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A Methodological Framework for Economic Evaluation of Existing Roadway Assets

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A Methodological Framework for Economic Evaluation of Existing Roadway Assets

by

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Abstract

A Methodological Framework for Economic Evaluation of Existing Roadway Assets

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Asset management is an integral part of maintaining and preserving the transportation infrastructure. In order to better manage the roadway assets, a value based on their economic contribution should be assigned. The actual monetary contribution a roadway makes to the overall economy can be difficult to quantify. Because of this difficulty, most agencies use asset valuation techniques that are based on construction and material costs, rather than utilization. This proposed study aims to establish a framework to quantify the economic value of existing roadways. Traditionally in transportation asset management, economic evaluation research has been mostly qualitative in nature and insufficient in generating a numerical value. Although there are many techniques to project the economic impact of a future roadway, there has not been much work done on evaluating the economic value of existing roadway infrastructure. In this thesis, some of the tools used in economic impact studies are adopted as a means to evaluate the value of existing roadways, leading to the development of comprehensive methodological framework as a guide to perform economic evaluation on existing roadways.

Table of Contents

List of Tables

List of Figures

1. INTRODUCTION

America's economy hinges on the overall efficiency of the roadway network. Everything we do revolves around having the mobility to perform our daily activities and transport various goods. America's roadway network influences businesses, education, health-care, jobs, recreation, and government services by providing the links to perform the necessary functions. The return of investments in roadway infrastructure is difficult to quantify, but generally accepted to be vital to the nation's economic success. U.S. businesses and individuals earn over $788 billion in direct economic benefits from roadways and public transportation (Shapiro 2003). About $474 billion of this total amount is simply from time savings to and from work. The rest is through lower costs and increased productivity based on roadway efficiency (Shapiro 2003). In comparison, the cost of taking care of these roadways is only $185 billion, creating a benefit to cost ratio of over 4 to 1 by direct benefits alone. It is clear that roadway infrastructure has a tangible benefit on a macro scale, but what about on a smaller scale? How much is a single roadway worth?

It is difficult to assess and quantify the economic benefit of existing roadways, especially when it comes to the impact on the economy of a localized area. Roadways have a variety of different types of impact, whether it be connecting commuters to their business, allowing freight to travel with the highest mobility, or connecting major cities and allowing services that provide "just in time" delivery. In this thesis, a framework will be put in place to assess such economic values using available traffic and economic data. This framework can be used as a basis of comparison for asset management.

1.1 MOTIVATION FOR RESEARCH

Economic prosperity relies heavily on the efficiency of adequate transportation infrastructure, which facilitates the movement of people and goods. Millions of tons of goods are transported each year. In addition, millions of Americans commute to and from work each day by car. Roadways have an astounding impact on our daily lives and ability to function. It is generally known that the more a roadway is used, the higher the impact it has on the overall economy. Despite a general consensus on this principle, most asset valuation techniques fail to capture the value generated by the utilization of the roadway. A more comprehensive economic evaluation technique to measure economic impact is needed to capture the value of roadway utilization.

1.2 SIGNIFICANCE OF RESEARCH

The research developed in preparation of this thesis represents a synthesizing of economic impact analysis and asset valuation techniques. There are a variety of methods used to describe and quantify the economic impact of roadways being built. The factors used to represent the economic impact of future roadways were applied to capture the economic impact of existing roadways. This includes using data available to most state DOTs to convey the utilization of roadways and the economic value of that utilization. A methodological framework was established that allows agencies to quantify the economic value of existing roadways according to their own set of strategic goals. The framework is flexible to provide easy adaption on large networks and based on local conditions.

1.3 THESIS ORGANIZATION

The remainder of this thesis is organized into 5 chapters. Chapter 2 includes the background information regarding the concept of economic evaluation, asset valuation, economic development, and economic impact. Chapter 3 lays out a methodological framework for economic evaluation of existing roadways. This chapter includes the factors needed for evaluation and sets the guidelines in applying the framework. The methodology includes the economic impact factors used to represent both direct and indirect economic impact, the significance in comparing individual economic factors, and a guide to applying appropriate weights to each factor.

Chapter 4 addresses the formulation used to capture each economic impact of existing roadways. The formulas were developed to best capture the value in utilization and production. Next, Chapter 5 represents a case study that applies the methodological framework to a theoretical case study. The case study represents a common asset management dilemma, which is the question of which roadway should receive preventive maintenance on a limited budget based on economic value. After the case study is analyzed, conclusions, implementation strategies, and recommendations for future work are discussed in Chapter 6.

2. BACKGROUND

Economic evaluation of roadways is an essential component in the process of efficiently managing roadway assets. It allows highway agencies to perform maintenance and rehabilitation in the most efficient and least invasive ways possible. The difficulty lies in conducting a quantitative estimate of the roadways value. As a result of this difficulty in quantifying the economic value of an existing roadway, a variety of asset valuation techniques have been applied to roadway networks.

2.1 TRADITIONAL ASSET VALUATION TECHNIQUES

There are many different types of valuation methods used for asset management. Economic evaluation is often mentioned in literature, but rarely ever applied in practice because of its difficulty to implement. Some of the valuation techniques applied to roadway networks include (Saarinan 2007):

Book Value – This is the value of an asset used in most accounting systems. It is usually the original acquisition cost of a roadway adjusted to the present day value. This includes material and labor cost and is adjusted for depreciation. Book value is the most common valuation technique used for asset management of transportation assets.

Replacement Cost – The cost it would take to a roadway with its condition being identical to the one under evaluation, based on present day labor and material costs. This would be recreating the asset in its exact current condition.

Market Value – The market value is the direct price a buyer is willing to pay. It doesn't apply to roadways very often because most roadways are publicly owned and operated.

Equivalent Present Value – The equivalent present value represents the value "as is". It is based on historic costs adjusted for inflation, depreciation, depletion, and wear. (Zhang, 2013)

Utility Value – The utility value represents the quantitative and qualitative benefit of a roadway asset to the user. It is the value derived from usage of a roadway.

The economic value is very similar to the utility value. It is a way to measure the benefit of a roadway to the user, while also conveying the benefit to society as a whole. The benefit to users can be categorized as direct or indirect. The direct benefits include factors that roadway users can perceive while utilizing a roadway, such as time savings or comfort. The indirect benefits to users are benefits to the overall system that will benefit both the individual and the economy, but cannot be directly felt by the user.

It is important to understand that asset valuation is a subset of economic evaluation. Asset valuation techniques have been used as a means to compare roadway value, but fail to recognize the monetary economic gains attributed to utilization. Asset valuation often mimics the actual material and construction cost rather than the value added by the roadway asset.

2.1.1 Previous Studies

Though there have been many network corridor and economic impact studies for future roadways, research on economic evaluation of existing roadways has been almost nonexistent. One study, as briefly discussed in the following section, did look at economic evaluation of existing highways in the Appalachian region (Wilbur 1998).

Appalachian Development Highways

The Appalachian Development Highways Economic Impact Study was performed in 1998 to measure the economic success of a large highway project and determine if the project should be seen to completion (Wilbur 1998). The Appalachian Development Highway System (ADHS) was begun in 1965 and about 75 percent complete at the time of the study. The local tax payers had spent over $4 billion on the project, and the study was issued to determine the economic value that could be attributed to the completed portions of the project. A decision on whether the project should be completed would be based on the economic impact of the built highways. To perform this evaluation, several economic factors were considered and a regional economic model was applied to the highways in an unorthodox fashion. Traditionally, economic models are used to predict future economic impacts, but, for the purposes of the study, the model was significantly adjusted to measure the existing economic value of the highways. The study successfully estimated the value of existing highways and lead to the completion of the ADHS.

Network Corridor and Economic Impact Studies

Despite very few studies being conducted on the economic value of existing roadways, there have been a variety of network corridor studies. Bruinsma, Reinstra, and Reitvald studied the economic impact of construction of the A1 highway corridor in the Netherlands (Bruinsma 1997). Boarnet and Chalermpong examined the link between highways and urban development in their study of new highways in California (Boarnet 2001). Forkenbrock and Foster looked at the economic benefits of highway investment (Forkenbrock 1990). Gaegler looked at the economic effects of the Connecticut Turnpike (Gaegler 1975).

The economic impact evaluation of new projects has been common and spanned over many decades. Adler (Adler 1971) provided a comprehensive manual of case studies dealing with economic appraisal of transport projects back in 1971. Iacono and Levinson (Iacono 2009) looked at the economic impact of upgrading roads in terms of property values. They found for most construction or reconstruction projects, property values were unaffected.

There have been varying perspectives on the relationship between transport and regional development. Voigt found that transport is a crucial factor in economic development and has many positive indirect impacts on the regional economy (Voigt 1973). However, Banister and Berechman came to the conclusion that transport investment does not always lead to economic development, it is dependent on specific regional variables (Banister 1999). The competing viewpoints both acknowledge the importance of regional evaluation and that transport can often play an important role in economic development.

There are many network corridor studies and economic impact studies that provide economic relationships that are important when evaluating roadway assets.

However, most studies have dealt with new construction and investment analysis, rather than roadway assets that have already been built.

2.2 Economic Evaluation

Economic value includes any value contributed by a roadway and added to the economy. Such values include the direct impact the road has on users' mobility and vehicle operating costs, and indirect impact through the movement of goods, provision of services, and labor.

