Texas A&M Transportation Institute

Travelers' Value of Time and Reliability as Measured on Katy Freeway

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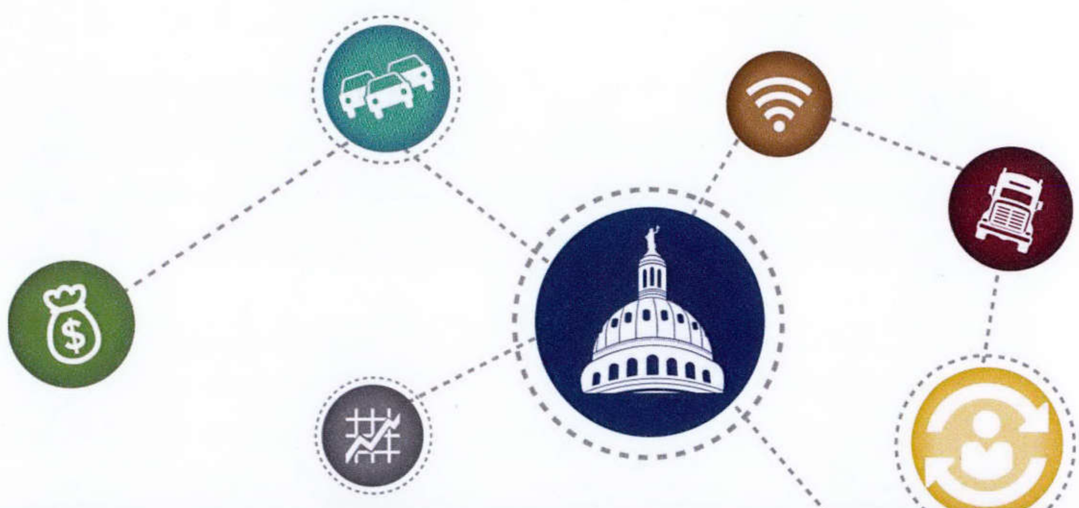

TRANSPORTATION
Policy Research CENTER

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Executive Summary

The value of travel time savings (VOT) is an estimate of what travelers would be willing to pay in order to save time on a particular trip. If travelers would pay $1 to reduce their travel time by six minutes, then they have a VOT of $10 per hour. VOT allows the measurement of benefits derived from transportation projects that reduce congestion and travel time, and is used to justify infrastructure investments or help determine toll road viability. The Texas Department of Transportation (TxDOT) requires accurate estimates of traveler VOT in various project selection and contracting processes.

Travelers also place value on trips that are reliable and would be willing to pay for trips that have a predictable travel time regardless of when that trip occurs. The value of reliability (VOR) is therefore equivalent to the amount of money travelers would be willing to pay to reduce the variation in their expected travel time. VOR is less commonly used than VOT but is becoming an increasingly prominent metric in assessing the value of mobility improvement projects. TxDOT does not currently use VOR in its various contract selection or contracting processes.

VOT and VOR are commonly estimated using stated-preference (SP) methods where travelers are presented with a series of different travel scenarios with an associated cost and asked to indicate their preference. VOT estimates used by TxDOT are based on SP methods using data from a 1986 TxDOT research project. These VOT estimates have been adjusted each year by the change in the consumer price index. In 2014, the TxDOT-recommended VOT was $21.73 per hour for passenger travel. This value is similar to VOTs used by other departments of transportation and Federal Highway Administration guidance. However, because this value is based originally on 1986 data, there may be a need to update it with more recent data sources.

Technology is increasingly enabling the generation of VOT and VOR estimates based on revealed preference (RP)–based methods. These methods differ from SP methods in that they are based on actual travel behavior. This report presents an effort by researchers at the Texas A&M Transportation Institute to generate new VOT and VOR estimates based on RP methods using data collected over a three-year period from transponders on Katy Freeway in Houston, Texas.

Initial VOT was estimated to range from $1.96 per hour to $8.06 per hour for all travelers with a transponder, which is considerably lower than most research results and what is generally used in practice. This could be due to the fact that approximately 11 percent of travelers chose to pay to use the tolled managed lanes even when these lanes were running slower than the adjacent general-purpose lanes. The research team also found that only a small percentage (7 percent) of vehicles that had a transponder and were therefore able to use the tolled managed lanes actually did so. When only paid trips on the managed lanes are examined, those travelers are paying the equivalent of $39.65 per hour on average. Therefore, those who do use the lanes appear willing to pay a high amount per time saved. Since this is a small percentage of travelers, the overall VOT for all transponder-equipped vehicles was quite low.

Initial VOR estimates were inconsistent with what might be expected. The research team therefore examined a smaller sample of trips that did not include uneconomical trips (i.e., those where travel time was slower or the travel time was less reliable in the tolled managed lane). These new estimates revealed VOT ranges from approximately $0 per hour to over $26 per hour and VOR ranges from −$8 per hour to $3 per hour, with many estimates being close to $0 per hour.

These VOT results are much lower than what is used in practice, which is derived from SP surveys in which travelers are asked what route they would take given specific travel times and tolls. These VOTs have been used to predict toll road demand with reasonable accuracy. Thus, the values found in this research would appear to be too low, but the values are what travelers are actually paying. Similarly, there appears to be little value placed on added reliability.

The research team attempted to determine why this difference exists, but they do not have a definitive answer. It may stem from the fact that a fairly small proportion of Katy Freeway travelers are willing to pay for the managed lanes. Only 7 percent of trips of vehicles with transponders chose to pay to use the managed lanes. A transponder is required to pay the toll, meaning a large portion of eligible vehicles are using the general-purpose lanes in addition to all of the vehicles without transponders that are also making general-purpose lane trips. This small percentage of total trips in the managed lanes brings down the average VOT. This is occurring even though the travelers who are paying for the managed lanes pay an average of nearly $40 per hour for travel time savings. Further research is needed to determine if this difference in VOT is unique to the Katy Freeway managed lanes or managed lane facilities in general.

Introduction

People generally place value on their time, and in the transportation realm this means that travelers place a value on their travel time. The value of a particular driver's travel time influences his or her travel decisions, meaning that if he or she has a high value of time, he or she might be willing to pay to use a toll road if it saves travel time. Transportation planners, engineers, and economists therefore try to estimate travelers' value of travel time savings (VOT). This VOT is the equivalent amount of money a traveler would pay for a reduction in the amount of time to complete a trip. For example, if travelers would pay $1 to reduce their travel time by six minutes, then they have a VOT of $10 per hour. This allows for the measurement of benefits derived from transportation projects that reduce congestion and travel time.

Similarly, travelers also value trips with a consistent and reliable travel time where they can expect to arrive on time. Reliable trips are defined as trips with a small day-to-day variation in the amount of time to complete a trip, and travelers often place value on having a reliable trip time versus an unreliable trip time. Quantitatively, the economic worth of a reduction in travel time variation is referred to as the value of reliability (VOR). The VOR is equivalent to the amount of money travelers would be willing to pay to reduce the variation in their expected travel time.

Providing improved travel time and travel time reliability is generally among the largest societal benefits from transportation infrastructure projects. Thus, having a good estimation of travelers' VOT and VOR is needed to accurately value the societal benefits of transportation infrastructure projects because the potential VOT and VOR from the infrastructure may be significant enough to justify the monetary investment in that infrastructure. Furthermore, the Texas Department of Transportation (TxDOT) requires accurate estimates of traveler VOT and VOR because they are critical components for project selection and contracting processes. For example, TxDOT uses VOT for:

- **A + B bidding.** This process is where a contractor bids on a project and is awarded the project based on the cost of construction (A) and the cost to travelers due to construction-related traffic delays (B), of which VOT is a component.
- **Lane rental.** This is where a contractor can rent a traffic lane for use in speeding up construction and/or reducing the cost of construction. The cost of renting that lane is based on the cost of delay to travelers caused by the loss of that lane, which requires an accurate estimate of VOT.
- **Incentive provision.** TxDOT provides incentives for the early completion of construction projects and levies penalties for construction projects that are not completed on time. These incentives and penalties can be based, in part, on the additional costs to travelers of delay due to the construction project.

As of March 2014, TxDOT used a VOT of $21.73 per passenger-car-hour and does not use or have a VOR. The VOT that TxDOT uses is similar to values used by many other state departments of transportations (DOTs) and metropolitan planning organizations (MPOs). Additionally, most DOTs and MPOs do not have or use a VOR. Therefore, TxDOT's VOT and non-use of VOR is in line with its peer agencies.

However, these values deserve reexamination and possible updating because they are based on data that are at least 30 years old. In Texas, the VOT was originally calculated based on a 1985 telephone survey of 500 randomly selected Texas residents who answered questions regarding their driving habits, personal characteristics, and willingness to pay for driving on a safer road. With these data, the VOT was calculated to be approximately $10.40 per hour (in 1986 dollars) by McFarland and Chui (1986). The values have been adjusted by the consumer price index (CPI) to the current value of $21.73 for autos.

Data are currently being collected from toll transponders on Katy Freeway in Houston, Texas, that provide an opportunity to reexamine VOT and establish VOR using actual behavior data, not surveys. Given that the currently used VOT for autos is based on a 1985 survey of 500 people, it is at least reasonable to check how it compares to what Katy Freeway travelers are actually willing to pay now for travel time savings and reliability.

This report discusses a research effort undertaken by the Texas A&M Transportation Institute (TTI) and Texas A&M University that used data from Katy Freeway in Houston to estimate VOT and VOR using transponder data from the facility's users. This report presents:

- An overview of how VOT is estimated.
- The relative merits of the estimation methods in existence.
- An overview of how VOT has been estimated in Texas.
- A discussion of how estimates of VOT and VOR were determined for Katy Freeway users and the results of that effort.
- Conclusions and implications from the findings of that analysis.

This research used data from Katy Freeway travelers collected during 2012, 2013, and 2014. These data include travel times on all lanes and tolls paid to use the Katy Freeway managed lanes (MLs). Therefore, it is possible to know how much travelers spent to use the MLs, how much travel time they saved (if any), and how much more reliable the MLs were (if at all) as compared to the general-purpose freeway lanes (GPLs). Although these data are not exactly the same as VOT,[1] they will help indicate whether the current VOT in use is reasonable.

[1] The data contain the toll that travelers actually paid. Those travelers who chose to pay the toll may have been willing to pay much more and would therefore have a much greater VOT than what the researchers can measure. Additionally, information on travelers not paying a toll is very limited. The researchers could only determine that their VOT is less than the toll rate divided by the travel time savings.

The main body of this report presents a basic, high-level overview of these topics. However, the appendices provide more detailed discussion of the topics.

Value of Time and Value of Reliability

Value of Travel Time

VOT measures travelers' willingness to pay for a reduction in their travel time. It is expressed in terms of dollars per hour, meaning that a traveler would be willing to pay a certain amount to reduce their travel time by one hour.

The first analysis of VOT was a 1925 Bureau of Public Roads report (U.S. Bureau of Public Roads and the Cook County Highway Department 1925), which estimated VOT to be $3 per hour in 1925 dollars. If adjusted for inflation to 2015 dollars, that would be a VOT of approximately $41 per hour. These early estimates where calculated through one of two ways:

- Assume that VOT is equal to the travelers' wage rate.
- Estimate how much travelers would be willing to pay to use a faster mode of travel. For example, how much more would a traveler be willing to pay to travel by car than by bus?

Most of the studies in the last 40 years have used stated-preference (SP) surveys to estimate VOT. Travelers being surveyed are generally given a set of predetermined, hypothetical travel alternatives and asked to give their preference. For example, would they choose option 1, which takes 10 minutes and requires a $2 toll, or option 2, which takes 15 minutes but has no toll (Carrion and Levinson 2012). The results of these surveys are used to develop logit equations that predict mode choice and estimate VOT.

VOT studies have found a strong relationship between the traveler's hourly wage rate and his or her VOT (Concas and Kolpakov 2009). Estimated VOTs have ranged, depending on the study and data sources used, from 20 percent to 100 percent of the traveler's hourly wage rate. However, most literature has suggested that the VOT should be around 50 percent of the hourly wage rate for personal trips. For commercial trips, VOT can be higher than the hourly wage rate, perhaps as high as 1.7 times the average wage rate (Waters 1992).

VOT depends on various factors such as the type of travel; the characteristics of the traveler (e.g., age and gender); transportation mode (e.g., bus, car, or walk); travel condition; time of the year, week, or day; location; and trip purpose. Therefore, many agencies recommend using different VOTs for different types of travel. The U.S. Department of Transportation (USDOT) has recommended values of time of $10.60 per hour for commuter travel and $21.46 per hour for business travel. The latest update to these guidelines (Ayala 2014) suggested a VOT of $12.50 in 2009 dollars for all purposes of travel combined.

Many countries have incorporated VOT into their economic evaluation of transportation projects. As mentioned by Elliasson (2013), Dutch VOTs were estimated based on a national survey conducted in 1998. Since then, the values have been adjusted every year for inflation and for real income changes. In 2010, the recommended VOTs were €9.92 per hour for commuter trips and

€34.36 per hour for business trips (approximately $9 per hour and $31 per hour in U.S. dollars, respectively).

New Zealand's *Economic Evaluation Manual* provides guidelines to incorporate VOT into economic evaluations for surface transportation projects (e.g., highway, transit, and rail). New Zealand suggested different VOT ranges based on types of vehicles, roadway networks, and day of the week. In 2013, the VOT ranged from NZ$14.96 per hour to NZ$25.84 per hour (approximately $22 per hour and $38 per hour in U.S. dollars, respectively).

Value of Travel Time Reliability

The VOR is equivalent to the amount of money travelers would be willing to pay to reduce the variation in their expected travel time. Essentially, it measures how much travelers would be willing to pay in order to have a more predicable trip in terms of travel time. Although the VOR concept is not new, its methods of estimation are not well established, and estimated values are a subject of continuous debate (Carrion and Levinson 2012). A main reason for this is that researchers use different approaches to measure travel time reliability. These methods use different measures, data sources, and calculation methods. A more detailed discussion of these methods can be found in Appendix A.

Revealed-Preference Studies

The majority of the analyses have used SP data to estimate VOT and VOR, and have not been consistent. Each study had different data collection methods, geographic locations, and sample sizes, which led to differences in reported VOR estimates. A study of travelers on SR-91 in the greater Los Angeles area estimated the VOR to be $19.56 per hour, or 85 percent of the average wage rate of the sample (Small et al. 2005), while another study found the VOR was equivalent to the VOT (Tilahun and Levinson 2007). Yet another study used global positioning system (GPS) and revealed-preference (RP) data to estimate travelers' VOR, which ranged from $0.32 per hour to $8.60 per hour (Carrion and Levinson 2012). As shown in this example, VOR estimates can vary significantly.

Rather than relying on SP survey data, the study discussed in this report relies on RP data. RP studies use actual preferences based on an analysis of actual behavior data. RP studies have more advantages than SP surveys because they do not require travelers to select their preferences from among various predetermined scenarios. A well-designed SP survey should be able to obtain reasonable answers to the choice a traveler would typically make. For example, for most trips, a particular traveler might choose a toll-free route and indicates that on a survey. What the SP data would miss, but RP data obtain, is that for some trips the traveler chooses the toll route.

In comparison to the large number of SP studies, there are very few studies that have used RP data to estimate VOT and VOR. One reason for this is that proper experimental design for an RP study is exceedingly difficult compared to studies using SP data.

One example of an RP study is the use of vehicle speed and survey data to estimate the VOR for SR-91 travelers in Orange County, California (Lam and Small 2001). However, one of the limitations of the study was that speed data had been collected one year prior to the mail survey. Therefore, it was not really an RP study because the travel times were estimated. That study estimated VOR to be $15.12 per hour for men and $31.91 per hour for women.

A subsequent study used a combination of RP and SP data from SR-91 travelers in California to estimate VOR (Small et al. 2005). The study used telephone interviews and mailed surveys as the data source. A major limitation of the study was that only 55 participants completed both the interview and the survey, restricting the capability of the research team to compare perceptions from different research instruments. A much larger sample size of 522 participants came from the RP (telephone interview) survey, and 633 participants came from the SP (mail) survey. An analysis that combined both datasets was believed to result in erroneous findings. Moreover, the researchers concluded that using these RP data was not realistic and can lead to erroneous results. The study estimated a median VOR of $19.56 per hour.

A study of MnPass travelers in Minnesota used a GPS-based experiment to estimate VOR (Carrion and Levinson 2013). The researchers used a web-based application to recruit 18 commuters, whose vehicles were then equipped with GPS devices to track their travel activity. For a two-week observational period, the commuters traveled on each of the three alternatives (high-occupancy toll [HOT] lanes, GPLs, and adjacent signalized arterials) separately. During those two weeks, the commuters better understood the travel time and reliability on each route. After that, they were instructed to travel on their preferred route. The design was able to depict a real-world scenario, though the sample size was too small (18 respondents) to draw any unbiased conclusion. In addition, some participants did not like being constrained on the route they used and left the study. The study produced a wide range of VORs depending on the definition of VOR.

Federal Guidance for VOT and VOR

In 1997, USDOT began publishing guidance on the VOT (Ayala 2014). The guidance explained how the VOT can be estimated and incorporated within economic analyses. Since then, the guidance has been revised three times, with the latest revision in 2014. USDOT has reaffirmed its guidance to be consistent with other methods used internationally. The recommended values of travel time for intracity and intercity travel correspond to 50 percent and 70 percent of hourly income, respectively. National averages were $12.80 per hour for local travel and $18.70 per hour for intercity travel, both in year 2009 dollars (Ayala 2014 http://www.transportation.gov/sites/dot.gov/files/docs/USDOT%20VOT%20Guidance%202014.pdf). The USDOT did not provide a specific dollar amount for freight-based VOT due to the complexity of valuing a wide array of commercial industries.

The federal government provided funds for extensive research on travel time reliability. The second Strategic Highway Research Program (SHRP 2) was authorized by the U.S. Congress to conduct short-term research projects that focused, in part, on reliability-related issues. Two studies were notable from SHRP2, one from the University of Arizona and Portland Metro, and another from the University of Maryland and the Maryland State Highway Administration. Both research studies used simulation software to estimate a reliability ratio (RR), which is the VOR divided by the VOT. The studies found the following:

- The University of Arizona (2014) study used surveys to estimate an RR value of 0.45 for personal travel in autos and 1.06 for transit.
- The University of Maryland (2014) study used historical travel time data to estimate an RR value of 0.75.

Both studies suggested the RR was the most useful measure for incorporating VOR into economic evaluations.

Many states follow the USDOT recommended methodology to estimate VOT for autos, and no state DOT has or uses a VOR. Some states, such as New Jersey and Texas, have developed their own method to estimate VOT. Texas' VOT estimation technique will be discussed in the next section.

VOT and VOR in Texas

VOT and VOR Statewide

VOT can be used in analyzing the benefits of a construction project and thus could be influential in project selection. TxDOT uses a speed-choice model to estimate VOT for personal vehicles, which was originally derived from a 1986 TxDOT research project (McFarland and Chui 1986). TxDOT adjusts the VOT each year from the 1986 report by factoring increases in the CPI. TxDOT uses an older model to estimate VOT for trucks and commercial vehicles that was derived from a 1975 TxDOT research project (Buffington and McFarland, 1975). In 2014, TxDOT recommended a VOT of $21.73 per hour for passenger travel and $31.71 per hour for commercial traffic. TxDOT recommended using these values to estimate road user costs used in construction project bidding and incentives/disincentives for milestones, final substantial completion, and lane rentals.

A 1999 TxDOT report compared the TxDOT-derived VOT to values from nine other states and found them to be consistent (Daniels et al. 1999). The same 1999 TxDOT research report also found that TxDOT's model generates VOTs for trucks and commercial vehicles that are consistent with those found in other states (Daniels et al. 1999). However, the report suggested additional research to revise these VOT estimates because the sample size of trucks was relatively small. TxDOT has not conducted any extensive research on VOT or VOR since 1999, a span of roughly 16 years. However, the current VOT used in Texas is similar to the VOTs used in other states (see Table 4 in Appendix A).

VOT and VOR on Katy Freeway

Due to the importance of VOT, the length of time since it had been originally established, and the availability of new travel data, it was felt a new investigation of VOT was warranted. This section of the report discusses an analysis conducted by TTI researchers aimed at providing an updated, and perhaps more accurate, VOT using data collected from a Houston-area ML facility. Furthermore, recent research has shown that travelers also place value on the reliability of travel times. Therefore, researchers conducted an analysis to calculate both VOT and VOR.

The I-10 Katy Freeway connects the City of Katy with downtown Houston. This 12-mile section of freeway has up to six GPLs and two variably priced MLs running in each direction. These MLs generally require less travel time and are usually more reliable than the adjacent GPLs. Drivers are required to pay a toll to use the MLs depending on the time of day and the number of people in the vehicle. High-occupancy vehicles (HOVs) with two or more occupants and motorcycles can use the MLs for free during HOV-free hours, which are Monday through Friday from 5 a.m. to 11 a.m. and 2 p.m. to 8 p.m. HOVs and motorcycles pay the same toll as single-occupancy vehicles (SOVs) at all other times. In order to avoid the toll during the HOV-free hours, HOVs and motorcycles need to pass the toll plazas in the HOV lane, the leftmost lane of MLs.

TxDOT operates automated vehicle identification (AVI) sensors located on both the MLs and GPLs along Katy Freeway that detect vehicles with transponders and record the unique transponder ID from the vehicle and the time of detection. All vehicles that pay a toll on the MLs are required to use a transponder, but many other vehicles traveling on Katy Freeway also have transponders. The Harris County Toll Road Authority (HCTRA) is in charge of operating the MLs and also collects AVI data along the MLs at the three toll plaza locations.

Assigning Random IDs

To ensure that no transponder owner could be identified using the transponder IDs, each transponder ID was assigned to a unique random ID, and the original transponder IDs were deleted. Therefore, the dataset could never be used to identify specific individuals traveling on Katy Freeway. The dataset could still be used to track the trips of vehicles throughout the three years based on the random ID that each vehicle was assigned.

Collecting Data

To generate new VOT and VOR estimates, TTI researchers used data collected from the Katy Freeway AVI sensors from 2012 to 2014. These data were used to develop the trips taken by vehicles with transponders, which came out to over 100 million trips in the dataset. This included over 7 million trips that paid a toll to use the MLs. Thus, the data included millions of travel decisions that involved taking either the toll-free GPLs or paying a toll to use the MLs expecting/hoping to save travel time and have a more reliable travel time.

The data also provided information on the travel time and travel time reliability of the lanes. Thus, the research team was able to determine the travel time, travel time reliability, and any toll paid for the trip the traveler took plus the same information on the alternate lanes that the traveler did not take. The focus of this RP analysis was on understanding how much travelers were willing to pay to use the faster and more reliable MLs.

Developing Route Choice Models

With these data, route-choice models were developed to estimate travelers' VOT and VOR. To begin, only VOT was estimated. Initial results ranged from $1.96 per hour to $8.06 per hour. This is considerably lower than most research results as well as what is generally used in practice. This is likely due in part to the fact that approximately 11 percent of travelers chose to pay to use the MLs even when the ML speed was slower than the GPL speed. It was unknown why these travelers took the MLs, but it resulted in negative VOTs for those travelers because they essentially paid money to have a slower trip. Another reason for the low VOT is that only a small percentage of trips by transponder-equipped vehicles, approximately 7 percent, chose to pay to use the MLs. For those 7 percent of trips, the average VOT was $39.65 per hour, a fairly high willingness to pay. However, when combined with the 93 percent of travelers not willing to pay the toll, the average VOT dropped to between $1.96 per hour and $8.06 per hour.

For the calculation of VOR, the models initially developed by the research team yielded similarly inconsistent results. In addition to the fact that many drivers paid to use the MLs even when the GPLs provided a better travel time, the research team observed that a large percentage of travelers never changed lanes, regardless of travel times in the MLs or GPLs. About 79 percent of transponders were always in the GPLs, and 3.4 percent of transponders were always in the MLs, regardless of travel times.

