are binary; Q^1_{ij} and Q^{2k}_{ij} are real.

The objective function (A. 1) seeks to minimize the overall transportation cost. Equations two and four impose the maximum number of routes. Constraints (A.2) to (A.5) balance the number of vehicles entering and leaving each node. Equations A.6, A.7, A.8, and A.9 ensure that each route returns to its departure point and each node receives its corresponding demand. Vehicle capacity constraints are expressed by equations A.10 and A.11. Constraints (A.12) and (A.13) ensure the connection between the two echelons. Constraint (A.14) assigns each customer to one and only one satellite.

To test the two-echelon model, four test cases are adapted from Christofides and Eilon (1969). These test cases represented as 12, 21, 32, and 50 customers, respectively. Then, 102 two-echelon test cases were created in the following way. Given a reference dataset (one of the chosen Christofides and Eilon's test cases), two satellites are added. The second-echelon vehicle fleet is taken from the reference and then the first echelon vehicles are added. The number of such vehicles is two, and their capacity is 2.5 times the capacity in the reference. After creating the test cases we solve them using XPress 2006 (see Gonzalez-Feliu 2008 for the detailed computational issues). All test cases up to 21 customers, and two having 32 customers, were solved to optimality. The Xpress solver thus gives the global optimum solution. The other test cases were not solved to optimality in the given time (45 minutes), but at least one solution was provided by the solver in less than 20 minutes. Although there is a gap between the best solution and the best lower bound (i.e., a bound lower than the optimum calculated by Xpress solver), only test cases with 50 customers and a central depot present solutions too far from it. In the other cases, on average a gap of less than 10% was obtained between the best solution and its best lower bound found with Xpress solver, which is considered as a good result (Toth and Vigo 2002).

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Acknowledgement

The author would like to acknowledge Christian Ambrosini, Mathieu Gardrat, Aurélie Mercier, Joëlle Morana, and Jean-Louis Routhier (Laboratoire d'Economie des Transports, France) for their suggestions as well as Carlos Peris Pla (TComm, Spain) for his help in algorithmic development. The author would also like to acknowledge the co-editors in chief, as well as the two anonymous reviewers, for their suggestions to improve the paper.

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Methodology to Measure the Benefits and Costs of Rural Road Closure: A Kansas Case Study

by Michael W. Babcock and Abhinav Alakshendra

While rural roads are essential to state economies, increasing farm size and the corresponding increase in farm vehicle size coupled with declining rural population have stressed the rural road system. As county population declines the financial ability of counties to maintain and rebuild the road and bridge system isn't keeping up with the rate of deterioration. If counties can't maintain the rural road system as it currently exists, reducing the size of the system should be considered.

The overall objective of the paper is to estimate the economic impact on selected county road systems from reducing the size of the system. The specific objectives include (a) for a sample of three Kansas counties, measure the benefits and costs of keeping the road system as it currently exists and (b) for the same sample of Kansas counties, measure the benefits and costs of several scenarios of county road closure.

The main conclusion is that rural counties will be able to save money by closing some relatively low traffic volume roads and redirecting the savings toward increasing the quality of other county roads. Counties with relatively extensive road systems (miles of road per square mile) and relatively high population density are less likely to realize savings from road closure. In contrast, counties with less extensive road systems and relatively low population density are more likely to realize significant savings from closure of relatively low volume roads.

INTRODUCTION

Rural roads are an essential component of the U.S. transportation system. Though rural roads exist in every state, they are especially important to the economies of the northern and southern plains states. Table 1 includes 2008 public road length for the top dozen states in terms of the percent of U.S. total rural road miles. As indicated in Table 1 these dozen states account for nearly 44% of U.S. rural road miles. The table also contains the percent of each state's total road length that are rural roads. These range from a low of 69.5% (Texas) to a high of 97.8% (North Dakota) with an average of 83.7% for the 12 states as a group.

In general, rural roads are owned and administered by counties and townships. Table 2 contains 2008 public road miles owned by counties and townships in the same dozen states as in Table 1. The data in Table 2 indicate that the county plus township miles as a percent of state total miles averages 86.1% for the dozen states and 76% for the U.S. as a whole.

Table 3 displays 2008 rural vehicle miles as a percent of state total vehicle miles for the dozen states. In nine of the 12 states, rural roads account for at least 42% of the state's total vehicle miles. The corresponding percent for the U.S. as a whole was 33%.

The rural road system is important to the agricultural economies of the dozen states since the states with the largest rural road miles also account for a large percentage of U.S. crop production. Table 4 displays the 2010 combined production of corn, wheat, soybeans, and sorghum for the dozen states. Nearly 72% of the combined production of these four crops is produced in these states.

While rural roads are essential to state economies, increasing farm size and the corresponding increase in farm vehicle size coupled with declining rural population have stressed the rural road system.

Table 1: 2008 Public Road Length, Top Dozen States (Miles)

State	Rural	Urban	Rural Percent of U.S. or State Total	Rural Percent of U.S. Total
Texas	212,999	93,405	69.5%	7.2%
Kansas	127,859	12,750	90.9%	4.3%
Minnesota	117,613	20,626	85.1%	4.0%
Missouri	106,765	22,952	82.3%	3.6%
Iowa	102,919	11,307	90.1%	3.5%
Illinois	98,202	41,290	70.4%	3.3%
Oklahoma	97,268	16,057	85.8%	3.3%
Wisconsin	92,572	22,271	80.6%	3.1%
Arkansas	87,627	12,185	87.8%	2.9%
Michigan	85,853	35,813	70.6%	2.9%
Nebraska	87,297	6,318	93.3%	2.9%
North Dakota	84,945	1,897	97.8%	2.9%
Total - Top Dozen States			83.7% (Ave)	43.9%
U.S. Total	2,977,228	1,065,540	73.6%	-

Source: U.S. Department of Transportation, Federal Highway Administration.
State Statistical Abstracts 2008. http://www.fhwa.dot.gov/policyinformation/statistics/abstracts

When the county road grid was established in the U.S., each road was used by a large number of households and farms operating small vehicles. Today, each road is used by a small number of households and farms operating large vehicles. The typical vehicle types include automobiles, pickup trucks, farmer-owned tandem axle and semi-trucks, farm combines, and farm tractors pulling various types of farm equipment. Other vehicle types include commercial trucks, garbage trucks, and school buses.

In many counties the road and bridge characteristics are not sufficient to handle the stresses of the large vehicles. These characteristics include (1) narrow lanes that create safety problems, (2) overweight vehicles that break up road surfaces, (3) lack of hard surfaces that create rideability problems, and (4) road widths and design characteristics that are inadequate for large farm equipment and heavy trucks.

It is well known that U.S. agriculture has consolidated into fewer, larger farms due to economies of scale from larger farming operations. The increased size of farms has been accompanied by increasing farm vehicle size as well. Tractor and combine weight and width has increased and the great majority of farmers deliver their grain in semi-trucks.[1] Tandem axle trucks are used to deliver farm supplies. Declining rural population has caused school districts to use larger buses to transport fewer children over longer distances to consolidated schools. The road width and design characteristics of rural roads and bridges are inadequate for the larger and heavier vehicles that are using them.[2]

As county population declines, the financial ability of counties to maintain and rebuild the road and bridge system isn't keeping up with the rate of deterioration. Many rural counties don't have the funds to maintain the existing system with the heavier vehicles that are using the system. Current economic conditions have resulted in most states reducing their budgets. Thus, increased state aid for rural road maintenance is unlikely to occur.

Table 2: 2008 Public Road Length Owned by Counties and Townships, Top Dozen States (Miles)

State	County	Percent of State Total	Township	Percent of State Total	County & Township Percent of U.S. or State Total
Texas	145,632	47.5%	79,729	26.0%	73.5%
Kansas	113,338	80.6%	15,725	11.2%	91.8%
Minnesota	44,876	32.5%	77,397	56.0%	88.5%
Missouri	73,024	56.3%	21,684	16.7%	73.0%
Iowa	89,564	78.4%	15,095	13.2%	91.6%
Illinois	16,367	11.7%	106,130	76.1%	87.8%
Oklahoma	80,079	70.7%	19,706	17.4%	88.1%
Wisconsin	20,717	18.0%	81,449	70.9%	88.9%
Arkansas	66,139	66.3%	14,575	14.6%	80.9%
Michigan	89,306	73.4%	21,108	17.3%	90.7%
Nebraska	60,949	65.1%	22,227	23.7%	88.8%
North Dakota	10,067	11.6%	67,825	78.1%	89.7%
Average, Top 12 States		51.0%		35.1%	86.1%
U.S. Total	1,788,046	44.2%	1,286,446	31.8%	76.0%

Source: U.S. Department of Transportation, Federal Highway Administration. *State Statistical Abstracts 2008*. http://www.fhwa.dot.gov/policyinformation/statistics/abstracts

The purpose of this paper is to present a methodology that county road supervisors and county engineers can use to evaluate rural road investment or disinvestment proposals and to provide information to state DOTs and legislators in developing rural road policies. The methodology will be illustrated using data from a recently completed Kansas study (Babcock and Alakshendra 2011).

