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University Transportation Center

U28: Longer Combination Vehicle's Impact on Improving Operational Efficiency, Freight Flows and Traffic Congestion

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16. Abstract

Longer Combination Vehicles (LCVs) are able to carry more freight than conventional single trailer trucks. As a result, these trucks can increase efficiencies and benefits for freight movements as less fuel and less labor is used per ton of cargo. However, LCVs are allowed in only 19 U.S. states primarily due to concerns over safety and infrastructure costs. This study investigates these concerns, performs a Cost-Benefit Analysis of operating LCVs, talks to private and public sector experts regarding their use, and completes a public survey to gauge the public's perception of the use of LCVs in terms of both their concerns and the public's prioritization of the potential benefits of using LCVs. Overall, this study finds there are sufficient benefits to consider the expansion of LCV operations. The per vehicle mile benefit ranges from $0.32 to $0.61 in 2011 dollars.

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List of Abbreviations and Acronyms

Abbreviation or Acronym	Definition
CBA	Cost-Benefit Analysis
CFIRE	The National Center for Freight and Infrastructure Research and Education
USDOT	US Department of Transportation
LCV	Longer Combination Vehicle
FAK	Freight of All Kinds
FHWA	Federal Highway Administration
NTRCI	National Transportation Research Center, Inc.
ORNL	Oak Ridge National Laboratory
RMD	Rocky Mountain Double
TPD	Turnpike Double
TT	Triple Trailer

Units of Measurement

Unit	Meaning
kg	kilogram
km/h	kilometer per hour
kPa	kilopascal
m	meter
m/s	meter per second
m/s^2	meter per second squared
mm	millimeter
N•m	Newton-meter
s	second

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Executive Summary

Longer combination vehicle (LCV) operations are currently allowed in thirteen states (with some restrictions), and in six additional states on turnpikes only.[1] These longer combination trucks, consisting of two or three trailers, provide more space to transport increased cargo volumes. As a result, cargo can be shipped more efficiently at a reduced cost because it requires less labor and fuel per ton of cargo transported. The use of LCVs creates further benefits related to lower emissions and reduced congestion. However, due to the Intermodal Surface Transportation Efficiency Act of 1991, the use of LCVs on the federal-aid highway system cannot be expanded beyond their current permitted uses – a grandfathering allowance only. As operational costs (including personnel, fuel, and equipment) in the freight industry have risen, so has the interest in the potential benefits of LCVs. Policy makers and industry professionals alike have requested information on expanding the use of LCVs. As a result, there is increased interest in the costs and benefits of LCVs, and discussion surrounding the repeal of the current restrictions.

When Congress passed the Intermodal Surface Transportation Efficiency Act concerns about safety and pavement damage emerged as the primary reasons for the freeze on LCV use. However, rising fuel prices, increasing costs associated with noxious emissions, and surging congestion costs have recently made the use of LCVs more attractive. This study evaluates both the negative and positive outcomes concerning longer combination vehicle use.

Longer Combination Vehicle's Impact on Improving Operational Efficiency, Freight Flows and Traffic Congestion took a critical look at LCV use to determine whether the expanded use of LCVs would be beneficial to society. This study consisted of four parts: 1) a literature review summarizing past research on LCVs; 2) a representative cost-benefit analysis involving the operation of LCVs on the Ohio Turnpike; 3) interviews with direct stakeholders from both the public and private sectors to get input relative to the benefits and costs they foresee with increased LCV use; and, 4) a survey of the general public to gain a better understanding of their views related to the use of LCVs on the highway.

Based on this research, the project team was able to draw a number of conclusions. First, the literature review revealed inconsistency and a lack of consensus relative to the safety of LCVs. Researchers were able to neglect pavement damage cost because a general consensus is emerging that this damage is directly related to weight per axle rather than overall weight. Therefore if the maximum allowable axle load for an LCV is the same as for a conventional tractor and semitrailer, we can assume no additional pavement damage. The cost-benefit analysis of allowing LCV use on the Ohio Turnpike revealed as much as $167 million in cumulative benefits over a twenty-year planning horizon. The estimated per LCV mile benefit ranges from $0.32 to $0.61. Interviews with stakeholders showed that both the public and private sectors expect benefits from expanded LCV use. Both sectors also predicted that LCV use would

[1] Alaska, Colorado, Idaho, Nebraska, Nevada, North Dakota, Nebraska, Oklahoma, Oregon, South Dakota, Utah, Washington, Wyoming. Turnpike Authority only: Florida, Indiana, Kansas, Massachusetts, New York and Ohio.

increase significantly if allowed. The public survey suggested that the public understands the potential benefits of LCV use; however, education, outreach, and awareness campaigns would be required to mitigate safety and infrastructure concerns.

For the future, the project team recommends further study examining the safety of LCVs, as current studies provide inconsistent, and often conflicting, findings. In particular, the relative safety of LCV vehicles compared to the standard configuration tractor and semitrailer appears to be unknown. Similarly, research investigating the impact on infrastructure costs directly related to adapting for LCVs would be beneficial. At present, studies cannot differentiate the incremental changes associated with LCV uses.

Chapter 1 – Introduction

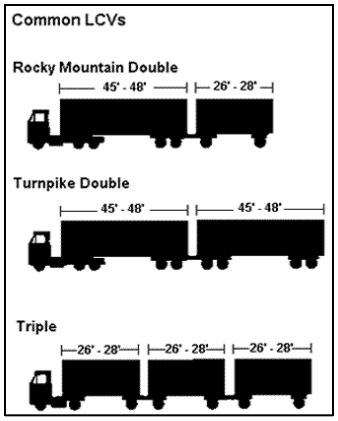

Figure 1-1. Illustration. Common Types of LCVs *(1)*.

Longer Combination Vehicles (LCVs) are trucks that have two or three trailers (Figure 1-1). Because of their added cargo space, they are able to transport freight more efficiently. However, current federal law limits the use of LCVs nationwide. Because of efficiency gains along with other benefits such as lower emissions and reduced congestion, there is increased interest in formulating policy that would allow expanded use of LCVs throughout the country.

1.1 Background

In 1991, Congress passed the Intermodal Surface Transportation Efficiency Act, which banned states from changing laws to allow the use of longer combination vehicles on the federal highway system. States that allowed LCV travel at the time were grandfathered in and could maintain their 1991 standards of use (Figure 1-2). Concerns about safety and pavement damage appeared to be the primary reasons for the freeze on LCV use.

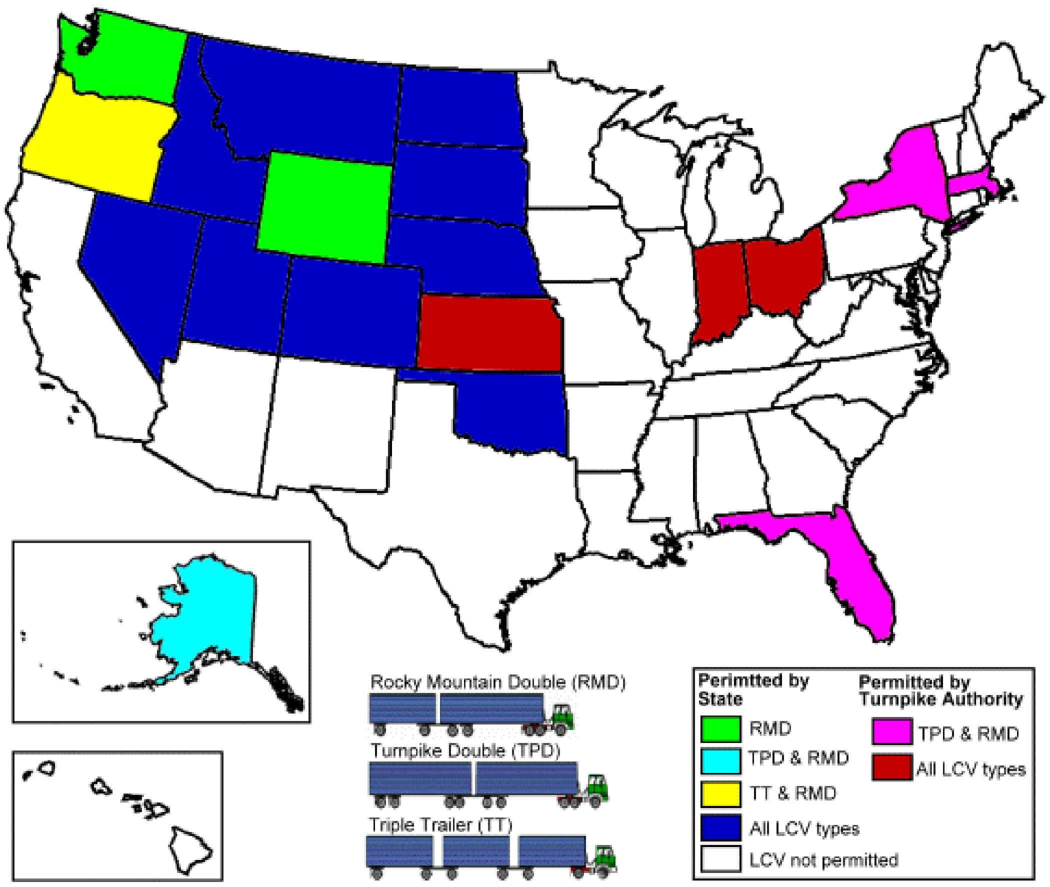

Figure 1-2. Illustration. Map of state regulations of LCVs (*2*)

1.2 Project Team

1.2.1 National Center for Freight and Infrastructure Research and Education (CFIRE)

CFIRE was responsible for the overall execution of the project. Dr. Teresa Adams was the principal investigator for the effort with assistance from the listed co-authors.

1.2.2 NTRCI

NTRCI staff played an active role in managing the project and coordinating the activities of the numerous contractor teams. The research team acknowledges the input and advice from NTRCI Director Joseph Petrolino and Tony Spezia, among others.

1.3 Project Description

This project was composed of five primary tasks: 1) literature review, 2) interviews with public and private representatives, 2) cost-benefit analysis, 4) public survey, and 5) reporting.

1.3.1 Literature Review

The project team conducted a literature review to acquire a thorough understanding of the issues and research related to the operation of LCVs and to discover which states currently allow the use of LCVs on their highways. Additionally, researchers focused on safety issues associated with the use of LCVs. The results of this effort appear in Chapter 2.

1.3.2 Interviews with Public and Private Representatives

The public and private sectors will often have differing opinions when it comes to policy ideas. In order to gain a better understanding of the viewpoint of each, the project team interviewed expert representatives from both sectors. These interviews included a DOT official from a state that currently allows LCVs, a high-ranking official of a major freight carrier, and the owner of a mid-sized transport and storage firm. Findings are presented in Chapter 4 of this report.