2.2.1 Direct Economic Impacts

Direct economic impacts from roadways traditionally relate to mobility and accessibility. They are the most direct means in which economic impact can be measured. As such, they provide the easiest method of quantifying economic value. There have been many network corridor studies that use mostly direct economic evaluation methods. Most economic evaluations involve quantifying the time and costs saved by a particular roadway. Other costs that are used less often include accident cost, environmental cost, and vehicle operation cost. The time cost can relate to the delay and congestion of a roadway, or simply how much time a particular roadway saves in total system travel time for a network.

2.2.2 Indirect Economic Impacts

Indirect economic impacts are generally economic value added that is not directly seen by the user. For economic evaluation of roadways, indirect economic impact can include the employment added, price of goods and services, tourism, and roadside service businesses (Rodrigue 2013). These factors have an effect on the economic contribution of roadways, but the dollar amount is often difficult to determine. Certain roadways, like interstate highways, are commonly thought to have a much larger economic impact than connector roadways. This is because interstates often have much larger daily passenger vehicle and truck usage.

Many traditional economic evaluation methods fail to address these indirect economic impacts. This can be an egregious error because the transportation costs relating to the direct economic impacts tend to be relatively low compared to the indirect impact on economic processes. Some of the major impacts of transport on these economic processes include (Rodrigue 2013):

- **Geographic specialization** – Geographic specialization refers to the geographic concentrations of industry. Certain roadways favor the process of geographical specialization, which increases productivity and interaction. An example of this is how businesses tend to agglomerate in one area. This increases the economic value of the vital roadways in the geographic area.
- **Large scale production** – Roadway networks and corridors can provide certain connectivity to larger markets that promote mass production. Roadways that connect large market areas, like cities, facilitate production. Thus roadways, like large highways, that connect different markets provide a greater economic impact relating to productivity and distribution.
- **Increased competition** – As the transportation network becomes more efficient, a larger array of goods and services become available to consumers. This tends to reduce costs and create competition among businesses (Rodrigue 2013).

- **Increased land value** – Businesses, especially roadside services, adjacent to roadways tend to have a greater economic value due to the traffic carried by the roadway. For residential areas, the opposite may be true in the case of highways or busy streets.

2.3 ECONOMIC DEVELOPMENT

Economic development refers to increased productivity, employment, income, property values, and tax revenues (Ellis 2013). Economic development relates to many of the indirect economic impacts. In transportation, this economic development can be captured for the evaluation of a roadway in its contribution to productivity, increased competition, and increased labor markets. The following diagram illustrates some of the factors of economic development:

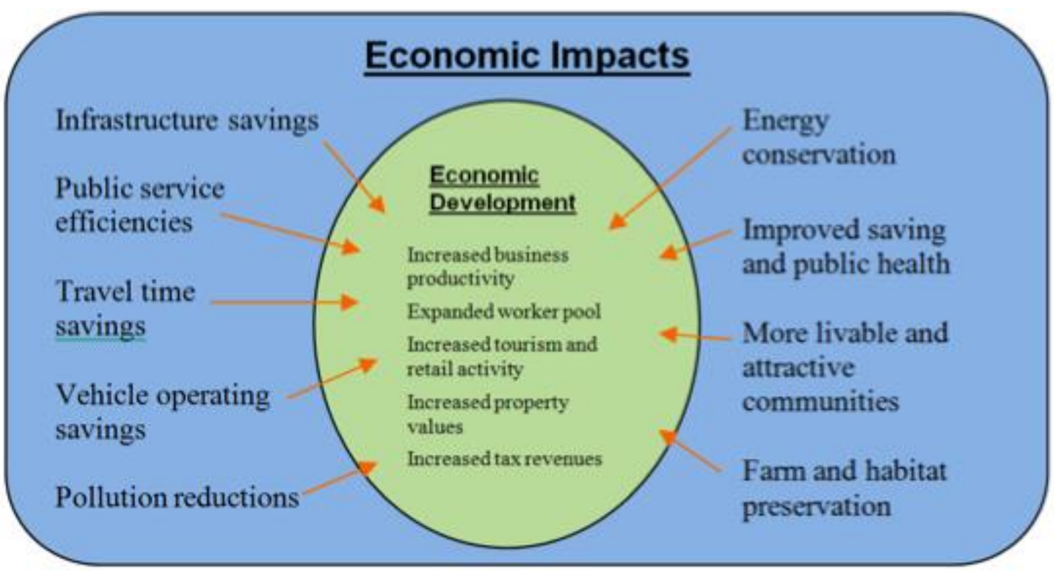

Figure 1: Economic Development of Roadways (Litman 2013).

Most economic development factors are a consequence of direct economic impacts. For example, the direct economic impact of travel time savings occurs along a major highway, while the economic development that occurs from that travel time savings can be seen in increased business productivity as commuters can reach their destination on time. Many of these factors are interdependent of one another. When there is an increase in employment for a region, there is typically also an increase in business competition. Some of the economic development factors include:

Roadside businesses – This comprises all businesses that sell goods and services along a roadway. They cater to the traffic and include gasoline stations, hotels/motels, restaurants, shops, and other businesses. As traffic increases, so do the number of roadside service establishments (Wilbur 1998).

Goods and services – In addition to businesses being located along a roadway, roadways can provide a means for goods and services to travel quickly and efficiently. The value added in this category can be attributed to truck commodity value and increased competition between businesses. There is also the concept of "on time delivery" in which some businesses base their profitability on being able to utilize the roadway network efficiently. Package delivery businesses, such as FedEx and UPS, require the use of roadways in order to profit based on timely deliveries and overall efficiency.

Jobs and competition – Roadways can provide a means for economic development in the region and result in an increase in employment (Whitelegg

1994). The amount of employment along a roadway can reflect its value added to the economy. Roadways can also provide a means to increased competition. As a network becomes more connected, businesses must deal with the users having access to other competitors, creating a more competitive business environment.

The economic value of an asset can be evaluated by capturing these factors quantitatively. A framework can be developed by including certain quantifiable aspects of a roadway that exemplify these factors.

2.4 FACTORS FOR ECONOMIC IMPACT

Defining the factors used to represent economic impact is essential for creating an accurate economic evaluation framework. The factors used must capture both direct and indirect impacts. They also must adequately measure the value generated from utilization of the roadway, movement of goods and services, and added employment.

2.4.1 Direct Economic Impact Factors

The most direct way to quantify the economic value of an existing roadway is by looking at its time savings on a network. In other words, if the roadway did not exist, the additional time that would result on a network in terms of total system travel time. Another technique that can be used to find time savings is computing trip detour times in comparison to regular free flow times. Once the time savings attributed to a roadway is found, it can be used to determine the value added through delay cost, vehicle operating cost, and environmental cost.

Delay cost for a roadway is simply the time savings associated with a roadway multiplied by the value of time. The value of time used for previous studies varies from $10 to $30 per hour. Calfee and Winston studied this value of automobile travel time and how it is adjusted by commuter time (Calfee 1998). This value of time fluctuates based on location and time. For example, users of a roadway in a very low income area may have a low value of time because the average income is close to minimum wage, i.e., $8 per hour, while users of a roadway in a high income area may value time at a much higher level. In addition, the value of time is often higher during rush hour of weekdays because users' time spent in traffic directly affects their work pay and output. On weekends, most users do not have the same time constraints, so the value of time is lower.

The value of time can be separated into two main categories: the first category being the value of time for passenger vehicles and the second being the value of time for truck vehicles. It is generally accepted that the value of time for truck vehicles is higher than passenger vehicles because businesses rely on truck efficiency and on time delivery. Delay has larger monetary value on businesses because of their movement of goods.

Vehicle operating cost is simply the added cost of running a vehicle over a time increment. This cost is associated with fuel and vehicle maintenance. If the time savings a roadway provides is high, users are seeing a direct economic return in the cost of operating their vehicles.

The environmental cost is the cost of the added pollution to the environment based on the time or distance traveled. Vehicles release numerous harmful emissions, including carbon dioxide. As the time savings of a roadway increases, less harmful emissions are released into the atmosphere which pollute the environment.

Some of the direct economic impact factors that are more difficult to quantify include construction, maintenance and rehabilitation, and crash costs. Roadways vary in the cost of construction based on when they were built, materials used, type of roadway, and construction techniques. Roadway maintenance and rehabilitation have a broad range based on agency strategic goals and types of pavement. Crash costs are often based on weather conditions and skid resistance. It is difficult to calculate all of these factors as they relate to the present condition of a roadway.

2.4.2 Indirect Economic Impact Factors

Quantifying the indirect economic value of existing roadways presents a much more difficult challenge. As described in the economic development section, there are a large number of factors that contribute to the economy. Many of these factors overlap as well. For example, a roadway that sees an increase in trucks will not only have increased utilization in terms of goods and commodities, but may serve larger scale production that rely on timely delivery. If the value of goods and commodities are added in addition to added labor, the true economic value may be overestimated.

An important concept to the economic value of a roadway is the overall connectivity of the network. Networks with low connectivity may require users to utilize a single roadway as the only option in reaching a destination, while highly connected networks give users more options in making a route choice. An example of the difference in connectivity is shown in Figure 2. The connectivity of roadways in Austin varies greatly depending on location. The downtown area operates on a grid system, while the surrounding areas often contain tree-like network patterns.