LITERATURE REVIEW

There is a large literature on various aspects of low volume roads, and this review is not a comprehensive discussion of that literature. Instead, only the previous studies that are most closely related to this study are discussed.

The objective of the Tolliver et al. (2011) study was to quantify the investment and maintenance needs of the county and local roads that serve as agricultural logistics routes in North Dakota. To accomplish the objectives they developed an integrated system of models to predict crop production, truck movements, and roadway investment and maintenance needs for individual road segments. Their model predicts flows from 1,406 crop-producing zones to 317 elevators and plants and forecasts improvements and maintenance costs for paved and unpaved roads.

The authors found that the estimated resurfacing costs per mile of major agricultural distribution routes is 40% greater than the estimated resurfacing cost per mile on non-agricultural routes. They also discovered the average annual cost to resurface and maintain paved agricultural roads is $18,300 per mile. Other findings include:

Table 3: 2008 Rural Vehicle Miles Traveled as a Percent of State Total Vehicle Miles, Top Dozen States

State	Rural Percent of U.S. or State Total
Texas	30.0%
Kansas	48.7%
Minnesota	43.9%
Missouri	41.8%
Iowa	60.3%
Illinois	25.7%
Oklahoma	48.0%
Wisconsin	46.9%
Arkansas	59.5%
Michigan	31.3%
Nebraska	56.9%
North Dakota	71.8%
U.S. Total	33.3%

Source: U.S. Department of Transportation, Federal Highway Administration. *State Statistical Abstracts 2008*. http://www.fhwa.dot.gov/policyinformation/statistics/abstracts

Table 4: 2010 Combined Production of Corn, Wheat, Soybeans, and Sorghum in Central Plains States (Millions of Bushels)

State	Bushels	Percent of U.S. Total
Texas	553.7	3.0%
Kansas	1,250.4	6.8%
Minnesota	1,709.2	9.3%
Missouri	594.6	3.2%
Iowa	2,650.0	14.5%
Illinois	2,432.6	13.3%
Oklahoma	190.0	1.0%
Wisconsin	599.2	3.3%
Arkansas	178.1	1.0%
Michigan	439.4	2.4%
Nebraska	1,807.8	9.9%
North Dakota	748.2	4.1%
U.S. Total	18,330.0	71.8%

Source: U.S. Department of Agriculture, National Agricultural Statistics Service: http://www.usda.nass.gov.

1. The average annual cost to maintain gravel surface agricultural roads ranges from approximately $3,900 per mile for roads with the lowest traffic levels to roughly $6,600 per mile for roads with 150 to 200 ADT.
2. The estimated cost to maintain 20-year pavement life cycles and acceptable levels of service on county and local roads in North Dakota is roughly double the historical funding level.

Jahren et al. (2005) conducted a study of Minnesota rural roads for the Minnesota Department of Transportation (DOT). The objective of the study was to identify the methods and costs of maintaining and upgrading a gravel road. The research involved three parts with the first one being a historical analysis based on the spending history for low-volume roads in the annual reports of a sample of Minnesota counties. The second part is development of a method for estimating the cost of maintaining gravel roads. The final part of the study is the development of an economic analysis example that can be used for making specific road investment decisions.

The authors concluded that the historical costs to maintain both gravel and bituminous roads were between $1,500 and $2,500 per mile. The authors concluded that maintenance cost savings alone can't justify the investment in a hot mix asphalt upgrade.

The South Dakota DOT sponsored a study conducted by Applied Pavement Technology Inc. (2004). The objective of the study was to create a process that allows the user to compare the costs associated with different types of roads in order to provide assistance in deciding which surface type, hot-mix asphalt (HMA), blotter, gravel or stabilized gravel, is most economical under a certain set of circumstances.

To achieve the objectives, the authors used life-cycle cost analysis (LCCA) that focuses on selecting the most cost effective road surface to meet a specific need. The results of the LCCA for each road section were combined for use in model development to determine whether statistically significant relationships existed between variables, including surface type, ADT, terrain type, subgrade type, and truck traffic. The final results showed that ADT is statistically significant in calculating agency and vehicle operating costs on HMA, blotter, and gravel roads.

Jerry Anderson and John Sessions (1991) used mixed integer linear programming (MIP) to analyze the intermittent road management problem in *Managing Low-Volume Road Systems Intermittent Use*, published as Transportation Research Record 1291. The paper is written in the context of timber harvesting regions. The objective is to minimize the discounted value of transportation costs, road opening costs, road closing costs, and road maintenance costs. The authors compute the minimum value of simultaneous consideration of all four costs in the objective function. The solution also indicates the open road segments in the network that minimizes costs. Next, they compute the total costs and open road segments if opening and closing costs are not considered simultaneously with transport and road maintenance costs. The total costs are 13% higher than the optimal solution that considers all four costs simultaneously.

C. Phillip Baumet et al. (1986) estimated the benefits of keeping groups of existing roads in the county road system. The authors selected three cases study areas in Iowa. They discovered that in areas with a large non-farm population, only a small number of roads can be abandoned without increasing vehicle travel cost more than the savings from eliminating them. They also found that in areas with a relatively small rural population and a large percent of gravel roads, only a small number of roads with no property access can be abandoned before the additional travel costs exceed the cost savings from eliminating the roads from the system. The authors discovered that in areas with a small rural population and a high percent of paved roads, a relatively large number of miles of county roads with no property access can be abandoned, and the savings from abandoning the roads will exceed the additional travel costs.

Steven D. Hanson et al. (1985) describe the variable costs of the predominant types of vehicles operating on Iowa rural county roads. The authors found that cost per mile is lowest on paved surfaces for all vehicles. For automobiles, pickup trucks, and commercial vans, the cost per mile increases 38% to 40% on gravel surfaces and 77% to 80% on earth surfaces. The costs per mile for farmer-owned tandem trucks increases 42% to 45% on gravel, and 84% to 91% on earth surfaces. Both farmer-owned and commercial semi trailer costs rose 50% on gravel and 100% on earth surfaces relative to the costs of paved surfaces.

Peter S. Helmberger et al. (1990) develop a method to assess the economic impact of a rural road management study. The strategy considers rural road abandonment and/or improvement, and it is employed in a case study of a Minnesota county. The management scenarios used in the study include the following:

1. The baseline scenario simulates traffic flows prior to any change in strategy, using data obtained from a survey. The scenario develops travel and maintenance costs to examine changes in these costs of various scenarios.
2. Minimum Mileage System. This scenario eliminates all road links that are dead ends.
3. All Paved System. This scenario upgrades the road network and brings all bridges in the system up to acceptable standards.
4. Improve and Remove. This scenario is a combination of rural road and bridge improvements and closures.

A scenario that reduces county road mileage with no adverse effect on travel costs resulted in total costs of $98,373, or $24,433 below the baseline costs. Thus the study demonstrated that net benefits can be increased by reducing the mileage of the county road system.

A report by the Kentucky Transportation Center examines the question of when to pave a gravel road. The authors calculate an example comparing the maintenance costs per mile of paved and gravel roads and conclude that gravel roads have lower maintenance and construction costs. However, the report points out that vehicle costs for the road user are two to three times higher for a gravel road compared to a paved road. Passenger car user costs are 40% higher on a gravel road than a paved road. Thus, when user costs are considered, paving the roadway may minimize the combined county costs and user costs.

Peter E. Sebaaly et al. (2003) evaluate the impact of agricultural equipment on the actual response of low-volume roads in South Dakota. To accomplish this objective, one gravel section and one blotter section were instrumented in South Dakota and tested under various amounts of agricultural equipment use.

The authors concluded that the impacts of agricultural equipment on low-volume roads depends on factors such as season, load level, thickness of crushed aggregate base (CAB), and soil type. They said damage can be reduced with a thicker CAB or by subjecting the agricultural equipment to the legal load limit, i.e. about 20,000 lb.

In "Modeling the Rationalization of Rural Road Networks: The Case of Saskatchewan," Paul Christensen, James Nolan, and Gordon Sparks develop a mathematical model of rural road investment/abandonment based upon traffic flows and the cost of maintaining a given road surface type. The authors note that by incorporating demand, maintenance costs, and routing decisions they can develop a systematic approach to the problem of rural road abandonment and make planning decisions easier and more politically justifiable.

The authors use a network model that contains a set of road decisions (M) where the set M includes (1) the status quo, (2) abandonment, and (3) upgrade of road surface. The network configurations examined by the authors involved a considerable amount of road abandonment and rerouting of users. They found that the scenario with an unconstrained capital budget resulted in the most convenient network for users. They indicated that the future of the rural road network in Saskatchewan will involve a tradeoff between cost and convenience.

The contribution of our paper to the literature in this area is two-fold. First, it is the only road rationalization paper that focuses on how to do such a study. The network model employed in the study (TransCAD) is more technically advanced than models used in previous studies.

PROCEDURES

Measurement of the benefits and costs of retaining all the rural roads in a county as opposed to closure of selected links requires the following eight step procedure, developed by the authors, which is illustrated with Kansas data (Babcock and Alakshendra 2011).