1.3.3 Cost-Benefit Analysis

The project team performed a cost-benefit analysis to obtain an overall monetized measurement of the benefits or costs that occur when LCVs are operated. Using 2008 data, this analysis compared the truck travel on the Ohio Turnpike when using LCVs to a counterfactual scenario in which LCVs were not used. Calculations based on a foot-by-foot replacement rate provided an estimate for the number of single trucks needed to replace the LCVs that were used. The analysis then calculated the differences in cost for the variables of labor, fuel, capital costs, wear and tear, emissions, maintenance, the cost to develop and maintain breakdown areas on the highways and the cost of assembling and disassembling the LCV cargo units[2]. These costs were calculated on a yearly basis and totaled over a twenty year horizon. Initial up-front costs were also determined and used in the final calculations. The details on this process are addressed in Chapter 3.

[2] The term “breakdown” is also used to mean the process of disassembling an LCV into separate units.

1.3.4 *Public Survey*

This survey was created and distributed to gain a sense of the public's attitude toward LCVs. More specifically, the project team sought information about how the public thought the use of LCVs would impact the numerous potential outcomes associated with their use. Additionally, this survey was used to gauge the relative importance of the many potential benefits of LCVs. By compiling a public prioritization, the benefits ranked as the highest could then be the issues focused upon when introducing policy initiatives that expand the use of LCVs. Details are provided in Chapter 5 of this report.

1.3.5 *Reporting*

This task is the compilation of the previous tasks into a single document for distribution.

1.4 Project Schedule

This project was conducted from April 2011 to December 2011. Figure 1-3 is the project schedule. The project was granted a brief time and scope extension to include the survey described above.

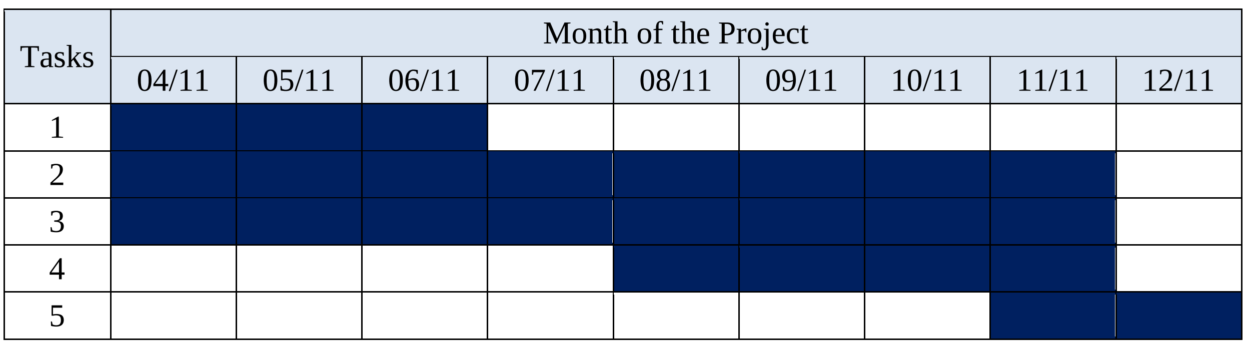

Figure 1-3. Chart. Schedule of Tasks.

Task 1: Literature Review Task

Task 2: Interviews Task

Task 3: Cost-Benefit Analysis Task

Task 4: Survey Task

Task 5: Reporting

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Chapter 2 – Literature Review

Numerous questions and issues surround the employment of LCVs to transport freight. This chapter summarizes current literature regarding five of these issues: safety, regulation, costs and benefits, infrastructure, and environmental issues.

2.1 Safety

Safety is the number one issue associated with the expanded use of LCVs. The increased length and weight of an LCV intuitively leads to the assumption that they are less safe than the standard long-haul truck. However, other characteristics of LCV trucks, such as greater stability while turning due to the increased length, counter this assumption. Current literature and studies offer no clear consensus on the safety of LCVs. Some studies find LCVs to be less safe in terms of fatal crashes (*3*), or when cars are passing LCVs (*4*). Some conclude LCVs to be safer because of lower collision rates (*5*,*6*,*7*,*9*), or lower total crash costs (*9*). Additionally, other studies offer no definitive conclusion due to a lack of sufficient data (*10*), a lack of control data (*11*), contradicting information (*12*), or different methodologies (*13*). Further study is needed with a greater focus and more comprehensive data collection on LCVs specifically (*14*,*15*,*3*,*16*), to offer a clearer understanding on the overall safety effects of operating LCVs.

2.2 Regulation

Regulation of LCVs is another issue to consider. While some states currently allow the use of LCVs, the regulations are not uniform across these states. For example, some states allow the travel of all LCV types, while others only allow for the Rocky Mountain Double. Additionally, drivers in all states are required to get specific training and licensing to operate an LCV. If LCVs were allowed in every state, additional states would likely have to increase regulatory supervision, and it would be beneficial to institute uniform operation regulations across states. However, as we can see from issues related to the movement of oversize and overweight trucks, establishing uniform standards across states is far from easy (*17*).

2.3 Costs and Benefits

Costs of LCV use and benefits deriving from this use present a third issue. The use of LCVs, and their ability to carry nearly twice the cargo load appears to provide economic benefits. For example, a tractor towing two trailers requires one driver instead of two. Next, while towing two loads will require more fuel than for towing one, it will not require twice the amount, thus reducing the amount of fuel needed to transport the two loads and lowering the operating costs for carrier companies and the businesses they serve. Along those same lines, carriers may experience less wear and tear on their tractors as they can transport two loads in one trip instead making two trips, again lowering costs for both the carriers and the shipper. Also, carriers will need a smaller fleet of tractors, thus lowering costs even further. However, it should be noted that adoption of LCVs would require most fleets to purchase different length trailers than they have now. This would be an additional cost for some unless replacement decisions occur when older long trailers are being retired. Tractors may experience higher tire wear due to the extra traction needed to pull two (or more) trailers. Additionally, LCVs may lower the amount of trucks on the road resulting in congestion improvement which would have a positive impact on the economy and consumers. In 2010 truck delay cost due to congestion was $23 billion. In total, there was $101 billion in congestion costs for 439 urban areas in 2010 (18). However, it has been theorized that the lowered costs of truck transportation may cause a modal shift from rail to road, which could add to congestion and cause a negative impact on the economy.

2.4 Infrastructure

Infrastructure is another issue relative to the use of LCVs. The primary is the cost to reinforce bridges in order to support potentially higher gross vehicle weight limits (*12*). Another concern is damage to pavements. Truck weights, defined by pounds per axle, do a significant amount of damage to roads. For example, a "20,000-pound truck axle consumes over 2,000 times as much pavement life as a 2,000-pound automobile axle" (*19*). Because LCVs carry more cargo and thus more weight than a standard truck, there is the perception by some that LCVs will naturally cause more pavement damage. However, this line of thinking is flawed, as the amount of pavement damage depends on the axle loads and the spacing of the axles. Therefore, an LCV may inflict less, more, or the same amount of pavement damage relative to a standard truck depending on how much weight is to be carried, how many axles are supporting that weight, and how the axles are spaced. LCVs may also impact infrastructure because of their increased dimensions. LCVs have larger off-tracking on curves compared to standard tractor-trailers, and because roadways are designed for standard vehicles and trucks, the use of LCVs can result in damage to infrastructure such as road shoulders, curbs, and roadway-side signs.

2.5 Environmental Issues

LCVs, like all other trucks, have an environmental impact. If there are fewer tractors on the road because the tractors are pulling multiple trailers, then there will be fewer emissions. An estimation from a carrier representative noted that LCVs get six percent fewer miles per gallon *(20)* than conventional trucks. However, simple multipliers to determine fuel usage and therefore combustion pollution, fail to examine the impacts of the vehicles speed and the differences between LCVs and conventional trucks when in 'stop and go' traffic conditions. As the aerodynamics and friction of LCVs will differ from conventional trucks, so too will the amount of fuel used per ton mile. Although the benefits to reducing the number of tractors on the road will outweigh these potential negatives, they may provide some counter to this positive.

Chapter 3 – Cost-Benefit Analysis

The Cost-Benefit Analysis (CBA) used a counterfactual approach. Specifically, the total net benefits are the costs saved when LCVs are used in comparison to the scenario in which they are not used. Cash flows representing costs associated with the infrastructure, equipment, and operation of LCVs on the Ohio Turnpike were subtracted from cash flows for the counterfactual scenario in which LCVs were not used. In order to do this, we compared two scenarios; 1) actual tractor trailer travel on the Ohio Turnpike which involves the use of LCVs, and 2) the counterfactual "non-LCVs" scenario in which LCVs are replaced by standard 53-foot tractor trailers. Variables such as fuel costs, equipment costs, emission costs, labor costs, etc. are calculated for each scenario. The total net benefits are the costs for the "non-LCVs" scenario minus costs for the current LCV scenario.

3.1 Approach

The analysis uses truck trips and vehicle counts from the Ohio Turnpike. The Ohio Turnpike was chosen because both doubles and triple LCVs are allowed. The turnpike serves the large, congested metropolitan areas of Toledo, Cleveland, and Akron. In 2009, Cleveland experienced total congestion costs of $489 million, Akron $148 million, and Toledo $102 million. Because LCVs are not permitted in the metropolitan areas, the analysis assumes no congestion impacts. The turnpike is a toll facility and the analysis assumes toll costs would be adjusted to mitigate congestion impacts from the counterfactual scenario. Thus congestion impacts can be ignored. The CBA ignores tolls because they are a cost transfer from the facility users to the facility operators. Best practice in CBA for transportation facilities is to ignore tolls *(21).* Finally, truck trips and mileage data were made available from the Ohio Turnpike Commission *(22).*

The project team used 2008 data for truck travel (including LCVs) on the turnpike (see Table 3-1) to estimate an equivalent number of single trucks for the counterfactual (non-LCVs) scenario that would have been used in 2008 if LCVs were not allowed on this route. More specifically, rather than using an approach that assumes standard trucks are replaced by LCVs; we are replacing LCVs with standard trucks. From this estimation we were able to monetize the costs of two scenarios; one where LCVs were employed, and another where they were not.

Table 3-1. Truck Travel on the Ohio Turnpike (2008).

Type of truck	Trips	VMT (vehicle miles traveled)
Standard	7,232,767	987,363,637
Turnpike Double	40,313	5,705,432
Triple	101,413	13,641,949
Total	7,374,493	1,006,711,018

The CBA conducted on LCVs on the Ohio Turnpike uses national standing in order to capture the benefits resulting to the US as a whole rather than a smaller population. Therefore, the authors monetized the costs and benefits from fuel consumption, labor costs, emissions, vehicle and trailer wear and tear, training costs, and the costs of breaking down LCVs at the border of non-LCV areas. In order to monetize the benefits of LCVs, the project team counts many of the benefits of LCVs as added costs when LCVs are taken off the road and standard combination trucks replace them. Therefore, tables and figures should be read as the benefits or costs of LCVs rather than the benefits or costs of a “non-LCV” policy.

Given the uncertainty of safety outcomes associated with the use of LCVs, safety impacts were not included in any total cost calculations. Similarly, pavement performance impacts were not included.

It should also be noted that breakdown costs, the costs associated with converting from a LCV to a standard truck at state borders, was in the range of $105 million to $75 million over the twenty year horizon. If more highways permit LCVs then fewer facilities and less time would be required for assembling and dissembling cargo units thus reducing costs.