Excluding Uneconomical Trips

To develop more refined estimates of VOT and VOR, the research excluded these uneconomical trips from the models. The new models were developed using only those travelers who used each lane at least once during the three years of the analysis. The 17.4 percent of total detected transponders that used each lane at least once, and are therefore shown to be willing to choose between the lanes, represented 55.4 percent of all trips. These new models generated VOT that ranged from approximately $0 per hour to over $26 per hour, while VOR ranged from −$8 per hour to $3 per hour, with many estimates being close to $0 per hour. This represented a small improvement in the results but uses a biased set of data, and results were still inconsistent.

Since there were so many uneconomical trips, the research team conducted a separate analysis to identify patterns that may shed insight into why travelers were using the MLs when they were slower than the GPLs. The research team found that:

- Long-distance (more than 20 miles) ML trips had a higher percentage of uneconomical ML trips.
- Westbound ML trips (traveling away from downtown Houston) had a higher percentage of uneconomical ML trips.
- ML trips where the only toll plazas that were crossed were either the Eldridge toll plaza or the Wirt toll plaza (in either direction) had a higher percentage of uneconomical ML trips.
- ML trips that were made during the off-peak period, particularly from midnight to 6 a.m., had a higher percentage of uneconomical ML trips.
- The percentage of uneconomical ML trips was higher during weekends than on weekdays.
- ML trips during May 2012, August 2012, and May 2013 had a higher percentage of uneconomical ML trips.
- Travelers who traveled less frequently on the MLs during the previous 30 days had a higher percentage of uneconomical trips.

The research team also conducted a more detailed analysis of the travel patterns of 30 travelers who frequently made uneconomical trips. This analysis reconfirmed the finding that travelers preferred to use MLs when they were traveling the entire length of the ML facility. However, it yielded little additional insight into the use of the MLs during periods when they are slower than the GPLs.

Conclusions

VOT is an important measure that is used in any number of transportation project selection and contracting–related processes. Current VOT estimates used by the state are based on a small sample of data from over 15 years ago. This report presents analyses of empirical data collected from Katy Freeway's transponder reader network to generate RP-based estimates of VOT.

The analysis yielded results that are much lower than what was expected and what is currently used in practice. The values currently used in practice are often derived from SP surveys in which travelers are asked what route they would take given specific travel times and tolls. These VOTs have been used to predict toll road demand with reasonable accuracy in the past. Thus, the RP-based values found in this research would appear to be too low. However, the RP values reflect what travelers are *actually paying* to use the Katy Freeway MLs. Furthermore, travelers on that facility appear to place little value on added reliability.

The TTI research team attempted to determine why this difference exists but do not have a definitive answer. It may stem from the fact a fairly small proportion of Katy Freeway travelers are willing to pay for the MLs on that facility. Only 7 percent of trips of vehicles with transponders chose to pay to use the MLs. Since a transponder is required to pay the toll, there are many vehicles without transponders that are making GPL trips. Thus, the small percentage of total trips that chose the MLs brings the average VOT down, even though the travelers who are paying for the MLs pay an average of nearly $40 per hour for travel time savings. Further research is needed to determine if this difference in VOT is unique to Katy Freeway MLs or MLs in general.

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Appendix A: Literature Review

The Value of Travel Time

The VOT is the measure of travelers' willingness to pay for a reduction in their travel time. Existing literature on the VOT is very comprehensive and well developed. The first analysis of VOT was a 1925 Bureau of Public Roads report (U.S. Bureau of Public Roads and the Cook County Highway Department 1925), which estimated VOT to be $3 per hour (in 1925 dollars; approximately $41 per hour when increased by inflation to 2015 dollars). Studies between 1925 and the 1970s generally used one of two methods to estimate VOT:

- The VOT was assumed to be equal to the travelers' wage rate.
- The VOT was assumed to be how much travelers would be willing to pay to use a faster mode of travel. For example, how much more would a traveler be willing to pay to travel by car than by bus?

Since then, most studies have used SP survey data to estimate VOT. These SP studies generally asked travelers to choose between modes and developed logit equations to predict mode choice. VOT was estimated based on the coefficients in those equations.

Concas and Kolpakov (2009) summarized many VOT studies (Table 1 summarizes some of the results). They found that many analyses had found a strong relationship between the travelers' hourly wage rate and their VOT. The estimated VOTs ranged from 20 percent to 100 percent of the travelers' hourly wage rate, and most of the literature suggested that the VOT should be around 50 percent of the hourly wage rate for personal trips. This is similar to USDOT guidance (Ayala 2014, http://www.transportation.gov/sites/dot.gov/files/docs/USDOT%20VOT%20Guidance%202014.pdf). Brownstone and Small (2005) conducted a study on SR-91 and I-15 in Southern California and estimated the VOT for personal trips to range from $20 per hour to $40 per hour. For commercial trips, the VOT can be higher than the hourly wage rate. Waters (1992) found that travelers' VOT for commercial travel could be as high as 1.7 times their average wage rate.

The VOT depends on various factors such as the type of travel; the characteristics of the traveler (e.g., age and gender); transportation mode (e.g., bus, car, or walk); travel condition; time of the year, week, or day; location; and trip purpose. Many agencies have recommended using different VOTs for different types of travel. The USDOT-recommended VOTs were $10.60 per hour for commuter travel and $21.46 per hour for business travel. The latest update to these guidelines (Ayala 2014) suggested VOTs of $12.50 in 2009 dollars for all purposes of travel combined.

Most of the studies in the last 40 years have used SP surveys to estimate VOT. As mentioned by Carrion and Levinson (2012), early studies were based on questions that asked travelers to choose between hypothetical travel alternatives. For example, would they choose option 1, which takes 10 minutes and requires a $2 toll, or option 2, which takes 15 minutes but has no toll.

Table 1. Empirical Estimates of VOT.

Study	Data Used	VOT Estimate
U.S. Bureau of Public Roads and the Cook County Highway Department (1925)	Survey of highway transportation	$3.00
City of Houston (1949)	Unknown	$1.20
American Association of State Highway Officials (1953)	Current opinion	$1.35
Beesley (1965)	Data from the survey of government employees in London, the United Kingdom	31%–50% of wage rate
Lisco (1967)	Survey of multiple route-choice models	60% of gross wage (on average)
Small (1992)	Values derived from multiple mode-choice transportation models	20%–100% of gross wage; 50% reasonable average
Waters (1996)	Travel data from 15 commuting studies in North America	40%–50% of after-tax wage rate (mean: 59% of after-tax wage rate; median: 42% of wage rate)
Small and Yan (2001)	Data on commute travelers on SR-91 in California	Average VOT was $22.87/hour, or 72% of sample wage rate
Brownstone and Small (2005)	Travel data from electronic toll collection (ETC) facilities in HOT lanes on SR-91 and I-15 in southern California	VOT saved on the morning commute: $20–$40 per hour, or 50%–90% of average wage rate in the sample
Ayala (2014)	Estimates based on multiple sources of data	50%–120% of the wage rate depending on type of travel (personal versus business); 50% of wage rate for personal local travel and 100% of wage rate for commercial local travel
Ayala (2014)	Compilation of many sources	Local travel, all purposes, is $12.80 in 2012 dollars

Source: Concas and Kolpakov (2009) and Haney (1967)

Many countries have incorporated the VOT into their economic evaluation of transportation projects. As mentioned by Ellison (2013), Dutch VOTs were estimated based on a national survey conducted in 1998. Since then the values have been adjusted every year for inflation and for real income changes. In 2010, the recommended VOTs were €9.92 per hour for commuter trips and €34.36 per hour for business trips (approximately $9 per hour and $31 per hour, respectively, in U.S. dollars).

New Zealand's *Economic Evaluation Manual* provides guidelines to incorporate VOT into economic evaluations for surface transportation projects (e.g., highway, transit, and rail). New Zealand suggested different VOT ranges based on types of vehicles, roadway network, and day of the week. In 2013, the VOT ranged from NZ$14.96 per hour to NZ$25.84 per hour (approximately $22 per hour to $38 per hour in U.S. dollars).

The Value of Travel Time Reliability

Although the concept of travel time reliability is not new, valuing travel time reliability is not well established. The VOR is equivalent to the amount of money travelers would be willing to pay to reduce the variation in their expected travel time. Researchers have attempted to quantify the VOR, and the estimated values are a subject of continuous debate (Carrion and Levinson 2012). A main reason for the discrepancy is that researchers use different approaches to measuring travel time reliability. Table 2 gives definitions of commonly used reliability measures.

Table 2. Commonly Used Reliability Measures.

Reliability Performance Metric	Definition
Buffer index	The difference between the 95th percentile travel time and the average (or median) travel time, divided by the average (or median) travel time
Failure/on-time measures	The percentage of trips with travel times less than 1.1 × median travel time or 1.25 × median travel time
	The percentage of trips with space mean speed less than 50 mph, 45 mph, or 30 mph
80th percentile travel time index	The 80th percentile travel time divided by the free-flow travel time
Planning time index	The 95th percentile travel time divided by the free-flow travel time
Skew statistic	The 90th percentile travel time minus the median, divided by the median minus the 10th percentile
Misery index (modified)	The average of the highest 5 percent of travel times divided by the free-flow travel time
Standard deviation of travel time or travel rate	The root-mean-square deviation of travel time $$\sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i-\mu)^2}$$ Where: x_i = travel time of trip i μ = average travel time N = total number of observations
Shorten right range	The difference between the 90th percentile travel time and the median travel time
Interquartile range	The difference between the 75th percentile and 25th percentile travel time

Early studies used standard deviation as the measure of travel time reliability. More recent studies have used the difference between two percentile values within a travel time distribution (95th and 50th, 90th and 50th, or 80th and 50th) to estimate reliability. Tilahun and Levinson (2010) used three measures to estimate VOR:

- The probability of early or late arrival compared to the usual travel time.
- The difference between the maximum travel time and the median (the median travel time is the travel time where half of travelers were slower and half were faster).

- Standard deviation.

Their findings suggest that all three approaches yield a similar output.

Van Lint et al. (2008) found that using different measures of reliability would provide inconsistent results. They compared results from using the standard deviation, coefficient of variation, buffer index, and misery index. Alemazkoor and Burris (2014) examined how well different VOR measures matched actual traveler behavior data from Katy Freeway. Their results were inconclusive and possibly indicated that many travelers did not consider reliability, or it was far less important than other variables, when making their travel decisions.

The National Cooperative Highway Research Program suggested using the standard deviation as a measure of travel time reliability (Cambridge Systematics, Inc., 1998). Many countries including New Zealand, Australia, the Netherlands, and the United Kingdom prefer using standard deviation as a measure of travel time reliability for passenger travel.

Carrion and Levinson (2012) found that in some cases researchers who conducted SP studies presented survey data in a format that reflected the researchers' intended outcome. The literature suggests that most researchers did not validate survey data and that estimates were hard to evaluate for plausibility. Very few RP studies were found that could be used to validate the outcome of SP studies.

Studies have used different reliability measures to estimate the VOR. However, the majority of the analyses that used SP data to estimate the VOR and VOR have not been consistent in terms of value. A study of travelers on SR-91 in the greater Los Angeles area by Small et al. (2005) estimated the VOR to be $19.56 per hour, or 85 percent of the average wage rate of the sample. A Tilahun and Levinson (2007) study found the VOR was equivalent to the VOT. Carrion and Levinson (2012) used GPS and RP data to estimate travelers' VOR. The VOR that was estimated from that study ranged from $0.32 per hour to $8.60 per hour. Each study had different data collection methods, geographic locations, and sample sizes, which led to differences in reported VOR estimates. Table 3 summarizes the empirical estimates of VOR from several studies.

Many countries, such as New Zealand and Australia, use the term *reliability ratio* to define their VOR (Nevers et al. 2013). Black and Towriss (1993) introduced the term *reliability ratio*. This is simply the VOR divided by the VOT.

Table 3. Empirical Estimates of VOR.

Study	Data Used	VOR Estimate	Definition of Reliability
Lam and Small (2001)	Travel time data from loop detectors on SR-91 and RP data through a mail survey	\$15.12/hour for men and \$31.91/hour for women	Standard deviation and the difference between 90th percentile and median travel time
Brownstone and Small (2005)	Travel data from ETC facilities in HOT lanes on SR-91 and I-15 in southern California in 1996–2000	95%–140% of the median travel time	Difference between 90th and 50th percentile travel time
Small et al. (2005)	Travel data from SR-91 in the greater Los Angeles area in 1999–2000	VOR estimated at \$19.56/hour, or 85% of the average wage rate	Difference between 75th and 25th percentile travel time
Devarasetty et al. (2012)	Internet-based SP survey	\$28/hour	Coefficient of variability
Carrion and Levinson (2012)	GPS-based RP data	\$0.32/hour–\$3.84/hour for men and \$4.9/hour–\$8.6/hour for women	Standard deviation

Source: Many of the above are from Concas and Kolpakov (2009).

Other countries have acknowledged the benefits of providing improved travel time reliability estimates for transportation projects. New Zealand and Australia developed guidance for how to incorporate the VOR into transportation project economic evaluations. New Zealand and Australia recommend using standard deviation as the measurement of reliability, and a reliability ratio of 0.9 for urban traffic, 0.8 for significantly different vehicle mixes, and 1.2 for auto and commercial vehicles. The Netherlands, the United Kingdom, and Sweden are planning to incorporate VOR into their economic evaluation. The Netherlands undertook the VOTVOR Project to provide the time VORs (Significance et al. 2012). As of 2015, the Netherlands recommended using standard deviation as the measurement of travel time reliability and a reliability ratio of 0.8 for cars and 1.4 for other modes.

Revealed-Preference Studies

In comparison to the large number of SP studies, very few studies have used RP data to estimate VOT and VOR. Proper experimental design for an RP study is exceedingly difficult in comparison to studies using SP data.

Lam and Small (2001) used vehicle speed data and survey data to estimate the VOR for SR-91 travelers in Orange County, California. One of the limitations of the study was that the speed data had been collected one year prior to the mail survey. Therefore, it was not a true RP study because the travel times were estimated. The study found that if the travel time reliability is expressed as the difference between 90th percentile and the median of travel time, it provides the best fit model. According to the model, the VOR was \$15.12 per hour for men and \$31.91 per hour for women.

Small et al. (2005) used a combination of RP and SP data from SR-91 travelers in California to estimate the VOR. The studies used telephone interviews and mailed surveys as the data source. A major limitation from the study was that only 55 participants completed both the interview and the survey, restricting the capability of the research team to compare perceptions from different research instruments. A much larger sample size of 522 participants came from the RP (telephone interview) survey and 633 participants came from the SP (mail) survey. An analysis that combined both datasets was believed to result in erroneous findings. Moreover, the researchers concluded that using RP data was not realistic and can lead to erroneous results. The study estimated a median VOR of $19.56 per hour.

Carrion and Levinson (2013) designed a GPS-based experiment to estimate the VOR of I-394 MnPass travelers in Minnesota. The researchers used a web-based application to recruit 18 commuters. Respondents' vehicles were equipped with GPS devices to track their travel activity. For a two-week observational period, the commuters traveled on each of the three alternatives (HOT lanes, GPLs, and adjacent signalized arterials) separately. During those two weeks, they better understood the travel time and reliability on each route. After that they were instructed to travel on their preferred route. The design was able to depict a real-world scenario, though the sample size was too small (18 respondents) to draw any unbiased conclusion. In addition, some participants did not like being constrained on the route they used and left the study. The study produced a wide range of VORs depending on the travel time reliability definition.

Federal Guidance for VOT and VOR

In 1997, USDOT began publishing guidance on the VOT (Ayala 2014). The guidance explained how the VOT can be estimated and incorporated into economic analyses. Since then, the guidance has been revised three times, and the latest revision occurred in 2014. USDOT has re-affirmed its guidance to be consistent with other methods used internationally. The recommended VOT for intracity and intercity travel was 50 percent and 70 percent of hourly income, respectively. National averages were $12.80 per hour for local travel and $18.70 per hour for intercity travel, both in 2009 dollars (Ayala 2014). USDOT did not provide a specific dollar amount for freight-based VOT due to the complexity of valuing a wide array of commercial industries.

The federal government provided funds for extensive research on travel time reliability. The U.S. Congress authorized SHRP 2 to conduct short-term research projects that focused, in part, on reliability-related issues. Two studies were notable from SHRP2, one from the University of Arizona and Portland Metro, and another from the University of Maryland and the Maryland State Highway Administration. Both research studies used simulation software to estimate RR. The studies found the following:

- The University of Arizona (2014) study used surveys to find an RR value of 0.45 for personal travel in autos and 1.06 for transit.

- The University of Maryland (2014) study used historical travel time data to estimate a RR value of 0.75.

Both studies suggested the RR was the most useful measure for incorporating VOR within economic evaluations.

Many states follow the USDOT-recommended methodology to estimate VOT for autos (see Table 4). No state DOT has or uses a VOR. Some states, such as New Jersey and Texas, have developed their own method to estimate VOT.

Texas Guidance for VOT and VOR

TxDOT uses a speed-choice model to estimate VOT for personal vehicles. This model was originally derived from a 1986 TxDOT research project (McFarland and Chui 1986). TxDOT adjusts the values each year from the 1986 report by factoring increases in the CPI. A 1999 TxDOT report (Daniels et al. 1999) compared the TxDOT-derived VOT to values from nine other states and found consistent results. TxDOT has not conducted any extensive research on VOT or VOR since 1999, roughly 16 years.

TxDOT uses an older model to estimate the VOT for trucks and commercial vehicles. That model was derived from a 1975 TxDOT research project (Buffington and McFarland 1975). A 1999 TxDOT research report (Daniels et al. 1999) found that model to be consistent with values derived from other states. The 1999 TxDOT report suggested additional research to revise the VOT for trucks because the sample size was small from the McFarland and Buffington study.

In 2014, TxDOT recommended a VOT of $21.73 per hour for passenger travel and $31.71 per hour for commercial traffic. TxDOT recommended using these values to estimate road user costs that are used in construction project bidding and incentive/disincentives for milestones, final substantial completion, and lane rentals.

Table 4. Value of Travel Time Used by a Sample of DOTs.

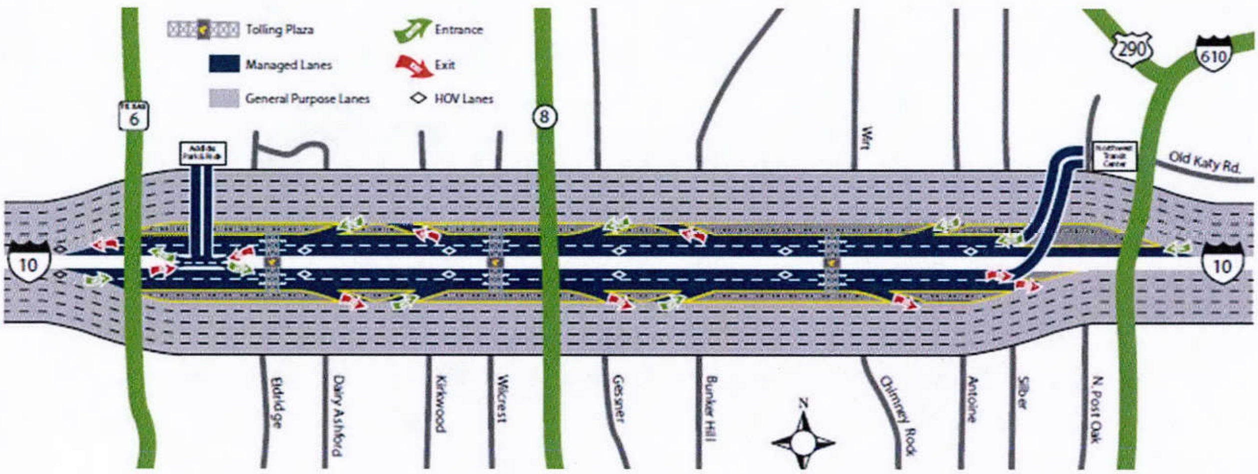
Agency (DOT)	Auto VOT ($/Hour)	Truck VOT ($/Hour)	Reference/Source	Uses
Arkansas	$19.02	$27.16 single unit and $41.63 for combination trucks	Primarily the Federal Highway Administration's *Work Zone Road User Costs Concepts and Applications* (December 2011), according to personal communication with Andrew Brewer of the Arkansas State Highway and Transportation Department	Incentive/disincentive contracting charges to discourage lane closures outside permitted hours
California	$12.5	$28.7	USDOT guidance	
Colorado	—	—	Personal communication with the Colorado DOT	Working on developing a VOT for statewide models
Idaho	$13.63	$33.00	USDOT guidance	
Kansas	$17.45	$25.18	N/A	
Michigan	$11.61	$84.65	USDOT guidance	
Minnesota	$16.00	$27.30	USDOT guidance as noted in http://www.dot.state.mn.us/planning/program/appendix_a.html, and personal communication with John Wilson of the Minnesota DOT	Benefit-cost analysis focused on the alternatives analysis stage of project development, as well as related decision-support tools (e.g., ranking of accelerated bridge construction candidates) and road user cost calculations for A + B bidding
Nevada	$11 for personal and $34 for business		Personal travel is calculated as 50% of the local median wage, while business travel by truck/bus drivers is 100% of the mean wage, according to personal communication with Peter Aiyuk of the Nevada DOT	Benefit/cost analysis and for other applications
New Jersey	$14.51	$24.18	Curry and Anderson (1972)	
Ohio	$19.22	$51.88	Road User Cost Spreadsheet and personal communication with Clint Bishop of the Ohio DOT	Incentive/disincentive contracts and A + B bidding

Agency (DOT)	Auto VOT ($/Hour)	Truck VOT ($/Hour)	Reference/Source	Uses
Oregon	50%–70% of median house-hold income, $25.78	$22.12 for delivery/ medium trucks, $31.32 for heavy trucks	Derived from the Federal Highway Administration's *Highway Economic Requirements System—State Version, Technical Report* (August 2005); and USDOT's *The Value of Travel Time Savings: Departmental Guidance for Conducting Economic Evaluations Revision 2 (2014 Update)* (July 9, 2014). Found in https://www.oregon.gov/ODOT/TD/TP/Reports/Value_of_TravelTime.pdf , sent by John Svadlenak of the Oregon DOT.	
Tennessee	$16	$100	Local university studies have been based on the speed-choice model from TTI research, according to personal communication with Brad Freeze of the Tennessee DOT	Benefit-cost studies
	$20.08	$29.32		Road user cost for construction manager/general contracting projects
Texas	$21.73	$31.71	McFarland and Chui (1986)	
Vermont	$18.93	$18.93	FHWA Highway Cost Allocation Study (2001) updated to 2014 by CPI, according to personal communication with Costa Pappis of the Vermont Agency of Transportation	Transportation Investment Generating Economic Recovery (TIGER) grant applications
Washington State	50% of average wage rate	$20.5–$27.7	USDOT guidance	

Appendix B: Study Data and Research Methodology

Surveys are the most common method to estimate travelers' VOT and VOR. Very few studies used actual traveler data. However, in this research, a unique dataset from Katy Freeway travelers allowed for a detailed analysis of travelers' actual trips to estimate VOT and VOR.

The I-10 Katy Freeway connects City of Katy to downtown Houston. This 12-mile section of freeway has up to six GPLs and two variably priced MLs in each direction (see Figure 1). The Katy Freeway MLs generally require less travel time and are usually more reliable than the adjacent GPLs. Drivers are required to pay a toll depending on the time of day and the number of people in the vehicle. HOVs with two or more occupants and motorcycles can use MLs for free during HOV-free hours. HOV-free hours are Monday through Friday from 5 a.m. to 11 a.m. and 2 p.m. to 8 p.m. HOVs and motorcycles pay the same toll as SOVs at all other times. To avoid the toll during the HOV-free hours, HOVs and motorcycles must pass the toll plazas in the HOV lane, the leftmost lane of MLs.



Source: Harris County Toll Road Authority (n.d.)

