MICHIGAN OHIO UNIVERSITY TRANSPORTATION CENTER

Alternate energy and system mobility to stimulate economic development.

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DEVELOPING TranslinkeD CORRIDOR INVESTMENT STRATEGIES and ASSESSING their SOCIO-ECONOMIC IMPACTS on the DETROIT METROPOLITAN AREA and the NORTHWEST OHIO REGIONAL COMMUNITY

FINAL REPORT

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DISCLAIMERS

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ABSTRACT

Due to mounting fiscal pressures over the last few years, the federal government as well as many state and municipal governments in the United States (U.S.) have had to re-examine their transportation policies and projects such as the TranslinkeD program in the Detroit metropolitan area which seeks to "link" new economic growth with infrastructure, logistics, and distribution development. Tax increases and/or spending cuts which aim to trim budget deficits are currently major preoccupations of most policy makers and legislative bodies. With regard to the task of building new or rehabilitating bridges, highways, and toll gates, cost-benefit analysis and economic impact studies are often undertaken by various government entities to rank and prioritize spending in the hopes of maximizing fiscal efficiency and road usage benefits. Since much of highway construction and maintenance expenditures is absorbed by state governments, it is mostly up to state policy makers to decide transportation priorities. However, no research to date has been conducted to evaluate the comparative efficiency of state road provisions to commuters and shippers which often affect the state government's budgetary allocation and spending plans. This report is one of the first to assess and rank the comparative efficiency of all 50 states in the U.S. by using data envelopment analysis and then explain variations in efficiency ratings by using Tobit regression analysis.

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1. Introduction

The transit time it takes people to commute to work or for businesses to ship goods have very important economic ramifications due to their influence on the workers' quality of life and customer responsiveness. Both commuting and shipping times also have important public policy implications, because they can dictate what motor vehicle owners and shippers should pay in taxes and fees each year for road/highway/bridge construction, maintenance, debt service, and so forth. That is to say, local business competitiveness may rest heavily on commuting and shipping times that are affected by the basic transportation infrastructure such as roads, highways, and bridges (roads for short hereafter). Nevertheless, the United States (U.S.) investment in preservation and development of basic transportation infrastructure lags so far behind that of China, Russia and European countries that it will lead to a steady erosion of the social and economic foundations for American prosperity in the long run (Halsey III, 2010). To make matters worse, the ongoing worldwide economic crisis coupled with severe government budget shortfalls continue to limit the U.S. government's effort to increase its spending on infrastructure development and maintenance. In order to align public transportation policy with economic goals, federal, state, and municipal governments in the U.S. have actively sought ways to generate more revenue streams by increasing toll fees, gasoline/property taxes, mass transit fares, and road-congestion prices. However, these revenue generating ideas may backfire since they can further increase the financial burdens of cash strapped citizens and businesses.

There is a growing concern over road provision especially when the government spends its budget excessively on certain construction projects or wastes its resources on low priority (i.e., "pork barrel") projects. To ease this concern, public policy makers (especially state and municipal government authorities) should justify their actions on road provision for their constituents and businesses, since road provision is primarily financed locally with some projects partially funded with federal government aid, although the road projects receiving federal funding are usually locally identified and prioritized (U.S. Department of Transportation 2011). As state and municipal governments face financial problems that continue to persist after the conclusion of the latest economic recession, the efficiency and effectiveness of all governmental programs including road provision have come under closer scrutiny. If commuters and shippers are facing more delays in their travels and suffering from higher transportation costs despite rising road spending, there is a need for a systematic study which can examine and then evaluate road provision policies (Texas Transportation Institute, 2011). In response to such a need, this paper aims to examine ways the state governments in the U.S. provide transportation infrastructure through road provision and help policy makers develop transparent/wise road provision strategies and improve long-term road investment plans. In addition, this paper identifies factors that may significantly influence road provision and infrastructure investment decisions.