3.2 Estimated Benefits of LCVs

The results of the CBA indicate net benefits when LCVs are employed. Over a 20 year planning horizon, the CBA estimated present worth net social benefits is up to $167 million.

Table 3-2 lists the benefit and cost categories and the associated estimates from the analysis. More details of the assumptions for each cost category are provided in Appendix B.

Table 3-2 Quantified Benefits of LCVs.

	Present Worth ($2011)	
Cost category	**3% Discount Rate**	**7% Discount Rate**
Labor cost savings (drivers)	$ 67,518,421	$ 49,945,936
Tractor equipment cost savings	$ 17,700,000	$ 17,700,000
Tractor Wear and Tear cost savings	$ 43,313,362	$ 32,040,536
Trailor Wear and Tear cost	$ (10,115,730)	$ (7,482,989)
Construction of breakdown areas	$ (9,000,000)	$ (9,000,000)
Periodic maintenence cost of breakdown areas	$ (4,512,715)	$ (3,027,923)
Labor cost to assemble/breakdown cargo	$ (104,245,476)	$ (77,114,331)
LCV driver training cost	$ (220,798)	$ (164,760)
Emissions cost savings	$ 16,647,357	$ 13,018,544
Diesel fuel cost savings for predicted fuel cost:		
Low cost	$73,885,510	$54,748,365
Mid-cost	$109,294,632	$79,534,152
High-cost	$150,452,458	$108,711,572

Table 3-3 summarizes the present worth of the net benefits of LCV operations on the Ohio Turnpike. These benefits are gained for approximately 19.3 million LCV vehicle miles traveled per year over a 20 year planning horizon. Thus, the per vehicle mile benefit of LCV operations on the Ohio Turnpike has an annual benefit in the range of $0.32 to $0.61 as shown in Table 3-4.

Table 3-3. Present Worth of LCV Operations on the Ohio Turnpike.

	Present Worth ($2011)	
Predicted fuel costs:	**3% Discount Rate**	**7% Discount Rate**
Low- cost	$90,970,000	$70,660,000
Mid-cost	$126,380,000	$95,450,000
High-cost	$167,540,000	$124,630,000

Table 3-4. Benefit per LCV Mile Travelled on the Ohio Turnpike ($2011).

	Annual Worth ($2011)		**Benefit Per LCV Mile**	
Predicted fuel costs:	**3% Discount Rate**	**7% Discount Rate**	**3% Discount Rate**	**7% Discount Rate**
Low- cost	$6,115,000	$6,670,000	$0.32	$0.35
Mid-cost	$8,495,000	$9,010,000	$0.44	$0.47
High-cost	$11,261,000	$11,764,000	$0.58	$0.61

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Chapter 4 – Public and Private Perspectives

There are a number of issues with which users and regulators of longer combination vehicles are confronted. The project team sought to gain insight into the benefits, costs, and concerns that affect public and private stakeholders. Researchers asked questions that examined the cargo replacement rate of a LCV versus a conventional tractor-trailer combination, the impact of policy decisions that have affected LCV usage, LCV versus conventional tractor-trailer safety issues, and the associated costs and the associated benefits that may be attributed to LCV use. The project team interviewed a representative of the freight delivery industry, an official of a state DOT that currently allows LCVs on a turnpike, and an owner of a mid-sized transport and storage firm.

Both the freight carrier representatives and the state DOT official thought that with changes in policy there would be a dramatic increase in LCV usage. The freight carrier representative noted that they currently use LCVs wherever and whenever it is possible. It makes financial sense and they would like to use them more. For example, line hauls (such as distribution center to distribution center) could be as high as 100 percent LCVs, whereas urban hauls could be made up of 40 percent LCVs. The DOT official noted that there would be a productivity gain with fewer drivers and fewer trucks, which in turn would cost less.

They both noted that the permitting would have to take into account elevation changes, weather conditions (especially snow, ice, and wind), and current infrastructure. Both also suggested that if LCVs are safe on toll-roads and turnpikes, they would also be safe on interstate highways. The DOT official added that with increased use there would also need to be some education for enforcement personnel. This would ensure that they would be up to date on the changes to the law, but noted that this would not be critical. Ultimately though, the DOT official said that perceptions regarding LCVs, especially safety concerns, will need to be tempered before significant expansion of LCVs occurs.

4.1 Public Sector Perspective

According to the state DOT official the cargo typically transported by LCVs is “Freight of All Kinds” (FAK). FAK is usually general merchandise and finished goods as opposed to raw bulk materials. Although LCVs get approximately six percent less miles-per-gallon (MPG) than a single tractor-trailer combination, the ton-mile savings more than makes up for this both financially and environmentally.

LCV drivers tend to be the most experienced and safest drivers. While these drivers receive a few percentage points more in pay, compared to conventional truck drivers, LCV drivers also require an extra endorsement on their commercial driver’s licenses that requires additional training that allows them to legally haul LCVs.

Currently only 19 states allow the use of longer combination vehicles. The discontinuity across jurisdictional borders has created a system that requires LCVs to "breakdown," (i.e., disconnect trailer units) to become compliant in the state that they are entering. Where these breakdowns occur, how long they take, and who pays for and maintains these breakdown areas were questions addressed to the state DOT official and the freight industry representative. In certain states LCVs use breakdown facilities, which are owned and operated by the carriers, and only rarely do they take advantage of public rest areas. This is something that varies greatly from state to state and agency to agency. In this project's study area, the Ohio Turnpike Commission established eight breakdown areas at an initial cost of approximately $9 billion. These areas are expected to last twenty years without any major rehabilitation. However, regular maintenance is required and has been estimated to cost between $3.2 million to $4.7 million over the twenty year horizon.

4.2 Private Sector Perspective

From the perspective of the carrier, these breakdowns incur costs of labor as the drivers have to perform the breakdowns. With hours of service limits on drivers, this can affect the number of runs that a driver can make in a day. However, with properly planned logistics, freight movers can make this operation efficient. Loads that are dropped off can quickly be attached to another trailer, as long as that trailer is there, with little time lost in the transfer.

LCVs could also require additional registration and insurance costs. However the freight carrier representative noted that the registration is per combination, thus there was a potential registration cost savings because of fewer LCVs combinations than typical tractors semi-trailer combinations. In regards to potential increases in insurance costs the representative explained that their policy applies to the fleet in general, rather than to individual loads or trucks, and that the costs of insuring the fleet did not change significantly when LCVs were added.

The representative from the mid-sized transfer and storage firm that currently uses non-LCVs would certainly employ them if legal nationwide. In their case, the use of LCVs would be used primarily for long-range and high-volume lower-weight cargo shipments.

Chapter 5 – Public Opinion on the Benefits and Impacts of LCVs

5.1 Overview

If policy for the expanded use of LCVs is developed and proposed, it is important to consider the public's view of LCV trucks to ensure successful implementation. This is necessary so that the policy can be crafted and presented in a fashion that will focus on the outcomes most important to the public while also addressing the issues the public regards as problematic. To that end, the project team created and distributed a survey (complete survey in Appendix C) to solicit input primarily related to 1) a prioritization of potential benefits associated with the use of LCVs, and 2) the expected impacts of expanded use of LCVs nationwide. The following results suggest that decreasing fuel use and increasing the safety of all vehicles on the road were most important to those surveyed. The survey was sent out to numerous private agencies and interest groups from August 2011 to November 2011. We received 224 partially completed, but useful surveys. Of these, 207 were fully completed.

5.2 Distribution

This survey was sent to numerous organizations, groups and individuals with a request to further distribute it by email to their contacts.

- Indiana Trucking Association
- Ohio Trucking Association
- Wisconsin Trucking Association
- New York Trucking Association
- Massachusetts Trucking Association
- Texas Trucking Association
- Florida Trucking Association
- Washington Trucking Association
- Nebraska Trucking Association
- National Transportation Research Center, Inc.
- Federal Highway Administration
- American Trucking Association
- State Environmental Leadership Program
- Energy interest groups email list

5.3 Analysis of Survey Results

Survey takers distributed 100 percentage points among nine potential policy benefits associated with the expanded use of LCVs. Table 5-1 contains the power report associated with the analysis. The power report indicates the chances of detecting difference in the means for the limited sample size of 224. Table 5-1 also lists the mean percentage points for each policy benefit and, given the sample size and variation, the 95 percent confidence intervals for the means. Figure 5-1 is a graph of the mean values and confidence ranges with the policy benefits ranked from highest to lowest mean.

Table 5-1. Power Report for the One-Way ANOVA of Ranked Policy Benefits.

Power

What is the chance of detecting a difference?

Based on your samples and alpha level (0.05), you have at least a 90% chance of detecting a difference of 7.4885, and at most a 60% chance of detecting a difference of 2.3236.

What difference can you detect with your sample sizes?

Difference	Power
2.3236	12.3 - 60.0
5.4811	60.0 - 100.0
6.0201	70.0 - 100.0
6.6408	80.0 - 100.0
7.4885	90.0 - 100.0

Power is a function of the sample sizes and the standard deviations. To detect differences smaller than 6.6408, consider increasing the sample sizes.

Statistics

Policy Benefit	Sample Size	Mean	Standard Deviation	Individual 95% CI for Mean
Increasing safety of all vehicles on the road	224	17.594	21.131	(14.811, 20.376)
Reducing congestion	224	21.174	14.321	(19.288, 23.060)
Creating cost savings for truck drivers	224	8.5893	11.761	(7.0407, 10.138)
Reducing government costs	224	4.6116	7.1182	(3.6743, 5.5489)
Decreasing pollution	224	13.964	12.463	(12.323, 15.605)
Creating cost savings for consumers	224	9.2232	12.029	(7.6394, 10.807)
Fighting climate change	224	7.1339	9.6917	(5.8578, 8.4100)
Creating cost savings for businesses	224	10.442	13.926	(8.6083, 12.276)
Reducing congestion	224	7.2679	8.1466	(6.1952, 8.3405)

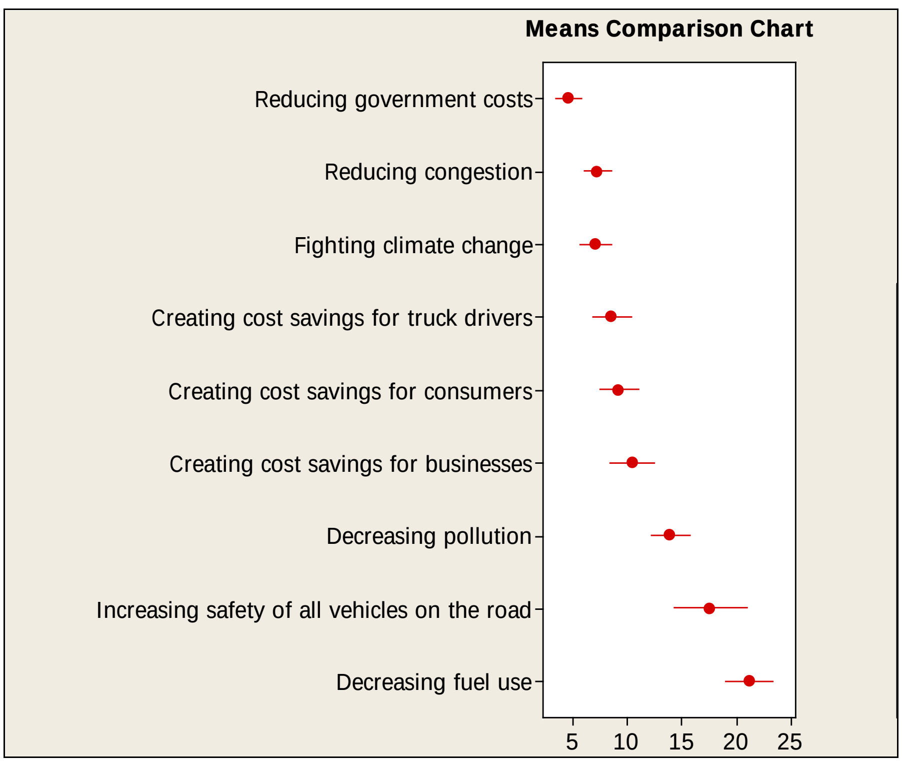

Figure 5-1. Chart. One-Way ANOVA of Potential Policy Benefits Associated with the Use of LCVs.