Figure 1. Katy Freeway.

TxDOT operates AVI sensors located on both the MLs and GPLs along Katy Freeway. Figure 2 shows the location of the sensors, with each number indicating a specific sensor. These sensors detect vehicles with transponders and record the unique transponder ID from the vehicle and time of detection. All vehicles that pay a toll on the MLs are required to use a transponder. Many other vehicles traveling on Katy Freeway also have transponders. The AVI data obtained from TxDOT consists of all sensor detection records from most of 2012, 2013, and 2014. Some days at the end of December 2012 were missing, and therefore December 2012 was not included in the analysis. Also, the data were gathered in October 2014, so the data include only through September 2014.

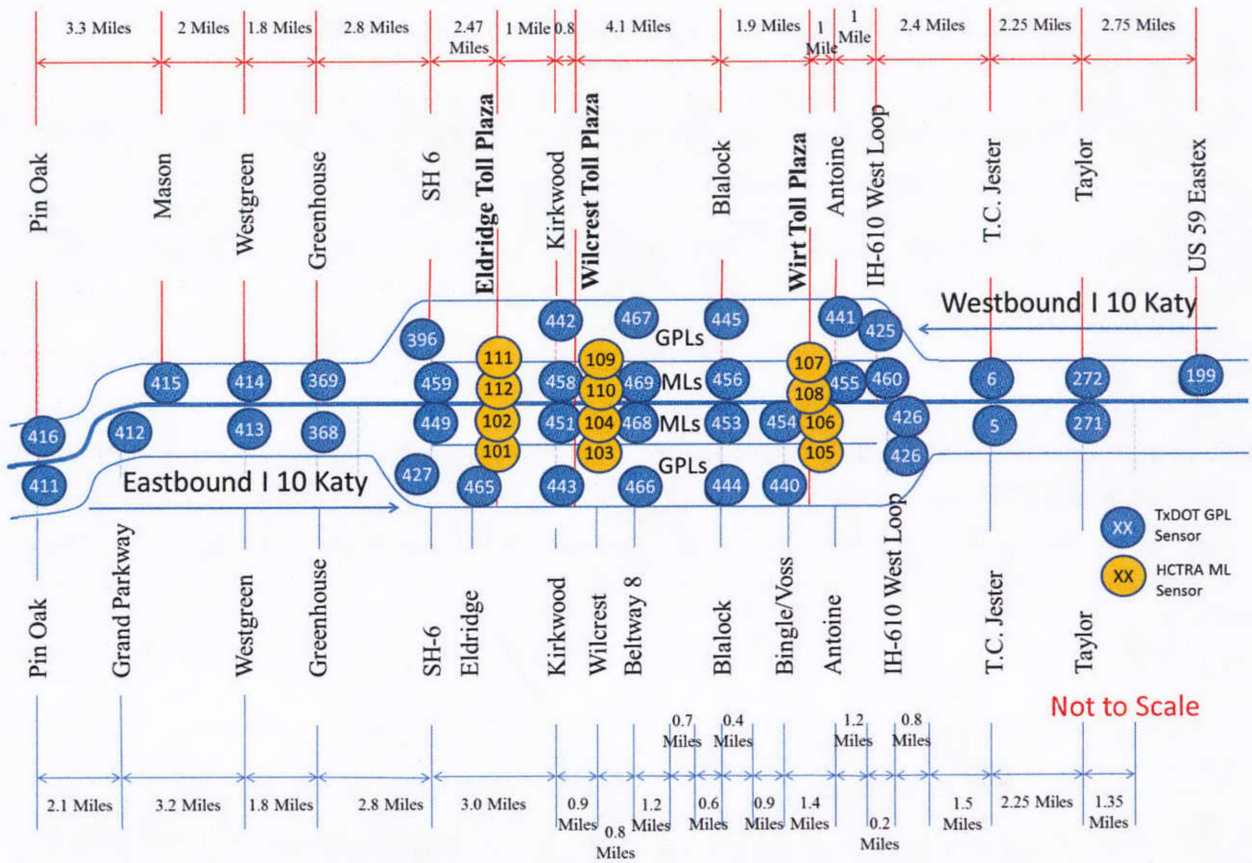


Figure 2. AVI Sensors along Katy Freeway.

HCTRA operates the MLs and collects AVI data along the MLs at the three toll plaza locations (see Figure 2 for HCTRA sensors). These data obtained from HCTRA included the unique transponder ID, date and time of record, and toll paid (if applicable) for each vehicle traveling within the MLs for 2012, 2013, and 2014 (only through September because the data were obtained in October 2014). Some travelers, including HOVs, used the MLs without paying a toll during the HOV-free hours. The focus of this research was to understand how much travelers were willing to pay to use the faster and more reliable MLs. Since those travelers did not pay a toll, they were not included in the analysis.

To ensure that no transponder owner could be identified using the transponder IDs, each transponder ID was assigned a unique random ID, and the original transponder IDs were deleted. Therefore, the dataset could never be used to identify specific individuals traveling on Katy Freeway. The dataset could still be used to track the trips of vehicles throughout the three years based on the random ID that each vehicle was assigned.

Based on these AVI reads, the trips of all vehicles with transponders along the freeway could, in theory, be estimated using AVI data that indicate specific points where drivers were located. In other words, individual AVI records can be matched together to form a collective series of points that represent a trip along a highway. The GPL sensors were not originally designed to achieve 100 percent accuracy for all recorded trips, and some GPL trips were not accurately recorded.

The total number of missed trips was unknown. However, millions of other trips were identified, and a large enough sample size was found to perform the analysis. Travel time and distances from freeway travelers were calculated using the time and location of sequential detection of unique IDs. The time difference between two consecutive detections had to be less than 15 minutes to assume that each record was part of the same trip. Otherwise it was assumed the vehicle exited the freeway, possibly to purchase gas, coffee, etc., and then returned to the freeway; this would be two separate trips. Both 20- and 30-minute time limits were examined and resulted in almost no change in the number of trips removed from the dataset. This indicated that using a 15-minute cut-off time did not result in a significant number of real but very slow trips being removed from the dataset.

Based on the time of detection and the toll schedule, tolls were assigned to the trips that were detected at toll plazas in the MLs. The total toll for each trip was equal to the sum of tolls paid along the trip at up to three toll booths. Table 5 shows the toll rates and schedule.

Table 5. Katy Managed Lane Toll Rates.

Dates	Direction	Time of Day	Toll at Eldridge (See Figure 2)	Toll at Both Wilcrest and Wirt (See Figure 2)
Opening day (April 2009) to Sept. 7 2012	Westbound	Peak: 5–7 p.m. weekdays	$1.60	$1.20
		Shoulder: 4–5 and 7–8 p.m. weekdays	$0.80	$0.60
		Off-peak: all other times	$0.40	$0.30
	Eastbound	Peak: 7–9 a.m. weekdays	$1.60	$1.20
		Shoulder: 6–7 and 9–10 a.m. weekdays	$0.80	$0.60
		Off-peak: all other times	$0.40	$0.30
Sept. 8, 2012–Sept. 7 2013	Westbound	Peak: 4–6 p.m. weekdays	$2.20	$1.40
		Shoulder: 3–4 and 6–7 p.m. weekdays	$1.10	$0.70
		Off-peak: all other times	$0.40	$0.30
	Eastbound	Peak: 7–9 a.m. weekdays	$2.20	$1.40
		Shoulder: 6–7 and 9–10 a.m. weekdays	$1.10	$0.70
		Off-peak: all other times	$0.40	$0.30
Sept. 7 2013–today	Westbound	Peak: 4–6 p.m. weekdays	$3.20	$1.90
		Shoulder: 3–4 and 6–7 p.m. weekdays	$2.10	$1.20
		Off-peak: all other times	$0.40	$0.30
	Eastbound	High peak: 7–8 a.m. weekdays	$3.20	$1.90
		Low peak: 8–9 a.m. weekdays	$2.60	$1.70
		High shoulder: 6–7 a.m. weekdays	$2.10	$1.20
		Low shoulder: 9–10 a.m. weekdays	$1.50	$1.00
		Off-peak: all other times	$0.40	$0.30

To estimate how much travelers value their travel time and travel time reliability, it was necessary to model the decision each traveler makes between the MLs and GPLs. Therefore, it was necessary to know both the attributes of the trip they made and the attributes of the trip on the alternate lanes. So for each trip on the MLs, the attributes of a similar trip on the GPLs were needed, and vice versa. For each trip, a simulated trip was created for the lane set that was not chosen. Simulated trips had the same start time and passed through the same section of the freeway but on the other set of lanes. For trips on the toll lane, the simulated trip was free on the GPLs. For trips on the GPLs, a tolled trip was created. In cases where the GPL sensor and the ML sensor were not in the same location, the travel time was adjusted to account for the difference.

Travel times were calculated for each simulated trip by averaging travel times for similar freeway trips on the alternative lane (the lane that was not chosen). The simulated trips had to occur within the same 15-minute interval in which the actual trip was made. Approximately 50 percent of peak-period and 35 percent of shoulder-period alternate trip speeds were derived from actual trips on the alternate lanes. In some cases (50 percent in the peak, 63 percent in the shoulder, and 80 percent in the off-peak), a portion of the alternate trip had vehicles from which a speed could be measured, but a portion of the trip had to estimate the speed based on speeds on the surrounding segments. For a small percentage of time (less than 2 percent in the peak and shoulder, and 8 percent in the off-peak), no speeds were available for the alternate lanes, and average speeds based on previous data were used. In this case, average speeds were calculated using actual trips during the same time frame (off-peak, shoulder, and peak), averaged across an entire month. In some cases, the GPL and ML sensors were not in the same location. The travel times were adjusted to account for any differences.

Some vehicles changed lanes from the GPLs to MLs, or vice versa. Determining the exact location of the switch was impossible because vehicles were only detected at the AVI sensors. As a result, the amount of travel time savings could not be estimated. Consequently, those trips that switched between the GPLs and MLs were removed from the dataset for analysis. Also, toll-exempt ML trips during HOV-free hours and holiday time periods were excluded from the analysis.

Lane closure and weather data were incorporated into the analysis to assess whether these factors influenced lane-choice behavior. Data containing information about roadway incidents and lane closures on Katy Freeway for all of 2012, 2013, and 2014 were obtained from TxDOT. A significant number of incidents were found during this three-year period. Only incidents that resulted in lane closures were included in the analysis. For this project, it was hypothesized that only trips starting at an upstream location were impacted by the incident. A weather dataset, including hourly rainfall in inches near Katy Freeway, was obtained from the National Climatic Data Center (http://www.ncdc.noaa.gov/cdo-web/search?datasetid=PRECIP_HLY) .A variable that indicated heavy rain during an hour (rainfall greater than 0.4 inches in an hour) was added to the trip dataset. This occurred 78 times over the three years of analysis.

The final dataset contained two records for each trip. The two records represented the two choices for the trip: the one that was made and the one on the lanes not chosen. The trip parameters included in the final dataset were the random ID, lane choice, travel time, total toll paid, trip length, lane closure, precipitation greater than 0.4 inches in an hour, and a time-of-day indicator of peak, off-peak, or shoulder period.

Appendix C: Detailed Study Results

Overview of Paid ML Trips

An initial examination of the general size and scope of the data used in this analysis was undertaken. This began with a simple tally of the number of trips that were recorded in the dataset (see Table 6). Over 100 million trips were assessed. Despite the high number, the sample is only a fraction of all Katy Freeway trips taken during the three-year period. These data do not include trips taken by vehicles without transponders, free ML trips (e.g., carpools), and trips where the location of sensors restricted the capability of determining where a trip had occurred. However, researchers believe this dataset is well beyond what is needed to estimate travelers' willingness to pay for travel time savings and reliability, considering previous research is based on a few hundred to a few thousand travelers. ML trips represent approximately 7 percent of the trips recorded.

Table 6. Number of Recorded Trips.

Year	Number of Trips on General Purpose Lane	Number of Trips on Managed Lane	Number of Total Trips
2012 (January–November)	31,247,230	2,011,608	33,258,838
2013 (January–December)	36,017,349	2,601,242	38,618,591
2014 (January–September)	2,400,737	2,400,737	29,653,252

Table 7 shows the number and percentage of paid ML trips. A surprisingly large number of trips, almost 3.4 million, use the MLs in the off-peak period. However, the off-peak period constitutes the majority of the day and includes busy times of day in the off-peak direction. Figure 3 presents the toll those trips paid, and Figure 4 shows the travel time savings.

The travel time saved on those trips ranged from −200 seconds (the MLs were slower) to over 1,200 seconds. Approximately 11 percent of all paid trips on the MLs did not save any travel time. The average travel time savings was 155 seconds. There were many short trips on the MLs (as can be seen from the tolls paid in Figure 3), and this likely accounts for many of the smaller time savings. Figure 5 shows the toll paid for a specific ML trip divided by the time saved on that trip. The mean willingness to pay was $39.65.

Table 7. Paid Trips on Managed Lane.

Time Period (See Figure 5 for Times of Day)	Number of Trips on Managed Lane	Percentage of All Trips That Were Paid Trips on Managed Lane
Off-peak	3,379,635	4.31%
Shoulder	1,300,189	11.55%
Peak	2,333,763	19.28%

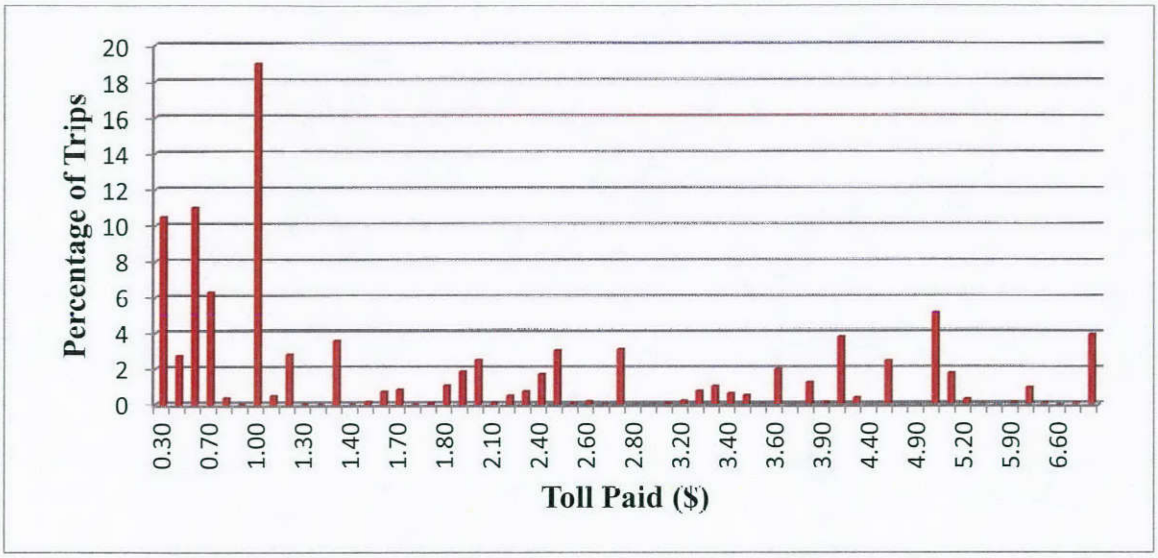


Figure 3. Total Toll Paid on the Managed Lanes.

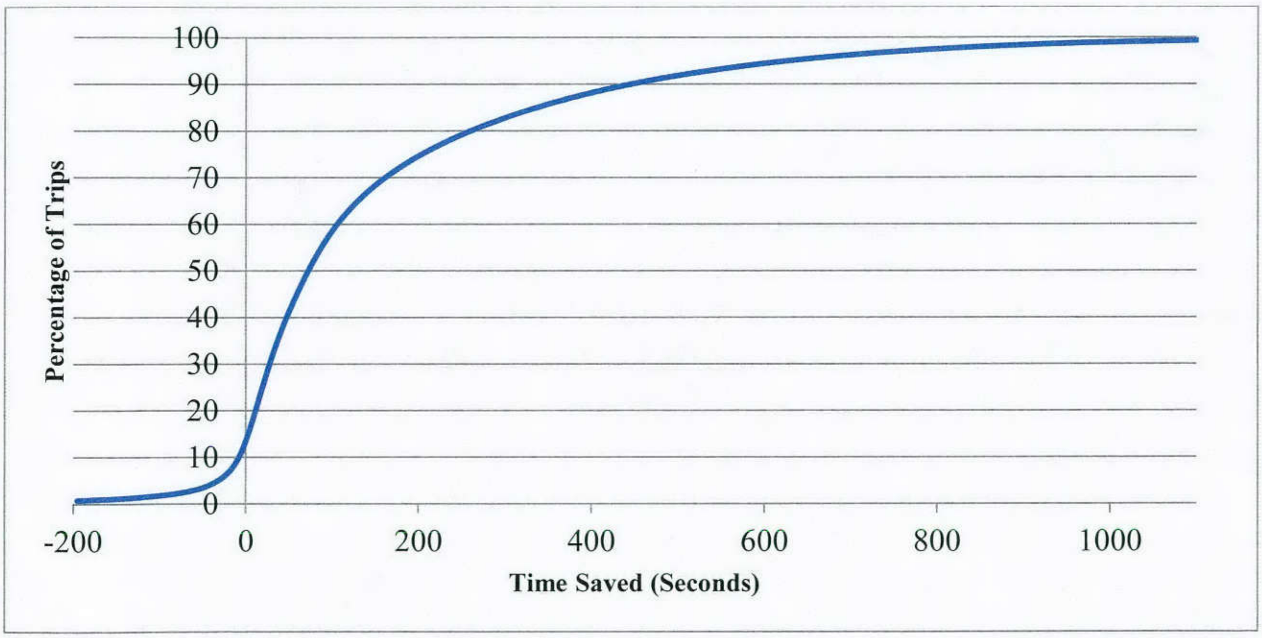


Figure 4. Travel Time Saved (Seconds) on the Managed Lanes.

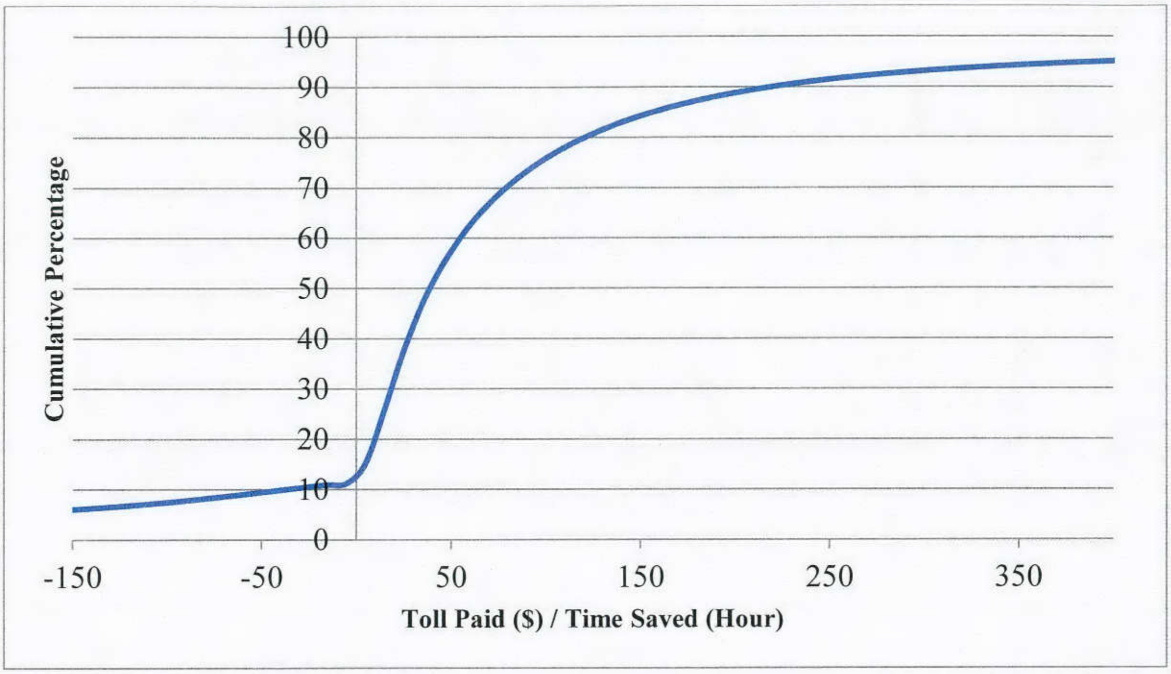


Figure 5. Toll Paid Divided by Time Saved.

Travel Time Reliability

One reason travelers are likely to pay for the MLs, even though the MLs do not always save them travel time, is that the MLs are more reliable. In this study, reliability was based on the consistency of travel times over the 20 weekdays prior to a given trip. To calculate the reliability measures for a given time of day and section of freeway, several statistical values such as mean, median, standard deviation, and percentile (10th, 25th, 50th, 75th, 80th, 85th, 90th, and 95th) VOT over the previous 20 weekdays were needed.

Each day was divided into 10-minute intervals. The required statistical values of travel time between a given pair of sensors for a given time interval on a specific day were calculated using the average travel time observed during the previous 20 weekdays. For example, to calculate reliability for a trip between sensors 465 and 444 (see Figure 2) during 12:00 p.m.–12:10 p.m. on July 29, 2012:

1. Calculate the average travel time observed between sensors 465 and 444 during 12:00 p.m. and 12:10 p.m. on each weekday from July 1 to July 28.
2. Calculate the required statistical values using these travel times.

Ideally, there would be 20 travel times to use to calculate the reliability measures. However, there were often less than 20 days with traffic during specific periods of the day at specific locations, particularly overnight. If there were less than three days of data available, then there was insufficient data to determine the reliability for that specific 10-minute period. This removed approximately 4 percent of the overall trip data.

In some cases, no trip was observed starting and ending at a pair of sensors located close together because vehicles were traveling longer distances. In those cases, the average travel time between a pair of closely located sensors was approximated using data from longer trips, given that the travelers who made those longer trips also passed the closely spaced sensors.

Suppose, on a specific day during 12:00 p.m.–12:10 p.m., there were no trips that started at sensor 443 and ended at sensor 466 (see Figure 2). However, on that day during that time period, there might be many trips from sensor 465 to sensor 466, from sensor 443 to sensor 444, or from sensor 465 to sensor 440. From the trip data between the pairs of sensors mentioned above, the time required to travel between sensor 443 and 466 could be estimated based on the speeds of vehicles traveling between sensor 465 and 466, 443 and 444, and 465 and 440. The estimated speed could be used to approximate the average travel time between sensor 443 and 466 during that that specific 10-minute period.

The free-flow travel time was required to calculate some of the reliability measures. The free-flow travel time is a function of free-flow speed and trip length. The free-flow speed is the speed of a traffic stream when the traffic density is very low. For this study, the median speed of vehicles that traveled between 11:00 p.m. and 12:00 p.m. during weekends in July 2012 and August 2012 was used as the free-flow speed. The result suggests that the free-flow speed was 68.8 mph on the MLs and 67.1 mph on the GPLs.

The results do indicate that the MLs are more reliable, although the difference in standard deviation of travel time on the MLs versus the GPLs is not very large (see Figure 6 through Figure 8).