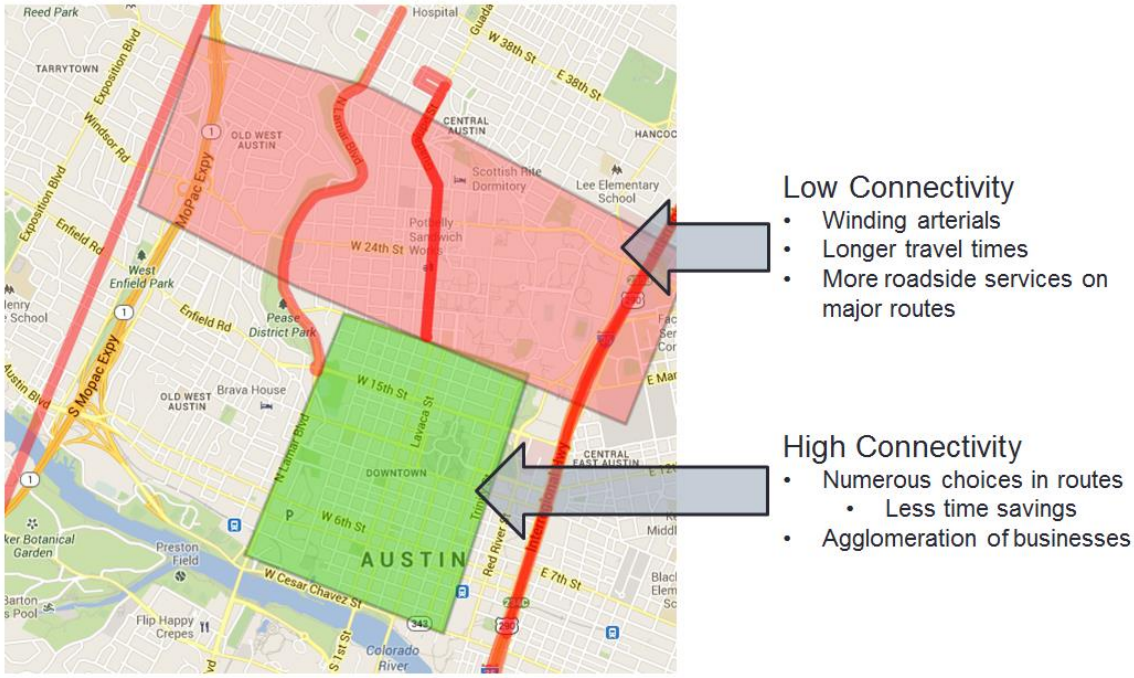

Figure 2: Connectivity of Austin Area.

There are a variety of factors that capture the indirect economic impact of a roadway. These factors are often interdependent and fluctuate with one another. Though the interdependency is very difficult to measure, it can allow some factors to reflect others that are not quantifiable.

Connectivity – As described previously, the economic effects of the different levels of connectivity are very significant. Low connectivity can create higher utilization on major roadways due to the lack of alternative routes. This leads to an increase in roadside services, which rely on accessibility and utilization. A network with high connectivity, on the other hand, has more route choices which lower the time savings associated with an individual roadway. However, high connectivity networks encourage business agglomeration for particular industries because of the higher accessibility and connectivity can often reflect areas with higher employment. Connectivity is a very important concept to consider when analyzing the varying factors that can quantify economic impacts.

Goods and Services – The flow of goods and services on roadways provide a measure of the overall productivity and utility of a roadway. The movement and value of goods and services can be quantified using truck flow for different industries. Truck flow by industry changes by location, with more valuable roadways for goods and services connecting major cities and carrying valuable commodities.

Roadside Businesses – Roadside businesses are services that rely on the utilization of a roadway for economic benefit. Gas stations are particular roadside services that show the value of a roadway by number of stations and agglomeration near important connectors. Other roadside services include hotels, restaurants, and food marts. The value of these roadside businesses can be quantified by assigning an economic value, based on service type, and multiplying by the number of services along a particular roadway.

Added Employment – A roadway can provide a means to connect laborers to their employment and even create employment in the case of drivers and transportation-reliant industries. This factor is also related to the overall utilization of the roadway. Highways usually have higher average annual daily traffic (AADT), which reflects a higher number of commuters. Major businesses that house a large number of employees often pick their location based on accessibility from major highways and large networks. Efficient roadway networks often encourage business agglomeration as well, creating a large increase in jobs for the regional area.

Large Scale Production – The capability of connecting large metro centers and airports gives roadways the added value of large-scale production. This includes transport between major cities and interconnectivity of different transportation assets to carry out mass production. For example, many industries rely on roadways that provide an efficient connection to airports or seaports to transfer goods for on time delivery. Roadways function as part of an overall transportation system and allow business to capitalize on regional, national, or global connectivity.

Tourism – The efficiency and effectiveness of a roadway network can also lead to or contribute to the popularity of tourist areas. Roadways can provide economic benefits to the tourism industry and "big" events. "Big" events include any event that attracts visitors from outside regions, such as the Olympics. An efficient transportation network cannot only enhance the economic returns of tourist destinations, but also can attract large events that require an effective transportation network.

A framework can be developed using some of these economic development factors. The factors used in this framework are by no means an exhausted list of economic contributions. In addition to the factors described, there are alos other factors such as increased competition, fluctuating land value, and logistics. Each of these factors also has an effect on the overall economic value of a roadway, but are much more difficult to quantify on a large scale. For this thesis, some of these factors will be used to capture the direct and indirect economic impacts of roadways.

3. METHODOLOGICAL FRAMEWORK

The methodological framework provides an overview of the major components and the relationships among them for performing economic evaluation on existing roadways, as shown in Figure 3. Economic value is split into two categories, direct impact value and indirect impact value. The direct economic value represents user time savings, while the indirect economic value is representative of the contribution a roadway makes to economic development. Agencies can choose to look at these factors individually, based on regional and project specific needs, or as a whole, as a means to evaluate roadway asset value.

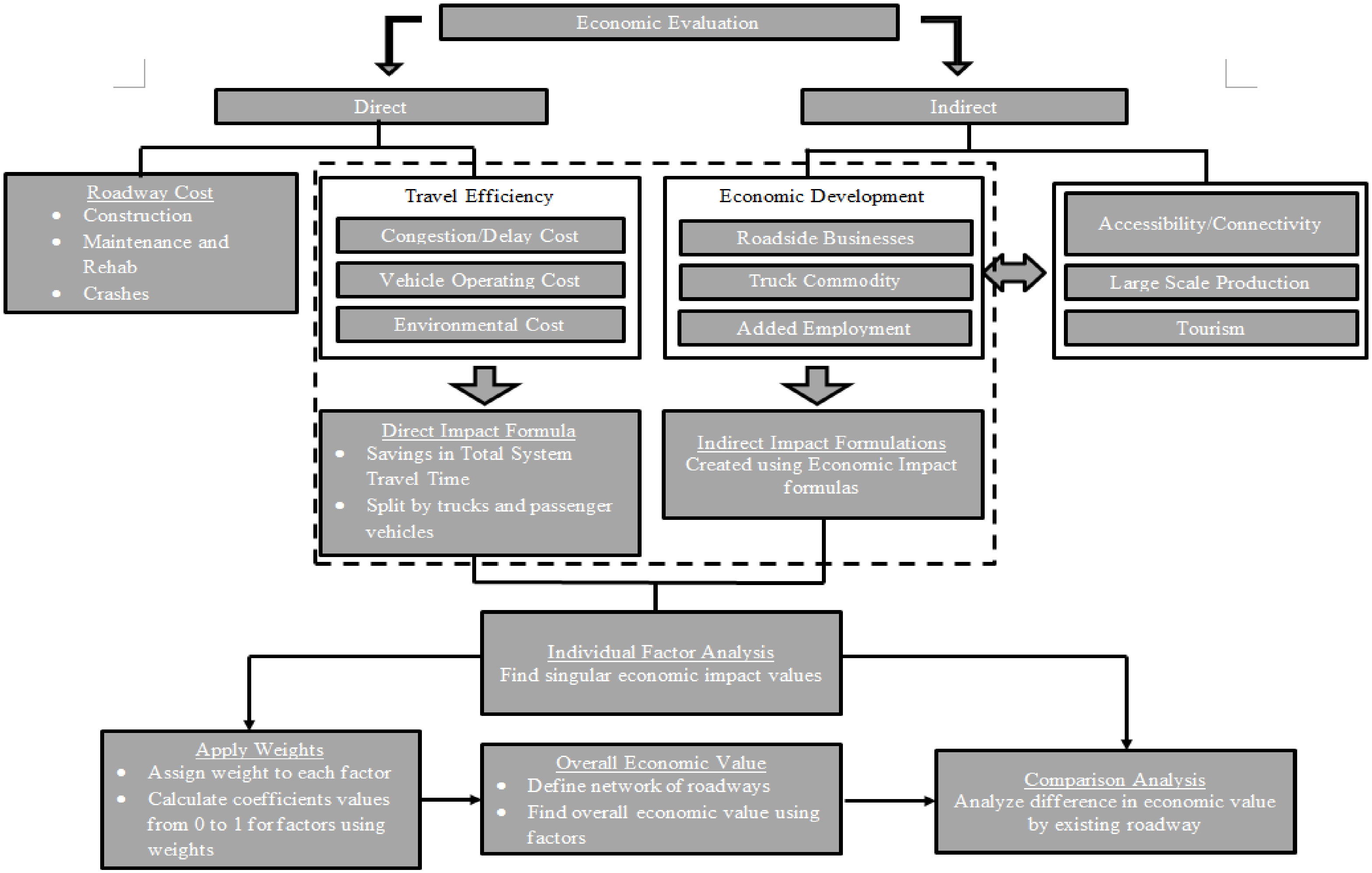

Figure 3: Methodological Framework for Economic Evaluation.