Some of the confidence intervals shown in Figure 5-1 overlap so we cannot conclude with certainty that the mean values are different for these policy benefits. 2-Sample t Tests and One-

Way ANOVA tests were used to determine if there are significance differences between the factors with overlapping confidence intervals. Details of these analyses are in Appendix C.

Table 5-2 lists the policy benefits in ranked order. The analysis could not determine differences in the mean value for the three factors related to cost savings. These factors were all ranked fourth. Similarly, the analysis could not determine differences between the rankings for “reducing congestion” and “fighting climate change”. Two possible reasons are limitations of the sample size, or possibly that there is actually no difference between the rankings for these policy benefits.

Table 5-2. Ranked Policy Benefits Associated with the Use of LCVs.

Rank	Potential Policy Benefit
1	Decreasing fuel use
2	Increasing safety of all vehicles on the road
3	Decreasing pollution
4*	Creating cost savings for businesses Creating cost savings for consumers Creating cost savings for truck drivers
7*	Reducing congestion Fighting climate change
9	Reducing government costs

*Benefits ranked together showed no significant differences

The study included analyses to determine potential bias of respondents that living in states that allow or don’t allow LCV travel on the highways, and for respondents that have experience driving on highways with LCVs as opposed to those that do not. Table 5-3 contains the characterization of the survey responses for these parameters. Some respondents did not provide these characterization factors.

Table 5-3. Characterization of Survey Respondents.

	Number of respondents where:		
	Home state prohibits LCVs	Home state allows LCVs	Total
Respondents who often or sometimes drive in traffic with LCVs	86	22	108
Respondents who rarely or never drive in traffic with LCVs	89	9	98
Total	175	31	

The analysis investigated whether responses are biased according to whether a respondent is from a state that prohibits or allows LCVs. Significant difference appear between the two groups on the importance of three of the policy benefits: creating cost savings for consumers, fighting climate change, and reducing congestion. As listed in Table 5-4, the most notable difference is for “fighting climate change.” Respondents in states prohibiting LCVs ranked this benefit about the same as the other policy benefits. However, among the respondents from states allowing

LCVs, the mean for "fighting climate changes" is significantly less than the mean rating for the other two policy benefits.

Table 5-4. Opinions of Respondents Living in States that Allow vs. Prohibit LCVs.

Policy Benefit	States prohibiting LCVs		States allowing LCVs	
	Mean	Std.Dev	Mean	Std.Dev.
Creating cost savings for consumers	7.920	9.892	14.61	18.87
Fighting climate change	8.023	10.317	3.290	5.204
Reducing congestion	6.540	7.264	12.48	10.56

The survey contained two simple questions to determine the public's knowledge of basic requirements for LCV drivers. Table 5-5 lists the questions and indicates the percent responses bifurcated according to the prohibition or allowance of LCVs in the respondent's home state.

Table 5-5. Survey Respondents' Awareness of Basic Requirements for LCV Drivers.

	Percent of respondents answering			
	YES, and home state		NO, and home state	
Survey Question	prohibits LCVs	allows LCVs	prohibits LCVs	allows LCVs
Are LCV drivers required to have a good driving record?	84	86	16	14
Are LCV drivers required to receive additional training?	80	87	20	13

Another survey question asked respondents to indicate their opinion about the potential impacts if LCVs are allowed on all highways. Respondents indicated whether the impact would increase, slightly increase, slightly decrease, or decrease. Table 5-6 summarizes the responses from all respondents. For each row, the percentages sum to 100. Most impacts are expected to slightly increase or slightly decrease.

Table 5-6. Potential Impacts if LCVs are allowed on all Highways: All respondents.

	Percent of Survey Responses			
Impact	Increase	Slightly increase	Slightly decrease	Decrease
Fuel usage by trucks	10.45	14.09	51.82	23.64
Number of trucks on the road	5.91	6.82	62.73	24.55
Level of safety on the highway	6.36	35.00	35.45	23.18
Cost for truck drivers	5.00	17.27	64.09	13.64
Cost for pavement construction and maintenance	23.18	37.73	35.45	3.64
Pollution	5.91	7.73	70.45	15.91
Cost of Consumer Products	0.909	9.545	80.909	8.636
Climate change concerns	3.18	15.45	72.73	8.64
Cost to businesses	3.18	6.36	70.45	20.00
Highway congestion	7.73	16.36	65.00	10.91
Infrastructure damage	20.00	40.00	35.45	4.55
Chance of auto/LCV crash compared to auto/semi-truck crash	25.00	58.18	14.09	2.73

Further analysis focused on determining if there are any significant differences among respondents who often or sometimes (OS) drive in traffic with LCVs compared to respondents who rarely or never (RN) drive in traffic with LCVs. Table 5-7 summarizes the responses amongst the two groups. Analysis showed differences in the opinions of the OS and RN groups about whether allowing LCVs would cause the impacts to increase or decrease. The analysis looked at the differences in the percent of respondents who expected the impacts to increase, slightly increase, slightly decrease, or decrease. Figure 5-2 shows the means comparison chart for the differences between the OS and RN columns for each level of impact increase or decrease. The mean difference between the OS and RN sub-columns for increasing impacts is negative means that drivers who rarely or never drive in traffic with LCVs believe that allowing LCVs will increase the impacts more than drivers who often or sometime drive in traffic with LCVs. The mean difference between the last two sub-columns is positive meaning that more drivers who often or sometimes drive in traffic with LCVs than drivers who rarely or never drive in traffic with LCVs, believe the impacts will decrease if LCVs are more widely allowed. An ANOVA indicated the differences among the means for the difference between the OS and RN sub-columns are significant at the 95 percent confidence level.

Table 5-7. Potential Impacts if LCVs are allowed on all Highways: Comparison of respondents who often or sometimes drive with LCVs vs. those who never or rarely drive with LCVs.

	Percent of Survey Responses							
	Increase		Slightly increase		Slightly decrease		Decrease	
Impact	OS	RN	OS	RN	OS	RN	OS	RN
Fuel usage by trucks	10.34	10.58	12.93	15.38	50.86	52.88	25.86	21.15
Number of trucks on the road	3.45	8.65	7.76	5.77	62.93	62.50	25.86	23.08
Level of safety on the highway	8.62	3.85	34.48	35.58	30.17	41.35	26.72	19.23
Cost for truck drivers	3.45	6.73	18.10	16.35	65.52	62.50	12.93	14.42
Cost for pavement construction and maintenance	25.00	21.15	36.21	39.42	36.21	34.62	2.59	4.81
Pollution	4.31	7.69	7.76	7.69	71.55	69.23	16.38	15.38
Cost of Consumer Products	0.862	0.962	9.483	9.615	80.172	81.731	9.483	7.692
Climate change concerns	3.45	2.88	12.93	18.27	72.41	73.08	11.21	5.77
Cost to businesses	0.86	5.77	6.90	5.77	71.55	69.23	20.69	19.23
Highway congestion	6.03	9.62	14.66	18.27	68.97	60.58	10.34	11.54
Infrastructure damage	19.83	20.19	38.79	41.35	35.34	35.58	6.03	2.88
Chance of auto/LCV crash compared to auto/semi-truck crash	26.72	23.08	55.17	61.54	14.66	13.46	3.45	1.92

The analysis looked for specific impacts opined to be significantly difference between the two groups. Figure 5-3 shows the plots of the individual differences between the mean OS and RN responses for each potential impact. As shown, the ANOVA identified two statistical outliers among the impacts being opined to slightly decrease. The first is level of safety on the highway. A significantly larger percent of the RN respondents than OS respondents opined that safety on the highways would slightly decrease if LCVs are allowed. The second outlier is related to highway congestion. Significantly more OS respondents than RN respondents opined that highway congestion would decrease slightly if LCVs are allowed on all highways.

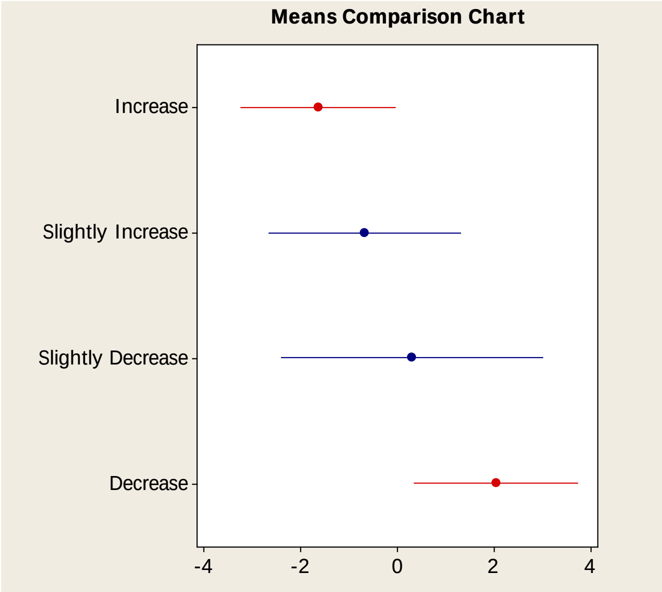

Figure 5-2. Chart. One-Way ANOVA of Difference between OS and RN Respondent Groups.