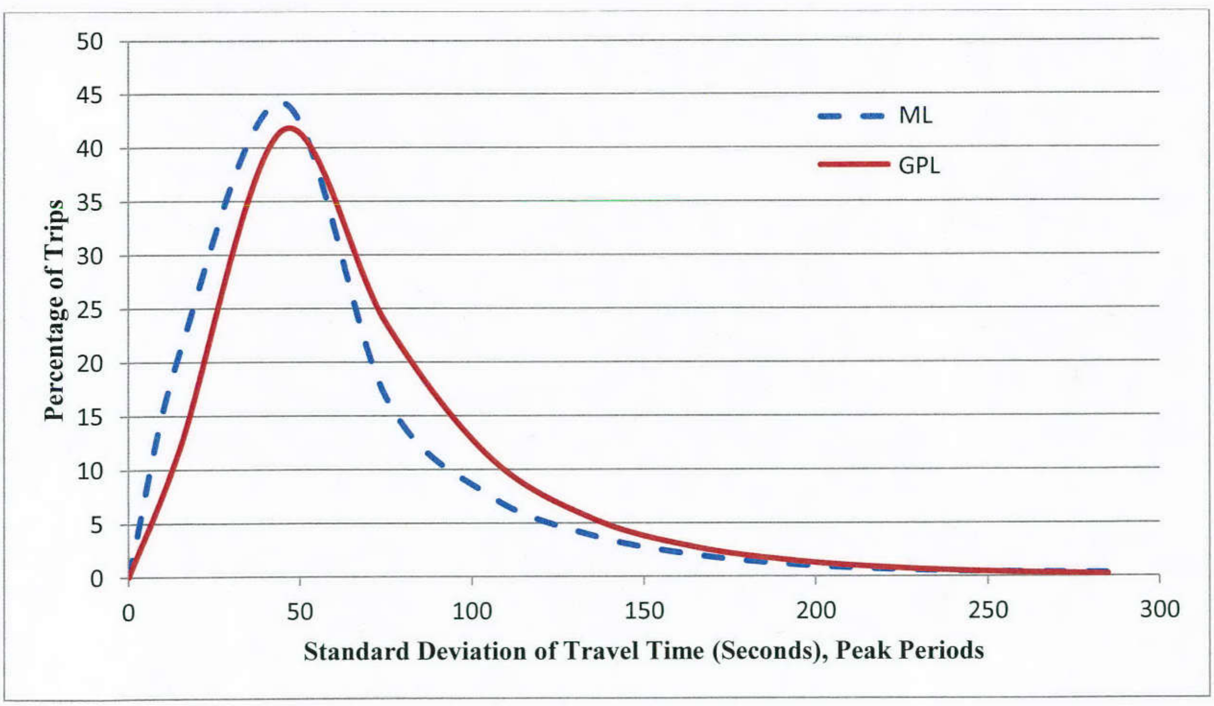


Figure 6. Reliability of the Lanes as Measured by the Standard Deviation of Travel Time during Peak Periods.

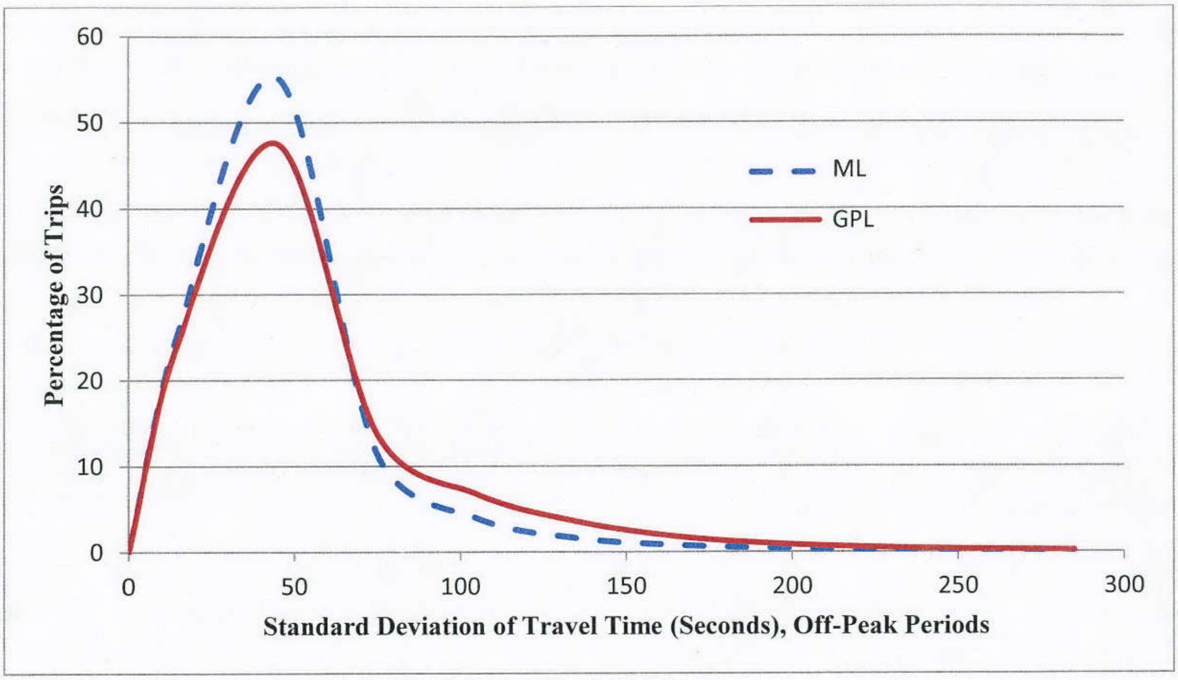


Figure 7. Reliability of the Lanes as Measured by the Standard Deviation of Travel Time during Off-Peak Periods.

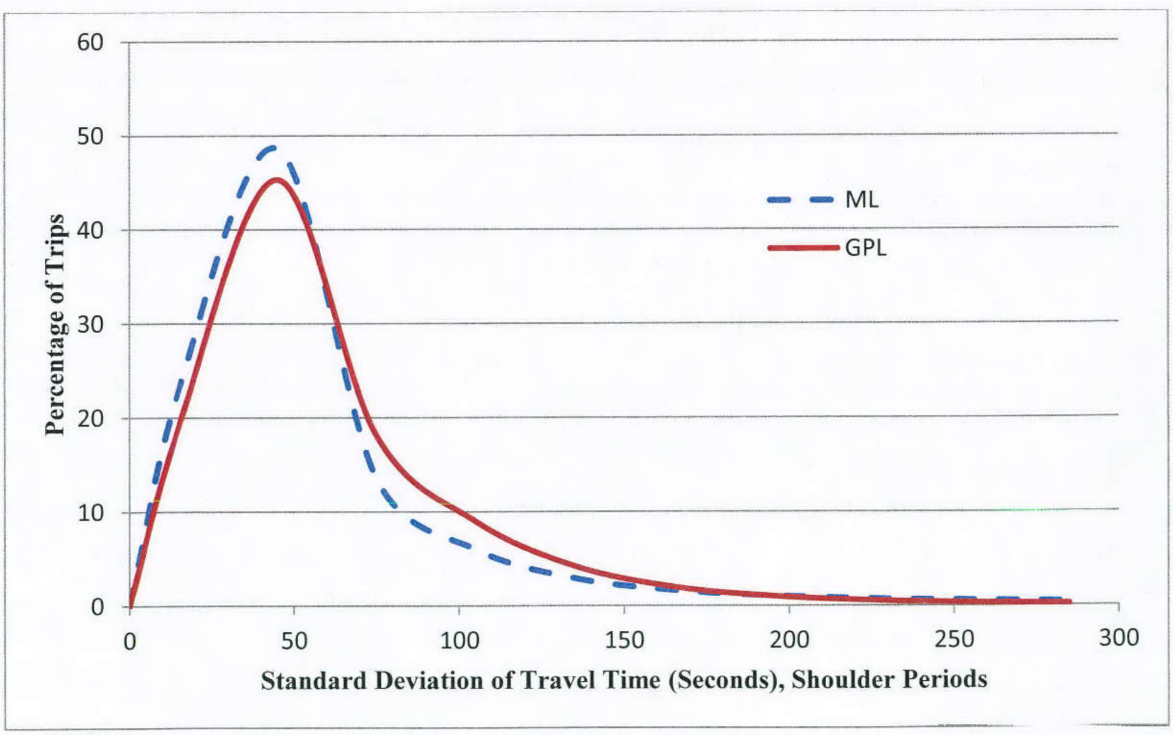


Figure 8. Reliability of the Lanes as Measured by the Standard Deviation of Travel Time during Shoulder Periods.

Frequency of Paid ML Use

Next, the amount of paid ML use by the different transponders was examined. Not surprisingly, a majority (79 percent) of the different transponder IDs identified on Katy Freeway never used the MLs during this entire three-year period (see Figure 9). They likely purchased their transponder for travel on different toll facilities.

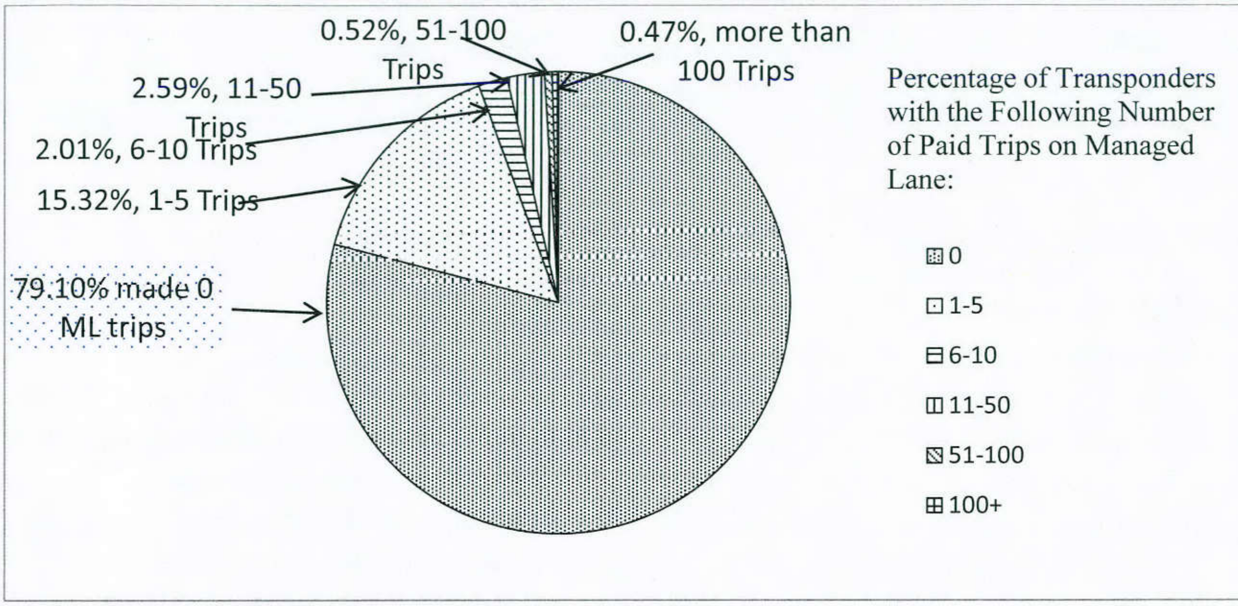


Figure 9. ML Trips Made by All Transponders Recorded on the Freeway.

The travelers' likelihood to use the paid MLs when they traveled on Katy Freeway was also examined. As before, 79 percent never used the MLs for any of their trips (see Figure 10); 9.4 percent used the lanes for a small percentage (1–10 percent) of their Katy Freeway trips. Some travelers (3.5 percent) used the MLs for all of their Katy Freeway trips.

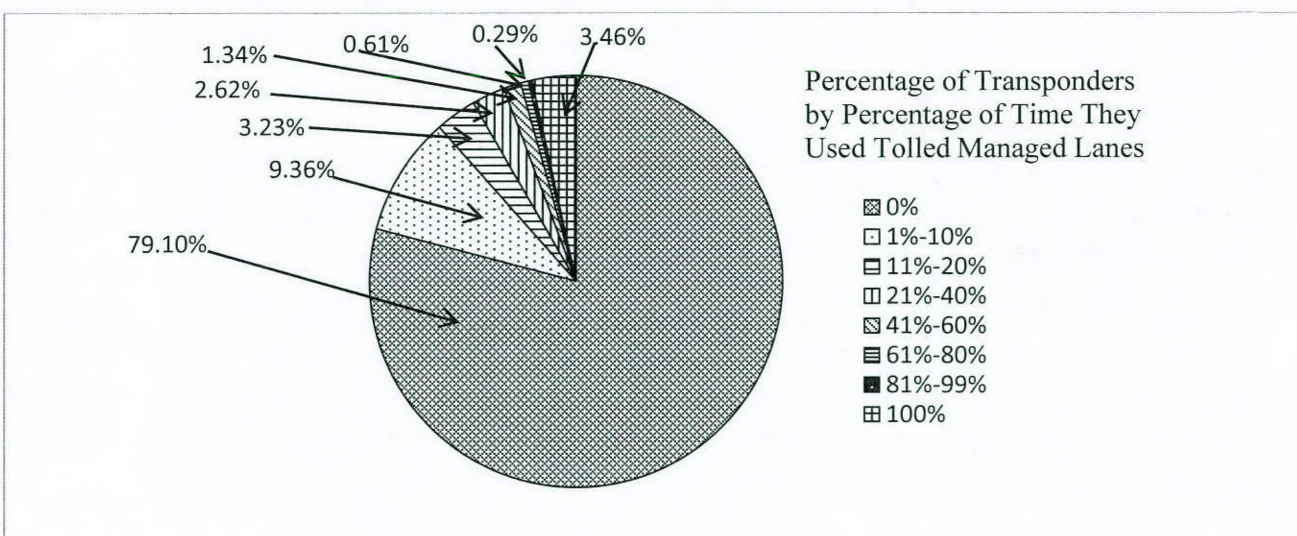


Figure 10. Percentage of Trips That Were Paid ML Trips, by Transponder.

With this understanding of the data, the next step was to focus on how much travelers were willing to pay to save travel time and get a more reliable trip on the MLs. This willingness to pay is highly related to a traveler's VOT and VOR. However, with this dataset it is only possible to know how much a traveler did pay. It is impossible to know how much more, if any, they would have paid if the toll had been higher. The total amount that the traveler would pay is his or her true VOT. The data here are the minimum that ML travelers were willing to pay; researchers cannot know their maximum willingness to pay. In addition, these values are only for those travelers who were willing to pay the toll. The travelers remaining on the GPLs valued their time less than the toll divided by the travel time savings. It is impossible to know how much less; it is only possible to know that their VOT was less.

VOT and VOR Analysis

Model Development

To determine a traveler's VOT, route-choice models were developed. The travel time, a measure of reliability, and the cost of any tolls were included in the utility functions of each route. However, the length of the actual trip and the generated alternate trip were not always equal due to the location of sensors on the MLs and GPLs. The two trips were made equivalent by multiplying the travel time and some reliability measures for the alternate trips by the ratio of the actual trip length to the alternate trip length. For example, assume the actual trip was on the GPLs and the sensors were spaced 1 mile apart. Then the alternate trip would be on the MLs. If the corresponding ML sensors were located 1.1 miles apart, then some ML data would be multiplied by 0.91 (1/1.1) to adjust it to be equivalent to the trip on the GPLs.

The route-choice models were estimated using standard logit models. The logit model inherently assumes that the user has knowledge of the value of the attributes of his or her choice, which in this case are travel cost, travel time, and travel time reliability. Travelers did have several sources of travel time information, including their own experience; travel time information was also provided to the public through media reports, displays on roadside electronic message signs, and the Houston Transtar website. Therefore, it would be reasonable to expect that travelers could estimate their travel time and possibly their travel time reliability. The toll rate was set in advance and could be found online. Therefore, one would expect travelers to have a good idea of what their toll would be.

The Statistical Analysis System (SAS) was used to generate binary discrete-choice models. Except for the randomized IDs, no information about the travelers, such as income, gender, and purpose of trips, was available. This study used only the information extracted from the trip data (see the methodology section in Appendix B). Choice models were developed based on travelers' lane choice. Typical examples are shown in Equations 1 and 2:

$$U_{GPL} = \beta_{TT}\, TravelTime_{GPL} + \beta_{TTR}\, TravelTimeReliability_{GPL} \quad (1)$$

$$U_{ML} = \beta_{ML} + \beta_{Toll}\, Toll + \beta_{TT}\, TravelTime_{ML} + \beta_{TTR}\, TravelTimeReliability_{ML} \quad (2)$$

Where:

- Ui = utility derived by choosing lane i where i is GPL or ML.
- GPL = general-purpose lane.
- ML = managed lane.
- TT = travel time.
- TTR = travel time reliability.
- β = coefficient derived from the logit model.

Basic Models of VOT

Models were estimated using many combinations of trip data to find the best model. Due to the size of the dataset, it was possible to model each direction of traffic (eastbound or westbound) and time period (peak, off-peak, and shoulder) separately and create one model per month. Intuitively, a decrease in travel time and toll should lead to an increase in utility. Simple models were developed with only two independent variables: travel time and toll. Models of two-way traffic had negative coefficients, as expected.

The results suggested that the VOT varied from $1.96 per hour (May 2013) to $8.06 per hour (September 2012) (see Table 8). When separated by direction, models of westbound traffic had negative coefficients for both time and toll. In models of eastbound traffic, there were several cases where the coefficient of travel time was positive (see Table 8), which is counterintuitive because it could only occur if travelers were paying tolls in the ML even though they were not saving travel time. This will be examined in more detail later in this appendix. In all of these models and all models in this research, the resulting coefficients were significant at greater than the 95 percent level of significance.

To observe the effect of an incident and/or heavy rain on lane choice, models were developed using toll, travel time, incident, and rain data. The results showed that the incidents and rain did not have a significant impact on travelers' lane-choice decision.

Table 8. Basic VOT Results by Month.

Model: $U_{ML} = \beta_{Time} \times Time_{ML} + \beta_{Toll} \times Toll$, $U_{GPL} = \beta_{Time} \times Ttime_{GPL}$

Year	Month	Two-Way			Eastbound			Westbound		
		βTime	βToll	VOT ($/Hour)	βTime	βToll	VOT ($/Hour)	βTime	βToll	VOT ($/Hour)
2012	January	−0.264	−2.152	7.37	−0.141	−1.993	4.26	−0.320	−2.291	8.40
	February	−0.234	−2.018	6.97	−0.133	−1.828	4.36	−0.307	−2.214	8.34
	March	−0.188	−1.993	5.67	−0.078	−1.829	2.56	−0.268	−2.165	7.44
	April	−0.195	−1.871	6.28	−0.082	−1.669	2.96	−0.285	−2.091	8.19
	May	−0.091	−1.328	4.13	0.000	−1.181	−0.02	−0.156	−1.481	6.35
	June	−0.161	−1.770	5.47	0.012	−1.576	−0.46	−0.275	−1.984	8.32
	July	−0.182	−1.888	5.78	−0.029	−1.726	1.02	−0.256	−2.036	7.57
	August	−0.141	−1.441	5.89	−0.073	−1.394	3.15	−0.173	−1.482	7.04
	September	−0.174	−1.301	8.06	−0.190	−1.295	8.83	−0.167	−1.309	7.67
	October	−0.186	−1.432	7.80	−0.115	−1.411	4.91	−0.216	−1.448	8.95
	November	−0.144	−1.587	5.44	−0.037	−1.699	1.33	−0.192	−1.522	7.57
2013	January	−0.149	−1.545	5.80	−0.045	−1.643	1.66	−0.160	−1.435	6.71
	February	−0.125	−1.418	5.31	−0.029	−1.456	1.23	−0.164	−1.381	7.13
	March	−0.138	−1.602	5.20	−0.023	−1.681	0.83	−0.198	−1.546	7.70
	April	−0.139	−1.361	6.14	−0.027	−1.373	1.20	−0.183	−1.345	8.19
	May	−0.033	−1.014	1.96	0.015	−1.084	−0.87	−0.058	−0.954	3.68
	June	−0.069	−1.095	3.82	0.070	−1.028	−4.12	−0.124	−1.141	6.57
	July	−0.123	−1.363	5.42	0.007	−1.354	−0.33	−0.197	−1.402	8.45
	August	−0.063	−1.129	3.37	0.003	−1.271	−0.15	−0.095	−1.021	5.59
	September	−0.062	−0.825	4.56	−0.075	−0.899	5.01	−0.049	−0.762	3.93
	October	−0.058	−0.883	3.95	−0.073	−1.046	4.23	−0.042	−0.758	3.33
	November	−0.040	−1.105	2.19	−0.016	−1.156	0.84	−0.064	−1.066	3.63
	December	−0.066	−1.390	2.86	0.012	−1.514	−0.49	−0.122	−1.305	5.61
2014	January	−0.079	−0.938	5.07	−0.043	−0.990	2.63	−0.083	−0.885	5.68
	February	−0.042	−0.709	3.58	−0.042	−0.790	3.20	−0.032	−0.635	3.07
	March	−0.051	−0.814	3.80	0.019	−0.768	−1.51	−0.087	−0.858	6.10
	April	−0.072	−0.782	5.54	−0.081	−0.776	6.30	−0.069	−0.789	5.32
	May	−0.090	−0.752	7.20	−0.078	−0.735	6.42	−0.097	−0.767	7.58
	June	−0.067	−0.719	5.59	−0.024	−0.685	2.10	−0.087	−0.751	7.02
	July	−0.060	−0.770	4.71	0.018	−0.744	−1.46	−0.091	−0.795	6.87
	August	−0.062	−0.710	5.27	−0.010	−0.704	0.92	−0.079	−0.710	6.68
	September	−0.073	−0.666	6.62	−0.075	−0.644	7.00	−0.075	−0.686	6.58

Basic VOT and VOR Models by Month

Next, models were developed using travel time, toll, and a reliability measure. This study considered six measures of travel time reliability:

- Standard deviation (SD).
- Coefficient of variation (CV).
- 95th percentile value.
- Shorten right range (SRR).
- Interquartile range (IR).

- Buffer time index (BTI).

The definitions of the reliability measures can be found in Table 2. An increase in one of these reliability measures indicates a decrease in reliability. Therefore, an increase in the reliability measure should lead to a decrease in utility. In this study, an expected result for a model means all the model coefficients (time, toll, and reliability) are negative. Table 10 summarizes the frequency of expected results for different combinations of traffic data and reliability measures. Because one model per month was created, each combination had 29 cases. During the off-peak period, the models of two-way and eastbound traffic had the expected results in all cases when SD, 95th percentile, IR, or SRR was used as a reliability measure. For most reliability measures, the models of westbound traffic had the expected results in less than 10 out of 29 cases, which could only occur if travelers were paying to use the MLs even though the MLs were less reliable and/or slower than the GPLs.

For most combinations of traffic data, only the models with BTI as the reliability measure had expected results in 20 or more cases. The model results are documented in Appendix D. The correlation between time and the reliability measures ranged from strongly correlated to uncorrelated. The correlation coefficients were as follows:

- Time with SD = 0.56.
- Time with CV = 0.06
- Time with 95th percentile = 0.86.
- Time with IR = 0.51.
- Time with SRR = 0.46.
- Time with BTI = −0.02.

In summary, lane-choice behavior is different in the eastbound and westbound directions. In the westbound direction, no model with a reliability measure yielded expected results on a consistent basis. For eastbound and two-way traffic, during the off-peak period, most of the models yielded anticipated results. Due to the many negative VOT and VOR results, the VOTs and VORs were not presented for each case.

Table 9. Value of Travel Time (Dollars per Hour) by Time Period.