3.1 APPLICATION OF METHODOLOGICAL FRAMEWORK

The framework captures the economic impact of an existing roadway using travel efficiency and economic development factors. Travel efficiency factors represent direct economic impacts, while economic development factors represent the indirect economic impacts.

The factors used for travel efficiency were delay cost, vehicle operating cost, and environmental cost. Each of these factors conveys a direct value of road usage and can be quantified by various agencies. The direct economic impacts of construction, maintenance and rehabilitation, and crashes were not included chiefly because they require large amounts of historical data and may be unavailable to many agencies. They also do not reflect the direct utilization of a roadway, as they are a consequence of physical condition.

The factors included for economic development were truck commodity value, added employment value, and roadside business value. These factors portray the movement of goods and services, added employment, and adjacent business from utilization. Economic development factors that were not used in the framework include accessibility/connectivity, large scale production, and tourism. These factors were too difficult to quantify accurately, and will be explained in the problem solution. Despite not being included directly in the framework, the factors interact and have interdependency with the economic development factors that were included. For instance, a roadway that has significant importance for large scale production often shows an increase in truck commodity flow.

After the factors for economic impact have been defined, formulation for the added value of each factor can be created. The formulation for each factor can be found in the problem solution of this thesis.

The actual monetary value for each factor calculated from formulation can be compared individually or as an overall economic value. If a particular economic impact factor is essential for the local condition, the roadway values for that factor can be compared directly and used for asset management. However, if an agency would like to use a combination of each factor for an overall economic value, relative weights must be applied to normalize the final values. Without relative weights for each factor, truck commodity value would significantly outweigh the economic impact of all other factors.

The final step of the framework is comparison analysis, which represents the asset management portion of the methodology. Decision makers can use the quantified economic values to compare assets for maintenance and rehabilitation projects. Depending on the goals and local conditions, decision makers can weigh the economic factors and use both individual factor analysis and overall economic impact analysis.

4. PROBLEM SOLUTION

In order to find the economic value of roadways, a formulation must be created that incorporates the variety of economic impacts. There has not been a common formula used in previous studies. The formulation must capture both the direct and indirect economic value of roadways.

One of the main difficulties in coming up with the formulation is deciding which economic factors should be included. For this thesis, two basic criteria must be met in order to be included in the formulation. First, the factors must have the ability to be quantified in a timely manner using available data. Timely manner meaning that the data must be simple to find and implement for different agencies so it can be applied to roadway asset networks. Secondly, the factors must adequately capture the utility and economic contributions of a roadway. The economic values will be based on overall utility, businesses adjacent to the roadway, connection to employment, and movement of commodities.

Using this criterion, the factors for economic evaluation used for this thesis are time savings, truck commodity flow, roadside businesses, and added employment. The time savings represents the direct economic impact of roadways, while truck commodity flow, roadside businesses, and added employment represent the indirect contributions in terms of economic development.

The economic development factors have some degree of interdependency with each other in terms of economic contributions. For example, truck commodity flow contributes to added employment and roadside businesses, roadside businesses positively contribute to truck commodity flow and added employment, and added employment positively contributes to truck commodity flow and roadside businesses. To accommodate this overlap resulting from interdependencies in contributions, coefficients were included for each factor that will range from 0 to 1. A coefficient of one would represent a network that has little to no overlap for the specified factor and the two other economic development factors. A coefficient of zero would represent a network where there is complete overlap between the specified economic development factor. This would mean the factor should not be included in the formulation. The amount of interdependency will differ based on location and the agency using the framework; therefore the coefficients are adjustable, based on the needs of the user.

The time savings formulation does not have a coefficient because that is the most direct way to find the economic impact of a roadway. The time savings reflects the utility and efficiency of a roadway.

Some factors briefly discussed in the background are not included in the problem solution because they do not meet the criterion. Tourism is too difficult to quantify and does not have many variables that can represent the data. It also varies greatly depending on the area of study. Connectivity was not included as a factor because it has an impact on many of the other factors. The higher the connectivity of a network, the more route choices are available to the user. This results in lower time savings for a single roadway. In addition, lower connectivity often results in many roadside businesses on the major roadways in a network.

Another factor that effects the economic value of a roadway but was not included is the large scale production contributions. Roadways often provide a connection to airports or between large cities, which can greatly enhance an area's economic output. Despite this being a well-known factor of economic contribution, the amount of the impact is very difficult to quantify. Many businesses rely on the roadways that connect major cities and airports, but the benefit is usually seen in the overall prosperity of the city or regional area. The difficulty in measuring large scale production impacts is in distinguishing the roadways that enhance it and by how much.

4.1 TIME SAVINGS

Time savings measures the amount of time an average vehicle will save by using one roadway over any other roadway. In other words, the time savings is equal to the amount of time that would be added to one's trip if that roadway segment did not exist. The total impact that can be attributed from the time savings is found using three values; value of time (VOT), vehicle operating cost (VOC), and environment cost (EC). The time savings were split into two categories, passenger vehicles (pv) and trucks (t). Trucks have a much more significant impact than passenger vehicles in all three value characteristics. The formulation for the time savings direct economic impact used is as follows:

$$\text{Direct Economic Benefit} = (\text{Time Savings}_{pv})*(VOT_{pv} + VOC_{pv} + EC_{pv}) + (\text{Time Savings}_{t})*(VOT_{t} + VOC_{t} + EC_{t})$$

Value of time is the amount of monetary value placed on a specific amount of time. The value of time varies among users, with people of varying socio-economics and risk aversion having a wide range of value. The value of time also varies from one region to another because of the income associated with the region and culture. For example, in some regional areas and countries it is fine to arrive reasonably late to work. In this instance, the value of time would decrease because businesses are more flexible with users' timeliness. Trucks have a much higher value of time than passenger vehicles because of the concept of on-time delivery. There are often monetary repercussions for trucks that arrive late with deliveries, which cause their value of time on the roadway to increase. In addition, truck drivers are working while on the roadway, while passenger vehicles are usually not working. Value of time is higher while working because it has a direct effect on one's income. The value of time of $12.50 was given for each passenger vehicle and a value of time of $24.70 was given for each truck. These values are based on the suggested values of time that are in use by the U.S. Department of Transportation based on all-purpose travel (Belenky 2009).

Vehicle operating cost is the cost of operating a vehicle over a particular time interval. Time savings results in savings in fuel and maintenance for a vehicle in addition to the user's value of time. The vehicle operating cost is higher for trucks than passenger vehicles because they require more fuel and maintenance. Trucks also use significantly more fuel while idling, which is often associated with congestion. For this report, a vehicle operating cost of $0.205 per mile was attributed to each passenger vehicle and a vehicle operating cost of $0.40 per mile was attributed to each truck (AAA) (Barnes 2003).

The environmental cost is the cost associated with the amount of harmful emissions released into the atmosphere from vehicle exhaust. This cost is usually given in dollars per ton, so it must be adjusted to dollars per minute in order to be applied to the time savings formulation. Trucks use diesel fuel and have lower miles per gallon, so they will have a slightly higher environmental cost than passenger vehicles. For this paper, only CO2 was analyzed for environmental cost. The environmental cost used for trucks is $0.11 per gallon at a value of $10 per ton of carbon, and the environmental cost used for passenger vehicles is $0.10 per gallon. These values were found using Climate Change Emission Valuation issued by the Victoria Transport Policy Institute (2012).

4.2 TRUCK COMMODITY FLOW

Another major factor that conveys the economic value of a roadway is truck flow and its associated movement of goods. This value is indirect because roadways and users usually do not receive any monetary value for utilization, but the net benefit to society is substantial. The value of commodities moving through a roadway can show the value of the roadway asset. For example, highway assets are often associated with a higher value in asset management because they allow commodities to move from one region to another. For this thesis, the value of commodities in truck flow is found through summation of the different commodity types multiplied by the truck flow, as shown in the following formula:

Added Truck Commodity Value = $c_T \ * (Truck\ Flow) \sum_{i=1}^{n} (P)_i \left(\frac{Tons}{Truck}\right)_i \left(\frac{\$}{Ton}\right)_i$

Where,

c_T = Truck coefficient (0 to 1)

$(P)_i$ = Percentage of trucks for industry sector *i*

$\left(\frac{Tons}{Truck}\right)_i$ = Tonnage per truck for industry sector *i*

$\left(\frac{\$}{Ton}\right)_i$ = Dollar value per ton of industry sector *i*

The industry sectors used in this study include fuel oils, gasoline, gravel, coal, nonmetal mineral products, scrap, cereal grains, crude petroleum, machinery, electronics, chemicals, and other. The industry sectors were picked based on ton-miles in Texas. The sectors used come from the freight analysis framework (FAF) data for the state of Texas, which is available through the Federal Highway Administration (FHWA) website. The percentage of trucks in each sector can be found using state freight data from FAF, as was the dollar value per ton. A truck coefficient from 0 to 1 can be applied depending on how much emphasis an agency would like to place on the truck commodity value passing over a roadway. The tonnage per truck can be specified based on the local condition and/or available data, for this case study it was assumed to be 10 tons per truck for each industry sector.

