

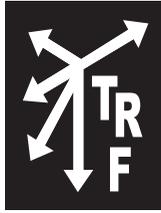
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On the cover: The Canadian grain supply chain has experienced significant changes including deregulation in grain handling. Brewin, Nolan, Gray, and Schmitz explore the impacts of these changes in “Bringing in the Sheaves: Changes in Canada's Supply Chain Through the Post Canadian Wheat Board Era.”

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A Message from the JTRF Co-General Editors

The Fall 2017 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:

- Railroad infrastructure
- Transportation workforce skills gap
- Profile of short line railroads
- Feasibility of vehicle miles traveled to finance the transportation system
- Changes in Canada's grain supply chain
- Private vehicle ownership in China

In "Preserving Railroad Infrastructure: The Case of Iowa Branch Rail Lines," the authors (Phillip Baumel and Craig O'Riley) analyze the results of Iowa programs to preserve branch lines and evaluate the potential economics of future subsidy programs. The purpose of the study is to (1) describe the branch line preservation programs, (2) describes how two Iowa agencies implemented the program, (3) compare the results of the two methods of implementation, and (4) suggest conditions under which future programs might produce economic results. The authors suggest five alternatives for future branch line survival.

Zamira Simkins and Rubana Mahjabeen analyze the transportation workforce skills gap in "Measuring the Transportation Workforce Skills Gap Using New Indices and Survey of Employers and Workers." The study uses four indices to measure skills gaps and calculates them from a survey of transportation workers and employers. The authors found that worker competencies do not match employers' requirements. Particularly large gaps include knowledge of transportation distribution and logistics, knowledge of machine tools and equipment, equipment operation, critical thinking and problem solving skills, and ability to apply knowledge.

In "Profile of Short Line Railroads in High Grain Production States," Michael Babcock analyzes how changes in the grain logistics system have affected short line railroad viability. The overall objective of the paper is to assess the state of the short line industry and its role in the grain logistics system, including who they are, where they are, and what agricultural products they ship in what amounts in major grain corridors. Specific objectives include identification of the key factors that determine short line success or failure and compile a profile of a successful grain oriented short line, and identify infrastructure needs such as the ability to handle 286,000-pound rail cars. The methodology included personal interviews and surveys of executives of short line railroads and state departments of transportation rail personnel. The sample included 47 short lines in 17 states. The author found that the three characteristics most essential to short line success are strong shipper support, adequate traffic levels, and access to more than one connecting carrier.

Marketa Vavrova, Carlos Chang, and Ladislava Bina present a framework to analyze the feasibility of VMT fees as an alternative method to finance transportation projects in "A Framework to Analyze the Feasibility of Vehicle Miles Travelled Fees to Finance a Sustainable Transportation System." The VMT feasibility framework addresses major factors related to public acceptance, revenues, technology, type of contract, government policies, enforcement, administration, and invoicing. The authors claim that VMT charges will motivate fleet owners to renew vehicles or switch to alternate modes such as mass transit.

In "Bringing in the Sheaves: Changes in Canada's Grain Supply Chain Through the Post Canadian Wheat Board Era," Derek G. Brewin, James F. Nolan, Richard S. Gray, and Troy G.

Schmitz explore the behavior of participants in the increasingly liberalized Canadian grain handling supply chain. The authors explore past, present, and future viability of participants in the grain handling system. They analyze these markets by modeling grain supply and demand relationships. They also develop a game theoretic construct that is applicable to help understand the system and its subsequent evolution. The authors conclude that the changes seem to be creating new winners and losers in the system. They also find that while current railroad regulations in Canada have led to efficiencies, deregulation of grain handling seems to have generated gains for grain companies at the expense of farmers.

Patrick McCarthy and Junda Wang analyze China's provincial demands for private vehicles during the 2000-2012 period in "Private Vehicle Ownership in Provincial China." Based on estimates from pooled, fixed effects and Hausman-Taylor models, private vehicle ownership during this period grew at an annual rate of over 20%. The authors find that increases in GDP per capita and vehicle use cost reinforce and constrain, respectively, the strong trend toward increased ownership. The authors also measure the impact on vehicle ownership of population density, percent of population in urban areas, municipal restrictions, income elasticity, and infrastructure investments.

In "On-Demand, App-Based Ride Services: A Study of Emerging Ground Transportation Modes Serving Los Angeles International Airport (LAX), Karina Hermawan and Amelia C. Regan estimate and compare travel times and costs of transport by Uber and Lyft against other forms of ground transportation. The authors develop estimates of airport ground transportation mode choice decisions. The authors found that their preferred nested logit specification implies that if TNS (transportation network companies) fares were raised to match the current cost of taking a taxi to the airport, demand for TNC's would fall by 21% to 23% for business and leisure passengers, respectively.

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Preserving Railroad Infrastructure: The Case of Iowa Branch Rail Lines

by C. Phillip Baumel and Craig O'Riley

In the 1970s, huge grain exports, deteriorating branch rail lines, poor railroad earnings and increased demand for new railroad locomotives and grain cars led railroads to apply for the abandonment of the deteriorating branch lines. The state of Iowa developed a program to subsidize the upgrading of 1,984 miles of branch lines. This paper analyzes the results of these programs and evaluates the potential economics of future branch rail line subsidy programs.

INTRODUCTION

The influx of settlers into Iowa in the late 1850s was the motivation for the construction of the Iowa railroad system. Railroads became the only available form of public transportation. Most people wanted access to a railroad and railroad companies were anxious to oblige. The Iowa railroad system expanded rapidly. By 1911, there were 10,500 miles of track in Iowa, one of the largest rail systems in the United States (Iowa Department of Transportation 1995). Nearly everyone in the state lived within seven miles of a railroad (Iowa Department of Transportation 1995).

Construction of paved roads in Iowa began around 1910. Since then, the development of automobiles and trucks and huge government investments in paved roads and inland waterway locks and dams have diverted large amounts of traffic away from the railroads. Railroads responded to these developments with mergers, bankruptcies, and abandonment applications. By 1970, the Iowa railroad system had declined to just over 8,000 miles of track (Iowa Department of Transportation 1978).

Declining passenger traffic, major competition from trucks and barges, and government regulation of railroad rates and operations resulted in major reductions of railroad earnings. Of the five Class I railroads operating significant mileage in Iowa in the mid-1970s, only the Burlington Northern Railroad earned substantial profits (Iowa Department of Transportation 1978). The Chicago and Northwestern and the Illinois Central Gulf railroads operated just above breakeven (Iowa Department of Transportation 1978). The other two Class I railroads, the Chicago, Rock Island and Pacific Railroad (Rock Island RR) and the Chicago, Milwaukee, St. Paul, and Pacific Railroad (Milwaukee RR), operated with large losses in income (Iowa Department of Transportation 1978). The latter four railroads had little or no money to buy new locomotives and rail cars or to upgrade their rapidly deteriorating railroad track and bridges.

Lightweight rail and rotting ties on many branch rail lines were in such bad condition that derailments were common events. Trains operating on many of these lines were constantly going uphill. The weight of the locomotives and cars forced the lightweight rail to bend down into the rotting ties, causing the train to constantly travel up the rail.

The 1970s began a period of rapid growth in U.S. grain exports (U.S. Department of Agriculture). Corn exports grew from 506 million bushels in 1970 to 2,403 million bushels in 1979. Adding to this growth, the U.S. government signed an agreement to sell and deliver large amounts of wheat and corn to Russia. The purpose of the agreement was to improve the diets of the Russian people, to improve relations between the U.S. and Russia, and, most importantly, to reduce the huge quantities of wheat and corn the U.S. government had purchased and placed in long-term storage to increase the prices paid to U.S. farmers. Most of this wheat and corn was delivered to export

elevators in New Orleans, Louisiana, and in Houston, Texas for shipment to Russia. The deliveries to New Orleans were by railroads and barges down the Mississippi River. Deliveries to Houston were all by rail. The Russian wheat and corn sales effectively required the delivery of two U.S. wheat and corn crops in a few months.

During the 1970s, the railroads began shifting from single 60-ton box car shipments to 100-ton covered hopper grain cars and then to unit-trains. The first unit-trains consisted of 50 100-ton capacity covered hopper grain cars loaded at one grain elevator and delivered to one export elevator at New Orleans or Houston. The covered hopper grain cars were more efficient and less costly per ton of grain than the old 40-foot box cars that had been used for decades for grain shipments. Demand escalated for new jumbo covered hopper cars, more powerful locomotives to pull the heavy loaded covered hopper grain cars, and upgraded branch rail lines. But four of the five railways, operating 84% of the rail lines in Iowa, did not have enough cash to buy new cars and locomotives and, at the same time, rebuild the rail lines and bridges to the capacity needed to carry the new heavy rail cars and locomotives.

The cost efficiencies of the unit-trains enabled the railroads to reduce the rates for unit-train shipments below the charges for single car shipments. These lower rates encouraged some grain elevators, mostly those located on main lines and a few selected branch lines, to make the necessary investments to load the unit-trains in the short time period required under the lower unit-train tariffs. The lower rates allowed these elevators to increase their bid prices to encourage more grain farmers to deliver grain from longer distances. Grain farmers responded by buying larger trucks to haul grain longer distances to capture the higher bids offered for their grain.

The cash shortages of many railroads, combined with the huge demand for grain to be delivered quickly to New Orleans and Houston, created major shortages of new covered hopper grain cars. These shortages motivated many unit-train loading elevators to lease and/or buy their own grain cars. Thus, the unit-train loading elevators had two major advantages over the grain elevators on deteriorating branch lines: first, they could bid higher prices to grain producers for grain; second, they had access to grain cars for rapid shipments. These two advantages motivated grain farmers to buy larger trucks, including semi-tractor-trailer trucks, and to bypass the local grain elevator located on deteriorating branch rail lines. More grain producers then delivered their grain to the train loading elevators.

The new covered hopper grain cars weighed 263,000 pounds when loaded. This weight restricted their use to rail lines that had been upgraded with at least 90-pound rail—the weight of three feet of rail—that would safely carry these heavy loads. New railroad ties/ballast and some bridge work were also needed for the safe movement of these heavy loaded jumbo covered hopper grain cars and the new, more powerful, locomotives.

The success of the 50-car unit-trains motivated the railroads to increase the trains size to 75 cars and later to 100 cars. Today, the lowest cost rail shipments are in shuttle trains consisting of 110 cars in each train with each car carrying approximately 110 tons of cargo. The cargo weight of each shuttle train is approximately 12,000 tons. Shuttle trains require a commitment for a fixed number of multiple loaded train trips.

Most of the branch lines in Iowa needed to be upgraded with 90-pound rail, new ties, ballast, and some bridge work. Given that the railroads did not have enough cash to upgrade all branch rail lines that could not carry the new heavy loaded grain cars, railroads filed petitions to abandon many miles of low traffic, deteriorated branch lines in Iowa. Most of the deteriorated branch lines served smaller grain elevators located in small towns. Managers of these elevators, as well as many small-town business owners, petitioned state and federal governments to do something to “save my rail line!” The U.S. was facing severe fuel shortages during those years. They also argued that saving these lines by upgrading them would save fuel if grain producers could deliver their grain to the local elevators rather than haul them to the distant unit-train elevators located on the main lines. The state of Iowa and the federal government responded to these pleas with railroad preservation

programs. The purpose of this paper is to

- describe the branch rail line preservation program enacted by the state of Iowa
- describe how the two Iowa agencies implemented this program
- compare the results of the two methods of implementation
- suggest the conditions under which similar future programs should not be enacted and conditions under which future programs might produce economic results

LITERATURE REVIEW

There is a rich literature available on the economics of branch rail lines in the United States and particularly in the Midwest. Using a network model, Baumel et al. (1979) evaluated the benefits and costs of upgrading 71 branch rail lines in Iowa. Only seven of the 71 lines that were evaluated generated benefits that exceeded the cost of upgrading.

Casavant and Tolliver (2001) estimated how shippers and short line railroads are affected by heavy cars (loaded weights of 286,000-pounds) on state of Washington branch rail lines with 90-pound or less weight rail or deferred maintenance. They concluded that even with innovative short-run solutions, upgrading the track to carry 286,000-pound cars was the only long-term solution. Approximately 480 miles of track needed to be upgraded to effectively carry 286,000-pound cars at a cost of \$110 to \$141 million. Failure to upgrade the track would likely result in abandonment, and the economic benefits of the heavier cars would be lost to shippers.

Sage et al. (2015) examined the role of and problems facing 22 short line railroads in the state of Washington. The major problem facing these railroads is the railroad industry shift to heavy axle (286,000-pound capacity) rail cars. Much of the existing short line rail systems in Washington cannot safely carry these cars at economic speeds. The estimated cost of upgrading these short line rail and bridge systems is about \$610 million. Sage et al. (2015) present three case studies showing the economic benefits of investments in the Washington short line railroad system.

Fengxiang et al. (2016) examined 45 short line railroads in Texas. They evaluated the impact of short line railroads on safety, congestion, noise, environment, road infrastructure, employment, and the local community. Their conclusion was that “short line railroads provide significant benefits to the state. However, many short line railroads operate railroad infrastructure that is in a deteriorated condition because of deferred maintenance by previous owners. Most short line railroads do not have sufficient revenues or access to large amounts of capital that are necessary to rehabilitate their infrastructure.”

The Federal Railroad Administration (2014) reported that there are more than 560 short line railroads operating in the United States. The short line railroad industry has been consolidating under the control of holding companies. There are 27 holding companies that control 270 small railroads. These holding companies reduce the risk that lenders will not be repaid for their loans to short line railroads. A survey indicated that current investment needs in the short line industry is \$1.2 billion. Future investment needs total another \$5.3 billion. Holding companies indicate that they need a mix of funding sources for these investment needs.

Babcock and Sanderson (2004) used a rate of return on investment analysis to determine if five Kansas short line owners would likely upgrade their rail lines to carry 286,000 gross vehicle weight rail cars or abandon them. None of the five short line railroads could earn an adequate rate of return on upgrading track and bridges to justify the investment. Today all five are still operating.

Laurens and Richardson (2014) assessed the economic role and impact of short line railroads in Louisiana. They found that short line railroads while small in scope play a significant role in supporting the state’s core economic drivers. As a result, short line policies (e.g., grant programs for capital improvements) should be considered by the state of Louisiana to accommodate the flow of goods.

Baumel and Wisner (1974) examined the effect of rail line abandonment on a country elevator’s grain and farm supply business. The results indicated that a country elevator located on an abandoned rail line could continue to operate. They would need to continue to perform the necessary function of receiving, drying, and storing grain at harvest time and to provide a local source of feed, fertilizer, and other farm supplies.

O’Riley (2008) described the growth in ethanol production in Iowa and the modes used to transport ethanol out of Iowa.

Yu and Hart (2009) described the impact of the rapidly expanding ethanol industry in Iowa and the significant impact of ethanol in the utilization of Iowa’s corn production.

Iowa Railroad Preservation Assistance Programs

In 1974, the Iowa Legislature created the Iowa Rail Assistance Program and appropriated \$3 million to begin rehabilitating Iowa’s rail network. The program began under control of the Iowa Energy Policy Council (IEPC) but was transferred to the Iowa Department of Transportation (IDOT) in 1975. IEPC developed the following point system to analyze and rank potential branch rail line candidates for financial assistance to upgrade the rail lines (The Council of State Governments 1976):

Rating Category	Maximum Points
Historic Viability (number of cars per mile)	15
Potential Viability (potential cars per mile)	20
Safety (derailments)	10
Track Structure (condition)	20
Shipper Funding Participation	20
Railroad Funding Participation	15
	100

The higher the number of points, the higher the priority that the IEPC assigned to the rail line. IEPC used this system to allocate \$3.4 million to upgrade six branch lines. Shippers and railroad companies also allocated \$2.8 million to these six branch lines. These six branch lines were upgraded with 90-pound rail and new ties to carry the new loaded covered hopper unit grain trains.

In 1975, the Iowa Rail Assistance Program was transferred to the newly formed IDOT. In 1974, the Iowa Legislature passed Senate File 1141 creating IDOT, which assumed responsibility for transportation operations, planning, building and regulatory activities formerly performed by six separate state agencies (Iowa Department of Transportation 1980). IDOT used a benefit-cost model to determine whether a given branch line would generate enough traffic to become profitable and remain in operation over a long period of time. The model, based on an earlier study to estimate the benefits and costs of upgrading 71 branch rail lines in Iowa (Baumel, Miller and Drinka 1979) was estimated using the following steps:

1. Establish the line alternatives
2. Estimate the project costs
3. Determine what will happen if the line is not upgraded
4. Use a standard planning horizon
5. Establish a discount rate
6. Estimate transportation benefits
7. Estimate secondary benefits
8. Estimate salvage values
9. Calculate the benefit cost ratio

The IDOT benefit-cost model, a more sophisticated economic model than the point system used by IEPC, was used to allocate \$27.7 million in state funds and \$35.7 million in federal funds to 35 branch line projects from 1975 to 2005 (Iowa Department of Transportation 2005). Shippers added \$35.0 million and railroad companies added \$52.2 million to these 35 branch lines from 1975 to 2005 (Iowa Department of Transportation 2005). Table 1 compares the results of the IEPC procedures with those of IDOT's.

Table 1: Iowa Energy Policy Council and Iowa Department of Transportation Branch Rail Line Preservation Programs, 1974-2005

	Iowa Energy Policy Council	Iowa Department of Transportation
Miles of line upgraded	271	1,713
Total actual cost	\$6,198,523	\$150,676,157
Average cost per mile	\$22,873	\$87,960
Total cost paid by		
Shippers	\$1,341,000 (22%)	\$35,008,506 (23%)
Railroads	\$1,497,917 (24%)	\$52,221,459 (35%)
State of Iowa	\$3,359,606 (54%)	\$27,705,241 (18%)
Federal government	\$0 (0%)	\$35,740,951 (24%)
Miles abandoned	159	243
Percent abandoned	59	14
Cost per mile preserved by		
Shippers	\$11,973	\$23,815
Railroads	\$13,374	\$35,525
State of Iowa	\$29,996	\$18,847
Federal government	\$0	\$24,313
Total	\$55,344	\$102,501

Source: Iowa Department of Transportation (2005)

Table 1 shows that from 1974 to 2005, a total of 1,984 miles of deteriorated Iowa branch rail lines were upgraded under IEPC and IDOT programs. Fourteen percent of the lines were upgraded under IEPC and 86% under IDOT. IEPC paid 54% of the cost of the 271 miles of upgraded track under their control while IDOT paid only 18% of the total cost. Railroad companies paid one-fourth to one-third of the costs and shippers paid almost one-fourth of the costs under both programs. However, the shipper contributions were loans to the railroads and the shippers were reimbursed per car shipped on each line. The federal government paid none of the costs under the IEPC program and about one-fourth of the costs under the IDOT program. The IEPC contributions were grants to the railroads for upgrading the selected lines.

A major difference between the two programs was that 59% of the lines that were upgraded under the IEPC program were eventually abandoned, whereas only 14% were abandoned under the IDOT program. A likely reason for the high level of abandonments under the IEPC program was the method used to allocate funds among applications. The IEPC method relied largely on the historic level of traffic and derailments on each line. There was no measurement of the net benefits expected from upgrading the lines under the IEPC program and the length of time the upgraded lines would remain in operation. Sixty percent (95 miles) of the abandoned lines under the IEPC program miles were from one line on the Milwaukee RR (Iowa Department of Transportation 2005). Eighty-two

of the 95 miles of upgraded Milwaukee RR line were abandoned just five years after they were upgraded (Iowa Department of Transportation 2005). The remaining 13 miles were abandoned 15 years after the upgrading. This suggests that there was little effort made to estimate the years that the line would remain in operation. If there were estimates of the useful life of the investment, the estimates were incorrect.

The high level of abandonment under the IEPC program resulted in a higher state of Iowa cost per mile of upgraded lines that remain in operation. The total Iowa cost per mile of upgraded lines that remain in operation was almost 1.6 times (\$29,996 divided by \$18,847 from Table 1) greater under the IEPC program than under the IDOT program. This was the case even though the average cost per mile over all upgraded lines was greater under the IDOT program than under the IEPC program. In addition to the high level of abandonments of lines upgraded under the IEPC program, a second reason for the lower state of Iowa cost per mile of remaining upgraded lines was that the state contributed only 18% of the total upgrading cost while the IEPC program contributed 54% of the total cost.

A third difference between the two programs was the level of funding provided by the state of Iowa. More than half (54%) of the total funding under the IEPC program was from State of Iowa funds. These funds were grants to the railroad company and were not repaid. Under the IDOT program, only 18% of the funding came from State of Iowa funds. Initially the IDOT funds were provided as a grant to the railroads. In July 1984, the Iowa Transportation Commission changed the grant program to a no-interest loan program (Iowa Department of Transportation 1985).

Table 2 shows the amount of upgrading on branch lines operated by Class I, II, and III railroads under the IDOT program. The class groupings are based on the level of annual gross operating income. In 2015, Class I railroads included those with annual operating income of \$457.9 million or more (Surface Transportation Board 2017). Class II railroads had less than \$457.9 million but more than \$36.6 million while Class III railroads had less than \$36.6 million of gross operating income (Surface Transportation Board 2017). The importance of Class II and III railroads (often referred to as short lines) to Iowa was evident from the dramatic increase in their operations from 1980 to 1985 resulting from the abandonment of Class I branch lines and the Rock Island RR and Milwaukee RR bankruptcies. Many communities and small businesses depend on rail service to move their goods and provide a base for their local economy, which the short lines could provide at an operating cost lower than Class I railroads (Iowa Department of Transportation 1985). Other Midwest states that have established rail financing programs to enhance the service and capacity of short line railroads include Kansas, Michigan, Minnesota, Ohio, Wisconsin, and Oklahoma (American Association of State Highway and Transportation Officials 2017).

A large percent of the upgraded miles under the IDOT program were on Class I railroads. That was because Class I railroads owned a large percent of the rail lines in Iowa, particularly in 1975 when the Iowa Rail Assistance program began. Seventy percent of the upgraded miles and 76% of the expenditures were on Class I lines. Class I railroads contributed 35% of the upgrading expenditures on their lines while Class II railroads contributed 43% on their lines and Class III railroads contributed 28% of their expenditures. Shippers on Class I railroads contributed 28% of the expenditures while shippers on Class II and III railroads contributed much less, only 8% and 5% of the expenditures on those lines, respectively. Moreover, the railroads repaid the shippers for their contribution per car shipped on the line based on a flat per-car rebate or a graduated revenue per-car rebate as negotiated by the shippers and railroad (The Council of State Governments 1976).

A total of 243 miles of upgraded lines under the IDOT program were abandoned with Class I railroads accounting for 232 miles and Class II 11 miles. Of the total of 243 miles of upgraded and then abandoned lines, 172 were abandoned on the Rock Island Railroad, 38 miles were on the Chicago and Northwestern Railroad, 22 miles were on the Burlington Northern Railroad, and 11 miles were on the Iowa Interstate Railroad (Iowa Department of Transportation 2005). There were no abandonments on the Class III railroads.

Table 2: Class I, II and III Railroad Upgrading Costs for the Iowa Department of Transportation Branch Rail Line Preservation Program, 1975-2005

	Class I*	Class II**	Class III***
Miles of line upgraded	1,207	250	256
Total cost	\$115,123,102	\$18,408,229	\$17,144,826
Average cost per mile	\$95,380	\$73,633	\$66,972
Percent of total cost paid by			
Shippers	28	8	5
Railroads	35	43	28
State of Iowa	16	18	33
Federal government	21	31	34
Miles abandoned	232	11	0
Percent abandoned	19	4	0
Cost per mile preserved by			
Shippers	\$33,510	\$6,291	\$3,254
Railroads	\$40,667	\$32,714	\$18,565
State of Iowa	\$19,202	\$14,041	\$21,979
Federal government	\$24,696	\$23,976	\$23,174
Total	\$118,075	\$77,022	\$66,672

Source: Iowa Department of Transportation (2005)

*63 miles were upgraded by the Rock Island RR (a Class I railroad) and later sold to the Iowa Interstate Railroad (a Class II railroad).

**170 miles were upgraded by the Chicago Central & Pacific Railroad (a Class II Railroad) which is now a subsidiary of the Canadian National Railway (a Class I Railroad).

***83 miles were upgraded by the Cedar River Railroad (a Class III Railroad) which is now a subsidiary of the Canadian National Railway (a Class I Railroad).

Shippers and railroads contributed 63% of the total cost of Class I lines. The state of Iowa contributed only 16% of the Class I upgrading. The state of Iowa paid 18% of the costs of the Class II upgrading and 33% of the Class III upgrading. Many states have provided support to their Class II and III railroads. Such investments ensure that these railroads can continue to serve their shippers in helping to retain shipper employment and prevent the diversion of traffic to truck and the consequent maintenance impacts to the road system (Iowa Department of Transportation 2017). Freight moving by rail lowers congestion on the road system, lowers fuel consumption, reduces greenhouse gas emissions, and provides for safer roadways (Sage, Casavant, and Eustace 2015 and Fengxiang Qiao et al. 2016).

In summary, the IDOT program was more efficiently operated than the IEPC program. First, the IDOT program decisions were based on a more rigorous economic model than the IEPC program. Second, the state of Iowa contributions under the IEPC program were gifts to the railroads, whereas the IDOT prior to July 1984 were grants to the railroads. After July 1984, the IDOT funds became a no-interest loan to the railroads. Third, over half of the upgraded lines in the IEPC program were abandoned while only 14% of the lines in the IDOT program were abandoned. Since the purpose of the programs were to preserve the selected rail lines, the IEPC program preserved only 41% of the subsidized lines while the IDOT program preserved 86% of the selected lines.

FUTURE USE OF SUBSIDY PROGRAMS TO PRESERVE RAIL LINES

The fundamental assumption behind the initial state of Iowa effort to preserve certain Iowa branch rail lines was that Iowa corn and soybean exports would continue to grow over the years and that railroads would remain as the major carrier of Iowa's agricultural output. Therefore, branch rail lines would be needed to transport grain to the main lines for shipment to export ports. The programs also assumed that rail line preservation was necessary to maintain and grow rural Iowa communities.

The first assumption turned out to be false. U.S. corn exports peaked in 1979 (U.S. Department of Agriculture). Except for a temporary spike in 2007, caused by major droughts in competing countries, U.S. corn exports have trended downward since 1979. Iowa corn exports trended downward even faster than U.S. corn exports. There were two reasons why Iowa corn exports declined so rapidly. The first and most important reason was the rapid growth in the use of corn as the feedstock for ethanol production. Iowa produces more ethanol than any other state in the U.S. (Iowa Corn Growers Association 2017). The second reason for the decline in Iowa corn exports was that the growth in livestock production in Iowa was made possible with the use of corn and soybeans in animal feed production. Most of the increased animal production was in the growth of confinement swine production. There was also a large increase in the production of eggs in Iowa.

Will the rapid growth in the use of corn in ethanol production and corn and soybeans used in swine and egg production continue to use a high percent of the corn and soybeans produced in Iowa? Technology continues to increase the per-acre yields of corn and soybeans. Technology also continues to make automobiles more fuel efficient and therefore use less ethanol as a transportation fuel. There is also an effort underway to increase the blend of ethanol in gasoline from 10% to 15%. This would likely mean an increase in the use of ethanol. On the issue of feed consumption, there is a belief that it is more efficient and less costly to increase the production of livestock in the U.S. and export meat rather than export corn and soybeans. The net result of these conflicting forces is that corn and soybean exports are likely to increase, but the rate of increase is uncertain and could range from low to modest growth.

If grain exports do increase, will it create a need to continue upgrading Iowa branch rail lines to transport the grain? If there is a large local demand for corn, Iowa elevators will have a local truck market and the need for branch lines will continue to decline. If, however, the local market for grain decreases and the export demand increases, the need for branch lines may increase. The reasons that major changes are occurring in the Iowa grain distribution system are the following:

1. The size of Iowa farms has been increasing with many farmers operating 3,000 acres or more. These large-size operations require large combines to harvest the crops in time to do the post-harvest work before the ground freezes. Many of these farmers have purchased used semi tractor-trailer trucks to increase their capacity to move their corn and soybeans to on-farm storage and to commercial storage sites. Some farmers own up to five semi-trucks. Effectively, these farms have become small trucking firms. Depending on price differentials, these trucks, hauling up to 1,000 bushels per load, can economically haul grain 100 miles or more. This enables these farmers to bypass local grain elevators located on branch rail lines and haul their grain directly to ethanol plants, feed mills, and grain elevators on main lines that buy enough grain to contract for low-cost shuttle trains that make multiple consecutive trips.
2. Iowa grain cooperatives have undergone a period of mega mergers. As of April 2016, there were only 55 grain cooperatives in Iowa, down from about 300 cooperatives in 1980 (Jacobs 2016). This means that each cooperative owns and operates multiple grain handling locations. Landus Cooperative, located in Ames, Iowa, operates 65 grain elevators. Landus is served by all seven railroads operating in Iowa. Its 7,000 members can choose to deliver grain at any of the 65 elevators. Grain bids vary among the 65 elevators depending on the markets available to each elevator. Some of the 65 elevators do not have rail service, yet

some of these non-railroad elevators have expanded their receiving and storage facilities to enable them to serve local ethanol, and other processing plants and feeder markets. Figure 1 shows a grain elevator at Luther, Iowa. It was originally located on the Chicago, Milwaukee, St. Paul, and Pacific Railroad, which was abandoned in 1976. The elevator remained in business without rail service. In 2016, the new storage capacity shown in Figure 1 was added to the elevator even with no rail service.

Figure 1: New Addition to Elevator Located on an Abandoned Rail Line at Luther, Iowa, 2016



The new elevator addition offers storage capacity to farmers located around the elevator and provide corn and soybeans to local truck markets, including ethanol plants, feed mills, and corn and soybean processors. Other elevators without rail service are located throughout Iowa serving other truck markets. In today's markets, grain elevators function profitably without rail service, and there is little or no need for governmental programs to preserve rail service to grain shippers in Iowa. Most of these changes in the structure of the Iowa grain distribution system are also occurring in other corn belt states (Zelenka 2017).

Another argument for upgrading branch rail lines is that the railroads are in the process of shifting to larger capacity cars that carry 110 tons or more of product. These loaded heavy cars can only move safely over 90-pound rail at slow speeds. These slow speeds increase the cost of transporting over most branch lines. However, declining corn exports, farmers shifting to semi-trucks, and the railroad shift to shuttle trains means that the amount of corn moving over branch lines has been declining. This reduces the net benefits of upgrading branch lines, including Class II and III railroad lines. However, increasing shipments of ethanol and DGS (dried grains from the

production of ethanol) by rail has partially offset the decline in corn shipped by rail. Ethanol and DGS will also increasingly be shipped in 286,000-pound cars, which would add to the potential benefits of upgrading branch lines with the rail weighing 112 pounds per 36 inches of rail.

The financial condition of Iowa railroads is much different today than in the 1970s when two Class I railroads were bankrupt and two others had little or no money to upgrade their infrastructure. The current rail network is in much better physical condition, as the railroads have made considerable progress in the last two decades in upgrading their track and equipment. Table 3 shows the miles of rail lines in Iowa that are not able to handle 286,000-pound cars.

Table 3: Iowa Mileage of Class I, II and III Railroads in Need of Potential Future Upgrading to Handle 286,000-Pound Rail Cars, 2017

	Total Miles Operated in Iowa	Miles Unable to Handle 286,000- Pound Rail Cars	
		Total Miles	Miles Located on Ethanol Routes
Class I Railroads	3,225	343	250
Class II Railroads	298	5	0
Class III Railroads	328	136	40
Total	3,851	484	290

Source: Iowa Department of Transportation (2017)

A total of 484 miles (12.5% of the total Iowa miles) are not able to handle the 286,000-pound cars and may need to be upgraded if the movements on these lines require the larger cars. Of the total 484 miles, 343 miles are located on Class I railroads while the remaining 141 miles are located on Class II and III railroads. In the case of ethanol movements, Table 3 shows that 290 miles (7.5% of the total Iowa miles) located on ethanol routes are not able to handle 286,000-pound cars. Class I railroads account for 250 miles (86%) while Class III railroads account for the remaining 40 miles (Iowa Department of Transportation 2017).

Class I railroads are generally considered capable of funding their own capital projects. However, self-funding is more challenging for Class II and III railroads. There are seven ethanol plants in Iowa located on lines that are currently not capable of carrying 286,000-pound cars at normal speeds. Five of these lines are located on Class I railroads. These Class I railroads should be financially strong enough to upgrade these lines themselves. The other two ethanol plants are located on Class III railroads. If these two railroads are not financially strong enough to finance the upgrading of the lines to carry 286,000-pound cars from the efficiencies of heavier cars, one alternative method of financing the upgrading is for the shippers to loan the needed amounts to the railroads to upgrade the track and for the railroad to use the efficiencies of the upgraded track to repay the shippers for the loaned funds. While the 2017 Iowa State Rail Plan describes possible future railroad improvements and investments, the plan identified just a few projects that addressed the potential need to upgrade Iowa’s branch lines (Iowa Department of Transportation 2017).

CONCLUSIONS

Most Iowa grain is now being delivered in farmer owned semi-trucks. The dominant markets for corn are now local ethanol plants, feed mills, corn processing plants, and swine and poultry feeders. U.S. grain exports have trended downward since 1979. Most existing Class I railroad companies are in strong financial condition. Therefore, it is unlikely that government programs are or will be needed to preserve branch rail lines in Iowa and other Corn Belt states. However, if exports become

the major market for corn, and if Class II and III railroads are unable to finance the upgrading of their lines to carry 286,000-pound loaded cars, alternative sources of capital include:

- Shippers located on those lines could loan the needed funds to the railroads. The Class II and III railroads could then use the efficiency gains from the upgrading to repay the shippers per car shipped on the lines.
- The short lines could try to become part of a holding company.
- The short lines could be repurchased by Class I railroads.
- If none of these alternatives are possible, individual short lines should be evaluated to see if upgrading is economically sound. If so, state and or federal funds could be sought. Improved economic models should be developed so that no lines upgraded with government funds would likely be abandoned.
- If upgrading is uneconomic, the line should be considered for abandonment.

References

American Association of State Highway and Transportation Officials, Rail Council. State Financing Programs for Short Line Railroads. Washington D.C., 2017. Website at <http://rail.transportation.org/freight-rail>.

Babcock, Michael, W., and James Sanderson. "Should Short Line Railroads Upgrade Their Systems to Handle Heavy Axle Load Cars?" *Transportation Research Part E* 42, (2006):149-166.

Baumel, C. Phillip, John J. Miller, and Thomas P. Drinka. "The Economics of Upgrading Seventy-One Branch Rail Lines in Iowa." *American Journal of Agricultural Economics* 59(4), (1979):64-70.

Baumel, C. Phillip, Jerry Vanderkamp, and Robert Wisner. "Corn Belt Farmers: This is Not Your Father's Grain Transportation and Distribution System." Unpublished.

Baumel, C. Phillip and Robert N. Wisner. "What Happens When an Elevator Loses Its Railroad Line?" *Feedstuffs* 46(14), (1974).

Casavant, K. and D.D. Tolliver. "Impacts of Heavy Axle Loads on Light Density Lines in the State of Washington." State Department of Transportation, Olympia, WA. 2001.

Federal Railroad Administration. "Summary of Class II and III Railroad Capital Needs and Funding Sources, A Report to Congress." October 2014.

Fengxiang Quio et al. Transportation and Economic Impact of Texas Short Line Railroads. National Technical Information Service, Springfield, Virginia, 2016.

Iowa Corn Growers Association, 2017. Website at <http://www.iowacorn.org/corn-uses/ethanol/ethanol-plants/>. Johnston, Iowa.

Iowa Department of Transportation, Office of Rail Transportation. 2017 Iowa State Rail Plan. Ames, Iowa, 2017.

Iowa Department of Transportation, Planning and Programming Division. Iowa Rail Plan. Ames, Iowa, 1978.

Iowa Department of Transportation, Planning and Programming Division. 1980 Iowa Railroad Analysis Update. Ames, Iowa, 1980.

Preserving Railroad Infrastructure

Iowa Department of Transportation, Planning and Programming Division. 1995 Iowa Rail Plan. Ames, Iowa, 1995.

Iowa Department of Transportation, Planning and Programming Division. Iowa Rail Assistance Project Status Report. Ames, Iowa, 2005.

Iowa Department of Transportation, Rail and Water Division. Iowa Rail Program Reference Book. Ames, Iowa, 1985.

Jacobs, Kerri L., "Consolidation of Iowa Cooperatives." IIC's Winter Workshop, Iowa State University. January 2016.

Lorens, Jared and James Richardson. Economic Impact Analysis of Short Line Railroads. Public Administration Institute, Louisiana State University, Baton Rouge, LA. October 2014.

O'Riley, Craig. "Impacts of Ethanol on Iowa's Transportation System." Presented at the Legislative Agriculture Chairs Summit VI, St. Louis, Missouri, 2008.

Sage, Jeremy, Kenneth Casavant, and Bradley Eustace. Washington State Short Line Rail Inventory and Needs Assessments, National Technical Information Service, Springfield, VA, 22616, June, 2015.

Surface Transportation Board. Website FAQs located at <https://www.stb.gov/faqs.html>. Washington, D.C., 2017.

The Council of State Governments. Railroad Rehabilitation: A Program to Upgrade Selected Branch Lines in Iowa. Lexington, Kentucky, 1976.

U.S. Department of Agriculture. U.S. Corn Exports by Year. <https://www.indexmundi.com/agriculture/?country=us&commodity=corn&graph=exports>

U.S. Federal Railroad Administration. Summary of Class II and III Railroad Capital Needs and Funding Sources, October 2014.

Yu, Tun-Hsiang and Chad Hart. "Impact of Biofuel Industry Expansion on Grain Utilization and Distribution: Preliminary Results of Iowa Grain and Biofuel Survey." Presented at the Southern Agricultural Economics Association Annual Meeting, Atlanta, Georgia, 2009.

Zelenka, Bob. State Issues Minnesota. *Minnesota Grain and Feed Assn. Grain Journal*. January-February, 2017.

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Measuring the Transportation Workforce Skills Gap Using New Indices and Survey of Employers and Workers

by Zamira Simkins and Rubana Mahjabeen

Skills gap is a significant mismatch between the knowledge, skills, and abilities (KSAs) required by employers and those held by workers. This study proposes four innovative indices to measure such KSA-gaps and calculates them using data from a survey of transportation workers and employers. The results suggest that the workers' competencies do not match the employers' requirements. Areas of particularly extensive KSA-gaps include knowledge of transportation, distribution, and logistics; knowledge of machines, tools, and equipment; equipment operation, maintenance, repair, and troubleshooting skills; critical thinking and problem-solving skills; work prioritization and resource-management skills; and ability to apply knowledge.

INTRODUCTION

Concerns over a perceived skills gap have intensified over the last decade for three main reasons: first, in light of the 2007-2009 recession, the U.S. unemployment rate and average unemployment duration have increased; second, due to the ongoing massive retirement of baby boomers, employers have faced increasing challenges replacing the departing human capital; and third, due to technological developments, employers' workforce demands have changed. The U.S. unemployment rate has increased from 5% in December 2007 to its peak of 10% in October 2009, but so did the average unemployment duration, from 16.6 weeks in December 2007 to its peak of 40.7 weeks in July 2011 (U.S. Bureau of Labor Statistics 2017a). Proponents of the skills gap use these statistics to support their view, arguing that the unemployed workers cannot quickly find new jobs because they lack the skills demanded by employers. Skills gap opponents argue, however, that these statistics are simply a result of a particularly deep recession.

Whether the increase in unemployment and unemployment duration were structural or cyclical in nature may be debatable, but the demographic and technological changes are undeniable. On average, around 10,000 baby boomers currently retire every day, a trend that is expected to continue through 2031 (Social Security Administration 2011). Some industries are impacted by the retirement of baby boomers more than others, with agriculture, public administration, and transportation ranking as the top three aging sectors. Specifically, in 2016, median workers' age in these industries was 47.5 years in agriculture, 45.6 years in public administration, and 45.4 years in transportation (U.S. Bureau of Labor Statistics 2016). In 2016, transportation was the largest of these three sectors, accounting for 5.29% of the labor force; whereas, public administration and agriculture accounted for 4.53% and 1.62% of the labor force, respectively (U.S. Bureau of Labor Statistics 2016). Further, over 50% of workers in the transportation and warehousing industry will be eligible to retire over the next decade, which is double the retirement rate of the national workforce (U.S. Department of Transportation 2015). Not surprisingly, a labor market study of truck drivers by Costello and Suarez (2015) identified that baby boomers' retirement was the primary reason behind the labor shortages in transportation. According to the same study, the second factor behind the labor shortages was industry growth. Employment in the transportation and warehousing industry has grown from 4.5 million in 2007 to 5 million in 2017 (U.S. Bureau of Labor Statistics 2017b). These trends, along with the workforce turnover, create several hundred thousand transportation and warehousing job

openings annually (U.S. Bureau of Labor Statistics 2017c). Many of these vacancies require new skill sets to match the technological developments in the industry. The PWC (2012) report calls these the “e-skills” or the information-communication-technology skills, such as traffic management, driver assistance, and car-to-infrastructure system operation skills.

Due to the above factors, many transportation and warehousing industry employers have been reporting difficulties filling job vacancies, attributing their hiring challenges to the skills gap phenomenon (Cronin 2014). Skills gap opponents argue, however, that the perceived skills gap explanation behind hiring challenges lacks empirical support, as employers truly facing the skills gap would have increased wages to attract qualified candidates. Empirical evidence shows, however, that mean real wages have stayed nearly constant for over a decade now (Holzer 2012; Rothstein 2012; Levine 2013).

Given the conflicting views on skills gap and demographic changes expected to take place in the transportation and warehousing industry, the objective of this research is to answer the following questions: Is there a skills gap in the transportation and materials moving occupations?¹ If so, what competencies, or knowledge, skills, and abilities (KSAs), do the workers lack and to what extent? What KSAs do the unemployed lack? What KSAs do the employed lack, if any? What proportion of vacancies are difficult to fill because of the skills gap? Answers to these questions can help the transportation stakeholders identify and address the specific KSA-gaps facing the industry. This study’s approach, key research findings, and contributions to current literature are summarized below.