2. Relevant Literature

Since approximately 70 percent of road provision decisions regarding highway construction and maintenance spending are made by state governments, it is primarily up to state policy makers to decide transportation budget priorities (U.S. Department of Transportation, 2010). Despite the significance of road provision to state fiscal plans and regional economic development, no research to date has been conducted to compare the 50 states with respect to their efficiency in providing road services to commuters and shippers. Though not directly related to state road provision issues, Deller and Nelson (1991) assessed the economic efficiency of a sample of Midwest (Illinois, Minnesota, Wisconsin) Township governments in providing low-volume, rural road services. Their empirical test revealed that the local government's separate, small scale operations were less efficient and more costly than the multiple local governments' consolidated but larger scale operations due to economies of scale. This finding implies that road provision decisions have to be made at the state government level as opposed to the local township level. Extending the concept that the efficient allocation of financial resources by the government could affect the quality of road services, Min and Lambert (2006) attempted to compare a group of states on their abilities to raise and spend tax dollars with regard to their road provision. Although their study is one of the first to measure the comparative efficiency of state governments' highway expenditures and road finances relative to their peers and previous years of performances using data envelopment analysis (DEA), it is still confined to the comparison of only 11 states. Its other shortcoming is the failure to identify exactly what environmental factors might have caused the inefficiency. Later, De la Garza, Triantis, and Fallah-Fini (2009) attempted to measure the relative efficiency of highway maintenance operations undertaken by the state department of transportation and its private contractors. Their study also tried to assess the effects of environmental variables such as climate, geographic conditions, pavement conditions, and privatization on road maintenance efficiency. This study, however, is limited to the comparison of local highways within 200-250 miles of Virginia's interstate highways. In other words, this study neither provided any cross-state comparison, nor discussed any state road provision implications of highway maintenance. To overcome the aforementioned shortcomings of prior studies on road provision, this paper measures the comparative efficiencies of all 50 states in the U.S. using DEA and then uncovers the main sources of relative efficiency or inefficiency of state road provision using a series of Tobit regression analyses.

3. Research Methodology

To gauge the efficiency of many different organizations and institutions, data envelopment analysis (DEA) has been employed. DEA is a special application of linear programming based on the frontier methodology of Farrell (1957). In general, DEA is a nonparametric modeling or estimation method that uses a linear programming technique to construct a production possibility frontier based on common inputs and common outputs used by similar "decision making units (DMUs)".

Herein, DMUs refer to the collection of private firms, non-profit organizations, departments, administrative units, and groups with the same (or similar) goals, functions, standards and market segments. The frontier represents the optimal amounts of output given various combinations of inputs, and DMUs are ranked relative to one another according to how close they come to reaching an optimal level of output on the frontier with a score of 1.0 representing efficiency, which means a DMU has matched an optimal point on the frontier (Cook and Zhu, 2005). As such, unlike the Cobb-Douglas production function, DEA does not develop an absolute performance standard. Instead, it establishes a "relative" benchmark standard that no other competing DMUs can outperform. Also, DEA production techniques can have either constant returns to scale (CRS) or variable returns to scale (VRS), while the analysis of DMUs can be approached from either an input minimization or output maximization orientation as one is a dual of another. DEA can be employed for measuring the comparative efficiency of any entities including banks (Casu and Molyneux, 2003), hospitals (Ferrier and Valdmanis, 2004; Anderson et al., 2008), municipal services (Moore, Nolan and Segal, 2005), transit agencies (Nolan, Ritchie, and Rowcroft, 2001), trucking firms (Min and Joo, 2006), third party logistics (3PL) providers (Min and Joo, 2006), hotels (Min et al., 2008), national economies (Leibenstein and Maital, 1992; Lovell, Pastor, and Turner, 1995; Margaritis, Fare, and Grosskopf, 2007; Afonso, Schuknect and Tanzi, 2010), paratransit systems (Min and Lambert, 2011) and many other different types of DMUs. The general DEA model can be mathematically expressed as (Charnes, et al., 1978; Fare et al., 1994; Nolan et al., 2001):

$$\text{Maximize Efficiency score } (jp) = \frac{\sum_{r=1}^{t} u_r y_{rjp}}{\sum_{i=1}^{m} v_i x_{ijp}} \quad (1)$$

$$\text{Subject to} \quad \frac{\sum_{r=1}^{t} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \le 1, \quad \text{j} = 1, \ldots, n, \quad (2)$$

$$u_r, v_i \ge \varepsilon, \qquad \forall r \text{ and } i, \quad (3)$$

where

y_{rj} = amount of output r produced by DMU j,

x_{ij} = amount of input i used by DMU j,

u_r = the weight given to output r,

v_i = the weight given to input i,

n = the number of DMUs,

t = the number of outputs,

m = the number of inputs,

ε = a small positive number.

The fractional, non-linear programming model described above can be converted to a linear programming (LP) model without much difficulty. A major assumption of LP is a linear relationship among variables. Therefore, an ordinary LP for solving DEA often utilizes a constant returns-to-scale so that all observed production combinations can be scaled up or down proportionally (Charnes et al. 1978). On the other hand, by using a piecewise LP, DEA can consider a non-proportional returns-to-scale including increasing or decreasing returns-to-scale (Banker et al. 1984). The aforementioned DEA model was utilized to compare the relative efficiency of providing road services to commuters, mass transit riders, and trucking shipper based on the following input and output secondary data (US Department of Transportation, FHWA, OHPI 2007, 2008, and 2009):

1. Average of Total Tax Receipts for Highways in thousands, 2007 to 2009. Since state tax revenue was invested for highway maintenance and construction, this data is categorized as an input in the delivery of road services to commuters and transit riders.

2. Average of Total Disbursements for Highways, Operating and Capital Expenditures, in thousands, 2007-2009. This represents a major source of road provision, and is also regarded as an input to the delivery of road services to commuters and transit riders.