1. Establish objectives.
2. Select study areas (counties).
3. Identify rural residents in the selected study areas.
4. Identify managers of grain elevators and road supervisors of study areas.
5. Design questionnaires for rural residents, grain elevator managers, and study area road supervisors.
6. Conduct a survey of road supervisors and grain elevator managers in the study area.
7. Calibrate the network model (TransCAD).
8. Calculate benefit-cost ratios of closing selected road segments in the study areas' road system rather than retaining them.

Any study must start with clear objectives to provide a framework for the research effort. In this type of study, the objectives are determined by the information needed by the sponsoring agency, usually the state DOT. In a study recently completed for the state of Kansas, the following objectives were established by the Kansas Department of Transportation (KDOT).

The overall objective of the research is to estimate the economic impact on selected county road systems from reducing the size of the system. The specific objectives include:

1. For a sample of three Kansas counties, measure the benefits and costs of keeping the road system as it currently exists.
2. For the same sample of Kansas counties, measure the benefits and costs of several scenarios of county road closure.

Study-area counties that vary significantly in socio-economic characteristics should be selected in order to achieve the objectives of the study. These characteristics include location, geographic size, population density, population characteristics (age, sex, race), per capita income, unemployment rates, and industry mix. Also, since the study is concerned with rural roads, the selected counties should have large crop production.

The counties selected for analysis in the Kansas study were Brown (northeast), Pratt (south-central), and Thomas (northwest). The populations of the selected counties are similar (between 7,300 and 9,900 in 2009), but they vary greatly in size and population density (2009-2010 Governor's Economic and Demographic Report, Appendix F). Brown County has 571 square miles and 19 people per square mile while Thomas County has 1,075 square miles and only eight people per square mile. The distribution of population within the counties varies substantially. In Pratt County, the city of Pratt (the county seat) accounts for nearly 68% of the total county population while Hiawatha (county seat of Brown County) represents only 31% of the county population (2009-2010 Governor's Economic and Demographic Report, Appendix F).

Local government was the largest employer in all three counties but ranged from a low of 14.3% of total county employment (Pratt County) to a high of 23.8% (Brown County) (U.S. Department of Commerce). The industry employment distribution of the counties also varied. Large employers in one county but not the others were manufacturing (9.2% of Brown County employment) and accommodations and food service (10.3% of Thomas County employment) (U.S. Department of Commerce).

In 2008, per capita income ranged from a high in Pratt County of $38,638 to a low of $35,019 (Brown County) (U.S. Census Bureau). Median personal income varied from a high of $45,735 (Thomas County) to a low of $38,162 (Brown County) (U.S. Census Bureau).

All three counties have large agricultural production. In Brown County, the 2007-2009 average total production of corn, wheat, sorghum, and soybeans was 21.5 million bushels with corn accounting for 75% and soybeans 23% of the total (Kansas Department of Agriculture). The 2007-

2009 average total production for the same four crops in Pratt County was 18.7 million bushels with corn accounting for 55% of the total production and wheat representing 30% (Kansas Department of Agriculture). The corresponding figure for Thomas County was 30.8 million bushels with corn and wheat accounting for 63% and 25% of total production (Kansas Department of Agriculture).

After the counties are selected, the third step is identification of the rural residents in each county. This can be done by obtaining a directory of the county with each resident's mailing address. In the Kansas study, the mailing addresses for the rural residents of Pratt and Thomas County were obtained from Farm & Home Publishers for Pratt County and Central Publishing Inc. for Thomas County. These directories have the name, mailing address, township, and phone number of each county resident. In Brown County, the questionnaires were distributed to rural residents by township representatives.

In addition to the travel data of rural residents, the study requires motor carrier inbound grain and outbound fertilizer shipments of grain elevators. The names of grain elevator managers along with mailing addresses and phone numbers are usually found in a directory published by the state grain and feed association. In the Kansas study, this information is available in the *2010 Kansas Official Directory* published by the Kansas Grain and Feed Association.

Brown County crops are stored and marketed by Ag Partners Coop, Fairview Mills, Morrill Elevator Inc, and Farmers Coop Elevator (Sabetha). These four grain companies collectively operate 10 grain elevators with a total storage capacity of 9.6 million bushels (Kansas Grain and Feed Association, *2010 Official Kansas Directory*).

The elevator system in Pratt County includes ADM Grain, Cairo Coop Exchange, Kanza Coop Association, and Farmers Coop Equity Exchange. These four grain companies collectively operate 23 grain elevators with total storage capacity of 20.2 million bushels (Kansas Grain and Feed Association, *2010 Kansas Official Directory*).

Thomas County agriculture is served by ADM Grain, Frontier Ag Inc, Bartlett Grain, Cooper Grain, Cornerstone Ag LLC, and Hi Plains Coop Assn. These six grain companies collectively operate 39 grain elevators with total storage capacity of 49.4 million bushels, although not all of the elevators operated by these grain companies are located in Thomas County (Kansas Grain and Feed Association, *2010 Kansas Official Directory*).

Contact information for county road supervisors can be easily obtained from the county website.

SURVEY DESIGN

Step 5 is to design questionnaires to be distributed to residents of the sample counties, grain elevator managers, and county road supervisors to obtain the data to estimate the network model. In the Kansas study, the rural resident transportation questionnaire has three parts: Transportation Equipment, Outbound Trips, and Inbound Trips. The first part asks the respondents what types and amounts of farm equipment, trucks, and automobiles are owned by members of the household. The second part of the rural resident questionnaire requests information on the following:

- Number of tractor, combine, and grain wagon trips on the county roads
- Number of miles of county roads used to make tractor and combine trips
- Number of times the county roads are used to make auto, pickup truck, single axle truck, tandem axle truck, semi truck, and grain wagon trips
- Destinations and number of trips by auto, pickup truck, single axle truck, tandem axle truck, and semi truck

The last part of the rural resident survey asks the respondents how many trips are made to their location in various types of vehicles. The residents are also asked to provide the origins of trips to their location by various types of vehicles.

Managers of grain elevator companies completed a questionnaire that has three parts: Grain Receipts, Market Area, and Fertilizer Delivery to Farms. The first part of the survey asks the grain company managers for their corn, wheat, sorghum, and soybean receipts for the 2007-2009 period and what percent of their total receipts were delivered to their elevator(s) by various types of trucks. In the next part of the survey, the respondents were asked the average distance from which farmers deliver their grain and the number of county road miles by surface type that farmers use to deliver grain to their elevator(s). The last part of the survey requests data for the percent of the grain company's fertilizer deliveries that were made in various types of trucks. Other information requested in the last part of the questionnaire includes the following:

- Number of miles by road surface type that were used to deliver fertilizer to farms
- The average distance (miles) that fertilizer is delivered to farms
- The number of trips made to deliver fertilizer to farms by season of the year

The county road supervisors for Brown, Pratt, and Thomas County each completed two questionnaires. One is titled County Road Supervisor's Survey and the other is County Maintenance, Construction, and Reconstruction Costs.

The County Road Supervisor's Survey has two parts, Current Condition of County Roads and Revenue and Expense. The first part of the questionnaire asks the road supervisors how many miles of road and bridges is the county responsible for (by surface type), and to rate the condition of the county's cement, asphalt, and unpaved roads. The second part of the survey requests the county's annual expenditure for road and bridge maintenance for the 2007-2009 period, and the sources of revenue for the county's road and bridge maintenance budget.

The County Maintenance, Construction, and Reconstruction Costs questionnaire has four parts as follows:

Part A - Maintenance
Part B - Construction/Reconstruction Costs
Part C - Types of Paved Road Treatments
Part D - Types of Gravel Road Treatments

In Part A, the county road supervisors were asked to provide a general description of maintenance activities in the county, including chip seals, overlays, and recycle. In Part B, the respondents were asked to give a general description of the construction/reconstruction activities for paved and gravel roads as well as bridges. They were also asked how often these activities occur as well as the cost per mile of paved and gravel roads and the cost per average county bridge. In Part C, the respondents were asked to give a general description of paved road treatments, including crack seal, seal coat, overlay, striping and marking, mill and overlay, and patching. They were also requested to provide a general description of gravel road treatments such as blading, re-gravel, reclaiming, reshape cross section, and routine annual maintenance in Part D.

In Pratt County, a large generator of truck traffic is Pratt County Feeders, LLC, one of the largest cattle feedlots in Kansas. There are five parts to the questionnaire, including the following:

Part A - Capacity and Production
Part B - Inbound Truck Shipments
Part C - Outbound Truck Shipments
Part D - Origins of Inbound Truck Shipments
Part E - Truck Shipments on the Pratt County Road System

In Part A, the respondent is asked to provide data on the number of cattle on feed in the 2007-2009 period, the number of bushels of feed grains delivered to the feedyard in the same period, the number of tons of distillers grain and feed supplements, and the amount of feeder cattle delivered to the feedyard. In Part B, the respondent is asked the percentage of various feed grains and supplements delivered to the feedyard in single axle truck, tandem axle truck, and semi-tractor trailer/trucks. In Part C of the questionnaire, the manager provided data on the percentage of total finished cattle and manure shipped from the feedyard in tandem axle trucks and semi-tractor trailer trucks. In Part D, the manager indicated the percentages of total inbound feed grains, distillers grain, feed supplements, and feeder cattle that originated at various distances from the feedyard. In

Part E, the Pratt Feeders manager was requested to provide the numbers of miles of paved and gravel Pratt County roads used by a typical inbound truck shipment of feed grains, distillers grain, feed supplements, and feeder cattle. The complete surveys are available upon request.