Skills gap can be defined as a shortfall or a mismatch of skills (Shimer 2007; Sahin et al. 2011; Cappelli 2015; Deloitte 2015). Skills can be measured using various proxies, including educational attainment, IQ tests, SAT scores, and occupational competencies (Manacorda and Petrongolo 1999; Handel 2003). All of these measures aim to proxy human capital. As described in the literature review though, use of different proxies often leads to different findings and conclusions. Generally, since human capital reflects the knowledge, skills, and abilities embodied in a worker, this study defines skills gap as a significant mismatch between the KSAs required by employers and those actually held by workers. We adapt the mismatch definition, as opposed to the shortage approach, because any misalignment in KSAs can lead to unfilled vacancies, long-term unemployment, decreased worker productivity, labor turnover, and foregone business revenue. In turn, through economic linkages, skills gap in a given occupation and industry can negatively impact other industries and the economy as a whole. To mitigate these negative effects of skills gap, it is important to understand what specific KSAs employers require, what KSAs workers actually possess and what they lack, and the extent of these KSA gaps. Since KSAs, as opposed to education or IQ scores, are directly linked to the occupational requirements, identifying the exact KSA gaps, if any, is the first step in developing effective skills gap mitigation policies and programs aimed at minimizing the identified competency gaps.

To answer the research questions posed above, we developed four innovative indices and measured them using data from a survey of transportation workers and employers. Due to funding sources, our data collection was limited to 10 counties in northwest Wisconsin. Hence, the results are not representative of the national labor market. However, the study’s findings offer interesting insights to transportation stakeholders. Further, the study’s methodology can be replicated in other areas.

The main finding of this study is that the competencies of transportation workers do not match the employers’ requirements. For example, workers reported having no KSA gaps in equipment operation and maintenance skills, whereas employers reported workers as having severe KSA gaps in this area. These divergent views on the occupational KSA gaps illustrate that workers are pursuing the wrong KSAs, from the employers’ point of view. This, in turn, explains the employers’ complaints about the skills gap. This mismatch in KSAs between the transportation and materials moving employers and workers was found to be particularly extensive in the following areas: knowledge of

transportation, distribution, and logistics; knowledge of machines, tools, and equipment; equipment operation, maintenance, repair, and troubleshooting skills; critical thinking and problem-solving skills; work prioritization and resource-management skills; and ability to apply knowledge.

The research presented in this paper contributes to the existing literature on skills gap and the transportation labor market in several ways. First, most existing studies on skills gap survey only employers (Deloitte 2015), then attribute the reported hiring difficulties to the skills gap. To accurately assess the occupational skills gap, however, it is important to compare workers' qualifications with employers' requirements. Such comparison can help address the criticism that employers facing hiring difficulties do so not because of the workers' skills gap, but because these employers are overly selective in their hiring choices, do not properly screen applicants, or simply do not pay fair wages (Holzer 2012; Levine 2013).² One study that did examine the occupational competencies possessed by workers and those required by employers found that a significant proportion of workers reported a mismatch between the skills they possess and those required for their jobs (OECD 2013). Similarly, our study contributes to the existing literature by surveying both workers and employers. Second, existing studies on labor mismatch tend to focus solely on the unemployed (Sahin et al. 2014). Focus on the unemployed, however, misses the effects of productivity losses arising from the employed workers having KSA gaps. According to the OECD (2016) study, labor force skills gap is one of the reasons behind a significant decline in labor productivity growth in developed economies. Hence, our study contributes to the existing literature by quantifying the skills gap not only among the unemployed, but also among the employed. Third, current literature mostly utilizes aggregate level data, with very few studies using micro-level data. This observation led Holzer (1994) to call for more micro-economic studies that examine the mismatch between the jobs' skill requirements and workers' skill levels. Handel (2003) also noted that few studies actually identify the specific skills that workers lack. This study helps fill this gap by analyzing the microeconomic data on vacancies and worker competencies, which allows us to identify the specific KSA gaps.

The rest of the paper is organized as follows: the literature review outlines several theoretical labor market models that can be linked to skills gap, followed by a discussion of relevant empirical studies. The proposed skills gap indicators are described next, followed by a description of survey methodology, findings, and conclusions.

LITERATURE REVIEW

Theoretical Models

The standard neoclassical model of a competitive labor market predicts that labor markets, such as the one illustrated in Figure 1, always clear over time. In this model, wage serves as the adjustment mechanism that equates the labor supply and demand. Disequilibrium states, such as labor surplus or labor shortage, can occur temporarily if wages start out above or below the equilibrium. Over time, as wages adjust, markets would clear again. This market clearing prediction is subject to several critical neoclassical assumptions: there are many workers and employers, wages and prices are flexible, information is perfect and symmetrically distributed, and nobody has market power. If these assumptions hold, there would be no surplus of labor, i.e., no unemployment, and no labor shortages, i.e., no vacancies.

The neoclassical labor market model is frequently criticized for being unrealistic in its assumptions, as labor market inefficiencies and other factors keep the markets from clearing. Further, this model cannot explain the coexistence of unemployment and labor shortages that manifested in the post 2007-period. Review of literature for models that can explain such simultaneous existence of unemployment and vacancies revealed a strand of alternative models studying the labor markets with search frictions (Pissarides 1985, 2011; Shimer 2007; Daly et al. 2012). A simple graphical

Figure 1: Neoclassical Model of a Competitive Labor Market

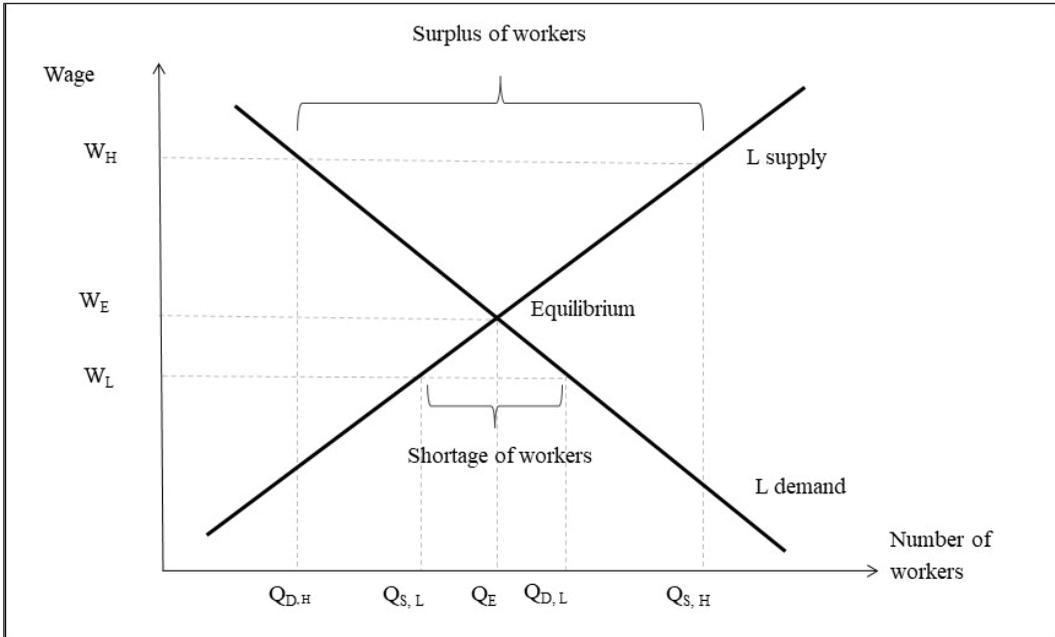
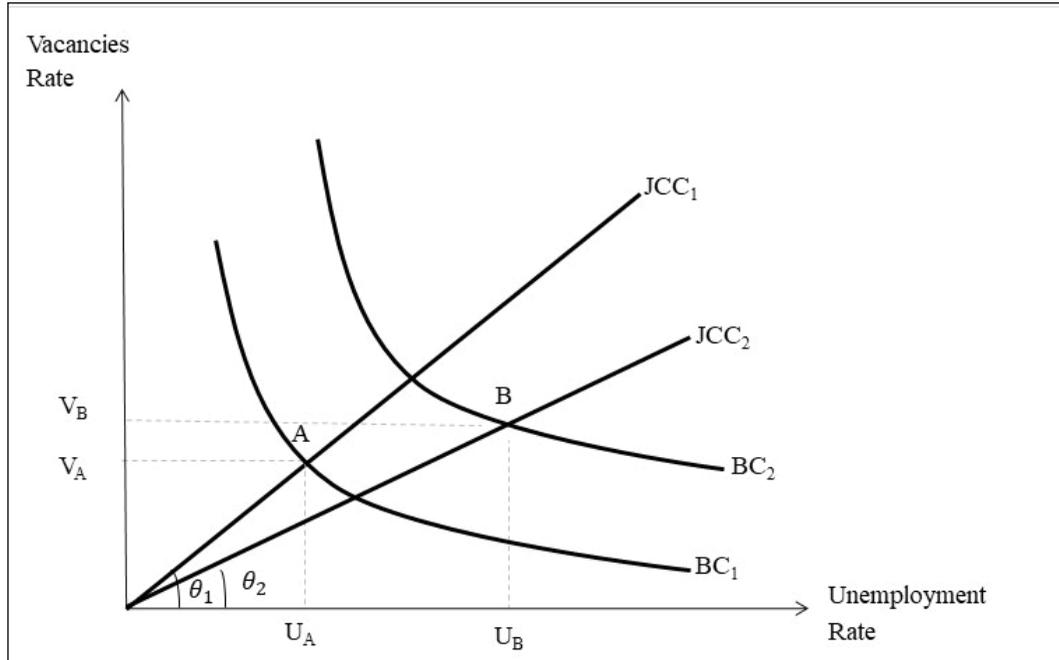


illustration behind the mathematics of these alternative models, as presented in Pissarides (2011), is replicated in Figure 2.

Figure 2 illustrates two curves, the Beveridge Curve (BC) and the Job Creation Curve (JCC), the latter named by Pissarides (2011). The point of intersection of these two curves determines the equilibrium vacancy and the equilibrium unemployment rate. The downward-sloping BC, as developed by Dow and Dicks-Mireaux (1958), represents an aggregate relationship between the unemployment and vacancies rate. Over the course of a business cycle, the economy moves along the BC, while labor market frictions and structural changes shift the BC (Diamond 2013). The JCC represents the employers' decisions to hire and can be viewed as an aggregate labor demand curve. The JCC slopes upward because a higher unemployment rate raises the employer's likelihood of filling a job (Daly et al. 2012). The JCC's slope, tangent of θ , also represents the labor market tightness and the workers' bargaining power over wages (Pissarides 2011). During recessions, declining aggregate demand lowers the marginal product of labor and the value of job creation, so the JCC would rotate to the right, the labor market would become less tight, and the workers' bargaining power over wages would weaken. The opposite would be true during an expansionary phase of a business cycle. The first intersection of the two curves, point A in Figure 2, describes the initial equilibrium vacancy and unemployment rate in the labor market. If the labor market becomes less efficient, i.e., frictional or structural unemployment increases, and the economy falls in a recession, the BC would shift to the right and the JCC would rotate to the right, leading to a new equilibrium point B. Under these circumstances, the new equilibrium would reflect a significantly higher unemployment rate, while the vacancies rate may be higher or lower than the initial level, depending on the extent of the BC's shift. On the contrary, if active labor market policies are implemented and can completely resolve all frictions and structural labor market challenges, while aggregate economic activity and the JCC remain the same, the BC would shift toward the origin, eliminating the vacancy rate and the unemployment rate. Empirically, however, unemployment and vacancies have historically persisted. Hence, the labor market model with search frictions explains the reality better than the neoclassical labor market model.

Given the 2007-2009 recession, the above-depicted model suggests that the JCC would rotate to the right, from JCC_1 to JCC_2 , and the economy would move along the BC_1 . This would lower the

Figure 2: Labor Market with Frictions and Mismatch

Source: Adapted from Pissarides (2011).

Notes: Vacancies Rate = Number of Vacancies/Labor Force; Unemployment Rate = Number of Unemployed/Labor Force.

vacancy rate and raise the unemployment rate, a prediction that is consistent with the 2007-2009 empirical data (FRED 2017). Is it possible that the BC has shifted to the right during that time as well? If so, the model predicts that a simultaneous rightward rotation of the JCC and a rightward shift of the BC would produce a substantially higher unemployment rate and an ambiguous change in the vacancies rate. Empirical studies suggest that the BC did shift to the right (Daly et al. 2012; Diamond and Sahin 2014), as illustrated in Figure 2, by a shift from BC_1 to BC_2 . According to the literature, the reasons behind this BC's outward shift included wage rigidity, mismatch between the competencies sought by employers and those actually possessed by the unemployed, differences in the geographical location of employers and prospective workers, information dissemination problems, coordination failures, unemployment insurance, and uncertainty over economic conditions (Pissarides 2011; Rothstein 2012; Daly et al. 2012). All of these factors effectively question the validity of the neoclassical assumptions and support the alternative theory of labor markets filled with frictions and structural mismatches.

Empirical Studies

Review of empirical studies on human capital shortages and mismatch between the supply and demand for labor, generalized here as the skills gap literature, revealed two distinct types of findings: some studies find evidence of skills gap, while others find no evidence of it. Partly, these divergent findings result from using different empirical measures of skills gap, such as educational attainment (Carnevale, Smith, and Strohl 2010; Cappelli 2015), wages (Holzer 2012; Levine 2013), outward shift of the Beveridge Curve (Daly et al. 2012; Davis, Faberman, and Haltiwanger 2013), competency mapping (Gurdjian and Triebel 2017), and surveys of employers reporting hiring difficulties (Career Builder 2017).

Educational attainment has been long-used as a proxy for human capital. Hence, studies that compare the workers' educational attainment to the jobs' educational requirements can shed some light on the skills gap debate. Carnevale, Smith, and Strohl (2010) estimate that by 2018 there will be a shortage of about three million workers with post-secondary degrees. This finding suggests that the U.S. economy is experiencing a human capital shortage. Cappelli (2015), however, makes an opposite conclusion and asserts that "overeducation remains the persistent and even growing condition of the U.S. labor force with respect to skills" (p. 251). Other opponents also argue that if skills gap was a real phenomenon, real wages would rise (Holzer 2012; Levine 2013). This, however, has not been the case, as mean real wages have remained stable since 2005 (Rothstein 2012).

Literature studying the Beveridge Curve shifts also yields mixed evidence of skills gap. On one side, the post-2007 increase in unemployment, unemployment duration, and vacancies intuitively support the skills gap hypothesis: unemployed workers cannot quickly find jobs because they lack the necessary skills, while companies cannot easily fill jobs because of a lack of qualified applicants. On the other side, empirical studies show that the increase in natural unemployment at the time was largely a result of the extension of unemployment insurance benefits, with skills gap playing only a very limited role (Daly et al. 2012). Studies examining the increase in unemployment by sector, occupation, and geographic location (Sahin et al. 2011) found that the labor mismatch across industries and occupations was a statistically significant factor behind the higher unemployment rate, while the geographical mismatch was statistically insignificant. Nevertheless, Daly et al. (2012) emphasized that the recent increase in natural unemployment was transitory in nature. Hence, the rise in natural unemployment was caused by frictional and not structural factors. It is structural unemployment, however, that is linked to the skills gap. This deeper investigation into the causes of natural unemployment growth suggests that the observed BC shifts were not directly linked to skills gap.

Numerous employer-driven studies consistently support the skills gap hypothesis (Deloitte 2015; Manyika et al. 2017; Career Builder 2017). For example, according to Career Builder (2017), 55% of employers reported that skills gap was negatively affecting their businesses, primarily by reducing workers' productivity, increasing employee turnover, and lowering morale and quality of work. According to Manyika et al. (2017), by 2020, the U.S. will have a shortage of 1.5 million workers with college degrees and a shortage of six million workers with a high school diploma. Further, Deloitte (2015) predicts that "over the next decade, nearly three and a half million manufacturing jobs likely need to be filled and the skills gap is expected to result in two million of those jobs going unfilled" (p. 2). These employer-based studies, however, are often criticized for being biased and not being scientifically designed (Cappelli 2015). Neutral, scientifically designed studies are scarce though. Also, extensive review of the literature for studies that looked at both, competencies held by workers and those required by employers, revealed only two such studies (OECD 2013; Weaver and Osterman 2017). An OECD (2013) report examined the occupational competencies possessed by workers and those required by employers and found that a significant proportion of workers reported a mismatch between the skills they possess and those required for their jobs. Weaver and Osterman (2017) carried out a scientifically designed national survey of manufacturing employers and workers and found that, at most, 16% to 25% of manufacturing firms face the skills gap.

Empirical studies on the transportation skills gap are even more limited. The literature review revealed one study by the U.S. Department of Education (2015). The study utilized the U.S. Bureau of Labor Statistics data and the Economic Modelling Specialists International reports to analyze skills gap in the transportation industry. According to this study, from 2012-2022, growth in the transportation sector and job separations would lead to the hiring of 4.6 million transportation workers. Most of these jobs, 4.2 million to be exact, would be a result of retirements and occupational transfers, as 53% of U.S. transportation workers are currently 45 years or older. The study projects

that the highest demand for transportation workers will be in the operation and maintenance field. Further, the study estimates that the annual job openings in the transportation sector will be 68% higher than the number of college graduates with relevant degrees. All of these facts point to significant skill shortages in the industry and explain the calls for developing a trained and qualified workforce for the transportation sector. As a solution to these skills gap challenges, the study recommends using the Career Pathways Models, a collaboration among educational institutions, business community, and workers. The idea is to build the education and training strategies that would help individuals obtain the industry-related certifications and employment. The Employment and Training Administration (2007) has supported this recommendation by investing around \$80 million in various training programs related to the transportation industry.

SKILLS GAP INDICATORS

In line with the labor market model with search frictions, in which unemployment and vacancies co-exist, in this section we propose four new skills gap indicators that identify and measure the extent of KSA gaps among the transportation and materials moving workers and assess the impact of KSA gaps on employers. While the above-described model with search frictions (Pissarides 2011) focused on the initial matching of the unemployed with vacancies, this paper extends this theory by matching the skills of all workers, employed and unemployed, with jobs. Specifically, the view presented in this paper is that job matching is a continuous process. As jobs evolve, even the employed workers may develop skill gaps, so they may no longer meet the job requirements but may be maintained by their employer due to labor contracts and other reasons. Such skills gap among the employed, however, can also cause productivity losses and other negative effects mentioned earlier. Hence, this paper argues that skills gap is not only a problem applicable to the unemployed, but also those employed as well. Further, we argue that not all of the unemployed lack the KSAs needed for a job, but they may remain unemployed because of inefficiencies in the labor market matching process, as some may be looking in a wrong location, industry, or occupation. Hence, due to such inefficiencies, the unemployed and jobs may be simply mismatched.

As stated earlier, skills gap is defined in this study as a significant or severe mismatch between the KSAs required by employers and those actually held by workers. Our indices are designed with a theoretical framework in mind similar to Shimer (2007): “Many local labor markets, each of which represents a particular geographic location and a particular occupation. The wage clears each market at each instant, but there may be unemployed workers in one market and job vacancies in another” (p. 1075), as “two wages [are] paid, $p(t)$ to workers in markets with vacancies and z to all other workers” (p. 1097). Likewise, we do not aggregate the labor market; instead we focus on the transportation and materials moving occupational labor market within a specific geographic location, northwest Wisconsin, with the goal of identifying which KSAs are lacking in the market and to what extent. Further, similar to the labor market model with search frictions, we do not attribute all vacancies to the structural or skills gap factors. Instead, we differentiate and identify the proportion of vacancies that were difficult to fill due to the skills gap, with the rest attributed to low wages and labor market inefficiencies. Low wages can actually perpetuate a vicious cycle: if wages offered by the employers are set too low, current workers with the necessary skills would not apply for the open positions, while prospective workers would not have the incentives to pursue the KSAs needed for this occupation. The ensuing lack of applicants, however, should not be immediately interpreted as evidence of skills gap, as higher wages would have attracted the qualified applicants. Hence, before confirming the skills gap, it is important to know whether the employers with vacancies offered higher wages to prospective workers or not. To differentiate between the vacancies that were difficult to fill due to low wages and skills gap, we build in wage questions in our survey of employers and workers.

Finally, while many existing studies proxy the skills gap by surveying only employers and documenting the percentage of respondents who reported facing hiring difficulties or by citing the number of jobs that allegedly went unfilled because of skills gap (Deloitte 2015; Career Builder 2017), this study uses data from a survey of both employers and workers to quantitatively assess the exact competencies or KSAs lacking in the transportation workforce. Hence, the indices proposed below communicate information from both sides of the labor market, workers and employers:

$$\text{Occupational skills gap } j = \frac{\text{Labor force lacking } j}{\text{Labor force}}$$

$$\text{Employed skills gap } j = \frac{\text{Employed lacking } j}{\text{Labor force}}$$

$$\text{Unemployed skills gap } j = \frac{\text{Unemployed lacking } j}{\text{Labor force}}$$

$$\text{Vacancy skills gap } j = \frac{\text{Vacancies with applicants lacking } j}{\text{Total vacancies}}$$

In the indices proposed above, *j* stands for the occupational knowledge, skill, or ability. The exact classification of *j*-KSAs follows the Occupational Information Network (O-NET) classification of occupational competencies.³ Generally, the higher the index value the higher the extent of a respective *j*-KSA gap. The details of each index are explained below:

- The occupational skills gap index measures the percentage of labor force within the occupation that has a major or severe lack of *j*-KSA.⁴ This index is estimated using data from the survey of workers. The purpose of this index is to identify the specific KSAs that all transportation and materials moving workers lack, regardless of whether they are employed or unemployed, and the extent of the specific *j*-KSA gap. By identifying these specific KSA gaps, this study contributes to the existing literature, as recommended by Handel (2003).
- The employed skills gap index measures how many employed as the percentage of labor force have a major or severe lack of *j*-KSA. This index is estimated using data from the survey of workers. The purpose of the index is to proxy productivity losses resulting from having a less than qualified worker performing a job. Hence, this index contributes to the existing literature by extending the skills gap analysis beyond the unemployed.
- The unemployed skills gap index measures how many unemployed as the percentage of labor force have a major or severe lack of *j*-KSA. This index is estimated using data from the survey of workers. The purpose of the index is to identify the specific *j*-KSAs that are lacking among the unemployed and the extent of such gaps.
- The vacancy skills gap index measures the percentage of vacancies within the occupation that were difficult to fill because the applicants had a major or severe lack of *j*-KSA. This index is estimated using data from the survey of employers. The purpose of the index is to identify the specific *j*-KSAs that are severely lacking among the workers, from the employers' point of view, and measure the impacts of these skill shortages on the employers.

SURVEY METHODOLOGY

This paper's survey data and methodology are based on a larger skills gap study by Simkins et al. (2015). Due to funding sources, the study's data collection was limited to 10 counties in northwest Wisconsin, namely Ashland, Bayfield, Burnett, Douglas, Iron, Price, Rusk, Sawyer, Taylor, and Washburn. The original survey covered 16 industries, 20 occupations, and 29 KSAs. The methodology behind this original study is described below.

Simkins et al. (2015) survey data were generated by surveying both employers and workers.⁵ Survey respondents were drawn randomly from the ReferenceUSA database.⁶ To collect data, survey packets were mailed to 2,000 businesses and 1,000 workers in the study area.⁷ Both respondent groups, workers and employers, were asked to complete the survey and return it by mail or by answering a web-based version of the survey. All survey responses were kept anonymous. To encourage participation, survey incentives were offered five randomly selected \$50 Amazon gift cards for businesses and 100 randomly selected Redbox movie rental codes for workers. Survey responses were collected from March 2015 through mid-May 2015, with survey reminders sent several weeks after the initial surveys were mailed. Of the 2,000 business surveys distributed, 236 were returned as undeliverable and 126 surveys were completed, which yielded a response rate of 7.14% and a theoretical margin of error of 8.63%.⁸ Of the 1,000 worker surveys distributed, 113 surveys were completed, which yielded a response rate of 11.3% and a theoretical margin of error of 9.21%.⁹ The collected data were then processed as follows: first, to categorize and code all employers and industries appropriately, reported industry information was validated and write-in responses were re-coded; second, BLS two-digit occupational classification codes were used to categorize all reported workers' occupations; finally, labor force status and other entries were verified for data entry errors and corrected as appropriate.

This paper draws on a subset of data from the above-described, original survey by focusing on the transportation and materials moving occupations. Specifically, the indices presented below were computed using data from 21 employers, who reported having 23 vacancies in transportation and materials moving occupations, and seven workers who reported transportation and materials moving as their occupational classification. Given these small sample sizes, skills gap indicator results discussed below should be interpreted with caution, as they are not representative of the national labor market. However, the study's findings offer several interesting insights to the transportation stakeholders.

SKILLS GAP INDICATOR RESULTS AND ANALYSIS

Table 1 illustrates the computed skills gap indices for the transportation and materials moving occupations. When considering these results, keep in mind that the first two indices were computed using the workers' survey responses, while the last index, the vacancy skills gap index, was computed using the employers' survey responses. The unemployed skills gap index could not be computed because there were no unemployed transportation and materials moving workers among those who responded to the survey. Also, the occupational and the employed skills gap indices returned the same value because there were no unemployed captured in the survey.

A review and analysis of the occupational and the employed skills gap indices reported in Table 1 reveal that the transportation and materials moving workers are primarily concerned with knowledge gaps. In select knowledge areas, e.g., knowledge of business management, marketing and sales, computers and information technology, and audio/video technology and communications, 75% of the responding occupational labor force reported having major and severe gaps. In contrast, according to the vacancy skills gap index, employers reported more concerns over the workers' skill gaps, as opposed to the knowledge gaps. Specifically, employers reported that 38% of their occupational vacancies were difficult to fill because the applicants had major and severe gaps in the equipment operation skills. Also, 24% of occupational vacancies were difficult to fill because the applicants had major and severe gaps in equipment maintenance, repair, and troubleshooting skills. A comparison between the employer-reported vacancy skills gap index and the worker-reported occupational skills gap index revealed that employers reported KSAs as being particularly difficult to find in applicants, but workers reported having no gaps. For example, employers reported that 19% of their vacancies were difficult to fill because the applicants had major and severe gaps in knowledge of transportation, distribution, and logistics. At the same time, 0% of workers reported

Table 1: Skills Gap Indices for Transportation and Materials Moving Occupations

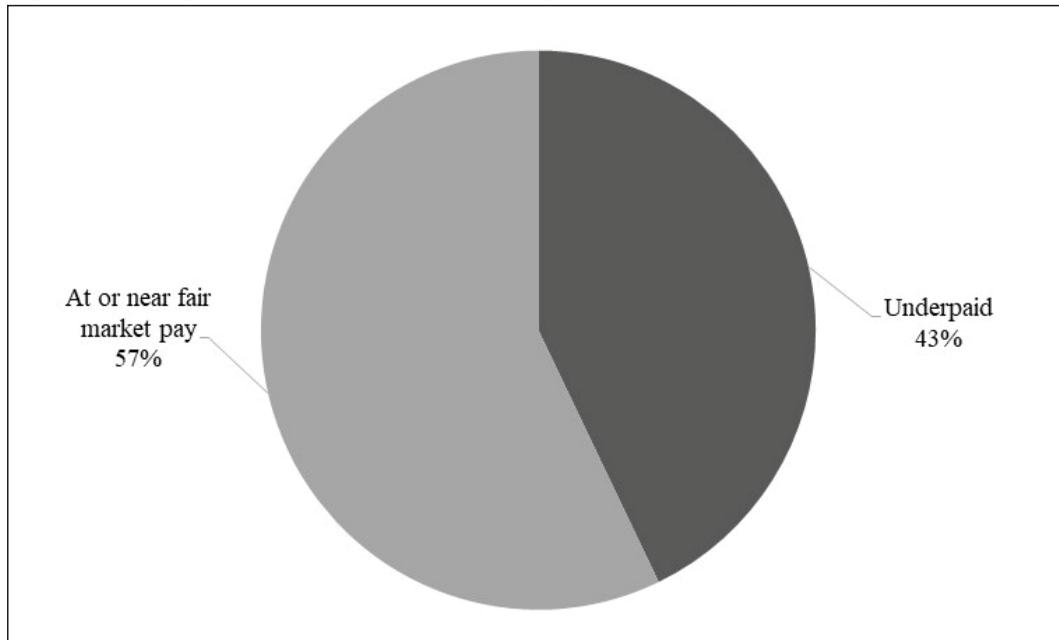
KSA	Occupational Index	Employed Index	Vacancy Index
Knowledge			
Knowledge of administrative rules and procedures	25%	25%	5%
Knowledge of business management, marketing and sales	75%	75%	10%
Knowledge of computers and information technology	75%	75%	10%
Knowledge of audio/video technology and communications	75%	75%	5%
Knowledge of machines, tools and equipment	0%	0%	19%
Knowledge of production processes and practices	25%	25%	10%
Knowledge of transportation, distribution and logistics	0%	0%	19%
Skills			
Business operation skills	25%	25%	10%
Judgment and decision-making skills	25%	25%	10%
Critical thinking and problem-solving skills	25%	25%	14%
Work prioritization and resource management skills	0%	0%	14%
Oral and written communication skills	50%	50%	5%
Listening and reading comprehension skills	25%	25%	5%
Customer service skills	0%	0%	5%
Interpersonal relations and teamwork skills	25%	25%	5%
Equipment maintenance, repair and troubleshooting skills	0%	0%	24%
Equipment operation skills	0%	0%	38%
Math and analytical skills	50%	50%	0%
Abilities			
Intellectual abilities (e.g., ability to apply knowledge)	0%	0%	9%
Physical abilities (e.g., strength and endurance)	25%	25%	5%
Psychomotor abilities (e.g., limb coordination, reaction time)	0%	0%	10%
Sensory abilities (e.g., hearing, vision)	25%	25%	10%

Source: Authors' calculations.

Notes: Unemployed skills gap index could not be computed because there were no unemployed transportation workers among those who responded to the survey.

having knowledge gaps in this area. Similarly, according to employers, 38% of vacancies were difficult to fill because the applicants had major and severe gaps in equipment operation skills, yet workers reported having no gaps in this specific skill set. These divergent views on occupational KSA gaps suggest that a mismatch in perceptions exists between the KSAs employers are looking for and the KSAs workers think they need for a given job. This mismatch in perceptions, in turn, explains why workers may be developing competencies different from those sought by employers, and why the employers' complaints about skills gap are not completely unsubstantiated.

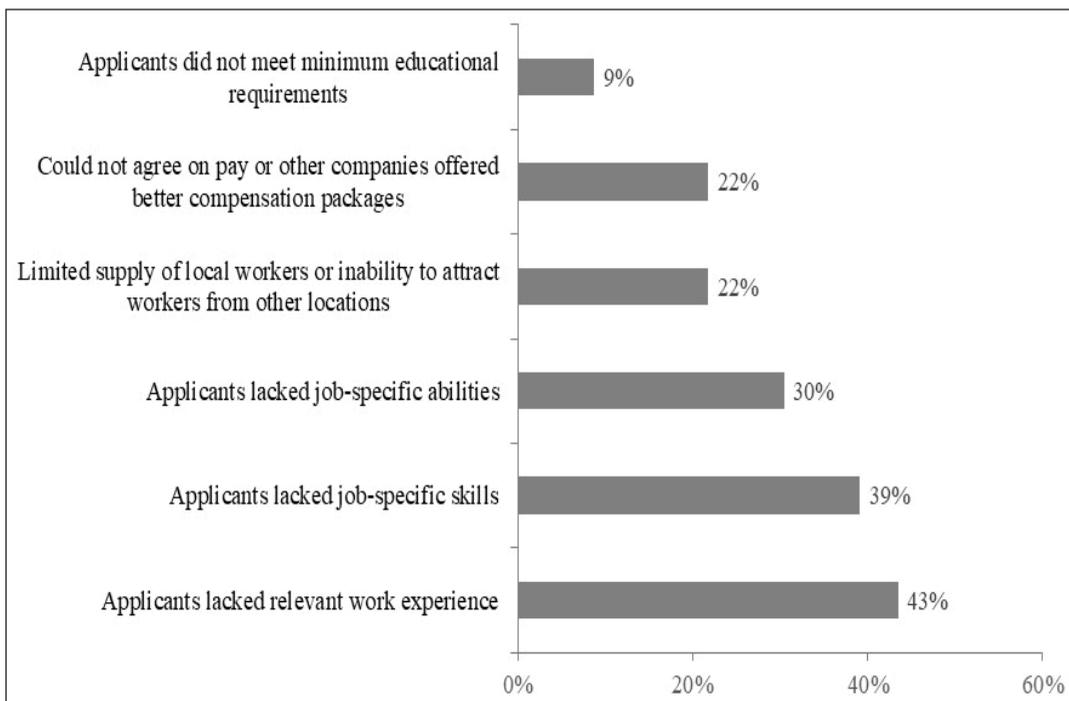
Figure 3: Transportation and Materials Moving Workers' Perceptions on Pay



Source: Authors' calculations.

As discussed in the literature review, skills gap opponents often argue that employers find it difficult to fill vacancies not because of the skills gap but because they do not pay fair wages. To determine whether wages have played a role in our study, we built in wage questions in the employer and worker survey. According to our survey findings, illustrated in Figure 3, 57% of workers engaged in the transportation and materials moving occupations reported being at or near their fair market pay, whereas the other 43% reported being underpaid. Further, as illustrated in Figure 4, employers reported that 22% of the transportation and materials moving vacancies were difficult to fill because they could not agree on pay with their candidates, or other companies offered better compensation packages to their preferred applicants. This finding is consistent with the larger data sample (Simkins et al. 2015), where 27% of employers reported inadequate pay as being one of the reasons behind their hiring challenges. Hence, while inadequate wages do account for a portion of hiring difficulties, the majority of difficult-to-fill transportation and materials moving vacancies were a result of gaps in job-specific KSAs and lack of relevant work experience (see Figure 4). According to Table 1, the transportation and materials moving workers' KSA gaps were found to be particularly extensive in the following areas: equipment operation, maintenance, repair and troubleshooting skills; knowledge of machines, tools, and equipment; knowledge of transportation, distribution, and logistics; ability to apply knowledge; critical thinking and problem-solving skills; and work prioritization and resource-management skills.

Figure 4: Employers' Reasons for Hiring Difficulties, % of Transportation Vacancies



Source: Authors' calculations.

CONCLUSION

This study quantitatively assessed the skills gap in transportation and materials moving occupations by using data from a survey of both employers and workers. Four innovative indices were used to quantify the transportation workforce skills gap. The results point to a misalignment in the occupational competency expectations: what employers are looking for is difficult to find because the workers' perceptions about KSAs needed for a job are different from those sought by the employers. Specifically, according to this study, employers reported that the transportation and materials moving occupation workers have particularly extensive KSA gaps in the following areas: knowledge of transportation, distribution, and logistics; knowledge of machines, tools, and equipment; equipment operation, maintenance, repair and troubleshooting skills; critical thinking and problem-solving skills; work prioritization and resource-management skills, and ability to apply knowledge. These KSA gaps explain the employers' difficulties filling vacancies. At the same time, workers reported competency gaps predominantly in the knowledge areas, which were also different from those reported by employers. This divergence in workers' and employers' perceptions of KSAs needed for a job illustrates that skills gap is a real phenomenon among transportation and materials moving workers. Unfortunately, we were unable to differentiate between the KSA gaps of the employed and the unemployed transportation and materials moving workers, as no unemployed transportation workers responded to our survey. Employer and worker survey responses suggest, however, that the KSA gaps are not the only reason behind the employers' hiring challenges. Inadequate pay accounted for about 22% of the difficult-to-fill transportation vacancies, and lack of relevant work experience accounted for about 43% of these vacancies. Unresolved skills gap arising from the differences in employers' and workers' perceptions about the KSAs needed for a job and inadequate pay can lead to larger skills shortages in the future.

Given the KSA gaps identified in this study and the analysis presented above, we recommend several approaches to lessen the transportation and materials moving occupations skills gap. First, it is critical to align the employers' and workers' expectations as to what KSAs are necessary to perform a given job. To do so, employers may want to partner with workforce development agencies, colleges, and similar organizations to develop the employer-specific KSA training programs that directly reflect their needs. Second, since certain skills are best developed through on-the-job training, employers may want to establish the ongoing apprenticeship programs and work with outside parties to develop real-world simulations for novice workers. Alternatively, employers may need to develop their own internal workforce training programs. Vinci (2008) describes a successful example of one such internal workforce training program, which was started by the Tri-County Metropolitan Transportation District of Oregon in 2008. Third, to reduce the labor market frictions and mismatches, active labor market policies, such as government-funded job-search assistance and employment incentives programs, should be explored. Finally, to avoid productivity losses associated with the employed lacking adequate skills, incentives need to be built in for workers to continue improving their KSAs.

Endnotes

1. The classification "transportation and materials moving" occupations was derived from the Occupational Information Network (O-NET) database.
2. Vaughan-Whitehead (2010) provides a comprehensive definition of a fair wage as a regular and full compensation for work that does not require longer hours and is based on education, skills, and experience (p. 66-67).
3. The detailed list of KSAs can be found in the survey questionnaire in Simkins et al. (2015).
4. Labor force in all indices is calculated as a sum of the employed and the unemployed within the occupation.
5. For survey questionnaires, see Simkins et al. (2015).
6. ReferenceUSA is a subscription-based database that contains records of 24 million U.S. businesses and 147 million U.S. residents.
7. Sample sizes were determined based on projected response rates and the goal to obtain a margin of error of about 5% for each survey group.
8. Margin of error was computed based on N=5,234 business establishments in 10 counties and n=126 completed business surveys. The calculations were based on a margin of error formula with finite population correction, 95% confidence level, and an equal split in opinions.
9. Margin of error was computed based on N=88,466 labor force in 10 counties and n=113 completed worker surveys. The calculations were based on a margin of error formula with finite population correction, 95% confidence level, and an equal split in opinions.

References

Cappelli, Peter H. "Skill Gaps, Skill Shortages, and Skill Mismatches: Evidence and Arguments for the United States." *ILR Review* 68 (2), (2015): 251–290.

Career Builder. “The Skills Gap Is Costing Companies Nearly \$1 Million Annually.” Press Room, Career Builder, 2017. <http://press.careerbuilder.com/2017-04-13-The-Skills-Gap-is-Costing-Companies-Nearly-1-Million-Annually-According-to-New-CareerBuilder-Survey>.

Carnevale, A., N. Smith, and J. Strohl. “Help Wanted: Projections of Jobs and Education Requirements Through 2018.” Center on Education and the Workforce. Georgetown University, Washington, D.C., 2010. <https://cew.georgetown.edu/cew-reports/help-wanted/>.

Costello, B. and R. Suarez. “Truck Driver Shortage Analysis.” American Trucking Associations, 2015. <http://www.trucking.org/ATADocs/NewsandInformation/ReportsTrendsandStatistics/10062015ATAsDriveShortageReport2015.pdf>.

Cronin, Brenda. 2014. “Help Wanted: Jobs in Trucking Go Unfilled.” *Wall Street Journal*, July 7, 2014. <http://www.wsj.com/articles/help-wanted-jobs-in-trucking-go-unfilled-1404770060>.

Daly, M.C., B. Hobijn, A. Şahin, and R.G. Valletta. “A Search and Matching Approach to Labor Markets: Did the Natural Rate of Unemployment Rise?” *Journal of Economic Perspectives* 26 (3), (2012): 3–26.

Davis, S.J., R.J. Faberman, and J.C. Haltiwanger. “The Establishment-Level Behavior of Vacancies and Hiring.” *The Quarterly Journal of Economics* 128 (2), (2013): 581–622.

Deloitte. “The Skills Gap in U.S. Manufacturing: 2015 and Beyond,” 2015. <http://www.themanufacturinginstitute.org/~media/827DBC76533942679A15EF7067A704CD.ashx>.

Diamond, Peter. “Structural Unemployment.” Research Department Public Policy Briefs No. 13-6. Federal Reserve Bank of Boston, 2013. <https://www.bostonfed.org/publications/public-policy-brief/2013/structural-unemployment.aspx>.

Diamond, P.A. and A. Sahin. “Shifts in the Beveridge Curve.” Staff Report No. 687. Federal Reserve Bank of New York, 2014. https://www.newyorkfed.org/medialibrary/media/research/staff_reports/sr687.pdf.

Dow, J.C.R. and L.A. Dicks-Mireaux. “The Excess Demand for Labour. A Study of Conditions in Great Britain, 1946-56.” *Oxford Economic Papers* 10 (1), (1958): 1–33.

Employment and Training Administration. *High Growth Industry Profile: Transportation*. U.S. Department of Labor, 2007. <https://www.doleta.gov/BRG/pdf/Transportation.pdf>.

FRED. *Vacancy to Unemployment Ratio*. Federal Reserve Bank of St. Louis, 2017. <https://fred.stlouisfed.org/series/DHIDFHVTUR>.

Gurdjian, P. and O. Triebel. “Identifying Employee Skill Gaps.” McKinsey & Company, 2017. <http://www.mckinsey.com/business-functions/organization/our-insights/identifying-employee-skill-gaps>.

Handel, Michael J. “Skills Mismatch in the Labor Market.” *Annual Review of Sociology* 29, (2003): 135–165.

Holzer, Harry J. “Job Vacancy Rates in the Firm: An Empirical Analysis.” *Economica* 61 (241), (1994): 17–36.

———. “Good Workers for Good Jobs: Improving Education and Workforce Systems in the US.” *IZA Journal of Labor Policy* 1(5), (2012): 1-19.