3. Average of Total Tax Receipts and Disbursements for Mass Transit, in thousands, 2007 to 2009. Revenues and disbursements for each state matched for mass transit for each year, so just one input is used here. Some states did not raise taxes or spend any financial resources on mass transit. This is used as an input for the delivery of mass transit services.

4. Total Urban Lane Miles, 2009. Urban lane miles are used as an input since these are used by most commuters and transit riders and because most trucking bottlenecks and delays are in urban areas (US Department of Transportation, FHWA 2011b).

5. Average of Construction Cost Index, 1997-2005 (1987 base year prices). This index measures how much costs have increased from one year to the next for each state for road maintenance and construction projects that have received federal highway funding. Some states have seen more rapid and higher increases in costs than others. (US Department of Transportation, FHWA 2011b). Thus, this index affects the efficiency of road provision and is treated as an input.

For DEA outputs, the following data are used:

1. Average Time to Work in minutes for those not working at home and using Car, Truck or Van, 2007-2009 (US Census Bureau, American Community Survey, 2007-2009). Since commuting time reflects the efficiency of road provision, this data is regarded as the output.

2. Average Time to Work in minutes for those not working at home using Mass Transit, 2007-2009 (US Census Bureau, American Community Survey, 2007-2009). Taking into account those who commute to work using the mass transit system, this data is also viewed as the output.

3. Average Score on Estimated Trucking Congestion (1=weak, 2=moderate, 3=strong). Since most choke points are in the urban metropolitan areas, the average score on estimated trucking congestion is calculated primarily based on the extent of traffic jams and bottlenecks in the selected urban metropolitan areas representing the state (e.g., Detroit in the state of Michigan; Chicago in the state of Illinois; Indianapolis in the state of Indiana). Given that no statewide estimates of traffic congestion exist, we used maps showing chronic bottlenecks in the urban metropolitan areas throughout the U.S. as the surrogate traffic congestion measure of each state (US Department of Transportation, FHWA, 2011c). Those states which had metro areas that had severe bottlenecks (often more than an hour of delays) received a score of 3, whereas those that showed no metro areas displaying bottlenecks received a score of 1. Those that displayed moderate traffic delays scored a 2.

Since DEA constructs a production frontier based on output maximization, the reciprocals of the above three output variables are used to make the longer commuting or shipping times smaller. The descriptive statistics for the preceding input and output variables are summarized in Table 1, and the scores of the constant returns to scale (CRS) and variable returns to scale (VRS) generated by DEA for each form of travel are displayed in Tables 2, 3 and 4. CRS efficiency assumes that there is a constant or fixed increase in output for each equivalent increase in inputs. For instance, under this scale, a 10% increase in inputs should yield a 10% increase in output. VRS efficiency is slightly different from CRS efficiency in that it assumes that any increases in output due to increases in inputs are variable. For example, under this scale, a 10% increase in inputs can yield a 5%, 10%, or 20% increase in output. VRS efficiency is perhaps a more realistic assumption for many production settings, especially those involving large economies of scale, although assuming CRS efficiency as a typical form of production is often thought to be a more cautious assumption because CRS efficiency scores are usually lower than those of VRS efficiency, so CRS scoring uses a stricter measure of efficiency and gives out fewer high scores than VRS scoring.

In examining the CRS and VRS efficiency score averages, all the states tend to have higher average scores for efficiency with regard to commuting to work by car, truck or van as compared to computing time via mass transit.

This result is not unexpected given that average travel times via mass transit tend to be much higher than commuting by motor vehicle, since the mass transit system is not a door-to-door transportation means.

With regard to the scores themselves, Alaska, Hawaii, Mississippi, Nebraska, North Dakota, Rhode Island and Vermont are states that score 1.0 either under CRS or VRS efficiency for at least one of the three forms of transportation. Thus, we can conclude that more sparsely populated states tend to have higher average efficiency scores than the more densely populated ones such as New York or California due to a limited number of roads to maintain and less traffic congestion.

Table 1—Descriptive Statistics

Variable	Mean	St. Dev.
CRS Efficiency Commuters	0.5533	0.2189
VRS Efficiency Commuters	0.6197	0.2412
CRS Efficiency Mass Transit	0.2343	0.2562
VRS Efficiency Mass Transit	0.2935	0.2892
CRS Efficiency Truck Shipping	0.3802	0.2887
VRS Efficiency Truck Shipping	0.5649	0.215
Climate	0.6	0.4949
Percent Population Urban 2009	69.62	14.2
Median Household Income, 2007-2009	$51,124	8476
Land Area of State in Square Miles	70748	85987

Inputs for DEA, Commute to Work, Mass Transit, and Truck Shipping Efficiency:

Variable	Mean	St. Dev.
Avg. Total Receipts , 2007-2009, thousands	$2,738,668	2,927,361
Avg. Total Disbursements, 2007-2009, thousands	$2,565,914	2,717,528
Total Urban Lane Miles, 2009	169,609	114,036
Avg. Receipts and Disbursements, Mass Transit, 2007-2009, thousands	$77,097.3	195,119.5
Average of Construction Cost Index, 1997-2005	146.25	40.3

Outputs for DEA, Commute to Work, Mass Transit, and Truck Shipping Efficiency

	Mean	St. Dev.
Avg. Time to Work in Minutes for those not working at Home 2007-2009	23.35	3.5
Avg. Time to Work in Minutes Using Mass Transit, 2007-2009	42.473	6.805577
Avg. Score on Trucking Congestion (1=weak, 2=moderate, 3=strong)	2.06	0.89

Table 2—DEA Scores for Commuting to Work Using Truck, Van or Car

DMU Name	*VRS Efficiency*	*CRS Efficiency*
Alabama	0.50832	0.48656
Alaska	1.00000	0.92854
Arizona	0.51848	0.50251
Arkansas	0.61220	0.59543
California	0.25001	0.23529
Colorado	0.41930	0.38930
Connecticut	0.80800	0.73456
Delaware	1.00000	0.78872
Florida	0.42877	0.40062
Georgia	0.37740	0.35346
Hawaii	1.00000	1.00000
Idaho	0.76206	0.65208
Illinois	0.26889	0.23522
Indiana	0.38183	0.33897
Iowa	0.48411	0.46678
Kansas	0.95979	0.66931
Kentucky	0.59618	0.55423
Louisiana	0.43668	0.42955
Maine	0.58534	0.50216
Maryland	0.62055	0.57805
Massachusetts	0.55996	0.41107
Michigan	0.43672	0.41262
Minnesota	0.35581	0.33676
Mississippi	1.00000	0.91509
Missouri	0.31520	0.30766
Montana	0.59975	0.54022
Nebraska	1.00000	0.57870
Nevada	0.94474	0.67198
New Jersey	0.57096	0.48688
New Mexico	0.71818	0.56637
New York	0.62577	0.43657
North Carolina	0.36004	0.34253
North Dakota	0.77461	0.69913
Ohio	0.33518	0.28790
Oklahoma	0.56332	0.54317
Oregon	0.60219	0.51922
Pennsylvania	0.37161	0.29353
Rhode Island	1.00000	1.00000
South Carolina	0.75040	0.74176

South Dakota	0.99198	0.90666
Tennessee	0.41820	0.38882
Texas	0.29599	0.26959
Utah	0.65876	0.60607
Vermont	1.00000	1.00000
Virginia	0.49068	0.42801
Washington	0.30998	0.26688
West Virginia	1.00000	1.00000
Wisconsin	0.52237	0.49472
Wyoming	0.73566	0.71383

Table 3—DEA Scores for Commuting to Work Using Mass Transit

DMU Name	***VRS Efficiency***	***CRS Efficiency***
Alabama	0.23172	0.22194
Alaska	1.00000	1.00000
Arizona	0.11251	0.10022
Arkansas	0.13430	0.10309
California	0.02463	0.02326
Colorado	0.06406	0.06264
Connecticut	0.20906	0.16684
Delaware	0.80551	0.71537
Florida	0.11407	0.08294
Georgia	0.12056	0.07973
Hawaii	1.00000	1.00000
Idaho	0.29608	0.19788
Illinois	0.10041	0.06942
Indiana	0.23611	0.20472
Iowa	0.38603	0.12517
Kansas	0.10744	0.10106
Kentucky	0.16065	0.07338
Louisiana	0.19211	0.16156
Maine	1.00000	1.00000
Maryland	0.16563	0.13489
Massachusetts	0.14045	0.13673
Michigan	0.04418	0.03825
Minnesota	0.07878	0.04030
Mississippi	0.13934	0.12030
Missouri	0.17431	0.15662
Montana	0.16381	0.14690

Nebraska	0.16289	0.15867
Nevada	0.65554	0.48895
New Hampshire	0.55115	0.40419
New Jersey	0.11299	0.08974
New Mexico	0.09048	0.07018
New York	0.08693	0.06482
North Carolina	0.21110	0.20361
North Dakota	1.00000	0.23373
Ohio	0.11653	0.09568
Oklahoma	0.10293	0.10130
Oregon	0.23392	0.19427
Pennsylvania	0.03752	0.03633
Rhode Island	0.70436	0.63493
South Carolina	0.13509	0.12547
South Dakota	0.37428	0.15049
Tennessee	0.08615	0.06611
Texas	0.02746	0.02313
Utah	0.49780	0.45667
Vermont	0.79343	0.70795
Virginia	0.29201	0.23817
Washington	0.15261	0.11836
West Virginia	0.27254	0.24461
Wisconsin	0.11202	0.10550
Wyoming	0.66193	0.43778