Model: $U_{ML} = \beta_{Time} \times Time_{ML} + \beta_{Toll} \times Toll,\ U_{GPL} = \beta_{Time} \times Ttime_{GPL}$

Year	Month	Peak period			Shoulder Period			Off-Peak Period		
		Two-Way	Eastbound	Westbound	Two-Way	Eastbound	Westbound	Two-Way	Eastbound	Westbound
2012	January	4.44	10.59	2.54	7.17	5.13	7.49	1.12	1.89	0.08
	February	6.11	14.12	3.67	6.77	3.84	7.56	1.47	2.39	0.42
	March	5.07	14.30	1.61	6.68	4.54	7.02	2.16	2.78	0.70
	April	5.36	11.57	3.22	6.96	3.02	7.78	2.02	2.68	0.71
	June	5.27	4.54	3.82	7.65	4.03	7.84	2.40	3.01	0.89
	July	5.65	8.61	4.51	6.86	3.77	7.2	1.62	2.46	0.24
	August	0.57	11.17	−13.40	5.82	3.14	5.24	1.64	2.74	−0.34
	September	5.60	19.48	−4.51	3.95	5.05	3.19	2.08	3.15	−0.27
	October	5.58	14.45	0.66	3.48	3.76	3.14	1.94	3.09	−0.59
	November	6.10	11.11	2.83	3.23	4.51	2.37	2.00	2.46	0.07
2013	January	3.90	6.57	1.21	2.16	2.05	1.71	1.49	2.47	−0.68
	February	4.79	11.99	−1.31	1.15	3.05	−0.17	1.97	2.63	0.14
	March	7.02	14.36	2.05	2.72	1.96	2.3	2.31	2.86	−0.12
	April	5.48	7.28	0.71	2.84	2.28	2.46	1.91	2.90	−0.38
	May	−8.92	2.72	−50.36	−3.54	−1.44	−6.5	1.85	2.62	−2.55
	June	−0.79	−8.11	−10.48	1.35	0.03	0.81	2.50	3.34	−0.73
	July	6.26	0.92	2.56	4.36	2.1	4.13	2.94	3.47	−0.65
	August	−2.12	6.13	−25.61	2.61	1.34	1.52	2.87	3.56	0.75
	September	2.51	20.79	−14.52	2.57	4.05	1.28	3.04	3.84	0.21
	October	3.07	16.72	−14.39	2.05	6.88	−0.78	2.55	3.63	0.18
	November	4.04	16.47	−3.98	2.32	8.48	−0.19	2.85	3.21	0.64
	December	7.42	15.36	5.11	2.55	1.83	1.97	2.81	3.34	0.30
2014	January	6.44	18.46	3.37	2.61	5.2	1.71	2.60	3.79	0.36
	February	1.95	16.55	−9.36	1.65	5.81	−0.93	2.59	3.97	0.35
	March	4.69	13.30	2.00	2.35	1.7	2.14	2.41	3.65	0.35
	April	3.14	16.93	−2.55	3.95	6.67	2.64	2.85	4.81	0.06
	May	7.61	21.36	2.35	4.79	6	3.84	3.13	5.20	−0.03
	June	5.29	12.85	0.61	4.45	6.71	3.18	3.55	5.40	−0.49
	July	5.35	0.75	1.37	4.25	4.25	3.01	3.24	5.08	−0.32
	August	6.56	16.94	0.92	3.52	2.03	2.49	3.22	5.02	0.15
	September	8.75	20.93	5.46	3.31	2.66	3.6	2.99	4.81	0.08

Table 10. Model Results Summary.

Direction	Reliability Measure→ / Time of Day↓	Standard Deviation	Coefficient of Variation	95th Percentile	Interquartile Range	Shorten Right Range	Buffer Time Index
Two-way	Peak	less than 10	less than 10	less than 10	less than 10	less than 10	20–28
	Shoulder	less than 10	less than 10	10–19	less than 10	20–28	20–28
	Off-peak	29	10–19	29	29	29	20–28
Eastbound	Peak	20–28	less than 10	20–28	10–19	20–28	10–19
	Shoulder	less than 10	less than 10	less than 10	10–19	less than 10	less than 10
	Off-peak	29	20–28	29	29	29	10–19
Westbound	Peak	less than 10	less than 10	less than 10	less than 10	less than 10	less than 10
	Shoulder	less than 10	less than 10	less than 10	less than 10	20–28	10–19
	Off-peak	less than 10	less than 10	less than 10	less than 10	less than 10	20–28

Legend:

- (white) Expected results in 29 out of 29 cases
- (grey) Expected results in 20–28 out of 29 cases
- (vertical lines) Expected results in 10–19 out of 29 cases
- (dark) Expected results in less than 10 out of 29 cases

VOT and VOR Models without Uneconomical Trips and Non-switching Travelers

None of the reliability measures used in this study yielded the expected results on a consistent basis. One reason might be that approximately 11 percent of all paid trips on the MLs did not save any travel time (termed uneconomical trips). Therefore, new models were developed excluding these uneconomical trips. Exclusion of these uneconomical trips increased the number of cases with expected results (see Table 11), but again, no reliability measures yielded consistent results. Among the six reliability measures, 95th percentile value, SRR, and BTI more often yielded the expected results.

Another reason might be that 82.6 percent of total detected transponder-equipped vehicles never changed their lane choice: 79.1 percent of transponders always used the GPLs, and 3.4 percent of transponders always used the MLs. Since these travelers appear to have had a set lane and did not deviate regardless of time saved or toll paid, researchers estimated the route-choice models without them. Therefore, new models were developed using only those travelers who used each lane at least once during the three years of the analysis. The 17.4 percent of the total detected transponders that used each lane at least once represented 55.4 percent of all trips. The 95th percentile value, SRR, and BTI were tested as reliability measures because they yielded better results in the previous models. The exclusion of these 44.6 percent of all trips, which were mostly GPL trips, resulted in a large increase in the models, providing results as expected (see Table 11 and Table 12). However, no reliability measure yielded consistent results.

Finally, models were developed that excluded both uneconomical trips and those transponders that always chose the same lane. This resulted in only a small reduction in the number of travelers included in the model because the model still contained 17.3 percent of total transponders and 53.5 percent of total trips. The results yielded a small improvement in terms of expected results (Table 13). However, despite removing 46.5 percent of all trips from the dataset, no reliability measure consistently provided results as expected—many yielded VOT and VOR that were negative for at least some time periods in some directions.

Table 11. Models of Reliability Measures.

Direction	Traffic Data→ / Reliability Measure→ / Time of Day↓	Number of Cases Where the Anticipated Result Was Obtained (/29)					
		All trips			All Trips Excluding Uneconomical Trips		
		95th Percentile	Shorten Right Range	Buffer Time Index	95th Percentile	Shorten Right Range	Buffer Time Index
Two-way	Peak	3	9	6	29	29	27
	Shoulder	19	26	23	11	18	29
	Off-peak	29	29	28	29	29	22
Eastbound	Peak	22	22	16	29	27	12
	Shoulder	6	3	3	25	22	16
	Off-peak	29	29	19	5	3	2
Westbound	Peak	1	2	10	29	29	29
	Shoulder	11	10	8	2	9	23
	Off-peak	4	7	12	24	29	6
Total (out of 261 cases)		124	137	125	183	195	166

Table 12. Model Results Summary for the Travelers Who Had at Least One Trip on Each Lane.

Direction	Reliability Measure→ Time of Day↓	95th Percentile	Shorten Right Range	Buffer Time Index
Two-way	Peak			
	Shoulder			
	Off-peak			
Eastbound	Peak			
	Shoulder			
	Off-peak			
Westbound	Peak			
	Shoulder			
	Off-peak			

Legend:

- Expected results in 29 out of 29 cases
- Expected results in 20–28 out of 29 cases
- Expected results in 10–19 out of 29 cases
- Expected results in less than 10 out of 29 cases

Table 13. Models of Reliability Measures (for Travelers Who Had at Least One Trip on Each Lane).

Direction	Traffic Data→ / Reliability Measure→ / Time of Day↓	Number of Cases Where the Anticipated Result Was Obtained (/29)					
		Travelers Who Had at Least One Trip on Each Lane			Travelers Who Had at Least One Trip on Each Lane Excluding Uneconomical Trips		
		95th Percentile	Shorten Right Range	Buffer Time Index	95th Percentile	Shorten Right Range	Buffer Time Index
Two-way	Peak	8	16	26	17	27	29
	Shoulder	26	28	27	29	29	25
	Off-peak	29	29	28	29	29	27
Eastbound	Peak	25	23	20	25	24	20
	Shoulder	19	5	10	14	4	7
	Off-peak	29	29	20	29	28	16
Westbound	Peak	1	6	18	6	14	25
	Shoulder	23	27	24	29	29	22
	Off-peak	28	28	28	29	29	28
Total (out of 261 cases)		188	191	201	207	213	199

Many months had a VOT and VOR with unexpected (negative) results. Table 14 provides a summary of the range of values. VOT ranged from just under $0 per hour to over $26 per hour, while VOR ranged from −$8 per hour to $3 per hour, with many estimates being close to $0 per hour.

Table 14. Range of VOT and VOR.

Dataset	Minimum or Maximum	95th Percentile		Shorten Right Range		Buffer Time Index	
		VOT ($/Hour)	VOR ($/Hour)	VOT ($/Hour)	VOR ($/Hour)	VOT ($/Hour)	Value of Reducing BTI by 1% ($)
Whole dataset	Minimum	−0.88	−0.05	1.21	−6.40	1.97	−0.079
	Maximum	8.79	0.07	8.89	2.70	8.46	0.016
Whole dataset except uneconomical ML trips	Minimum	5.38	−0.10	5.30	−7.17	4.38	−0.068
	Maximum	14.18	0.02	12.08	0.93	10.43	0.001
Travelers who chose either lane at least once, excluding uneconomical ML trips	Minimum	9.88	−0.11	11.02	−8.54	10.20	−0.12
	Maximum	26.60	0.02	23.36	0.37	21.18	−0.01

Examination of Uneconomical Trips

ML trips that did not save travel time compared to the alternative (GPL trip) even though a toll is paid are frequently observed in the dataset. In this report, these ML trips are defined as *uneconomical managed lane* (U-ML) trips because the economic factors would not fully explain these ML trip choices. These U-ML trips account for about 11 percent (11.3 percent in 2012, 11.5 percent in 2013, and 10.8 percent in 2014) of total ML trips in the dataset. Exclusion of these U-ML trips in lane-choice models improved model results (see Appendix E), but there could be much more to learn from these trips. Therefore, this report examines these U-ML trips in more depth.

Based on frequency of travel, researchers identified trip characteristics where the U-ML trips are frequently observed, the time of travel when the U-ML trips were frequently made, and travelers who frequently made the U-ML trips. The findings are summarized as follows:

- Long-distance (more than 20 miles) ML trips have a higher percentage of U-ML trips.
- Westbound ML trips have a higher percentage of U-ML trips.
- ML trips that passed only the Eldridge toll plaza or Wirt toll plaza (either direction) have a higher percentage of U-ML trips.
- ML trips that were made during the off-peak period have a higher percentage of U-ML trips, particularly from midnight to 6 a.m.

- The percentage of U-ML trips is higher during weekends than on weekdays.
- ML trips during May 2012, August 2012, and May 2013 have a higher percentage of U ML trips.
- Travelers who traveled less frequently on the MLs during the previous 30 days had a higher percentage of U-ML trips.

If the MLs were frequently slower than the GPLs during these periods, then travelers might often make U-ML choices regardless of their intention. Therefore, researchers examined the percentage of time the MLs were slower than the GPLs.

First, four cases were selected where the U-ML trips were frequently observed:

- Off-peak hours (from midnight to 6 a.m.).
- Specific months (May 2012, August 2012, and May 2013).
- The westbound direction.
- Long-distance (more than 20 miles) ML trips.

Then, the average speeds of all ML trips and all GPL trips for every 10-minute interval in each direction were compared to determine if the MLs provided faster travel than the GPLs during that 10-minute period. This examination of U-ML trips revealed several instances where the proportion of travelers making U-ML trips is greater than the proportion of the time the ML is slower than the GPLs (see Appendix E for details). Thus, there are clearly factors influencing their choice of the MLs other than travel time, toll, and travel time reliability.

Examination of Individual Travelers Who Made U-ML Trips

The analysis of the Katy Freeway travelers as a whole and in groups yielded some interesting trends, but conclusions or reasons for those U-ML trips were not clear. Therefore, individual travelers were examined next. First, the entire dataset was reduced to only those travelers who made both ML and GPL trips in 2012. This included over 214,000 travelers who made over 13.5 million trips in 2012.

This was further reduced to limit the analysis to only those travelers who made more than five ML trips and at least half of those trips were uneconomical. This reduced the dataset to 2,350 travelers. The goal was to see whether there were certain types of trips where these travelers were more likely to use the ML and whether these travelers more often had U-ML trips. Thirty of these travelers were selected at random, and their trips on Katy Freeway for all of 2012 were examined. This included the time of travel, length of trip, day of the week, whether there was a crash on the freeway, and whether there was more than 0.4 inches of rain reported.

The trips of these 30 travelers followed similar trends as the entire dataset, and it was difficult to garner any additional insight into the U-ML trips. In general, the travelers tended to make U-ML trips more often in the westbound direction and more often when they could use the MLs for the entire length of the MLs. Many of the 30 travelers made trips of varying distance on Katy Freeway. When the entire ML section was within their trip, they were more likely to use the ML, and it was more likely to be a U-ML trip. For this group of 30 travelers:

- 18 were more likely to choose the MLs over the GPLs when they had trips covering the entire length of the MLs.
- 11 were equally likely to choose the MLs and the GPLs when they had trips covering the entire length of the MLs. This includes travelers with no trips that covered the entire length of the MLs.
- 1 was more likely to take the GPLs when his or her trip covered the entire length of the MLs.

This may imply that the ease of getting on and off the MLs at the start and end points contributes to their use. It may also be the uncertainty of congestion on the GPLs ahead that influences ML use. Unfortunately, even looking at individual travel records did not shed much additional insight into U-ML trips.

Appendix D: Route-Choice Model Results

Table 15. Model Coefficients Using Different Measures of Reliability (for Whole Day Two-Way Traffic).

Model: $U_{ML} = \beta_{Time} \times Time_{ML} + \beta_{Toll} \times Toll + \beta_{TTR} \times TravelTimeReliability_{ML}, U_{GPL} = \beta_{Time} \times Ttime_{GPL} + \beta_{TTR} \times TravelTimeReliability_{GPL}$

Reliability Measure		Standard Deviation			Coefficient of Variation			95th Percentile			Interquartile Range			Shorten Right Range			Buffer Time Index		
Year	Month	β_{Time}	β_{Toll}	β_{SD}	β_{Time}	β_{Toll}	β_{CV}	β_{Time}	β_{Toll}	β_{P95}	β_{Time}	β_{Toll}	β_{IR}	β_{Time}	β_{Toll}	β_{SRR}	β_{Time}	β_{Toll}	β_{BTI}
2012	February	−0.243	−1.995	0.073	−0.255	−1.863	4.640	−0.147	−2.326	−0.002	−0.168	−2.139	−0.371	−0.213	−2.122	−0.080	−0.234	−2.019	−0.006
	March	−0.193	−1.980	0.041	−0.212	−1.887	3.448	−0.122	−2.233	−0.002	−0.108	−2.152	−0.495	−0.172	−2.065	−0.057	−0.188	−1.993	0.007
	April	−0.189	−1.889	−0.054	−0.218	−1.764	3.506	−0.145	−2.051	−0.001	−0.136	−1.983	−0.362	−0.187	−1.915	−0.034	−0.198	−1.858	0.127
	May	−0.077	−1.373	−0.151	−0.098	−1.276	1.855	−0.040	−1.548	−0.002	−0.016	−1.516	−0.555	−0.082	−1.406	−0.059	−0.092	−1.328	0.007
	June	−0.139	−1.819	−0.160	−0.181	−1.693	2.488	−0.097	−1.984	−0.002	−0.105	−1.851	−0.329	−0.149	−1.824	−0.044	−0.164	−1.753	0.139
	July	−0.203	−1.817	0.208	−0.199	−1.726	5.137	−0.166	−1.956	−0.001	−0.123	−2.006	−0.341	−0.190	−1.843	0.036	−0.186	−1.852	0.320
	August	−0.157	−1.389	0.197	−0.142	−1.343	3.752	−0.109	−1.567	−0.001	−0.086	−1.551	−0.411	−0.140	−1.453	−0.008	−0.142	−1.414	0.189
	September	−0.170	−1.312	−0.033	−0.186	−1.205	2.841	−0.163	−1.340	0.000	−0.142	−1.357	−0.205	−0.179	−1.279	0.017	−0.177	−1.258	0.311
	October	−0.201	−1.402	0.137	−0.195	−1.349	3.634	−0.150	−1.528	−0.001	−0.135	−1.492	−0.295	−0.186	−1.435	−0.002	−0.187	−1.428	0.048
	November	−0.167	−1.544	0.170	−0.162	−1.463	4.331	−0.107	−1.701	−0.001	−0.114	−1.620	−0.123	−0.144	−1.590	−0.002	−0.144	−1.590	−0.023
2013	February	−0.165	−1.350	0.268	−0.152	−1.290	4.879	−0.104	−1.474	0.000	−0.094	−1.448	−0.128	−0.128	−1.409	0.008	−0.128	−1.404	0.148
	March	−0.175	−1.516	0.273	−0.161	−1.474	4.097	−0.114	−1.689	−0.001	−0.105	−1.652	−0.158	−0.138	−1.606	−0.003	−0.140	−1.593	0.083
	April	−0.164	−1.305	0.177	−0.155	−1.205	4.667	−0.093	−1.495	−0.001	−0.112	−1.401	−0.130	−0.128	−1.405	−0.036	−0.140	−1.359	0.020
	May	−0.049	−0.979	0.147	−0.051	−0.928	4.047	0.017	−1.164	−0.001	0.011	−1.075	−0.240	−0.022	−1.067	−0.048	−0.033	−1.014	0.009
	June	−0.069	−1.096	−0.002	−0.084	−1.026	3.049	−0.018	−1.215	−0.001	−0.022	−1.157	−0.244	−0.059	−1.134	−0.039	−0.071	−1.089	0.072
	July	−0.138	−1.340	0.084	−0.158	−1.236	4.458	−0.091	−1.435	−0.001	−0.112	−1.375	−0.051	−0.121	−1.369	−0.007	−0.123	−1.365	−0.019
	August	−0.114	−1.058	0.342	−0.108	−1.013	5.329	−0.036	−1.189	−0.001	−0.057	−1.135	−0.029	−0.061	−1.136	−0.007	−0.061	−1.140	−0.134
	September	−0.118	−0.734	0.444	−0.106	−0.706	6.187	−0.065	−0.821	0.000	−0.080	−0.810	0.097	−0.070	−0.808	0.032	−0.060	−0.830	−0.132
	October	−0.120	−0.772	0.509	−0.091	−0.763	5.550	−0.067	−0.865	0.000	−0.066	−0.874	0.042	−0.076	−0.843	0.063	−0.060	−0.879	0.070
	November	−0.110	−1.005	0.449	−0.091	−0.972	5.440	−0.056	−1.073	0.000	−0.066	−1.083	0.105	−0.063	−1.054	0.066	−0.043	−1.098	0.115
	December	−0.121	−1.267	0.281	−0.128	−1.087	6.860	−0.080	−1.352	0.000	−0.062	−1.397	−0.014	−0.089	−1.309	0.073	−0.071	−1.366	0.227
2014	February	−0.072	−0.668	0.185	−0.075	−0.592	6.365	−0.025	−0.736	0.000	−0.022	−0.730	−0.078	−0.049	−0.700	0.017	−0.044	−0.707	0.073
	March	−0.107	−0.732	0.378	−0.083	−0.689	6.606	−0.062	−0.795	0.000	−0.058	−0.807	0.026	−0.068	−0.778	0.055	−0.056	−0.802	0.246
	April	−0.116	−0.700	0.334	−0.082	−0.675	4.604	−0.084	−0.759	0.000	−0.076	−0.779	0.016	−0.086	−0.747	0.047	−0.079	−0.754	0.465
	May	−0.141	−0.660	0.384	−0.107	−0.627	5.746	−0.090	−0.754	0.000	−0.074	−0.776	−0.090	−0.101	−0.724	0.040	−0.098	−0.728	0.437
	June	−0.111	−0.647	0.307	−0.082	−0.603	5.860	−0.054	−0.741	0.000	−0.063	−0.724	−0.018	−0.072	−0.707	0.018	−0.073	−0.698	0.408
	July	−0.121	−0.676	0.415	−0.087	−0.636	6.464	−0.074	−0.750	0.000	−0.066	−0.765	0.027	−0.078	−0.733	0.064	−0.070	−0.741	0.569
	August	−0.112	−0.645	0.388	−0.072	−0.626	5.249	−0.059	−0.715	0.000	−0.071	−0.703	0.049	−0.069	−0.697	0.024	−0.069	−0.695	0.379
	September	−0.122	−0.586	0.322	−0.098	−0.534	6.042	−0.093	−0.632	0.000	−0.064	−0.676	−0.043	−0.092	−0.622	0.066	−0.084	−0.642	0.506

Note. Some data were missing from December 2012 so reliability could not be calculated for January 2012 since reliability is calculated based on previous 20 days of data. Because of this, and the unusual traffic during the Christmas season, January data was not included in this analysis. This is the same for all analyses in this appendix.

Table 16. Model Coefficients Using Different Measures of Reliability (for Whole Day Eastbound Traffic).