- Levine, Mark. "The Skills Gap and Unemployment in Wisconsin: Separating Fact from Fiction." Milwaukee, WI: University of Wisconsin-Milwaukee, Center for Economic Development, 2013. http://www4.uwm.edu/ced/publications/skillsgap_2013-2.pdf.
- Manacorda, M. and B. Petrongolo. "Skill Mismatch and Unemployment in OECD Countries." *Economica* 66 (262), (1999): 181–207.
- Manyika, J., S. Lund, B. Auguste, and S. Ramaswamy. "Help Wanted: The Future of Work in Advanced Economies." McKinsey & Company, 2017. <http://www.mckinsey.com/global-themes/employment-and-growth/future-of-work-in-advanced-economies>.
- OECD. "OECD Skills Outlook 2013: First Results from Survey of Adult Skills." OECD Publishing, Paris, 2013. http://www.oecd-ilibrary.org/education/oecd-skills-outlook-2013_9789264204256-en
- . "OECD Compendium of Productivity Indicators 2016." OECD Publishing, Paris, 2016. http://www.oecd-ilibrary.org/industry-and-services/oecd-compendium-of-productivity-indicators-2016_pdtvy-2016-en
- Pissarides, Christopher A. "Short-Run Equilibrium Dynamics of Unemployment, Vacancies, and Real Wages." *The American Economic Review* 75 (4), (1985): 676–90.
- . "Equilibrium in the Labor Market with Search Frictions." *The American Economic Review* 101 (4), (2011): 1092–1105.
- PWC. "Volume 5: Winning the Talent Race." *Transportation and Logistics 2030*, 2012. <http://www.pwc.com/gx/en/transportation-logistics/pdf/pwc-tl-2030-volume-5.pdf>.
- Rothstein, Jesse. "The Labor Market Four Years into the Crisis: Assessing Structural Explanations." Working Paper 17966. National Bureau of Economic Research, 2012.
- Sahin, Ayşegül, Joseph Song, Giorgio Topa, and Giovanni L. Violante. "Measuring Mismatch in the U.S. Labor Market," 2011. https://www.newyorkfed.org/medialibrary/media/research/economists/topa/USmismatch_v14.pdf.
- . "Mismatch Unemployment." *The American Economic Review* 104 (11), (2014): 3529–64.
- Shimer, Robert. "Mismatch." *The American Economic Review* 97 (4), (2007): 1074–1101.
- Simkins, Z., R. Mahjabeen, D. Johnson, and J. Hembd. "Northwest Wisconsin Skills Gap Analysis." Superior, WI: University of Wisconsin-Superior, 2015. https://static1.squarespace.com/static/576011158a65e232a69844bb/t/57b1c09146c3c4e559a7d133/1471266964511/SkillsGap+Report_Final.pdf.
- Social Security Administration. *Social Security Administration Annual Performance Plan for Fiscal Year 2012*. Social Security Administration, Publication 04-001, 2011. <https://www.ssa.gov/agency/performance/2012/APP%202012%20508%20PDF.pdf>.
- U.S. Bureau of Labor Statistics. *Employed Persons by Detailed Industry and Age*. U.S. Department of Labor, 2016. <https://www.bls.gov/cps/cpsaat18b.htm>.
- . *Mean Duration of Unemployment and Civilian Unemployment Rate*. FRED, Federal Reserve Bank of St. Louis, 2017a. <https://fred.stlouisfed.org/series>.

———. *Industries at a Glance: Transportation and Warehousing: NAICS 48-49*. U.S. Department of Labor, 2017b. <https://www.bls.gov/iag/tgs/iag48-49.htm>.

———. *Table 1. Job Openings Levels and Rates by Industry and Region, Seasonally Adjusted*. U.S. Department of Labor, 2017c. https://www.bls.gov/news.release/jolts.t01.htm#jolts_table1.f3.

U.S. Department of Education. *Strengthening Skills Training and Career Pathways Across the Transportation Industry*. Office of Career, Technical, and Adult Education. Washington, D.C., 2015. https://s3.amazonaws.com/PCRN/docs/Strengthening_Skills_Training_and_Career_Pathways_Across_Transportation_Industry_Data_Report.pdf.

U.S. Department of Transportation. *Grow America: Transportation Careers*, 2015. <http://www.dot.gov/grow-america/fact-sheets/careers>.

Vaughan-Whitehead, Daniel. “Fair Wages: Strengthening Corporate Social Responsibility.” Cheltenham, United Kingdom/Northampton, Massachusetts, United States, Edward Elgar Publishing, 2010.

Vinci, Sandy. “Leadership from Within: TriMet Develops Its Next Generation of Leaders Through the Operations Leadership Development Program.” *Journal of the Transportation Research Forum* 47(3), (2008): 185-189.

Weaver, A. and P. Osterman. “Skill Demands and Mismatch in U.S. Manufacturing.” *ILR Review* 70 (2), (2017): 275–307.

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Profile of Short Line Railroads in High Grain Production States

by Michael W. Babcock

INTRODUCTION

The Central Plains region leads the nation in many areas of agricultural activity. In terms of total production of corn, wheat, sorghum, and soybeans, Iowa leads the nation followed by Illinois, Nebraska, Minnesota, and Kansas. Because many locations in these states are remote from markets and processing centers they are somewhat dependent on railroads for transport of their grain.

After deregulation in 1980 the Class I railroads adopted a cost reduction strategy that involved the sale or lease of their branch lines to short line railroads. Today, in the eight leading states in wheat production, short lines collectively account for about one-third of the total track miles in that region. These short lines provide rail service to many rural shippers whose access to rail service might otherwise have been lost. Abandonment has several potential negative effects on rural areas such as lower grain prices received by farmers, higher transportation costs and reduced profits for rail shippers, loss of market options for rural shippers, foreclosed economic development options in rural communities, and higher road maintenance and reconstruction costs.

This paper analyzes how changes in the grain logistics system have affected short line railroad viability. For example, how have Class I shuttle trains impacted the role of short lines in the grain logistics system? Alternatively, how has the development of multi-short line holding companies affected the competitiveness of short lines relative to motor carriers?

Short lines play a critical role in originating and terminating grain transported by rail and promoting economic development along these lines. Particularly important is providing rail service to rural America and its link to the Class I rail network. In the decade following the passage of the Staggers Rail Act in 1980, more than 250 short lines were formed, adding to the approximately 220 short lines that existed as of 1980 (Llorens and Richardson 2014). Today, 562 short lines are operating (AAR 2016).

Definition of Short Lines

Three classes of railroads are designated by the Surface Transportation Board (STB) based on their operating revenue. In 2015, Class I railroads had \$457.9 million or more. Class II railroads had \$36.63 million or more but less than the Class I threshold. Class III railroads had less than the Class II minimum. These thresholds are adjusted annually for inflation (AAR 2016). All switching and terminal railroads are Class III.

The AAR identifies two groups of non-Class I railroads based on revenue and mileage characteristics. Regional railroads are line-haul railroads below the Class I revenue threshold operating at least 350 miles of road and earning at least \$20 million in revenue or earning revenue between \$40 million and the Class I revenue threshold regardless of mileage operated. Local railroads are line-haul railroads below the regional criteria as well as switching and terminal railroads (AAR 2016).

Objectives

The overall objective of the paper is to assess the state of the short line industry and its role in the grain logistics system, including who they are, where they are, and what agricultural products they

ship in what amounts in major grain corridors. Specific objectives are to identify the key factors that determine short line success or failure, compile a profile of a successful grain oriented short line railroad, identify infrastructure needs such as the ability to handle 286,000-pound GVW railcars, and trace the history of short line railroads since the Staggers Act.

Methodology

The methodology involves personal interviews and surveys of short line railroad executives and state departments of transportation (DOTs) rail personnel. The sample includes the states listed in Table 1. They were selected on the basis of large crop production and geographic diversity. They include Iowa, Illinois, Nebraska, Minnesota, Kansas, South Dakota, Indiana, North Dakota, Ohio, Missouri, Wisconsin, Texas, Michigan, Montana, Oklahoma, Idaho, and Washington. There is at least one agricultural oriented short line in each of these states. In some cases, a short line will own other short lines, so all together the sample includes 47 agriculture oriented short lines (i.e., Class II and III railroads).

Table 1: 2015 Ranking of Crop Production*
(thousands of bushels)

State	Production	Rank
Iowa	3,060,080	1
Illinois	2,593,816	2
Nebraska	2,067,816	3
Minnesota	1,903,834	4
Kansas	1,332,270	5
South Dakota	1,157,659	6
Indiana	1,114,680	7
North Dakota	950,803	8
Ohio	767,940	9
Missouri	663,885	10
Wisconsin	600,930	11
Texas	524,890	12
Michigan	472,795	13
Montana	238,738	14
Oklahoma	167,865	15
Idaho	160,120	16
Washington	128,805	17
*Includes corn, wheat, sorghum, and soybeans Source: U.S. Department of Agriculture, National Agricultural Statistics Services. <i>Annual Statistical Bulletin</i> .		

In the summer of 2016, personal interviews of short line personnel were conducted in the states of Kansas, Oklahoma, Missouri, Arkansas, Nebraska, Iowa, and Illinois. Nearly all the railroads interviewed completed a detailed survey. The rest of the sample short lines were contacted by phone and most of them completed the survey. The survey (available upon request) has five parts, which are General Questions, Traffic by Commodity, Equipment, Markets and Competition, and Short Line Success Profile.

Short line state DOT personnel of the 17 states were contacted by phone and nearly all of them completed a separate survey that included questions on the characteristics of the state short line assistance programs, eligibility requirements, benefits and costs, and the impact of short line assistance programs on short line profitability and rural economic development (available upon request).

THE STRUCTURE OF THE U.S. SHORT LINE RAILROAD INDUSTRY

Short line railroads (Class II and III railroads) have grown from 8,000 miles of track in 1980 to 47,500 miles in 2017 (ASLRRA 2017). In 2015 there were 24 Class II railroads and 579 Class III railroads (ASLRRA 2017, p. 12) that transport aggregates, chemicals, coal, lumber, paper, metal products, motor vehicles, petroleum products, and trailers and containers. Grain and food products rank second in 2015 short line carloads with slightly more than 1 million carloads, 12% of total 2015 carloads (ASLRRA 2017, p. 11).

The most significant change in the short line industry has been the consolidation of the Class III railroads under the control of holding companies. In 2014 there were 27 holding companies that control nearly 270 short lines (Federal Railroad Administration 2014). Holding companies have geographic and commodity diversity resulting in a lower risk of default on loans. Holding companies have relied on multiple sources of funds to finance infrastructure projects. Holding companies say there are still investments to be made particularly the upgrade of track to handle 286,000-pound rail cars as well as repair and replacement of bridges. Thus the consolidation trend is likely to continue.

LITERATURE REVIEW

Most short line railroad research in the last 20 years focuses on the economic benefits of short line railroads and the difficulty they face in maintaining their tracks and bridges.

Resor et al. (2000) conducted a study on the effects of 286,000-pound railcars on the U.S short line and regional railroad system. The objectives of the study were to estimate the amount of short line and regional railroad trackage that met minimum standards for the use of heavy axle load (HAL) rail cars, and to estimate the investment in components required to bring the entire short line and regional railroad system up to the minimum standard.

Resor et al. (2000) developed a survey of track conditions and characteristics for the U.S. short line and regional railroad industry. A questionnaire was sent to all American Short Line and Regional Railroad Association members and 46 railroads responded.

The study found that the U.S. 50,000-mile short line and regional railroad system would need 10,000 miles of new rail and 20 million ties to bring the entire system up to minimum standard. The total cost to upgrade the system to handle HAL cars was estimated at \$6.80 billion.

The Casavant and Tolliver study (2001) was designed to provide information on the potential impact of 286,000-pound railcars on light density track and short lines railroads in Washington state. The study assessed the likelihood of heavier cars being used, and it examined the condition of the track in the state. The study included technical analysis using railroad track models, and it was determined that 90 pounds per yard rail may perform marginally at slow speeds if there is good tie and ballast support. The authors concluded that 480 miles of track would need to be upgraded to handle the 286,000-pound rail cars at a cost of between \$250,000 and \$300,000 per mile with the total cost ranging from \$117 to \$140 million.

Bitzan and Tolliver (2001) discuss the economics of heavy covered hopper cars. The authors performed simulations of HAL cars to determine what track weight would handle HAL cars. Engineering equations were used to simulate track performance for light rail and for heavier rail. The authors found that any track of less than 90 pounds per yard to be inadequate for HAL rail car traffic.

Bitzan and Tolliver (2003) provided insights into specific areas where abandonment was likely to occur. Abandonment was treated as a result of inability to handle 286,000-pound rail cars and insufficient returns from investment in track upgrades. The study modeled a railroad's decision to upgrade as an investment decision. A firm will invest in a project as long as the internal rate of return to the project exceeds the return available from alternative investments. The investment decision approach to line upgrading was a unique aspect of this study.

The authors concluded that railroads were unlikely to upgrade a short line with traffic of less than 200 cars per mile. However, the study also discussed alternatives to abandonment. Longer term financing may allow short lines to upgrade track with traffic density of 150 cars per mile. They said increased revenue splits with Class I railroads and partial subsidies in the amount of avoided highway damage would also provide greater incentives to upgrade track.

Martens (1999) examined the effects of 286,000-pound rail cars on U.S. short line and regional railroads. He developed a 16-question survey, which was sent to 88 railroads with 39 being returned. The survey requested information on the amount of track miles likely to be closed or upgraded due to the use of HAL cars. It also requested the effects of HAL cars on train speed and how shippers would be affected. In addition, Martens (1999) analyzed the impacts of rail line abandonments attributable to the use of HAL railcars.

The study found that 38% of the U.S. short line rail system was incapable of handling 286,000-pound rail cars even at the slowest operating speeds. It was also determined that the average track upgrading cost for lines, which would otherwise be abandoned due to increased use of HAL cars, would be \$118,662 per mile.

Babcock and Sanderson (2006) published a study titled, "Should Short Line Railroads Upgrade Their Systems to Handle Heavy Axle Load Cars?" Motivated by lower costs per ton-mile, U.S. Class I railroads have been replacing 263,000-pound covered hopper cars with 286,000 pound cars. In many cases, short line railroads would have to upgrade their tracks and bridges to handle the heavier cars. The authors used rate of return analysis for a sample of U.S. short lines to determine if short line owners will likely upgrade their infrastructure or abandon the railroad. Analysis revealed that the total cost to upgrade 1,583 miles of mainline track and 1,352 bridges of five short lines in Kansas was estimated to be \$308.7 million. None of the short lines in the analysis can earn an adequate rate of return on upgrading track and bridge investment. If the short lines in the study are abandoned, the annual road damage cost will increase by over \$58 million.

The Iowa Department of Transportation study (2002) was motivated by the state's recognition of the need to assess the potential magnitude of rail line abandonment due to increasing use of HAL railcars. An important aspect of the study was the physical inspection of 97% of the short line track in Iowa. Track information such as weight and general condition was recorded during the inspection. Data were collected on the number of good ties per 39 feet of rail length and depth and condition of ballast. Tables from Resor (2000) were used to evaluate track components, and necessary upgrading costs were calculated using material and labor costs from railroads.

The minimum short term cost reflected immediate needs utilizing "marginal" rail and upgrading of ties and ballast to an "OK" status. The minimum short term upgrade cost was estimated at \$117,000 per mile or a total of \$297 million for the state. The study also determined a long-term cost of \$154,000 per mile.

Sage et al. (2015) develop an inventory of short line rail infrastructure that can be used to support a data-driven approach to identifying rail system needs. The study provided an inventory of existing infrastructure conditions on short line railroads in Washington state. It developed a detailed preliminary estimate of the total investment needed to bring the system up to modern industry standards. The study contained case studies highlighting the role short line railroads and regional transload centers play within the state's regional economies. The study provided a review of funding strategies employed by other states to support short line railroads.

Sage et al. found that more than 55% of all short line miles within Washington are not able to efficiently handle 286,000-pound rail cars. Overcoming this deficiency would require infrastructure investments of about \$610 million. The authors said that this need exceeds the current funding support by the state even if considered over a 20-year horizon with private industry and/or local jurisdictions providing significant matching funds. These authors also found that much of the existing short line system in Washington doesn't meet the state's current or future capacity and velocity needs for efficient operations. Productivity and safety of the system suffers from deferred maintenance. For example, over 55% of the short lines' road miles are less than 112-pound rail, the recommended weight to efficiently operate 286,000-pound rail cars.

Jared Llorens and James A. Richardson (2015) assess the economic role and impact of short line railroads in the state of Louisiana in "Economic Impact of Short Line Railroads." According to the authors, short line railroads are small but significant components of the state's business connections. They describe the scope and presence of the 11 short line railroads currently operating in Louisiana paying attention to their role in facilitating the transportation of goods to and from Class I railroads. Next they provide a detailed description of the broader economic contribution of short line railroads focusing on employment levels and industries served as well as estimates of the economic impact of the short line railroads on the state and selected regions of the state.

The authors found that short lines account for about 1,821 direct and indirect jobs in the state. They found that short lines directly support the state's leading industries (agriculture, oil, and gas), which represent the major drivers of the state's overall economy. These major industries support over 260,000 jobs or close to 15% of all jobs in the state. Also these core industries create the opportunity for other businesses to be successful. Also they discuss short line policies that should be considered by Louisiana. These would include (1) state rehabilitation grants, (2) state loan programs, and (3) state loan/grant hybrid programs.

The U.S. Department of Transportation, Federal Railroad Administration examines short line capital needs and government assistance programs in *Summary of Class II and Class III Railroad Capital Needs and Funding Sources (2014)*. The report says short line railroads have relied on state and federal programs to invest in infrastructure and maintain facilities. Many states have robust programs to assist short line railroads. At the federal level, short lines can access loans through the Railroad Rehabilitation and Improvement Financing (RRIF) program. Also, the Transportation Infrastructure Generating Economic Recovery (TIGER) Program has a competitive grants program. The 456 tax credit is another federal assistance program. The report notes that many states have implemented short line railroad assistance programs that provide low interest loans and grants to improve service, upgrade tracks and bridges, and add capacity. Local benefits of the assistance programs include increased farm and business opportunities, shipper cost saving, and avoided business closures.

Qiao et al. authored *Transportation and Economic Impact of Texas Short Line Railroads (2010)*. The authors sent survey invitations to 43 Texas short line railroads, and 20 responses were received. The software IMPLAN was used to measure the economic impact of short line railroads at both the state and county levels. A transportation impact analysis was conducted to estimate the cost by rail and the cost by truck. Shipping cost, safety cost, maintenance cost, highway congestion costs, and emission cost were calculated in the analysis. Results indicated that, on average, the shipping cost of a short line is 7.5% less than truck. The total transportation cost of short lines is 24.3% less than that of truck. The estimation also shows that the operation of 14 surveyed short lines took 417,177 trucks off Texas highways in 2015. The economic impact analysis results indicate that, at the state level, the operation of short line railroads in Texas contribute about 1,416 jobs, \$113,769,627 in labor compensation, and \$354,443,588 in economic output.

The report also found that Texas short lines have substantial infrastructure needs. The need for more state funding was mentioned by several railroads during the survey and interviews. As Texas short lines play a significant role in the state economy, there is a necessity to establish assistance

programs for short lines to help maintain and improve the existing infrastructure according to the authors. However, most Texas short lines do not have sufficient revenues or access to the large amounts of capital necessary to rehabilitate their infrastructure. Track and bridge conditions often cause short lines to operate at minimal train speed, which reduces operating efficiency and limits their ability to attract new business to the line.

FEDERAL AND STATE SHORT LINE FINANCIAL ASSISTANCE PROGRAMS

Many short lines have deferred maintenance but not enough revenue to fund it. Given the significant public benefits of short lines, the federal government and many states have instituted financial assistance programs to help them develop their infrastructure. Many states have short line assistance programs with the goal of ensuring transportation options and maintaining a balanced transportation program.

Federal Programs

Since 1998, the RRIF program has provided \$70 million in loans to Class II and III railroads (Sage et al. 2015). The act and its amendments provided loans to improve or rehabilitate intermodal facilities and railroad equipment of Class II and III railroads.

In 2009, the American Recovery and Reinvestment Act (ARRA) was passed. It is more commonly known as Transportation Investment Generating Economic Recovery (TIGER). TIGER grants are typically used to leverage other funds for larger projects (Sage et al. 2015).

In 2004, a federal short line tax credit, commonly known as a 45G, was passed to enable and encourage private investment in rail line rehabilitation. The 45G is a federal tax credit for up to 50% of track maintenance and qualified infrastructure expenses. The credit is allowable up to the product of \$3,500 by the sum of the number of miles of railroad track owned or leased and the number of miles assigned to the taxpayers by a Class II or III railroad (Sage et al. 2015, page 25).

State Programs

State assistance to short lines can be classified into three categories: (1) rehabilitation grants, (2) loan programs, and (3) loan/grant hybrid programs. The first awards funds on a competitive basis for capital improvements that directly benefit economic development interests (Llorens and Richardson 2014). This would include construction of a new line, existing track upgrades, or construction of rail yards.

State loan programs are intended to provide financing alternatives for short line railroads where there may not be viable financing for capital improvements. This would include rail track upgrades, as well as purchasing or rehabilitating rail equipment necessary to maintain essential rail service.

Loan/grant hybrid programs combine elements of both grants and loans. While the state programs differ in form, they all support the goal of maintaining a viable short line network in their state, given the challenge of handling 286,000-pound railcars (Llorens and Richardson 2014). Questions 1 and 2 of the DOT survey (available upon request) deals with the characteristic and eligibility requirement aspects of short line assistance programs of the sample states with the exception of Nebraska, South Dakota, and Texas, which do not have assistance programs for short lines.

COSTS, BENEFITS AND RURAL ECONOMIC DEVELOPMENT IMPACTS OF STATE SHORT LINE ASSISTANCE PROGRAMS

Questions 3 and 4 of the survey deals with the economic effects of the state short line assistance programs. A sample of the responses included Idaho, Iowa, Kansas, Minnesota, and North Dakota.

According to Idaho DOT, the primary benefit of the assistance programs is facilitating the short line railroad's ability to upgrade aging tracks while maintaining profitability with low profit margins. In particular, the track upgrades have enhanced the short line's ability to connect to the Class I railroad in southern Idaho.

The Idaho assistance program allowed the short line to upgrade tracks and make essential connections to Class I railroads in Idaho that had a positive effect on the railroads' profitability. This allowed the short line to serve the agricultural community in the region.

According to Iowa DOT, some short lines have made improvements to encourage business development, increase yard efficiency, and improve resiliency in the event of future flooding that they may not have been able to make without the Railroad Revolving Loan and Grant (RRLG) program funding. Several short lines have made good use of the funding, creating opportunities for rural economic development while increasing revenue. Other short lines have been able to increase the level of service to customers with yard or line improvements.

Kansas DOT rail officials said the short line railroad assistance plan has had many benefits, including continued rail service (lines that would have been abandoned were not), improved customer service (car turn time improved service schedule). Other benefits include improved operating efficiencies (increased operating speeds, improved use of crew time, and removal of slow orders). It also increased rail carloads, resulting in fewer trucks on the highways and reduced highway maintenance costs. The Kansas State Rail Service Improvement Fund (SRSIF) has improved short line profitability through improved operating efficiencies, which allows the railroads to put additional funds into their capital maintenance programs.

The SRSIF has had a positive economic impact on rural economic development in that short lines that may have been abandoned were not. Service continued, providing rural shippers a more cost effective shipping method for both outbound and inbound carloads.

According to Minnesota DOT rail program officials, the typical benefits of rail rehabilitation projects are decreased travel time, resulting in decreased costs for customers. Additional benefits include decreased railroad maintenance costs. Also, if a rehabilitation project increases the maximum rail car weight that can be shipped on the line, additional operating efficiencies can be realized and passed on to shippers. Another benefit is decreased wear and tear on highways if highway shipments are diverted to rail, or if existing shipments on rail stay on rail because of more competitive rail service.

The Minnesota officials pointed out that many small communities have medium-sized businesses that are rail dependent to both ship and receive goods. The loss of rail service would be detrimental to these businesses because the high cost of other modes may be unsustainable. The Minnesota Rail Service Improvement Plan (MRSIP) program provides short lines with financing tools to improve rail service and, in some cases, prevent rail lines from embargo due to track condition and capital needs. Often, the availability of such financing tools is either absent in the private market or the cost is unrealistic for the viability of the line.

The Wisconsin DOT rail program personnel said that Wisconsin has a program, the Freight Railroad Preservation Program, which is a grant program that provides up to 100% funding for line acquisition and up to 80% funding toward the cost of rehabilitation of publically owned lines to preserve essential rail service.

The FRPP has benefitted Wisconsin by facilitating rehabilitation of rail lines and preserving essential rail service. It has resulted in a broad array of improvements to the rail system, such as rail-related projects like loading and transloading facilities.

According to Wisconsin DOT rail program personnel, Wisconsin programs are designed to provide capital that enhances transport efficiency. Thus, the assistance programs succeeded in preserving freight railroad lines that are economically feasible. The program reduces the cost of capital for facilities, thus improving their profitability and reliability in servicing the shippers. Since 1980, if measured by gross carloads and carloads per mile, the number and size of shippers on assisted lines have grown substantially.

RESULTS OF THE SHORT LINES AND AGRICULTURE SURVEY

The principal data source for this study is the survey administered to 47 short line railroads (Class II and III railroads). A few railroads had incomplete surveys, but additional information to complete the survey was obtained for the railroads that were visited on-site in the summer of 2016. The personal visits occurred in Kansas, Missouri, Arkansas, Oklahoma, Nebraska, Iowa, and Illinois. The survey contains five parts which are:

- Part A – General Questions
- Part B – Traffic
- Part C – Equipment
- Part D – Markets and Competition
- Part E – Short Line Success Profile

Results – Part A

Part A contains general information about the agriculturally oriented railroads. Part A requests the following information:

- When did the railroad begin operating?
- Employment?
- Ownership?
- Route miles?
- How many track miles can handle 286,000-pound rail cars?
- Connecting railroads?
- Received state government financial assistance?
- Received federal government financial assistance?

Table 2 contains the results for initiation of operations. As indicated by the data in Table 2, about 42% of the sample railroads began operating in the 1990s. The 2000s accounted for about 29% and the 1980s for about 27%. Therefore, 98% of the sample railroads began operations after the Staggers Rail Act was passed in October 1980.

Table 2: Decade of Start of Operations of Agriculture-Oriented Short Lines

Decade	Number of Railroads	Percent of Total
2000s	12	29.3
1990s	17	41.5
1980s	11	26.8
1970s and earlier	1	2.4

Employment per railroad varies from two to 1200. The top nine accounted for nearly 70% of the total employment. The top railroad alone had nearly 30% of total sample railroad employment. Railroads with 100 employees or more together accounted for 44.2% of total sample railroad employment of 4,038.

Table 3 contains track mile data and miles of track capable of handling 286,000-pound rail cars. The track miles of the sample short lines vary widely from a low of 29 to a high of 937. A total of 14 railroads said that 100% of their track miles are capable of handling HAL (heavy axle load) railcars, i.e., 286,000-pound cars while only five railroads said that none of their track miles can support the heavier cars. For 39 short line sample railroads, total track miles are 11,094 while track miles capable of handling HAL cars is 7,358, or 66.3% of the total miles.

The higher the number of connections, the greater the revenue since the short line would have access to more Class I railroad equipment and access to more markets. Also the greater the number of connections the greater bargaining leverage over revenue splits with Class I railroads. A total of 10 of the 41 sample railroads have connections to one railroad and are thus “captive” to the connecting railroad. However, the mean number of connections is about three.

Of 42 sample short lines, 28 reported that they received state assistance in the last five years, and 14 reported that they had not received state assistance. A total of 25 short lines reported that they received federal assistance (mainly 45G tax credits) and 17 said they had not received federal assistance in the last five years.

Results of Short Line and Agriculture Survey-Part B

This section provides agricultural-related traffic by commodity, which are:

- Originated-agricultural-related traffic that originates on your railroad and terminates on another railroad.
- Terminated-agricultural-related traffic that originates on another railroad and terminates on your railroad.
- Local-agricultural-related traffic that originates and terminates on your railroad.
- Overhead-agricultural-related traffic handled by your railroad but which originates and terminates on other railroads.

Table 3: Percent of Total Track Miles That Are Capable of Handling 286,000-Pound Rail Cars

Total Track Miles	286,000 Miles	Percent
937	875	93
904	159	18
850	850	100
802	802	100
600	555	93
576	391	68
561	82	15
512	273	53
433	24	6
400	350	88
359	324	90
356	205	58
347	0	0
300	300	100
276	276	100
265	178	67
253	180	71
250	159	64
237	0	0
221	221	100
155	155	100
147	4	3
143	143	100
135	0	0
130	130	100

Total Track Miles	286,000 Miles	Percent
122	122	100
104	93	89
94	94	100
87	87	100
87	75	86
68	68	100
63	32	51
57	57	100
56	32	57
53	15	28
44	44	100
40	3	8
38	0	0
29	0	0
Grand Totals:		
11,094	7,358	66.3%

2015 Originated Carloads by Commodity

Table 4 displays the top nine 2015 originated commodities in terms of carloads. Of course the sample short lines ship many more commodities than those in Table 4, but these nine were largest commodity groups shipped by the 47 sample short line railroads. Table 4 also shows the percentage distribution by the nine commodity groups. As indicated by the data in Table 4, corn, soybeans, and wheat collectively accounted for about 80% of the top nine commodity groups.

Table 4: 2015 Originated Carloads by Commodity

Commodity	Carloads	Percent of Total
Corn ¹	116,298	42.6
Soybeans ²	57,668	21.1
Wheat ³	46,380	17.0
Ethanol & DDGs	40,061	14.7
Durum Wheat	4,467	1.6
Sorghum	2,657	1.0
Molasses and Sugar	2,520	0.9
Barley	1,921	0.7
Canned and Frozen Vegetables	1,345	0.4
Total	273,317	100

¹ In addition to corn the figure includes corn oil, corn syrup, corn gluten feed, corn starch, corn germ, and wet corn milling.

² In addition to soybeans the figure includes soybean meal, soybean oil, soybean cake, soybean flour, and soybean flake.

³ In addition to wheat the figure also includes wheat flour.

2015 Terminated Carloads by Commodity

Table 5 summarizes the short line terminated traffic for the top six commodities. Table 5 also contains a percent distribution among the top six. Corn accounts for 46.1% of the total top six carloads. Corn, fertilizer, and wheat account for almost 90% of the top six commodity carloads. The total terminated traffic of sample short lines was 54,584 carloads.

Table 5: 2015 Terminated Carloads by Commodity

Commodity	Carloads	Percent of Total
Corn ¹	25,156	46.1
Fertilizer	14,404	26.4
Wheat ²	9,386	17.2
Fruits and Vegetables ³	2,452	4.5
Soybeans ⁴	2,108	3.7
Animal Feed	1,168	2.1
Total	54,584	100

¹ The figure for corn also includes corn syrup, wet process corn milling, corn oil, and corn meal.

² The figure for wheat includes flour and grain mill products.

³ The figure for fruits and vegetables includes vegetable oil, vegetable oilseed cake, canned fruits, frozen vegetables, vegetable meal, and catsup/tomato sauce. The figure for fruits and vegetables includes vegetable oil, vegetable oilseed cake, canned fruits, frozen vegetables, vegetable meal, and catsup/tomato sauce.

⁴ The figure for soybeans also includes soybean oil, soybean cake, and soybean meal.

2015 Local Carloads by Commodity

Table 6 summarizes the local traffic for the major commodities. The total local carloads of the top five commodities are 38,263 with corn accounting for 65% of the total local carloads.

Table 6: 2015 Local Carloads by Commodity

Commodity	Carloads	Percent of Total
Corn ¹	24,494	65.2
Wheat	6,916	18.1
Soybeans ²	5,671	14.8
Other Grains ³	727	1.9
Total	38,263	100

¹ In addition to corn the figure includes corn meal.
² In addition to soybeans the figure includes soybean meal.
³ Other grains include sorghum, barley, and oats.

2015 Overhead Carloads by Commodity

Overhead carloads for corn and soybeans are complicated by the presence of a large outlier railroad that identified 92,846 overhead carloads. On the survey, the 92,846 carloads were evenly split between corn and soybeans, resulting in 46,423 carloads for each of the two commodities. This figure is 12 times higher than the mean corn carload and 11 times higher than the mean soybean carload. Therefore, the overhead carloads for corn and soybeans are calculated with and without the outlier carloads included in the analysis.

Table 7 contains 2015 overhead carload data when the outlier railroad's corn and soybean carloads are included in the analysis. An examination of Table 7 data indicates that corn is the top commodity with 38.1% of the top eight overhead commodity.

Table 8 contains 2015 overhead carload data excluding the outlier railroad's corn and soybean carloads. The corn percentage of the top eight overhead commodities declines from 38.1% to 25.9%. The soybean percentage falls from 29.3% to 7.9%. The share of the top eight overhead carloads for wheat increased from 12.2% to 24.8%.

Table 7: 2015 Overhead Carloads by Commodity Including Outlier Railroad

Commodity	Carloads	Percent of Total
Corn ¹	69,820	38.1
Soybeans ²	53,605	29.3
Wheat ³	22,318	12.2
Sorghum and Oats	10,060	5.5
Fruits and Vegetables ⁴	8,299	4.5
Fertilizer	8,105	4.4
Molasses and Sugar ⁵	6,979	3.8
Barley	4,018	2.2
Total	183,204	100

¹ In addition to corn, the figure in the above table includes corn syrup, corn starch, corn meal, and wet corn milling products.

² In addition to soybeans, the figure in the above table includes soybean oil and soybean cake.

³ In addition to wheat, the figure in the above table includes wheat flour, wheat bran, and grain mill products.

⁴ The figure in the above table includes frozen vegetables, vegetable oil, and vegetable seed cake.

⁵ The figure in the above table includes molasses, blackstrap molasses, sugar mill products, sugar refining byproducts and granulated sugar powder.

Table 8: 2015 Overhead Carloads by Commodity Excluding Outlier Railroad

Commodity	Carloads	Percent of Total
Corn ¹	23,397	25.9
Wheat ³	22,318	24.8
Sorghum and Oats	10,060	11.1
Fruits and Vegetables ³	8,299	9.2
Fertilizer	8,105	9.0
Soybeans ⁴	7,182	7.9
Molasses and Sugar ⁵	6,979	7.7
Barley	4,018	4.4
Total	90,358	100

¹ In addition to corn, the figure in the above table includes corn syrup, corn starch, corn meal, and wet corn milling products.

² In addition to wheat, the figure in the above table includes wheat flour, wheat bran, and grain mill products.

³ The figure in the above table includes frozen vegetables, vegetable oil, and vegetable seed cake.

⁴ In addition to soybeans, the figure in the above table includes soybean oil and soybean cake.

⁵ The figure in the above table includes molasses, blackstrap molasses, sugar mill products, sugar refining byproducts and granulated sugar powder.

SUMMARY OF SHORT LINE CARLOADS BY TYPE OF TRAFFIC

Table 9 data summarizes sample short line carloads by type of traffic with and without the outlier overhead carloads. The distribution of carloads with the outlier overhead carloads results in about half the total carloads in the originated category, about 10% is terminated carloads, 7% local traffic, and 33.3% overhead carloads. When the outlier overhead carloads are removed from the analysis, the originated traffic share of the total carloads rises from 50% to 60%. The terminated and local shares rise slightly while the overhead share fell to about 20%.

Thus originated traffic is the major traffic type with and without the outlier overhead carloads in the analysis. Local traffic has the fewest carloads of the four types of traffic.

Table 9: Total Carloads with and without Outlier Overhead Carloads by Type of Traffic

Total Carloads with Outlier Overhead Carloads		
Type of Traffic	Carloads	Percent of Total
Originated Carloads	273,317	49.8
Terminated Carloads	54,484	9.9
Local Carloads	38,263	7.0
Overhead Carloads	183,204	33.3
Total	549,368	100
Total Carloads without Outlier Overhead Carloads		
Originated Carloads	273,317	59.9
Terminated Carloads	54,584	11.9
Local Carloads	38,263	8.4
Overhead Carloads	90,358	19.8
Total	456,522	100

Part C: Results of the Short Line and Agriculture Survey

Part C asks the short lines if they are dependent on Class I railroads for locomotives and railcars. Table 10 reveals that, for locomotives, only 12.5% said they were very dependent, 22.5% said they were somewhat dependent, and 65% said they were not dependent. A few of the short lines qualified their response by stating that they were somewhat dependent on Class I unit trains but not dependent for non-unit trains.

In the dependence on Class I railroads for railcars, 50% of the sample short lines said they were very dependent, 25% responded that they were somewhat dependent, and 25% said they were not dependent. A few short lines said they were very dependent on unit trains but not dependent on non-unit trains.

Also in Part C, the short lines were asked if their railroad was dependent on Class I railroads for equipment (locomotives and railcars), did they have trouble obtaining needed equipment during peak periods such as grain harvest. Only about 3% said all of the time, 60.5% replied some of the time, and about 37% said none of the time.

Thus the majority of sample short lines are not dependent on Class I railroads for locomotives but half the short lines said they are very dependent on Class I railroads for railcars. Short lines do not appear to have difficulty obtaining equipment during peak periods.

Table 10: Short Line Dependence on Connecting Class I Railroads for Locomotives and Railcars

Locomotives		
Dependency	Number of Short Lines	Percent of Total
Very Dependent	5	12.5
Somewhat Dependent	9	22.5
Not Dependent	26	65
Total	40	100
Railcars		
Dependency	Number of Short Lines	Percent of Total
Very Dependent	20	50
Somewhat Dependent	10	25
Not Dependent	10	25
Total	40	100

Table 11: Number of Railroads Identifying Agricultural Commodities as Subject to Intermodal Competition – Originated Traffic

Commodities	Number of Railroads
Corn	24
Wheat	21
Soybeans	13
Animal Feed	8
Ethanol	5
Sugar and Molasses	5
DDGs	4
Sorghum and Oats	3

Part D: Results of the Short Line and Agriculture Survey

The first question of Part D asks short lines how dependent they are on Class I railroads to reach the principle markets they serve. A total of 85% of the short lines said they are very dependent and another 12.5% said they are somewhat dependent. This is consistent with local traffic being the smallest traffic category and originated traffic being the largest traffic type.

The next several questions deal with identification of the modes that compete with short lines for agricultural traffic. Short lines were asked to identify modes that compete with respect to originated traffic. Of the short line respondents, 46.7% said motor carriers are competitors while 30.7% said Class I railroads compete with them. A total of 12% said they compete with other short lines and 10.7% said water carriers compete with them.

The next question asks what agricultural commodities are subject to competition for originated traffic. Table 11 contains the commodities and the number of railroads identifying the commodity

as subject to intermodal competition. As indicated by Table 11, corn, wheat, and soybeans were identified as subject to intermodal competition by most short lines.

Question 4 of Part D asks short lines to identify the modes they compete for terminated traffic. A total of 54.4% of short lines said motor carriers are the principal intermodal competitor, and 20.5%, 11.8%, and 7.3% of sample short lines identified Class I railroads, other short lines, and water carriers, respectively, as intermodal competitors.

Question 5 of Part D asks short lines what agricultural commodities are subject to intermodal competition for terminated traffic. Table 12 indicates that corn, fertilizer, wheat, soybeans, and animal feed were the commodities selected by most sample short lines as the commodities subject to intermodal competition.

Table 12: Number of Railroads Identifying Agricultural Commodities as Subject to Intermodal Competition – Terminated Traffic

Commodities	Number of Railroads
Corn ¹	20
Fertilizer	19
Wheat and Flour	11
Animal Feed	9
Soybeans ²	5
¹ The figure for corn also includes corn syrup and corn oil.	
² The figure for soybeans also includes soybean oil and meal.	

Table 13: Number of Railroads Identifying Agricultural Commodities as Subject to Intermodal Competition – Local Traffic

Commodities	Number of Railroads
Corn ¹	19
Wheat ²	18
Soybeans ³	10
Barley	5
Sorghum	5
Oats	4
Fertilizer	4
¹ The figure for corn also includes corn syrup and corn oil.	
² The figure for wheat also includes wheat flour.	
³ The figure for soybeans also includes soybean oil and meal.	

One of the short lines said fertilizer plants have trucks that go to other rail terminals and inland ports to pick up most types of fertilizer. Another short line manager said some shippers have shipped fertilizer via a Class I railroad and then by truck to local buyers. Another short line manager said fertilizer is shipped to a central location by Class I railroads and distributed by truck to local users.

Question 6 of Part D asks short line managers which modes compete with them with respect to local traffic. The mode identified as a competitor by most short lines was motor carriers (74.4% of sample short lines), Class I railroads, other short lines, and water carriers were mentioned by 15.4%, 7.7%, and 2.6% of the sample short lines as competitors for local traffic.

Question 7 of Part D asks short line managers which agriculture commodities are subject to intermodal competition for local traffic. Table 13 indicates that corn, wheat, and soybeans were mentioned by most of the short line managers as being subject to competition for local traffic.

The next question in Part D asks managers of short lines which modes are intermodal competitors for overhead agricultural traffic. The number of railroad managers indicating modal competitors was much less than the other three types of traffic. Only nine managers mentioned trucks as intermodal competitors and seven indicated Class I railroads are a competitor for overhead agricultural traffic.

The next question asks short line managers which agricultural commodities are subject to intermodal competition for overhead traffic. Reflecting the lower intensity of competition for overhead traffic, wheat and flour and corn and corn oil had only eight and seven short line managers indicating the agricultural commodities subject to intermodal competition for overhead traffic (Table 14).

Table 14: Number of Railroads Identifying Agricultural Commodities as Subject to Intermodal Competition – Overhead Traffic

Commodities	Number of Railroads
Wheat and Flour	8
Corn and Corn Oil	7
Soybeans and Soybean Oil	3
Fertilizer	2

In summary, managers of sample short lines cited motor carriers as competition for all four types of traffic more often than the other modes of transportation. The commodities most subject to intermodal competition were corn, wheat, and soybeans for originated traffic. For terminated freight, the commodities cited most often by managers of sample short lines as being impacted by intermodal competition were corn, wheat, and fertilizer. In the case of local freight, the most cited commodities by managers of short lines as impacting intermodal competition were corn, wheat, and soybeans. The corresponding information for overhead traffic were wheat and corn.

Part D ended with some open-ended questions about competition facing short line railroads. The first question is: Are shifts in Class I pricing and the move to shuttle trains in grain transport creating an opportunity or a threat to your railroads' competitiveness? The short lines are evenly split on this question of whether changes in grain logistics systems are a threat or an opportunity to the railroads' competitiveness.

Then the short lines were asked if their agricultural traffic will increase or decrease if current trends continue. Of the 41 railroads that answered this question, 44% expected an increase while 42% expected no change and 15% expected a decrease.

The next question was whether Class I railroad policy (i.e., shuttle train loaders) affect competition between trucks and short lines. A total of 77% of the short line managers agree that Class I policy affects competition between trucks and short lines.

The final question is what modes are becoming more of a challenge to short line success and why?