4.3 ADDED EMPLOYMENT

The existence of roadways has been proven to have an impact on job creation and employment rates (Whitelegg 1994). Roadways often have a positive impact on employment, especially in the case of highways, which connect users and businesses from greater distances. It is difficult to capture the economic impact of roadways in terms of job creation and job existence because of the amount of roadway lane-miles and the varying factors that can contribute to job creation. The economic benefit of existing roads must often be traced back to when the road was built and connected to the present state. This process is cumbersome and difficult to perform because of the sheer number of roadways in a network, therefore it was not applied in this framework.

An added employment value is given to roadways based on utilization and overall employment in the regional area. The utilization is represented by the ratio of roadway vehicle-miles traveled (VMT) to the total VMT for the region. The formulation of the added employment value is as follows:

Added Employment Value = $c_E * (\frac{VMT}{Total\,VMT})(OE) * (Average\ Salary)$

Where,

c_E	= Coefficient for employment
(OE)	= Overall employment
$(Average\ Salary)$	= Average salary for local area

The formula captures the utilization of each roadway and relates it to the income generated in the region. It is an estimation and does not reflect an exact contribution to employment.

4.4 ROADSIDE BUSINESSES

The final factor considered in this framework for economic evaluation is roadside businesses. This includes all businesses adjacent to roadways that base their business at least in part on the utilization of the roadway. For example, the profitability of gas stations hinges directly on the number of vehicles that pass adjacent to the station. The formulation for the roadside business added value is as follows:

Roadside Business Value = $c_R \ * \sum_{j=1}^{m} \left(\#of\ roadside\ businesses\right)_j (\$/business)_j$

Where,

c_R	= Roadside business coefficient
$\left(\#of\ roadside\ businesses\right)_j$	= Number of roadside service businesse in type *j*
$(\$/business)_j$	= Value of average business in type *j*

The types of businesses include Retail-Auto, Retail-Food, Retail-Other, Hotel/Acc., Services, and Agriculture/Construction/Manufacturing. These businesses were picked from a set of businesses used in a study by Harrison and Waldman on mitigation of adverse business impacts from construction (Harrison 1998). Each type of business is designated a value based on revenue and number of establishments from the 2007 Economic Census. The data used is for the entire United States, which provides a rough estimate. In reality, the value for each business type can change based on location. For example, a finance company in Manhattan would have a larger average value than a finance company in a lower income area.

4.5 OVERALL FORMULATION

The direct and indirect economic impacts are combined into one formula as a means to compare existing roadway assets. The formula is as follows:

$$
\begin{aligned}
\text{Economic value} &= (\text{Time Savings}_{pv})*(\text{VOT}_{pv} + \text{VOC}_{pv} + \text{EC}_{pv}) \\
&+ (\text{Time Savings}_{t})*(\text{VOT}_{t} + \text{VOC}_{t} + \text{EC}_{t}) \\
&+ c_T * (Truck\ Flow) \sum_{i=1}^{n} (P) i \left(\frac{Tons}{Truck}\right) i \left(\frac{\$}{Ton}\right) i \\
&+ c_R * \sum_{j=1}^{m} \left(\#of\ roadside\ businesses\right) j (\$/business) j \\
&+ c_E * \left(\frac{VMT}{Total\ VMT}\right)(OE) * \left(Average\ Salary\right)
\end{aligned}
$$

The formula can be weighted based on agency preference. The coefficients, representing the relative importance, for each economic development unit can be a value of 0 to 1. This value will change based on an agency's strategic goals and preference towards overlapping economic impact. Relative weights of each direct and indirect impact factor can be assigned to normalize the associated coefficients for each factor. If each coefficient were given a value of 1, the truck commodity flow value would be significantly larger than all the other factors, rendering each other factor insignificant. Therefore it is very important for the framework user to apply weights associated with each factor. In addition to the economic development factors being adjustable, the value of time, vehicle operating cost, and environmental cost can be adjusted based on agency preference and location.

5. CASE STUDY

A case study was necessary to exemplify how the methodological framework could be applied to a real world problem. The framework can be applied to asset management problems in which limited funding allows only a small number of roadway projects to be executed out of a large group of roadways in need of the same treatment. A common example of this type of asset management problem is choosing roadways to perform preventive maintenance on a limited preventive maintenance budget.

5.1 THEORETICAL EXAMPLE

In order to better illustrate the economic evaluation framework, a theoretical analysis was performed using local area roadways. The overall formulation was applied to five roadways as a means to compare their economic asset value. The roadways were each a mile in length as a way to compare similar projects in need of funding. The five roadways used range in usage, type of roadway, and location. Table 1 lists the roadways and their description.

Table 1: Case Study Roadways.

Roadway	Description
Mopac 1	Highway with no roadside business access and low truck flow
Cesar Chavez St.	Urban arterial with low truck flow
Martin Luther King Blvd. (MLK)	Urban arterial with low usage and truck flow
Interstate 35 (I-35)	Highway and access road with high truck flow
South Lamar St.	Urban arterial with low truck flow

Each roadway is located in Austin, Texas. The exact location of each roadway section is shown in Figure 4. As can be seen from the figure, the connectivity of the roadway to the overall network varies by location.

Figure 4: Map of Case Study Roadways.

Each of the roadways was analyzed for time savings, truck commodity flow value, added employment value, and roadside business value. Interstate 35 (I-35) included both the highway and the access roads that run parallel with the highway.

5.2 TIME SAVINGS VALUE

The time savings were determined by creating the shortest path detour around the roadway in consideration and comparing with the free flow travel times. The roadway considered was assumed to require a complete detour during maintenance. The difference between detour path travel time and original roadway travel time determined the time savings. The times were based on free flow because congestion considerations would become too difficult to accurately predict for this study. Creating the shortest path detour was the closest equivalent to shutting down the roadway for maintenance. For other studies, agencies have the ability to find the time savings value by this simple approach or by using traffic simulation software to determine the difference in total system travel time (TSTT). Traffic software calculations for the TSTT can improve accuracy, but require more local traffic data and analysis time. Time savings were split into passenger vehicles and trucks because trucks have lower acceleration, deceleration, and turning times. Based the analysis procedure described, the time savings of each roadway is listed in Table 2. The two highways, I-35 and Mopac, had the highest time savings per vehicle, which is expected as they have much higher speed limits than their surrounding roadways.

Table 2: Time Savings by Roadway.

	Time Savings (min/veh)	
	Passenger Vehicle	Truck
Mopac	2	3
Cesar Chavez	1	1
MLK	3	4
I-35	4	5
South Lamar	1	1

The value of time used for passenger vehicles and trucks were $12.50 and $24.70, respectively. These values were found using U.S. DOT standard values for all purpose travel. The vehicle operating cost and environmental cost in dollars per hour were determined based on vehicle operating cost, carbon emission cost, and speed of the roadway. Passenger vehicles were assumed to operate at 20 miles per gallon, while trucks were assumed to operate at 9 miles per gallon. The tables for these values can be found in the Appendix.

The overall time savings values for each roadway are shown in Figure 6, while the time savings by truck and vehicle is shown in Figure 5. The highways had much higher direct economic value. I-35 had much higher time savings value based on its higher truck flow. MLK had a reasonably high time savings value because of the low connectivity associated with the area around it. If MLK was closed for maintenance, the alternative routes increase travel time more than at Cesar Chavez or South Lamar. Areas with high connectivity and low speeds, like Cesar Chavez and South Lamar, had considerably lower time savings.

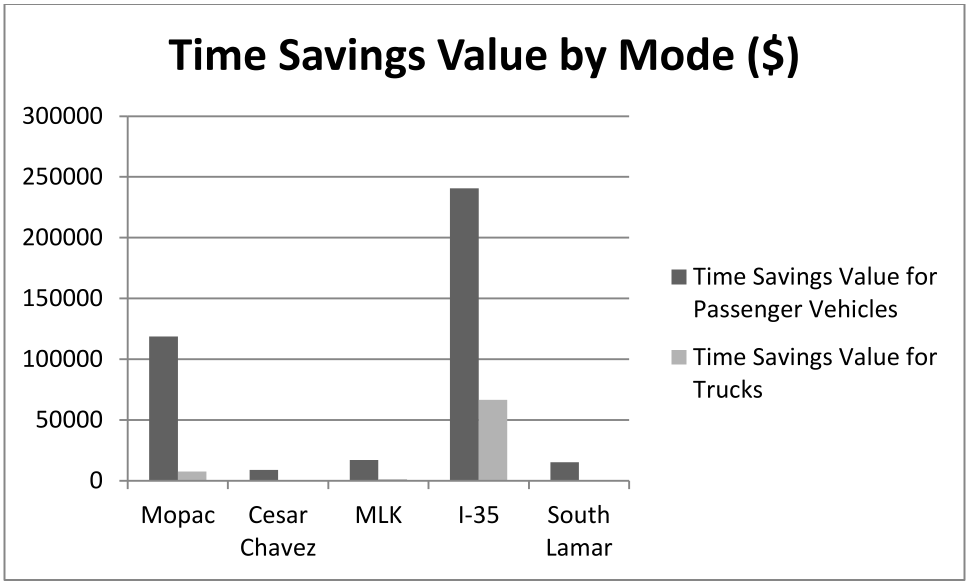

Figure 5: Time Savings Value by Mode.