Model: $U_{ML} = \beta_{Time} \times Time_{ML} + \beta_{Toll} \times Toll + \beta_{TTR} \times TravelTimeReliability_{ML}, U_{GPL} = \beta_{Time} \times Ttime_{GPL} + \beta_{TTR} \times TravelTimeReliability_{GPL}$

Reliability Measure		Standard Deviation			Coefficient of Variation			95th Percentile			Interquartile Range			Shorten Right Range			Buffer Time Index		
Year	Month	β_{Time}	β_{Toll}	β_{SD}	β_{Time}	β_{Toll}	β_{CV}	β_{Time}	β_{Toll}	β_{P95}	β_{Time}	β_{Toll}	β_{IR}	β_{Time}	β_{Toll}	β_{SRR}	β_{Time}	β_{Toll}	β_{BTI}
2012	February	−0.139	−1.808	0.068	−0.156	−1.694	3.363	−0.135	−1.820	0.000	−0.077	−1.951	−0.417	−0.150	−1.763	0.095	−0.140	−1.822	0.327
	March	−0.075	−1.840	−0.028	−0.099	−1.732	2.011	−0.084	−1.812	0.000	−0.013	−2.028	−0.515	−0.095	−1.780	0.061	−0.086	−1.816	0.293
	April	−0.101	−1.618	0.163	−0.113	−1.536	3.147	−0.112	−1.579	0.001	−0.041	−1.757	−0.295	−0.114	−1.576	0.126	−0.102	−1.633	0.754
	May	−0.015	−1.133	0.176	−0.018	−1.086	2.524	−0.034	−1.048	0.002	0.052	−1.294	−0.373	−0.021	−1.073	0.151	−0.013	−1.128	0.854
	June	−0.028	−1.503	0.286	−0.026	−1.460	2.905	−0.051	−1.434	0.002	0.042	−1.604	−0.154	−0.045	−1.458	0.194	−0.018	−1.512	1.054
	July	−0.080	−1.583	0.474	−0.070	−1.571	3.879	−0.100	−1.505	0.003	−0.010	−1.761	−0.136	−0.083	−1.563	0.241	−0.056	−1.691	0.997
	August	−0.095	−1.335	0.241	−0.095	−1.303	2.808	−0.124	−1.228	0.002	−0.034	−1.473	−0.330	−0.106	−1.270	0.178	−0.093	−1.347	0.899
	September	−0.194	−1.285	0.033	−0.209	−1.206	2.275	−0.224	−1.191	0.001	−0.150	−1.404	−0.363	−0.228	−1.184	0.151	−0.215	−1.238	0.930
	October	−0.133	−1.380	0.159	−0.145	−1.338	2.996	−0.131	−1.376	0.001	−0.068	−1.483	−0.399	−0.146	−1.354	0.116	−0.129	−1.406	0.437
	November	−0.078	−1.600	0.358	−0.076	−1.502	4.801	−0.076	−1.586	0.001	−0.024	−1.717	−0.074	−0.078	−1.585	0.170	−0.055	−1.660	0.854
2013	February	−0.061	−1.385	0.259	−0.074	−1.333	3.985	−0.081	−1.322	0.002	0.007	−1.509	−0.220	−0.076	−1.341	0.171	−0.048	−1.445	0.570
	March	−0.066	−1.585	0.283	−0.072	−1.507	3.924	−0.074	−1.561	0.001	0.008	−1.728	−0.170	−0.065	−1.578	0.124	−0.042	−1.648	0.610
	April	−0.065	−1.280	0.300	−0.070	−1.201	4.147	−0.062	−1.281	0.001	−0.003	−1.415	−0.152	−0.060	−1.288	0.120	−0.041	−1.352	0.496
	May	−0.016	−1.027	0.240	−0.029	−0.994	3.628	−0.025	−0.990	0.001	0.043	−1.114	−0.139	−0.022	−1.002	0.136	−0.007	−1.066	0.740
	June	0.032	−0.978	0.248	0.026	−0.953	3.204	0.002	−0.928	0.002	0.117	−1.078	−0.250	0.015	−0.956	0.162	0.047	−1.013	0.678
	July	−0.056	−1.264	0.365	−0.056	−1.226	4.069	−0.051	−1.256	0.002	−0.002	−1.345	0.043	−0.048	−1.281	0.149	−0.012	−1.340	0.551
	August	−0.067	−1.188	0.421	−0.058	−1.150	4.518	−0.071	−1.158	0.002	−0.001	−1.268	0.020	−0.055	−1.191	0.157	−0.027	−1.244	0.903
	September	−0.134	−0.814	0.460	−0.131	−0.769	5.756	−0.128	−0.816	0.002	−0.071	−0.904	−0.024	−0.122	−0.843	0.189	−0.094	−0.892	0.818
	October	−0.134	−0.941	0.428	−0.126	−0.884	5.424	−0.118	−0.957	0.001	−0.070	−1.051	−0.019	−0.123	−0.962	0.149	−0.095	−1.022	0.783
	November	−0.083	−1.031	0.428	−0.076	−0.967	5.044	−0.072	−1.033	0.002	−0.023	−1.148	0.033	−0.067	−1.049	0.147	−0.035	−1.125	0.676
	December	−0.070	−1.289	0.416	−0.068	−1.152	5.446	−0.068	−1.301	0.002	−0.006	−1.486	0.060	−0.058	−1.301	0.186	−0.024	−1.403	1.181
2014	February	−0.073	−0.747	0.206	−0.091	−0.693	4.439	−0.068	−0.754	0.001	−0.019	−0.823	−0.136	−0.080	−0.751	0.100	−0.074	−0.766	1.047
	March	−0.034	−0.700	0.364	−0.037	−0.668	5.104	−0.037	−0.686	0.002	0.006	−0.755	0.056	−0.033	−0.706	0.164	−0.010	−0.744	1.133
	April	−0.115	−0.716	0.252	−0.112	−0.682	3.577	−0.117	−0.714	0.001	−0.079	−0.780	−0.015	−0.117	−0.720	0.110	−0.104	−0.737	0.979
	May	−0.141	−0.628	0.506	−0.127	−0.623	5.211	−0.135	−0.638	0.002	−0.056	−0.771	−0.153	−0.126	−0.665	0.191	−0.113	−0.715	1.412
	June	−0.055	−0.638	0.227	−0.064	−0.618	3.618	−0.050	−0.649	0.001	−0.024	−0.686	−0.003	−0.055	−0.649	0.112	−0.044	−0.675	0.828
	July	−0.036	−0.687	0.323	−0.037	−0.679	3.622	−0.025	−0.697	0.001	−0.018	−0.718	0.156	−0.024	−0.712	0.109	0.000	−0.737	0.558
	August	−0.092	−0.655	0.493	−0.078	−0.647	4.701	−0.077	−0.652	0.002	−0.061	−0.679	0.243	−0.062	−0.680	0.135	−0.030	−0.704	0.583
	September	−0.128	−0.565	0.373	−0.121	−0.527	4.622	−0.128	−0.554	0.002	−0.068	−0.651	−0.037	−0.124	−0.571	0.163	−0.104	−0.610	1.175

Table 17. Model Coefficients Using Different Measures of Reliability (for Whole Day Westbound Traffic).

Model: $U_{ML} = \beta_{Time} \times Time_{ML} + \beta_{Toll} \times Toll + \beta_{TTR} \times TravelTimeReliability_{ML}, U_{GPL} = \beta_{Time} \times Ttime_{GPL} + \beta_{TTR} \times TravelTimeReliability_{GPL}$

Reliability Measure		Standard Deviation			Coefficient of Variation			95th Percentile			Interquartile Range			Shorten Right Range			Buffer Time Index		
Year	Month	β_{Time}	β_{Toll}	β_{SD}	β_{Time}	β_{Toll}	β_{CV}	β_{Time}	β_{Toll}	β_{P95}	β_{Time}	β_{Toll}	β_{IR}	β_{Time}	β_{Toll}	β_{SRR}	β_{Time}	β_{Toll}	β_{BTI}
2012	February	−0.319	−2.185	0.085	−0.328	−2.055	6.003	−0.159	−2.889	−0.004	−0.238	−2.333	−0.345	−0.267	−2.523	−0.163	−0.307	−2.232	−0.103
	March	−0.284	−2.133	0.117	−0.295	−2.084	5.074	−0.148	−2.718	−0.004	−0.182	−2.275	−0.444	−0.237	−2.384	−0.129	−0.268	−2.177	−0.078
	April	−0.245	−2.187	−0.295	−0.305	−2.010	4.098	−0.160	−2.650	−0.003	−0.209	−2.212	−0.409	−0.253	−2.358	−0.148	−0.285	−2.102	−0.065
	May	−0.104	−1.629	−0.509	−0.159	−1.463	1.072	−0.019	−2.232	−0.005	−0.055	−1.743	−0.721	−0.131	−1.867	−0.211	−0.159	−1.541	−0.331
	June	−0.191	−2.189	−0.587	−0.285	−1.946	1.732	−0.117	−2.703	−0.005	−0.192	−2.142	−0.505	−0.230	−2.347	−0.202	−0.275	−2.015	−0.173
	July	−0.255	−2.043	−0.018	−0.264	−1.884	6.541	−0.191	−2.434	−0.002	−0.168	−2.231	−0.465	−0.247	−2.155	−0.065	−0.257	−2.016	0.110
	August	−0.185	−1.439	0.157	−0.163	−1.392	4.491	−0.097	−1.905	−0.002	−0.110	−1.615	−0.453	−0.164	−1.650	−0.082	−0.174	−1.480	0.010
	September	−0.153	−1.341	−0.095	−0.176	−1.205	3.636	−0.117	−1.516	−0.001	−0.144	−1.342	−0.129	−0.156	−1.417	−0.059	−0.167	−1.289	0.098
	October	−0.229	−1.417	0.124	−0.214	−1.361	4.086	−0.154	−1.672	−0.002	−0.171	−1.502	−0.238	−0.207	−1.529	−0.055	−0.216	−1.459	−0.073
	November	−0.204	−1.503	0.081	−0.200	−1.449	3.503	−0.121	−1.758	−0.002	−0.160	−1.555	−0.119	−0.184	−1.608	−0.063	−0.193	−1.551	−0.205
2013	February	−0.211	−1.312	0.291	−0.179	−1.255	5.442	−0.114	−1.531	−0.001	−0.145	−1.396	−0.067	−0.153	−1.439	−0.036	−0.164	−1.376	0.035
	March	−0.227	−1.471	0.239	−0.203	−1.460	3.797	−0.146	−1.804	−0.002	−0.168	−1.591	−0.129	−0.188	−1.642	−0.053	−0.199	−1.555	−0.051
	April	−0.202	−1.305	0.121	−0.188	−1.217	4.889	−0.106	−1.634	−0.002	−0.160	−1.380	−0.105	−0.159	−1.487	−0.081	−0.184	−1.359	−0.083
	May	−0.064	−0.939	0.059	−0.055	−0.865	4.425	0.041	−1.327	−0.003	−0.006	−1.043	−0.301	−0.033	−1.157	−0.131	−0.060	−0.981	−0.179
	June	−0.103	−1.188	−0.183	−0.128	−1.089	2.426	−0.021	−1.512	−0.003	−0.080	−1.210	−0.235	−0.103	−1.358	−0.140	−0.125	−1.157	−0.106
	July	−0.176	−1.443	−0.128	−0.209	−1.281	4.201	−0.119	−1.642	−0.002	−0.174	−1.428	−0.109	−0.183	−1.518	−0.082	−0.198	−1.425	−0.154
	August	−0.132	−0.955	0.277	−0.124	−0.912	5.769	−0.024	−1.250	−0.002	−0.081	−1.032	−0.061	−0.082	−1.117	−0.078	−0.093	−1.061	−0.341
	September	−0.103	−0.664	0.437	−0.082	−0.652	6.618	−0.028	−0.816	−0.001	−0.083	−0.737	0.188	−0.045	−0.781	−0.024	−0.046	−0.783	−0.304
	October	−0.102	−0.642	0.571	−0.061	−0.672	5.494	−0.030	−0.784	0.000	−0.059	−0.740	0.102	−0.047	−0.743	0.021	−0.041	−0.766	−0.095
	November	−0.135	−0.991	0.455	−0.104	−0.987	5.801	−0.053	−1.090	0.000	−0.113	−1.040	0.177	−0.073	−1.046	0.024	−0.064	−1.068	−0.011
	December	−0.136	−1.278	0.073	−0.162	−1.056	8.575	−0.083	−1.422	−0.001	−0.102	−1.337	−0.063	−0.118	−1.328	−0.020	−0.122	−1.313	−0.065
2014	February	−0.063	−0.592	0.182	−0.059	−0.510	8.376	0.004	−0.703	−0.001	−0.017	−0.651	−0.051	−0.028	−0.646	−0.014	−0.031	−0.640	−0.092
	March	−0.142	−0.762	0.386	−0.103	−0.715	7.779	−0.079	−0.879	0.000	−0.088	−0.857	0.005	−0.092	−0.840	0.019	−0.088	−0.850	0.115
	April	−0.118	−0.694	0.378	−0.071	−0.684	5.303	−0.069	−0.791	0.000	−0.078	−0.780	0.039	−0.076	−0.764	0.026	−0.074	−0.759	0.384
	May	−0.136	−0.688	0.292	−0.102	−0.634	6.379	−0.060	−0.866	−0.001	−0.085	−0.786	−0.064	−0.091	−0.796	−0.026	−0.099	−0.747	0.225
	June	−0.138	−0.656	0.361	−0.083	−0.588	7.972	−0.057	−0.824	−0.001	−0.082	−0.758	−0.022	−0.085	−0.767	−0.015	−0.089	−0.722	0.332
	July	−0.152	−0.661	0.477	−0.089	−0.595	8.766	−0.092	−0.794	0.000	−0.077	−0.812	−0.067	−0.099	−0.753	0.046	−0.092	−0.742	0.566
	August	−0.113	−0.630	0.330	−0.065	−0.608	5.671	−0.055	−0.767	−0.001	−0.071	−0.722	−0.050	−0.078	−0.716	−0.005	−0.080	−0.683	0.344
	September	−0.118	−0.606	0.280	−0.093	−0.545	8.094	−0.070	−0.697	0.000	−0.065	−0.700	−0.050	−0.081	−0.667	0.022	−0.081	−0.664	0.349

Table 18. Model Coefficients Using Different Measures of Reliability (for Peak Period Two-Way Traffic).

Model: $U_{ML} = \beta_{Time} \times Time_{ML} + \beta_{Toll} \times Toll + \beta_{TTR} \times TravelTimeReliability_{ML}, U_{GPL} = \beta_{Time} \times Ttime_{GPL} + \beta_{TTR} \times TravelTimeReliability_{GPL}$

Reliability Measure		Standard Deviation			Coefficient of Variation			95th Percentile			Interquartile Range			Shorten Right Range			Buffer Time Index		
Year	Month	β_{Time}	β_{Toll}	β_{SD}	β_{Time}	β_{Toll}	β_{CV}	β_{Time}	β_{Toll}	β_{P95}	β_{Time}	β_{Toll}	β_{IR}	β_{Time}	β_{Toll}	β_{SRR}	β_{Time}	β_{Toll}	β_{BTI}
2012	February	−0.079	−0.513	0.184	−0.053	−0.495	3.089	0.000	−0.631	−0.001	−0.066	−0.540	0.051	−0.022	−0.612	−0.090	−0.048	−0.560	−0.387
	March	−0.062	−0.498	0.157	−0.042	−0.493	2.183	0.022	−0.689	−0.002	−0.066	−0.498	0.114	−0.015	−0.635	−0.126	−0.039	−0.560	−0.523
	April	−0.056	−0.485	0.071	−0.046	−0.451	2.699	0.025	−0.605	−0.001	−0.057	−0.477	0.076	−0.001	−0.582	−0.121	−0.034	−0.523	−0.664
	May	0.047	−0.306	−0.087	0.043	−0.267	0.732	0.096	−0.477	−0.002	0.045	−0.309	−0.064	0.046	−0.445	−0.160	0.035	−0.342	−0.886
	June	−0.059	−0.498	0.085	−0.045	−0.464	2.695	0.025	−0.622	−0.001	−0.056	−0.496	0.084	−0.012	−0.590	−0.102	−0.040	−0.537	−0.457
	July	−0.068	−0.498	0.165	−0.041	−0.482	3.192	−0.026	−0.590	−0.001	−0.068	−0.510	0.096	−0.043	−0.562	−0.034	−0.049	−0.546	−0.210
	August	−0.013	−0.327	0.118	0.004	−0.322	1.693	0.048	−0.451	−0.001	−0.007	−0.343	0.026	0.015	−0.417	−0.078	−0.006	−0.376	−0.403
	September	−0.043	−0.309	0.093	−0.026	−0.238	3.456	0.005	−0.396	−0.001	−0.038	−0.320	0.050	−0.012	−0.391	−0.073	−0.030	−0.342	−0.138
	October	−0.050	−0.363	0.165	−0.020	−0.321	3.938	0.052	−0.488	−0.002	−0.049	−0.374	0.090	0.000	−0.442	−0.120	−0.029	−0.398	−0.481
	November	−0.071	−0.406	0.237	−0.035	−0.380	4.098	0.032	−0.543	−0.002	−0.072	−0.412	0.155	−0.007	−0.515	−0.151	−0.038	−0.460	−0.688
2013	February	−0.054	−0.364	0.174	−0.027	−0.303	4.877	0.061	−0.479	−0.002	−0.048	−0.379	0.073	0.032	−0.475	−0.157	−0.022	−0.416	−0.659
	March	−0.084	−0.403	0.276	−0.048	−0.415	2.934	−0.008	−0.517	−0.001	−0.075	−0.427	0.109	−0.023	−0.504	−0.079	−0.049	−0.462	−0.255
	April	−0.070	−0.323	0.233	−0.026	−0.260	5.172	0.041	−0.450	−0.001	−0.049	−0.353	0.076	0.015	−0.429	−0.099	−0.027	−0.387	−0.399
	May	0.027	−0.221	0.122	0.037	−0.219	2.039	0.115	−0.383	−0.002	0.032	−0.237	0.034	0.071	−0.345	−0.125	0.044	−0.275	−0.730
	June	0.017	−0.312	−0.136	0.005	−0.280	0.676	0.133	−0.424	−0.002	0.010	−0.297	−0.036	0.060	−0.390	−0.192	0.013	−0.327	−0.992
	July	−0.026	−0.421	−0.088	−0.051	−0.376	2.582	0.082	−0.505	−0.002	−0.061	−0.390	0.119	0.033	−0.464	−0.208	−0.021	−0.425	−1.068
	August	0.012	−0.296	−0.011	0.002	−0.266	3.300	0.138	−0.438	−0.003	−0.006	−0.288	0.086	0.070	−0.379	−0.199	0.035	−0.318	−1.167
	September	−0.044	−0.212	0.281	−0.016	−0.185	4.845	0.043	−0.320	−0.001	−0.056	−0.234	0.252	0.021	−0.295	−0.125	0.004	−0.265	−0.821
	October	−0.045	−0.237	0.336	−0.010	−0.232	3.585	0.046	−0.336	−0.001	−0.035	−0.263	0.148	0.012	−0.299	−0.077	−0.005	−0.283	−0.396
	November	−0.053	−0.314	0.300	−0.026	−0.312	3.941	0.035	−0.422	−0.001	−0.061	−0.322	0.236	0.019	−0.395	−0.135	−0.003	−0.359	−0.927
	December	−0.064	−0.429	0.056	−0.055	−0.362	3.460	0.004	−0.531	−0.001	−0.075	−0.405	0.105	−0.024	−0.518	−0.138	−0.047	−0.467	−0.732
2014	February	−0.003	−0.243	−0.032	−0.012	−0.171	4.061	0.089	−0.342	−0.002	−0.020	−0.226	0.054	0.048	−0.308	−0.156	0.008	−0.254	−0.838
	March	−0.042	−0.269	0.129	−0.023	−0.245	3.997	0.085	−0.370	−0.002	−0.044	−0.270	0.103	0.044	−0.334	−0.164	−0.009	−0.294	−0.760
	April	−0.045	−0.203	0.235	−0.008	−0.189	3.222	0.044	−0.308	−0.001	−0.030	−0.232	0.093	0.021	−0.298	−0.096	−0.008	−0.257	−0.350
	May	−0.067	−0.206	0.258	−0.030	−0.191	3.900	0.035	−0.311	−0.001	−0.043	−0.236	0.067	0.009	−0.291	−0.103	−0.021	−0.254	−0.489
	June	−0.029	−0.249	0.045	−0.021	−0.237	1.513	0.076	−0.334	−0.002	−0.029	−0.252	0.029	0.029	−0.316	−0.139	−0.010	−0.270	−0.761
	July	−0.022	−0.292	−0.028	−0.025	−0.268	1.773	0.064	−0.358	−0.002	−0.043	−0.281	0.083	0.016	−0.334	−0.147	−0.016	−0.297	−0.731
	August	−0.023	−0.258	−0.035	−0.026	−0.250	0.588	0.080	−0.320	−0.002	−0.029	−0.254	0.008	0.030	−0.301	−0.145	−0.013	−0.263	−0.958
	September	−0.025	−0.239	−0.054	−0.032	−0.201	1.924	0.033	−0.297	−0.001	−0.028	−0.235	−0.034	0.003	−0.273	−0.113	−0.019	−0.235	−0.693

Table 19. Model Coefficients Using Different Measures of Reliability (for Peak Period Eastbound Traffic).

Model: $U_{ML} = \beta_{Time} \times Time_{ML} + \beta_{Toll} \times Toll + \beta_{TTR} \times TravelTimeReliability_{ML}, U_{GPL} = \beta_{Time} \times Ttime_{GPL} + \beta_{TTR} \times TravelTimeReliability_{GPL}$

Reliability Measure		Standard Deviation			Coefficient of Variation			95th Percentile			Interquartile Range			Shorten Right Range			Buffer Time Index		
Year	Month	β_{Time}	β_{Toll}	β_{SD}	β_{Time}	β_{Toll}	β_{CV}	β_{Time}	β_{Toll}	β_{P95}	β_{Time}	β_{Toll}	β_{IR}	β_{Time}	β_{Toll}	β_{SRR}	β_{Time}	β_{Toll}	β_{BTI}
2012	February	−0.126	−0.730	−0.438	−0.142	−0.597	0.485	−0.119	−0.741	−0.002	−0.127	−0.714	−0.287	−0.140	−0.663	−0.094	−0.144	−0.614	−0.121
	March	−0.132	−0.739	−0.308	−0.148	−0.584	1.278	−0.120	−0.777	−0.002	−0.146	−0.651	−0.032	−0.145	−0.680	−0.080	−0.152	−0.630	0.155
	April	−0.087	−0.651	−0.346	−0.107	−0.556	0.068	−0.080	−0.671	−0.002	−0.101	−0.583	−0.065	−0.105	−0.593	−0.087	−0.107	−0.561	−0.192
	May	0.009	−0.424	−0.337	−0.006	−0.384	−1.664	0.010	−0.411	−0.001	0.009	−0.401	−0.159	−0.005	−0.382	−0.092	−0.001	−0.349	−0.342
	June	−0.040	−0.575	−0.067	−0.042	−0.561	0.084	−0.042	−0.567	0.000	−0.044	−0.545	0.080	−0.040	−0.558	0.019	−0.041	−0.561	0.089
	July	−0.080	−0.608	−0.119	−0.082	−0.564	0.895	−0.085	−0.576	0.000	−0.081	−0.594	−0.040	−0.081	−0.572	0.039	−0.081	−0.582	0.296
	August	−0.093	−0.518	−0.043	−0.092	−0.485	0.778	−0.097	−0.493	0.000	−0.093	−0.515	−0.027	−0.094	−0.501	0.012	−0.092	−0.495	0.299
	September	−0.141	−0.530	−0.190	−0.145	−0.398	1.886	−0.149	−0.492	0.000	−0.130	−0.514	−0.155	−0.157	−0.455	0.039	−0.155	−0.450	0.672
	October	−0.106	−0.516	−0.198	−0.104	−0.434	2.109	−0.085	−0.545	−0.001	−0.115	−0.484	−0.013	−0.114	−0.491	−0.039	−0.117	−0.481	0.209
	November	−0.101	−0.557	−0.040	−0.096	−0.522	1.216	−0.091	−0.581	−0.001	−0.106	−0.531	0.059	−0.101	−0.554	−0.021	−0.101	−0.548	−0.086
2013	February	−0.096	−0.532	−0.102	−0.091	−0.445	2.205	−0.099	−0.517	0.000	−0.092	−0.533	−0.098	−0.101	−0.513	−0.013	−0.102	−0.498	0.394
	March	−0.129	−0.661	−0.215	−0.142	−0.560	1.360	−0.123	−0.673	−0.001	−0.134	−0.623	−0.078	−0.135	−0.640	−0.070	−0.144	−0.598	0.072
	April	−0.035	−0.523	−0.274	−0.050	−0.408	1.722	−0.018	−0.558	−0.002	−0.047	−0.478	−0.076	−0.042	−0.518	−0.129	−0.054	−0.461	−0.180
	May	−0.019	−0.388	0.021	−0.018	−0.390	0.219	−0.011	−0.418	0.000	−0.021	−0.383	0.040	−0.015	−0.406	−0.033	−0.014	−0.390	−0.196
	June	0.067	−0.397	−0.246	0.045	−0.376	−1.233	0.065	−0.414	−0.001	0.049	−0.358	−0.012	0.035	−0.389	−0.104	0.044	−0.360	−0.348
	July	−0.008	−0.488	0.006	−0.008	−0.504	−1.146	0.015	−0.531	−0.002	−0.044	−0.453	0.244	−0.026	−0.506	−0.194	−0.019	−0.487	−1.088
	August	−0.037	−0.485	−0.213	−0.045	−0.450	0.470	−0.035	−0.489	−0.001	−0.043	−0.462	−0.038	−0.047	−0.476	−0.068	−0.047	−0.460	−0.233
	September	−0.135	−0.394	−0.008	−0.137	−0.318	3.282	−0.116	−0.424	−0.001	−0.132	−0.398	−0.029	−0.135	−0.394	−0.007	−0.139	−0.393	0.157
	October	−0.107	−0.459	−0.170	−0.113	−0.392	1.812	−0.078	−0.489	−0.001	−0.117	−0.435	−0.024	−0.110	−0.447	−0.064	−0.117	−0.430	−0.230
	November	−0.122	−0.464	−0.048	−0.118	−0.421	1.477	−0.102	−0.506	−0.001	−0.132	−0.437	0.071	−0.118	−0.475	−0.061	−0.121	−0.459	−0.570
	December	−0.109	−0.606	−0.230	−0.136	−0.475	1.516	−0.100	−0.617	−0.001	−0.143	−0.500	0.059	−0.127	−0.567	−0.074	−0.135	−0.527	−0.011
2014	February	−0.080	−0.391	−0.172	−0.099	−0.320	1.631	−0.060	−0.413	−0.001	−0.101	−0.350	0.019	−0.083	−0.382	−0.083	−0.097	−0.355	−0.067
	March	−0.070	−0.343	−0.081	−0.070	−0.308	1.272	−0.067	−0.348	0.000	−0.071	−0.336	−0.028	−0.073	−0.331	−0.006	−0.071	−0.323	0.388
	April	−0.104	−0.251	0.282	−0.084	−0.226	3.554	−0.105	−0.269	0.001	−0.089	−0.331	−0.029	−0.098	−0.279	0.089	−0.096	−0.269	1.329
	May	−0.122	−0.304	0.100	−0.116	−0.285	2.236	−0.111	−0.333	0.000	−0.110	−0.335	−0.048	−0.116	−0.320	0.013	−0.119	−0.324	0.290
	June	−0.059	−0.352	−0.165	−0.068	−0.321	−0.351	−0.059	−0.353	−0.001	−0.064	−0.333	−0.064	−0.070	−0.329	−0.040	−0.067	−0.316	−0.021
	July	0.005	−0.370	−0.222	−0.018	−0.369	−2.303	0.002	−0.358	−0.001	−0.012	−0.324	0.084	−0.019	−0.354	−0.066	−0.015	−0.340	−0.447
	August	−0.054	−0.386	−0.595	−0.096	−0.371	−3.212	−0.052	−0.402	−0.002	−0.077	−0.350	−0.129	−0.088	−0.371	−0.195	−0.086	−0.335	−1.404
	September	−0.055	−0.361	−0.443	−0.097	−0.278	0.055	−0.050	−0.346	−0.002	−0.068	−0.317	−0.209	−0.086	−0.300	−0.071	−0.093	−0.282	−0.372

Table 20. Model Coefficients Using Different Measures of Reliability (for Peak Period Westbound Traffic).