The short lines pointed to lower truck fuel prices and thus low rates. Also, increased size and weights of trucks were frequently mentioned by the short lines. Trucks have greater scheduling and routing flexibility than short lines, resulting in competition based on price.

The short lines mentioned that shuttle trains on Class I railroads have resulted in increased trucking to these locations as opposed to short line shipments. Also, the short lines mentioned their dependency on Class Is for rail cars, switching rates, and price structures.

SHORT LINE SUCCESS PROFILE

The survey contains 12 service characteristics of a profitable short line railroad obtained from previous research. From the choices given, the short line managers were asked to select the three most important determinants of success (profits). They were asked to put a 1 next to the most important, 2 next to the next important, and 3 to the third most important. The characteristics were ranked by the number of short lines selecting the characteristic with a 1, 2, or 3 importance rank.

The top three most important characteristics are adequate traffic levels (ranked number 1), strong shipper support (ranked number 2), and access to more than one connecting carrier (ranked number 3). Table 15 provides a summary.

A second group of characteristics that received some support was access to more than one connecting carrier (ranked number 4), ship many different commodities (number 5), and adequate track quality (number 6).

The short line managers suggested some additional characteristics, including high quality service, controlled expenses, and adequate traffic density. Others include economic development support, ongoing profitability as primarily a function of traffic density and vulnerability of the traffic base. Another short line manager said generating enough revenue to keep the tracks in good condition is a huge issue.

Table 15: Ranks of the Top 6 Service Characteristics

Rank	Characteristic
1	Adequate traffic levels
2	Strong shipper support
3	Access to more than one connecting carrier
4	Cooperation from connecting carriers on joint rates and revenue splits
5	Ship different commodities
6	Adequate track quality

CONCLUSION

Short line railroads play a critical role in originating and terminating agricultural products transported by rail and promote economic development along these lines. Particularly important is providing rail service to rural America and their link to the Class I rail network. In the decades following the passage of the Staggers Rail Act in 1980, more than 250 short lines were formed, adding to the approximately 220 short lines that existed as of 1980. Today 562 short lines are operating in the U.S.

Many short lines have deferred maintenance but not enough revenue to fund it. Given the significant public benefits of short lines, the federal government and many states have instituted financial assistance programs to help them develop their infrastructure. Many states have short line assistance programs with the goal of insuring transportation options and maintaining a balanced transportation program. These assistance programs have had substantial positive impacts on the short lines, the agricultural shippers, and the rural economy.

Total 2015 carloads for the four types of traffic (excluding the outlier overhead carloads) originated carloads total 273,317 (59.9% of total carloads). Terminated and local carloads were 54,584 (11.9% of total carloads) and 38,263 (8.4% of total carloads), respectively. Overhead carloads were 90,358 (19.8% of total carloads). When the outlier overhead carloads are included, originated traffic is still the top traffic type followed by overhead, terminated, and local carloads.

The majority of sampled short lines are not dependent on Class I railroads for locomotives but half the short lines said they were very dependent on Class I railroads for railcars. Sample short lines do not appear to have difficulty obtaining equipment during peak periods.

Managers of sampled short lines cited motor carriers as competition for all four traffic types more often than other modes of transportation. The commodities most subject to intermodal competition were corn, wheat, and soybeans for originated traffic. For terminated freight, the commodities cited most often by managers of sample short lines as being impacted by intermodal competition were corn, wheat, and fertilizer. In the case of local freight, the most cited commodities by managers of sample short lines as being impacted by intermodal competition were corn, wheat, and soybeans. The corresponding information for overhead traffic were wheat and corn.

Sample short line managers answered four open-ended questions about competition facing short line railroads. The short lines were evenly split on whether changes in the grain logistic system (i.e., Class I shuttle trains) are a threat or an opportunity to their railroads' competitiveness.

The managers of sample short lines were asked whether their agricultural traffic will increase or decrease if current trends continue (i.e., focus on shuttle trains and increased ethanol production). Only six railroads expected their agriculture-related traffic to decrease while 18 railroads expected an increase and 17 expected no change. So of the 41 railroads that answered the question, 43.9% expected an increase while 41.5% expected no change and 14.6% expected a decrease.

The sample short line managers were asked if Class I railroad policy (i.e., shuttle train loaders) affect competition between trucks and short lines. Of the 39 short lines that answered the question, 77% agree the Class I policy affects competition between trucks and short lines.

Short line managers were asked which modes are becoming more of a challenge to short line success. The short lines pointed to lower truck fuel prices and thus low rates. Also, increased size and weights of trucks were frequently mentioned by the short lines. The short lines mentioned that shuttle trains on Class I railroads have resulted in increased trucking to these locations as opposed to short line shipment. Also, some short lines mentioned their dependency on Class I railroads for rail cars, switching rates, and price structures.

This study concludes with a profile of a successful (profitable) short line. The survey contains a dozen service characteristics of profitable short line railroads obtained from previous research. From the choices given, the short line managers were asked to select the three most important determinates of success, which were adequate traffic levels (number 1), strong shipper support (number 2), and access to more than one connecting carrier (number 3).

References

Association of American Railroads (AAR). *Railroad Facts*, September 2016.

American Short Line and Regional Railroad Association (aslrra), *Shortline and Regional Railroad Facts and Figures*, 2017.

Babcock, Michael W and James Sanderson. "Should Short Line Railroads Upgrade Their Systems to Handle Heavy Axle Load Cars?" *Transportation Research, Part E*, (2006): 149-166.

Bitzan, John D. and Denver D. Tolliver. "Heavier Loading Rail Cars." Upper Great Plains Transportation Institute, MPC Report No. 01-127.4, Fargo, ND, 2001.

Bitzan John D. and Denver D. Tolliver. "The Impacts of an Industry Switch to Larger Rail Grain Hopper Cars on Local Infrastructure: A Case Study of North Dakota." *Journal of the Transportation Research Forum* 59(2), (2003): 135-154.

Casavant, Kenneth and Denver D. Tolliver. "Impacts of Heavy Axle Loads on Light Density Lines in the State of Washington." Washington Department of Transportation, Olympia, WA, 2001.

Federal Railroad Administration *Summary of Class II and Class III Railroad Capital Needs and Funding Sources – A Report to Congress*, October 2014.

Iowa Department of Transportation, Office of Rail Transportation, *Heavy Axle Load Upgrade Report*, Des Moines, Iowa, 2002.

Llorens, Jared J. and James A. Richardson. *Economic Impact Analysis of Short Line Railroads*, Federal Report 527, Natural Center for Intermodal Transportation, 2015.

Martens, B.J. "An Economic Analysis of Heavy Axle Loads: The Effects on Short Line Railroads and the Tradeoffs Associated with Heavy Cars."

Qiao, Fengxiang. *Transportation and Economic Impact of Texas Short Line Railroads*. Texas Department of Transportation, Research and Technology Office, Austin, TX, September 2016.

Resor, R.R., A.M. Zarembski, and P.K. Patel. "An Estimation of the Investment in Track and Structures Needed to Handle 286,000 Pound Rail Cars on Short Line Railroads." Zeta-Tech Associates Inc., Chevy Hill, NJ, 2000.

Sage, Jeremy, Ken Casavant, and J. Bradley Eustice. *Washington State Short Line Rail Inventory and Needs Assessment*. Washington Department of Transportation, June 2015.

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Disclaimer

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A Framework to Analyze the Feasibility of Vehicle Miles Traveled Fees to Finance a Sustainable Transportation System

by Marketa Vavrova, Carols M. Chang, and L. Bina (deceased)

This paper presents a framework to analyze the feasibility of vehicle miles travelled (VMT) fees as an alternative to finance maintenance, rehabilitation, and new construction transportation projects. The VMT feasibility framework addresses major factors related to public acceptance, revenues, technology, type of contract, government policies, enforcement, administration, and invoicing. We argue that our suggested VMT fee policy is an equitable usage-based system since in our analysis, VMT fees are differentiated by vehicle axles and emissions. In turn, VMT charges will also motivate fleet owners to renew vehicles or switch to alternative transportation modes such as mass transit, walking, and biking. An example based on data from the state of Texas illustrates some of the potential revenues and benefits associated with a VMT fee policy.

INTRODUCTION

A safe, reliable and well-maintained transportation network that serves users of all ages and incomes should be the ultimate goal of a sustainable transportation system. Due to aging, increasing traffic, and growing population, the U.S. transportation system demands larger investments to maintain expected levels of service. Unfortunately, limited budgets from traditional sources of revenues (e.g., taxes on fuels, vehicle registration fees) are not sufficient to cover future transportation needs. To support a sustainable transportation system, we need to consider alternative financial tools designed to generate sufficient revenues to cover the costs of maintenance, rehabilitation, and new transportation projects. The objective of this paper is to present one framework to analyze the feasibility of a Vehicle Miles Travelled (VMT) policy as a tool to finance a sustainable transportation system. The framework outlines the decision context for the implementation of VMT fees and identifies factors necessary to best evaluate its feasibility as a transportation funding alternative.

VMT fees could be used as a self-financing policy alone or in combination with other sources of transportation related revenue, including tolls, increased sales taxes on fuel, higher registration fees, or higher local taxes. Here, VMT fees are assigned to three classes of vehicles: [1] light duty vehicles, including passenger cars, light trucks, vans, and sport utility vehicles regardless of wheelbase (FHWA 2009), [2] single-unit trucka, [3] combination trucka, along with three emission classes differentiated according to Tier II emission standard: [1] BIN 11-6, [2] BIN 5-3, and [3] BIN 2-1. Tolling systems based on a combination of a vehicle class and emissions have been successfully implemented in the European Union (EU) and could be introduced to the U.S. to induce lower emissions and less damaging road use.

HOW IS THE TRANSPORTATION SYSTEM BEING FUNDED?

Based on the theory of taxation, Balducci et al. (2011) organized established revenue systems into four categories: vehicle ownership, highway user fees, energy consumption, and beneficiary and local option fees. These are shown in Table 1. Vehicle ownership revenue streams include income from registration fees, licensing fees, and personal property taxes. Highway user fees can include income from tolls, congestion/cordon pricing, high occupancy toll lanes, or VMT fees. Revenue from energy consumption can include fuel taxes, sales taxes on fuel, as well as utility fees. There are

also beneficiary and local option fees that can be sources of revenue, including beneficiary charges and value capture, transportation impact fees, local option sales taxes, and local option property taxes.

Table 1: Established Revenue Systems (Balducci et al. 2011)

Vehicle ownership	Highway user fees	Energy consumption	Beneficiary and local option fees
Registration fees	Toll roads	Motor fuel taxes	Beneficiary charges/value capture
Licensing fees	Congestion/cordon pricing	Sales taxes on motor fuels	Transportation impact fee
Personal property taxes	High occupancy toll lanes VMT fees	Utility fees	Local option sales taxes Local option property taxes

Currently in the U.S., highway revenues are mainly derived from the fuel tax. Apart from federal and state fuel taxes, there is also revenue generated from tolls, vehicle registrations and ownership taxes. Contrast this with what has happened in the EU, where the fuel tax is three times higher than in the U.S. Vehicles over 7,000 lbs. are charged distance-based fees, and vehicles below 7,000 lbs. must purchase a time-based vignette to travel on the European Interstate network. Certain road sections are also tolled. The majority of the revenue from EU fuel taxes goes to a general fund and about 20% is dedicated to road infrastructure (Silnice 2004).

Fuel taxes are becoming a less reliable source of revenue due to increasing fuel efficiency and alternative-fuel vehicles entering the market. Whitty (2007) points out that the fuel tax has now become “rather a general tax unrelated to use than a fee for service” as the correlation between fuel consumption and road usage is changing. Even though Baker et al. (2011) indicated that “government regulation and continued increases in fuel prices could cut fuel consumption in the United States by 20 percent by 2025,” declining fuel prices in 2014 seem to indicate that demand for gasoline is still relatively inelastic as “it takes a 25% to 50% decrease in the price of gasoline to raise automobile travel 1%” (U.S. Energy Information Administration 2014).

When considering the problem from a government perspective, approximately 83% to 87% of revenues from the fuel tax (depending on the fuel type) are deposited into the U.S. Highway Account and then redistributed to road infrastructure (FHWA 2010). Other contributions to the highway account come from excise taxes on the sale of tires, trucks, buses, trailers and heavy vehicle use, but compared with income generated by the fuel tax, they can be considered insignificant. As Elmendorf et al. (2008) highlight, balances in the highway account were stable at around \$10 billion during the 1980s and in the first half of the 1990s.

Since 2001 expenditures have exceeded revenues. Based on this trend, Elmendorf et al. (2008) predicted that balances in the highway account would be depleted during the fiscal year 2009. In reality, the highway account was depleted even earlier (September 2008) when Congress had to transfer \$8 billion from general funds to cover a shortfall in the highway account. This occurred again in 2009, when the highway account was unable to meet obligations and required an infusion from general funds of \$7 billion in 2009 (Elmendorf et al. 2010). In 2010, the highway account required another \$14.7 billion, followed by \$2.4 billion in 2012, \$6.3 billion in 2013, and \$10.4 billion in 2014 (FHWA 2015). Based on these figures, many conclude that the current highway financing system is experiencing serious problems and is far from being self-sufficient.

BACKGROUND ON VEHICLE-MILES TRAVELLED (VMT) FEES

While “distance traveled” may be a more accurate term to describe vehicle-miles traveled (or VMT), the term VMT fee or mileage-based user fee (MBUF) is more widely recognizable among policymakers and media in the U.S. A VMT fee policy can be designed to influence drivers and many argue that it is also more economically sustainable in the long run, offering greater consumer transparency. On the other hand, drawbacks include difficulty in passing a new user charge, costly implementation, as well as potential fights for transparency on returning money to those districts that contributed to the revenues (Schank and Rudnick-Thorpe 2011).

Elmendorf et al. (2011) reported on four trial run projects in the U.S. investigating the feasibility of implementing a VMT fee. These were in Atlanta, Georgia (2003-2004), Seattle, Washington, (2005-2007), Portland, Oregon, during 2007 and 2012 (Whitty 2007), and a mileage-based road user charge pilot in 12 U.S. states during 2009-2010 (Hanley and Kuhl 2011). More recently, Oregon’s Voluntary Road Usage Charge Program (OreGo) was launched in July 2015. It comprises a fleet of 5,000 volunteer cars and light commercial vehicles with a fuel efficiency of 55 mpg or better (ODOT 2015). Volunteers in the project receive a gas tax credit but are charged a fee of 1.5 cents per mile. California also launched a nine-month VMT fee program in July 2016, where up to 5,000 participants did not pay any fuel tax in exchange for reporting their driving data from GPS or an odometer, data which will be used to help design a VMT program in the near future (Jones 2016). Other states, including Delaware, Vermont, Pennsylvania, New Hampshire, and Connecticut, are also interested in testing a multistate VMT fee program (Jones 2016).

As Rufolo (2011) points out, a VMT fee policy is already used for heavy vehicles when traveling the U.S. Interstate system. According to the International Fuel Tax Agreement, heavy vehicles are obliged to report mileage driven in every state to calculate the difference between the actual tax paid and the theoretical tax that should be paid according to state regulations. Trucking companies are either returned some amount or requested to pay the shortfall.

The possibility of replacing truck highway taxes with a satellite-based VMT fee is being explored in the state of New York, which reports diesel tax under payments of about \$90 million per year (Delcan et al. 2011). The latter observation points to the fact that the design and implementation of VMT fees applied to the U.S. interstate highway network may be a useful remedy for infrastructure funding issues. Some observe that the collection cost of a VMT fee system is notably higher than for a fuel tax. Rough estimates of operating cost per 1,000 VMT is \$0.10 for a fuel tax, versus \$1.79 for a VMT fee paid at the pump (as done in the Oregon study, see Whitty 2007) versus \$6.26 for the VMT fee collected in the Netherlands, the latter being withdrawn in 2009 before its implementation (Rufolo 2011). Fuel taxes were introduced in 1911 when Oregon became the first state to tax motor fuels (McCormally 2014). At the federal level, President Herbert Hoover signed the Revenue Act in 1932 (FHWA 2005), hence any prospective switch to a VMT fee policy must be gradual and well considered from the view of both financing and public acceptance.

Robitaille et al. (2011) examined the impact of a \$0.10 increase in the federal fuel tax, as well as the impact of a \$0.015/mi VMT fee in each state. Relevant to this study, the annual net change in revenue in the case of Texas would be \$514.9 million (for a \$0.10 increase in the federal fuel tax) or \$482.2 million (for a \$0.015/mi VMT fee) (Robitaille et al. 2011). This indicates in the short-term, the revenues from the fuel tax and from the VMT fee are essentially comparable. However, we offer that it is important for legislators to consider a switch to a VMT policy as a long-term solution because of increases in overall fuel efficiency and the large number of alternative-fuel vehicles coming on the road. As Robitaille et al. (2011) reported, VMT fees reduced vehicle miles travelled by users, resulting in lower fuel consumption, a situation beneficial to both energy policy and the environment. Research in variable pricing strategies indicates that VMT fees tend to affect travel behavior as well as activity participation and rescheduling patterns (Keuleers et al. 2006).

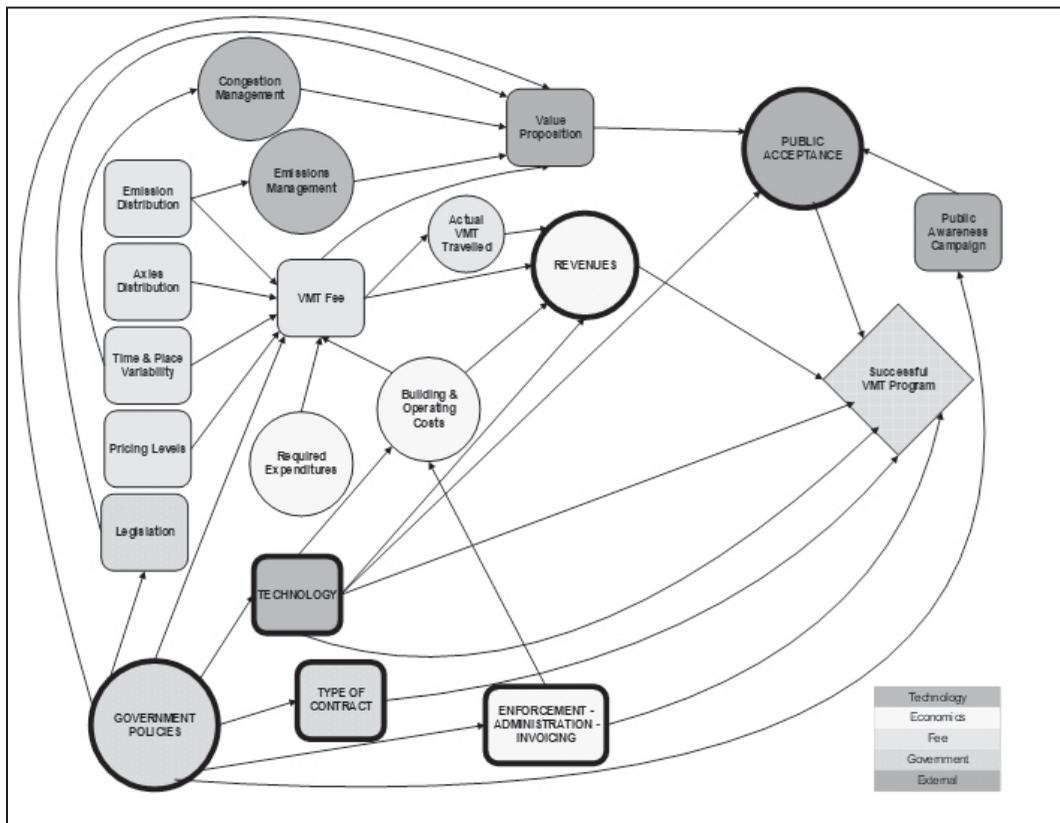
FRAMEWORK TO ANALYZE THE FEASIBILITY OF VMT FEE PROJECTS

An evaluation framework is presented here to assess the feasibility of implementing a VMT fee-based system for a transportation network. The ultimate goal of implementing new financial tools will be to generate sufficient revenues to finance existing and new road infrastructure, including operating and maintenance costs. In addition to revenues, there are well known secondary benefits associated with VMT implementation, including lower emissions and fleet renewal, as experience in the EU has shown (Vierth and Schleussner 2012). Additionally, the data collected for a VMT fee project could also be used for congestion management analysis to reduce travel time and mitigate air pollution.

Factors Affecting the Implementation of VMT Fee Projects

An influence diagram illustrates the decision context for VMT fee implementation, including technological, economical, governmental, and external factors. The influence diagram applicable to this analysis is shown in Figure 1, where a circle is used to represent uncertain events and a rectangle represents decisions. This visualization indicates that a successful implementation of a VMT fee policy will be influenced several factors, including [1] public acceptance, [2] revenues, [3] technology, [4] type of contract, [5] government policies, and [6] enforcement, administration and invoicing. These factors are highlighted in the diagram and will be discussed in turn (Vavrova 2012).

Figure 1: Influence Diagram of Factors Influencing VMT Implementation (after Vavrova 2012)



Public Acceptance and Government Policies. As CURACAO (2008) noted, “We live in a democratic society, so societal, political and technological innovations must be introduced via the democratic process.” Since the users of such a system are not only the VMT fee payers, but also voters and payers of many other public taxes, it is vital for the success of a program to help the public understand that a VMT fee will also promote equity and fairness and that generated revenues will be used wisely, while the entire system will remain transparent to implement and monitor (Zmud and Arce 2008). Public acceptance is facilitated by extensive communication, where the items previously mentioned are discussed and clarified. To this end, Langmyhr and Sager (1997) describe a step-by-step implementation of the Trondheim urban road pricing project initiated in 1985 in Norway. They highlight the issues faced by the public and politicians during the implementation process. Ultimately, they suggest deploying contemporary communicative planning theory during the planning process.

We offer that a VMT fee policy should differ by emission class to support fleet renewal, manifesting in lower emissions and better air quality. This outcome could be one of the best ways to gain public support for a new road user fee structure (Dill and Weinstein 2007). However, it is important to consider that even though cleaner vehicles lead to less air pollution, other externalities such as congestion or accidents cannot necessarily be mitigated.

Other social aspects of VMT fee implementation to be considered are equity/distributive issues that will need to be addressed by appropriate legislation. For example, the affected public should possess available alternative modes of transportation, such as mass transit, cycling, or walking to make their daily trips to work and to other destinations in a convenient, safe, and reliable manner. We offer that such a transportation system would promote sustainability and livability, fundamental principles that are becoming popular within modern cities.

Revenues from a VMT fee could also be used for enhancing multi-modal transportation networks. An equity analysis done in Houston, Texas, indicates that implementation of VMT fees “would not have a pronounced effect on the current distribution of what household pays versus what they receive in transportation expenditures” (Carlton and Burris 2014). As for the current fleet of commercial vehicles, including heavy trucks, there is a possibility that an increase in road user fees would temporarily drive up prices of goods. However, there is evidence that in the long term we should expect changes in logistics behavior, including modal shifts to rail transportation, which is four times more energy efficient than a truck (AAR 2012a), along with fleet renewal as the effect of an emission class differentiated fee. To this end, Railex (AAR 2012b) estimates that each 70-car unit train removes 250 trucks off highways, alleviating highway congestion and reducing CO₂ emissions by 135,000 metric tons annually.

Increasing the awareness of miles traveled can lead to a decrease of total VMT and, as Cooper (2007) notes, a reduction in VMT will necessarily reduce air pollution. A VMT fee can also be designed to vary across time and place to facilitate congestion management. For example, in the Czech Republic, a 25% to 50% increase in VMT fees for trucks on Friday afternoon peak hours (3 pm–9 pm) induced a reduction of congestion along with savings in travel time (Bina, Cerny, and Novakova 2012).

“A strong public resistance may inhibit implementation as political parties fear consequences for their next election” (CURACAO 2008). Without question, political commitment is very important. Another vital step to public acceptance is to carefully plan changes in current tax laws concerning fuel taxes. Absence of this step in the planning process was probably the major reason for the VMT fee implementation failure in the Netherlands referred to earlier. In this case, the VMT fee was supposed to substitute for the property tax rather than the fuel tax. In fact, the public saw the new fee as a double taxation on travel. The implementation was cancelled a few months before it should have been launched.

To support such change, a stable government policy is needed since a VMT fee is a long-term policy decision and the highest level of support is vital for its success. An example of such support

is the Stockholm congestion charging trial, where surveys showed that less than 30% public support before the trial changed to 50% support toward the end of the trial, finally going up to 70% after the reintroduction of the policy (Eliasson 2008).

Another major issue in planning for VMT fee implementation surrounds privacy, as the need for tracking technology may arouse public fears of surveillance. For example, in the 2012 Oregon study, drivers were able to choose the way they wanted to report their miles driven (ODOT 2012). In Singapore, the privacy issue of electronic payment systems for parking and other facilities was solved with a smart cash type card that contains only account balance and no user data (Arnold et al. 2010). Ultimately, since the number of vehicles connected in some way to the internet is projected to rise in the near future, this may significantly open the door to pay-as-you-drive methods for both road user charges as well as car insurance.

Revenues. Revenues are vital for successful implementation of a VMT fee-based system, so the level of revenues is the fundamental objective considered in this study. This effectively depends on [1] vehicle miles travelled estimate, [2] vehicle class distribution, [3] emission class distribution, [4] target VMT fee revenue, and [5] pricing levels for each combination of vehicle class and distribution class. Apart from these, VMT revenues are influenced by annual costs and technology reliability.

Technology. Current possible technologies for electronic fee collection are microwave and satellite systems. Additionally, these can be combined with odometer readings or cellular network technology. Depending on the VMT fee and road length, various technologies might be preferred to others. The 2012 Oregon study (ODOT 2012) proposed an open technology system, where drivers had an option to choose how to report their miles – either directly from their odometer, or their own GPS unit, or they could choose a non-technological option and purchase unlimited miles in advance. A pre-paid unlimited mile option should remain an alternative for drivers with high privacy concerns but who are willing to pay for this, taking into account projected mileage and uncertainty, but also, in this latter case, technology costs are minimal.

Type of contract. The decision of how to finance the project is vital for future revenues and therefore the whole success of such a project. There are traditional methods for project delivery, such as design-bid-build, and design-build, but also newer methods, such as public-private-partnership (PPP). In the EU, PPP is a popular design-build-finance-operate-maintain concept, where countries like the United Kingdom and Portugal finance with PPP in more than 20% of their infrastructure projects (Engel et al. 2011). A PPP contract, when correctly designed, helps to manage public risk by shifting some of it onto the provider. The Hamilton project (Engel et al. 2011) discusses the opportunities for PPP in U.S. infrastructure, including the conditions when a PPP is suitable, as well as different types of contracts and best practices of PPP projects in the U.S. and Europe.

Enforcement – Administration – Invoicing. Enforcement is a vital part of the management system, as together with the chosen technology it affects the success rate of fee collection. A reasonable collection success rate, where a majority of those who are required to pay actually pay, is crucial in order to maintain public trust in the equity and fairness of a VMT fee system. Administration and invoicing can raise operating costs dramatically, so electronic bills or paying at a fuel station together with the fuel are ways to cut these costs.

HOW TO DETERMINE THE FEASIBILITY OF A VMT FEE PROJECT

The steps to determine the feasibility of a VMT fee project are outlined in Figure 2. First, a background study is conducted to investigate which alternative funding source is the best solution. A feasibility study follows performing a technology study and the consequences of implementing

different levels of VMT fees. The last step is to analyze the external relationships with a public opinion poll and a trial run. All steps are discussed in the following section.

Step 1. Background Study

First, the VMT fee is compared with other alternative funding options. The National Surface Transportation Infrastructure Financing Commission (NSTIFC 2009) offers a set of criteria to assign weighting factors taking into consideration revenue streams, economic efficiency/impact, implementation and administration, and equity.

A background study explores, through a series of questions, if there are stable government policies and legislative support. At this early stage, a public awareness campaign should be launched to explain the reasons why a VMT policy is under consideration. This should prevent the problem that occurred in Netherlands in 2010, when the distance-based fee was shelved after elections when the ruling party changed. To support public acceptance, extensive legislation changes regarding taxes and privacy need to be carried out.

Step 2. Feasibility Study

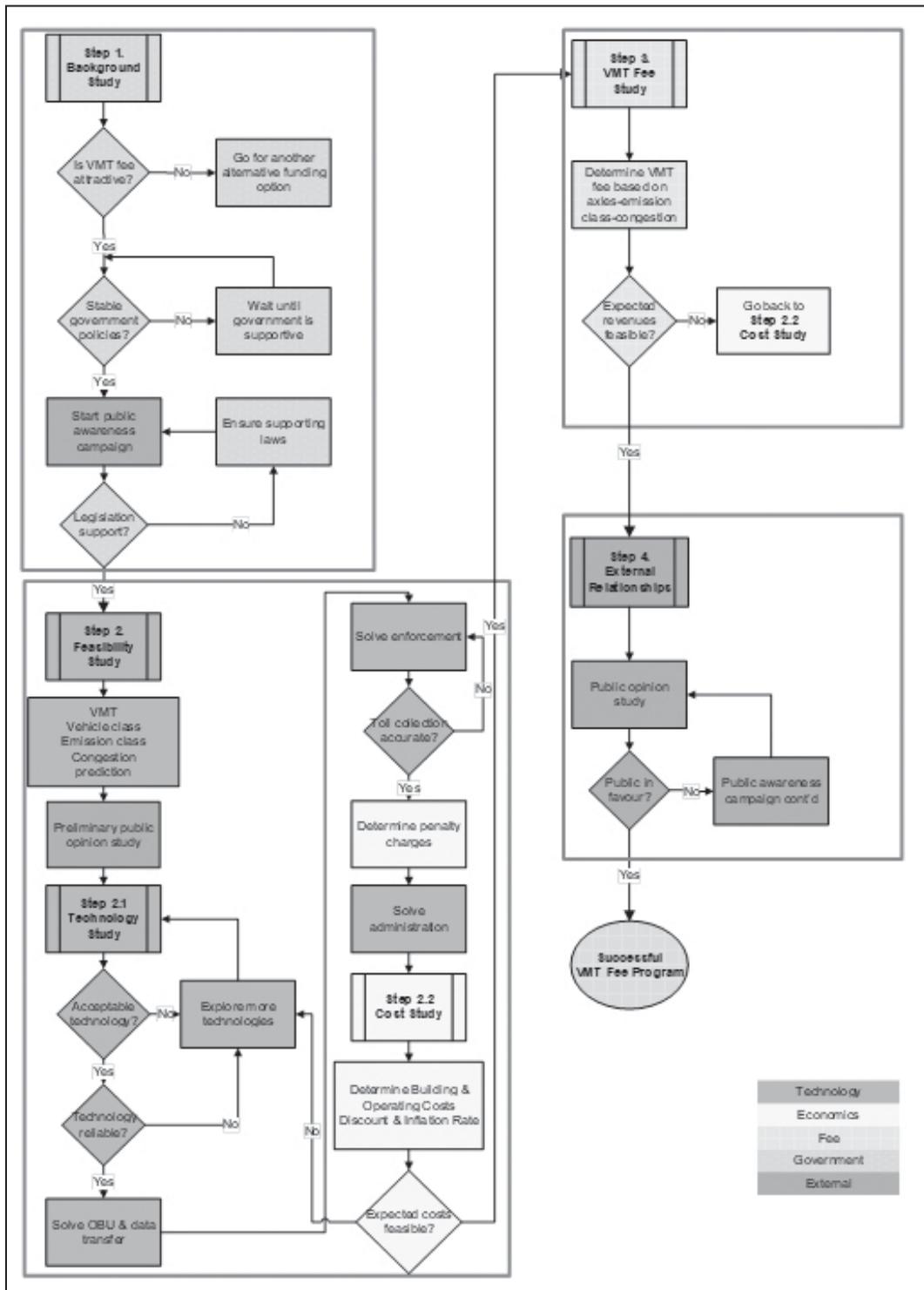
The feasibility study consists of a preliminary technology and cost study. A preliminary study of public opinion is recommended to explore the perceptions of the public, how much they would be willing to pay, what technology would be most acceptable, and what method of payment would be most convenient. The next task is the technology study. It is fundamental to find a technology, or a combination of technologies, that will comply with privacy issues and are acceptable from a building and operating costs perspective. For example, odometer reading technology is potentially a good candidate, because there are minimal privacy issues and also building and operating costs of a system based on this technology are reasonable. However, this technology is easily tampered with and will not necessarily satisfy the requirement of reliability and a reasonable fee collection success rate. For that reason, we consider acceptability and reliability as separate components as shown in the flowchart.

In addition, penalty charges should be determined and administration issues resolved, addressing such issues as whether drivers will pay at the fuel station, online, or by mail with a bill, and the possible cooperation between adjoining systems (bordering states) on how to charge the miles traveled beyond the border of the area. The cost study is the next step in the analysis process. All previous decisions influence operating costs and building costs. These costs should be determined, along with the discount and inflation rate. In case the expected costs are not covered by existing financial sources, even with a PPP contract, planning should be diverted toward exploring more cost-efficient technologies. Also, the income from possible violations of the system, such as failure to report miles, failure to pay bills, evasion of the system, and other heavy violations, should be taken into consideration.

Step 3. VMT Fee Study

Having all previous issues addressed, a VMT fee is differentiated by vehicle class and emission class. Results of preliminary public opinion can be used to adjust the VMT fee. For example, for the transition years, the VMT fee can be lowered to make the process more viable. This approach can give users more experience on the efficiency of the VMT fee system, with the possibility of eliminating flaws before beginning full operation.

Figure 2. Flow Chart Step-by-Step Framework to Determine the Feasibility of a VMT fee
(from Vavrova 2012)



Step 4. External Relationships Study

As mentioned earlier, public acceptance influences the success of implementing a VMT fee-based revenue system. The acceptability of VMT fee charging is “closely linked to the perception of freedom, fairness and efficiency” (Di Ciommo et al. 2013) and can be analyzed from both a psychological and sociological standpoint. When compared with other road pricing schemes, a VMT fee ranks highest on preference compared with other road pricing alternatives that vary based on the time of day and place (Francke and Kaniok 2014). Gaunt et al. (2007) report that, in the case of a city of Edinburgh poll regarding acceptability of road user charging, car users were strongly opposed to a road user fee while non-car owners weakly supported it. Retrospectively, “more attention should have been paid to designing a simpler, more easily communicated scheme and convincing residents, particularly public transport users, of its benefits” (Gaunt et al. 2007).

After a successful completion of these steps, a trial run in a restricted geographic area or in full-scale with volunteers (e.g., government vehicles, alternative fuel vehicles, new vehicles) should be carried out. The trial run should be conducted in conditions similar to the full operation as possible, using the same technology, rates, and billing options. We also recommend that public polls be conducted before and after the trial run to identify the strengths and weaknesses of the project. The output from the polls should be used for future improvement before the full operation is initiated.

CASE STUDY ON VMT FEE RATES

A case study to illustrate a basic comparison with the current fuel taxation system uses Texas historical VMT data, vehicle class VMT distribution data, and average miles travelled per gallon for each vehicle class in the years 2001-2014. Based on past trends as well as expert judgment, the data were projected for years 2015-2060, where VMT miles were assumed to increase 1% every year, the latter being a simplification for the analysis based on the average yearly difference of 1% in Texas VMT between years 2001 and 2014. To clarify, our VMT forecast in the year 2035 is about 20% below the estimate found in the Texas Statewide Long-Range Transportation Plan 2035 (TxDOT 2010).

The VMT fee scheme proposed in this study differentiates the VMT fee according to three classes of vehicles: [1] light duty vehicle - including passenger cars, light trucks, vans, and sport utility vehicles regardless of wheelbase (FHWA 2009), [2] single-unit truck, [3] combination truck, and three emission classes according to the Tier II emission standard: [1] BIN 11-6, [2] BIN 5-3, and [3] BIN 2-1. In this case study, for simplification, VMT fee prices were set at the levels imposed as of 2011 in the Czech Republic, where the cleanest vehicles received an adjustment coefficient of 1.00 and the dirtiest combination trucks were given a coefficient of 4.46.

A VMT fee based on a combination of a vehicle class and an emission class is not commonly used in the U.S., but it has been successfully implemented in the EU. It seems to have motivated lower emissions and noise reductions and boosted fleet renewal. For instance, in the Czech Republic and Germany, the yearly increase in tolls for trucks with the cleanest emission classes (EURO 5 and higher) is not as high as the toll increase for the dirtier classes with lower EURO emission standards. This led to a substantial increase in the EURO 5 truck fleet with a positive impact on the environment (Bina, L. unpublished data, Jun. 2, 2012).

A sensitivity analysis was performed to identify the major factors affecting the revenues. To address uncertainty in the projection of revenues from the VMT fee, all these data were modeled with triangular probability distributions. A triangular distribution was chosen due to limited data and expert knowledge considerations. Top Rank® software was used to conduct the analysis and, according to the Spearman correlation coefficients, factors that influence revenues are (in descending order): VMT volume (0.61), vehicle class share (0.50), VMT fee pricing levels (0.50), emission class share (0.29), and violations (0.18). The correlation coefficients reflect the statistical

dependence between variables, therefore we expect that even under the assumption of a different probability distribution, as a normal distribution, the relative values of the coefficients would be similar.

Table 2 shows the estimated current fuel taxation per mile for the classes of vehicles considered in our study. These values were obtained by dividing the current state fuel tax per gallon on gasoline (\$0.208/gal) by average miles traveled by every vehicle class per gallon (22.3 mi/gal, 8.2 mi/gal, 5.6 mi/gal). It is important to note that this projection is generated with the state fuel tax, but apart from the state fuel tax on fuel (\$0.208/gal), there is also a federal fuel tax (\$0.184/gal on gasoline and \$0.244/gal on diesel).

Table 2. Estimation of the Current State Fuel Taxation per Mile, Texas

Type of vehicle	Estimated state fuel tax
Light duty vehicle	\$0.009/mi
Single-unit truck	\$0.025/mi
Combination truck	\$0.037/mi

Data for the VMT Fee Scenarios

Based on these estimates, we developed three different scenarios to illustrate potential revenues available from a VMT fee system. To start, we considered the estimates of the 2030 Committee (2011) made up of experienced and respected business leaders and transportation researchers. This analysis reported that the funds needed in Texas to ensure at least minimum competitive conditions in pavements, bridges, and urban and rural system performance from 2011- 2035 is approximately \$217 billion, which is about twice the projected income from the fuel tax (\$100 billion), resulting in a funding gap of \$117 billion. Based on these estimates, we analyzed three alternative scenarios: (1) a VMT fee designed to generate similar revenues as the fuel tax—100% revenues, (2) a fee comprising 150% of the fuel tax revenues, and (3) a fee set to collect 200% of current fuel tax revenues. These are done in an effort to fully address the financial needs indicated by the 2030 Committee.

Scenario 1 represents VMT fee taxation levels similar to what a driver pays in the current fuel tax system. In this scenario, the VMT base fee is set to \$0.009/mi, which should generate revenues similar to the current fuel tax. The \$0.009/mi fee proposed in this scenario is similar to the level of revenue-neutral VMT fees identified by Robitaille et al. (2011). Drivers of vehicles with high emission standards would benefit from this scenario by paying a lower fee than under the fuel tax, and the fee would increase only for vehicles with low emission standards. This should motivate the usage of cleaner vehicles, while concurrently not forcing an overall greater cost of transportation. The estimated break-even year is 2055.

Scenario 2 has the VMT base set to \$0.013/mi. This reflects about a 50% increase in the fee from the previous scenario, which should generate revenues roughly 150% of current fuel tax revenues. A similar fee was charged per vehicle mile in the Oregon Mileage Fee Project. In addition, Durden (2010) reported that to generate total revenues for Texas highways equal to the \$258 billion needed between 2012 and 2030, a VMT fee would need to be set between \$0.0143/mi and \$0.0164/mi. According to our VMT fee projection, prices for Scenario 2 are similar to those Durden (2010) reported for Texas. However, the revenues generated between 2012 and 2030 according to our projection are \$99 billion (gross) and \$61 billion (net). The difference between our total revenues projection and Durden's estimate are due to the interpolation of the expected VMT volume, as well as different building costs, operating costs, penalty income, and discount rate used in Scenario 2.

Scenario 3 sets the VMT base fee to \$0.018/mi, which is double what a driver pays under the current fuel tax system. We understand that these pricing levels might not be acceptable to the public

or, in a more optimistic case, these fees would simply motivate users to opt for alternative modes of transportation such as mass transit, biking, and walking. In the case of freight transportation, the high fee might induce a modal shift to rail and force usage of trucks for shorter distance hauls. To compare the hypothetical fee with the current tolling situation in Texas, the actual toll rate on specific sections of interstates, according to the North Texas Tollway Authority, is \$0.153 per mile (NTTA 2011) and by 2017 is expected to increase to \$0.1801 per mile. However, NTTA charges drivers by section, not distance, and the toll is differentiated only by number of axles into five classes.

Results of the VMT Fee Scenario Analysis

Table 3 shows a summary of the VMT fee revenue results for each scenario as compared with the fuel tax. VMT fees, building costs, operating costs, assumed average funding levels for transportation projects, average net revenues, and break-even year are all shown in this table.

Our assumption of building costs of \$6 billion across Texas was based on a GPS/GSM cost model developed for Germany and Austria (IBTTA 2004). In this model, costs were estimated to be three times greater for a sixfold larger network. The majority of the building costs for a satellite/cellular data collection system comes from on-board units, so that the idea to build the system as an open architecture and let the users and market decide how they want to report mileage helps to mitigate costs. Operating costs were assumed to be 6.6% of revenues (based on Balducci et al. 2011). Annual average funding for transportation projects was set to \$1,759,177,973 (average through the years 1-60), and is based on current spending as of 2010-2011, coupled an increase of 0.5% every year. Not surprisingly, the scenario with a \$0.018/mi VMT fee was estimated to breakeven in 2006.

Based on the scenario results we find that, all things considered, a base fee of at least \$0.018/mi should be sufficient to cover the projected funding needed to address current road transportation needs in Texas. For less expansive states in the U.S., building costs/miles ratio may be higher, so that implementation of VMT fees concurrently in several states would result in lower costs.