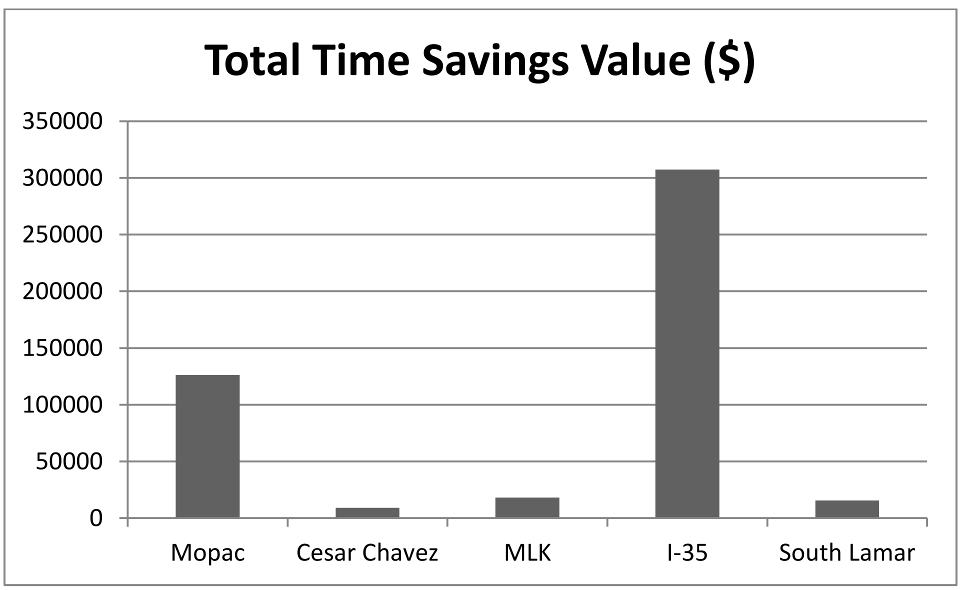

Figure 6: Total Time Savings Value.

Overall the travel time savings coincided well with the Average Annual Daily Traffic (AADT), truck flow, and connectivity of the roadway in the local network. The next step in finding the overall economic value of each roadway was quantifying the indirect economic factors; truck commodity flow value, added employment value, and roadside business value.

5.3 TRUCK COMMODITY FLOW VALUE

The truck commodity flow value was calculated for each roadway using the formulation previously stated. The truck flow was separated into thirteen industry sectors shown in Table 3. Each industry sector was assigned a commodity flow value based on domestic commodity values in Texas found using the Freight Analysis Framework.

Table 3: Commodity Values for Case Study.

Commodity Type	Percent of Truck Flow	Value ($)	Tons	Commodity Value ($/ton)
Fuel oils	12%	33,042,390,000	52,095,590	**634**
Gasoline	11%	59,116,720,000	84,602,820	**699**
Gravel	6%	1,019,430,000	111,198,390	**9**
Coal-n.e.c.	9%	29,588,860,000	36,280,770	**816**
Nonmetal min. prods.	5%	13,327,040,000	106,948,800	**125**
Waste/scrap	6%	5,732,660,000	74,716,520	**77**
Coal	5%	177,370,000	12,787,460	**14**
Cereal grains	5%	8,487,710,000	54,306,730	**156**
Crude petroleum	9%	1,007,000,000	2,228,010	**452**
Basic chemicals	4%	19,778,130,000	21,265,020	**930**
Electronics	1%	50,224,870,000	3,630,030	**13836**
Machinery	2%	114,901,820,000	14,929,930	**7696**
Other	26%	520,705,960,000	356,278,240	**1462**

It was assumed that each truck carried a payload of 10 tons for each industry type. More research needs to be done on payload tonnage by commodity type. For the purpose of this thesis, a broad assumption of 10 tons per truck was made.

The truck commodity flow value was calculated based on the commodity values and truck flow for each roadway. Figure 7 shows the truck commodity flow values. As expected, I-35 had a much higher truck commodity flow value than any other roadway. The value for each roadway mimicked the truck flow because each had the same percent of truck flow associated with the same industry sectors. If roadways being compared for asset valuation were in different regional locations, the industry sectors would vary and create results likely incongruous with truck flow.

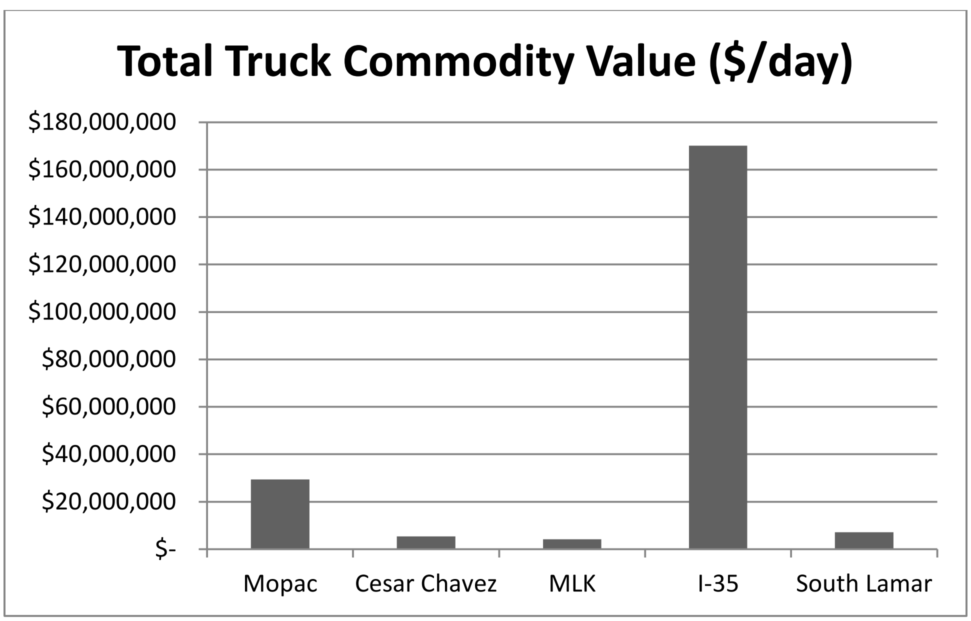

Figure 7: Total Truck Commodity Value.

Another result evident from the graph is that the overall values associated with truck commodity flow are much higher than the amounts from time savings. This can be attributed to the fact that trucks carry commodities of high value. To make up for this large difference in total dollars per day, a coefficient reflecting the relative weight must be applied to the truck commodity value for the amount of weight an agency would like to place on truck commodity value.

5.4 ADDED EMPLOYMENT VALUE

The added employment value was computed for each roadway and can be seen in Figure 8. The values coincided with the AADT of the roadway. Although Mopac had much lower economic value in terms of truck commodity flow, it had comparable value in added employment based on the high number of passenger vehicles.

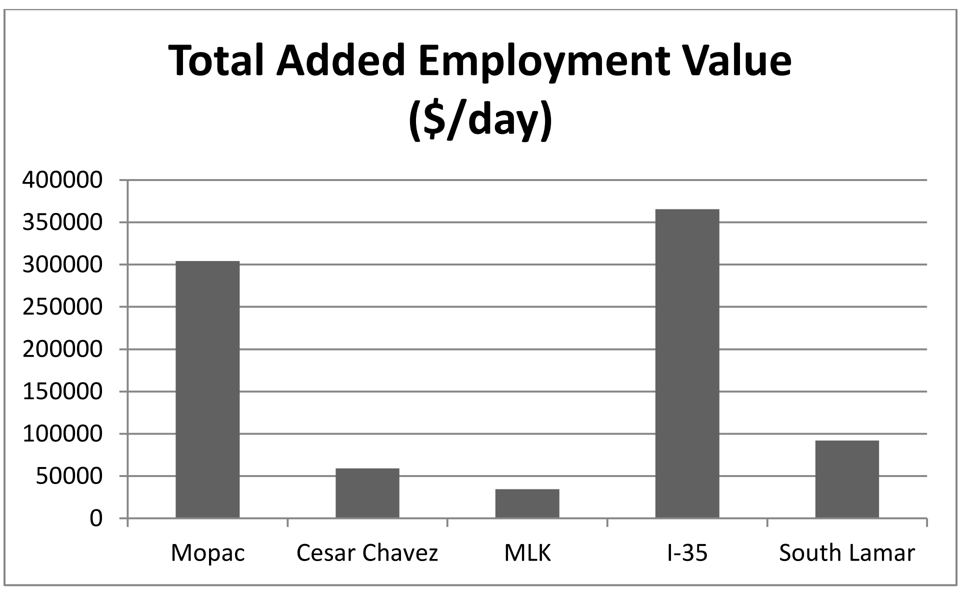

Figure 8: Total Added Employment Value.

5.5 ROADSIDE BUSINESS VALUE

The final indirect economic impact factor evaluated was the roadside business value. Only businesses that rely on traffic flow for revenue were considered. The value placed on each type of business was estimated using 2007 economic census data and can be seen in the Appendix. The roadside business value for each roadway is shown in Figure 9. This result differed the most with the other economic evaluation values. South Lamar had the highest roadside business value based on the large number of retail businesses adjacent to the roadway. On the other hand, Mopac had no roadside business value because no businesses relying on traffic flow lie adjacent to the roadway. It is important to note that the access road for I-35 was included as a part of the highway. The access road is traffic is directly affected by the flow of traffic along I-35. Therefore, the values of businesses along the access road are a direct result of I-35 traffic flow.