Table 4—DEA Scores for Truck Shipping Efficiency

DMU Name	*VRS Efficiency*	*CRS Efficiency*
Alabama	0.50832	0.16944
Alaska	0.78004	0.78004
Arizona	0.51849	0.25924
Arkansas	0.57994	0.28997
California	0.25001	0.08334
Colorado	0.41930	0.13977
Connecticut	0.80797	0.26932
Delaware	0.71390	0.23957
Florida	0.42878	0.14293
Georgia	0.37740	0.12580
Hawaii	1.00000	1.00000
Idaho	0.76206	0.76206
Illinois	0.26889	0.08963
Indiana	0.38183	0.19092

Iowa	0.48410	0.48410
Kansas	0.55871	0.55871
Kentucky	0.52985	0.26492
Louisiana	0.42656	0.14219
Maine	0.58715	0.58715
Maryland	0.62053	0.20684
Massachusetts	0.55995	0.18665
Michigan	0.43674	0.14558
Minnesota	0.35581	0.11860
Mississippi	0.84541	0.84541
Missouri	0.31520	0.10507
Montana	0.59973	0.59973
Nebraska	0.47433	0.47433
Nevada	0.55599	0.55599
New Hampshire	0.70367	0.70367
New Jersey	0.57095	0.19032
New Mexico	0.71816	0.71816
New York	0.38184	0.12728
North Carolina	0.36004	0.18002
North Dakota	0.77461	0.77461
Ohio	0.27311	0.09104
Oklahoma	0.53090	0.26545
Oregon	0.48158	0.24079
Pennsylvania	0.26787	0.08929
Rhode Island	1.00000	0.38612
South Carolina	0.73397	0.36698
South Dakota	0.99195	0.99195
Tennessee	0.41819	0.13940
Texas	0.25997	0.08666
Utah	0.65877	0.32938
Vermont	1.00000	1.00000
Virginia	0.40610	0.20305
Washington	0.30997	0.30997
West Virginia	1.00000	1.00000
Wisconsin	0.52236	0.26118
Wyoming	0.73566	0.73566

To further identify the main sources of efficiency or inefficiency of road provision, we paired these DEA scores against a set of independent variables using a special form of regression analysis called Tobit regression. In general, Tobit regression is intended for analyzing continuous data that are censored, or bounded at a limiting value.

The Tobit regression model is well suited to measure the transformed efficiency such as DEA efficiency scores, when dependent variables have sensible partial effects over a wide range of independent variables (see, e.g., Amemiya, 1985; Breen 1996; Wooldridge, 2006 for details of Tobit regression). A Tobit regression model assumes that the dependent variable has its value clustered at a limiting value, usually zero. But, in the DEA model that was proposed in this paper, the dependent variable is right censored at 1.0 and the model can be written in terms of the underlying or the latent variable that is mathematically expressed as:

$$y_i^* = X_i \beta + \varepsilon_i$$

and $\varepsilon_i \sim N(0,\sigma^2)$. In our sample, we observe y (=y*) only when $y_i^* < c$ (right censored). The values of Y are censored to the right at 1, and thus we need to estimate

$$E(y_i \mid y_i < c, x_i) = E(y_i \mid \varepsilon_i \le c - x_i \beta_i)$$

The probability that $\varepsilon_i \le c$ is

$$\Phi\left[\frac{c}{\sigma}\right] = \int_{-\infty}^{c/\sigma} \frac{1}{\sqrt{2\pi}} \exp(-t^2/2)dt$$

The expected value is

$$E(y_i \mid y_i < c, x_i) = x_i^{'}\beta - \sigma \frac{\phi(c)}{\Phi(c)}$$

$$= x_i^{'}\beta - \sigma\hat{\lambda}_i(c), \text{ where } c = \frac{c - x_i^{'}\beta}{\sigma}$$

It should be noted that the Tobit model accounts for truncation. A regression of the observed '*y*' values on '*x*' will lead to an unbiased estimate of β (or the independent variables). While the Tobit regression analysis does not yield a measure of variation in the dependent variable as opposed to the coefficient of determination (r-squared) in ordinary least squares regression, but it does yield a log-likelihood statistic that indicates the explanatory power of the model employed, and the larger the absolute value of the log-likelihood statistic, the greater the explanatory power of a model.

The following variables were used as independent variables to predict the DEA efficiency scores for each form of travel for each state:

1. Climate. Since extreme temperatures and/or the extent of precipitation can lead to sub-optimal road provision, the state's climate is regarded as an explanatory or environmental variable (Ladd, 1992; Garcia-Sanchez, 2006). For example, the greater the precipitation, the slower the traffic movement

(i.e., greater commuting or shipping time). The US National Oceanic and Atmospheric Administration provided data for average temperatures, precipitation, and other weather conditions within the US at the city level but not at the state level (NOAA 2011). Because weather can vary so much within some states, an attempt to provide such data would be very problematic, yet some attempt to account for weather variation must be made since weather (particularly temperature and precipitation) is such an important factor in road construction and rehabilitation costs/expenditures. This paper used a dummy variable where northern states (northeastern, mid-western, north central and northwestern states including Alaska) were coded with a "1" and southern states (southeastern, south central, and southwestern states including California and Hawaii) were coded with a "0". This dichotomy was based mostly upon differences in precipitation and temperature, where southern states usually have warmer year round temperatures and in some cases less precipitation. This dichotomy is not perfect, but is the best that can be done with the absence of other data. The hypothesis is that warmer states should have lower DEA scores because of higher maintenance costs due to warmer weather.