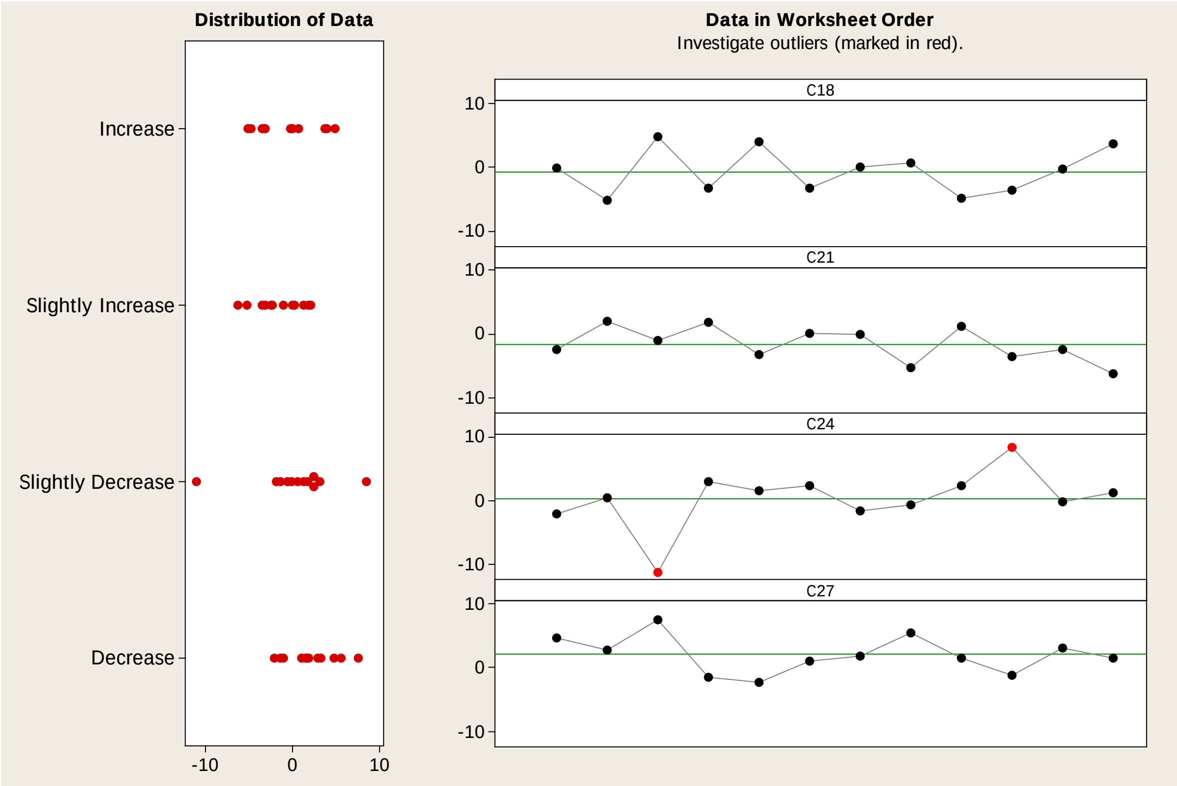

Figure 5-3. Chart. ANOVA Diagnostics Showing Outliers for Comparison of OS and RN Respondent Groups.

5.4 *Discussion*

Overall, the survey results indicate the public has a good understanding of LCV issues. Specifically, research suggests the public expects to see decreases in fuel usage by trucks, number of trucks on the road, costs for truck drivers, pollution, costs of consumer products, climate change concerns, costs to businesses, and highway congestion.

However, in terms of safety, public opinion predicts an overall decrease in safety and increased probability of a collision when travelling with LCVs. This is not surprising. Current research does not validate these conclusions (current research is limited and inconsistent on safety outcomes). In terms of pavement costs and maintenance and overall infrastructure damage, the public predicts a slight increase. Therefore, if policy for expanded LCV use is proposed, it is important to specifically address the topics of safety and infrastructure during the policy debate process.

The survey also produced a ranking of importance relative to the primary potential outcomes associated with expanded use of LCVs. The most important potential benefits included decreasing fuel use, increasing safety of all vehicles on the road, and decreasing pollution. Therefore, advocates for expanding LCV use would be well served to focus on these potential benefits for society when explaining the policy to the public.

Additionally, analysis indicated there is a difference in how respondents from an LCV states and non-LCV state prioritize three potential policy benefits (creating cost savings for consumers, fighting climate change, and reducing congestion). Also, analysis showed differences in the opinions about the impacts of expanding LCV travel between groups of respondents who have or not experience driving in traffic with LCV vehicles.

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Chapter 6 – Conclusions

6.1 Conclusion

The net benefits projected in this study's cost-benefit analysis, along with private and public industry input, indicate that serious consideration for the expansion of LCV operations is warranted. Cutting costs to move freight is a savings that can be passed onto the consumer and keep U.S. goods competitive in a global market. Cost savings and reducing greenhouse gasses are sufficient reasons to repeal the ban on expanding LCV use. Using longer combination vehicles to move freight more competitively and with fewer environmental impacts is a step in the right direction.

Current research also suggests that safety, the primary concern associated with all highway travel, is the most pressing concern for the motoring public. Therefore, policy that opens up routes that can efficiently and safely serve LCVs should be formulated and submitted for debate.

6.2 Further Research

As noted above, the research team has determined that specifically investigating the effect of LCVs on highway safety is necessary. While research has been completed in this area, it is inconclusive at best. Ultimately, the lack of definitive evidence to suggest that LCVs are as safe or safer than standard tractor and semitrailers may prevent future expansion of LCV operations.

Additionally, as noted in the conclusion, if LCV operations are allowed to expand, investigation of the most efficient routes by carriers will be necessary. This route network would need to meet minimum criteria for length of haul, turning radii, and similar characteristics.

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Chapter 7 – References

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Appendix A – Literature Review Summary

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Appendix A – Literature Review Summary

Source	Conclusion
LESS SAFE	
Forkenbrock, D.J. and P.F. Hanley. "Fatal Crash Involvement by Multiple-Trailer Trucks." Transportation Research Part A Policy and Practice, 2003, 37:5, p 419-433.	"the AID analysis shows substantial differences of up to 60% between the most and least likely circumstances for fatal crash involvement by multiple-trailer trucks. The additive MCA analysis corroborates these findings, showing conditions with relatively high involvement to include darkness; snow, slush, or ice on the road surface; involvement of three or more vehicles, indicating at least a moderate traffic volume; and higher-speed facilities with 65–75 mph limits. Overall, the MCA model predicts that under certain conditions, multiple-trailer trucks are heavily represented in fatal crashes."
Hanley, P. F. and D. Forkenbrock. "Safety of Passing Longer Combination Vehicles on Two-Lane Highways." Transportation Research Part A: Policy and Practice, 2005, 39:1, p 1-15.	"A safety issue related to LCVs operating on two-lane highways is the potential risk to occupants of vehicles overtaking LCVs. To help assess the added risk of passing a longer vehicle, we developed a passing model that takes into account different performance levels of overtaking autos, varying levels of aggressiveness of drivers, volume of oncoming traffic, and lengths of vehicles being overtaken. We conclude that with moderate oncoming traffic, the odds of failure to pass a 120 ft LCV versus a 65 ft standard truck are about 2–6 times greater."
SAFER	
Scientex Corporation. Accident Rates For Longer Combination Vehicles, 1996. In: The American Trucking Associations. The Case for More Productive Vehicles (MPVs).	"the study found the following accident rates (expressed in crashes per million miles traveled): Single tractor-trailers: 1.93, Double 28' trailers (non-LCV):1.70, Rocky Mountain Doubles (48' + 28'): 0.79, Turnpike Doubles: (e.g. 48' + 48'): 1.02, Triples: 0.83."
Smid, Michael J., Statement to the House, Subcommittee on Highways and Transit Committee on Transportation and Infrastructure. Truck Weight and Lengths: Assessing the Impacts of Existing Laws and Regulations, Hearing July 9, 2008. Available at: http://www.truckline.com/Newsroom/Testimony1/Hearing%20on%20Truck%20Weights%20and%20Lengths%20-%20Michael%20J%20Smid.pdf	"A study conducted by Trialpha Consulting (2000) noted the Saskatchewan Special Haul Programs fleet (that includes LCVs) had a collision rate of 0.15 collisions per million vehicle kilometers -- one-fifth of the provincial average for a traditional fleet. At the collision rates noted, and the annual number of kilometers traveled each year, this was estimated to save 18 truck collisions per annum."

Source	Conclusion
Woodrooffe, J. "Long Combination Vehicle (LCV) Safety Performance in Alberta 1999 to 2005", 2007.	LCVs as a group had the best safety performance of all vehicle types with 25 collisions per 100 million vehicle-kilometers traveled (VKT) on the LCV network. The collision rates for other vehicle types in descending order of performance were: tractor semitrailers—42 collisions per 100 million VKT, legal-length tractor doubles—44 collisions per 100 million VKT, passenger vehicles—83 collisions per 100 million VKT, and straight trucks and bobtails—123 collisions per 100 million VKT. • Turnpike doubles had the lowest collision rate of all individual vehicle types (16 collisions per 100 million VKT), followed by Rocky Mountain doubles (32 collisions per 100 million VKT). The collision rate for triple trailer combinations was 62 collisions per 100 million VKT.
Jonathan D. Regehr, Jeannette Montufar, Garreth Rempel. Canadian Journal of Civil Engineering. "Safety performance of longer combination vehicles relative to other articulated trucks", December 20, 2008. Available from: http://www.nrcresearchpress.com/doi/full/10.1139/L08-109	"[…]LCVs operating in Alberta in this period provided increased freight productivity and reduced the number of collisions that would have occurred if standard configurations had been used to haul the same freight."
Lemp, J. D., K. Kockelman and A. Unnikrishnan. "Analysis of large truck crash severity using heteroskedastic ordered probit models." Accident Analysis and Prevention, Jan 2011, 43:1, p 370-380.	"Results suggest that the likelihood of fatalities and severe injury is estimated to rise with the number of trailers, but fall with the truck length and gross vehicle weight rating (GVWR). While findings suggest that fatality likelihood for two-trailer LCVs is higher than that of single-trailer non-LCVs and other trucks, controlling for exposure risk suggest that total crash costs of LCVs are lower (per vehicle-mile traveled) than those of other trucks."
NO DEFINITIVE CONCLUSION	
Braver, E.R., P.L. Zador, D. Thum, E.L. Mitter, Baum H.M. and F.J. Vilardo. "Tractor-Trailer Crashes in Indiana: A Case Control Study of the Role of Truck Configuration." Accident; Analysis and Prevention, 1997, 29:1, p 79-96.	"Because truck configuration was highly associated with driver age and work operation attributes among trucks in crashes, the absence of control data on these potential confounders precluded definitive assessment of the intrinsic risk of multiple versus single-trailer vehicles."
Craft, R. "Longer Combination Vehicles Involved in Fatal Crashes, 1991-1996." In Proceedings of the 6th International Symposium on Heavy Vehicle Weights and Dimensions, Saskatoon, Sask., June 18-22, 2000. Edited by C.L. Borbely, p 59-68.	"Based on the data presented in this brief, no conclusions can be made on the relative safety of LCVs compared to other truck combinations. First, data on mileage driven mentioned above are based strictly on trailer number and length, while the definition of LCV used in this study is based partly on weight. Second, since travel by LCVs is rare, it is difficult to calculate the precise number of miles driven. Similarly, LCV fatal crashes are so infrequent that the number varies greatly from year to year. For example, LCV crashes dropped from 46 in 1992 to 31 in 1993 (down 33 percent), then rose to 43 in 1994 (up 39 percent). Based on the existing data, LCVs do not appear to be considerably more or less safe than other combination trucks. A more definitive conclusion could be reached only after further collection of data and additional analysis."