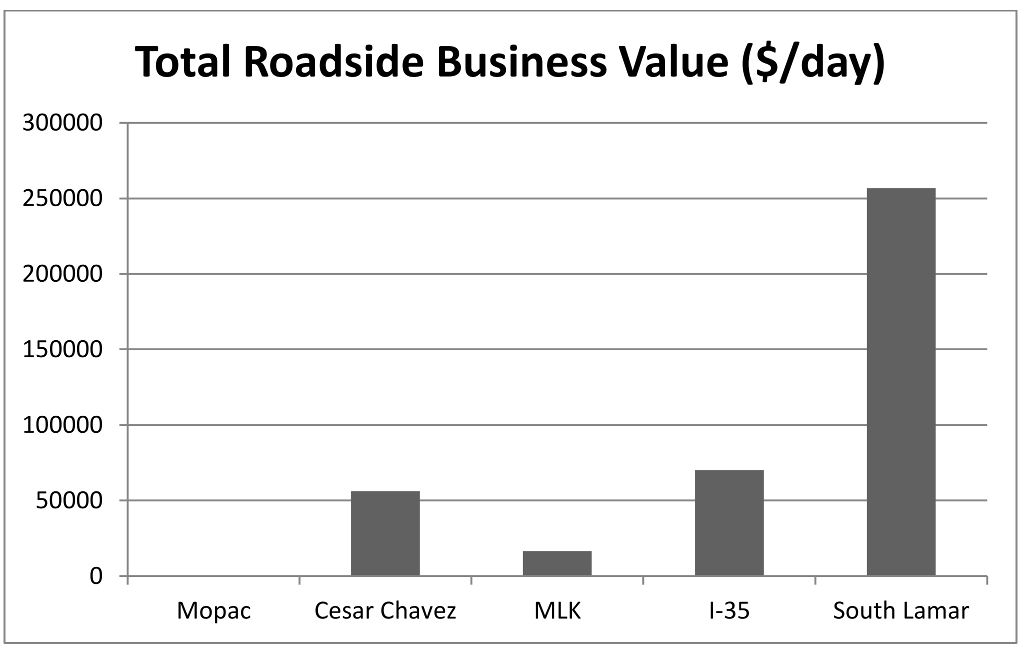

Figure 9: Total Roadside Business Value.

5.6 OVERALL ECONOMIC VALUE

The overall economic value of each roadway was found by adjusting the indirect economic impact values by weight factors. The direct economic impact of time savings was kept with a weight of 1, while each indirect economic impact element was assigned a weight of 1/3, as shown in Figure 10. This was done because without weighting the final monetary results, the economic impact elements, particularly the truck commodity flow value, would significantly overtake the final economic value. By weighting the indirect economic impact elements, each element has equal impact on the final economic value.

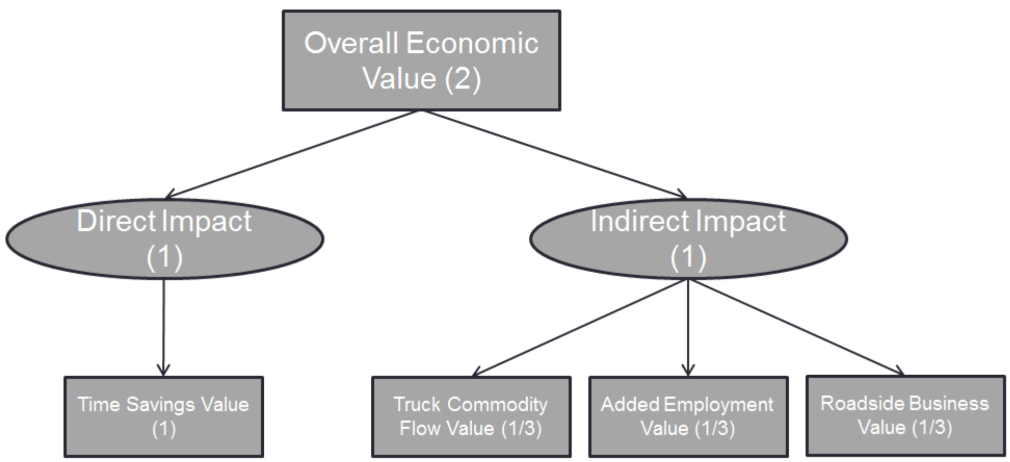

Figure 10: Weight of Economic Impact Factors

By assigning these weights to the overall economic value elements, the coefficients of each indirect economic element were computed. The coefficients serve to normalize the economic values to the relative weights assigned. The coefficients for each element are shown in Table 4.

Table 4: Coefficient Values for Indirect Economic Impact Factors.

Time Savings	1.0000
Truck Coefficient (c_T)	0.0007
Employment Coefficient (c_E)	0.1856
Roadside Business coefficient (c_R)	0.3974

The truck factor must be very low to avoid results skewed to only considering truck commodity flow value when using this framework. The low coefficient for truck commodity flow value is a result of the comparably high monetary values. Multiplying the coefficient by the total amount of truck commodity flow value will return a value that is one-third of the total direct time savings value.

The overall economic value of the roadways coincided with the overall traffic flow of the roadways. The economic values for each roadway are shown in Figure 11. For agency purposes, I-35 would have the highest economic value, followed by Mopac, South Lamar, Cesar Chavez, and MLK, respectively.

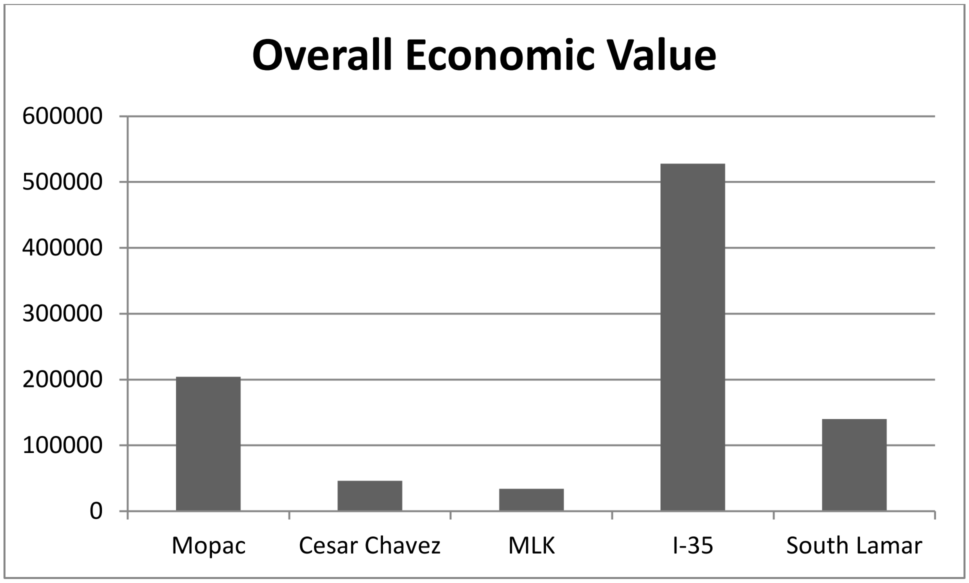

Figure 11: Overall Economic Value.

When compared to the AADT of each roadway, the overall economic value shows that it does not simply measure utilization. It also includes increases in value from truck flow and roadside businesses. Figure 12 shows the overall economic value alongside AADT amounts.

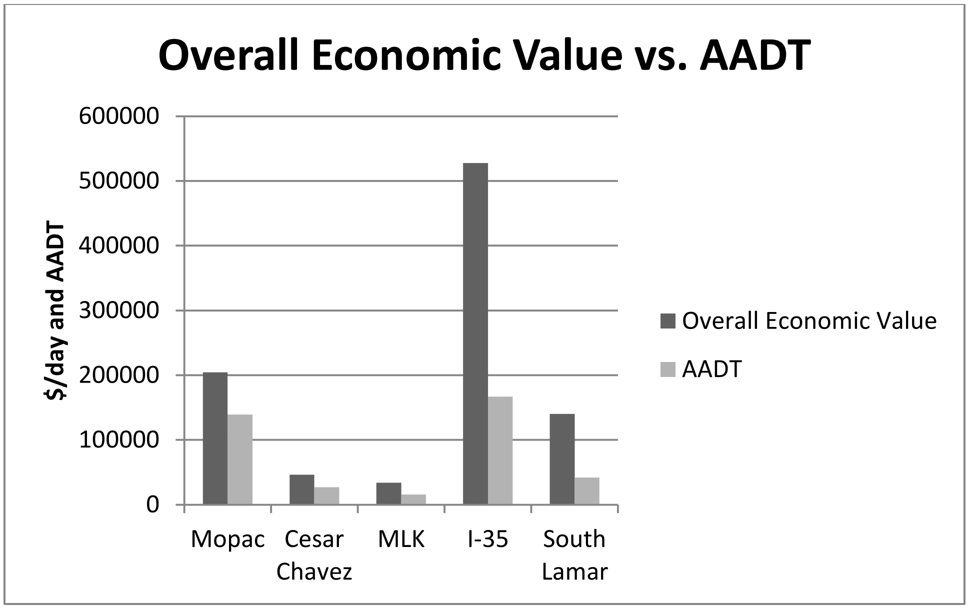

Figure 12: Economic Value Compared to AADT.

I-35 saw a huge spike in value because of truck flow and roadside business along the access road. South Lamar also saw a spike in value due to the high volume of retail stores along the roadway. This further indicates that though traffic volume is important to the value of a roadway, but other factors could be just as important.