VMT fees may be perceived by the public in the short term as a significant increase in costs compared with the current fuel tax. But in a VMT regime, vehicle owners may be motivated to renew their fleet to cleaner vehicles (Bina, L. unpublished data, Jun. 2, 2012) or, in the case of commercial transport, induce a shift to rail. However, a VMT regime may also result in either higher priced for rail services or less readily available consumer goods. Therefore, alternative transportation modes, including mass transit, walking, and biking, may become more attractive to the public due to their affordability.

These changes would promote societal benefits, including environmental sustainability, generating fewer emissions of greenhouse gases, and less use of non-renewable resources.

Table 3: Comparison of the State Fuel Tax and the VMT Fee Scenarios

		Fuel tax	Scenario 1	Scenario 2	Scenario 3
Type of Vehicle	Base Fee	–	0.009/mi	0.013/mi	0.018/mi
Light Duty Vehicle	BIN 11-6	\$0.009	\$0.015 (69%)	\$0.022 (144%)	\$0.031 (239%)
	BIN 5-3	\$0.009	\$0.011 (26%)	\$0.016 (81%)	\$0.023 (150%)
	BIN 2-1	\$0.009	\$0.009 (0%)	\$0.013 (44%)	\$0.018 (100%)
Single-Unit Truck	BIN 11-6	\$0.025	\$0.028 (10%)	\$0.040 (59%)	\$0.055 (120%)
	BIN 5-3	\$0.025	\$0.022 (-14%)	\$0.031 (25%)	\$0.043 (72%)
	BIN 2-1	\$0.025	\$0.017 (-31%)	\$0.025 (0%)	\$0.035 (38%)
Combination Truck	BIN 11-6	\$0.037	\$0.040 (9%)	\$0.058 (57%)	\$0.080 (117%)
	BIN 5-3	\$0.037	\$0.031 (-16%)	\$0.045 (22%)	\$0.062 (69%)
	BIN 2-1	\$0.037	\$0.025 (-32%)	\$0.036 (-2%)	\$0.050 (35%)
Building costs		–	\$6,000,000,000	\$6,000,000,000	\$6,000,000,000
Operating costs (6.6% of revenues)		–	\$180,737,384	\$261,065,110	\$361,474,768
Assumed average funding for transportation projects in year 2001-2060, incl. 3% discount rate		\$1,759,177,973	\$1,759,177,973	\$1,759,177,973	\$1,759,177,973
Average net revenues in year 2001-2013		\$2,951,383,398	\$2,696,003,024	\$4,060,271,035	\$5,765,606,049
Break-even year		–	2055	2024	2006

CONCLUDING REMARKS

Since revenues from the current transportation funding system in the United States are not nearly sufficient to address the needs of a future transportation network, alternative funding approaches are gaining more interest if for no other reason than to bridge this funding gap. A VMT fee is one interesting alternative to flat user fees since it accounts for the actual usage of the transportation network by vehicles, and also helps to internalize environmental externalities. The literature indicates that the key factors influencing the development of a VMT fee regime can be grouped in the following categories: [1] public acceptance, [2] revenues, [3] technology, [4] type of contract, [5] government policies, and [6] enforcement, administration, and invoicing. We conclude that the basic policy framework needed to analyze the feasibility of VMT fee implementation consists of four steps: [1] background study, [2] feasibility study, [3] VMT fee study, and [4] external relationships study.

At present, there have been a number of small scale trial runs of distance-based user charges throughout the U.S. Distance-based truck charges are popular in Europe, where major highways in some countries are equipped with toll gantries with microwave technology that enables communication with on-board units. However, with ongoing progress in satellite navigation, the usage of a GPS/Galileo/GLONASS signal seems like the best choice for future broad-based tolling systems. In the U.S., we offer that statewide VMT fee implementation is an interesting option that can be used to better address transportation funding needs. A VMT fee-based charging system ensures a more sustainable source of revenues, although it can be strongly affected over time by changes in fuel efficiency or increased use of alternative-fuel vehicles.

Implementation costs of a VMT fee system may be perceived as high over the short term, but we argue that it will be a more reliable source of revenues in the long term. A VMT fee is also designed to be equitable. It is usage-based since it can be differentiated by axles (an indicator of road damage) and by vehicle emission class (an indicator of pollution). Significant improvements in air quality and savings in non-renewable resources are to be expected due to VMT fee implementation because emission class differentiation will ultimately motivate drivers to own cleaner vehicles.

Further research about pricing levels for a VMT policy as well as more consideration about the factors that influence the acceptance of those levels is needed, since there is justifiable concern about the public reaction to a financially acceptable VMT fee. Uncertainty can also be considered in the future using a probabilistic approach in scenario analysis. This would allow the researcher to evaluate the sensitivity of these results to a number of factors, including changes in fleet composition as well as traffic volumes associated with different pricing levels.

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References

2030 Committee: Walton, C.M., D. Marcus, K. Allen, D. Crutcher, E. Emmet, J. Hawley, T. Johnson, C. Looney, R. Nober, and G. Thomas. "It's About Time: Investing in Transportation to Keep Texas Economically Competitive." 2011. http://texas2030committee.tamu.edu/documents/final_03-2011_report.pdf, accessed September 12, 2013.

Association of American Railroads. "Freight Rail: Moving More Goods on Less Fuel." 2012a. <http://freightrailworks.org/#innovation/fuel>, accessed March 18, 2013.

Association of American Railroads. "Freight Rail: The Best Way to Ship Perishable Products." 2012b. <http://freightrailworks.org/#agriculture/perishable>, accessed March 18, 2013.

Arnold, R., et al. "Reducing Congestion and Funding Transportation Using Road Pricing in Europe and Singapore." Federal Highway Administration (FHWA), Research Report FHWA-PL-10-030, 2010.

Baker, T., G. Goodin, and C. Pourteau. "Is Texas Ready for Mileage Fees? A Briefing Paper." Texas Transportation Institute for Texas Department of Transportation (TXDOT), 2011.

Balducci, P., G. Shao, A. Amos, and A. Rufolo. "Costs of Alternative Revenue-Generation Systems." Transportation Research Board of the National Academies, National Highway Cooperative Research (NCHRP) Report 689, 2011.

Bina, L., F. Lehovc, P. Moos, H. Novakova, and P. Karlicky. "Analysis of Electronic Toll System in the Czech Republic and Conformity with EU Directives, Tariffs and Toll Revenue in Connection to Investment and Maintenance Costs." – Report in Czech. Prague, Czech Republic: Ceske vysoké ucení technické v Praze, Fakulta dopravní, 2011.

Bina, L., V. Cerny, and H. Novakova. "Road Charging in the Czech Republic and EU and External Costs of Transport." *Journal of Civil Engineering and Architecture*, ISSN 1934-6 (5), (2012): 562-568.

Carlton, J. and M. Burris. "Comprehensive Equity Analysis of Mileage-Based User Fees: Taxation and Expenditures for Roadways and Transit." *Journal of the Transportation Research Forum*, 53 (2), (2014): 21-43.

Cooper, C.D. "Air Pollution Control Methods." Kirk-Othmer Encyclopedia of Chemical Technology, 2007.

CURACAO. "Acceptability." Coordination of Urban Road-User Charging Organizational Issues, 2008. <http://www.curacaoproject.eu/workfiles/files/workpackages/WP4/Fact%20Sheets/Final%20Version%20Themes/Acceptability.pdf>, accessed February 8, 2012.

Delcan Corporation, Calmar Telematics. "A Practical Approach to Truck VMT Fees, Including Some Financial Implications and Possible Impacts on Traffic Congestion." by Delcan Corporation, Calmar Telematics, and Greater Buffalo Niagara Regional Transportation Council with support from Capital District Transportation Committee Binghamton Metropolitan Transportation Study, NY, 2011.

Di Ciommo, F., A. Monzon, and A. Fernandez-Heredia. "Improving the Analysis of Road Pricing Acceptability Surveys by Using Hybrid Models." *Transportation Research Part A* (2013). <http://dx.doi.org/10.1016/j.tra.2013.01.007>

Dill, J. and A. Weinstein. "How to Pay for Transportation? A Survey of Public Preferences in California." *Transport Policy* 14 (4), (2007): 346-356.

Durden, D.J. "Funding Texas Highways for the Next 20 Years." *Texas Civil Engineer*, Winter 2010, Volume 81, 2010.

Eliasson, J. "Lessons from the Stockholm Congestion Charging Trial." *Transport Policy*, Decision-Support for Sustainable Urban Transport Strategies 15 (6), (2008): 395-404.

Francke, A. and D. Kaniok. "Responses to Differentiated Road Pricing Schemes." *Transportation Research Part A*. <http://dx.doi.org/10.1016/j.tra.2012.10.002>, 2014.

Elmendorf, D.W., J. Holland, B. Blom, R. Arnold, C. Hawley Anthony, M. Booth, A. Marcellino, S. Vallinas, J. Brewster, and H. Battelle. "Trust Funds and Measures of Federal Debt." *The Budget and Economic Outlook: Fiscal Years 2010 to 2020*, The Congress of the United States - Congressional Budget Office, 2008. <http://www.cbo.gov/ftpdocs/108xx/doc10871/AppendixD.shtml>, accessed October 30, 2011.

Elmendorf, D.W., P. Beider, J. Kile, and D. Moore. "Alternative Approaches to Funding Highways." The Congress of the United States - Congressional Budget Office, 2011. <http://www.cbo.gov/ftpdocs/121xx/doc12101/03-23-HighwayFunding.pdf>, accessed October 30, 2011.

Engel, E., R. Fischer, and A. Galetovic. "Public-Private Partnerships to Revamp U.S. Infrastructure." The Hamilton Project, Washington D.C., 2011. http://cowles.econ.yale.edu/~engel/pubs/efg_revamp.pdf, accessed November 11, 2012.

Federal Highway Administration, "Annual Vehicle Distance Traveled in Miles and Related Data 2009 By Highway Category and Vehicle Type." Highway Statistics 2009, Federal Highway Administration, 2009. <http://www.fhwa.dot.gov/policyinformation/statistics/2009/vm1.cfm>, accessed March 2, 2012.

Federal Highway Administration, "Motor Fuel Tax Compliance Outreach." Frequently Asked Questions, 2010. <http://www.fhwa.dot.gov/motorfuel/faqs.htm>, accessed October 30, 2011.

Federal Highway Administration. "Status of the Highway Trust Fund." 2015. <http://www.fhwa.dot.gov/highwaytrustfund/index.htm>, accessed January 31, 2015.

Federal Highway Administration. "General Highway History: When Did the Federal Government Begin Collecting the Gas Tax?" 2005. <https://www.fhwa.dot.gov/infrastructure/gastax.cfm>, accessed July 15, 2017.

Gaunt, M., T. Rye, and S. Allen. "Public Acceptability of Road User Charging: The Case of Edinburgh and the 2005 Referendum." *Transport Reviews* 27 (1), (2007): 85-102.

Hanley, P.F. and J.G. Kuhl. "National Evaluation of Mileage-Based Charges for Drivers - Initial Results," *Transportation Research Record: Journal of the Transportation Research Board*, 2221, (2001): 10-15.

International Bridge, Tunnel and Turnpike Association, "State of the Art Analysis of European Toll Collection Systems." Fall Technology Workshop, November 2004, Spain. http://www.ibtta.org/files/FileDownloads/Sage_Dieter.pdf, accessed November 12, 2012.

Jones, P. "Several States Give Green Light to Mileage Fee Pilot Programs." 2016. <http://www.taxanalysts.org/content/several-states-give-green-light-mileage-fee-pilot-programs>, accessed July 17, 2016.

Keuleers, B., V. Chow, N. Thorpe, H. Timmermans, and G. Wets. "Behavioural Change in Activity-Travel Pattern in Response to Road User Charging." *Journal of Transport Economics and Policy* 40 (1), (2006): 119-134.

Langmyhr, T. and T. Sager. "Implementing the Improbable Urban Road Pricing Scheme." *Journal of Advanced Transportation* 31 (2), (1997): 139-158.

McCormally, K. "A Brief History of the Federal Gasoline Tax." Kiplinger, 2014. <http://www.kiplinger.com/article/spending/T063-C000-S001-a-brief-history-of-the-federal-gasoline-tax.html>, accessed July 15, 2017.

National Surface Transportation Infrastructure Financing Commission. "Paying Our Way. A New Framework for Transportation Finance." 2009. http://financecommission.dot.gov/Documents/NSTIF_Commission_Final_Report_Advance%20Copy_Feb09.pdf, accessed November 13, 2012.

North Texas Tollway Authority. "Toll Rates." North Texas Tollway Authority, 2011. <http://www.ntta.org/AboutUs/TollRates/Toll+Rate+FAQ>, assessed March 28, 2012.

Oregon Department of Transportation. "Road Usage Charge Pilot Program." 2012. <http://www.oregon.gov/ODOT/HWY/RUFPP/Pages/rucpp.aspx>, accessed November 11, 2012.

Oregon Department of Transportation. "Road Usage Charge Program." 2015. <http://www.oregon.gov/ODOT/HWY/RUFPP/pages/index.aspx>, accessed January 31, 2015.

Robitaille, A.M., J. Methipara, and L. Zhang. "Effectiveness and Equity of Vehicle Mileage Fee at Federal and State Levels." *Transportation Research Record: Journal of the Transportation Research Board*. Report number 11-4102, (2011): 27-98.

Rufolo, A.M. "Cost Estimates for Collecting Fees for Vehicle Miles Traveled." *Transportation Research Record: Journal of the Transportation Research Board*. Report number 11-2168, pp. 39-45, 2011.

Silnice-Zeleznice.cz. "Financování rozvoje dopravní infrastruktury." – Report in Czech. 2014. <http://www.silnice-zeleznice.cz/clanek/financovani-rozvoje-dopravni-infrastruktury>, accessed April 20, 2012.

Schank, J. and N. Rudnick-Thorp. "End of the Highway Trust Fund? Long-Term Options for Funding Federal Surface Transportation." Presented at the Transportation Research Board Annual Meeting, 2011, Washington, D.C.

Texas Department of Transportation. "Total Daily Statewide 2035 Forecast Vehicle Miles Traveled (VMT) Map." Texas Statewide Long-Range Transportation Plan, 2010. http://ftp.dot.state.tx.us/pub/txdot-info/tpp/plan_2035/boards/vmt_map.pdf, accessed on February 20, 2015.

U.S. Energy Information Administration. "Gasoline Prices Tend to Have Little Effect on Demand for Car Travel." 2014. <http://www.eia.gov/todayinenergy/detail.cfm?id=19191>, accessed February 20, 2015.

Vavrova, M. "Development of an Electronic Vehicle Miles Travelled Toll Model." MSc. Thesis, Dept. of Civil Engineering, University of Texas at El Paso, 2012.

Vierth, I. and H. Schleussner. "Impacts of Different Environmentally Differentiated Truck Charges on Mileage, Fleet Composition and Emissions in Germany and Sweden." Centre for Transport Studies Stockholm, 2002.

Whitty, J.M. "Oregon's Mileage Fee Concept and Road User Fee Pilot Program, Final Report," Oregon Department of Transportation, 2007.

Zmud, J. and C. Arce. "Compilation of Public Opinion Data on Tolls and Road Pricing." Transportation Research Board of the National Academies, National Cooperative Highway Research Program (NCHRP) Report 377, 2008.

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Bringing in the Sheaves: Changes in Canada's Grain Supply Chain Through the Post Canadian Wheat Board Era

by Derek G. Brewin, James F. Nolan, Richard S. Gray, and Troy G. Schmitz

Vast distances in the Canadian grain handling system means that the supply chain is highly reliant on rail transportation. After years of relative stability, the grain supply chain has recently undergone many significant changes, including deregulation in grain handling. However, the consequences emerging from some of these changes were unexpected. In this paper, we explore the evolving behavior of participants in the increasingly liberalized Canadian grain handling supply chain. The changes seem to be creating new winners and losers in the system. To this end, we find that while current railroad regulations in Canada have led to efficiencies, deregulation of grain handling seems to have generated gains for grain companies at the expense of farmers.

INTRODUCTION

Canada's grain production is concentrated in the northern prairie region of North America. Distances in the Canadian grain supply chain are extreme, meaning that the system is very reliant on rail for transportation of grain. And the industry moves a considerable amount of grain. For example, Canada is expected to export about 40 million metric tonnes of grain in the 2016/17 crop year (AAFC 2016).

In Canada, grain farmers pay for transportation. So by industry definition, the difference between the export grain price at port position and an average prairie grain elevator price is referred to in Canada as the export basis, or simply "basis." As calculated, the basis is used by industry to estimate how much farmers pay to move their grain to port. The lower the basis offered by grain companies, the more farmers are incentivized to move grain into the system, while a high basis does just the opposite. The basis estimates serve as a broad metric of how the system is operating and is critical to farm level decision making. Export basis for both wheat and canola is currently estimated by Quorum Corporation, a private company currently serving as a data monitor for the grain handling system.

The 2012/13 crop year was the first crop year after the cessation of the historically important single desk marketing function of the Canadian Wheat Board (CWB) in Canada. Quorum Corp reported that the export basis for wheat was around \$54/t (Quorum 2015). But by 2013/14 and a record grain crop being harvested, the Canadian export wheat basis eventually grew to \$133/t, a level never before seen in Canada. This situation and its consequences regarding the overall viability of the grain supply chain prompted a review by the Canadian government. This review led to temporary new regulations in the system, including short-term car spot requirements for railways, as well as modified regulations designed to promote more inter-railroad competition for the movement of grain (Nolan and Peterson 2015).

The Canadian grain supply chain remains in major transition. We explore the past, present, and future viability of participants in the Canadian grain handling sector. To this end, a recent study suggested a nearly competitive outcome was achieved by the system over that 2012/13 crop year, but subsequently the system transitioned to a near cartel by 2013/14 (Brewin 2016). Why did this happen? Who did it affect? We analyze these markets by modeling explicit grain supply

and demand relationships. Subsequently, we develop some game theoretic constructs that may be applicable to help understand the system and its subsequent evolution, and then we highlight the implications of our findings for the long run.

THE CANADIAN GRAIN SUPPLY CHAIN

The major participants in Canada's grain supply chain are farmers, elevator companies, railways, and terminal port operators (where the latter are mostly the same set of firms who buy and process grain on the prairies), all marketing Canadian grain to export buyers. About 82% of Canada's crop land is located in the three prairie provinces of Alberta, Saskatchewan and Manitoba (see Figure 1). Wheat and canola are by far the largest share of agricultural exports (76%) from the prairie region (AAFC 2016). Due to growing demand for grains and oilseeds from Asia, much of this crop moves into export position through the West Coast port of Vancouver.

For exposition, Table 1 lists the shares of interior primary elevator capacity in Canada, as well as port terminal capacity in the port of Vancouver. On the ground, about 70,000 Canadian farms earn at least some of their income from grain and oilseed sales (Statistics Canada 2016a), while recent data show that in Alberta, Saskatchewan, and Manitoba, average farm size is 473, 675, and 460 hectares, respectively (Statistics Canada 2016b). For example, a typical Manitoba grain farm has variable costs of about \$496 and \$635 per hectare for wheat and canola, respectively, with average yields of about 3.7 and 2.2 tonnes per hectare (MAFRD 2016). Farmers plant seed and fertilize in the spring, control weeds and irrigate (if available) in the summer, and harvest grain in the fall. Most of the grain harvested goes into on-farm storage and, once sold, is later moved (by truck) from the farm to the elevator system.

Three large companies - Viterra, Cargill, and Richardson/Pioneer - dominate Canada's primary grain elevation as well as port terminal grain elevation in Vancouver. The largest of the three, Viterra, emerged from several decades of mergers and acquisitions among Canada's once dominant farmer-owned grain cooperatives (Brewin 2014). But changes in the industry are still in process. Viterra was in turn recently purchased by the international commodity trader Glencore in 2013 (Brewin 2016).

Table 1: The Canadian Grain Handling Sector

Canadian Grain Exporters	Primary Elevator Capacity (000 t)	Vancouver Terminal Capacity (000 t)
Cargill	681.8	237
Louis Dreyfus	377.6	0
P & H	548.2	25*
Patterson	544.5	25*
Pioneer (RI)	1449.7	108 and 71**
Viterra	1812.0	136 and 212**
All Others	1050.5	50*

Source: Brewin 2016

Rail Regulation and Grain Rates

The two Canadian Class 1 railways (CN and CP) dominate transportation in the Canadian grain supply chain, with a number of short line railways still serving the region (Nolan 2007). Both

of the Class 1 railways have major hubs in Winnipeg, where they can move grain into the Great Lakes port of Thunder Bay (Figure 2). This eastbound grain is moved through the Saint Lawrence Seaway and often is transshipped through the port of Montreal for movement across the Atlantic Ocean. While both CN and CP have access into the port of Vancouver, CN has sole access to the other Pacific freight handling port at Prince Rupert, a slightly more remote location where terminal capacity is jointly owned by the major grain companies.

Figure 1: Agricultural Land in Canada (Eilers et al. 2010)

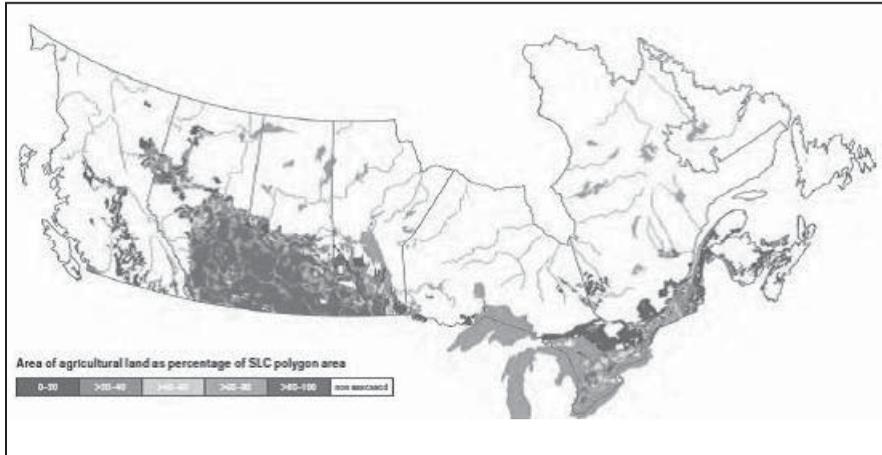


Figure 2: Railway Network, Western Canada (Government of Alberta 2016)



To further encourage individuals to settle western Canada in the late 1800s, a regulated “Crow Rate” was negotiated between the private Canadian Pacific Railway and the Federal Government of Canada (Nolan 2007). This legislation fixed low rates for grain and settlers’ goods in exchange for mineral rights in the Rocky Mountains. Eventually, the Crow Rates were made statutory and were applicable for all Canadian railways by 1925. The statutory rates were gradually adjusted through successive regulatory reforms, with major reforms occurring in 1985 (the Western Grain Transportation Act), 1987 (the National Transportation Act), 1996 (Canadian Transportation Act) and finally again in 1999 (as an amendment to the Canadian Transportation Act).

In June 2000, Bill C-34 became law. This was a modification of the extant Canada Transportation Act, stemming directly from an extensive system review process. The review recommended removal of the extant rate cap policy, to be replaced instead with regulation on railway revenues

from grain movement. In effect, the resulting Bill C-34 replaced rate regulation with the maximum revenue entitlement (MRE) policy for grain. The MRE was intended to mitigate railway market power in grain movement, but also to give the railways more rate flexibility than existed under the former rate cap.

The MRE is still a somewhat unique regulatory policy in the transportation sector. It is effectively a cap on average railway revenue per tonne for all grain movement in a crop year, allowing for some degree of price discrimination by the railway. The novelty of the MRE meant that it took some time for the Canadian railways to fully understand how to make it work to their advantage (Riegle 2001). Since it was focused on revenues, what became clear to the railways under the MRE was the need to constantly seek cost reductions over grain movements to sustain or increase profitability. Under the MRE, Canadian railways have developed new mechanisms to create cost efficiencies and generate increasing profits.

One method for generating cost savings in the MRE era has been the growth of shipper incentives for larger train movements. If a shipper can assemble large volumes of grain, this will result in a highly cost efficient use of locomotives and crew. This engineering-based cost saving is the reason why the railways in Canada under the MRE began to offer reduced freight rates for 50- and 100-car blocks of grain. In addition, both major Canadian railways have at various times offered "shuttle" discounts for long grain trains that move from a single delivery point to export position and back again. All of these discounts typically fall somewhere between 5% to 20 % of a reference standard single car quoted rate.

Rate discounts effectively represent a degree of sharing with shippers some of the cost efficiencies associated with the assembly of a unit train. Since under the MRE average freight rates within a given year do not change, smaller grain shippers delivering fewer hopper cars often pay relatively higher rates, in effect offsetting lower rates offered to larger shippers who can deliver more grain cars. Under the MRE, large unit train incentives remain important to rail operations and grain transportation planning.

Since the MRE provides the railways with incentives to seek cost economies, it has led to the current dominance of large unit grain trains in the industry. But all parties in the supply chain must coordinate their actions in order to load a large unit train in a timely manner, and this coordination effort can be more costly to some participants. What is not well understood is the total amount of logistics and transportation cost savings that a railway obtains through the assembly and movement of unit grain trains, and by extension little is known about the proportion of this latter cost saving that may or may not be passed on to other participants in the grain supply chain.

The former Canadian Wheat Board (CWB) served as a major regulatory factor in Canada's grain supply chain. The CWB, created in 1935, coordinated wheat and barley marketing for Canada (Brewin 2014). And from 1943 to 2012 the CWB was the "single desk" marketer of Canadian wheat and barley for export or domestic human use. The CWB operated as a non-profit organization and was not designed to curtail farm production. They did, however, manage producer delivery of grains to the commercial system through a series of delivery quotas, and later through contract calls. Due to their position in the industry, the CWB was also able to price discriminate among major buyers of Canadian wheat and barley (e.g., Brooks and Schmitz 1999). The CWB was ultimately given wide powers within the supply chain, including managing publicly owned rail cars, calling grain into specific rail corridors as well as negotiating elevation and unregulated rail rates with grain companies and railways (Nolan and Drew 2002).

Losing the CWB was bound to have profound effects on the grain supply chain. The hope was that opening up marketing and logistics to the grain companies in Canada would ultimately lead to more and competitive choices for all industry participants, including farmers. And in the immediate transition period, this seems to have been the case. Just after the CWB was dissolved in the summer of 2012, the relatively small grain and oilseed crop that year appears to have led to significant price competition between grain companies and railways to the benefit of farmers. With

a high port price and a narrower export basis, farmers were offered near record domestic prices for their grain in 2012. But by the fall of 2013, Canadian farmers were facing their widest export basis in many decades. The next section motivates economic models that will help us assess who gained and who lost in the transition away from the CWB in the Canadian grain supply chain.

A MODEL OF CANADIAN GRAIN TRANSPORTATION REGULATION

Previous research about the Canadian grain supply chain often focused on the level and value of price discrimination practiced by the CWB among buyers of Canadian wheat and barley. Only a few studies examined the effect of the CWB on grain logistics and transportation services for farmers, grain companies, and railways. To start, Fulton et al. (1998) modeled this as a bargaining process but assumed the railways were fully deregulated, while another study peripherally modeled the Canadian grain sector as an oligopoly (Zhang et al. 2007). More recently, Çakir and Nolan (2015) developed a vertical model of the sector (without the CWB) and found that, under a set of reasonable assumptions, considerable market power could be exercised by the railways in the absence of rail regulation.

Prior theoretical work examining revenue based regulatory policies mostly highlights the implementation and potential consequences of a so-called average revenue cap on a monopolist. The latter literature formed part of the extensive utility deregulation discourse that originated in the United Kingdom through the 1980s and early 1990s (Bradley and Price 1988). This discourse offered mixed reviews of the effectiveness of revenue-based regulation over other forms of natural monopoly regulation, such as price or rate caps.

Under the MRE as currently implemented in Canada, allowable revenues on grain and oilseeds movement by each of Canada's two Class 1 railways are calculated every year using the following formula:

$$(1) \quad m_{it} = \left[\frac{a_i}{b_i} + (g_{it} - d_i) \times k \right] \times e_{it} \times f_t$$

where: m_{it} is the maximum revenue entitlement for firm i for crop year t ; a_i and b_i are base year revenues and tonnes of grain hauled for railway i as of 1999/2000; g_{it} and d_i are current year t and base year average distance hauled for railway i ; k is a constant used to approximate the costs of transporting grain longer average distances; e_{it} is the number of tonnes of grain moved in year t by railway i ; and f_t is a cost adjustment factor applicable for the current year t that helps account for input price changes across a range of major inputs employed by the railways.

Several of the MRE components are relatively static, while others have undergone considerable changes. For example, average grain distance hauled has not changed significantly since the implementation of MRE. But there have been significant adjustments to the cost factor used in the MRE calculation, adjustments that are beyond the control of the railways (Quorum 2016).

If we ignore the terms g_{it} , d_i , k , and f_t in the subsequent discussion, m_{it} can essentially be interpreted as a profit maximization constraint. For illustrative purposes, consider the following example in which we assume there are just two grain companies who move grain and that each grain company has a different cost structure. Referring to the base year aspect of the MRE, average rates to move grain were fixed at that time by government, and the volume of grain moved was linked to car allocation schemes managed at that time by the CWB and not the grain companies. Knowing this, the individual railway's profit maximization problem would be to choose optimal quantities sourced from either of two shippers (i.e., grain companies 1 and 2) with different cost structures, thus maximizing the following Lagrangian with respect to variables q_{1t} , q_{2t} , λ_m , and λ_q :

$$(2) \quad L_{it} = \frac{P_{1t}q_{1t} + P_{2t}q_{2t}}{q_{1t} + q_{2t}} - c_1q_{1t} - c_2q_{2t} + \lambda_m \left(\frac{P_0q_{10} + P_0q_{20}}{q_{10} + q_{20}} - \frac{P_{1t}q_{1t} + P_{2t}q_{2t}}{q_{1t} + q_{2t}} \right) + \lambda_q (\bar{q} - q_{1t} - q_{2t})$$

where: L_{it} is the Lagrange value function for railway i for crop year t ; p_{jt} and q_{jt} are the prices and quantities for grain company j in crop year t (with the base year value here equal to 0), λ_m and λ_q are the shadow values of the MRE and the fixed supply of grain to haul (\bar{q}), and c_j is the cost to the railway of shipping from grain company j . Note that if the costs are fixed for each grain company and $c_1 > c_2$, the constrained profit function is linear and maximized when all of \bar{q} is shipped to the lower cost shipper (#2 in this case), and the price of rail services is the same as the base value price P_0 .

But understanding the overall effectiveness and need for grain transportation regulation is linked to the active players operating in the supply chain. While many understood that the role of the former CWB in Canadian grain handling and transportation was significant, almost no research exists that formally assessed the role of the CWB as a “countervail” to both railway and grain company market power in the Canadian supply chain. In order to better understand the future of grain supply chain regulation in Canada, we need other perspectives to help assess the role played by the CWB in this regard.

Since late 2012, grain companies in Canada have played a more significant role in grain marketing and logistics. Interestingly, some offer evidence that grain companies in fact priced their services at near cartel levels as early as 2013 (Brewin 2016; Brewin et al. 2017). To clarify what has happened, we illustrate this situation applied to the grain sector through Figure 3. Here, we assume D is the domestic demand curve for grain while S is the domestic supply curve. P_w is assumed to be the world price available at port (for export), while P_c is the price offered to domestic producers if the internal market chain is free of regulatory distortions. The latter is equal to P_w minus the cost of moving goods through the chain. P_m is any price offered by grain handlers that happens to be lower than the world grain price, minus their real costs.

From a supply chain perspective, we offer that the difference between P_c and P_m is a measure of competition in the supply chain. The more competition in the supply chain, the nearer P_m will approach P_c . Note that Q_{dc} and Q_{dm} represent the quantity of domestic grain consumption at P_c and P_m , respectively, while Q_{sc} and Q_{sm} represent domestic grain supply at P_c and P_m , respectively. Grain exports equal the quantity supplied minus domestic consumption under either price. For the grain trade in Canada, the difference between P_w and P_m is referred to as the “export basis.” We can also observe that a drop in the price received by producers from P_c to P_m leads to welfare changes – this translates to a gain of area d for the grain companies, and a gain to domestic consumers of areas a and b , but a loss of areas a, b, c, d and e in producer surplus. Given this lens of analysis, this study represents a very preliminary attempt to measure the scale of welfare changes among participants that have occurred through time in the Canadian grain supply chain.

In its heyday, the CWB advertised itself in the public domain as a countervail against the market power of the railways with respect to grain movement (Fulton, 2006; Schmitz and Furtan 2000). So to paraphrase the contribution of this analysis, we will evaluate the former CWB’s success at working alongside both grain companies and railways in order to mitigate their potential for market power exertion over farmers in the Canadian grain supply chain.

To this end, there is a small body of related research that uses the well-known Shapley value (Roth 1988) to compute relative market power measures when applied in context to resource supply chains. For example, recent papers by Hubert et al. (2014, 2015) use Shapley values to evaluate relative market power exertion among participants within European natural gas networks. But most closely related to this work is research assessing relative market power in a major U.S. coal

supply chain (Wolak and Kolstad 1988). In the coal producing Powder River Basin, competition for relative market position was believed to have occurred between states (who can charge taxes to participants) and railroads (who can charge rates to coal shippers). The authors argued that coal movement was in effect a lucrative rent-seeking game in which the participants maneuvered over time so as to extract rent from the coal market. Assuming participant interaction in this supply chain market power/rent extraction game manifested in various state/railroad coalitional structures, the latter's structure and consequences were measured through imputations based on Shapley calculations.

Under the assumption that the Canadian grain supply chain has evolved as a cooperative supply chain game in a similar manner, we estimate relative historical market power in the chain by valuing grain handling coalitions that could be formulated among the participants. Using available industry data, we compute a set of Shapley values over grain industry revenue in order to assess the relative strength of each participant in a stylized grain supply chain game.

THE CURRENT CANADIAN GRAIN SUPPLY CHAIN

With a long history of regulation, grain transportation in Canada at present relies on regulations that incentivize particular behavior. For example, equation (2) means that under the current MRE policy on grain rail revenues, railways should avoid serving high cost shipping points. From a rail perspective, such an incentive eventually translates into service cuts or line abandonment. While rail line abandonment in Canada began in earnest under the former WGTA, important changes in the sector still occurred between the 1999/2000 crop year and up to the 2014/15 crop year (Quorum 2016). Over this time, there has been:

- 67% reduction in primary elevators in Western Canada, from 976 to 326 elevators
- 1% increase in total storage capacity of all elevators, from 1.60 to 1.64 million tonnes
- 38% increase in turnover rate for the primary elevators, from 4.8 to 6.6 turns
- 98% increase in turnover rate for terminals, from 9.1 to 17.1 turns
- 67% increase in share of grain car rail movements in lots over 50 cars, from 50.4% to 84.2%
- 147% increase in total volume moved by rail, from 12.9 to 31.9 million tonnes
- 111% increase in average incentives for 50-plus car movements, from \$3.54 to \$7.47/tonne.

These basic measures indicate that, over time, it has gradually become less costly for the system to handle and move grain for export. However, as mentioned, it remains an open question as to who has benefitted from these industry cost savings (Figure 3).

Figure 4 shows that the export basis in Canada has generally increased over time (Quorum, 2016), save for the very first year without the CWB (2012/13). Given the grain volumes moved in those years, some researchers have tried to compute the difference in farm level revenues that can be attributed to the increasing basis. While calculations vary depending on assumptions, the value is significant and typically estimated as somewhere in the single digit billions of dollars (\$Canadian) when accrued over the most recent few years. Further, some suggest that any system gains from basis growth accrued mostly to the Canadian grain companies (Torshizi and Gray 2017; Brewin et al. 2017).

In fact, the 2013/14 crop year was a significant challenge to North American grain supply chains because of rail service problems as well as record supplies of wheat and canola. The total supply of grains and oilseeds in western Canada increased by 34%, while ending stocks increased by 163%. Some offer that this situation led to basis increases of up to 148% over the previous year. However, during the CWB era, we noted there was a similar record supply shock (2008/2009) associated with a 24% increase in output over the previous year, coupled with a 68% increase in ending grain stocks. However, we note that the export basis actually fell for both wheat and canola

in that crop year (Figure 4). We conclude that significant basis differences in otherwise similar market situations is further evidence that the recent 2013/14 crop year was one where significant rents were captured by the grain companies.

Figure 3: Trade and Imperfect Competition in Intermediary Services

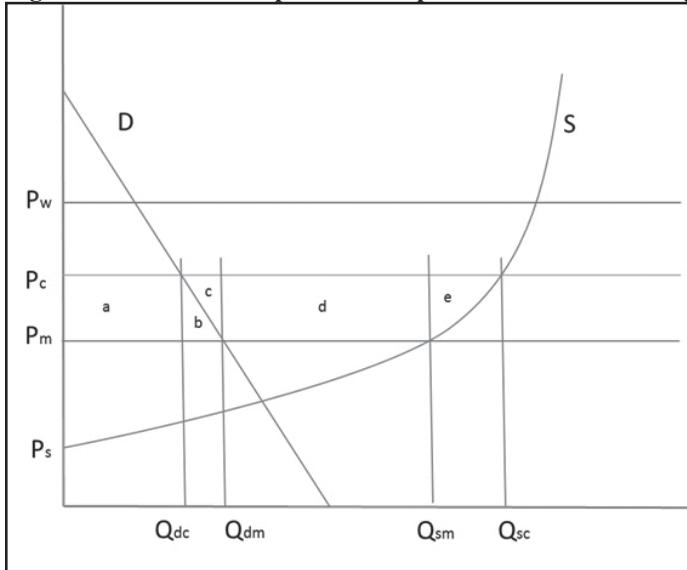
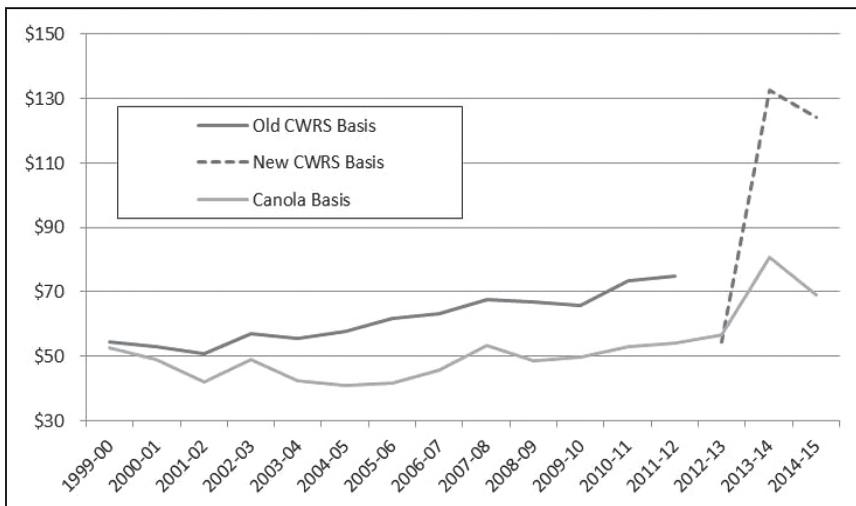


Figure 4: Export Basis (Canada) for CWRS Wheat and Canola, Western Canada



EVALUATING RELATIVE MARKET POWER IN THE GRAIN SUPPLY CHAIN

With industry level cost and production data from the years 2000-2015, we compute Shapley values applicable to the key participants in the Canadian grain supply chain. The Shapley computations will help clarify whether or not participants acted as oligopolists exploiting market power, while the results also provide us with a better sense of the role the CWB may have played in countervailing market power exercised by other participants in the supply chain.

We begin the exercise by referring to the relative shares of grain export values from the years 2000/01 to 2014/15 (all data here fall under the MRE regime) in Table 2. We assume here that the CWB during its existence was a major player in the supply chain, with railroads and grain companies also acting as major participants in the process of grain handling and movement. While the MRE era in Canada has been characterized by rail rates that have remained relatively static over time, grain companies have seen their relative value shares grow, especially so after the CWB was removed from the supply chain in late 2012. Therefore, we speculate that the division of revenues in the grain supply chain must have changed over time because various system participants altered their behavior, reacting to various market and policy changes.

While there are other individual or group contribution measures used in the theory of cooperative games, the Shapley value is popular because it is relatively simple to compute yet generates a relative contribution share measure among participants conducting a collective or cooperative action. Where data are available, they are computed using the assessed contribution of individual participants to various sub-groups or coalitions that could be formed within the full cooperative game situation (Shapley 1953; Young 1991). Effectively, the greater marginal contribution an individual player makes to the value (or payoff) associated with a given coalition, the higher is their relative contribution to the outcome and thus the greater will be their computed Shapley value. Formally, the Shapley value for an n-player cooperative game is computed in the following way (Roth 1988; d'Aspremont and Jacquemin 1985; Intriligator 1972);

$$(3) \text{ Shapley Value} = \sum \zeta_n(S) [v(S \cup \{i\}) - v(S)]$$

where $\zeta_n(S)$ is a weighting factor representing the likelihood that one of the players joins existing coalition S , and $v(\cdot)$ is a general value or payoff function, as defined by the specific game situation. The second term in the Shapley computation represents the marginal contribution to the value of coalition that now includes the i th player in a coalition that was formerly defined by S , whereby the latter necessarily excluded player i (by definition). The weighting or probability term $\zeta_n(S)$ is essentially a combinatorial representation of how an n-player coalition can be formed in the game. This weighting factor is written as;

$$(4) \zeta_n(S) = [(s! (n-s-1)!)/n!]$$

Using these equations and mapping the situation onto the Canadian grain supply chain, we need to first calculate the vertical shares of export values in the grain supply chain. In a system where each set of firms relies on the same volume moving through a vertical chain, it turns out that the Shapley values ultimately collapse into the vertical share of the final sale price. Considering this, if we assume that a cooperative game is being played among industry participants over grain export revenues, our computed share value measures the relative coalitional strength of each participant in the grain supply chain.

Data from Table 2 are used to compute Shapley values among the Canadian supply chain participants, with normalized Shapley values listed in Table 3. The computed values represent vertical shares of the export price, but under the additional assumption that there is only a single railway participant in the game.