2. Average of State Median Household Income, 2007-2009 (US Census Bureau, American Community Survey, 2007-2009). This is used as a proxy for a state's ability to raise the tax revenues necessary to carry out road construction and maintenance projects. In other words, we made a premise that higher income states, *ceteris paribus,* can afford to invest more in their road infrastructure because they have the better tax bases and the larger financial resources (Lambert and Meyer, 2008). The state resident's income level is also highly correlated with the State Growth Domestic Product (GDP), another measure of state tax capacity. The rationale being that greater financial capacity would lead to higher efficiency scores since wealthier state residents can afford to pay more for roads.

3. Urban Population as a Percentage of the State's Population, 2009 (US Census Bureau, American Community Survey, 2007-2009). Since most of a state's labor forces live and work in metro areas and most trucking bottlenecks occur in metro areas according to the FHWA (US Department of Transportation, 2011c), the urban composition of a state is essential for gauging the state's road provision efficiency. The rationale being that greater urbanization is associated with greater traffic congestion, which would lead to lower DEA efficiency scores.

4. Land Area of each state in square miles (US Census Bureau). Obviously, the larger the land mass of the state, the more it has to spend on roads, so this variable is used as a control variable that can account for road expenditures. Also, it is noted that the sheer size of the state may help to create economies of scale that can influence road provision efficiency.

Tables 5 to 7 show the results of the Tobit regression analysis used to assess the DEA scores for the three types of travel using roadways.

Table 5—Commuter Travel Efficiency Car, Truck or Van

Response Variable: CRS Efficiency Scores for Commuting by Car, Truck or Van

Regression Table

Predictor	Coefficient	SE	Z	P-value
Intercept	-0.52471	0.328533	-1.6	0.11
Climate	-0.09467	0.12403	-0.76	0.445
Median Household Income, 2007-2009	2.31E-05	1.01E-05	2.3	0.021
Percent Pop Urban 2009	-0.01474	0.005324	-2.77	0.006
Land Area of State in Sq. Miles	-6E-07	5E-07	-1.19	0.234

Log-Likelihood = 2.459

Response Variable: VRS Efficiency Scores for Commuting to Work by Car, Truck or Van

Regression Table

Predictor	Coefficient	SE	Z	P-value
Intercept	-0.34088	0.378276	-0.9	0.368
Climate	0.000559	0.136821	0	0.997
Median Household Income, 2007-2009	1.85E-05	1.13E-05	1.63	0.103
Percent Pop Urban 2009	-0.01319	0.006326	-2.08	0.037
Land Area of State in Sq. Miles	-1E-07	7E-07	-0.13	0.897

Log-Likelihood = -10.064

Table 6—Commuter Travel Efficiency, Mass Transit

Response Variable: CRS Efficiency Scores for Mass Transit

Regression Table

Predictor	Coefficient	SE	Z	P-values
Intercept	-3.83699	0.803703	-4.77	0
Climate	-0.174014	0.249668	-0.7	0.486
Median Household Income, 2007-2009	0.000102	2.26E-05	4.52	0
Percent Pop Urban 2009	-0.0385506	0.010221	-3.77	0
Land Area of State in Sq. Miles	-0.0000007	1.4E-06	-0.54	0.591

Log-Likelihood = 29.405

Response Variable: VRS Efficiency Scores for Mass Transit

Regression Table

Predictor	Coefficient	SE	Z	P-values
Intercept	-2.9398	0.837472	-3.51	0
Climate	0.0189713	0.254503	0.07	0.941
Median Household Income, 2007-2009	0.000092	2.38E-05	3.86	0
Percent Pop Urban 2009	-0.0422497	0.011634	-3.63	0
Land Area of State in Sq. Miles	-0.0000006	1.6E-06	-0.36	0.72

Table 7—Truck Shipping Efficiency

Response Variable: CRS Efficiency Scores for Truck Shipping

Regression Table

Predictor	Coefficient	SE	Z	P-va;ie
Intercept	0.061315	0.603358	0.1	0.919
Climate	-0.30149	0.209099	-1.44	0.149
Median Household Income, 2007-2009	3.79E-05	0.000016	2.36	0.018
Percent Pop Urban 2009	-0.03876	0.009619	-4.03	0
Land Area of State in Sq. Miles	-2E-07	1.1E-06	-0.16	0.873