A total of 410 and 426 rural resident questionnaires were mailed to Pratt County and Thomas County residents, respectively. A total of 125 questionnaires were returned by the residents of each county, resulting in return rates of 30.5% (Pratt County) and 29.3% (Thomas County). However, a few of the returned questionnaires were only partially completed. Unlike Pratt and Thomas County, the Brown County road system is a township system whereby the county operates and maintains a system of designated county roads and each of the 10 townships operates and maintains the roads in the township designated as township roads. The questionnaires were distributed to township residents by township representatives. This resulted in only 120 questionnaires being distributed, but 55 were returned (46%).

The sixth step is to conduct the survey of grain elevator managers and county road supervisors, which begins with a phone call to them explaining the objectives of the study and how the research project could benefit the company and the county. During the call, surveyers explain the research objectives thoroughly, emphasize confidentiality, and ask for an appointment. At the interview, they explain the questionnaire in detail and answer all questions.

In the Kansas study, a member of the research team interviewed every grain elevator manager and county road supervisor in the three counties. At the interview, each of the county road supervisors provided detailed county road maps and annual reports for the 2006–2009 period. The annual reports contain county road mileage by type of surface as well as maintenance expenditures by type of road surface and number of road miles receiving maintenance expenditure during the year.

In the Kansas study, 10 of the 11 grain elevator managers that were interviewed returned the questionnaire and all the county road supervisors returned at least one or both of the two questionnaires.

CALIBRATE THE NETWORK MODEL

In order to evaluate the feasibility of road closure, a benefit-cost technique was used and applied to the three Kansas counties. The benefits of rural road closure are avoided costs to the county of keeping the roads in the system, including maintenance, reconstruction, and resurfacing costs. The costs are the additional travel costs of the traveling public due to closure of lightly traveled roads. If the measured benefits exceed the costs, the evaluated roads should be closed or remain in the county road system if the costs of simulated closure exceed the benefits.

One way to measure these benefits and costs is through use of a network model for each sample county. The model estimates the minimum travel cost routings of all the trips in the county. The network model routes each of the trip classes from the trip origin, through the county road system to the destination at minimum travel cost. Then the network model measures the travel cost without the designated road segments in the network. The difference in the total travel costs of the two scenarios is the travel cost impact of keeping the designated roads in the system as opposed to closing them.

The network model used in the Kansas study is TransCAD. TransCAD is a geographic information system software product produced by Caliper Corporation for transportation and public transport applications. In addition to the standard point, line, area, and image layers in a GIS map, TransCAD supports route system layers and has tools for creating, manipulating, and displaying routes. TransCAD uses a network data structure to support routing and network optimization models. TransCAD includes trip generation, distribution, mode choice, and traffic assignment that support transportation planning and travel demand forecasting. For more information about TransCAD see www.caliper.com.

Procedure Used in the Kansas Study

Before getting into the details of the benefits and costs it is useful to discuss the general procedures used in the Kansas study. TransCAD calculates the total travel cost for all rural resident trips assuming the county road network as it currently exists. Then selected low-volume road segments are removed from the network and TransCAD recalculates total travel cost for rural resident trips. The difference between the two travel cost simulations is the cost of the assumed closed roads. The benefit of road closure is the avoided maintenance and reconstruction costs of the closed road segments. Total benefit is calculated by multiplying the number of miles assumed to be closed by the avoided maintenance cost per mile.

In each county, 10 road segments were selected as potential candidates for simulated closure. Ten road segments were selected in order to analyze the traffic impacts on alternative roads in the local area of the closed road segment. Selection of the road segments was based on many factors, but the most important criterion was the traffic volume on these roads.

The identification of the 10 road segments and calculation of traffic rerouting as a result of simulated closure was a three-step process. In the first stage, relatively low volume roads were identified by KDOT traffic count data. Single access roads (the only road between a specific origin and destination) were eliminated as candidates for simulated closure. The second stage involved identification of roads whose traffic would be affected by closure of an area road segment. For example, it was assumed that by closing a road segment, in most cases, traffic on a parallel road would increase. In the third stage, TransCAD rerouted all the previous traffic on the closed road segment to determine the traffic impact on other roads after the candidate road is deleted from the network.

Based on rural resident survey destination information, level of use of county roads, types of vehicles used, and trip origins, an Origin-Destination (O&D) matrix can be obtained. To create the O&D matrix, origin and destination information was used along with the average number of daily trips. The most important variable in the O&D matrix is the travel cost which is the total cost to travel from the origin to the destination. The rural resident survey provided length of trip information. Thus, in order to determine travel cost, free flow speed (the posted speed limit) was used. TransCAD reroutes traffic after deleting the selected roads from the county network. The simulated closure of roads impacts the travel cost for some rural residents since traffic is directed to alternate roads. TransCAD then calculates the minimum travel cost for each of the 10 simulated road closures, which are summed to obtain total travel cost.

It was assumed that rural residents would use cars and pickup trucks for grocery and pleasure trips while five axle semis and tandem axle trucks are used for grain hauling. In the rural resident survey, respondents were asked to indicate their destination for each type of vehicle. However, to simplify computation, only the most importation destination for each vehicle type was used. Also to simplify computation, all truck types (other than pickup) were combined into one category. Thus, there are three vehicle types in the analysis: cars, pickups, and trucks.

CALCULATION OF BENEFITS AND COSTS OF SIMULATED ROAD CLOSURE

The final step in the model is the calculation of benefits and costs of simulated road closure. The model is demonstrated using data from Brown County of the Kansas study. Benefits and costs of Pratt and Thomas counties were calculated in the same manner as Brown County.

Table 5 lists all the links selected for simulated closure in Brown County and the length of each link that varies from a minimum of two miles to a maximum of 6.51 miles.

Table 5: Deleted Links in Brown County

Link	Miles
Link 1	3.37
Link 2	3.96
Link 3	2.04
Link 4	4
Link 5	4
Link 6	4.44
Link 7	3
Link 8	2
Link 9	4.95
Link 10	6.51
Total (Miles)	38.27

Among the three selected counties, Brown County has the most extensive road network in terms of the ratio of the number of miles of road to the total area of the county. For this reason, Brown County had the highest mileage of simulated closure of the three counties in the analysis. The majority of links selected for simulated closure are in the northwest and southwest parts of the county, as most of the rural resident survey data were concentrated in these parts of the county. Every road segment selected for simulated closure has a superior or equivalent quality alternate route. For example, if Link 1 is a gravel road then the alternate route is a paved or an equivalent gravel road.

When road links from the Brown County road system were deleted from the network, one of the major challenges was identification of the other roads that were affected by the simulated closure of the road link. Identification of alternate routes was essential because of the need to estimate the traffic flow on the alternate roads. First, the traffic flow (Average Daily Traffic, ADT) on the selected alternate route was calculated using TransCAD with all the existing roads in the network. After deletion of the link from the system, the traffic on the alternate routes was recalculated. This results in the traffic flow on the alternate routes before and after deletion of the road link. Table 6 presents the percentage change in the traffic flow on the alternative routes after the selected links are deleted from the Brown County road network.

The data in Table 6 indicate that traffic volume per day is high on some of the alternative routes. The reason is that these alternative routes have better roads than the deleted links and some of the alternate routes include a state highway. The percentage change in ADT is less than 10% for eight of the 10 alternate routes and seven of the 10 have less than 4% change in ADT. The percentage increase in ADT for alternative route 6 is 123.6%. The ADT on alternate routes 8 and 9 decreased slightly.

Table 6 illustrates the variation in the traffic on alternative routes when the selected links are deleted from the network. Also, the data in Table 6 is a good indicator of whether selected links should be deleted from the county road network in the first place. For example, after link 6 is deleted, alternative route 6 experiences a large surge in ADT. Similarly, alternative route 2 experiences nearly a 20% increase in ADT after link 2 is eliminated from the network. In these cases, the traffic diversion to the alternative route is high, and congestion on the road increases. Thus, links 2 and 6 should not be deleted from the Brown County road system. It was decided that a 15% change in the ADT on alternative routes after the link is deleted would be the threshold level to determine whether a link should be deleted or remain in the county road network.[3] If the change in ADT on the alternative route after the link is deleted is greater than 15%, then the link should remain in the county road system. This threshold level of ADT provides an extra level of analysis to supplement the cost-benefit analysis in deciding whether to delete the link from the county road system.

Table 6: Brown County Traffic Variation on the Alternate Routes (ADT)

	Traffic Range Before Deletion (ADT)	Traffic Range After Deletion (ADT)	ADT Percentage Change
Alternate 1	>100 & <200	>100 & <200	3.47
Alternate 2	>300 & <400	>300 & <400	19.06
Alternate 3	>100 & <200	>100 & <200	8.47
Alternate 4	>400	>400	3.12
Alternate 5	>300 & <400	>300 & <400	3.25
Alternate 6	>300 & <400	>400	123.58
Alternate 7	>400	>400	1.94
Alternate 8	>400	>400	-1.07
Alternate 9	>400	>400	-0.77
Alternate 10	>400	>400	2.95

ADT is Average Daily Traffic

Table 7 provides the ADT by vehicle type for the links considered for simulated closure. Links 8 and 9 carry larger traffic so they cannot be considered to be low-volume roads and thus should not be deleted from the road system. It was decided that links should remain in the county road system if the total ADT on the link is higher than 60.[4] This was the case for all three counties.