Table 2: Approximate Breakdown of the Export Price of Wheat, 2000 to 2015

Average rates	Rail Rate	Grain Co	CWB/Farmer
2000-2001	\$25.8	\$28.8	\$154.8
2001-2002	\$25.3	\$27.6	\$167.3
2002-2003	\$24.5	\$26.4	\$198.3
2003-2004	\$25.7	\$31.4	\$160.3
2004-2005	\$25.9	\$29.6	\$152.3
2005-2006	\$27.9	\$34.0	\$141.2
2006-2007	\$29.8	\$33.4	\$156.0
2007-2008	\$28.2	\$39.4	\$314.3
2008-2009	\$30.9	\$35.8	\$253.1
2009-2010	\$28.8	\$37.1	\$181.1
2010-2011	\$30.6	\$42.8	\$286.2
2011-2012	\$31.4	\$43.4	\$268.4
2012-2013	\$34.0	\$19.5	\$275.3
2013-2014	\$33.6	\$98.8	\$194.7
2014-2015	\$35.3	\$88.9	\$199.2

Sources: Canadian Transportation Agency revenue cap data (various years), Quorum Corporation reports (various years).

Our computed Shapley values offer some novel insights into the evolution of the Canadian supply chain. To start, we find that during their existence, the CWB appears to have possessed greater coalitional power than any of the other players. Also, we find that at various times, farmers appear to have retained significant market power, even without the CWB. But over time, we also observe a significant shift in coalitional power from farmers to grain companies. Interestingly, this effect is likely compounded as well by the fact that farmers' shares can often be further parsed into their input suppliers (which are often the same grain companies).

The Shapley value evidence also suggests that railway market power in the Canadian grain supply chain has been effectively mitigated through the MRE era. Since the implementation of the MRE in 2000, railway Shapley values have remained relatively small, between .08 and 0.14, values that are considerably lower than other participants. Furthermore, the transition away from the CWB seems to have had little impact on the railways with respect to their computed Shapley value. Given the latter, we conclude that the major consequence of removing the CWB seems to have been a change in the way in which market rents are being divided between farmers and the grain companies.

While it is not theoretically possible to ascertain how high an individual Shapley value must be in order to determine whether or not a player is truly dominant in a cooperative game situation, *ceteris paribus* our calculations seem to indicate that Canadian grain companies are sitting at a point where any additional consolidation in that industry would only strengthen their position in the grain supply chain. The latter possibility would potentially allow them to capture even more rents from the system in the future (D'Aspremont and Jacquemin 1985).

What this analysis also highlights is that, from a regulatory perspective, grain supply chain participants in Canada can no longer be thought of as truly separate and distinct industries. The international nature of the grain trade means that participants in the grain supply chain are inter-linked now more tightly than ever before. Moreover, any future changes in regulatory policy in the Canadian rail sector will certainly percolate upstream and eventually affect the behavior of the

grain companies. The manner in which the grain supply chain will evolve in the future remains a major policy question in Canada. To this end, we now use the methodology to evaluate relative market power under different potential coalitional structures in the Canadian grain supply chain.

Table 3: Shapley Values, Single Railway Player

Crop year	CWB	Railways	Grain Co.
2000-2001	0.74	0.12	0.14
2001-2002	0.76	0.11	0.13
2002-2003	0.80	0.10	0.11
2003-2004	0.74	0.12	0.14
2004-2005	0.73	0.12	0.14
2005-2006	0.70	0.14	0.17
2006-2007	0.71	0.14	0.15
2007-2008	0.82	0.07	0.10
2008-2009	0.79	0.10	0.11
2009-2010	0.73	0.12	0.15
2010-2011	0.80	0.09	0.12
2011-2012	0.78	0.09	0.13
2012-2013	0.84 ^f	0.10	0.06
2013-2014	0.60 ^f	0.10	0.30
2014-2015	0.62 ^f	0.11	0.27

Note: f represents farmers' value without the CWB

Source: Authors' calculations.

Relative Market Power in the Rail Sector

Once again, Table 3 illustrates the relatively weak position of the Canadian railways in the grain supply chain through the MRE era. Although reliable data are not available to compute Shapley values for the privately held grain companies that dominate grain handling, we re-estimate Shapley values applicable to each of the two Class 1 railways, while alternatively assuming the CWB and farmers act as a single player. To perform these modified Shapley calculations, we must further assume there are three major grain handling firms in the market. The latter seems reasonable considering the era during which the CWB was involved in Canadian grain marketing there were several major grain companies operating in Canada.

The next problem we face is finding a defensible valuation for the coalitions, or equivalently the $v(\cdot)$ in equation (3). With little prior guidance from the literature, we propose that the relative value of our Shapley coalitions possesses an upper limit, defined by that point where the profits of each firm in the current supply chain are added together, and having a lower limit of zero. To wit, the share of revenues for the farmers/CWB with respect to the total tonnes moved would certainly be an overestimate of the value of their coalition. Given this, we will define the value of a coalition as the net gain relative to the lowest revenue shares observed in Table 2. In fact, this means there are potential gains to either party as a result of their potential coalition.

We also assume that any coalition formed between the CWB and the grain companies with either railway can be evaluated only by using the tonnes of grain moved by that railway. But this in turn means that in some years the valuation to either the CWB or a grain company of a coalition

with a railway could actually be negative if rail profits/tonnes are limited and computed on only part of the total tonnes moved. To correct for this, excess profits above the lowest share in Table 2 are used to proxy for the value functions. These data are available, and used to compute valuations over a four player Shapley game, again according to equations (3) and (4). Thus, Table 4 lists the Shapley values for this latter cooperative game that includes individual railways as players.

For these modified Shapley calculations, we acknowledge that treating grain companies as a single player with no CWB in the mix is unrealistic for the years 2012 through 2015. In spite of this, our analysis once again illustrates the relatively weak position of the railways under MRE regulation, as well as the shift in coalitional power away from the CWB/farmer player toward the grain company player. While neither major railway becomes as a significant market power threat to the supply chain over this time frame, we do find that their relative position in the supply chain improves when using the share of export values to compute Shapley values in Table 4.

Finally, we note there are two zero Shapley values in Table 4. One zero value appears for the CWB in 2005-06 and the other is for the grain companies in 2012-13. These Shapley values imply that particular players added zero marginal contribution to their coalitions within the supply chain in that year. The latter findings would seem to emphasize the ongoing positioning among key participants in the Canadian grain supply chain over relative shares of grain system revenues.

Table 4: Shapley Values, Separate Railway Players

	CWB/Farm	Grain Co.	CN	CP
2000-2001	0.425	0.289	0.147	0.138
2001-2002	0.554	0.171	0.140	0.135
2002-2003	0.657	0.079	0.117	0.147
2003-2004	0.443	0.274	0.148	0.134
2004-2005	0.371	0.336	0.152	0.141
2005-2006	0.000	0.628	0.203	0.169
2006-2007	0.341	0.318	0.175	0.167
2007-2008	0.652	0.075	0.136	0.137
2008-2009	0.623	0.090	0.141	0.146
2009-2010	0.488	0.214	0.152	0.146
2010-2011	0.620	0.099	0.150	0.131
2011-2012	0.602	0.113	0.149	0.136
2012-2013	0.699	0.000	0.151	0.149
2013-2014	0.285	0.420	0.151	0.145
2014-2015	0.318	0.379	0.152	0.151

Source: Authors' calculations

CONCLUSIONS

Limitations of the Analysis

While novel, we acknowledge that several relevant factors had to be left out of this preliminary analysis. For example, it is possible that large increases in the Canadian export basis may have in part been driven by higher storage costs (Brewin 2014). But with little change in overall storage capacity on the prairies, there is evidence (from 2008/09) that the record elevator turnover in

2013/14 should have been associated with decreased average costs. More data on actual firm level costs incurred by the railways and the grain companies would vastly improve our understanding about the nature of changes occurring in the supply chain.

The existence of the MRE regulation during the entire time period of study makes it difficult to infer relative market power among the participants in the supply chain in the absence of the MRE. Given historical complaints about railway behavior in Canada under other regulatory regimes, it would be useful to compare railway Shapley values across these regimes.

Finally, we offer that some of the value shocks observed in the years after the removal of the CWB could also be evidence of learning economies in the grain sector. In effect, grain companies may have gradually learned how to better manage foreign sales as well as their domestic logistics processes, while still also possibly engaging in novel cooperative games in the supply chain.

Implications of the Analysis

The evidence presented here about the relative share of market power as exercised by the CWB and railroads suggests that at least during the MRE era, the CWB possessed significant (countervailing) market power in the grain supply chain. However, the consequences associated with the CWB's coordinating role in grain movement are less clear. With the rise of canola and other crops in the region, the CWB gradually became involved with a smaller share of all agricultural rail movements in terms of foreign sales, but it always maintained considerable influence over car allocation and elevator returns. The tight export basis seen in the 2012/13 crop suggests that removal of the CWB may have resulted in initial efficiency gains, but as listed here, there are other factors that likely contributed to the tight export basis in that year.

Since the removal of the CWB in Canada, the evidence shows that grain companies seem to have positioned themselves in such a way as to shift system rents away from farmers. If grain industry consolidation continues, the former farmer-focused coordinating role of the CWB in grain car allocation and foreign shipping logistics might eventually be run by a grain company oligopoly. As Sexton (2013) notes, this may create a difficult situation for this supply chain. Repeated rent taking from market intermediaries will eventually reduce farmer investments and could lead to supply reductions, or it may trigger new entrants and erode system rents. Furthermore, Sexton argues that agricultural oligopolies may realize a benefit to sharing more gains with farmers in order to encourage reliable long-run supply from that link in the supply chain.

Recent concerns voiced by a Canadian federal government review about suspected system inefficiencies attributed to the MRE (Emerson 2016) are not supported by our findings. While the system seems to have remained relatively stable or improved somewhat with respect to efficiency, we do find that MRE regulation seems to have accomplished what it was initially designed to do: control the potential for exertion of market power in grain transportation by Canada's two Class 1 railways. But our findings also indicate that more work is needed both to understand how the Canadian grain supply chain continues to evolve and identify a set of regulatory mechanisms that will best support improved overall supply chain efficiency moving forward.

References

Agriculture and Agri-Food Canada (AAFC). Canada: Outlook for Principal Field Crops (April 13, 2016). Ottawa. Available at: http://www.agr.gc.ca/resources/prod/doc/misb/mag-gam/fco-ppc/fco-ppc_2016-04-13-eng.pdf (accessed May 16, 2016).

d'Aspremont, C., and A. Jacquemin. "Measuring the Power to Monopolize: A Simple Game-Theoretic Approach." *European Economic Review* (27), (1985): 57-74.

Bradley, I. and C. Price. "The Economic Regulation of Private Industries by Price Constraints." *The Journal of Industrial Economics* (37), (1988): 99-106.

Brewin, D.G. "Limitations on the Market Power Generated by the Single Desk of the Canadian Wheat Board." *Canadian Journal of Agricultural Economics* (62), (2014): 491-517.

Brewin, D.G. "Competition in Canada's Agricultural Value Chains: The Case of Grain." *Canadian Journal of Agricultural Economics* (64), (2016): 5-19.

Brewin, D.G., T. Schmitz, J.F. Nolan, and R.S. Gray. "Grain Transportation Policy Reform in Western Canada." *Canadian Journal of Agricultural Economics* (65), (2017): 643-665.

Brooks, H. and T.G. Schmitz. "Price Discrimination in the International Grain Trade: The Case of Canadian Wheat Board Feed Barley Exports." *Agribusiness: An International Journal* (15), (1999): 313-322.

Çakır, M. and J.F. Nolan. "Revisiting Concentration in Food and Agricultural Supply Chains: The Welfare Implications of Market Power in a Complementary Input Sector." *Journal of Agricultural and Resource Economics* (40), (2014): 203-219.

Eilers, W., R. MacKay, L. Graham, and A. Lefebvre. "Environmental sustainability of Canadian agriculture: Agri-Environmental Indicator Report Series." Report #3. Ottawa, Agriculture and Agri-Food Canada, 2010. Available at: http://publications.gc.ca/collections/collection_2011/agr/A22-201-2010-eng.pdf (accessed May 16, 2016).

Emerson D. *Pathways: Connecting Canada's Transportation System to the World*. Vol. 1. Tabled in Parliament by the Minister of Transport. Feb. 25, 2016. Ottawa, Transportation Canada. Available at: <http://www.tc.gc.ca/eng/ctareview2014/canada-transportation-act-review.html>. (accessed April 17, 2016).

Fulton, M. "The Canadian Wheat Board in an Open Market: The Impact of Removing the Single-Desk Selling Powers." Working paper, Dept. of Agricultural Economics, University of Saskatchewan, 2006.

Fulton, M., K. Baylis, H. Brooks and R. Gray. "The Impact of Deregulation on the Export Basis in the Canadian Grain Handling and Transportation System." Working paper, Dept. of Agricultural Economics, University of Saskatchewan, 1998.

Government of Alberta. Railways. Business in Alberta (2016). Available at: <http://www.albertacanada.com/business/overview/railways.aspx>. (accessed April 17, 2016).

Hubert, F. and E. Orlova. "Competition or Countervailing Power for the European Gas Market." Working paper, available at: http://www.ms-hns.de/files/publications/competition_countervailing.pdf (2014).

Hubert, F. and O. Cobanli. "Pipeline Power: A Case Study of Strategic Network Investments." *Review of Network Economics* (14), (2015): 75-110.

Intriligator, M. *Mathematical Optimization and Economic Theory*. Englewood Cliffs: Prentice Hall, 1972.

Manitoba Agriculture, Food and Rural Development (MAFRD). "Guidelines for Estimating Crop Production Costs - 2016." Available at: http://www.gov.mb.ca/agriculture/business-and-economics/financial-management/pubs/cop_crop_production.pdf (accessed May 2, 2016).

- Nolan, J.F. "Transportation." In B.D. Thraves, M.L. Lewry, J.E. Dale and H. Schlichtmann (Ed.) *Saskatchewan: Geographic Perspectives*. Regina: Canadian Plains Research Center, 433-444, 2007.
- Nolan, J.F. and B. Drew. "An Update on Regulatory Change in the Canadian Grain Handling and Transportation Industry." *Canadian Journal of Agricultural Economics* (50), (2002): 85-98.
- Nolan, J.F. and S. Peterson. "Grain Handling and Transportation Policy in Canada: Implications for the United States." *Choices* (30), (2015): 1-6.
- Quorum Corporation. *Annual Reports 2004-05 to 2014-15 Crop Years, Data Tables*. Edmonton. Available at: <http://quorumcorp.net/reports.html>. (accessed May 1, 2016).
- Riegle, J. "The Development of Western Grain Rates. A Transportation Odyssey." Proceedings of the 36th Annual Conference, Canadian Transportation Research Forum, Vancouver, 848-861, 2001.
- Roth, A. "Introduction to the Shapley Value." In A. Roth (Ed.), *The Shapley Value: Essays in Honor of Lloyd S. Shapley*, (Ch. 1), Boston: Cambridge University Press, 1988.
- Schmitz, A. and H. Furtan. *The Canadian Wheat Board: Marketing in the New Millenium*. Saskatoon: Canadian Plains Research Center, Regina, 2000.
- Sexton, R.J. "Market power, Misconceptions, and Modern Agricultural Markets." *American Journal of Agricultural Economics* (95), (2013): 209-219.
- Statistics Canada. CANSIM Table: 20048. Distribution of farms, by farm type and net operating income group, incorporated and unincorporated sectors, Canada and provinces, annual. Ottawa. Available at: <http://dc.chass.utoronto.ca.uml.idm.oclc.org/cansimdim/English/>. (accessed May 1, 2016), 2016a.
- Statistics Canada. CANSIM Table: 40002. Census of Agriculture, total area of farms and use of farm land, Canada and provinces, every 5 years. Ottawa. Available at: <http://dc.chass.utoronto.ca.uml.idm.oclc.org/cansimdim/English/>. (accessed May 1, 2016), 2016b.
- Shapley, L. "A Value for N-Person Games." *Ann. Math Studies* (28), (1953): 307-317.
- Torshizi, M. and R. Gray "An Economic Analysis of Western Canadian Grain Export Capacity." *Canadian Journal of Agricultural Economics*, in press.
- Wolak, F. and C. Kolstad. "Measuring Relative Market Power in the Western U.S. Coal Market Using Shapley Values." *Resources and Energy* (10), (1988): 293-314.
- Young, P. "Fair Division." In P. Young (Ed.) *Negotiation Analysis* (Chapter 2). Ann Arbor: University of Michigan Press, 1991.
- Zhang, J., E. Goddard, and M. Lehol. "Estimating Pricing Games in the Wheat-Handling Market in Saskatchewan: the Role of a Major Co-operative." In S. Novkovic, and V. Sena (Ed.) *Advances in the Economic Analysis of Participatory and Labor-Managed Firms - Co-operative Firms in Global Markets: Incidence, Viability and Economic Performance* (1), London: Elsevier, 2007, 151-184.

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Private Vehicle Ownership in Provincial China

by Patrick McCarthy and Junda Wang

Private vehicle ownership has rapidly grown with China's economic development and increasing incomes. This paper analyzes China's provincial demands for private vehicles during the post-opening period 2000 – 2012. Based on estimates from pooled, fixed effects and Hausman-Taylor models, private vehicle ownership during this period grew at an average annual rate of over 20%, all else constant. The study focuses on the roles of economic, spatial, investment and regulatory factors in shaping private vehicle demands. The study finds that increases in GDP per capita and vehicle use cost reinforce and constrain, respectively, the strong trend toward increased ownership. And absent changes in population density, higher percentages of the population in urban areas increase the demand for private vehicles. But increasing population density provides stronger incentives for reducing vehicle demands. Municipal restrictions aimed at reducing the congestion and environmental effects of vehicle ownership and use are effective in reducing provincial demands. A separate analysis of provinces that are at least 60% urbanized identifies important differences. Vehicle demands are income elastic and infrastructure investments have stronger effects in the most urbanized provinces than in less urbanized provinces.

INTRODUCTION

With the rapid development of China's automobile industry, continuous improvements in road infrastructure, and rising disposable incomes, China entered the era of increased private vehicle consumption in 1997. During the period of China's "planned economy" (1953-1980), its vehicle sector focused on the production of vehicles for firms, government agencies, and social groups. Subsequent to the opening in 1997, the vehicle sector expanded its focus toward private vehicle consumption. In 1997, the civilian (i.e., non-government) vehicle ownership was 12 million and private vehicle ownership was 3.6 million (29%). A short 15 years later, in 2012, civilian vehicle ownership was 109 million and private vehicle ownership was 88 million, accounting for 81% of civilian vehicles. These increases in civilian and private vehicle ownership represent a staggering 808% and 2,340% increase, respectively, and a substantial change in the structure of China's vehicle industry. China continues to have one of the highest annual motorization growth rates in the world (Figure 1). The total number of private vehicles in the country increased from 9.67 million in 2002 to 123.39 million in 2014. The motorization rate rose from 7.54 vehicles per 1,000 persons to 90.21 vehicles per 1,000 persons in the same time period. Whereas some analysts had predicted that China's motorization rate would grow to 54 vehicles per 1,000 by 2020, an average increase of 7.3% annually (Energy Information Administration 2000), Figure 1 indicates that China's motorization rate far exceeded those predictions well before 2020.

For the 2002-2014 period, Table 1 reports private vehicle ownership in total and per 1,000 persons, GDP per capita (Gu et al. 2010), and total and urban population. During this 13-year period, private vehicle ownership grew at an annual rate of 21.6%, 65% higher than the large increase in per capita GDP and nearly six times higher than annual growth in urban population. Further, due to lower birth rates that are often attributed to the overall level of socioeconomic development and to family planning programs in the 1970s and 1980s, including the government's well-known one-child policy, China's population growth remained small during this period, with an annual 0.48% increase per year. China's strong vehicle growth has also given rise to well-documented negative effects of

private vehicle ownership: significantly worsening traffic congestion, air pollution and associated health effects, vehicle-related fatalities and injuries, and greater dependence on oil imports (Ministry of Environmental Protection 2012). As a highly populated developing country and with increasing urbanization, road congestion and poor air quality are common phenomena in China’s megacities (e.g., Beijing, Shanghai, Guangzhou and Shenzhen). Shenzhen, for example, has the highest vehicle density in China at nearly 500 vehicles per square kilometer. Motor vehicles in China’s major cities are responsible for 50% to 60% of air pollution, emitting 46.12 million tons of pollutants in 2012 (National Bureau of Statistics China (<http://www.stats.gov.cn/enGLISH/>)). Globally, seven of the top 20 cities with the most serious air pollution are in China (Zhang and Crooks 2012). China recognizes the importance of this. In a report on key government initiatives for 2017, the seventh initiative focuses on environmental protection. Among its strategies for improving air quality is a significant reduction in older high polluting vehicles, retrofitting pollution abatement technologies on vehicles, and encouraging the use of clean energy vehicles (Keqiang 2017). Consistent with this, a number of larger and more congested cities in China have adopted various policies to reduce these negative externalities, including restrictions on vehicle ownership and use and, more recently, congestion pricing strategies.

Figure 1: Private Vehicle Ownership in China, 2002–2014

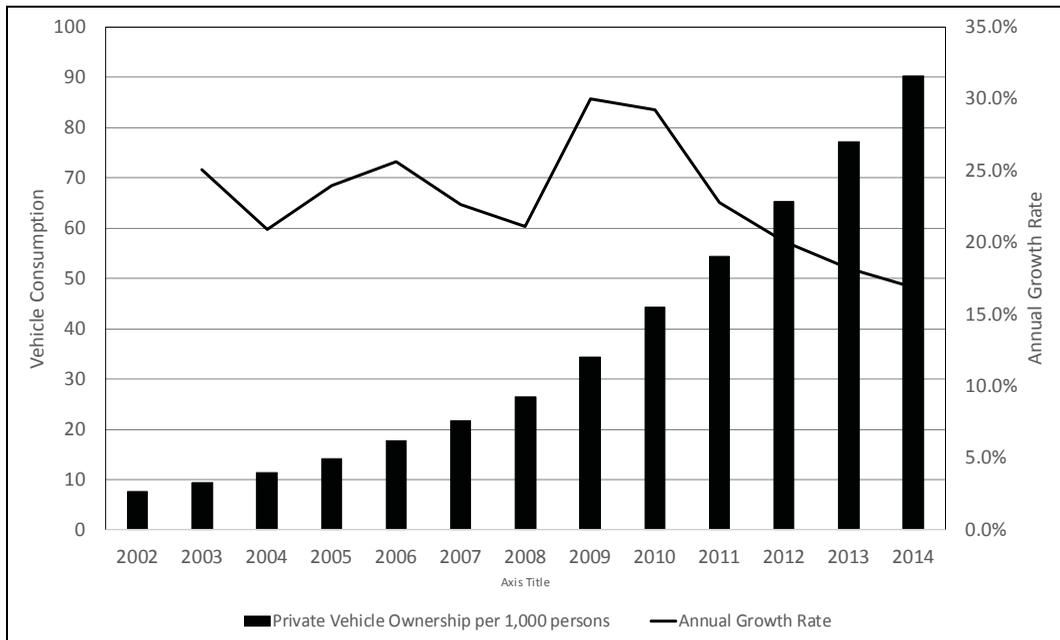


Table 1: Private Vehicle Growth in China, 2002–2014

Year	Private Vehicles (millions)	Per Capita GDP (Yuan)	Population	Urban Population (million)	Private Vehicles per 1,000 Persons
2002	9.69	9,419.94	1,284.53	502.12	7.54
2003	12.19	10,567.81	1,292.27	523.76	9.43
2004	14.82	12,363.79	1,299.88	542.83	11.4
2005	18.48	14,217.00	1,307.56	562.12	14.13
2006	23.33	16,558.38	1,314.48	582.88	17.75
2007	28.76	20,284.68	1,321.29	606.33	21.77
2008	35.01	23,851.43	1,328.02	624.03	26.37
2009	45.75	25,899.53	1,334.50	645.12	34.28
2010	59.39	30,494.44	1,340.91	669.78	44.29
2011	73.27	35,931.53	1,347.35	690.79	54.38
2012	88.39	39,446.62	1,354.04	711.82	65.28
2013	105.02	43,213.80	1,360.72	731.11	77.18
2014	123.39	46,490.77	1,367.82	749.16	90.21
Annual Growth Rate	21.62	13.07	0.48	3.13	21.04

Source: Authors' calculations. China Statistical Yearbook 2014 (National Bureau of Statistics of P.R. China, 2014).

The research reported in this paper focuses on provincial demands for private vehicles from 2000 to 2012. The paper's objectives are to identify those factors that are important determinants of private vehicle consumption in China's provinces and to explore how private vehicle ownership varies across provinces.

Relevant Literature

Reflecting the importance of motor vehicles and motor vehicle travel to a nation's economy, and mobility and a population's quality of life, there is an extensive literature on the demand for vehicles and a number of excellent studies that survey the state of knowledge on vehicle demands, including DeJong et al. (2004) and Xu (2011). Focusing on aggregate private vehicle demand across China's provinces, Table 2 reports the representative literature on aggregate vehicle demands in low income or developing countries. As is true for research on developed countries, the studies in Table 2 reflect two related aspects of car or vehicle ownership: 1) long-term forecasts that relate income growth to vehicle ownership, and that typically estimate ownership saturation at which point further increases in income have no or very little impact on ownership; and 2) analyses that focus on a broader set of determinants, including policy relevant factors.

Aggregate Saturation Models. When developing forecasts and modeling saturation, studies often adopt quasi-logistic and Gompertz growth models.¹ These are probability models that generally include vehicle ownership saturation over time (as a function of gross domestic product or other measure of income). In these frameworks, vehicle ownership increases slowly at low GDP per

capita, then rises more sharply, reaches an inflection point after which vehicle ownership rises more slowly. Tanner (1958) was first to construct and estimate an aggregate logistic model that provided insights on the behavior of vehicle ownership rates, marginal growth and a saturation level.

Dargay and Gately (1999) analyzed data for 26 countries from 1960 to 1992 using Gompertz growth models with a dynamic specification in order to estimate short-run and long-run income elasticities of car and vehicle ownership. The estimated income elasticities range from 2.0+/- for some low-income and middle-income levels, down to zero, as ownership saturation nears for the highest income levels. Based on 36 countries from 1960 – 2000, Wang (2005) adopts Gompertz growth models and finds a strong relationship between motorization and per capita GDP. The study concludes that with a growth rate of per capita GDP in the 3%-7% range, the inflection point will occur between 2015 and 2042 and total vehicle ownership in China could reach nearly 260 million vehicles. Bouachera and Mazraati (2007) uses three functional forms (Gompertz, logistic and quasi-logistic) to characterize the S-curve shape of car stock evolution in India. Assuming a saturation level of 0.85, the study predicts car ownership levels, accounting for the growth of per-capita income and per-capita road density. From the study, India's vehicle stock is expected to be four times larger in 2015 than in 2002, increasing to nearly 50 million cars.

Even though vehicle ownership in developed countries is expected to increase at a declining rate with per-capita income growth and ultimately reach a saturation level, many studies' estimates do not predict real observed ownership levels well. Ingram and Liu (1999) note that there is little direct evidence that saturation levels are stationary or that they have a straightforward behavioral interpretation. And Button, Ngoe, and Hine (1993) conclude that the saturation level is a technical model feature that improves the quality of the forecasts generated. The study also notes that different countries or regions will have different levels of saturation with the growth of the economy.

Policy-Oriented Aggregate Demand Models. In Ingram and Liu's (1999) study of motorization at the national and urban levels, economic variables are important determinants, although the income effects at the urban level are somewhat weaker. Huang, Cao, and Li (2012) explore spatial variations of urban private car ownership in 235 Chinese cities from 1990 to 2009. The study finds that the extent of urbanization has a positive effect on private car ownership in general but a negative in the largest areas, metropolises, and mega-cities. The study also finds that the availability of substitutes, public transportation, and taxis limits the growth of private cars in Chinese cities to some but not to a large degree.

Chin and Smith (1997) use time series data from 1968 to 1989 in Singapore to analyze the impact of Singapore's Vehicle Quota Scheme, finding that imposing a quota is an effective policy to limit the number of private vehicles. The study concludes that vehicle intervention policies that target ownership and use are complementary. In a study on fuel consumption, Hao, Wang and Ouyang (2011) analyze the vehicle limitation policies of Beijing, which targets vehicle use, and Shanghai, whose policy focuses on vehicle ownership. The study finds that both policies reduce fuel consumption but Shanghai's policy has larger and longer lasting effects, suggesting that the most effective policies are those aimed at vehicle ownership. And in a related study, Zhou and Shu (2014) employ financial and sales data in China from 1996 to 2011 to examine the effect on traffic by using odd/even license plate numbers to restrict vehicle use. The study finds that this control had a negative impact on private car ownership.

Wu, Zhao, and Zhang (2016) estimate random and fixed effects models on a panel data of provincial capitals in China from 2001 – 2011. The authors find that, in addition to income, the extent of highway mileage and the quality of roads (i.e., paved) increased car ownership. In addition, the study finds that the number of public transit vehicles per rider, a measure of public transit comfort, significantly reduces car ownership.

The present study adds to this literature, developing and estimating panel data models of private vehicle ownership in China's provinces. The unit of analysis is a province-year comprising China's

Table 2: Aggregate Models of Vehicle Ownership*

Year	Author(s)	Methodology	Data	Findings
1993	Button, J., Ngoe, N. and Hine, J.	Quasi-logistic model	58 developing countries, 1968–1987, car fleet; 29 developing countries, 1968–1987, commercial vehicles	Saturation level is seen as a technical aid to improve the quality of forecasts. Given data limitations and the considerable distance of most low income countries from the saturation estimates postulated for industrialized countries, a short-term maximum level of car ownership is adopted.
1997	Chin, A. and Smith, P.	OLS	Singapore, 1968–1989	Singapore's Vehicle Quota Scheme is an effective way to regulate the number of private automobiles. Policies regulating ownership and usage are complementary.
1999	Ingram, G. and Liu, Z.	OLS	50 countries and 35 urban areas in 1970, 1980, and 1990	Income growth is the primary determinant of car ownership at the national and urban levels. Income elasticity is constant (or falling) over the range of income levels in the study.
1999	Dargay, J. and Gately, D.	Gompertz model	26 countries, 1960–1992	Strong relationship between income and vehicle ownership growth. Lower income countries estimated to have income elasticity around 2.0 and China's growth will be at a high level.
2005	Wang, Y.	Gompertz model	36 countries, some 1960–2000, some 1978–1992	Assuming 3%–7% annual per capita GDP growth, the inflection point will occur between 2015 and 2042. Total vehicle ownership in china would reach nearly 260 million vehicles.
2007	Bouachera, T. and Mazraati, M.	Gompertz, Logistic and Quasi-logistic models	7 Asian countries, 1971–2002	India's car stock expected to be 50 million cars, just under four times the level in 2002. Barring significant technological innovations, motor vehicles and the transportation sector in general will rely heavily on fossil fuels.
2010	Gu J., Qi, F. and Wu, J.	Gompertz model	31 provinces, 1998–2007	Vehicle consumption differs among eastern, central, and western regions in China. Road density has a significant effect on vehicle consumption in the three regions.
2011	Hao, H., Wang, H. and Ouyang, M.	Formula calculations, various years	Beijing and Shanghai	Beijing's policy limiting vehicle use had immediate but relatively small effect on fuel consumption; Shanghai's policy limiting ownership had larger and longer term effects.
2012	Huang, X., Cao, X., and Li. T.	OLS	235 cities in China, 1990–2009	The extent of urbanization has a strong positive effect on private car ownership in general but a negative effect in metropolises and mega-cities. public transportation and taxis inhibit the number of private cars to a small degree.
2014	Zhou, M. and Shu, W.	OLS	Financial and sales data in China, 1996–2011; 31 provinces in 2012	New government policies, such as the traffic control via odd and even license numbers and total investment in fixed assets, have a negative impact on private car ownership.
2016	Wu, N., Zhao, S. and Zhang, Q.	Fixed/random effects models	32 Provincial capital cities, 2001–2011	Gross regional product per capita (large and medium cities) and average age (smaller cities) positively related to car ownership, as was paved roads and highway mileage. A measure of public transit comfort reduced car ownership.

* OLS is ordinary least squares.

31 provinces during the 13-year period 2000 – 2012. Similar to other studies, this analysis identifies the effects of income and fuel cost on private vehicle ownership and the impact that highway and transit infrastructure investments have on private vehicle ownership. In addition, the analysis explores the extent to which private vehicle ownership in China differs from ownership patterns in the eight most highly urbanized provinces. And the study identifies the impact of two specific vehicle restraint policies: Beijing’s municipal policy that restricts vehicle use versus Shanghai’s municipal policy that restricts private vehicle ownership.

Hypotheses

To motivate the empirical analysis, consider China’s provincial demand for private vehicles at time t in province j transportation $D_{Tj,t}$,

$$(1) D_{Tj,t} = D_{Tj,t}(P_{Tj,t}, P_{zj,t}, M_{j,t}^a, \phi_{j,t}^a)$$

where $j=1, \dots, 31$, P_{Tj} is price of private vehicle use in province j , P_{zj} is the price of all other consumption in province j , $M_{j,t}^a$ is aggregate income of province j in year t and $\phi_{j,t}^a$ reflects aggregate preferences for private transportation in province j and year t .

Since public transit is a primary competing transportation mode to the private vehicle, the price of public transit $c_{PTj,t}$ is assumed to capture the price effects of all other relevant goods $P_{jz,t}$ in the model.

In this framework, the price of transportation in general includes out-of-pocket monetary cost (e.g., fuel costs, tolls, transit fare) and the opportunity cost of the time spent traveling, which is a function of the value that the traveler places on travel time. That is,

$$(2) P_{jk,t} = f(c_{jk,t}, t(vot)_{jk,t}; \inf_{jk,t}, spdev_{j,t}, vr_{i,t})$$

where k represents private vehicle or public transit, $c_{ik,t}$ is the money cost and $t_{ik,t}$ is the time cost of travel on mode k in province j at time t , which depends on the value of time (vot). Further, the existing infrastructure ($\inf_{jk,t}$), the province’s spatial development and configuration, and vehicle restriction policies are conditioning factors that affect the monetary and time cost of travel on mode k . In China, these are of particular importance because investments on highway infrastructure and urban development have occurred at a rapid pace. In addition, seven provinces have imposed restrictions on vehicle use or vehicle ownership.

Thus, for this analysis, China’s demand for private transportation in province j at time t is:

$$(3) D_{Tj,t} = D_{Tj,t}(c_{jk,t}, vot_{jk,t}, c_{PTj,t}; \inf_{jk,t}, \inf_{PTj,t} spev_{j,t}, vr_{i,t}, M_{j,t}^a, \phi_{j,t}^a) \quad j = 1, 31$$

This framework motivates four sets of testable hypotheses related to the effects of economic factors, infrastructure, spatial form, and regulation on private vehicle ownership.

Hypothesis 1 – Economic Environment

- *1a. Per-capita GDP:* Holding all else constant, an increase in provincial per-capita income increases the demand for vehicle ownership.
- *1b. Price of vehicle and vehicle use cost:* Holding all else constant, an increase in the price of private vehicle ownership and cost of vehicle use reduces the demand for private vehicles.
- *1c. Public transit fare:* This is a substitute for private vehicles, which implies that an increase in public transit fares increases the demand for private vehicles.
- *1d. Average wage:* Through its effect on the value of time, increasing wages increase the

generalized (time and money) cost of travel. All else being constant, this increases the demand for modes that offer faster travel, the private vehicle.²

Hypothesis 2 – Infrastructure Investment

- *2a. Real Investments on roads and bridges:* Holding all else constant, an increase in the supply and quality of infrastructure for private transportation reduces the cost of traveling by private vehicle and increases the demand for private vehicles.
- *2b. Real Investments on public transit:* Holding all else constant, an increase in public transit infrastructure reduces the overall cost of taking public transit, increasing the demand for public transit and reducing the demand for private vehicles.
- *2c. Road density:* Holding all else constant, an increase in the number of highway kilometers per square mile increases capacity for transportation, reduces time costs, and stimulates the demand for private vehicles.

Hypothesis 3 – Spatial Environment

- *3a. Population density:* Increases in population density (persons per square kilometer) reduce travel speeds, increasing travel times and the time cost of highway travel. All else being constant, this reduces the demand for private vehicles.³
- *3b. Urbanization level:* Urbanization is a broader concept than population density and typically reflects areas with higher population densities and built environments. In contrast to rural areas, urban areas are typically more prosperous economically, have greater accessibility to resources, and benefit from various agglomeration economies. Holding constant economic factors, infrastructure, and population density, higher urbanization through larger built urban environments increases average distances traveled, which argues for increased vehicle ownership.

Hypothesis 4 – Regulatory Environment

- *4a. Vehicle limitations:* Policies that restrict vehicle ownership and use are negatively associated with private vehicle ownership. Holding all else constant, vehicle limitations increase the generalized cost of private vehicles (e.g. having to make other arrangements, inconvenience), which reduces the demand for private vehicles.

Data

Our empirical analysis uses data from a panel of 31 provinces in China for the period 2000 – 2012. The main data sources are the National Bureau of Statistics of the People`s Republic of China (NBS) and EPS China Data (EPS).⁴ Table 3 defines the variables used in analysis. There were several problems encountered in collecting the data. Urban populations for several provinces are missing in certain years. For these provinces we assume that urban population grew at the same rate as in the previous year. Also, data are not available for vehicle use cost so we use the consumer price index (CPI) for transportation as a proxy.⁵ All price and cost variables are converted to real or constant yuan with 2000 as the base year.

Limitations on vehicle purchasing and use reflect three types of limited quotas: a lottery for license plates, bidding for plates, and odd and even number rules on license plates. In order to account for these limitations on purchasing and using vehicles, we created a dummy variable that equals 1 if a municipality in the province adopted any of these restrictions and 0 if no restrictions were adopted.⁶

Table 3: Variable Definitions^a

Private Vehicle Ownership Per Capita	Provincial per capita private vehicle ownership (vehicles/person)
Independent Variables	Definition
<i>Economic environment</i>	
GDP Per Capita	Provincial per capita GDP
Vehicle Price	Provincial vehicle purchase taxes per vehicle divided by the tax rate
Wage Rate	Provincial average hourly wage
Vehicle Use Cost Index	Provincial Transportation Consumer Price Index
<i>Infrastructure</i>	
Highway Investments Per Capita	Provincial real per capita investment on roads and bridges (100 million yuan)
Public Transit Investments Per Capita	Provincial real per capita investment on public transit (100 million yuan)
Road Density	provincial highway mileage, divided by the province's area (km/km ²)
<i>Spatial Concentration</i>	
Population density	Provincial population divided by the province's area (persons/km ²)
Percent Urban	Provincial urban resident divided by the province population
<i>Regulatory environment</i>	
Vehicle Limitation	Limitation on vehicle ownership and use adopted by a province
<i>Other</i>	
Time trend	Year of observation

^aAll monetary values are in constant 2000 yuan. Base year for the transportation price index is 2000 and the index includes fuels and parts, intercity traffic fare, public transportation, fees for vehicles use and maintenance, and transportation facilities. The wage rate assumes working eight hours per day, 250 days of the year.

Descriptive Statistics. Table 4 provides descriptive statistics for the sample. The first line of Table 4 indicates that over the sample period there were 0.026 vehicles per 1,000 persons, ranging from a minimum of 0.001 to 0.196. On average, 45% of the population are in urban areas with an average population density of 402 persons per square kilometer. GDP per capita is 9,471 yuan and average hourly wage is equal to 10 yuan. Municipalities in 4% of the provinces have vehicle restrictions and per-capita spending on highways and bridges that is twice the spending on public transportation. Across time and across provinces, the variation in vehicle consumption is similar, whereas the standard deviations across provinces tend to be higher, reflecting greater cross-section heterogeneity than temporal heterogeneity. There is much greater variation in GDP per capita across provinces than across time (5,525 yuan versus 849 yuan). This is also true for population density. The sample mean is 402 persons per square kilometer with a standard deviation of 572.2 persons per square kilometer. This high variation reflects the large heterogeneity across provinces (575 persons/km²) in contrast to the temporal variation (27 persons/km²). An exception is the wage rate, which varied more over time (4.0 yuan/hour) than across provinces (3.2 yuan/hour). Average highway road density, highway investments per capita, and public transit investment per capita each varied more across provinces than over time.

Table 4: Descriptive Statistics^a

Group	Variable	# Obs	Mean	Std Dev	Min	Max
Full Sample	Private Vehicle Consumption per 1,000 persons	403	0.026	0.03	0.001	0.196
	Real Public Transport Spending per Capita (100 million Yuan)		0.008	0.02	0	0.195
	Real Highway/Bridge Spending per Capita (100 million Yuan)		0.023	0.03	0	0.254
	Vehicle Restriction (1 = yes; 0 = no)		0.045	0.21	0	1
	Percent Urban		0.450	0.15	0.139	0.893
	Road Kilometrage (km/km squared)		0.595	0.43	0.018	1.984
	Provincial Wage (Yuan/hour)		10.284	5.16	3.451	34.1
	Vehicle Use Cost Index (2000 base)		108.162	10.4	87.8	141.4
	Population Density (persons per km-squared)		402.417	572.2	2.1	3777.8
Provincial GDP per Capita (Yuan)		9,471.70	5535.4	2743.9	30047.0	
Provinces	Private Vehicle Consumption per 1,000 persons	31	0.026	0.02	0.01	0.115
	Real Public Transport Spending per Capita (100 million Yuan)		0.008	0.02	0	0.087
	Real Highway/Bridge Spending per Capita (100 million Yuan)		0.023	0.02	0.005	0.087
	Vehicle Restriction (1 = yes; 0 = no)		0.045	0.18	0	1
	Percent Urban		0.450	0.12	0.268	0.817
	Road Kilometrage (km/km squared)		0.595	0.35	0.038	1.471
	Provincial Wage (Yuan/hour)		10.284	3.23	7.966	19.892
	Vehicle Use Cost Index (2000 base)		108.162	7.3	92.6	122.9
	Population Density (persons per km-squared)		402.417	575.0	2.3	3161.2
Provincial GDP per Capita (Yuan)		9,471.70	5525.7	3622.0	27213.2	
Years	Private Vehicle Consumption per 1,000 persons	13	0.026	0.02	0.006	0.067
	Real Public Transport Spending per Capita (100 million Yuan)		0.008	0.01	0.002	0.016
	Real Highway/Bridge Spending per Capita (100 million Yuan)		0.023	0.01	0.002	0.044
	Vehicle Restriction (1 = yes; 0 = no)		0.045	0.03	0.032	0.129
	Percent Urban		0.450	0.06	0.375	0.534
	Road kilometrage (km/km-squared)		0.595	0.22	0.308	0.854
	Provincial Wage (Yuan/hour)		10.284	4.01	4.96	17.029
	Vehicle Use Cost Index (2000 base)		108.162	6.62	100.0	119.5
	Population Density (persons per km-squared)		402.417	27.4	366.1	445.8
Provincial GDP per Capita (Yuan)		9,471.70	849.4	8427.3	10811.9	

^aAll monetary values are in constant 2000 yuan. Base year for the transportation price index is 2000 and the index includes fuels and parts, intercity traffic fare, public transportation, fees for vehicles use and maintenance, and transportation facilities. The wage rate assumes working eight hours per day, 250 days of the year.