Source	Conclusion
Luskin, D. M. and C. M. Walton. Report 2122-1, “Effects of Truck Size and Weights on Highway Infrastructure and Operations: A Synthesis Report.” March 2001. Center for Transportation Research, University of Texas at Austin.	“Depending on the study, the LCVs or double-trailer combinations may have crash rates that are slightly lower, slightly higher, or the same as the crash rates for other heavy trucks.”
USDOT 2000, Comprehensive Truck Size and Weight Study, Vol. III: Scenario Analysis, Publication FHWA-PL-00-029 (Volume II), USDOT	“Many past studies have attempted to estimate the singular effect on crash propensity of size and weight differences among various truck configurations, with particular focus on double-trailer combinations, or more specifically longer combination vehicles (LCVs). Their conclusions vary from slightly positive to slightly negative, to no difference. This disparate in findings is explained, in large part, by the different methodologies and data sets used to conduct the various studies.”
NEED FURTHER STUDY	
GAO. “Truck Safety: The Safety of Longer Combination Vehicles is Unknown.” Publication GAOIRCED-92-66, 1992. Government Accounting Office, Washington D.C.	“Most studies contained little specific information on LCVs and therefore reported primarily on non-LCV trucks with twin 28-foot trailers, which are allowed nationwide and have some of the same operational characteristics as LCVs. Thus, the safety of LCVs is still largely unknown.”
USDOT. 2004. Western Uniformity Scenario Analysis: A Regional Truck Size and Weight Scenario requested by the Western Governors’ Association. U.S. Department of Transportation, Washington, D.C.	Triples analysis is conspicuously absent from most prior studies and databases. Obtaining data on Triples travel is difficult since data is collected on tractors and the same tractor can pull either one, two or three trailers depending upon the shipper’s needs
Forkenbrock, D.J. and P.F. Hanley. “Fatal Crash Involvement by Multiple-Trailer Trucks.” Transportation Research Part A Policy and Practice, 2003, 37:5, p 419-433.	“Our research suggests that until better data on comparative crash rates become available, caution should be exercised regarding more extensive LCV use when road surface conditions are not good, traffic is relatively heavy, and flow speeds are high.”
Scopatz, R.A. “Crashes Involving Long Combination Vehicles (LCVs): Data Quality Problems and Recommendations for Improvement.” 2001, Transportation Research Record, 1779.	The report concludes with a series of recommendations for improving the quality of data for crashes involving large trucks and for improving the states’ ability to analyze LCV crashes specifically.

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Appendix B – Additional Details for Cost-Benefit Analysis

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Appendix B – Additional Details for Cost-Benefit Analysis

To calculate the net benefits associated with the use of LCVs, this report compared the use of LCVs on the Ohio Turnpike with a situation in which LCVs were not used. In order to do this, we compared two scenarios; 1) actual tractor trailer travel on the Ohio Turnpike which involves the use of LCVs, and 2) a scenario in which LCVs are not used and are instead replaced with standard tractor trailers. Variables such as fuel costs, equipment costs, emission costs, labor costs, etc. are calculated for each scenario. In the end, the total net benefit is calculated as costs for the "non-LCV" scenario minus costs for the current LCV scenario. In other words, the net benefits are the costs saved when LCVs are used in comparison to the scenario in which they are not used.

Counterfactual Scenario

The Ohio Turnpike supplied 2008 data regarding LCV and standard truck travel on the turnpike. Turnpike Doubles constituted 40,313 trips and 5,705,432 miles. Triples constituted 101,413 trips and 13,641,949 miles. The average trip length was 136.51 miles. There were 7,374,493 truck trips on the Turnpike, and after accounting for the LCV trips, there were 7,232,767 standard truck trips. Using the calculated average trip length, there were 987,363,637 miles driven by standard trucks.

Type of truck	Trips (2008)	VMT (vehicle miles traveled-2008)
Standard	7,232,767	987,363,637
Turnpike Double	40,313	5,705,432
Triple	101,413	13,641,949
Total	7,374,493	1,006,711,018

The equivalent number of trips and miles for the counterfactual scenario assumes Turnpike Doubles use two 48' trailers and Triples use three 28' trailers.

Assuming a foot-by-foot cargo replacement, the additional number of trips required for the counterfactual scenario (non-LCVs) in which only standard trucks carry cargo is number of Turnpike Doubles*(96/53) + number of Triples*(84/53)= 40,313*(96/53) + 101,413(84/53)= 92,024. Assuming trucks are used 260 days a year and make two trips per day, then the number of additional trucks is 177 (92,024/260/2).

Type of truck	Trips	VMT (vehicle miles traveled)
Standard	7,466,517	1,019,273,425

Estimation of Cost Variables

The estimated costs for each scenario were calculated over a twenty year planning horizon. Below are explanations of these costs. The first set of explanations is for the one-time costs. The second set is for the recurring costs. Lastly, fuel costs and benefits were calculated. In the end, the costs and benefits from each of the three sections were used to produce the final estimate.

Three one-time costs were estimated: the cost for tractors, the cost for trailers and the cost of construction for breakdown areas.

Tractor Equipment Cost

In the scenario in which LCVs are employed, 177 fewer tractors are needed. At an estimated cost of $100,000 per tractor, this results in a benefit of $17,000,000.

Trailer Equipment Cost

In the scenario in which LCVs are employed, 13,909-53’ trailers, 155-48’ trailers, and 585-28’ trailers are being used.

The total cost for trailers is (13,909*25,000) + (155*23,500) + (585*20,000)= $363,067,500. In the counterfactual scenario with non-LCVS, 14,359 53’ trailers would be needed with a total cost of 14,359*25,000= $358,975,000. Thus, the counterfactual scenario has a cost savings of $4,092,500 for trailers.

Construction of Breakdown Areas

When LCVs exit onto a highway that prohibits LCVs, they must pull over and “breakdown” their shipment into single trailer loads. According to an engineer at the Ohio Turnpike Authority, the cost to build the current eight separate lots to enable this breakdown was approximately $9,000,000 in year 2011.

Recurring costs associated with either or both scenarios include emissions, labor, training, truck and trailer wear-and-tear, and breakdown area infrastructure and labor costs. Safety, congestion and toll costs were not included as explain in Chapter 3. Equipment salvage values were ignored.

Cost of Emissions

Quantifying emissions is a difficult process considering the variation in emissions between different years, makes, models, and maintenance of heavy duty vehicles. Therefore, the research team used emission factors from the EPA MOVES 2010 model in order to estimate the value of emissions. The benefit of using MOVES emissions factors is that they are expressed in grams per mile (g/mi) as opposed to grams per brake horsepower hour (g/bhp*hr). The research team recognizes that using g/bhp*hr is a more accurate method to estimate emissions but we lacked data on the brake horsepower used on the Turnpike by both LCVs and standard combination vehicles. Therefore, the research team compared the emissions under the LCV case and the non-LCV case to estimate the benefits of LCVs.

Also, the research team took the emissions of the 8b class in MOVES and added 6% to the emissions factors to account for LCVs added fuel consumption. The research team was forced to assume that emissions followed a linear path with fuel consumption because of data limitations. Therefore we had emission factors that were applied to LCV miles and non-LCV miles and then compared over the two scenarios. The research team also chose to use MOVES 8b category because it was primarily comprised on standard combination vehicles as opposed to the 8a category that was primarily enclosed vans.[3] Lastly, the MOVES emission factors that we used did not include SOx and VOCs which will result in an underestimation of the benefits of the LCV scenario as compared to non-LCV scenario.

Another assumption that we made in the estimation of emissions is in the distribution of ages of trucks in the fleet on the Ohio Turnpike. The research team assumed that ages of trucks in the fleet were evenly distributed from the year being analyzed back 20 years. This assumption was necessitated by a lack of data on the actual distribution of the years of the trucks and difference in emission factors depending on the age of the truck. It is unclear how this assumption will impact the analysis, because we are unsure about the actual distribution currently and into the

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[3] "SmartWay 2011 Truck Tool Technical Documentation." US EPA Smartway. Web. 18 Dec. 2011. <http://www.epa.gov/smartway/documents/partnership/trucks/techdoc.pdf>.

future. That being said, if the fleet is older than the 20 year average then the analysis underestimates the benefits from emissions and vice versa.

Lastly, CO_2 was calculated based on the amount of CO_2 produced from a gallon of diesel and then multiplied by the number of gallons burned in each scenario. We assume 100% oxidization of the CO_2 in a gallon of diesel. Also, all values for the social cost of a ton of pollutant were taken from Department of Transportation guidance on applying CBA for TIGER grants. Therefore a metric ton of PM is valued at $285,469[4], a metric ton of NOx is valued at $5,217[5], and a metric ton of CO_2 is valued differently depending on the year.[6]

Driver Labor Cost

Cost of labor was calculated using a per-mile wage for drivers. The wage-per mile varied quite a bit, but after review, a $.38 wage per-mile for driving a standard truck was settled upon. Input from a Carrier representative indicated a higher wage for LCV drivers, but not a significant increase. A 5% increase was used to calculate a $.40 wage-per mile for LCV drivers. The table below summarizes the labor costs between the two scenarios.

Scenario	Wage per mile	Miles	Total cost
LCVs	$.40	1,006,711,018	$382,917,787
Non-LCVs	$.38	1,019,273,425	$387,323,902
		Difference	$4,406,115

Tractor Wear-and-Tear

Wear and Tear on a cab was calculated to be $.225 per mile.[7] More specifically, maintenance is $.11 per mile, $.035 for tires, and $.08 for depreciation. The following table displays the wear and tear costs for both scenarios.

Scenario	Miles	Annual wear-and-tear cost (tractor)
LCVs	1,006,711,018	$226,509,979
Non-LCVs	1,019,273,425	$229,336,521
	Difference	$2,826,542

Trailer Wear-and-Tear

Wear and tear on a trailer was calculated to be $.032 per mile.[8] The following table displays the wear and tear costs for both scenarios.

Scenario	Miles	Annual wear-and-tear cost (trailer)
LCVs	1,006,711,018	$33,276,882
Non-LCVs	1,019,273,425	$32,616,750
	Difference	$660,132

[4] "TIGER Grants | Application Resources | U.S. Department of Transportation." Home | U.S. Department of Transportation. Web. 28 Dec. 2011. <http://www.dot.gov/tiger/application-resources.html>.

[5] ibid

[6] "Social Cost of Carbon for Regulatory Impact Analysis." Interagency Working Group on Social Cost of Carbon, United States Government, Feb. 2010. Web. 1 Dec. 2011. <http://www.epa.gov/oms/climate/regulations/scc-tsd.pdf>.

[7] Wear and Tear estimates derived from: Barnes, G. and P. Langworthy. "The Per-Mile Costs of Operating Automobiles and Trucks." Minnesota DOT, 2003-19 Final Report.