6. CONCLUSIONS, RECOMMENDATIONS, AND FUTURE WORK

Economic evaluation of roadways has traditionally been used as a tool for future development and new construction. The framework in this thesis provides an approach to evaluating the economic value of existing roadways as a means to better preserve our assets. Asset management has become an integral part in preserving our existing infrastructure as investment for new construction declines.

6.1 CONCLUSIONS

Economic evaluation has been a well-accepted strategy in valuing roadway assets, however the approach has been mostly qualitative. The practice of actually quantifying the economic impacts of roadways is tedious and difficult to apply on a large scale. The framework outlined can provide agencies with a way to quantify the value of roadway assets. It was applied to a theoretical asset management problem, where an agency must choose a roadway for construction based on value, or value added from the additional investment on the roadway for maintenance or rehabilitation work. Several important conclusions can be drawn from the analysis and results:

1. The methodological framework presented in this thesis is a practical tool that can be used for economic evaluation of existing roadway assets. The framework provides a means to quantify both direct and indirect economic impacts of roadways. It is also is adaptable to varying agency needs. The assumptions and

weights assigned in the case study can be altered to reflect the needs of a particular agency.

2. The weights associated with the application of the framework are vital to the economic evaluation results. Agencies using this framework must identify their most important evaluation factors and adjust the weights accordingly. Specifically, agencies must compare importance of time savings, truck commodity flow, added employment, and roadside businesses.
3. Each element of the framework can be looked at individually to help decision makers make a better informed choice. Certain geographic areas or types of agencies may just be interested in an individual factor of roadway economic value, whether it is truck flow commodity value, added employment value, or roadside business value. Each component can be looked at individually to make a more informed decision.
4. Economic value of existing roadways can only be an estimate. There are so many existing roadway assets and varying types of roadways that quantifying an economic value for each can only be looked at as an estimate and not a definite amount. In addition, some factors, like city to city connectivity or tourism, cannot be adequately quantified readily in a framework. It is important that the economic value be used for decision making and comparison rather than as a "concrete" value.

6.2 RECOMMENDATIONS

The use of economic evaluation of roadways in asset management is very limited. Agencies continue to rely on book value and replacement cost to evaluate roadways, which fail to capture the utilization and economic impact. Several recommendations can be reached from this paper including:

1. State DOTs should incorporate economic evaluation of existing roadway assets into their asset management program. Book value and replacement cost fail to adequately characterize the economic importance of existing roadways. This type of economic evaluation framework can be used to capture the utilization of the roadway using both direct and indirect economic impacts. Decision makers can use economic evaluation to better understand how maintenance and rehabilitation on particular roadways will affect the local economy.
2. Agencies should explore the relationship between transportation assets and the functioning economy. There has been work done relating some transportation venues to the economy, but most of the work focuses on general state of transportation and macroeconomics. Understanding the relationship between local roadway condition, such as its connectivity, and economic prosperity could enhance our ability to provide optimal transportation systems.
3. Greater importance should be placed on the indirect economic impacts of roadways. Many agencies focus on the direct economic impact of time savings and neglect indirect consequences. The indirect economic impacts can be very large with the increasingly connected transportation network.

6.3 FUTURE WORK

Though this thesis offers a framework for applying economic evaluation to existing roadways, there are still many issues that need to be addressed. There are areas that require more research and discussion.

Additional indirect economic impact factors could be applied to the framework if there was a method of quantification. This includes connectivity, land value, tourism, and large scale production. Each of these factors has an economic value to society and relies on the use of the roadway network, but is difficult quantify a dollar amount. Many indirect factors are interconnected, where one factor is dependent on a range of other factors. For example, large scale production is dependent on connectivity of a network, roadside businesses, tourism, and time savings. The interdependency among economic factors needs to be studied further.

There are several assumptions made in the framework that need further research. For the purpose of the framework, the values associated with the assumptions can be altered to better suit an agency, however, more work needs to be done in finding more accurate assumptions. For instance, the payload for truck commodity flows was given the same value across several industries, which may not be very realistic. In time savings value, the time savings was based on free flow detour times. A more realistic approach for an agency would be to find the change in total system travel time in performing maintenance or rehabilitation on that roadway. Agencies often have data and software enabling this more accurate estimate. In roadside business value, business value was based on typical U.S. business revenue and number of establishments. The values could be more accurate if work was done on finding typical regional values, or relating the business value to the real estate value.

Finally, more work needs to be done on implementation techniques for using economic evaluation at agencies. The framework provides a means to estimate the economic value and adjust factors based on local conditions, but it does not look at the current available data at agencies or a systematic approach in implementing this form of asset management. The issues in implementation would need to be identified and addressed in order to put in place a more functioning product.

APPENDIX

Table 5: VOT, VOC, and EC for Case Study.

	Passenger Vehicles	Trucks
Value of Time	$12.50/hour	$24.70/hour
Vehicle Operating Cost	$0.20/mile	$0.40/mile
Environmental Cost	$0.10/gallon	$0.11/gallon

Table 6: Mopac Truck Commodity Value.

		Mopac	
		Total Truck Flow	2920
Commodity Type	Percent of Truck Flow	Truck Flow by Commodity	Commodity Value ($/day)
Fuel oils	12%	346	2196994
Gasoline	11%	313	2183741
Gravel	6%	175	16018
Coal-n.e.c.	9%	254	2075076
Nonmetal min. prods.	5%	138	172060
Waste/scrap	6%	167	128412
Coal	5%	149	20735
Cereal grains	5%	134	208857
Crude petroleum	9%	256	1156802
Basic chemicals	4%	127	1183254
Electronics	1%	33	4559336
Machinery	2%	55	4271085
Other	26%	772	11286155
		Total Value	29458525

Table 7: Cesar Chavez Truck Commodity Value.

		Cesar Chavez	
		Total Truck Flow	540
Commodity Type	Percent of Truck Flow	Truck Flow by Commodity	Commodity Value ($/day)
Fuel oils	12%	64	406228
Gasoline	11%	58	403778
Gravel	6%	32	2962
Coal-n.e.c.	9%	47	383685
Nonmetal min. prods.	5%	26	31814
Waste/scrap	6%	31	23744
Coal	5%	28	3834
Cereal grains	5%	25	38618
Crude petroleum	9%	47	213895
Basic chemicals	4%	24	218786
Electronics	1%	6	843029
Machinery	2%	10	789731
Other	26%	143	2086830
		Total Value	5446933

Table 8: MLK Truck Commodity Value.

		MLK	
		Total Truck Flow	411
Commodity Type	Percent of Truck Flow	Truck Flow by Commodity	Commodity Value ($/day)
Fuel oils	12%	49	309034
Gasoline	11%	44	307170
Gravel	6%	25	2253
Coal-n.e.c.	9%	36	291885
Nonmetal min. prods.	5%	19	24202
Waste/scrap	6%	24	18063
Coal	5%	21	2917
Cereal grains	5%	19	29378
Crude petroleum	9%	36	162718
Basic chemicals	4%	18	166439
Electronics	1%	5	641327
Machinery	2%	8	600781
Other	26%	109	1587536
		Total Value	4143704

Table 9: I-35 Truck Commodity Value.

		I-35	
		Total Truck Flow	16867
Commodity Type	Percent of Truck Flow	Truck Flow by Commodity	Commodity Value ($/day)
Fuel oils	12%	2001	12688610
Gasoline	11%	1805	12612066
Gravel	6%	1009	92512
Coal-n.e.c.	9%	1469	11984475
Nonmetal min. prods.	5%	797	993722
Waste/scrap	6%	967	741639
Coal	5%	863	119755
Cereal grains	5%	772	1206240
Crude petroleum	9%	1478	6681039
Basic chemicals	4%	735	6833810
Electronics	1%	190	26332170
Machinery	2%	321	24667397
Other	26%	4460	65182516
			170135950

Table 10: South Lamar Truck Commodity Value.

		South Lamar	
		Total Truck Flow	714
Commodity Type	Percent of Truck Flow	Truck Flow by Commodity	Commodity Value ($/day)
Fuel oils	12%	85	537124
Gasoline	11%	76	533884
Gravel	6%	43	3916
Coal-n.e.c.	9%	62	507317
Nonmetal min. prods.	5%	34	42065
Waste/scrap	6%	41	31394
Coal	5%	37	5069
Cereal grains	5%	33	51062
Crude petroleum	9%	63	282816
Basic chemicals	4%	31	289283
Electronics	1%	8	1114672
Machinery	2%	14	1044200
Other	26%	189	2759253
			7202055

Table 11: Employment and Vehicle Miles Traveled for Case Study.

	Daily VMT	County VMT	Overall Employment
Mopac	139070	25593491	623598
Cesar Chavez	27000	25593491	623598
MLK	15800	25593491	623598
I-35	167000	25593491	623598
South Lamar	42000	25593491	623598

Table 12: Roadside Business Revenue.

	Revenue ($)	Number of Establishments
Retail-Auto	85887165000	165552
Retail-Food	2.07636E+11	408806
Retail-Other	3.91766E+12	1128112
Service	4.50413E+11	118756
Hotel/Acc.	1.8E+11	62000
Agr./Con./Man.	2.38264E+12	332530

Table 13: Roadside Businesses for Roadways in Case Study.

	Retail-Auto	Retail-Food	Retail-Other	Hotel/Acc.	Service	Agr./Con./Man.
Mopac	0	0	0	0	0	0
Cesar Chavez	0	8	1	2	0	1
MLK	3	2	1	0	0	0
I-35	2	2	1	3	3	0
South Lamar	12	13	20	0	3	0

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