Table 7: Traffic on the Selected Links to be Deleted in Brown County

	Total ADT	Car ADT	Pickup ADT	Truck ADT
Link 1	60	14	24	22
Link 2	**51**	**15**	**19**	**17**
Link 3	58	24	19	15
Link 4	35	13	13	9
Link 5	53	20	19	14
Link 6	**34**	**13**	**12**	**9**
Link 7	34	10	13	44
Link 8	**184**	**98**	**57**	**59**
Link 9	**151**	**67**	**50**	**34**
Link 10	48	19	17	12

An examination of Table 7 reveals the number of pickup trucks is very close to the number of cars using the roads. This interesting trend may be occurring because rural residents are using their pickup trucks for dual purpose trips such as combining their shopping trips with farm trips. Also, the number of trucks on some links is high, which is unusual. A possible reason for this could be the high concentration of rural resident data in one half of the county. Also, the number of grain elevators is high in that part of Brown County where most of the survey data originates.

Benefit-Cost Ratios

The benefit of deleting a road segment is the avoided maintenance cost of these roads. The maintenance costs are large and recurring in nature. The academic literature provides a large range from \$3000 to \$6000 per mile for gravel roads each year.[5] Road maintenance data were obtained from county road supervisors of each county, and some variation was found between counties and between years. It was decided to use two estimates of annual maintenance expense of \$3000 and \$4000 per mile per year.

In calculating the benefits, links 2, 6, 8, and 9 were not considered in the calculation for reasons explained above. When maintenance costs per mile are valued at the very conservative figure of \$3000 per mile, the benefits are \$68,760 and rise to \$91,680 for maintenance cost per mile of \$4000[6]. The benefits for each link are in Table 8.

The cost of deleting a road segment from the network is the additional travel cost borne by the road users due to more circuitous routes to destinations. To calculate total costs, an estimate is needed of the additional miles traveled after the link is deleted. This information is in Table 9.

Table 8: Benefits From the Deletion of Selected Links From Brown County

Link	Miles	Benefits @ \$3000 per mile	Benefits @ \$4000 per mile
Link 1	3.37	\$10,110	\$13,480
Link 2	**0**	**0**	**0**
Link 3	2.04	6120	8160
Link 4	4	12000	16000
Link 5	4	12000	16000
Link 6	**0**	**0**	**0**
Link 7	3	9000	12000
Link 8	**0**	**0**	**0**
Link 9	**0**	**0**	**0**
Link 10	6.51	19530	26040
Total	**22.92**	**\$68,760**	**\$91,680**

Table 9 contains the additional miles traveled when a link is deleted from the road system. These calculations are performed by TransCAD. In these calculations, TransCAD calculates the shortest route from origin to destination. As indicated in Table 9, the additional miles traveled for links 2, 6, 8, and 9 are zero since these links are not subject to closure for reasons explained above.

Operating cost per vehicle per mile for each of the three vehicle types is needed to calculate the total cost of simulated road closure. The operating costs per mile of the three vehicle types is from the AASHTO (1993)[7]. For cars, the cost per mile for gravel roads is 76.5¢; for pickup trucks 92.3¢, and for trucks 159.7¢. The operating cost per mile for trucks is the average of the tandem truck and semi-trailer costs per mile on gravel roads. To obtain the total cost by vehicle type the following equation is used.

(1) Total Cost = ADT x Operating Cost Per Mile x 365 Days x Average Extra Miles Traveled / 100

Table 9: Extra Miles Traveled Due to Road Closure in Brown County

	Distance Traveled Before Link is Deleted	Distance Traveled After Link is Deleted	Extra Miles Traveled Due to Road Closure
Link 1	3.37	5.46	2.09
Link 2	0	0	0
Link 3	2.04	4	1.96
Link 4	4	6.02	2.02
Link 5	4	5.99	1.99
Link 6	0	0	0
Link 7	3	5	2
Link 8	0	0	0
Link 9	0	0	0
Link 10	6.51	8.6	2.09
Total	**22.92**	**35.07**	**12.15**

The results are in Table 10. The total annual cost of simulated closure of six Brown County links is $226,147. Thus the ratio of benefits to costs assuming $3000 per mile maintenance cost is 0.30 ($68,760 / $226,147) and 0.41 ($91,680 / $226,147) when $4000 per mile is assumed. Thus, road maintenance per mile would have to increase to about $9,900 in order for the benefits to equal the costs. The conclusion is that all of the simulated links should remain in the Brown County road system.

Table 10: Annual Cost of Operating Vehicles in Brown County After Simulated Road Closure

Vehicle Type	ADT	Operating Cost Per Mile	Number of Days	Average Extra Miles Traveled*	Total Cost
Cars	100	76.5¢	365	2.025	$56,543
Pickup Trucks	105	92.3¢	365	2.025	71,632
Trucks	83	159.7¢	365	2.025	97,972
Total Cost					$226,147

*The sum of extra miles traveled due to simulated closure for links 1, 3, 4, 5, 7, and 10 which is 12.15 (Table 24) divided by 6.

The benefits and costs of simulated road closure for Pratt and Thomas County were calculated in the same manner as Brown County. In Pratt County, one of the 10 links was eliminated from simulated closure since the ADT on the alternative route increased by more than 15% when the link was removed from the Pratt County road system.

If it is assumed that annual maintenance cost per mile is $3,000, the ratio of benefits to costs for Pratt County is 0.995 ($93,810 / $94,236). The costs exceed the benefits by only $426. If annual maintenance cost per mile is assumed to be $4,000, the benefit-cost ratio is 1.33 ($125,080 / $94,236). Thus, if the very conservative maintenance cost of $3,000 per mile is assumed, the benefits of road closure approximately equal the costs. However, if $4,000 per mile is assumed to be the annual maintenance costs, the benefits exceed the costs by $30,844 so all nine of the links considered for closure should be closed.

In Thomas County, one of the 10 links was eliminated as a candidate for closure since ADT on the alternative route exceeded the ADT threshold of 60 after the link was deleted from the Thomas County road system.

If the annual maintenance costs per mile are assumed to be $3000, the benefit-cost ratio for Thomas County is 1.82 ($84,300 / $46,385). If the annual maintenance cost per mile is $4000, the benefit-cost ratio is 2.42 ($112,400 / $46,385). The conclusion is that even with the very conservative maintenance figure of $3000 per mile the benefits of road closure significantly exceed the costs. Thus, nine of the 10 links in Thomas County should be closed.

CONCLUSION

The rural road system is under stress in many U.S. states. The increasing size of farms has led to increasing farm vehicle size as well. The road width and design characteristics of rural roads and bridges are inadequate for the larger and heavier vehicles that are using them. As county population declines the financial ability of counties to maintain and rebuild the road and bridge system isn't keeping up with the rate of deterioration. Many U.S. counties don't have the funds to maintain the existing road system due to the heavier vehicles that are using them. If the county road and bridge system can't be maintained as it is, reducing the size of the system should be considered. This paper suggested a methodology to evaluate the benefits and costs of reducing the county road network. The methodology is flexible and can accommodate any number of, or location of, links to be considered for closure as well as the size of study areas.

Benefit-cost analysis was used to examine the question of road closure in the three counties. The cost of road closure is the additional travel cost of rural residents due to more circuitous routing to their destinations. The benefit is the avoided maintenance costs of roads removed from the county network. Total annual costs are measured by the following equation:

Total Cost = ADT (on road segments considered for simulated closure) x Vehicle Operating Cost Per Mile x 365 days x Average Extra Miles Traveled / 100. Total benefit is calculated by multiplying the number of miles assumed to be closed by the avoided maintenance cost per mile.

In each county, 10 road segments were selected as potential candidates for simulated closure. Ten road segments were selected in order to analyze the traffic impacts on alternative roads in the local area of the closed road segment. Selection of the road segments was based on many factors, but the most important criterion was the traffic volume on these roads.

Table 11 contains the benefit-cost ratios for simulated closure of roads in the three counties. One set of ratios is calculated assuming annual maintenance cost per mile of $3000, and the other set assumes $4000 per mile. The benefit-cost ratios for Brown County are 0.30 and 0.41. Thus, none of the 10 road segments evaluated in Brown County should be closed. For Pratt County, the benefits of simulated road closure are approximately equal to the costs if maintenance cost of $3000 per mile is assumed, but if maintenance cost per mile is assumed to be $4000, the benefit-cost ratio is 1.33. The latter ratio indicates that Pratt County would save money by closing the evaluated road segments. The benefit-cost ratios for Thomas County are 1.82 and 2.42, indicating that all of the evaluated road segments should be closed.