Model: $U_{ML} = \beta_{Time} \times Time_{ML} + \beta_{Toll} \times Toll + \beta_{TTR} \times TravelTimeReliability_{ML}, U_{GPL} = \beta_{Time} \times Ttime_{GPL} + \beta_{TTR} \times TravelTimeReliability_{GPL}$

Reliability Measure		Standard Deviation			Coefficient of Variation			95th Percentile			Interquartile Range			Shorten Right Range			Buffer Time Index		
Year	Month	β_{Time}	β_{Toll}	β_{SD}	β_{Time}	β_{Toll}	β_{CV}	β_{Time}	β_{Toll}	β_{P95}	β_{Time}	β_{Toll}	β_{IR}	β_{Time}	β_{Toll}	β_{SRR}	β_{Time}	β_{Toll}	β_{BTI}
2012	February	−0.081	−0.441	0.378	−0.042	−0.501	4.831	0.041	−0.716	−0.001	−0.065	−0.483	0.170	0.007	−0.661	−0.113	−0.022	−0.550	−0.472
	March	−0.050	−0.408	0.308	−0.024	−0.485	3.021	0.059	−0.746	−0.002	−0.054	−0.422	0.206	0.017	−0.640	−0.146	−0.003	−0.503	−0.682
	April	−0.059	−0.404	0.216	−0.042	−0.432	5.006	0.056	−0.683	−0.002	−0.050	−0.418	0.153	0.022	−0.658	−0.154	−0.015	−0.517	−0.821
	May	0.059	−0.209	0.035	0.065	−0.184	2.313	0.122	−0.690	−0.003	0.061	−0.226	−0.007	0.041	−0.622	−0.219	0.042	−0.361	−1.057
	June	−0.051	−0.375	0.180	−0.029	−0.365	4.139	0.039	−0.697	−0.002	−0.038	−0.410	0.099	−0.004	−0.643	−0.129	−0.027	−0.496	−0.499
	July	−0.055	−0.401	0.238	−0.028	−0.443	3.982	−0.014	−0.607	−0.001	−0.056	−0.427	0.133	−0.031	−0.548	−0.043	−0.036	−0.510	−0.265
	August	0.029	−0.160	0.158	0.044	−0.196	1.788	0.098	−0.397	−0.001	0.036	−0.172	0.048	0.059	−0.322	−0.095	0.035	−0.247	−0.664
	September	−0.004	−0.211	0.157	0.013	−0.166	5.073	0.077	−0.387	−0.001	−0.001	−0.219	0.154	0.053	−0.403	−0.127	0.019	−0.305	−0.541
	October	−0.029	−0.270	0.286	0.009	−0.258	4.688	0.100	−0.483	−0.002	−0.025	−0.291	0.142	0.035	−0.436	−0.150	0.001	−0.344	−0.593
	November	−0.055	−0.307	0.325	−0.012	−0.304	5.022	0.075	−0.523	−0.002	−0.052	−0.321	0.184	0.027	−0.497	−0.187	−0.013	−0.397	−0.777
2013	February	−0.028	−0.252	0.222	−0.005	−0.209	7.271	0.122	−0.430	−0.002	−0.030	−0.253	0.147	0.088	−0.435	−0.203	0.017	−0.340	−1.022
	March	−0.058	−0.291	0.347	−0.020	−0.347	3.050	0.026	−0.405	−0.001	−0.050	−0.283	0.190	0.016	−0.395	−0.076	−0.007	−0.341	−0.320
	April	−0.057	−0.187	0.351	−0.002	−0.160	6.868	0.058	−0.377	−0.001	−0.031	−0.231	0.137	0.034	−0.355	−0.089	0.000	−0.292	−0.369
	May	0.066	−0.056	0.184	0.091	−0.028	4.718	0.169	−0.318	−0.002	0.075	−0.084	0.047	0.113	−0.269	−0.139	0.079	−0.172	−0.803
	June	0.038	−0.191	−0.084	0.033	−0.144	2.454	0.155	−0.409	−0.003	0.035	−0.182	−0.025	0.077	−0.379	−0.214	0.031	−0.262	−1.104
	July	−0.009	−0.294	−0.019	−0.024	−0.215	4.758	0.094	−0.466	−0.002	−0.026	−0.272	0.092	0.044	−0.430	−0.205	0.000	−0.338	−0.953
	August	0.052	−0.130	0.079	0.043	−0.128	4.058	0.197	−0.377	−0.003	0.039	−0.130	0.114	0.127	−0.279	−0.215	0.088	−0.188	−1.250
	September	0.000	−0.123	0.350	0.029	−0.135	5.692	0.110	−0.270	−0.002	−0.020	−0.169	0.337	0.085	−0.243	−0.152	0.059	−0.200	−0.990
	October	−0.001	−0.128	0.455	0.039	−0.150	3.764	0.107	−0.239	−0.001	0.006	−0.167	0.225	0.074	−0.198	−0.080	0.052	−0.182	−0.389
	November	−0.031	−0.254	0.422	0.001	−0.282	5.342	0.096	−0.383	−0.002	−0.033	−0.273	0.290	0.088	−0.348	−0.178	0.048	−0.297	−1.059
	December	−0.052	−0.353	0.113	−0.041	−0.318	4.428	0.024	−0.483	−0.001	−0.054	−0.347	0.108	0.009	−0.467	−0.163	−0.020	−0.409	−0.901
2014	February	0.021	−0.149	0.018	0.013	−0.093	5.364	0.126	−0.309	−0.002	0.011	−0.143	0.056	0.084	−0.265	−0.173	0.039	−0.184	−0.907
	March	−0.036	−0.235	0.169	−0.019	−0.228	5.242	0.122	−0.397	−0.002	−0.041	−0.239	0.141	0.077	−0.353	−0.214	0.013	−0.266	−1.067
	April	−0.021	−0.172	0.190	0.004	−0.179	3.077	0.097	−0.321	−0.002	−0.017	−0.187	0.123	0.069	−0.298	−0.152	0.024	−0.219	−0.852
	May	−0.051	−0.154	0.299	−0.010	−0.147	5.017	0.079	−0.330	−0.002	−0.028	−0.188	0.103	0.045	−0.300	−0.144	0.006	−0.227	−0.733
	June	−0.019	−0.189	0.102	−0.002	−0.179	2.598	0.111	−0.335	−0.002	−0.015	−0.197	0.054	0.057	−0.315	−0.173	0.011	−0.236	−0.981
	July	−0.013	−0.213	0.058	−0.005	−0.190	3.194	0.083	−0.335	−0.002	−0.023	−0.215	0.085	0.039	−0.298	−0.166	0.004	−0.240	−0.749
	August	−0.008	−0.182	0.050	0.000	−0.181	1.135	0.107	−0.335	−0.002	−0.007	−0.186	0.032	0.047	−0.291	−0.148	0.007	−0.214	−0.848
	September	−0.021	−0.210	0.009	−0.023	−0.190	3.171	0.054	−0.317	−0.002	−0.020	−0.211	0.002	0.021	−0.285	−0.127	−0.003	−0.222	−0.772

Table 21. Model Coefficients Using Different Measures of Reliability (for Shoulder Period Two-Way Traffic).

Model: $U_{ML} = \beta_{Time} \times Time_{ML} + \beta_{Toll} \times Toll + \beta_{TTR} \times TravelTimeReliability_{ML}, U_{GPL} = \beta_{Time} \times Ttime_{GPL} + \beta_{TTR} \times TravelTimeReliability_{GPL}$

Reliability Measure		Standard Deviation			Coefficient of Variation			95th Percentile			Interquartile Range			Shorten Right Range			Buffer Time Index		
Year	Month	β_{Time}	β_{Toll}	β_{SD}	β_{Time}	β_{Toll}	β_{CV}	β_{Time}	β_{Toll}	β_{P95}	β_{Time}	β_{Toll}	β_{IR}	β_{Time}	β_{Toll}	β_{SRR}	β_{Time}	β_{Toll}	β_{BTI}
2012	February	−0.207	−1.378	0.348	−0.179	−1.241	6.062	−0.094	−1.753	−0.002	−0.171	−1.516	0.001	−0.136	−1.675	−0.106	−0.167	−1.541	−0.210
	March	−0.199	−1.404	0.269	−0.176	−1.305	4.676	−0.071	−1.781	−0.002	−0.178	−1.487	0.068	−0.116	−1.697	−0.126	−0.162	−1.544	−0.262
	April	−0.195	−1.407	0.214	−0.187	−1.291	5.486	−0.087	−1.703	−0.002	−0.187	−1.446	0.100	−0.141	−1.608	−0.108	−0.168	−1.493	−0.185
	May	−0.105	−1.096	0.058	−0.101	−1.044	2.345	−0.014	−1.352	−0.002	−0.071	−1.153	−0.166	−0.067	−1.255	−0.113	−0.096	−1.156	−0.353
	June	−0.160	−1.444	−0.117	−0.195	−1.371	1.838	−0.034	−1.659	−0.003	−0.135	−1.456	−0.216	−0.100	−1.566	−0.166	−0.167	−1.460	−0.464
	July	−0.208	−1.346	0.359	−0.182	−1.344	4.755	−0.124	−1.554	−0.001	−0.136	−1.494	−0.140	−0.156	−1.480	−0.031	−0.165	−1.450	−0.008
	August	−0.137	−1.025	0.400	−0.111	−1.003	4.273	−0.073	−1.271	−0.001	−0.104	−1.150	−0.054	−0.104	−1.187	−0.029	−0.110	−1.140	−0.002
	September	−0.100	−0.978	0.223	−0.076	−0.869	4.672	−0.042	−1.136	−0.001	−0.090	−1.026	0.107	−0.061	−1.109	−0.036	−0.070	−1.052	0.024
	October	−0.104	−1.091	0.281	−0.064	−1.000	6.166	−0.037	−1.213	−0.001	−0.062	−1.162	−0.019	−0.062	−1.171	−0.014	−0.068	−1.152	0.084
	November	−0.111	−1.148	0.279	−0.081	−1.022	6.522	−0.044	−1.270	0.000	−0.076	−1.215	0.030	−0.064	−1.230	−0.006	−0.066	−1.221	0.024
2013	February	−0.073	−1.049	0.277	−0.042	−1.027	4.665	0.017	−1.156	−0.001	−0.048	−1.085	0.088	−0.004	−1.131	−0.033	−0.020	−1.102	−0.034
	March	−0.087	−1.140	0.253	−0.058	−1.112	3.178	−0.031	−1.297	−0.001	−0.075	−1.200	0.064	−0.046	−1.262	−0.034	−0.055	−1.222	−0.007
	April	−0.106	−1.036	0.355	−0.056	−0.954	6.603	−0.005	−1.224	−0.001	−0.084	−1.095	0.117	−0.031	−1.182	−0.054	−0.051	−1.146	−0.209
	May	0.011	−0.783	0.419	0.057	−0.732	6.057	0.086	−0.960	−0.001	0.044	−0.863	0.048	0.059	−0.917	−0.041	0.052	−0.893	−0.189
	June	−0.050	−0.923	0.161	−0.043	−0.826	5.094	0.039	−1.073	−0.001	−0.040	−0.944	0.076	0.005	−1.050	−0.082	−0.019	−0.979	−0.178
	July	−0.109	−1.102	0.123	−0.108	−0.999	4.931	0.001	−1.239	−0.001	−0.109	−1.113	0.084	−0.044	−1.208	−0.096	−0.074	−1.161	−0.414
	August	−0.074	−0.976	0.163	−0.071	−0.897	5.270	0.039	−1.129	−0.002	−0.056	−1.001	0.042	−0.014	−1.102	−0.114	−0.034	−1.059	−0.683
	September	−0.079	−0.587	0.407	−0.040	−0.535	6.612	−0.002	−0.692	−0.001	−0.066	−0.625	0.223	−0.018	−0.688	−0.065	−0.023	−0.680	−0.588
	October	−0.072	−0.624	0.443	−0.024	−0.610	4.715	−0.004	−0.735	0.000	−0.055	−0.669	0.163	−0.022	−0.712	−0.010	−0.020	−0.720	−0.287
	November	−0.087	−0.748	0.301	−0.056	−0.715	4.108	−0.014	−0.815	0.000	−0.094	−0.782	0.190	−0.024	−0.806	−0.013	−0.024	−0.809	−0.238
	December	−0.076	−0.866	0.142	−0.095	−0.712	6.827	0.002	−0.959	−0.001	−0.061	−0.889	0.050	−0.016	−0.947	−0.056	−0.032	−0.923	−0.270
2014	February	−0.053	−0.580	0.187	−0.032	−0.510	7.577	0.042	−0.647	−0.001	−0.030	−0.599	0.033	0.003	−0.620	−0.053	−0.011	−0.613	−0.358
	March	−0.092	−0.612	0.329	−0.058	−0.553	7.677	0.013	−0.690	−0.001	−0.076	−0.630	0.152	−0.009	−0.674	−0.038	−0.023	−0.660	−0.115
	April	−0.096	−0.570	0.414	−0.032	−0.546	4.926	−0.012	−0.668	−0.001	−0.098	−0.603	0.236	−0.029	−0.656	−0.041	−0.040	−0.641	−0.155
	May	−0.123	−0.526	0.434	−0.057	−0.501	5.202	−0.031	−0.621	0.000	−0.084	−0.576	0.141	−0.044	−0.609	−0.011	−0.049	−0.598	0.080
	June	−0.099	−0.551	0.300	−0.043	−0.497	5.216	−0.006	−0.648	−0.001	−0.094	−0.582	0.149	−0.027	−0.646	−0.061	−0.043	−0.617	−0.157
	July	−0.099	−0.589	0.244	−0.077	−0.527	5.819	0.008	−0.674	−0.001	−0.075	−0.619	0.094	−0.021	−0.656	−0.052	−0.045	−0.630	0.001
	August	−0.085	−0.543	0.338	−0.027	−0.497	5.434	0.004	−0.625	−0.001	−0.068	−0.575	0.128	−0.021	−0.618	−0.050	−0.032	−0.599	−0.190
	September	−0.062	−0.494	0.177	−0.041	−0.424	4.566	−0.009	−0.565	0.000	−0.049	−0.522	0.064	−0.021	−0.557	−0.031	−0.029	−0.540	−0.068

Table 22. Model Coefficients Using Different Measures of Reliability (for Shoulder Period Eastbound Traffic).

Model: $U_{ML} = \beta_{Time} \times Time_{ML} + \beta_{Toll} \times Toll + \beta_{TTR} \times TravelTimeReliability_{ML}, U_{GPL} = \beta_{Time} \times Ttime_{GPL} + \beta_{TTR} \times TravelTimeReliability_{GPL}$

Reliability Measure		Standard Deviation			Coefficient of Variation			95th Percentile			Interquartile Range			Shorten Right Range			Buffer Time Index		
Year	Month	β_{Time}	β_{Toll}	β_{SD}	β_{Time}	β_{Toll}	β_{CV}	β_{Time}	β_{Toll}	β_{P95}	β_{Time}	β_{Toll}	β_{IR}	β_{Time}	β_{Toll}	β_{SRR}	β_{Time}	β_{Toll}	β_{BTI}
2012	February	−0.106	−1.459	0.202	−0.085	−1.339	4.096	−0.103	−1.487	0.001	−0.091	−1.559	−0.095	−0.092	−1.438	0.107	−0.092	−1.493	0.684
	March	−0.117	−1.571	−0.017	−0.116	−1.466	1.735	−0.112	−1.600	0.000	−0.118	−1.565	−0.001	−0.119	−1.539	0.030	−0.114	−1.517	0.620
	April	−0.083	−1.473	0.108	−0.078	−1.396	3.210	−0.075	−1.498	0.000	−0.081	−1.485	0.055	−0.074	−1.470	0.061	−0.075	−1.490	0.440
	May	−0.020	−1.101	0.248	−0.007	−1.057	2.961	−0.022	−1.060	0.001	−0.004	−1.165	−0.035	0.006	−1.077	0.127	0.003	−1.109	0.881
	June	−0.077	−1.500	−0.231	−0.098	−1.470	−0.115	−0.085	−1.499	−0.001	−0.050	−1.513	−0.508	−0.098	−1.464	0.009	−0.098	−1.465	0.103
	July	−0.124	−1.433	0.426	−0.105	−1.466	2.488	−0.132	−1.378	0.004	−0.055	−1.537	−0.328	−0.095	−1.461	0.270	−0.097	−1.518	0.512
	August	−0.085	−1.267	0.248	−0.078	−1.261	2.211	−0.098	−1.200	0.002	−0.051	−1.352	−0.206	−0.081	−1.225	0.158	−0.077	−1.297	0.670
	September	−0.093	−1.161	−0.053	−0.096	−1.102	1.144	−0.101	−1.119	0.000	−0.095	−1.153	−0.028	−0.099	−1.089	0.081	−0.097	−1.115	0.562
	October	−0.075	−1.217	−0.085	−0.073	−1.184	1.273	−0.076	−1.205	0.000	−0.067	−1.240	−0.253	−0.065	−1.174	0.106	−0.075	−1.208	0.266
	November	−0.108	−1.363	0.167	−0.093	−1.293	3.565	−0.114	−1.349	0.001	−0.104	−1.397	−0.010	−0.096	−1.345	0.101	−0.102	−1.379	0.744
2013	February	−0.072	−1.202	0.263	−0.064	−1.227	2.032	−0.092	−1.144	0.002	−0.064	−1.265	−0.021	−0.062	−1.186	0.156	−0.066	−1.265	0.207
	March	−0.052	−1.321	0.175	−0.034	−1.237	4.270	−0.062	−1.297	0.001	−0.039	−1.385	−0.093	−0.040	−1.313	0.095	−0.040	−1.343	0.746
	April	−0.072	−1.159	0.392	−0.040	−1.099	4.888	−0.056	−1.203	0.001	−0.054	−1.214	0.135	−0.041	−1.201	0.077	−0.045	−1.232	0.317
	May	0.011	−0.982	0.321	0.027	−0.910	5.391	0.008	−0.961	0.001	0.019	−1.030	0.106	0.032	−0.984	0.114	0.026	−1.022	0.945
	June	−0.014	−1.025	0.163	−0.003	−1.000	2.234	−0.015	−1.005	0.001	0.000	−1.049	−0.006	0.008	−1.013	0.096	0.003	−1.038	0.519
	July	−0.043	−1.208	0.005	−0.046	−1.193	1.005	−0.022	−1.247	−0.001	−0.058	−1.197	0.126	−0.044	−1.214	−0.043	−0.043	−1.206	−0.409
	August	−0.045	−1.189	0.322	−0.031	−1.160	4.658	−0.043	−1.174	0.001	−0.013	−1.226	−0.156	−0.022	−1.190	0.159	−0.025	−1.220	0.708
	September	−0.070	−0.730	0.250	−0.056	−0.701	3.813	−0.064	−0.733	0.001	−0.071	−0.731	0.193	−0.054	−0.747	0.090	−0.052	−0.761	0.163
	October	−0.104	−0.836	0.174	−0.091	−0.794	3.200	−0.101	−0.865	0.000	−0.103	−0.850	0.082	−0.099	−0.851	0.042	−0.100	−0.869	0.082
	November	−0.130	−0.956	−0.102	−0.125	−0.884	1.397	−0.128	−0.956	0.000	−0.132	−0.925	0.018	−0.132	−0.941	−0.019	−0.131	−0.936	−0.201
	December	−0.028	−1.030	−0.029	−0.034	−0.953	2.036	−0.033	−1.017	0.000	−0.031	−1.022	0.000	−0.031	−1.011	0.021	−0.031	−1.012	0.346
2014	February	−0.092	−0.664	0.433	−0.070	−0.647	5.111	−0.083	−0.677	0.001	−0.075	−0.693	0.150	−0.063	−0.693	0.127	−0.069	−0.713	0.949
	March	−0.046	−0.610	0.635	−0.011	−0.600	6.378	−0.048	−0.595	0.002	−0.035	−0.643	0.232	−0.004	−0.630	0.210	−0.010	−0.669	1.237
	April	−0.087	−0.657	0.282	−0.075	−0.661	2.398	−0.085	−0.670	0.001	−0.085	−0.677	0.174	−0.075	−0.678	0.077	−0.076	−0.691	0.645
	May	−0.108	−0.559	0.684	−0.071	−0.554	6.827	−0.093	−0.572	0.002	−0.081	−0.628	0.200	−0.065	−0.598	0.195	−0.068	−0.646	1.254
	June	−0.087	−0.641	0.233	−0.069	−0.627	2.919	−0.085	−0.654	0.001	−0.082	−0.657	0.151	−0.071	−0.654	0.080	−0.070	−0.667	0.844
	July	−0.039	−0.724	−0.142	−0.054	−0.679	1.836	−0.018	−0.766	−0.002	−0.078	−0.691	0.222	−0.054	−0.725	−0.081	−0.050	−0.706	−0.037
	August	−0.050	−0.635	0.466	−0.028	−0.618	5.461	−0.036	−0.641	0.001	−0.041	−0.654	0.180	−0.020	−0.650	0.102	−0.021	−0.664	0.398
	September	−0.017	−0.546	−0.124	−0.023	−0.519	0.031	−0.023	−0.518	0.000	−0.032	−0.506	0.091	−0.022	−0.511	0.015	−0.020	−0.508	0.206

Table 23. Model Coefficients Using Different Measures of Reliability (for Shoulder Period Westbound Traffic).