[8] Ibid

Breakdown Cost

When an LCV is leaving a state that allows LCVs and entering a state that doesn't, the truck must convert to a standard single trailer truck. This conversion takes time and resources. A Carrier representative estimated two hours of labor for each LCV trip. Using an estimated $24 per hour wage, the total cost for these breakdowns was $6,802,848 per year.

Maintenance Cost of Breakdown Areas

An engineer at the Ohio Turnpike said that the breakdown areas would require maintenance every four years. The breakdown areas total 423,000 sq. yards with an estimated cost of $3 per square yard every four years for maintenance. Therefore, one maintenance project would cost $1,269,000. These projects are completed five times over the twenty year horizon.

LCV Driver Training Cost

LCV drivers require extra training. This training requires approximately four hours. Using an hourly wage rate of $24, the estimated cost to train a driver is $96. On the Ohio Turnpike, if each driver makes two trips per day, approximately 273 LCV drivers are needed. Therefore, the initial cost for training 273 drivers at $96 per driver is $26,165. Assuming an attrition rate of 50 percent per year, the annual training cost for training is approximately $13,082 in years 1 to 20.

Fuel Costs

The benefits of LCVs in fuel consumption are derived from an LCV burning 6% more diesel per mile as compared to a standard combination vehicle. Similar to emissions, the research team used MOVES 2010 data on heavy duty diesel miles per gallon to calculate the quantity of diesel consumed. We also assumed a uniform distribution of vehicle ages to account for increasing miles per gallon in newer diesel engines. Our analysis used the Annual Energy Outlooks (AEO) estimate for the future of diesel mpg and we assumed that all pre 2007 vehicles had the same mpg rating. This assumption underestimates the benefits of LCVs because the trend has been lower miles per gallon ratings for older vehicles.

Lastly, the research team analyzed three different fuel price scenarios according to the high, low, and reference case in AEO 2011. The research team used the three different scenarios in order to show the range of fuel saving. Also, AEO 2011 forecasts changes in the diesel engine mpg according to proposed increases in minimum diesel mpg regulations. In the event that the regulations are not enacted, the forecasts of future diesel mpg will underestimate the benefits of LCVs.

Fuel Costs over the twenty year horizon were calculated using three sets of predicted prices. One set was a high estimate, another set was a low estimate, and the third set was a midpoint estimate. The table below displays the twenty year fuel cost savings (present worth) when using LCVs relative to the set of fuel predictions that were used and whether it was a 3% or 7% discount rate.

Fuel cost savings over a twenty year planning horizon

	Present worth		
Discount Rate	Mid	High	Low
3%	$109,294,632	$150,452,458	$73,885,510
7%	$79,534,152	$108,711,572	$54,748,365

The table below displays the three sets of fuel predicted fuel cost per gallon over twenty years.

Fuel Cost Predictions[9]

	Prediction Category ($ per gallon)		
Year	Mid	High	Low
2011	$ 3.21	$ 3.62	$ 2.52
2012	$ 3.09	$ 4.06	$ 2.41
2013	$ 3.14	$ 4.27	$ 2.41
2014	$ 3.20	$ 4.41	$ 2.40
2015	$ 3.26	$ 4.56	$ 2.40
2016	$ 3.38	$ 4.67	$ 2.40
2017	$ 3.48	$ 4.80	$ 2.38
2018	$ 3.58	$ 4.93	$ 2.41
2019	$ 3.67	$ 5.04	$ 2.37
2020	$ 3.72	$ 5.21	$ 2.48
2021	$ 3.75	$ 5.30	$ 2.36
2022	$ 3.82	$ 5.37	$ 2.38
2023	$ 3.84	$ 5.46	$ 2.39
2024	$ 3.93	$ 5.50	$ 2.44
2025	$ 3.95	$ 5.60	$ 2.42
2026	$ 3.97	$ 5.59	$ 2.44
2027	$ 4.02	$ 5.62	$ 2.49
2028	$ 4.04	$ 5.69	$ 2.54
2029	$ 4.09	$ 5.76	$ 2.53
2030	$ 4.05	$ 5.81	$ 2.56

The following table summarizes the cash flow for each scenario. The cash flow for the difference between the scenarios is the basis for computing the total net benefits.

Cost Summary ($2011)

	Scenario		
Variable	**LCV**	**non-LCV**	**Difference**
Purchase 177 tractors in year 0	$0	$17,700,000	$(17,700,000)
Fewer trailers cost savings in year 0	$0	$(4,092,500)	$4,092,500
Construction of breakdown areas in year 0	$9,000,000	$0	$9,000,000
Initial driver training cost in year 0	$26,165	$0	$26,165
Emissions (annual)	$146,039,733	$147,688,570	$(1,648,837)
Driver labor (annual)	$382,917,787	$387,323,902	$(4,406,115)
Tractor wear and tear (annual)	$226,509,979	$229,336,521	$(2,826,542)
Trailer wear and tear (annual)	$33,276,882	$32,616,750	$660,132
Breakdown of cargo (annual)	$6,802,848	$0	$6,802,848
Maintenance cost of breakdown areas (in years 4, 8, 12, 16, 20)	$1,269,000	$0	$,1269,000
LCV driver training cost (annual)	$13,082	$0	$13,082
Fuel costs (annual)			
High	$521,213,734	$527,109,971	$(5,896,238)
Mid	$462,181,239	$467,409,671	$(5,228,432)
Low	$362,833,870	$366,938,433	$(4,104,563)

[9] Component of Selected Petroleum Product Prices, United States. Annual Energy Outlook 2011 <http://www.eia.gov/oiaf/aeo/tablebrowser/#release=AEO2011&subject=9-AEO2011&table=70-AEO2011®ion=1-0&cases=lp2011lno-d022511a,hp2011hno-d022511a,ref2011-d020911a>.

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Appendix C – LCV Survey

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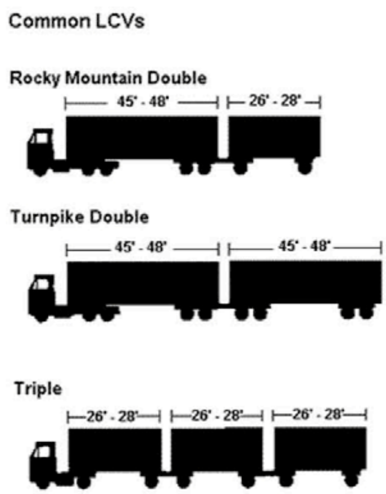
Appendix C – LCV Survey

WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

Recently there has been discussion about policy changes that would allow for the travel of Long Combination Vehicles (LCVs) in all states throughout the US. Specifically, LCVs are trucks that have more than one trailer attached to them. Common examples are shown below.



Listed below are 9 possible benefits of policies that allow the use of LCVs. Using the slider scales, please indicate what you feel like is the percentage importance of each benefit.

Remember, the total cannot exceed 100.

	0	10	20	30	40	50	60	70	80	90	100	
Increasing safety of all vehicles on the road												0
Decreasing fuel use												0
Creating cost savings for truck drivers												0
Reducing government costs												0

Decreasing pollution	0
Creating cost savings for consumers	0
Fighting climate change	0
Creating cost savings for businesses	0
Reducing congestion	0
Total:	0

What state do you live in?

How often do you drive on highways with LCV trucks?

- Never
- Rarely
- Sometimes
- Often

Are LCV drivers required to have a good driving record?

- Yes
- No

Are LCV drivers required to receive additional training?

- Yes
- No

Please indicate what you feel would happen if LCVs were allowed on all highways in the country.

	Increase	Slightly increase	Slightly decrease	Decrease

Fuel usage by trucks	○	○	○	○
Number of trucks on the road	○	○	○	○
Level of safety on the highway	○	○	○	○
Cost for truck drivers	○	○	○	○
Cost for pavement construction and maintenance	○	○	○	○
Pollution	○	○	○	○
Cost of consumer products	○	○	○	○
Climate change concerns	○	○	○	○
Cost to businesses	○	○	○	○
Highway congestion	○	○	○	○
Infrastructure damage	○	○	○	○
When traveling next to a LCV rather than a semi-truck, the chances of an accident...?	○	○	○	○

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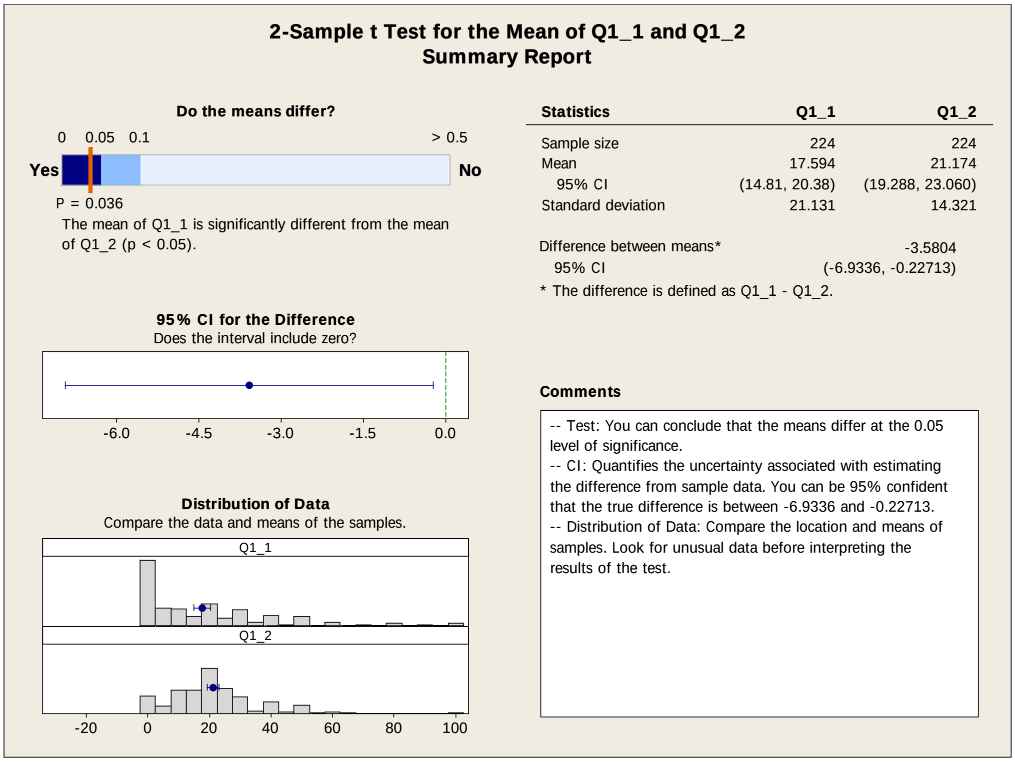
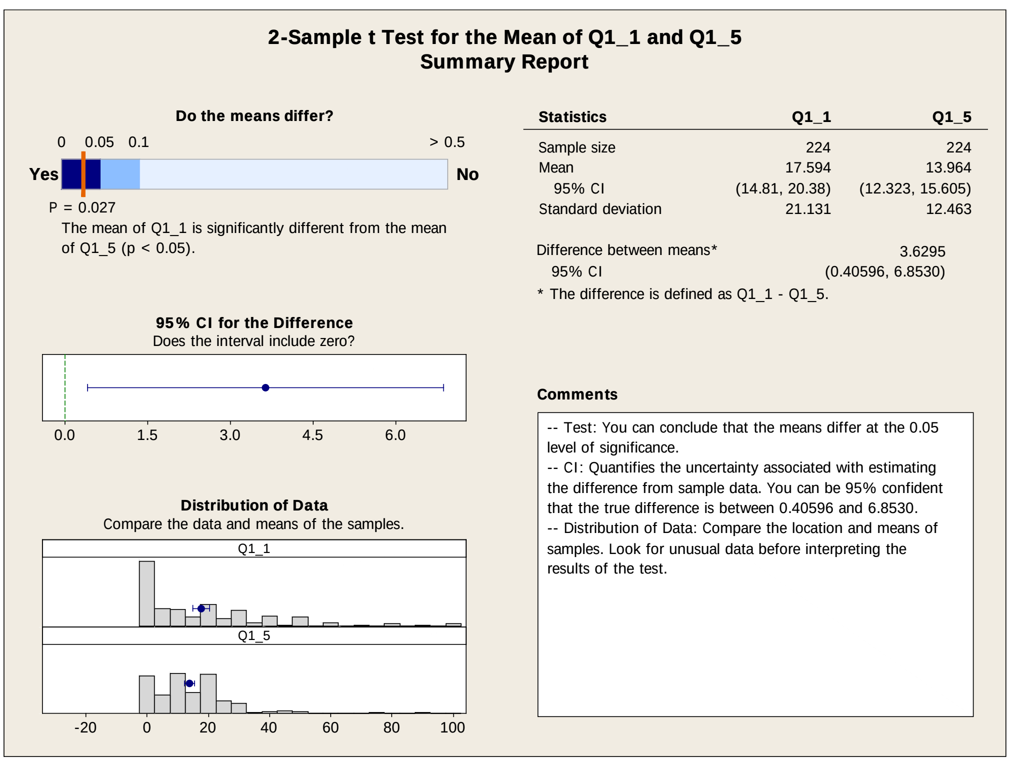
To supplement the analysis shown in Chapter 5, the researchers used One-Way ANOVA tests and 2-Sample t-tests for the Mean to determine the rank order of potential policy benefits of using LCVs