Table 11: Benefit-Cost Ratios of the Three Counties

Benefit-Cost Ratios Assuming Annual Maintenance Cost of $3000 Per Mile			
County	**Benefits**	**Costs**	**Benefit-Cost Ratio**
Brown	$68,760	$226,147	0.30
Pratt	$93,810	$94,236	1.00
Thomas	$84,300	$46,385	1.82
Benefit-Cost Ratios Assuming Annual Maintenance Cost of $4000 Per Mile			
County	**Benefits**	**Costs**	**Benefit-Cost Ratio**
Brown	$91,680	$226,147	0.41
Pratt	$125,080	$94,236	1.33
Thomas	$112,400	$46,385	2.42

The main conclusion is that rural counties will be able to save money by closing some relatively low-volume roads and redirecting the saving toward increasing the quality of other county roads. Counties with relatively extensive road systems (miles of road per square mile) and relatively high population density (i.e., Brown County) are less likely to realize savings from road closure. In contrast, counties with less extensive road systems and relatively low population density (i.e., Thomas County) are more likely to realize significant savings from closure of relatively low-volume roads.

This study did not consider the benefits and costs of bridges on the road segments considered for closure since it was beyond the scope of the study. The benefits of including bridges include the avoided cost of maintaining and reconstructing bridges. The costs would be unaffected since the additional travel costs would be the same. Rural residents would simultaneously lose access to the road and any bridges on the road. Thus, the inclusion of bridges in the analysis would increase the benefits relative to the costs, increasing the benefit-cost ratio.

Road supervisors should consider some demonstration projects where the roads with minimal ADT are closed, but no single access roads should be considered for closure so rural residents continue to have access to the county road system.

Endnotes

1. According to KDOT (2009), a survey of 21 Kansas grain companies found that 68% of total 2007 corn and sorghum receipts were delivered by semi-tractor trailers. Tandem axle trucks were used to deliver 16% of the 2007 total corn and sorghum receipts of the 21 companies.

2. According to KDOT (2009), a survey of eight Kansas counties found that 77% of county roads were unpaved and the respondents rated 52% of the road miles in very poor to fair condition. The KDOT study (2005) indicated that 24% of the county bridges in Kansas were either structurally deficient or functionally obsolete.

3. The 15% threshold for ADT change on alternate routes was set relatively high to keep most of the links in the benefit-cost analysis. Only three of the 30 links (10%) in the three county analysis exceeded the 15% threshold.

4. Keeping the link in the county road system if total ADT on the link was greater than 60 was done in order to keep most of the links in the benefit-cost analysis. Only three or 10% of the 30 links in the analysis had ADT greater than 60.

5. Tolliver et al. (2011) estimated annual county gravel road maintenance cost per mile as $3,913 per mile for roads with 0-50 ADT and $4,213 per mile for those with 50-100 ADT. Jahren et al. (2005) estimated average annual maintenance cost per mile of gravel roads at $4,160. Since 77% of the 30 links in the analysis have ADT of 50 or less, the assumption of $3,000 and $4,000 per mile annual maintenance cost seemed reasonable.

6. When traffic is diverted to alternate routes by closure of a link, maintenance costs on the alternative route would increase by an insignificant amount because the ADT diverted is small. Also, the maintenance cost per mile used in this study is a countywide average. The maintenance cost of individual links is unknown.

7. The operating costs per mile were computed in the following manner. The current cost of the auto was determined to be 55 cents per mile on paved roads. Based on information in AASHTO (1993), the 55 cents per mile on paved roads was converted to 76.5 cents per mile on gravel roads. The operating cost per mile of pickup trucks and heavy trucks was computed using the ratios of the auto cost per mile on gravel roads to the cost per mile for the other two vehicle types based on information in AASHTO (1993).

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Acknowledgement

Financial support for this research project was provided by the University Transportation Center, Kansas State University, and the Kansas Department of Transportation. The contents of this paper does not necessarily reflect the views or policies of the state of Kansas.

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Book Reviews

White, Richard. Railroaded: The Transcontinentals and the Making of Modern America. *New York: W. W. Norton & Co., 2011. ISBN 978-0393061260*

Railroaded

by William Huneke

Railroaded is an uneven book. Richard White's research effort is quite evident, and he tells some wonderful stories, but the analysis is weak and the writing is often tedious. White spent several years on this book, and at times he seems to have lost himself in the effort.

This book presents the history of the transcontinental railroads: the railroads that were built in the latter half of the nineteenth century from the Mississippi Valley to the Pacific Ocean. It is a story filled with great characters: Jay Gould, Collis P. Huntington, James J. Hill, Charles Francis Adams Jr., Eugene Debs and more. White even recounts some of the transcontinental railroad history in Canada and Mexico.

White is passionate about this subject, too passionate. He writes like a web blogger rather than an unbiased, dispassionate historian. In his telling, all the railroad moguls are crooks, charlatans, or imbeciles. His particular fondness for reciting the gaffes and stupidity of Leland Stanford is particularly ironic as White holds an endowed chair at Stanford University.

Perspective is a problem for White. He claims that the transcontinentals reoriented the United States from a north-south axis to an east-west axis. He cites how, prior to the transcontinentals, the United States was absorbed in slavery and the Civil War, which had a north-south orientation. But is that really true?

It is Columbus who refocused Europe to look west. Since Columbus, European settlers in the New World were always focused on moving west. White says that U.S. waterways primarily flow North-South except for the Erie Canal, which makes one wonder if he has looked at a map recently, e.g., Ohio, Missouri, St. Lawrence, and James Rivers are not primarily north-south. Moreover, the major eastern railroads, e.g., New York Central and Pennsylvania Railroads, ran east-west rather than north-south.

Another example of White's questionable perspective is his conclusion that the transcontinentals brought corruption to American politics, but corruption allegations have been part of the American political scene since the American Revolution. White reports the corruption and self-dealing that Jay Cooke engaged in to finance the Civil War and start the Northern Pacific Railroad, yet self-dealing and corruption allegations were also leveled at Robert Morris, the prime financier of the Revolution.

White's analysis is too simplistic when he tries to make economic judgments. He concludes that taxpayers got a bad deal from the Pacific Railroad Acts. He recites all the aid the transcontinentals received, and refers to the work of economists Robert Fogel (1960) and Heywood Fleisig (1973-1974). White never mentions the fact nor critiques Fogel's analysis that found the federal government's return on the Union Pacific exceeded the government's cost. If the terms the government received on the Pacific railroads were so poor, why were not other investors available to offer the government better terms? The fact is that the Pacific railroads were highly speculative ventures.

White concludes that the Central Pacific (CP) and Union Pacific (UP) investors made huge fortunes with very little risk. With more rigorous analysis, Fleisig also concluded that UP investors made greater returns than commensurate with the risk they bore. White's analysis adds nothing substantial. His parade of financial figures just fogs the issue.

His writing on the CP and UP financing can perplex a modern reader. White falls into the nineteenth century mode of referring to excessive distribution of stock as "watering." He then describes the railroads as being "overcapitalized," but this will mislead those familiar with the 2008 financial crisis. Henry Paulson led an effort to inject capital into U.S. banks because they had too little equity – they were undercapitalized. And this was precisely the problem with the CP and UP: too much debt and too little equity.

White's characterization of the investors and the building of the transcontinentals is a sharp contrast to Stephen Ambrose's version: *Nothing Like It in the World* (2000). Ambrose stresses the engineering feats performed to get the first transcontinental built. White is more interested in blogging about the financial chicanery and government corruption. You could not find two more different books discussing a lot of the same story.

Where White's book succeeds is in his discussion of labor issues involving the transcontinentals. Nineteenth century railroading was an extremely dangerous profession and railroads were not kind to their employees. This created pressures to unionize. In his labor history discussion, White includes Eugene Debs and the Pullman Strike. Debs is an exception in White's treatment of historical characters. White presents Debs as a strong leader who was trying to get the best he could for his followers.

Another serious weakness White has is his fondness for metaphors. On page 7 White uses a particularly opaque cake and frosting analogy to describe Tom Scott's relationship with the ethically challenged Secretary of War Simon Cameron in conducting government railroad business:

> The local rates and the corruption were, however, the frosting rather than the cake in the government-railroad relationship, and if Tom Scott's great flaw was that he could never resist the frosting, he never mistook the frosting for the cake. Since railroads lived on high-volume cargoes, the cake was the tremendous traffic in men and material that the Union war effort demanded.

White abruptly drops Scott's story and the reader is left to wonder what was the result (i.e., did Scott get cake or frosting or neither?)

White's early twenty-first century perspective seriously biases his analysis. In White's view, the transcontinentals were creatures of big business and as such were instruments, which if not caused, certainly accelerated the destruction of plains Indians and the buffalo. But how much effect did the transcontinentals truly have in these tragedies?

With the buffalo it is true that the railhead at Dodge City, Kansas, allowed buffalo hides to be shipped to the east, providing access to profitable markets; but those markets would not have existed if there had not been a significant improvement in tanning technology (Gwynne 2010, pp. 160-161). One should also note that the Dodge City railhead was not part of the original UP-CP route and might well have existed without federal support.

The transcontinentals' role in the destruction of the plains Indians is similarly modest. European settlers had been pushing the indigenous population westward well before the first rail was laid on the Baltimore & Ohio, let alone the UP and CP. Furthermore, if care is taken to read the accounts of the Plains Indian wars, one will not find troops being deployed by rail like the Prussians in 1866 or 1870 or like Longstreet's corps at the Battle of Chickamauga. Rather, it is columns of cavalry and some infantry marching and riding to battle (Gwynne 2010, pp. 160-161).