Urbanization Groups. To explore the characteristics of provinces by the extent of urbanization, we categorize the provinces into the highest urbanization ($\geq 60\%$ urban) and lower urbanization ($< 60\%$) groups.

Table 5 reports descriptive statistics for the sample and group means. Provinces in the highest urbanization group have higher per-capita private vehicle ownership, per-capita GDP, and investments in roads, bridges, and public transit. Road density in the most urbanized provinces is

nearly twice that in the remaining provinces. Population density in the highest urbanized provinces, on the other hand, is four times greater than in the 23 less urbanized provinces, 1,002 versus 227. Beijing, Shanghai, and Tianjin have the highest per-capita incomes (25,089, 27,213, and 18,126, respectively). These three provinces also have the highest average per-capita highway and public transport investments. Shanghai averages the highest population density at 3,161 persons/km², nearly triple that of Beijing and Tianjin due to its much smaller land area (6,341 km² versus 16,800 km² and 11,305 km² for Beijing and Tianjin). Tibet has the lowest average population density (2.31). On average, the highest urbanized provinces are 50% more urbanized (60% versus 40%) than the other provinces.

With the rapid development of China's economy, private vehicle ownership broke through 100 million vehicles in 2013 for the first time. Yet the variance in private vehicle ownership is large, reflecting the different rates of economic development and some unique individual characteristics of each province.

Seven cities have adopted limitation policies on purchasing and using vehicles, six of which are in the highest urbanized group. Among the lower urbanized provinces, Guiyang in Guizhou province also adopted a limitation policy.

Table 5: Descriptive Statistics for Urbanization Groups

Groups	Provinces
Highest urbanization ($\geq 0.60\%$)	Beijing, Shanghai, Tianjin, Guangdong, Zhejiang, Jiangsu, Liaoning, Fujian
Remaining Provinces ($< 0.60\%$)	Jilin, Shandong, Shanxi, Inner Mongolia, Chongqing, Heilongjiang, Hubei, Hainan, Shaanxi, Ningxia, Jiangxi, Qinghai, Hunan, Tibet, Xinjiang, Hebei, Anhui, Schuan, Guangxi, Henan, Yunnan, Gansu, and Guizhou

Variables	All Provinces	Highest Urbanization	Remaining Provinces
Private Vehicle Ownership per 1000 persons (vehicles)	0.026	0.045	0.021
GDP per Capita (yuan)	9471.7	17228.1	7209.4
Wage Rate (yuan/hour)	10.284	14.011	9.197
Vehicle Use Cost Index (2000 base)	108.2	103.8	109.4
Highway Investment per Capita (100 million yuan)	0.023	0.045	0.017
Public Transit Investment per Capita (100 million)	0.008	0.031	0.002
Road Density (km/km ²)	0.595	0.941	0.494
Percent Urban	0.450	0.607	0.404
Population Density (persons/km ²)	402.4	1002.7	227.3
Vehicle Restriction (1 = yes; 0 = no)	0.045	0.176	0.006

Source: National Bureau of Statistics of China (<http://www.stats.gov.cn/enGliSH/NBS>).eps net database (<http://www.epschinadata.com/>).

EMPIRICAL MODEL

Table 6 reports the results of four double-log regression models: pooled OLS [column (a)], fixed effects [column (b)] and two fixed effects models with instrumental variables [columns (c) and (d)]. Preliminary analyses found that a double-log specification provided the best model fit. In addition, including a proxy for vehicle price (see endnote 5) consistently led to inferior fits and sign reversals and was ultimately dropped from final model specifications.

Pooled Model. Column (a) reports the OLS results on pooled data that do not account for cross section or separate time effects, but the coefficient standard errors are heteroskedastic/autocorrelation consistent. The model explains 88.9% of the variation in private vehicle ownership and the variables generally have their expected signs. The positive time trend indicates that, during the sample period, provincial private vehicle ownership annually increased 14%, all else being constant. The role of the economic environment is consistent with expectations. A 1% increase in per-capita GDP increases private vehicle demand by 0.89%. And a 1% increase in the wage rate increases demand for vehicles, consistent with the value-of-time hypothesis that higher wages raise the opportunity cost of time. Although having the expected sign, vehicle use cost is not significant at any reasonable level of significance.

The infrastructure results are mixed. An increase (decrease) in road kilometers per square mile (real investments in public transportation) increases (decreases) private vehicle ownership, as expected, but the results for road density are not statistically significant. At the same time, real investments in highways decrease private vehicle ownership, contrary to expectations.

The spatial variables also have their expected signs but, similar to vehicle use cost, are not reliably estimated. In contrast, the regulatory policies that limit vehicle ownership or use are effective in reducing vehicle demands.

The OLS results in Table 6 provide a reasonable fit with parameter estimates whose signs generally conform to the underlying hypotheses. However, concerns with cross section heterogeneity and endogeneity, if present and not addressed, bias the OLS estimates reported in Column (a) and lead to incorrect inferences.

Fixed and Random Effects Models. Column (b) in Table 6 reports the results when re-estimating the model with cross-section fixed effects. There are two specification issues addressed in Column (b). First, the fixed effects model rejects at well below the .01 level the pooled model, that is, the null hypothesis that the fixed effects are jointly 0. Second, in controlling for cross-section heterogeneity, a common alternative specification is the random effects model. The Hausman test statistic for the random effects model rejects at the .01 level the random effects model in favor of the fixed effects specification.⁷

The results reported in Column (b) of Table 6 differ from those in Column (a) in a number of significant ways. First, the cross-section fixed effects model increases the adjusted R^2 from 0.889 to 0.983. Second, the time trend increases significantly, indicating that the annual growth in vehicle consumption per 1,000 persons was 23.0% during the sample period in comparison with 14.0% in the pooled model. In addition, real infrastructure spending on public transportation is no longer significant, although the variable maintains a negative sign.

Per-capita GDP continues to have a positive and significant effect on vehicle ownership (with a lower point estimate) and the index for vehicle use cost continues to reduce vehicle ownership, all else being constant. But the negative impact on ownership of vehicle use cost is now significant at a 0.15 level (two-tail test), which reflects a larger coefficient (in absolute value) and a more precisely estimated coefficient. Related, the vehicle ownership and use limitation policies are again negative and significant, but the magnitude of the effect has decreased (in absolute value) from -0.67 to -0.18.

Also in contrast to the OLS results, the spatial environment in Column (b) has its expected impact on vehicle ownership. A percentage point increase in the urbanization rate, all else being constant, increases vehicle demand 0.45%, whereas a 1% increase in population density, all else being constant, decreases demand 1.6%.

Omitted Variables and Endogeneity. In aggregate models, endogeneity bias and inconsistent estimates often occur by including variables that are simultaneously determined with the dependent variable or by excluding (e.g., due to data unavailability) relevant variables. When the omitted

Table 6: Panel Data Estimation Results^a

Dependent Variable - Private Vehicle Ownership Per 1,000 Persons								
Explanatory Variables	OLS		Fixed Effects (1 Way)		IV - Lagged		IV - Hausman-Taylor	
	Estimate	Std Error	Estimate	Std Error	Estimate	Std Error	Estimate	Std Error
	(a)		(b)		(c)		(d)	
<i>Economic Environment</i>								
GDP Per Capita	0.899***	0.179	0.638**	0.248	0.722***	0.278	0.996***	0.168
Wage Rate	0.681***	0.212	-0.033	0.179	0.075	0.195	0.034	0.115
Vehicle Use Cost Index	-0.404	0.652	-0.797	0.545	-1.028**	0.492	-1.041***	0.223
<i>Infrastructure</i>								
Highway Investments	-0.049	0.030	-0.015	0.015	0.015	0.021	0.027	0.017
Public Transit Investments	-0.055**	0.023	-0.006	0.010	-0.012	0.009	-0.007	0.007
Road Density	0.036	0.135	-0.033	0.046	0.032	0.081	0.057	0.049
<i>Spatial Concentration</i>								
Percent Urban	0.668	0.450	0.458***	0.167	0.384**	0.172	0.349***	0.112
Population Density	-0.076	0.092	-1.624***	0.352	-1.306***	0.391	-0.662***	0.170
<i>Regulatory Environment</i>								
Vehicle Limitation	-0.671**	0.275	-0.184***	0.048	-0.300**	0.126	-0.350***	0.095
<i>Other</i>								
Time Trend	0.138***	0.031	0.230***	0.019	-	-	-	-
Constant	-296.3***	60.0	-456.1***	34.7	3.743	3.376	-6.134***	2.238
Cross Section Fixed Effects	No		Yes		Yes		Yes	
Time Fixed Effects	No		No		Yes		Yes	
Standard error correction for								
Heteroskedasticity/ autocorrelation Clustering	Yes No		Yes No		Yes Yes		Yes ^a Yes	
Hausman Test (p-value)	-		0.008		<0.0001		0.864	
N	403		403		372		372	
MSE	0.104		0.0175		0.0157		0.0150	
Adjusted R ²	0.889		0.983		0.985		0.976	

^a p<0.10, **p<0.05, ***p<0.01. With the exception of Percent Urban, Vehicle Limitation, Time Trend, and Constant, all variables are in logarithmic form. For the IV models, all variables except the Constant, Wage Rate, Population Density, Urban and Vehicle Limitation are lagged one period. The instrument for Vehicle Limitation is the predicted value of Vehicle Limitation from a binary probit model on a constant term, time trend, and one-period lagged values of the logarithms of GDP Per Capita, Wage Rate, Public Transit Investment, Road Density, Percent Urban, and Population Density. The data analysis for this paper was generated using SAS/ETS software, Version 9.r of the SAS System for Windows. Copyright © 2002–2012 SAS Institute Inc., Cary, NC< USA.

* For the Hausman-Taylor (1981) estimates, a separate adjustment for heteroskedasticity is not necessary since the model estimates cross section variance components. The errors are not robust to serial correlation.

variables are correlated with included explanatory variables, the parameter estimates are not consistent, where the direction of the bias depends on the correlation between the excluded and included variables.⁸

Of particular concern in this analysis are included endogenous variables that lead to inconsistent estimates. Vehicle ownership depends on highway and bridge infrastructure, but real infrastructure

spending also depends on the extent of vehicle ownership and use. Higher vehicle ownership is expected to increase real spending on highways and bridges to accommodate the greater number of vehicles. Similarly, per-capita GDP, as a proxy for income, is potentially endogenous. While economic growth and development increase GDP per capita and generate more demands for private vehicles, the growth in private vehicles facilitates higher levels of production, productivity, and GDP growth.

To address these endogeneity concerns, we estimate models using instrumental variables (IV). Traditionally, an instrumental variable is one that is correlated with independent variable(s) and uncorrelated with the error term. For this analysis, we adopted two approaches. First, we include lagged values of potentially endogenous variables as instrumental variables in the model. Logically, lagged variables are predetermined and, as such, can serve as instrumental variables. Second, we searched for potential instrumental variables outside of those in the model.⁹

Column (c) of Table 6 reports the results of a two-way fixed effects models in which the lagged values instrument for variables are of primary concern – GDP per capita, vehicle use cost, infrastructure spending on highways/bridges and public transportation, and road density. Standard errors are heteroskedastic/autocorrelation consistent and also account for clustering effects.

Notwithstanding that the IV – Lagged results reported in Column (c) of Table 6 have 31 fewer observations due to lagging one period, the results are generally consistent with the fixed effects model in Column (b). The adjusted R² in the IV – Lagged model is a bit higher (0.985) and the mean squared error (MSE) is lower (0.015). Rather than a time trend, this model estimates separate time effects (not reported), which imply a 20.7% average annual growth in vehicle consumption per 1,000 persons, similar to the 23.7% estimate of the annual trend in Column (b). A Hausman test again rejects a random effects in favor of a fixed effects specification.

GDP per capita in Column (c) has a similar impact on vehicle consumption as in Column (b) but the effect of vehicle use cost increases (in absolute value) by about a third, from -0.797 to -1.028. The infrastructure variables have signs that are consistent with expectations and, in this case, real spending on public transportation is significant at a 0.20 level (two-tail test). The spatial variables in IV-Lagged are robust to their values in the fixed effects model. In contrast, the coefficient for vehicle limitation has increased (in absolute value), indicating that the presence of restrictions on vehicle ownership/use reduces vehicle demands per 1,000 persons 30%.

Hausman-Taylor IV Model. Column (d) in Table 6 reports estimates from a Hausman and Taylor (1981) specification of the model. This approach has two attractive features for the current problem. First, the Hausman-Taylor model is an instrumental variables regression in which some of the model's variables are assumed to be correlated with the individual effects but uncorrelated with the observation errors. Second, the approach essentially combines elements of a fixed-effects IV regression with a one-way random effects specification. For this analysis, the assumption is that real spending on highways and bridges, real spending on public transportation, and road density are correlated with the individual effects but uncorrelated with the observation error terms. Instrumental variables are based on the model's other variables, which include GDP per capita, vehicle use cost, wage rate, percent urban, and population density.¹⁰

Goodness of fit statistics from the Hausman-Taylor specification in Column (d) are similar to those for the IV-Lagged model. The adjusted R² is slightly smaller (0.976 vs. 0.985) but the mean-squared error is smaller (0.0150 vs. 0.0157). A p-value of 0.942 for a Hausman specification test (Hausman and Taylor, 1981) accepts the null hypothesis that real spending on highways/bridges, real spending on public transportation, and road density are correlated with individual effects but not with observation errors.

In general, the estimation results in Column (d) are robust. GDP per capita and vehicle use cost index have positive and negative impacts, respectively, on vehicle consumption. Interestingly, the point estimates in absolute value are essentially suggesting that a 1% increase in GDP per capita

and in the use cost index will have offsetting effects on provincial vehicle consumption per 1,000 persons. Wage rate has an expected positive sign but is not significant at any reasonable level of significance.

Infrastructure spending and road density variables again have their expected signs and are not significant at a 0.10 (or smaller) level. However, relative to IV-Lagged model, spending on public transit is less significant (0.30 level on a two tail test), whereas highway infrastructure investment is significant at a 0.11 level (two-tail test). Percent urban has a similar impact on vehicle consumption and the effect of population density is much lower in absolute value (-1.306 vs. -0.662). Also robust is the impact of vehicle limitation in the Hausman-Taylor specification, indicating that the effect of these policies reduces provincial vehicle consumption per 1,000 by 35%.¹¹

Highest Urbanization Provinces

In order to gain more insight on the variation in private vehicle ownership among the provinces, Table 7 reports separate Hausman-Taylor estimates for the highest ($\geq 60\%$) and less urbanized ($< 60\%$) provinces, as identified in Table 7.¹² Overall, each model fits the data well. Importantly, the estimation results identify the oftentimes large differential impacts that determining factors have on provincial vehicle private vehicle consumption.

Whereas private vehicle ownership grows a bit more than proportionately than GDP per capita in all of China's provinces, there is a strong disproportionate relationship in the highest urbanized provinces. In particular, a 1% increase in provincial GDP per capita more than doubles private vehicle ownership, 1.67% in the highest urbanized provinces compared with a 0.69% for the less urbanized provinces. Although not as dramatic as GDP per capita, the other economic variables also have larger coefficients (in absolute value) in the highest urbanized provinces. The one possible exception is the wage rate. The hypothesis was that an increase in the wage rate would increase private vehicle ownership, holding GDP per capita constant, since higher wages reflect higher values of time. The results for each group of provinces produced a positive sign, as expected, but are statistically insignificant in each case. The largest cities in China (e.g., Shanghai and Beijing) have significant congestion delays, more uniform spatial development in contrast to the hub and spoke networks in the West, and a large public transportation infrastructure. The net effect of these factors may be that the travel time advantage of privately owned vehicles relative to alternative means of travel is not significant.

The infrastructure variables for the highest urbanized provinces are uniformly stronger in their effects, carry their expected signs, and are statistically significant. Real investment in highway infrastructure and in road density increase, as expected, private vehicle ownership. Further, real investments in public transportation have their expected impacts, decreasing private vehicle ownership.

Characteristics in the spatial environment between the two groups also affect private vehicle demands differently, all else being constant. The extent of urbanization has nearly twice the impact on vehicle consumption in the highest urbanized provinces. At the same time, a 1% increase in population density reduces per-capita private vehicle ownership by 0.67% in the most urbanized areas. This compares with a much weaker 0.13% (0.13 p-value, not reported) impact in the less urbanized areas.

Increases in vehicle use cost significantly decrease private vehicle consumption in less urbanized areas but have a much weaker (and statistically insignificant effect in a two-tail test) in the most urbanized areas. Vehicle ownership and use restrictions have little statistical effect, in contrast to the much stronger results in Table 6. This may reflect separate explanations for each group. In the less urbanized areas, the absence of a significant effect likely reflects the lack of variation since only one province implemented a vehicle restriction during the sample period. For the highest urbanized areas, the sign on the vehicle limitation is consistent with expectations, but the p-value is much

lower 0.19. This group comprises only 84 observations, and the loss in degrees of freedom reduces the precision of the estimate.

Table 7: Hausman-Taylor Estimates by Level of Urbanization

Dependent Variable	Private Vehicle Ownership Per 1,000 Persons			
	< 60% Urbanized		≥ 60% Urbanization	
	Estimate	s.e.	Estimate	s.e.
Explanatory Variables	<i>Economic Environment</i>			
GDP Per Capita	0.696***	0.192	1.670***	0.278
Wage Rate	0.140	0.123	0.216	0.251
Vehicle Use Cost Index	-1.102***	0.484	-0.458***	0.478
	<i>Infrastructure</i>			
Highway Investments	0.012	0.019	0.053*	0.029
Public Transit Investments	-0.0002	0.008	-0.043***	0.014
Road Density	0.028	0.049	0.631***	0.153
	<i>Spatial Environment</i>			
Percent Urban	0.302*	0.162	0.529***	0.155
Population Density	-0.136	0.089	-0.676***	0.195
	<i>Regulation</i>			
Vehicle Limitation	0.226	0.184	-0.156	0.118
	<i>Other</i>			
Constant	-7.378***	2.257	-16.566***	3.596
Adjusted R ²	0.9794		0.9858	
Cross Section Fixed Effects	Yes		Yes	
Time Fixed Effects	Yes		Yes	
N	268		84	
MSE	0.0139		0.0096	
Adjusted R ²	0.9794		0.9858	

Note: Standard errors in parentheses. * p<0.15, ** p<0.1, *** p<0.05

DISCUSSION AND CONCLUDING REMARKS

The objective of this paper was to identify those factors that underlie China's significant growth in private vehicle ownership since 2000. Private vehicle consumption per 1,000 vehicles increased over 20% per year, with higher growth rates in the less urbanized areas and, more recently, with the annual growth rate falling (rising) in the more (less) urbanized areas.

The analysis developed and tested hypotheses on the impact that economic, infrastructure, spatial, and regulatory environments have upon private vehicle ownership across China's provinces during the period 2000–2012. The Hausman-Taylor (HT) specification provides the best overall fit of the model, and the results are relatively robust to one-way fixed effects and lagged instrumental variable models.

The HT estimates for the overall sample lead to the following conclusions. One, the model strongly rejects the null hypotheses that economic, spatial, and regulatory environments have no

effect on private vehicle ownership. Among the specific factors, the model did not provide reliable estimates for the wage rate – included as a proxy for the value of time. Also, the estimated results give a private vehicle demand elasticity (-1.041) for vehicle use costs that equal the income (GDP per capita) elasticity of demand (-0.996). This suggests that (e.g., tax) policies intended to increase a private vehicle's operating cost could be an effective tool to offset increases in GDP per capita. However, separate model estimates by level of urbanization argue against this, as discussed below.

Two, and contrary to expectations, the sample results accept the null hypothesis that infrastructure investments and road density have no impact on private vehicle provincial demands. Although these variables have the expected signs, at standard levels of significance the results do not reject the null hypothesis. When disaggregated by level of urbanization and separately estimated, model results shed additional light on the differential role of infrastructure spending.

Third, non-economic factors that drive private vehicle ownership in high urbanization provinces are not drivers of private vehicle ownership in less urbanized provinces. The general result is that for the most urbanized provinces, economic, infrastructure, spatial, and regulatory environments all drive private vehicle ownership decisions. But there are important differences from the results for the total sample. Per-capita GDP has a much stronger positive impact on vehicle ownership with a much larger 1.67 elasticity estimate. By comparison, the GDP per-capita elasticity for less urbanized areas is 0.70. Also, the results indicate that for high urbanized areas, increases in use cost have negative but unreliably estimated effects on private vehicle demands; increases in vehicle use cost have larger effects on demands than increases in GDP per capita. This accords with inferences that one could draw from the descriptive statistics in Table 5, where highly urbanized provinces have much higher GDP per capita, vehicle ownership rates, wages, and infrastructure investments.

The most important difference from the results for the full sample relates to infrastructure spending where highway and public transit investments have the expected positive and negative impacts, respectively, on provincial vehicle demands in the most urbanized provinces. Also consistent with expectations is a strong positive impact on private vehicle demands with increases in road density. Although on a two-tail test, the impact of vehicle limitation policies for the most urbanized areas is statistically insignificant, the model rejects the null hypothesis of no impact at a .10 level using a one-tail test.

Fourth, the disaggregated results for the lower urbanized provinces, although based on a sample three times as large, are much weaker. For these provinces, the model rejects the null hypothesis that economic factors have no effect on private vehicle demands where consumer demands are more sensitive to the use cost than to increases in GDP per capita. The spatial environment continues to be important but with weaker impacts on demands.¹³

A broad implication from these results relates to the set of factors that affect private vehicle demands as provinces become more urbanized. In less urbanized provinces, economic factors and, specifically, income and vehicle-related costs are primary drivers of private vehicle demands. As less urbanized provinces transition into areas with higher rates of urbanization, the findings in this study indicate that in addition to economic factors, infrastructure, spatial, and regulatory factors are important in shaping a province's private vehicle demands.

Areas for future research are numerous, many of which are additional robustness checks. Examples include: 1) updating the panel data while searching for better testing alternative instrumental variables; 2) analyzing private vehicle demands for smaller geographical units (e.g., city level) or from household survey data; 3) estimating the impacts of specific vehicle restrictions; 4) applying alternative estimation methodologies (e.g., dynamic models); 5) developing a better understanding of the roles that highway investments and alternative forms of public transit investments have on vehicle ownership; and 6) determining the consequences of these results for congestion, air quality and health, and highway safety.

Endnotes

1. A Gompertz function is a sigmoid function and a special case of the generalized logistic function that has a different position for the inflection point.
2. Since the model controls for per-capita GDP, average wage is expected to capture value of time more than income. Since the income effect and the value of time effect of average wage is expected to increase private vehicle consumption, there is an upward bias on the effect of average wage. The magnitude of the bias depends on the extent to which average wage is a good proxy for value of time.
3. Increases in population density also affect other highway modes (e.g., bus travel) and the relative effect could be a net shift from private vehicle to public transit. This analysis focuses on the demand for private vehicles rather than the share of private vehicles in the modal mix.
4. National Bureau of Statistics, China (<http://www.stats.gov.cn/enGliSH/>) and EPS China Data (http://edp.epsnet.com.cn/database_en.html). China's administrative structure includes three levels: provincial, autonomous regions, and municipalities. Provinces and autonomous regions are sub-divided into prefectures, counties, and cities. And counties are sub-divided into townships. Municipalities are city-provinces (Beijing, Chongqing, Shanghai, Tianjin) that the Central Government directly controls. This analysis includes the China's 22 provinces, five autonomous regions, and four municipalities. (<http://www.china.org.cn/english/kuaixun/64784.htm>).
5. Because there is no consumer price index (CPI) for transportation for Tibet, we use Xinjiang's CPI for transportation as a proxy since Tibet and Xinjiang provinces have similar economic environments. Also, in preliminary models, we created a proxy for vehicle price based on tax revenues from vehicle purchases, the vehicle tax rate, and changes in private vehicles from one year to the next. Except for some new energy vehicles, almost all vehicles are taxed. Because the variable consistently led to poorer results and perverse signs, we excluded the variable from the final versions. Part of the reason this was a poor proxy is that data on vehicle purchase taxes include public transit in addition to private vehicles.
6. Wang (2016, p. 31-36) reports the details of these policies, particularly for Shanghai and Beijing.
7. Rejecting the random effects model rejects the null that the error term and the explanatory variables are uncorrelated. Standard errors in these models are heteroskedastic/autocorrelation consistent.
8. For instance, there may be higher vehicle consumption than expected, given the urbanization rate. Excluding from the equation vehicle purchase credit policies will bias upward the coefficient of the urbanization variable if more lenient credit policies are expected to have a larger effect on urban relative to rural populations. Systematic measurement errors also produce inconsistent estimates.
9. We explored a number of instruments outside those included in the model. The most promising was road lamps. When governments invest money on roads and bridges, they also build road lamps on the roadsides. So the number of road lamps is expected to be highly correlated with investments on roads and bridges but uncorrelated with the error term. Preliminary analyses

found that the model fits with this instrument were inferior to those reported in Columns (c) and (d) in Table 6.

10. Consistent with IV-Lagged specification, GDP per capita and vehicle use cost are lagged one period. Wage rate, percent urban, and population density are unlagged.
11. Hausman and Taylor (1981) assume that the means of the regressors are uncorrelated with the individual effects. If the regressors rather than their means are uncorrelated with the individual effects, Amemiya-MaCurdy (1986) demonstrate that this leads to more efficient instruments. For this analysis, the Amemiya-MaCurdy (1986) estimates differ very little from the reported estimates in Column (d) of Table 6. SAS/ETS 14.1 User's Guide, Panel Procedure Details. Copyright © 2002-2012 SAS Institute Inc., Cary, NC, USA.
12. There was not sufficient variation in the vehicle limitation policies to estimate separate models for provinces whose urbanization was less than or equal to 50%, between 50% to 60%, and 60% or more.
13. On a one-tail test, population density is significant at a 0.10 level of significance.

References

- Amemiya, T. and T. E. MaCurdy. "Instrumental-Variable Estimation of an Error-Components Model." *Econometrica* 54, (2015):869–880.
- Bouachera, T. and M. Mazraati, "Fuel Demand and Car Ownership Modelling in India." *OPEC Energy Review* 31, (2007): 27-51.
- Button, K., N. Ngoe, and J. Hine. "Modeling Vehicle Ownership and Use in Low-Income Countries." *Journal of Transport Economics and Policy* 27 (1993):51-67.
- Chin, A. and P. Smith. "Automobile Ownership and Government Policy: The Economics of Singapore's Vehicle Quota System." *Transportation Research, Part A* 31, (1997): 129-140.
- Dargay, J. and D. Gately. "Income's Effect on Car and Vehicle Ownership, Worldwide: 1960-2015." *Transportation Research Part A* 33, (1999):101-138.
- De Jong, G., J. Fox, A. Daly, M. Pieters, and R. Smit. "Comparison of Car Ownership Models." *Transport Reviews* 24, (2004):379-408.
- Energy Information Administration. *International Energy Outlook 2000*. Washington D.C.: U.S. Department of Energy, 2000.
- EPS China Data. Website URL: <http://www.epschinadata.com/index.html>
- Gu J., F. Qi, and J. Wu. "Forecasting on China's Civil Automobile-owned Based on Gompertz Model." *Technology Economics* 2010 (Issue 01). Translation from Chinese (website URL: <http://oversea.cnki.net/Kns55/brief/result.aspx?dbPrefix=CJFD>).
- Hao, H., H. Wang, and M. Ouyang. "Comparison of Policies on Vehicle Ownership and Use Between Beijing and Shanghai and Their Impacts on Fuel Consumption by Passenger Vehicles." *Energy Policy* 39 (2011): 1016–1021.

- Hausman, J. and W. Taylor. "Panel Data and Unobserved Individual Effects." *Econometrica* 49, (1981):1377-98.
- Huang, X., X. Cao, and T. Li. "The Spatio-Temporal Variations of Urban Private Car Ownership in China and Their Influencing Factors." *Dili Xuebao/Acta Geographica Sinica* 67, (2012): 745-757.
- Ingram, G. and Z. Liu. "Determinants of Motorization and Road Provision." Ch. 10 in Gomez-Ibanez, J., Tye, W. and Winston, C. (Eds.) *Essays in Transportation Economics and Policy*. Washington D.C.: Brookings Institution Press, 1999.
- Keqiang, L. *Report on the Work of the Government*. Delivered at the Fifth Session of the 12th National People's Congress of the People's Republic of China, March 5, 2017. Website URL for Chinese and English versions: <https://blogs.wsj.com/chinarealtime/2017/03/05/china-npc-2017-the-reports/>.
- Ministry of Environmental Protection. *2012 China Motor Vehicle Pollution Prevention Annual Report*. Beijing: China, 2012 Website URL: http://www.zhb.gov.cn/gkml/hbb/qt/201212/t20121227_244340.htm and <http://english.mep.gov.cn/>.
- National Bureau of Statistics China, People's Republic of China. Website URL: <http://www.stats.gov.cn/enGliSH/>.
- Tanner, J.C. "An Analysis of Increases in Motor Vehicles in Great Britain." Research Note RN/1631, Road Research Laboratory, Harmondsworth, 1958.
- Wang, J. "Development of Private Vehicle Ownership Among Provinces in China: A Panel Data Analysis." MS Thesis, Center for Finance, Economics, and Management Studies, Hunan University, 2016.
- Wang, Y. "Car ownership forecast in China – an analysis based on Gompertz equation." *Research on Financial and Economic Issues* 11, (2005): 43-50.
- Wu, N., S. Zhao, and Q. Zhang. "A Study of the Determinants of Private Car Ownership in China from the Panel Data." *Transportation Research Part A* 85, (2016): 186-195.
- Xu, R. "Dynamic Discrete Choice Models for Car Ownership Modeling." Ph.D. Thesis, Department of Civil & Environmental Engineering, University of Michigan, 2011.
- Zhang, Q. and R. Crooks. *Toward an Environmentally Sustainable Future: Country Environmental Analysis of the People's Republic of China*. Philippines: Asian Development Bank 2012.
- Zhou M. and W. Shu. "Analysis of Influence Factors of Private Car Ownership Based on Spatio-Temporal Perspective." *Journal of Sichuan University Science and Engineering* (Social Sciences Edition), 2014, 47-55. Translated from Chinese. Website URL: http://oversea.cnki.net/kns55/oldnavi/n_Navi.aspx?NaviID=48&Flg=local.

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On-Demand, App-Based Ride Services: A Study of Emerging Ground Transportation Modes Serving Los Angeles International Airport (LAX)

by Karina Hermawan and Amelia C. Regan

This research estimates and compares travel times and costs of transportation by Uber and Lyft (the latter are referred to here as transportation network companies or TNCs) against other forms of ground transportation to Los Angeles International Airport (LAX). Using estimated travel times and costs derived from Google Maps and other sources as well as the 2015 LAX air passenger survey, we develop estimates of airport ground transportation access mode choice decisions. Among other findings, our preferred nested logit specification implies that if TNC fares were to be raised to match the current cost of taking a taxi to the airport, demand for TNC's would fall by 20.9% and 23.3% (relative to initial TNC shares) for business and leisure passengers, respectively.

INTRODUCTION

Approximately 37 million travelers initiated their flights from Los Angeles International Airport (LAX) in 2015. Passengers going to the airport have a number of airport ground transportation access options, including taxi, Flyaway bus service (a regional shuttle bus service that transports passengers non-stop to and from LAX), a shared van/shuttle, a private shuttle, public transit, or most recently, on-demand, app-based ride services provided by transportation network companies (TNCs) such as Uber and Lyft. These latter modes are now known by many names, including shared rides, rideshares, ridesource, or dynamic carpooling. Using mobile applications, they connect passengers with drivers who provide transportation using non-commercial vehicles.

On-demand app-based rides are increasingly more prevalent at major airports like LAX. Using TNCs around Los Angeles to travel to LAX has been permitted since 2011, but initially, only pricier, commercially licensed Uber services (UberBlack and UberSUV) were permitted to pick up passengers at airport curbsides. In December 2015, Lyft became the first standard TNC service allowed to provide airport pickups at LAX, while Uber followed suit in March 2016. Because of their highly reliable, convenient, and competitively priced services (except for some notable issues arising during surge or peak demand periods), TNC services attract customers who might otherwise have chosen another mode for airport ground transportation. Despite their growing presence and demand, the characteristics and usage of TNC services at airports like LAX are still not well understood. Using Google Maps among other sources, this research estimates and compares travel times and costs of trips in the Los Angeles area to LAX by TNCs as well as other modes of ground transportation. Then incorporating the 2015 LAX passenger survey, we also develop a model of LAX access mode choice decisions. In this light, we explore the following key questions:

- What is the current demand for TNCs for travel to LAX and how does that compare with the demand for other modes of ground transportation to the airport?
- For a number of reasons, we offer that TNCs are currently underpriced. Thus, on a policy level, what would happen to the demand for TNCs if their fares were regulated and set equal to more established private modal (i.e., taxi) fares?

Carpool versions of TNC services, such as Uber Pool and Lyft Line, that match small parties heading along similar routes are now also available in many cities, including Los Angeles. The

TNC's claim that with these new options, costs can be cut by up to half while detours are no more than 10 minutes. This latter possibility raises other questions, including how will the demand for standard TNCs respond to these newer services?

There are now many stakeholders involved with TNC activity in the LAX market. To this end, many transit agencies are now partnering with or considering partnering with TNCs and taxi services to improve aspects of both their standard and paratransit operations (Swegles 2016). Therefore, understanding regional airport access mode choice decisions should help provide insights to guide policies designed to measurably affect stakeholders with various transportation needs.

LITERATURE REVIEW

Statistical studies of ground transportation to airports date back to at least the early 1970s. Ellis et al. (1974) and Leake and Underwood (1977) were among the first papers to look at access mode choices for transportation to the airport using simple multinomial logit models. As is well known, a major limitation of the multinomial logit model is that it assumes independence of irrelevant alternatives (IIA - alternatives are not correlated through random disturbances) meaning that the ratio of two alternatives' probabilities is independent of the presence of the other alternatives. As it turns out, this assumption is not valid for many mode choice studies because some modes share common unobserved attributes.

Current research on surface transportation and modal choice has progressed to employing more complex generalized extreme value models, including nested logit models, in order to address this concern. Nested logit modal choice models are commonly used in airport ground access studies, usually nesting private modes such as automobiles separately from public or shared modes such as rail and buses. Recent work on airport ground transportation, including Tam et al. (2011), Akar (2013), Psaraki and Abacoumkin (2002), Alhoussein (2011), all use multinomial logit models, while others, including Pels et al. (2003), Cirrilo and Xu (2010), and Gupta et al. (2008), use nested logit to analyze airport ground passenger data. Alternatively, Manzano (2010) and Tsamboulas and Nikoleris (2008) relied on related discrete choice probit models to estimate travel demand to airports. On a more theoretical choice level, the elimination by aspect model of decision making (Tversky 1972), a model where, in stages, alternatives are viewed and evaluated as a set of aspects, has not been applied within an airport access mode choice setting. However, the latter has been used to analyze the demand for urban rail in Tokyo (Kato and Kosuda 2008).

Closely related to this research, Pels et al. (2003) analyzed not only ground transportation modes to the airport but also airport choice in the multi-airport Bay Area region in California. They found that access time plays a major role in airport choice decisions and confirmed that business passengers have a higher value of time, higher access time elasticity, and lower cost elasticity than do leisure passengers.

Since publicly available data are still scarce, there are few publications on the characteristics and usage of TNCs serving major airports. Rayle et al. (2014) conducted an intercept survey in San Francisco and investigated wait times for TNCs. They also analyzed trip purposes and reasons for using TNC services. Based on the data they collected as well as data on taxis from the San Francisco Municipal Transportation Agency, they found wait times for TNCs to be markedly shorter and thus the mode has become more reliable than even private taxis.

On the cost side, in Los Angeles, Goldman and Liu (2015) found that at least one TNC service has a lower price than private taxis almost all the time (i.e., on weekdays, on weekends, and even during dynamic pricing periods). An interesting study by Smart et al. (2015) deployed riders in low income neighborhoods in Los Angeles and instructed participants to take taxis or UberX. After controlling for the same ride (same origin and destination pairs and time of day), they found the average cost of UberX for any day of the week to be about \$6.40 per ride, lower than the average taxi cost of \$14.63 per ride.

Given these findings, if TNCs have lower wait times and fares, under what conditions might they be preferred to taxis? While previous works might suggest that TNC services are increasing access and mobility for people in low income neighborhoods, an NBER working paper by Ge et al. (2016) finds disparities in the number of cancelled requests, wait times, and ratings by drivers for TNC customers with different racial names or profile pictures. And finally, a recent dissertation (Masoud 2016) examines peer-to-peer ridesharing services from the point of view of optimizing large-scale systems.

Our extension to this literature will be to explore the impact of travel time and cost on the demand for TNC rides. We feel the cited studies provide only a first step toward modeling the demand for TNC services and that research is needed to better understand the characteristics of TNC's in important transportation markets.

DATA

2015 LAX Passenger Survey

The 2015 LAX passenger survey provided much of the revealed preference data used in this analysis. Commissioned by Los Angeles World Airports, this one-on-one survey is typically conducted every five years, with the 2011 and 2015 surveys conducted by Unison Consulting, Inc. Consisting of nearly 100 multiple choice and open-ended questions, the survey is extensive and is administered using electronic tablets at LAX boarding gates. Both visitors and Southern California residents were interviewed over the course of two nonconsecutive weeks, through April 13-19 and July 13-19, 2015, with over 13,400 surveys collected. The survey asks if the passenger(s) is (are) traveling for business or for leisure, the duration of the trip, and his or her primary mode of transportation to the airport. Critically for this analysis, the 2015 survey was the first time that TNC was included as an alternative mode.

Based on the responses, there were different follow-up questions. For example, respondents who specified that their primary form of transportation was a private vehicle were asked more specific questions regarding their chosen mode of ground transportation, such as whether they were dropped off, parked at the airport, or parked off site, and how many people in their travel party were in the same vehicle.

The data used for this research consist of travelers starting their air travel at LAX, but focuses on their chosen mode of one-way access to the airport.² Origin and destination pairs and estimated arrival times for each passenger were extracted based, respectively, on the zip code where the traveler came from before arriving at LAX, the terminal where he or she boards, and lead time (number of hours the passenger arrives before his or her flight).

Google Maps Driving and Transit Directions

Past studies calculate travel times solely as a function of distance, but travel time depends on a variety of other factors, such as location, route, and time of day. This research uses the Google Maps Directions Application Programming Interface (API) to compute travel times for each origin-destination pair. The benefits of geocoding with this method are that it allows the user to specify the location, route, and time of day of travel (via departure or arrival time), and is thus able to better map the actual transportation network.

The origin and destination pairs and estimated arrival times were entered into Google Maps to compute the distance between the origin and destination, shortest total travel time by car, and shortest total travel time by public transit. The destination was set to the exact terminal at LAX used by the survey respondent. Some observations with rare or distant origins such as Yosemite National Park or the town of Avalon (located on Catalina Island off the California coast) were excluded because Google Maps could not generate driving distance, driving duration, or transit duration for these origins. Meanwhile, other distant origins such as the city of Bakersfield generate

driving directions to LAX, but there are no public transit options listed on Google Maps. These latter observations were not excluded from the sample; rather, in these cases, the option of public transit was deemed as simply unavailable to the respondent.

EMPIRICAL MODEL

Access Mode Alternatives and Covariates

Since it is one of the busiest airports in the United States, the number of ground transportation alternatives serving LAX exceeds those at other airports in the Southern California area. This demand analysis focuses on 10 major alternative ground passenger modes serving LAX: 1) drive and park at the airport, 2) drive and park at an offsite parking lot, 3) taxi, 4) car rental, 5) limousine, 6) private shuttle, 7) shared van/shuttle, 8) TNCs, 9) public transit, and 10) the Flyaway, a non-stop regional shuttle bus service to and from LAX. Additionally, some air travelers have the option to take a hotel courtesy shuttle or simply to be dropped off by others. Individuals staying at hotels with courtesy airport shuttles have a strong incentive to use them over other modes because they are essentially zero cost to the passenger and in many cases are door-to-door. Similarly, individuals who have the option to be dropped off by family members, friends, or relatives also have a strong incentive to choose this mode because they typically do not have to pay compensation. Thus, individuals who reported in the survey that their primary form of transportation to LAX was by hotel courtesy or dropped off were excluded.

The independent variables analyzed are travel time and cost. Travel time is computed from the “driving option” of the Google API and is defined as total duration in the vehicle, whereas travel time by transit is defined as the sum of duration in the vehicle, walking to and from the stops, and waiting for transfers (if there are any transfers).

Not everyone has the same ground transportation choice set. But we did assume everyone has the option of taking a TNC, taxi, or limousine, while other modes are only available to some of the surveyed travel parties. As mentioned, depending on where they originated, some people do not have the option of taking public transit. For the purpose of this study, whether or not public transit is available to an individual was determined through Google Maps. Although service by public and private shuttles is much more extensive by than public transit, they also have limited service areas.

The availability of public and private shuttles was determined through the major shuttle providers’ websites (Primetime Shuttle, ShuttletoLAX, and SuperShuttle). For the regional “Flyaway” shuttle mode, we determined this was unavailable to individuals if the nearest Flyaway stop is located more than a 15-minute drive from their originating location. Lastly, we assumed that only Southern California residents have the options of driving and parking on- or off-site, or using a rental car to go to the airport and return it there. The assumption that all residents can drive (their own vehicle or a rental) is plausible since most people in Southern California (especially those who can afford to fly) have access to a car.³ The rental car option is unavailable to Southern California visitors because if they rented a vehicle for their trip, they must return it there (thus travelling to the airport by a rental car is the only choice for these individuals).