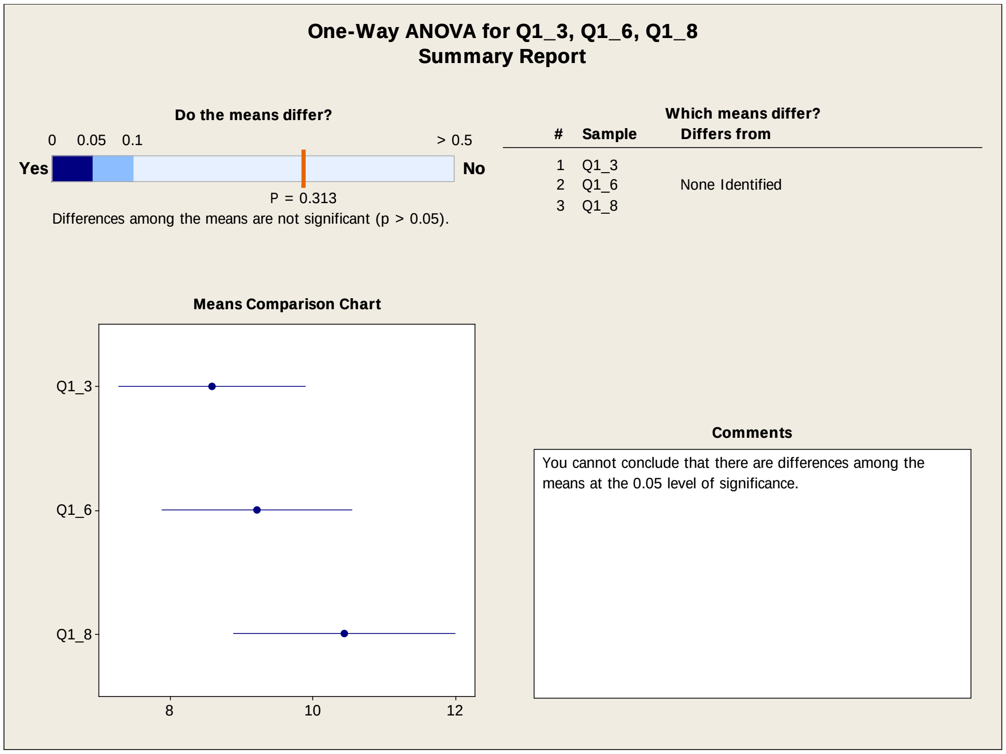


The analysis shown in the figure to the right indicates a significant difference between two policy benefits. Q1_1 is "Increasing safety of all on the road" and Q1_2 is "Decreasing fuel use". The survey respondents prioritizes "decreasing fuel use" significantly higher than "Increasing safety of all on the road".

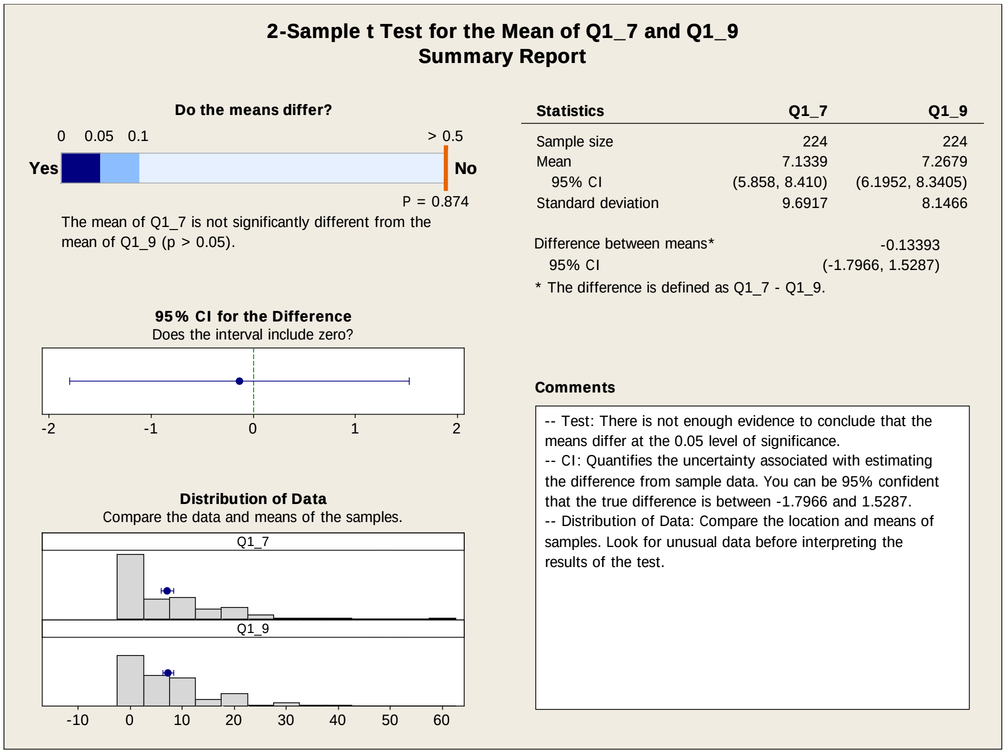


The figure to the left shows a significant difference between the policy benefits, Q1_1 "Increasing safety of all on the road" and Q1_5 "Decreasing pollution". The survey respondents prioritized "Increasing safety of all vehicles on the road" significantly higher than "decreasing pollution".

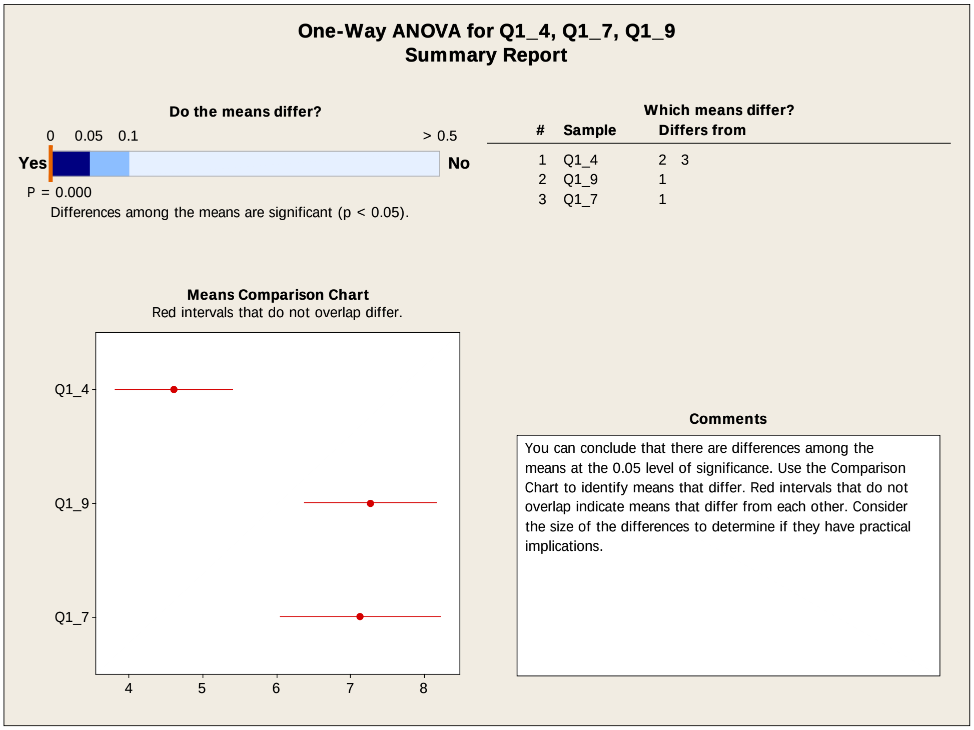
The analysis shown in the figure below indicates no significant difference between the three policy benefits. Q1_3 is “Creating cost savings for truck drivers,” Q1_6 is “Creating cost savings for consumer”, and Q1_8 is “Creating cost savings for businesses”.



The analysis shown in the figure below indicates no significant difference between the three policy benefits. Q1_7 is “Fighting climate change” and Q1_9 is “Reducing congestion”.



The analysis shown in the figure below indicates a significant difference between three policy benefits. Q1_4 is “Reducing government cost”, Q1_7 is “Fighting climate change”, and Q1_9 is “Reducing congestion”. The means of “Reducing congestion” and “Fighting climate change” are both significantly higher than the mean of “Reducing government cost”.



The analysis shown in the figure below indicates a significant difference between two policy benefits. Q1_5 is “Decreasing pollution” and Q1_8 is “Fighting climate change”. The mean priority for “Decreasing pollution” is significantly higher than for “Fighting climate change”.