When White sums up the transcontinetals' costs and benefits, he attempts to excoriate economic historians for not counting the costs incurred by Indians nor the cost of the destruction of the buffalo herds. Because the transcontinentals had little effect on these tragedies, other scholars have been correct in not making such adjustments.

As White claims that prior attempts to use reductions in transportation costs or increases in land values are inappropriate (because these measures do not include the costs of the Indian and buffalo tragedies), White comes up with a novel and thoroughly misguided method to judge the transcontinentals' effects. He compares the per capita incomes of the people living in the western states before and after the building of the transcontinentals.

This approach has so many flaws, it boggles the mind. For starters, White uses current not constant dollars. He does not adjust for the late nineteenth century deflation. Additionally, the economist's handy and often misused *ceteris paribus* assumption cannot be invoked here. In fact there were a lot of other things going on, such as crop failures and mining booms. White's approach also neglects to capture any benefits accruing to the U.S. economy in general.

Perhaps the core flaw is that White has not specified a precise effect to measure. Is he trying to measure the effects of premature enterprise in the building of early transcontinentals? Or is he trying to measure the general effect of western railroads? A reader of White's book often gets the sense that White would prefer the transcontinentals had not been built, which would have meant no Stanford fortune, no Stanford University, and no endowed Stanford history chair for Richard White.

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William Huneke *received his Ph.D. from the University of Virginia. His dissertation concerned the economic and financial history of the Union Pacific, 1862-1898. He has more than 30 years' experience in economics, management consulting, information systems, and business analysis in the commercial and government sectors. He has taught undergraduate and graduate business classes at the University of Maryland. Currently, he is chief economist, Surface Transportation Board. Views in this review are solely the author's and do not represent those of the Surface Transportation Board nor of its members.*

Washington, Simon P., Karlaftis, Matthew G., and Mannering, Fred. L. Statistical and Econometric Methods for Transportation Data Analysis, 2nd ed. *Boca Raton, London & New York: CRC Press, 2011. ISBN 9781420082869.*

Statistical and Econometric Methods for Transportation Data Analysis

By Brian W. Sloboda

Transportation statistics is an evolving field with a greater abundance of transportation data and improvements in computing power to handle the complexities in statistical methods that provide empirical results. *Statistical and Econometric Methods for Transportation Data Analysis* provides the reader a comprehensive presentation of statistical methods that can be applied in transportation.

The book does not overwhelm the reader with the analytical details for each of these methods, yet it still presents each of the statistical methods rather well. In addition, the description of the methods is detailed enough to provide a solid understanding of each technique. Also, the authors sprinkle throughout the book the pitfalls or oversights in the application of these methods. A major advantage of this book is the authors' inclusion of such statistical methods as Bayesian methods, logistic regression, ordered probability models, random parameter models, and additional time series methods.

The book is divided into 17 chapters, grouped by the authors into four sections. Section 1, which consists of chapters 1 and 2, provides a rudimentary review of statistical methods: descriptive statistics, confidence intervals, hypothesis testing for a single mean, hypothesis testing comparing two means, and some nonparametric methods. The authors clearly provide the reasoning for the use of nonparametric statistics rather than parametric methods. Because of the comprehensive nature of statistical methods covered in this book, the authors relegated the details of nonparametric methods to other references given in this book. The reader should consult these other references for those details.

The second section, comprising chapters 3 through 10, is dedicated to discussing *continuous* dependent variable models. Chapters 3 and 4 delve into the details of regression analysis, which forms the primary foundation of the methods used in transportation research. Chapter 3 provides a rudimentary introduction to regression analysis, but the authors stress the importance of checking the assumptions of regression analysis that are often mentioned briefly if at all in other books. Having covered the assumptions of regression analysis, the authors turn to variable manipulation, outlier identification, identification, goodness-of-fit measures, multicollinearity, model-building strategies, and causality.

Chapter 4 addresses violations of the regression assumptions, namely heteroscedasticity, serial correlation, and model specification errors. As each of the violations is presented, the authors discuss how to detect it and how to most appropriately correct it.

The remaining chapters in Section 2 cover more advanced methods pertaining to continuous variables. Chapter 5 delves into simultaneous equation models and when to use them. As the authors explain, the seemingly unrelated equations (SURE) method is used when there is contemporaneous correlation in the error terms. In an appendix, the authors present a brief discussion of generalized least squares (GLS), often used in econometric analysis. Chapter 6 deals with panel data methods, often used in microeconometric analysis. While not giving these methods a full treatment, the authors do provide a foundation for understanding their use.

Chapter 7 delves into the rudiments of time series data, which play an important role in transportation analysis. This chapter explains the descriptive assessment of time series data, smoothing techniques, and the concepts of stationarity and dependence. In the discussions of stationarity and dependence, the authors delve into unit root testing, namely the Dickey-Fuller test. There is also some discussion of fractional integration and long memory as applied to transportation data. The latter discussion is, however, rather brief, and the reader will need to consult references for greater details of this method. Chapter 8 continues the study of time series analysis through the autoregressive integrated moving average (ARIMA). Then the authors deal with variations of the ARIMA models and expand the discussion to nonlinear models as well as multivariate models. The final part of the chapter presents a discussion and brief descriptive analysis of neural networks, though with little attention focused on transportation.

Chapter 9 presents latent variable models, which are used in transportation analysis when there are measurement difficulties and unobservable variables. This chapter specifically covers the methods of principal component analysis, factor analysis, and structural equation modeling. Chapter 10 presents duration models, which deal with instances of elapsed time until the occurrence of an event or the duration of an event. Covered here are hazard-based duration models, nonparametric models, semi-parametric models, and fully parametric models.

Section 3, consisting of chapters 11 through 15, discusses discrete variable models, which have numerous applications to transportation analysis. Chapter 11 delves into count data models, covering the Poisson regression model, truncated Poisson regression models, the negative binomial regression model, and random effects count models. This chapter provides numerous examples as used in transportation analysis. Chapter 12 presents a discussion on logistic regression, that is, the use of binary outcome variables as a function of the predictor variables (regressors). This chapter is brief and provides a good introduction for the study of logistic regression. Chapter 13 covers discrete outcome models involving the application of discrete or nominal data; numerous transportation analyses deal with these types of data. More importantly, there is a discussion concerning multinomial logit models (MNL), which have numerous applications in transportation analysis. The final part of this chapter covers the nested logit model (also known as the Generalized Extreme Value Model), which is based on independence of irrelevant alternatives (IIA). Chapter 14 discusses ordered probability models, recognizing that many transportation applications use ordered discrete data. The presentation of standard or multinomial logit models in the preceding chapter does not account for the ordinal nature of the data which leads to a loss of information. The final chapter of this section does, though, deal with discrete/continuous models. This chapter is brief and presents instrumental variable methods, selectivity bias correction, and applications of discrete/continuous models.

Section 4 of the book presents other statistical methods that can be applied to transportation data. Chapter 16 delves into random parameter models, which, unlike models taken up in the previous chapters, assume the parameters in regression analysis are not fixed. The fixed parameter assumption may not be correct in some transportation applications. In the final chapter of this section, the authors present Bayesian methods, which apply Bayes' Theorem to classical statistical models. Any statistical model that can be estimated using a classical approach can also be estimated using a Bayesian approach. More importantly, subjective prior probabilities play a role in the estimation of classical statistical models. This chapter provides a foundation for the application of these methods as used in transportation analysis. The method of Markov Chain Monte Carlo (MCMC), widely used in transportation research, is covered exclusively in this chapter.

The final sections of the book include various appendices that provide a review of matrix algebra, fundamentals of statistics, a glossary of statistical concepts, and variables transformations. The reader will be able to refer to these appendices on an as-needed basis for a refresher on these topics.

All in all, this book provides a good repertoire of the methods that can be used in transportation research. Also, this book includes numerous references for readers seeking additional technical details and applications of these statistical methods. Because of the applied focus of this book, it will serve as a valuable reference for transportation practitioners, policymakers, and researchers. Given the presentation of the statistical methods in this book, it would make a good textbook for research methods in the transportation discipline. In the end, this is a solid reference for those engaged in transportation modeling work used in transportation policymaking.

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Hoel, Lester A., Giuliano, Genevieve, and Meyer, Michael D., eds. Intermodal Transportation: Moving Freight in a Global Economy. *Washington, DC: Eno Transportation Foundation, 2011. ISBN 978-0-9718175-5-5*

Intermodal Transportation: Moving Freight in a Global Economy

by Maria Boile

The Eno Transportation Foundation continues its tradition of quality publications to support research and education in transportation. Eno has produced a series of offerings on Intermodal Freight Transportation, including a volume by John H. Mahoney in 1985 and a volume by Gerhard Muller in 1999. These books served as valuable references for years, providing a broad and thorough coverage of issues pertaining to intermodal freight transportation.