Description of the Alternative Modes

Passengers who reported that their primary form of transportation to LAX is private automobile either drove and parked on-site, or drove and parked off-site. This is true even if the driver drops off passenger(s) at the terminal curb before parking. Parking at the airport is located in the Central Terminal Area. Currently, the daily parking rate at LAX is \$30. Parking off-airport can be at any number of locations, but the most popular among them is at the Economy Parking Lot C, which is less than a mile from the airport. This lot also has a free shuttle that stops at each terminal. The daily parking rate there is \$12.

Car rental companies are located in very close proximity to the airport, but none are on-site. Those taking a rental to go the airport must return the vehicle off-site and then board a free shuttle that stops at each terminal. The cost of a car rental is estimated here to be about \$76.00 per day (assuming it was picked up somewhere not at the airport and then returned at the airport).⁴

Public transit in Los Angeles does not directly drop off passengers at airport terminals, so transit users must also board shuttles to transfer from an off-site location to the airport. Public transit in Los Angeles consists of MTA (Metro) buses and light rail lines, Santa Monica/Big Blue Bus, Culver City Bus, and Torrance Transit. Those who take Metro rail and bus lines can take a free shuttle at the Metro Green Line Aviation Station, and those who take other public buses can take a shuttle from the Metro Bus Center. These shuttles stop at every terminal, which means that passengers have longer travel times than if being dropped off directly.

Unlike driving and parking off-site, rentals, or public transit, the Flyaway and the shared van/shuttle options take passengers directly to the airport terminals, but they stop at each terminal at LAX because they are shared modes and thus have multiple drop-offs. As mentioned, the Flyaway is a direct shuttle bus service to and from LAX. Its 2015 stations were located in Van Nuys, L.A. Union Station, Westwood, Hollywood, and Santa Monica. Applicable one-way fare is \$8 per person for all of the Flyaways, except the Westwood Flyaway, which costs \$10.

Shared vans/shuttles, operated by Super Shuttle or Primetime Shuttle, are shared door-to-door services. For passengers who travel from any part of a large service area in Southern California where these shuttles operate and they reserve the shuttle 24 hours in advance, the fare is a fixed \$21 for the first person and \$14 for each additional rider, independent of distance (ShuttletoLAX). Reservations made less than 24 hours before the pickup, or for rides outside of the service area, have different pricing schemes that depend on distance, location, and party size (ShuttletoLAX, Super Shuttle, and Primetime Shuttle).

Other alternatives, such as private shuttles, limousines, taxis and TNCs do not stop at every terminal and directly take passengers to their boarding terminal.⁵ Because they are private, these modes pick up and drop off only one party (or typically two at the most) and thus often have much shorter travel times than shared vans/shuttles. Private shuttles are similar to shared vans/shuttles, except they are nonstop services and direct to destination as they do not pick up or drop off other parties. In fact, Primetime Shuttle runs a variety of private shuttle services in addition to their shared vans/shuttles. Their standard van service, private or shared, seats a maximum of seven people. Other than its standard vans, Primetime Shuttle offers other private shuttle services, including the Execucar Sedan service, the Execucar SUV service, and the Business Express SVC by Express Shuttle, all of which include a driver. These services usually have a maximum of three, four, and five passengers, respectively. Based on the pickup locations, some nonstandard shuttle services may vary or be unavailable (Super Shuttle, and Primetime Shuttle).

Another direct access mode is a limousine. Although a stretched limousine can be very luxurious and provide seats for many passengers, these vehicles often do not have adequate trunk space for luggage. Therefore, the maximum number of seats in a limousine available for passengers traveling to LAX is actually lower than if they were not going to the airport (LAX Limousine Service).

Taxi and TNCs are the final set of direct airport access modes. Taxi companies operating in the Los Angeles have a minimum fare of \$2.85 and, after the first 1/9 of a mile, the fare is \$2.70 per mile (TaxicabsLA 2015). TNC fares were estimated based on the costs of Uber. At the time, services in Los Angeles had a booking fee of \$1.65, a per-mile cost of about \$0.90, and a minimum fare of \$4.65 (Uber 2015). The actual per-mile charge may vary depending on traffic, discounts or promotions, or surge (i.e., peak load) pricing.

We use the various descriptions above to help estimate the travel time and trip cost by each mode for travelers to LAX relative to their own pickup location. The travel costs were further adjusted⁶ by travel duration (number of days) and party size.

Model Specification

In our model development, the utility of each decision maker, n , for each alternative, a , is assumed to be a linear function of travel cost, travel time, and an alternative constant (ASC). Under the multinomial logit model specification, error terms are assumed to be drawn from independent and identically distributed extreme value distribution. The 10 alternatives chosen for the analysis cannot share common unobservable characteristics or their error terms will not be independent. Further, travel time and cost coefficients are general and do not vary over alternatives. Moreover, we assume the TNC modal alternative is fixed, making it the baseline for our alternative-specific constants. Following the utility specification shown in equation 1, equation 2 lists the associated multinomial logit probability of making a choice (Ben-Akiva and Lerman 1987).

$$(1) U_{na} = ASC_a + \beta_{cost} \cdot Cost_{na} + \beta_{time} \cdot Time_{na} + \varepsilon_{na} = V_{na} + \varepsilon_{na}$$

$$(2) P_{na} = \frac{e^{V_{na}}}{\sum_{a \in A} e^{V_{na}}}$$

We noted that modes such as limousine, drive and park on-site, and drive and park off-site are private, while public transit and shared van/shuttle are shared with multiple and different parties. Any of the private modes might be correlated with each other because they share many characteristics. Specifically, they do not put strangers in the same vehicle and they do not have multiple drop-offs and pickups. For the same reasons, shared modes might be correlated because they do put strangers in the same vehicle and they have multiple drop-offs and pickups. And since there are similarities besides travel time and costs between the alternatives, their error terms may not be independent.

This issue is not a problem for our analysis since we developed nested logit models to mitigate this concern. Formally, within a nest d , alternatives are correlated through the same error, while across the specified nests, the errors are assumed to be i.i.d. More generally, the nested logit marginal and conditional probabilities (Ben-Akiva and Lerman 1987) are given by:

$$(3) P_{na|d} = \frac{e^{V_{na|d}}}{\sum_{a \in A(d)} e^{V_{na|d}}}$$

$$(4) P_{nd} = \frac{e^{(\alpha_{nd} + \alpha_x \cdot X_{nd} + \tilde{V}_{nd})}}{\sum_{d \in D} e^{(\alpha_{nd} + \alpha_x \cdot X_{nd} + \tilde{V}_{nd})}}$$

In general, X_d are variables that vary within the nest (for example, in the transit nest, it may be a factor such as headway), but we did not have access to such variables in our study. In addition, the inclusive value is $\tilde{V}_{nd} = \frac{1}{\mu_d} \ln[\sum_{a \in A(d)} e^{(V_{na|d})\mu_d}]$, and $0 < \frac{1}{\mu_d} < 1$ or $\mu_d > 1$ (Ben-Akiva and Lerman 1987).

In addition to the multinomial logit specification (Figure 1), we test a nested logit model, consisting of two nests that separate shared and private modes (Figure 2). Each of our chosen nests has two levels. To list alternatives, these are drive and park at the airport, drive and park at an offsite parking lot, rentals, taxi, TNC, limousine, and private shuttle fall into the first category, while shared van/shuttle, Flyaway, and public transit fall into the second category. A limited number of TNC services can be shared with up to two different parties, but they are considered private in this study since we believe that this alternative is predominantly the standard UberX and Lyft services.

Figure 1: Multinomial Logit Model



Figure 2: Nested Logit Model with Two Nests - Private and Shared

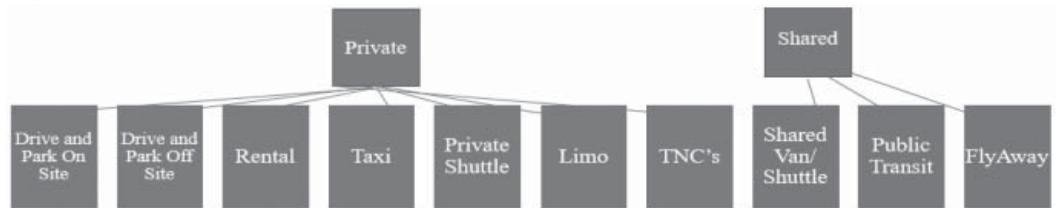


Figure 3: Nested Logit Model with Three Nests - Require Driving, Ride Services, and Transit, Non-Door-to-Door

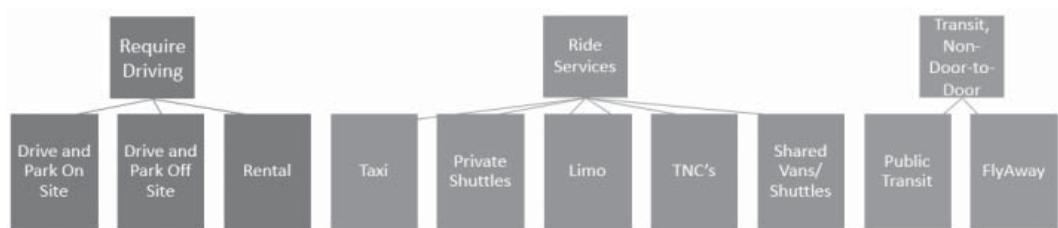
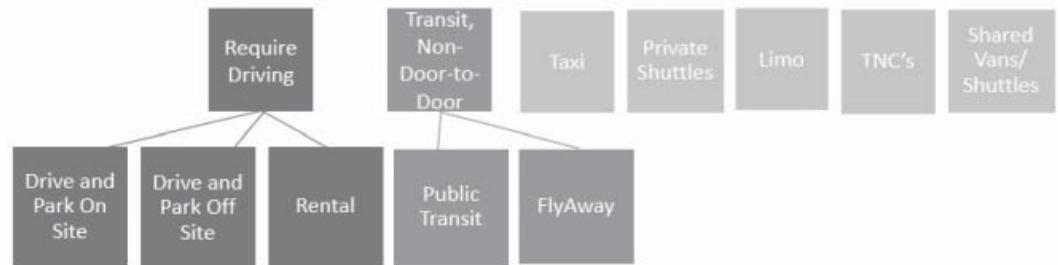


Figure 4: Nested Logit Model with Seven Nests - Require Driving, Transit, Non-Door-to-Door, Taxi, Private Shuttles, Limousines, TNCs, and Shared Vans/ Shuttles



We also tested other nesting and hierarchical structures. In Figure 3, the nested logit model has a nest grouping all modes that require driving (drive and park on-site, drive and park off-site, and car rental), and a second nest encompassing all ride services (taxi, TNC, shared vans/shuttles, private shuttles, and limousines), with a final nest containing all transit and non-door-to-door modes (public transit and the Flyaway). Under that specification, each nest contains two levels, while in Figure 4 only some nests contain two levels. In Figure 4, modes that are ride services are no longer grouped under one category, while modes that require driving and modes that are transit and non-door-to-door are grouped in their corresponding nests. In this specification, taxi, private shuttles, limousines, TNCs, shared vans/shuttles (all modes that require driving) and all modes that are transit and non-door-to-door are assumed to be distinct from each other, meaning they do not share common unobservables.

Finally, we suspect there might be additional disparities in airport access decisions between business and leisure passengers. Those who fly for business are typically reimbursed for their

travel and thus tend to be somewhat less sensitive to travel cost. And if individuals are traveling for business, they are probably less flexible to longer travel time duration as compared with people traveling for leisure. Given this, the coefficients of the travel cost and travel time variables (as well as other characteristics beside travel cost and travel time) may not be the same for passengers traveling for different purposes. So we also test for market segmentations under different travel purposes, here represented by mainly business vs. leisure passengers. All econometric specifications presented in this research were estimated with the public domain BIOGEME software.⁷

EMPIRICAL RESULTS

Descriptive Statistics

On a broader level, how do travel times and costs of TNCs compare with those of other ground transportation modes? Table 1 (below) shows average travel times and costs by each mode from downtown Los Angeles, for zip code 90012. We chose this area as a reference example because it is located in the downtown area, 20 miles from LAX, and also contains important sites like Union Station. The average travel cost estimates are calculated for one-way trips to the airport, and based on a travel party size of one person, while parking cost is based on a trip length of about three days. Travel time estimates are calculated for one-way trips as well.

From the start, a significant tradeoff between travel time and cost among the modes is apparent. Public transit, the Flyaway, and shared vans/shuttles cost about \$5, \$8, and \$21 respectively, while the other modes (not including TNCs) start at about \$40. The former travel times are at least 80-minute duration in our sample. This is much longer than the more expensive modes, which generate an average travel time of about 45 minutes. And as mentioned, TNCs are of special interest in this market because they have both low prices and low travel times.

Table 1: Cost and Travel Time Example from Downtown LA (zip code 90012) by Mode

Mode	Avg. Cost* (\$)	Avg. Travel Time (Min.)
Drive and Park Off Site	55.19†	74.8
Drive and Park On Site	121.94†	45.3
Rental	87.14	60.0
Flyaway	8.00	91.0
Limo	177.00	30.3
Private Shuttle	40.00	30.3
Shared Van/Shuttle	21	89.8
Public Transit	4.61	82.2
TNCs	28.65	30.3
Taxi	51.88	30.3

*Travel party size=1, †About 3 days of parking

Among the private modes, we find that a TNC is usually the most competitively priced option. Fares charged by a TNC in general (from downtown or elsewhere) amount to only about 55% of equivalent taxi costs. From downtown, the average cost of a TNC ride at \$28.65 is much lower than the average cost of taxis at \$51.88, car rental at \$87.14, drive and park at the airport at \$122, or limousine at \$177. It is also slightly less than private airport shuttles at \$40, or the drive and park off-site at \$55. Note that those who drive and park off-site, where parking is least expensive, still incur a higher average travel cost than someone using TNCs. However, compared with shared modes at LAX, TNCs are costlier. Public transit has the lowest average cost of all other modes, at \$4.61, followed by the Flyaway at \$8.00. Shared vans/shuttles, on the other hand cost an average of \$21, not much different than the cost of TNCs.

In addition to providing one of the more affordable services, we see that TNCs also have comparatively low travel times. Based on our estimates originating from downtown Los Angeles, a TNC can get passengers to the airport in about one-third of the time as compared with those modes with the greatest travel times. For the downtown origin, shared vans/shuttles and public transit have average travel times of 89.8 minutes and 82.2 minutes, respectively, while TNCs generate an average travel time of only about 30.3 minutes. We also find that taxis, private shuttle, and limousines have approximately the same average travel time as TNCs. These latter modes, including TNCs, have low travel times to LAX for good reason - passengers do not have to transfer, park, or take an off-site shuttle. Additionally, they also have fewer pickups and drop-offs since they are private by definition. All told, since TNCs are among the least expensive ground transportation options and also generate one of the lowest travel times, their services seem to provide a very competitive alternative for travelers heading to LAX.

Table 2 shows the availability and share of each ground transportation mode. Some modes are very limited in access and available to only about half of our sample. For example, recall that because the modes “Drive and Park Off-Site,” “Drive and Park On-Site,” and “rentals” are assumed to be only available to Southern California residents, only about 48% of the sample have access to these transportation options. The Flyaway service is available to about 41% of our sample since there are only five Flyaway stations. Many more individuals have the option of private shuttles, shared vans/shuttles, and public transit because these alternatives are available to both local residents and visitors, and they have greater coverage areas. These latter options are available to 97%, 89%, and 91% of the sample, respectively.

Our final sample contains 3,096 unique travel parties consisting of airline travelers originating their travel (but not connecting) at LAX. As mentioned, we dropped observations where the respondents chose an unavailable alternative. Of the 3,096 travel parties, 550 (17.8%) used Uber or Lyft. Even though TNCs were significantly less costly than taxis, a higher percentage of people (about 18.4%) took a taxi to the airport, and, in fact, taxis were the most frequently used alternative mode. Other modes comparable in use to TNCs were the private and shared shuttles, which had shares of 17.3% and 12.2%, respectively. Alternatively, some of the least frequently used modes were public transit at 1.5%, car rentals at 2.9%, Flyaway at 4.6 %, and limousines at 6.4%.

Table 2: Percent Mode Available and Mode Share

Mode	If Limited Availability, % Available	Mode Share (N) Total 3096	Mode Share (%)
Drive and Park Off Site	48	315	10.2
Drive and Park On Site	48	269	8.7
Rentals	48	90	2.9
Flyaway	41	141	4.6
Limo	-	199	6.4
Private Shuttle	97	537	17.3
Shared Van/Shuttle	89	378	12.2
Public Transit	91	46	1.5
TNCs	-	550	17.8
Taxi	-	571	18.4

A series of likelihood ratio tests (the first three are shown in Table 3) were conducted to formally compare choice specifications and to determine potential need for generalized extreme value models (nested logit), rather than simple multinomial logit (Ben-Akiva and Lerman 1987). First, we tested multinomial logit vs. two nest nested logit. Under the null hypothesis, both the log sum term (inclusive value) coefficients for the private and shared nests equal to unity (multinomial logit), whereas the alternative was that at least one of the log sum term coefficients was not equal to unity (nested logit). As shown in the table, the null (the simple logit model) was rejected, while the two nests nested logit model cannot be rejected. Subsequently, we tested the multinomial logit model against nested logit specifications with three nests, and a multinomial logit model against a nested logit model with seven nests. Similarly, we rejected the multinomial logit specification in the latter tests.

In the fourth test conducted in Table 3, we compared a nested logit model with seven nests against one with only three nests, also using a likelihood ratio test (Ben-Akiva and Lerman 1987).⁸ We failed to reject the model with seven nests, which also suggests there is no error correlation between the following alternatives: taxi, limousine, private shuttle, shared vans/shuttles, and TNCs. Thus our findings indicate that perhaps these modes should not be grouped together.

Our final specification test is more policy oriented. It explores the possible taste variations between business and leisure passengers. We re-estimated a nested logit model with seven nests for both business and leisure passengers, then just with business passengers, and then just with leisure passengers. From the first estimate, we attain a restricted log likelihood, while the remaining two (summed) give us the unrestricted log likelihood. In sum, we reject the null hypothesis that there was no market segmentation between business and leisure passengers, suggesting a future need to separate model specifications for business and leisure passengers.

In summary, based on a series of likelihood ratio specification tests, we conclude that the multinomial logit specification is inadequate, as some alternatives seem to share common unobservables. Additionally, we find that alternatives that seem to possess error correlation are modes that require driving and modes that are transit related and non-door-to-door, whereas the remaining modes do not seem to possess notable error correlations. Lastly, the specification tests also suggest a need to estimate choice models for airport transportation separately for business and leisure passengers because the two types of passengers clearly have different tastes.

Table 3: Specification Testing (Using Likelihood Ratio (LR) Test)

<p>Multinomial Logit vs. 2 Nests NL $H_0: \mu_{private} = \mu_{shared} = 1$ $H_A: \text{at least one } \mu_{private} \text{ or } \mu_{shared} \neq 1$</p> <p>LR: $-2 \times (L_R - L_U) = -2 \times (-5602.757 + 5599.911) = 5.692$ $5.692 > 4.61$ (the critical value of the chi-square distribution with 2 degrees of freedom at a 90% level of confidence)</p> <p>\therefore Reject the Null, or there is evidence of correlation between the alternatives in the multinomial logit model</p>
<p>Multinomial Logit vs. 3 Nests NL $H_0: \mu_{requires\ driving} = \mu_{ride\ services} = \mu_{transit,non-door-to-door} = 1$ $H_A: \text{at least one } \mu_{requires\ driving}, \mu_{ride\ services}, \text{ or } \mu_{transit,non-door-to-door} \neq 1$</p> <p>LR: $-2 \times (L_R - L_U) = -2 \times (-5602.76 + 5593.755) = 18.004$ $18.004 > 6.25$ (the critical value of the chi-square distribution with 3 degrees of freedom at a 90% level of confidence)</p> <p>\therefore Reject the Null, or there is evidence of correlation between the alternatives in the multinomial logit model</p>
<p>Multinomial Logit vs. 7 Nests NL $H_0: \mu_{requires\ driving} = \mu_{Taxi} = \mu_{Limousine} = \mu_{Private\ Shuttle} = \mu_{Shared\ Vans/Shuttles} = \mu_{TNC's} = \mu_{transit,non-door-to-door} = 1$ $H_A: \text{at least one } \mu_{requires\ driving}, \mu_{Taxi}, \mu_{Limousine}, \mu_{Private\ Shuttle}, \mu_{Shared\ Vans/Shuttles}, \mu_{TNC's} \text{ or } \mu_{transit,non-door-to-door} \neq 1$</p> <p>LR: $-2 \times (L_R - L_U) = -2 \times (-5602.76 + 5593.755) = 18.004$ $18.004 > 12.00$ (the critical value of the chi-square distribution with 7 degrees of freedom at a 90% level of confidence)</p> <p>\therefore Reject the Null, or there is evidence of correlation between the alternatives in the multinomial logit model</p>
<p>7 Nests NL vs. 3 Nests NL $H_0: \mu_{Taxi} = \mu_{Limousine} = \mu_{Private\ Shuttle} = \mu_{Shared\ Vans/Shuttles} = \mu_{TNC's} = 1$ $H_A: \text{at least one } \mu_{Taxi}, \mu_{Limousine}, \mu_{Private\ Shuttle}, \mu_{Shared\ Vans/Shuttles}, \text{ or } \mu_{TNC's} \neq 1$</p> <p>LR: $-2 \times (L_R - L_U) = -2 \times (-5593.755 + 5593.755) = 0$ $0 < 9.24$ (the critical value of the chi-square distribution with 5 degrees of freedom at a 90% level of confidence)</p> <p>\therefore Fail to reject the Null, or there is not enough evidence to rule out model with no error correlation between the alternatives: taxi, limousine, private shuttle, shared vans/shuttles, and TNC's</p>
<p>No Market Segmentation vs. Market Segmentation between Business and Leisure Passengers $H_0: \beta_{\text{just business passengers}} = \beta_{\text{just leisure passengers}}$ $H_A: \beta_{\text{just business passengers}} \neq \beta_{\text{just leisure passengers}}$ ** where β are the estimated coefficients in (1)</p> <p>LR: $-2 \times (L_R - L_U) = -2 \times (-5146.913 - (-3456.592 - 1647.356)) = 85.93$ $85.93 > 19.80$ (the critical value of the chi-square distribution with 13 degrees of freedom at a 90% level of confidence)</p> <p>\therefore Reject the Null, there is evidence of market segmentation (taste variations) between business and leisure passengers.</p>

Given these findings, in Table 4, we highlight the output from a nested logit model with seven nests for both leisure and business passengers. In both models, estimates of the covariates have expected signs. Since travel time and travel cost coefficients are significant and negative, this demonstrates that they have a significant impact on modal choice in that higher travel time or travel cost leads to a lower probability of that mode being chosen. Next, the implied value of travel time savings per hour from the estimates are calculated as follows: $\frac{\beta_{time(\$)}}{\beta_{cost(min)}} \times \frac{60 \text{ min}}{\text{hour}}$ (Ben-Akiva and Lerman 1987). For business passengers in the sample, we find that their value of time is approximately \$157/hr, while for leisure passengers in the sample it is about \$103/hr. Of course, this computed value of time is specific only to travel to and from LAX – and is interesting because both are greater than an expected value of time for either group as proxied by the wage rate in the region. However, we note that this computed value falls within the range found in previous airport access mode studies, including Landau et al. (2015).

In the model exclusive to leisure passengers, the alternative specific constants (ASC) for all of the modes are significant. Again, we used TNC as the baseline for the ASCs. Because the ASC for taxis is significant and positive, this suggests that, ceteris paribus, taxis are preferred over TNCs.

In fact, in this sample, most of the other modes, holding everything else constant, are preferred to TNCs as well, including alternatives such as drive and park on-site, drive and park off-site, Flyaway, car rentals, and private and shared shuttles. The only alternatives that were found to be less preferred to TNCs (all else being equal) were limousines and public transit.

The last three estimates to examine for this specification are the inclusive value coefficients of the chosen nests. In this likelihood ratio test, we examined whether: $\mu_{\text{requires driving}} \neq 1$, $\mu_{\text{ride services}}$ and $\mu_{\text{transit,non-door-to-door}} \neq 1$ was valid. But we can also examine whether just one or some of the inequalities are true ($\mu_{\text{requires driving}} \neq 1$ or just $\mu_{\text{transit,non-door-to-door}} \neq 1$), using a t-test (Ben-Akiva and Lerman 1987). The p-value with respect to $\mu_{\text{requires driving}} = 1$ is 0.02. Since the p-value is less than 5%, this indicates that the coefficient for $\mu_{\text{requires driving}}$ is significantly different from 1, meaning we can conclude there is significant correlation between the alternatives in the “requires driving” nest and that the alternatives in that nest should be grouped together. In contrast, the alternatives in the “transit, non-door-to-door” nest are not significantly different from 1, with a p-value with respect to $\mu_{\text{transit,non-door-to-door}} = 1$ of 25%, meaning there is not enough evidence to show that the modes in that nest should be grouped together.

In the specification exclusive to business passengers, we found that many of the ASCs are significant, except those for public transit, shared vans/shuttles, and FlyAway. Note that not only is the ASC of public transit insignificant, but its standard error is very large. We believe this may be because very few business passengers took public transit to go to LAX (only about six people in the sample), making the sample size applicable to this mode choice extremely limited. Additionally, the estimates suggest driving and parking on- or off-site, limousines, shared vans/shuttles, and taxis are all preferred over TNCs, all other things being equal, while Flyaway, private shuttles, public transit, and rentals are less preferred to TNCs.

Again, the last three estimates in the model are the inclusive value coefficients of our chosen nests. In this case, the coefficients are not significantly different from unity for the “requires driving” and “transit, non-door-to-door” nests. In fact, the inclusive value coefficient of the first nest is estimated to be equal to unity. Perhaps to business passengers, driving and parking on-site, driving and parking off-site, and rentals do not share some common unobservables or belong in a group. Meanwhile, the inclusive value coefficient of the third nest is estimated to be about 0.52.⁹

Table 4: Nested Logit with Seven Nests, Leisure versus Business Passengers

Description	Leisure				Business			
	Estimated Coefficient	Standard Error	t-stat (0)	p-val (0)	Estimated Coefficient	Standard Error	t-stat (0)	p-val (0)
Alternative Specific Constants:								
Drive and Park Off Site	1.84	0.162	11.36	0	1.61	0.278	5.78	0
Drive and Park On Site	1.74	0.148	11.73	0	1.85	0.209	8.86	0
Flyaway	0.65	0.201	3.25	0	-0.47	0.340	-1.38	0.17*
Limousine	-0.29	0.143	-2.00	0.05	0.48	0.216	2.21	0.03
Private Shuttle	0.34	0.078	4.38	0	-0.23	0.121	-1.93	0.05
Shared Vans/ Shuttle	1.00	0.186	5.37	0	0.40	0.323	1.24	0.21*
Public Transit	-0.89	0.291	-3.05	0	-2.16	1.800 ×	0.00	1.00*
Rental	0.44	0.192	2.29	0.02	-0.67	0.408	-1.64	0.10
TNC's	0.00	--fixed--			0.00	--fixed--		
Taxi	0.22	0.083	2.61	0.01	0.39	0.106	3.69	0
Covariates:								
Travel Cost (\$)	-0.00605	0.000705	-8.58	0	-0.00952	0.00125	-7.6	0
Travel Time (Minutes)	-0.0158	0.00259	-6.09	0	-0.0164	0.00487	-3.36	0
Inclusive Value Coefficients (1/μ):			t-stat (1)	p-val (1)			t-stat (1)	p-val (1)
Requires Driving Nest	0.72	0.175	2.24	0.02	1.00	0.126	0.01	0.99*
Ride Services Nest	1.00	--fixed--			1.00	--fixed--		
Transit, Door-to-Door Nest	0.77	0.265	1.15	0.25*	0.52	1.800×	0.00	1.00*
Additional Information:								
Number of Estimated Parameters	13				13			
Number of Obs.	1884				925			
Final Log Likelihood	-3456.592				-1647.356			

Scenario Analysis

The probabilities of choosing a TNC for each decision maker were calculated using the estimated coefficients of the linear utility functions. The average of these probabilities is the projected demand for TNCs (Table 5). Currently, TNCs account for 17.8% of the market among the alternatives we considered. If the TNC demands for passengers traveling on business and leisure are evaluated separately, they are estimated to be about 16.8% and 19.8%, respectively.

Possible changes to modal charges or costs, such as a 10% increase in TNC fares, an increase in TNC fares to match taxi fares, or a 50% fare cut plus 10-minute travel time increase, are considered. These scenarios are simulated by calculating the equivalent probabilities using the estimated coefficients, but changing the prices and/or travel times of TNCs.

Table 5: Projected Demand for TNC's Under Various Price & Travel Time Changes

	Business	Leisure
Initial Share Using TNC (%)	16.83	19.76
With 10% TNC Price Increase		
Share Using TNC With Price Increase (%)	16.42	19.24
Change Relative to Initial TNC Share (%)	-2.5	-2.7
With TNC Price Increase to Match Taxi Fares		
Share Using TNC with (Price Increase (%)	13.92	16.03
Change Relative to Initial TNC Share (%)	-20.9	-23.3
With 50% TNC Price-Cut & 10 min. Travel Time Increase		
Share Using TNC With Carpooling Changes (%)	16.80	19.99
Change Relative to Initial TNC Share (%)	-0.2	1.2

The first scenario (10% increase in TNC fares) can be expected to lower the demand for TNCs to about 16.4% for business passengers and 19.2% for leisure passengers or, respectively, 2.5% and 2.7 % decreases relative to the initial TNC shares. It seems that increasing TNCs cost by 10% does not affect demand very much.

The second event (increase in TNC fares to match taxi fares) is also expected to lower the demand for TNCs but by a much greater degree. In this scenario, prices had to be almost doubled (about 80% increase). The projected demands for TNC services of business and leisure passengers, respectively, were 13.9% and 16.0%. These represent a 20.9% drop with respect to the initial TNC share for business passengers and a 23.3% drop with respect to the initial TNC shares for leisure passengers.

Since the drop in demand is smaller for business passengers in the first two cases, it seems that business passengers are less responsive to modal price hikes. As found in other studies of business travel, people traveling on business are far less sensitive to price changes than those traveling for pleasure or personal reasons, most likely because their time is considered to be more valuable, and also that they might not be personally liable for the cost of their travel.

Finally, the third simulated change (50% fare cut plus 10-minute travel time increase, which represents the difference that would be imposed by pooled TNC services) is projected to decrease the demand for TNCs by business passengers by about 0.2% (relative to initial share), while increasing the demand for TNCs by leisure passengers by about 1.2% (relative to initial share). Essentially, we consider these values insignificant.

CONCLUSION

Using Google Maps and various other data sources, we estimated travel time and trip cost by each mode for ground travelers to LAX relative to their pickup location. Our estimated travel costs reflect each travel party's travel duration (number of days) as well as party size.

We found that in the absence of TNC services as a modal alternative, many air travel passengers heading to LAX would face stark tradeoffs between long travel times and high travel costs. They could choose a mode like shared vans/shuttles that do not cost a lot, but are characterized by multiple pickups and drop-offs generating long travel times. Alternatively, they can choose a mode like taxi, which costs considerably more but is private and direct. Meanwhile, few passengers to LAX take

public transit because those modes have even longer travel times than shared vans/shuttles and, unlike many major US cities, there is no direct rail service to LAX.

Multinomial logit and nested logit models of airport ground transportation decisions were estimated to help understand the drivers of current market shares of TNCs in this large market. Our measured travel time and trip cost by each mode were used as inputs. We also used our specifications to simulate demand for TNCs under policy events like regulated fare increases or decreases combined with a small modal travel time increase.

Likelihood ratio tests rejected the simple multinomial logit structure of demand estimation in this ground transportation market. Our preferred specification is nested logit. Statistical tests also provide some insights on how the alternatives should be grouped for this market, i.e., grouping all modes that require driving, grouping all modes that are transit and non-door-to-door, while we find that remaining modes seem to be dissimilar to each other. Finally, testing suggested a need to estimate separate models for airport destined passengers traveling with different purposes (business and leisure). After considering the simulation scenarios (increasing the cost of TNC rides by 10%, increasing the cost of TNC rides to match the cost of taxis, or cutting TNC fares for a 10-minute travel time increase), we find that these policy shocks would have differential effects on passengers traveling for business or for leisure. By way of example, in our second simulated scenario (a TNC fare increase to match the cost of taxis), the expected drop in demand for TNC (relative to the initial demand for TNC services) was estimated to be about 21% for business passengers and about 23% for leisure passengers. With respect to ground transportation at LAX, business passengers appear to be slightly more sensitive to travel time while leisure passengers are more sensitive to travel costs.

Future research will focus on improving airport ground access mode choice models by making them more robust. In addition, we plan to apply the methodology to explore the impacts of other relevant scenarios, such as an increase in the cost of airport parking.

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Endnotes

1. TNCs fares on average are much lower than taxis. It may be because they offer lots of promotions to passengers when they first operate in a city, or they can charge lower fares since they have lower operating costs, because they do not have fingerprint-based FBI background checks for their drivers (Farren 2017). With time and stricter regulations, we expect TNC fares to be more in line with that of taxis in the future.
2. These are one-way access trips to the airport. We assume that the access trip is independent of the egress trip, even though in some cases they are not independent. For example, some people drive to the airport because they want to have their car to drive home when they return from their air travel (egress trips).
3. The average vehicles per household in the city of Los Angeles is about 1.5 and this number increases with higher income (Governing the States and Localities [2015]).
4. The cost of the rental is higher than if the vehicle was returned at the same location where it was picked up. The estimate is based on rates by enterprise.

5. TNC services like Uber Pool or Lyft lines may have more than one party, but the maximum number of separate travel parties and stops is two.
6. Each observation in the passenger survey had different travel durations (number of days) and party size. Our adjustments for total travel time and costs were done in a standard way; for example, we multiplied the number of passengers in the travel party by the cost of individual bus fares to get the total bus fares.
7. Biogeme, developed by Michel Bierlaire at the Ecole Polytechnique Fédérale de Lausanne, Switzerland, is an open source freeware designed for the maximum likelihood estimation of parametric models in general, with a special emphasis on discrete choice models.
8. The two models are nested in a sense that all terms of a smaller model (nested logit with seven nests) occur in a larger model (nested logit with three nests). This is a necessary condition for using most model comparison tests like likelihood ratio tests.
9. The closer this value is to 0 means that alternatives in the nest are very similar and probably belong in a group; however, it is not significant.

References

Akar, G. "Ground Access to Airports, Case Study: Port Columbus International Airport." *Journal of Air Transport Management* 30, (2013): 25-31.

Alhussein, S.N. "Analysis of Ground Access Modes Choice King Khaled International Airport. Riyadh, Saudi Arabia." *Journal of Transport Geography* 19, (2011): 1361-1367.

Ben-Akiva, M. and S.R. Lerman, *Discrete Choice Analysis: Theory and Application to Travel Demand*, MIT Press, Cambridge, Mass., (1987).

Bierlaire, M., BIOGEME: A Free Package for the Estimation of Discrete Choice Models, Proceedings of the 3rd Swiss Transport Research Conference, Monte Verita, Ascona, Switzerland, (2003).

Cirrito, C. and R. Xu, "Forecasting Cybercar Use for Airport Ground Access: Case Study at Baltimore Washington International Airport." *Journal of Urban Planning Development*, (2010): 186-194.

City of Los Angeles Taxi Services <http://taxicabsla.org/> Accessed January 16, 2015.

Ellis, R.H., J.C. Bennett, and P.R. Rassam, "Approaches for Improving Airport Access." *Transportation Engineering Journal* 100, (No. TE3), (1974): 661-673.

Enterprise. <https://www.enterprise.com/en/home.html> Accessed November 26, 2017.

Farren, M. "Ridesharing Offers Reason to Rethink Taxi Regulations." *Inside Resources*. August 17, 2017. Accessed November 26, 2017.

Goldman J. and M. Liu, *Ride-Sharing in Los Angeles*. October 9, 2014. <http://blog.whatsthefare.com/2014/10/ride-sharing-in-los-angeles.html> Accessed March 5, 2015.

Ge, Y., C. Knittel, D. MacKenzie, and S. Zoepf, "Racial and Gender Discrimination in Transportation Network Companies." *NBER Working Paper* No. 22776, (2016).

Google. Google Maps Directions APIs. <https://developers.google.com/maps/documentation/directions/> Accessed May 13, 2015.

Governing the States and Localities. Car Ownership in U.S. Cities Map. <http://www.governing.com/gov-data/car-ownership-numbers-of-vehicles-by-city-map.html> Accessed January 16, 2015.

Gupta, S., P. Vovsha, and R. Donnelly, "Air Passenger Preferences for Choice of Airport and Ground Access Mode in the New York City Metropolitan Region." *Transportation Research Record* 2042, (2008), 3:11.

Kato, H. and K. Kosuda, "Choice Set Generation with Elimination-by-Aspects: A Case Study of Urban Rail-Use Commuters Travel Demand Analysis in the Tokyo Metropolitan Area." (2008).

Landau, S., G. Weisbrod, G. Gosling, C. Williges, M. Pumphrey, and M. Fowler, "Value of Time, Benefit-Cost Analysis and Airport Capital Investment Decisions. Volume 3." *The National Academies Press*, (2015): Table B-26. pp. B-96.

LAX Limousine Service. <https://ride2lax.com/> Accessed March 10, 2015.

Leake, G.R and J.R. Underwood. "An Inter-City Terminal Access Modal Choice Model." *Transportation Planning and Technology* 4(1), (1977): 11-21.

Los Angeles International Airport 2015 Passenger Survey. Los Angeles World Airports

Manzano, J. "The City-Airport Connection in the Low-Cost Carrier Era: Implications for Urban Transport Planning." *Journal of Air Transport Management* 16, (2010): 295-298.

Masoud, N. "Multi-Hop Peer-to-Peer Ridesharing." Dissertation (Ph.D). University of California, Irvine, 2016.

Pels, E., P. Nijkamp, and P. Rietveld, "Access to and Competition Between Airports: A Case Study for the San Francisco Bay Area." *Transportation Research Part A: Policy and Practice* 37, (2003): 71-83.

Primetime Shuttle <http://primetimeshuttle.hudsonltd.net/res> Accessed March 10, 2015.

Psaraki, V. and C. Abacoumkin, "Access Mode Choice for Relocated Airports: The New Athens International Airport." *Journal of Air Transport Management* 8, 89e98, (2002).

Rayle, L., S. Shaheen, N.D. Chan, D. Dai, and R. Cervero, "App-Based, On-Demand Ride Services: Comparing Taxi and Ridesourcing Trips and User Characteristics in San Francisco." *University of California Transportation Center UCTC-FR*, (2014).

ShuttletoLAX <http://shuttletoLAX.com/> Accessed January 17, 2015.

Smart, R., B. Rowe, A. Hawken, M. Kleiman, N. Mladenovic, P. Gehred, and C. Manning, "Faster and Cheaper: How Ride-Sourcing Fills a Gap in Low-Income Los Angeles Neighborhoods." *BOTEC Analysis Corporation*, (2015).

SuperShuttle <http://www.supershuttle.com/> Accessed January 25, 2015.

Swegles, F. "San Clemente Partners with Lyft to Fill Gaps After 2 OCTA Bus Routes End." *The OC Register*. October 5, 2016. Accessed on November 26, 2017.

Tam, M., W. Lam, and H. Lo, "The Impact of Travel Time Reliability and Perceived Service Quality on Airport Ground Access Mode Choice." *Journal of Choice Modeling* 4(2), (2011): 49-69.

Emerging Ground Transportation Modes

Tsamboulas, D.A. and A. Nikoleris, "Passengers' Willingness to Pay for Airport Ground Access Time Savings." *Transportation Research Part A: Policy and Practice* 42, (2008): 1274-1282.

Tversky, A. "Elimination by Aspects: A Theory of Choice." *Psychological Review* 79 (4), (1972): 281-299.

Uber <https://www.uber.com/cities/los-angeles/> Accessed April 2, 2015.

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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 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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Special Notice from TRF and the Editors of JTRF

The Journal of the Transportation Research Forum traces its origins back to 1961. From 1961 to 1986, JTRF contained the proceedings of the annual meetings of the American and Canadian sections of TRF.

JTRF became a refereed journal in its present form in 1987. With the exception of the volumes published from 2000 to 2003 when it was co-published with the Eno Foundation's Transportation Quarterly, JTRF has been produced, published and distributed by the Transportation Research Forum.

TRF and the journal editors are pleased to announce two initiatives that will continue to improve the visibility and reach of both JTRF and TRF.

To start, the complete set of JTRF archives are available online. Digitized editions of JTRF from 1987 through to 2003 have been archived by the HathiTrust Digital Library, available at: <https://www.hathitrust.org/>. Further, the web-based JTRF volumes (from 2004 through to 2017) are permanently housed at Oregon State University: <http://journals.library.oregonstate.edu/index.php/trforum/issue/archive>.

Second, this is the final volume of JTRF to be published and distributed by TRF. As of January 2018, we are pleased to announce that JTRF will occupy its own complete volume within the Research in Transportation Economics (RETREC) journal series published by Elsevier: <https://www.journals.elsevier.com/research-in-transportation-economics/>. The JTRF volume within Research in Transportation Economics will continue to carry the JTRF title as well as continue with JTRF volume numbering (beginning with volume 57 in 2018).

Potential JTRF authors will be given access to Elsevier's submission software, and will also benefit from the expanded reach and well documented impact factors of Elsevier's transportation journal products. However the editorship of JTRF, along with JTRF's traditional scope and research goals, will not change. We look forward to many more years building on the legacy of JTRF's commitment to superior transportation scholarship and research, as well as the dissemination of that research.

Journal of the Transportation Research Forum

Guidelines for Manuscript Submission

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Submissions in Process as of January 2018

The review process will be handled by the editors outside of the Elsevier submission software. Accepted papers will need to be formatted according to Elsevier's standard prior to publication.

New Submissions from January 2018

New JTRF submissions will need to be made through the *Research in Transportation Economics* website. Upon submission, authors will be asked to identify that their submission is for consideration by JTRF.

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