Log-Likelihood = 6.723

Response Variable: VRS Efficiency Scores for Truck Shipping

Regression Table

Predictor	Coefficient	SE	Z	P-value
Intercept	-0.46167	0.309308	-1.49	0.136
Climate	-0.08425	0.120707	-0.7	0.485
Median Household Income, 2007-2009	2.14E-05	9.4E-06	2.29	0.022
Percent Pop Urban 2009	-0.01399	0.005021	-2.79	0.005
Land Area of State in Sq. Miles	-9E-07	5E-07	-1.72	0.085

Log-Likelihood = 3.185

4. Results and Discussions

The results of the three different sets of Tobit models show that only two explanatory variables are statistically significant at $\alpha = .05$ in most experiments. The Tobit regression models explain only small amounts of variation in the dependent variable due to the low log-likelihood scores. The average median household income of state residents seems to be the indicator of road provision efficiency according to all but one model. Apparently, the greater the financial resources of a state resulted from a wealthier tax base, the more it could spend to build and maintain road infrastructure. This result may explain why some wealthier states such as Hawaii, Alaska, Rhode Island, and Vermont have done relatively well. Another variable with a slightly more consistent impact on either type of efficiency score, CRS or VRS, is the percentage of each state's population classified as urban. The greater the urban population, the lower the CRS or VRS scores due to longer commuting and shipping times resulted from more congested urban traffic. By nature, the urban setting is characterized by high population density and concentration of economic activities that are likely to create severe traffic congestion. To make traffic congestion problems worse, the urban setting often forces its residents to commute further and longer due to either less housing affordability or less desirable housing in the downtown or the center of economic activities where most of the employment remains (Rodrigue, Comtois, and Slack, 2009). For instance, less urbanized states with no cities exceeding one million in population such as Hawaii and Alaska have done well in terms of commuting and shipping times, whereas more urbanized states with major cities such as California, New York, Texas, Pennsylvania, Illinois, Ohio, Michigan, and Florida turned out be underperformers.

However, many public services such as road provision can gain efficiencies from the economies of scale that urban areas often provide. In our experiments, this potential efficiency gain was not sufficient enough to alleviate the potential efficiency loss caused by delayed commuting or shipping times. This finding is congruent with that of the earlier study conducted by Winston and Langer (2006) which showed that road infrastructure investment in highly urbanized areas tended to be inefficient, even when the investment was made for new road construction that intended to alleviate traffic congestion. According to Winston and Langer (2006), every dollar in urban road spending yields less than a dollar in benefits because the congestion relief is only temporary—as new roads are built to relieve traffic congestion in one part of an urban area, these new roads later become choke points themselves as drivers see them as good alternatives to old ways of traveling. Also, they believe that there will never be any way for road construction to keep up with annual increase in the total number of vehicles on the roadways. Instead, they recommended peak travel time or congestion pricing for major roadways during peak usage times, such as rush hour traffic. Such pricing could take the form of tolls with shippers probably willing to pay a little more to prevent delays. On the other hand, they suggested that exemptions to the peak load pricing or tolls, should be granted to mass transit systems or to commuters that carpool in order to relieve traffic congestion in the urban settings.

Defying common sense, we discovered that the climate of a state has no bearing on the road provision efficiency. For example, even though a warm/mild weather state such as Hawaii has done well in terms of commuting and shipping times, cold weather states such as Rhode Island, Vermont, and West Virginia have done equally well in terms of commuting times via individually operated vehicles. Also, we learned that the land mass of a state has nothing to do with its road provision efficiency. To elaborate, mega states exceeding ten million populations such as California, Texas, Florida, New York, Illinois, Pennsylvania, and Ohio did not produce high efficiency scores for their road provisions in terms of both CRS and VRS efficiencies in individual commuting, mass transit, and truck shipping times. On the other hand, smaller states such as Hawaii and Vermont were considered to be benchmarks for others to meet. Thus, the economies of scale alone did not seem to dictate road provision efficiency.

5. Concluding Remarks

To the best of our knowledge, this paper is one of the first to comprehensively measure and benchmark the comparative efficiency of state road provision in the U.S., while identifying the factors (e.g., resident income, urbanization) most influential on road provision efficiency. In all the models tested, the greater the level of state resident income, the higher the road provision efficiency. We also found that the greater the extent of urbanization, the less efficient the state road provision. Overall, the findings of the Tobit regression models suggest that states with more densely populated urban areas tend to be less efficient in offering road provision than the other states with less developed but more rural settings. This finding is contradictory to the notion that more dense development such as an urban environment usually accompanies economies of scale in providing public services such as road provision (Hirsch, 1973 and 1984; Ladd, 1992; Carruthers and Ulfarsson, 2003; Garcia-Sanchez, 2006; O'Sullivan 2007). More specifically, the worst performing states in terms of individual commuting times are California, Illinois, and Texas whose inefficiency gaps (1 – DEA efficiency score) are the largest (all surpassing inefficiency gaps of .70). With regard to mass transit commuting times, California, Texas, Pennsylvania, and Michigan were very poor performers with their inefficiency gaps exceeding .95. With respect to truck shipping times, California, Texas, Pennsylvania, Illinois, and Ohio turned out to be the worst performing states despite their relatively large transportation budgets.