The new book on Intermodal Transportation: Moving Freight in a Global Economy is not a continuation of the previous initiatives and departs from the model used in the previous volumes, as both the scope and the focus have changed. The book, published in 2011, is an edited volume of 652 pages. In this volume the editors, Lester A. Hoel, Genevieve Giuliano, and Michael D. Meyer, with another 25 expert contributors provide an overview of the evolution of freight transportation through a series of papers covering topics in freight planning, modeling, policy, economics, and finance and addressing issues relating to congestion, security, environment, labor, and human resources. The book consists of five parts, each containing three or four papers and covering about 100 pages.

The first part consists of four papers providing background on the context of intermodal transportation. The papers focus on the global economy, the components of the supply chain, the evolution of freight transportation, and the role of the public sector. This section of the book provides a historical overview of the origin and development of intermodal transportation, driving forces, and enabling factors. It addresses issues of globally organized production and distribution networks, deregulation policy, technological change, and institutional developments, highlighting the role of the public sector in freight transportation.

The second part presents an overview of intermodal freight transportation modes. The coverage embraces all conventional modes of transport, including shipping, rail, air cargo, and trucking. Each of the four papers included in this section presents an overview of the evolution, market, and policy context of the mode it addresses. Each contribution also provides information on relevant equipment and facilities, key players, issues, and challenges facing the industry. The structure of each chapter is different, and the treatment given to each of the above mentioned topics varies between chapters in the depth and the emphasis given to intermodal aspects.

The third part is an overview of intermodal freight transportation nodes and comprises four papers each treating a type of node, including seaports, airports, railroad terminals and yards, and warehousing and distribution centers. Papers in this section cover issues of governance, structure, services and facilities, operational models, funding, and finance, as well as environmental and security challenges. Similar to the previous section, each paper has a different structure and treats its topics with different emphasis and level of detail.

The fourth part, on planning and data analysis for intermodal transportation, consists of three papers. The first one, on freight transportation planning, describes how freight considerations can be included in the transportation planning process and the resulting challenges and opportunities. The second paper, on modeling freight flows, offers an appreciation of the complexity of intermodal transportation systems and the challenges faced in modeling these systems. The third paper, on financial strategies for delivering intermodal freight facilities, looks at the financing decisions for intermodal facilities and reviews the financial strategies for intermodal investments.

The last part of the book addresses external constraints on the intermodal transportation system, including network congestion, system security, environmental considerations, and labor and human resources.

Through a collection of papers, each written on a different yet relevant subject, the book provides a broad coverage and understanding of the freight transportation sector. A strong point of the book is its emphasis on the role of the public sector in intermodal freight transportation and the coverage of the importance of and the issues faced in including freight considerations in the transportation planning process. The role of the public sector in freight transportation is not always well understood and is often treated only superficially in books focusing on supply chain and freight logistics. As such, the treatment of the subject given in this book is much appreciated.

This interesting and valuable resource has some weaknesses. To provide a better and deeper understanding of the freight industry issues, a more explicit reference to the stakeholders and their role in intermodal transportation, as well as the interactions and interrelationships between them should be included in the book. In addition, a more integrated approach in the treatment of modes and nodes within an intermodal network setting would be appropriate. The elements of intermodal transportation systems are all tightly interwoven, with developments in one part of the system affecting other parts located hundreds or even thousands of miles away. Examining intermodal transportation from an integrated system's perspective, addressing the interrelations between the system's components would strengthen the book, which to a certain extent takes a modal approach in its representation of the transportation system. Although containerization as the key enabler of intermodal transportation is noted in several sections in the book, the role of technology and other developments also enabling and facilitating intermodal transportation is only treated superficially. The editing is, in places, a bit uneven, especially in sections presenting theoretical models and technical details, which are not supported by the overall book structure and content. Finally, data used in several papers are old, from 2006 or 2007, when more recent data would be available.

The book is an appropriate and useful reference for graduate and senior undergraduate students. It is a great supplement to a conventional textbook in several university programs, including transportation and systems engineering, urban and regional planning, policy and government, logistics and supply chain management. It is also a suitable reference for practitioners and policy makers and essential reading for everyone interested in freight transportation.

***Maria Boile** is research director at the Hellenic Institute for Transportation, Centre for Research and Technology Hellas in Greece. She has also been associate professor of transportation in the Department of Civil and Environmental Engineering, co-director of the Freight and Maritime Program at the Center for Advanced Infrastructure and Transportation, and academic fellow in the Center for Supply Chain Management at Rutgers University. Her areas of research and interest include passenger and freight intermodal network modeling, freight logistics, freight and maritime systems analysis, port and inland terminal operations, transit scheduling, and operations. Her research has been funded by the European Commission programs as well as by the U.S. Department of Transportation, National Science Foundation, Federal Highway Administration, Federal Transit Administration, state DOTs and metropolitan planning organizations. She has authored and co-authored over 150 scientific journal and conference articles, reports, and book chapters. She holds an M.S. degree in civil and environmental engineering from Rutgers University and a Ph.D. in transportation engineering from New Jersey Institute of Technology.*

Transportation Research Forum

Statement of Purpose

The Transportation Research Forum is an independent organization of transportation professionals. Its purpose is to provide an impartial meeting ground for carriers, shippers, government officials, consultants, university researchers, suppliers, and others seeking an exchange of information and ideas related to both passenger and freight transportation. The Forum provides pertinent and timely information to those who conduct research and those who use and benefit from research.

The exchange of information and ideas is accomplished through international, national, and local TRF meetings and by publication of professional papers related to numerous transportation topics.

The TRF encompasses all modes of transport and the entire range of disciplines relevant to transportation, including:

Economics	Urban Transportation and Planning
Marketing and Pricing	Government Policy
Financial Controls and Analysis	Equipment Supply
Labor and Employee Relations	Regulation
Carrier Management	Safety
Organization and Planning	Environment and Energy
Technology and Engineering	Intermodal Transportation
Transportation and Supply Chain Management	

History and Organization

A small group of transportation researchers in New York started the Transportation Research Forum in March 1958. Monthly luncheon meetings were established at that time and still continue. The first organizing meeting of the American Transportation Research Forum was held in St. Louis, Missouri, in December 1960. The New York Transportation Research Forum sponsored the meeting and became the founding chapter of the ATRF. The Lake Erie, Washington D.C., and Chicago chapters were organized soon after and were later joined by chapters in other cities around the United States. TRF currently has about 300 members.

With the expansion of the organization in Canada, the name was shortened to Transportation Research Forum. The Canadian Transportation Forum now has approximately 300 members.

TRF organizations have also been established in Australia and Israel. In addition, an International Chapter was organized for TRF members interested particularly in international transportation and transportation in countries other than the United States and Canada.

Interest in specific transportation-related areas has recently encouraged some members of TRF to form other special interest chapters, which do not have geographical boundaries – Agricultural and Rural Transportation, High-Speed Ground Transportation, and Aviation. TRF members may belong to as many geographical and special interest chapters as they wish.

A student membership category is provided for undergraduate and graduate students who are interested in the field of transportation. Student members receive the same publications and services as other TRF members.

Annual Meetings

In addition to monthly meetings of the local chapters, national meetings have been held every year since TRF's first meeting in 1960. Annual meetings generally last three days with 25 to 35 sessions. They are held in various locations in the United States and Canada, usually in the spring. The Canadian TRF also holds an annual meeting, usually in the spring.

Each year at its annual meeting the TRF presents an award for the best graduate student paper. Recognition is also given by TRF annually to an individual for Distinguished Transportation Research and to the best paper in agriculture and rural transportation.

Annual TRF meetings generally include the following features:

- Members are addressed by prominent speakers from government, industry, and academia.
- Speakers typically summarize (not read) their papers, then discuss the principal points with the members.
- Members are encouraged to participate actively in any session; sufficient time is allotted for discussion of each paper.
- Some sessions are organized as debates or panel discussions.

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Journal of the Transportation Research Forum
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2. E-mail submissions must be in MS WORD.

3. Final manuscript and abstract (hard or e-mail copy) must be received as soon as possible.

4. The text of manuscripts is to be double-spaced. Use one side of each page only. Articles are limited to a maximum length of 30 pages; industry issue papers and comments are limited to a maximum of 15 pages.

5. The manuscript should have a title page which includes the names, affiliations, address (mailing and e-mail) and phone numbers of all authors. Brief biographical sketches for all authors should be included with the manuscript.

6. The abstract should briefly describe the contents, procedures and results of the manuscript, not its motivation, and should not exceed 100 words.

7. Endnotes are to be used rather than footnotes, used sparingly and placed at the end of the manuscript. Do **NOT** use the endnote feature of the word processing software.

8. *The Chicago Manual of Style* is to be used for endnotes and references. At the end of the manuscript, complete references are listed alphabetically (not by number) by author surname, government agency, or association name. Use the following examples.

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   Chow, G., R. Gritta, and E. Leung. "A Multiple Discriminant Analysis Approach to Gauging Air Carrier Bankruptcy Propensities: The AIRSCORE Model." *Journal of the Transportation Research Forum* 31 (2), (1991): 371-377.

Ph.D Dissertation:

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9. Tables, figures, graphs, and charts should be titled and numbered by an Arabic numeral (e.g., Figure 2). All figures and charts should be submitted as **separate** files. Any graphics or photos must be 300 dpi and submitted as a separate .tif or .eps file.

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ISSN 1046-1469

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