It is somewhat ironic that these underperforming states have major transportation arteries (e.g., I-10, I-20, I-40, I-70, I-80 connecting east and west across the entire U.S.) intersecting them and contained major distribution hubs such as Los Angeles, Dallas, Houston, Chicago, and Columbus. In particular, it is surprising to learn that both California and Texas turned out to be the least efficient states in terms of every category of road provision. Perhaps California's struggle has something to do with its recent financial woes and political instability. In the case of Texas, despite its sustained economic growth, its explosive population growth out paces its ability to meet the rising demand for road infrastructure and more frequent road maintenance.

While most states struggled to maintain a high level of road provision efficiency, Hawaii, Alaska, West Virginia, and some New England states (i.e., Rhode Island, Vermont, Maine) scored a perfect efficiency in at least one of the three performance criteria (individual commuting times, mass transit commuting times, and truck shipping times). Overall, Hawaii is the clear benchmark after it registered a perfect efficiency score of one in every performance criterion. Including Hawaii, all but West Virginia are wealthier states. Hawaii's success is unique in that it is isolated from the mainland and thus its transportation access for visitors is limited to non-surface modes of transportation such as air carriers, cruise ships, and ferries that can cross the ocean. Since the lack of transportation access could undermine Hawaii's tourism industry which is the major economic engine for Hawaii, the state government of Hawaii has made a conscious effort to properly maintain transportation infrastructure and alleviate increased traffic congestion on state and county roads and highways. These efforts include: The Statewide Transportation Improvement Program which entails the improvement of overall ground transportation services, a $20 million investment for the commuter rail project in Honolulu, and the construction of a $3.7- $6 billion rail system in Honolulu. Hawaii's success in road provision is peculiar since its budget health is ranked one of the lowest (47 out of all 50 states) and it suffered from a budget deficit of $214 million in 2011 after state tax collection dropped by 0.9% in 2010 (Zimmerman, 2011; State Budget Solutions, 2011, http://statebudgetsolutions.org/state/detail/hawaii). This finding implies that a budget shortfall alone cannot be a legitimate excuse for road provision inefficiency.

Another case in point is that in benchmarking states such as Hawaii, Alaska, Rhode Island, Vermont, and West Virginia, it should be noted that they are geographically isolated and their road access is limited due to no or fewer interstate highways linked to other road networks. Thus, they can focus on the fewer number of roads and highways as well as limited mass transit systems. Based on these findings, transportation planners and policy makers in the underperforming states should consider the following options to improve their state road efficiency:

- Since newly constructed roads and highways are often swamped with previously suppressed new demand and subsequently will not ease traffic congestion in the long run, policy makers need to focus on the better utilization of existing road capacity which may include the introduction of rapid commuter rail systems, the use of dynamic road pricing (e.g., higher toll for fast-lanes) in the urban areas, and the identification of accident-prone areas and bottlenecks which often contributed to prolonged and unreliable commuting and shipping times.

- Since traffic congestion problems will worsen in highly-trafficked urban areas during the rush hours, the policy makers may consider installing a geographic information system (GIS) monitored signboard which can alert urban road users about the level of traffic congestion on a real-time basis. This idea may help mitigate traffic congestion by diverting some traffic to less busy alternative routes.

- In times of budget crisis, state transportation planners should consider prioritizing the state's investment in alternate road construction and existing road maintenance in the highly-trafficked urban areas over rarely used rural roads.

Despite our novel effort, this study is far from being perfect due in part to its reliance on the limited time frame (three year period) and surrogate measures extracted from secondary data available in the public domain. To overcome some of the shortcomings of this study, future research efforts can be geared toward:

- Expansion of time-series data across multiple time periods that can mitigate economic ups and downs;
- Examination of both short-term and long-term effects of state budget health, transportation budget, and highway maintenance patrols on road provision;
- Investigation of the impact of major road infrastructure development programs such as the TranslinkeD project in the Detroit metropolitan area on road provision. The TranslinkeD Detroit project, under the guidance of the Detroit Regional Chamber, seeks to create 66,000 new jobs in the transportation, logistics, and distribution sector by taking maximum advantage of Detroit's unique location and business, talent, and infrastructure assets;
- A comparison of road provision efficiency at the national level (e.g., U.S. versus Australia).

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7. Acronyms

3PL	Third Party Logistics
CRS	Constant Returns to Scale
DEA	Data Envelopment Analysis
DMUs	Decision Making Units
GDP	Growth Domestic Product
GIS	Geographic Information System
LP	Linear Programming
VRS	Variable Returns to Scale