Model: $U_{ML} = \beta_{Time} \times Time_{ML} + \beta_{Toll} \times Toll + \beta_{TTR} \times TravelTimeReliability_{ML}, U_{GPL} = \beta_{Time} \times Ttime_{GPL} + \beta_{TTR} \times TravelTimeReliability_{GPL}$

Reliability Measure		Standard Deviation			Coefficient of Variation			95th Percentile			Interquartile Range			Shorten Right Range			Buffer Time Index		
Year	Month	β_{Time}	β_{Toll}	β_{SD}	β_{Time}	β_{Toll}	β_{CV}	β_{Time}	β_{Toll}	β_{P95}	β_{Time}	β_{Toll}	β_{IR}	β_{Time}	β_{Toll}	β_{SRR}	β_{Time}	β_{Toll}	β_{BTI}
2012	February	−0.242	−1.206	0.537	−0.198	−1.114	7.395	−0.079	−1.924	−0.003	−0.207	−1.420	0.116	−0.131	−1.830	−0.161	−0.181	−1.532	−0.295
	March	−0.221	−1.212	0.479	−0.181	−1.169	6.432	−0.049	−1.897	−0.003	−0.191	−1.371	0.161	−0.104	−1.779	−0.159	−0.160	−1.492	−0.342
	April	−0.224	−1.235	0.393	−0.199	−1.145	6.759	−0.088	−1.845	−0.003	−0.213	−1.332	0.190	−0.154	−1.705	−0.137	−0.181	−1.449	−0.198
	May	−0.114	−1.030	0.004	−0.119	−0.986	2.051	0.037	−1.596	−0.003	−0.075	−1.104	−0.213	−0.046	−1.427	−0.201	−0.113	−1.142	−0.543
	June	−0.169	−1.328	−0.023	−0.195	−1.235	2.853	−0.011	−1.839	−0.003	−0.154	−1.355	−0.098	−0.080	−1.719	−0.226	−0.164	−1.413	−0.502
	July	−0.207	−1.178	0.431	−0.168	−1.159	6.190	−0.112	−1.643	−0.002	−0.155	−1.407	−0.055	−0.150	−1.500	−0.066	−0.165	−1.389	−0.071
	August	−0.099	−0.701	0.549	−0.060	−0.700	5.356	−0.045	−1.200	−0.001	−0.092	−0.901	0.107	−0.079	−1.052	−0.043	−0.082	−0.936	−0.014
	September	−0.107	−0.785	0.382	−0.054	−0.637	6.965	−0.012	−1.142	−0.001	−0.085	−0.912	0.152	−0.037	−1.117	−0.063	−0.052	−0.983	−0.043
	October	−0.117	−0.921	0.435	−0.036	−0.792	7.997	−0.022	−1.218	−0.001	−0.066	−1.096	0.031	−0.051	−1.146	−0.021	−0.058	−1.090	0.098
	November	−0.109	−0.913	0.398	−0.059	−0.790	7.672	−0.021	−1.150	0.000	−0.063	−1.041	0.064	−0.040	−1.095	−0.012	−0.043	−1.077	0.004
2013	February	−0.065	−0.889	0.308	−0.020	−0.824	6.256	0.059	−1.078	−0.001	−0.039	−0.929	0.117	0.035	−1.043	−0.053	0.003	−0.967	−0.039
	March	−0.078	−0.929	0.308	−0.042	−0.947	3.074	−0.022	−1.182	−0.001	−0.080	−1.012	0.120	−0.034	−1.144	−0.032	−0.041	−1.079	−0.007
	April	−0.104	−0.867	0.402	−0.047	−0.830	6.884	0.009	−1.169	−0.001	−0.083	−0.940	0.147	−0.016	−1.110	−0.057	−0.040	−1.044	−0.200
	May	0.022	−0.577	0.499	0.082	−0.575	6.076	0.128	−0.861	−0.001	0.063	−0.684	0.074	0.091	−0.800	−0.057	0.076	−0.755	−0.245
	June	−0.052	−0.757	0.246	−0.029	−0.632	6.166	0.056	−1.082	−0.001	−0.036	−0.810	0.110	0.018	−1.073	−0.108	−0.010	−0.898	−0.199
	July	−0.115	−0.931	0.224	−0.087	−0.771	6.100	0.005	−1.228	−0.001	−0.105	−0.979	0.112	−0.041	−1.197	−0.097	−0.068	−1.092	−0.363
	August	−0.084	−0.667	0.365	−0.042	−0.564	6.715	0.056	−1.010	−0.002	−0.051	−0.776	0.107	0.003	−0.991	−0.114	−0.017	−0.919	−0.655
	September	−0.083	−0.441	0.555	−0.018	−0.402	7.703	0.020	−0.632	−0.001	−0.056	−0.535	0.237	0.000	−0.636	−0.073	−0.009	−0.529	−0.614
	October	−0.063	−0.458	0.586	0.006	−0.496	4.897	0.030	−0.628	0.000	−0.038	−0.530	0.213	0.011	−0.600	−0.012	0.011	−0.513	−0.268
	November	−0.078	−0.647	0.374	−0.035	−0.642	4.588	0.025	−0.738	0.000	−0.082	−0.676	0.221	0.013	−0.724	−0.018	0.010	−0.729	−0.245
	December	−0.089	−0.724	0.228	−0.109	−0.519	10.281	0.016	−0.878	−0.001	−0.066	−0.757	0.085	0.006	−0.876	−0.074	−0.018	−0.836	−0.346
2014	February	−0.029	−0.483	0.168	−0.012	−0.405	8.750	0.091	−0.594	−0.001	−0.008	−0.503	0.035	0.045	−0.557	−0.084	0.016	−0.537	−0.522
	March	−0.094	−0.569	0.323	−0.059	−0.494	8.386	0.044	−0.718	−0.001	−0.080	−0.591	0.159	0.018	−0.698	−0.084	−0.015	−0.653	−0.313
	April	−0.093	−0.489	0.478	−0.012	−0.476	5.644	0.022	−0.649	−0.001	−0.096	−0.529	0.270	−0.001	−0.637	−0.072	−0.022	−0.600	−0.288
	May	−0.114	−0.451	0.433	−0.041	−0.438	4.954	−0.002	−0.609	−0.001	−0.075	−0.516	0.146	−0.022	−0.594	−0.041	−0.035	−0.560	−0.043
	June	−0.095	−0.448	0.372	−0.019	−0.383	6.239	0.015	−0.619	−0.001	−0.086	−0.493	0.175	−0.007	−0.628	−0.081	−0.028	−0.570	−0.218
	July	−0.102	−0.468	0.357	−0.055	−0.407	6.744	0.012	−0.620	−0.001	−0.063	−0.534	0.114	−0.011	−0.598	−0.041	−0.029	−0.556	0.066
	August	−0.079	−0.396	0.451	0.003	−0.359	5.908	0.011	−0.574	−0.001	−0.061	−0.474	0.163	−0.012	−0.570	−0.047	−0.021	−0.533	−0.151
	September	−0.095	−0.460	0.296	−0.055	−0.363	7.453	0.003	−0.603	−0.001	−0.055	−0.528	0.063	−0.016	−0.594	−0.049	−0.030	−0.559	−0.135

Table 24. Model Coefficients Using Different Measures of Reliability (for Off-Peak Period Two-Way Traffic).

Model: $U_{ML} = \beta_{Time} \times Time_{ML} + \beta_{Toll} \times Toll + \beta_{TTR} \times TravelTimeReliability_{ML}, U_{GPL} = \beta_{Time} \times Ttime_{GPL} + \beta_{TTR} \times TravelTimeReliability_{GPL}$

Reliability Measure		Standard Deviation			Coefficient of Variation			95th Percentile			Interquartile Range			Shorten Right Range			Buffer Time Index		
Year	Month	β_{Time}	β_{Toll}	β_{SD}	β_{Time}	β_{Toll}	β_{CV}	β_{Time}	β_{Toll}	β_{P95}	β_{Time}	β_{Toll}	β_{IR}	β_{Time}	β_{Toll}	β_{SRR}	β_{Time}	β_{Toll}	β_{BTI}
2012	February	−0.148	−6.644	−0.269	−0.164	−6.515	0.650	−0.108	−7.173	−0.004	−0.106	−6.733	−0.839	−0.134	−6.931	−0.225	−0.155	−6.613	−0.403
	March	−0.201	−6.471	−0.325	−0.230	−6.311	0.280	−0.152	−6.942	−0.004	−0.152	−6.492	−0.894	−0.182	−6.739	−0.208	−0.219	−6.406	−0.392
	April	−0.171	−6.362	−0.494	−0.202	−6.170	−0.647	−0.138	−6.815	−0.004	−0.133	−6.319	−0.809	−0.162	−6.619	−0.215	−0.199	−6.242	−0.437
	May	−0.066	−5.538	−0.682	−0.101	−5.377	−1.962	−0.042	−5.993	−0.004	−0.022	−5.435	−0.898	−0.073	−5.781	−0.235	−0.107	−5.431	−0.582
	June	−0.166	−5.925	−0.628	−0.215	−5.731	−1.229	−0.139	−6.399	−0.004	−0.121	−5.875	−0.783	−0.175	−6.147	−0.234	−0.218	−5.784	−0.487
	July	−0.124	−5.968	−0.433	−0.155	−5.761	−0.119	−0.094	−6.420	−0.004	−0.091	−5.993	−0.764	−0.117	−6.205	−0.204	−0.149	−5.851	−0.383
	August	−0.123	−5.239	−0.334	−0.139	−5.127	−0.154	−0.103	−5.553	−0.003	−0.068	−5.313	−0.997	−0.123	−5.381	−0.130	−0.136	−5.198	−0.301
	September	−0.148	−6.019	−0.687	−0.187	−5.792	−1.488	−0.139	−6.321	−0.003	−0.120	−5.964	−1.039	−0.160	−6.138	−0.184	−0.191	−5.812	−0.377
	October	−0.128	−6.345	−0.844	−0.175	−6.113	−2.517	−0.103	−6.806	−0.005	−0.100	−6.209	−1.220	−0.135	−6.588	−0.286	−0.180	−6.144	−0.783
	November	−0.163	−6.335	−0.466	−0.198	−6.210	−0.930	−0.127	−6.743	−0.004	−0.133	−6.274	−0.484	−0.159	−6.530	−0.218	−0.194	−6.261	−0.647
2013	February	−0.147	−6.058	−0.497	−0.185	−5.864	−0.688	−0.121	−6.407	−0.003	−0.106	−6.019	−0.704	−0.148	−6.221	−0.183	−0.179	−5.937	−0.515
	March	−0.186	−6.110	−0.397	−0.223	−5.943	−0.504	−0.142	−6.511	−0.003	−0.146	−6.092	−0.620	−0.181	−6.297	−0.190	−0.216	−6.012	−0.540
	April	−0.139	−5.790	−0.487	−0.173	−5.590	−0.578	−0.102	−6.283	−0.004	−0.092	−5.815	−0.773	−0.135	−6.027	−0.238	−0.167	−5.673	−0.615
	May	−0.078	−5.175	−0.693	−0.136	−4.990	−1.626	−0.050	−5.620	−0.004	−0.015	−5.094	−0.787	−0.102	−5.343	−0.234	−0.142	−5.034	−0.618
	June	−0.121	−5.240	−0.813	−0.176	−5.062	−3.067	−0.100	−5.600	−0.004	−0.075	−5.184	−1.018	−0.151	−5.358	−0.224	−0.194	−5.045	−0.591
	July	−0.168	−5.664	−0.723	−0.236	−5.386	−2.020	−0.141	−6.123	−0.005	−0.144	−5.502	−0.658	−0.189	−5.865	−0.278	−0.244	−5.427	−0.818
	August	−0.197	−5.074	−0.321	−0.237	−4.880	0.287	−0.148	−5.435	−0.003	−0.144	−5.114	−0.549	−0.188	−5.240	−0.168	−0.220	−5.038	−0.717
	September	−0.227	−4.953	−0.201	−0.258	−4.783	1.329	−0.171	−5.394	−0.004	−0.155	−5.123	−0.689	−0.211	−5.131	−0.171	−0.232	−4.940	−0.661
	October	−0.185	−4.900	−0.176	−0.212	−4.712	0.970	−0.131	−5.311	−0.003	−0.117	−5.059	−0.550	−0.163	−5.098	−0.148	−0.189	−4.899	−0.619
	November	−0.226	−5.313	−0.165	−0.258	−5.130	1.157	−0.176	−5.652	−0.002	−0.169	−5.415	−0.413	−0.209	−5.492	−0.130	−0.237	−5.300	−0.439
	December	−0.196	−5.710	−0.378	−0.262	−5.355	0.801	−0.153	−6.089	−0.003	−0.175	−5.624	−0.306	−0.201	−5.853	−0.184	−0.244	−5.547	−0.537
2014	February	−0.136	−4.949	−0.543	−0.198	−4.639	−0.234	−0.103	−5.272	−0.004	−0.109	−4.868	−0.545	−0.134	−5.080	−0.200	−0.185	−4.727	−0.543
	March	−0.146	−4.956	−0.456	−0.189	−4.653	0.228	−0.139	−5.147	−0.002	−0.088	−5.073	−0.613	−0.164	−4.946	−0.114	−0.182	−4.727	−0.258
	April	−0.209	−4.735	−0.136	−0.232	−4.543	1.579	−0.184	−4.988	−0.002	−0.136	−4.967	−0.589	−0.205	−4.812	−0.066	−0.222	−4.649	0.015
	May	−0.208	−4.654	−0.340	−0.235	−4.455	0.280	−0.181	−5.036	−0.003	−0.155	−4.769	−0.765	−0.212	−4.761	−0.139	−0.230	−4.534	−0.265
	June	−0.215	−4.558	−0.464	−0.258	−4.254	0.580	−0.185	−5.024	−0.004	−0.173	−4.621	−0.649	−0.228	−4.678	−0.178	−0.252	−4.355	−0.264
	July	−0.207	−4.466	−0.288	−0.242	−4.175	1.433	−0.178	−4.857	−0.003	−0.130	−4.748	−0.791	−0.204	−4.617	−0.144	−0.230	−4.325	−0.148
	August	−0.193	−4.476	−0.345	−0.231	−4.260	0.221	−0.166	−4.784	−0.003	−0.145	−4.572	−0.658	−0.195	−4.583	−0.136	−0.223	−4.357	−0.324
	September	−0.172	−4.451	−0.352	−0.216	−4.137	0.754	−0.147	−4.794	−0.003	−0.110	−4.563	−0.638	−0.176	−4.564	−0.137	−0.206	−4.258	−0.199

Table 25. Model Coefficients Using Different Measures of Reliability (for Off-Peak Period Eastbound Traffic).

Model: $U_{ML} = \beta_{Time} \times Time_{ML} + \beta_{Toll} \times Toll + \beta_{TTR} \times TravelTimeReliability_{ML}, U_{GPL} = \beta_{Time} \times Ttime_{GPL} + \beta_{TTR} \times TravelTimeReliability_{GPL}$

Reliability Measure		Standard Deviation			Coefficient of Variation			95th Percentile			Interquartile Range			Shorten Right Range			Buffer Time Index		
Year	Month	β_{Time}	β_{Toll}	β_{SD}	β_{Time}	β_{Toll}	β_{CV}	β_{Time}	β_{Toll}	β_{P95}	β_{Time}	β_{Toll}	β_{IR}	β_{Time}	β_{Toll}	β_{SRR}	β_{Time}	β_{Toll}	β_{BTI}
2012	February	−0.200	−6.262	−0.534	−0.234	−6.088	−1.017	−0.178	−6.563	−0.004	−0.162	−6.299	−0.731	−0.219	−6.215	−0.133	−0.241	−6 021	0.079
	March	−0.205	−6.040	−0.572	−0.252	−5.811	−1.473	−0.183	−6.303	−0.003	−0.186	−5.951	−0.727	−0.218	−6.051	−0.183	−0.257	−5 754	−0.367
	April	−0.198	−5.827	−0.504	−0.237	−5.588	−1.133	−0.185	−6.029	−0.003	−0.174	−5.734	−0.604	−0.211	−5.801	−0.138	−0.241	−5 536	−0.250
	May	−0.113	−4.979	−0.590	−0.153	−4.756	−1.429	−0.121	−5.044	−0.002	−0.058	−4.920	−0.748	−0.147	−4.796	−0.086	−0.162	−4.616	−0.001
	June	−0.190	−5.338	−0.531	−0.243	−5.062	−0.825	−0.185	−5.534	−0.003	−0.145	−5.288	−0.615	−0.223	−5.228	−0.110	−0.250	−4.976	−0.008
	July	−0.173	−5.494	−0.426	−0.207	−5.269	−0.744	−0.168	−5.637	−0.002	−0.146	−5.567	−0.644	−0.192	−5.389	−0.091	−0.213	−5.193	0.014
	August	−0.178	−4.660	−0.361	−0.200	−4.527	−0.658	−0.179	−4.698	−0.001	−0.125	−4.784	−0.781	−0.204	−4.484	−0.003	−0.212	−4.424	0.313
	September	−0.183	−5.303	−0.699	−0.237	−4.995	−1.748	−0.189	−5.369	−0.003	−0.173	−5.270	−0.880	−0.214	−5.141	−0.132	−0.248	−4.867	−0.177
	October	−0.179	−5.544	−0.798	−0.240	−5.251	−2.312	−0.174	−5.759	−0.004	−0.145	−5.444	−1.081	−0.204	−5.517	−0.210	−0.246	−5.185	−0.668
	November	−0.167	−5.701	−0.529	−0.215	−5.473	−0.971	−0.153	−5.948	−0.003	−0.153	−5.557	−0.362	−0.189	−5.663	−0.148	−0.220	−5.396	−0.066
2013	February	−0.160	−5.222	−0.488	−0.207	−5.027	−0.978	−0.157	−5.340	−0.002	−0.115	−5.224	−0.641	−0.189	−5.134	−0.100	−0.215	−4.956	−0.059
	March	−0.197	−5.260	−0.320	−0.239	−5.047	−0.139	−0.172	−5.467	−0.002	−0.162	−5.280	−0.481	−0.212	−5.227	−0.093	−0.241	−5.026	0.037
	April	−0.162	−5.089	−0.596	−0.219	−4.773	−0.983	−0.135	−5.395	−0.004	−0.131	−5.034	−0.636	−0.175	−5.077	−0.201	−0.217	−4.748	−0.437
	May	−0.090	−4.255	−0.585	−0.159	−4.016	−1.113	−0.085	−4.412	−0.003	−0.043	−4.193	−0.594	−0.140	−4.110	−0.104	−0.168	−3.944	−0.145
	June	−0.140	−4.248	−0.587	−0.196	−4.062	−2.020	−0.132	−4.347	−0.003	−0.089	−4.267	−0.796	−0.183	−4.096	−0.102	−0.205	−3.962	−0.401
	July	−0.161	−4.776	−0.615	−0.227	−4.460	−1.851	−0.141	−5.051	−0.004	−0.159	−4.577	−0.455	−0.184	−4.770	−0.213	−0.222	−4.476	−1.068
	August	−0.190	−4.440	−0.367	−0.243	−4.220	−0.479	−0.164	−4.631	−0.002	−0.157	−4.456	−0.433	−0.207	−4.404	−0.109	−0.243	−4.209	−0.198
	September	−0.238	−4.194	−0.214	−0.271	−3.958	1.412	−0.199	−4.501	−0.003	−0.171	−4.430	−0.583	−0.245	−4.170	−0.066	−0.263	−4.052	0.158
	October	−0.206	−4.442	−0.354	−0.252	−4.139	0.072	−0.170	−4.749	−0.003	−0.154	−4.518	−0.485	−0.211	−4.446	−0.126	−0.245	−4.209	−0.315
	November	−0.186	−4.776	−0.385	−0.236	−4.525	−0.436	−0.163	−4.998	−0.003	−0.165	−4.744	−0.378	−0.199	−4.801	−0.140	−0.230	−4.589	−0.555
	December	−0.215	−5.057	−0.299	−0.268	−4.669	0.489	−0.198	−5.243	−0.002	−0.206	−4.928	−0.201	−0.243	−4.946	−0.076	−0.265	−4.712	0.105
2014	February	−0.151	−4.284	−0.752	−0.237	−3.854	−1.365	−0.136	−4.419	−0.004	−0.136	−4.168	−0.688	−0.175	−4.173	−0.202	−0.238	−3.788	−0.355
	March	−0.138	−4.033	−0.609	−0.210	−3.708	−1.189	−0.146	−4.044	−0.002	−0.110	−4.061	−0.496	−0.190	−3.799	−0.099	−0.222	−3.589	0.130
	April	−0.227	−3.987	−0.484	−0.287	−3.704	−0.736	−0.206	−4.126	−0.003	−0.207	−3.975	−0.444	−0.253	−3.851	−0.108	−0.295	−3.624	0.142
	May	−0.287	−3.654	−0.188	−0.308	−3.482	0.473	−0.258	−3.872	−0.002	−0.201	−3.916	−0.768	−0.302	−3.552	−0.016	−0.313	−3.456	0.442
	June	−0.239	−3.654	−0.546	−0.289	−3.354	−0.900	−0.197	−3.973	−0.004	−0.224	−3.605	−0.451	−0.264	−3.540	−0.149	−0.290	−3.318	−0.284
	July	−0.223	−3.578	−0.423	−0.270	−3.339	−0.725	−0.195	−3.799	−0.003	−0.188	−3.738	−0.517	−0.239	−3.509	−0.122	−0.265	−3.342	−0.470
	August	−0.219	−3.697	−0.470	−0.276	−3.423	−0.612	−0.172	−3.995	−0.004	−0.219	−3.625	−0.368	−0.228	−3.683	−0.165	−0.265	−3.468	−0.666
	September	−0.227	−3.823	−0.413	−0.279	−3.409	0.293	−0.210	−4.009	−0.003	−0.162	−3.990	−0.650	−0.250	−3.689	−0.095	−0.277	−3.433	0.050

Table 26. Model Coefficients Using Different Measures of Reliability (for Off-Peak Period Westbound Traffic).

Model: $U_{ML} = \beta_{Time} \times Time_{ML} + \beta_{Toll} \times Toll + \beta_{TTR} \times TravelTimeReliability_{ML}, U_{GPL} = \beta_{Time} \times Ttime_{GPL} + \beta_{TTR} \times TravelTimeReliability_{GPL}$

Reliability Measure		Standard Deviation			Coefficient of Variation			95th Percentile			Interquartile Range			Shorten Right Range			Buffer Time Index		
Year	Month	β_{Time}	β_{Toll}	β_{SD}	β_{Time}	β_{Toll}	β_{CV}	β_{Time}	β_{Toll}	β_{P95}	β_{Time}	β_{Toll}	β_{IR}	β_{Time}	β_{Toll}	β_{SRR}	β_{Time}	β_{Toll}	β_{BTI}
2012	February	−0.052	−6.999	0.077	−0.062	−6.935	2.154	0.007	−7.694	−0.005	−0.026	−7.077	−0.704	−0.013	−7.571	−0.282	−0.037	−7.141	−0.549
	March	−0.090	−6.853	0.125	−0.102	−6.810	1.990	0.005	−7.443	−0.004	−0.043	−6.912	−0.969	−0.013	−7.337	−0.229	−0.059	−6.999	−0.473
	April	−0.073	−6.742	−0.145	−0.090	−6.661	1.612	−0.008	−7.452	−0.005	−0.027	−6.776	−1.168	−0.028	−7.322	−0.287	−0.064	−6.845	−0.538
	May	0.069	−5.960	−0.508	0.049	−5.885	−1.088	0.167	−6.849	−0.006	0.068	−5.839	−0.888	0.126	−6.722	−0.387	0.062	−6.135	−0.891
	June	−0.071	−6.336	−0.385	−0.092	−6.272	−0.153	−0.001	−7.067	−0.006	−0.046	−6.323	−1.045	−0.028	−6.904	−0.344	−0.079	−6.436	−0.690
	July	−0.016	−6.279	−0.155	−0.042	−6.150	2.211	0.073	−7.056	−0.005	0.028	−6.290	−0.816	0.040	−6.915	−0.306	−0.011	−6.395	−0.562
	August	0.031	−5.693	0.020	0.024	−5.659	1.444	0.085	−6.265	−0.004	0.061	−5.709	−1.245	0.063	−6.186	−0.223	0.041	−5.865	−0.522
	September	0.029	−6.602	0.031	0.022	−6.576	1.367	0.083	−7.163	−0.003	0.059	−6.584	−0.741	0.061	−7.073	−0.213	0.042	−6.750	−0.480
	October	0.085	−7.073	−0.286	0.067	−7.028	0.162	0.186	−7.785	−0.006	0.090	−6.995	−0.599	0.149	−7.649	−0.350	0.097	−7.177	−0.876
	November	−0.008	−6.879	−0.004	−0.014	−6.874	0.628	0.091	−7.359	−0.004	0.006	−6.863	−0.485	0.067	−7.242	−0.262	0.025	−6.965	−0.848
2013	February	0.001	−6.873	−0.268	−0.019	−6.764	0.488	0.079	−7.514	−0.004	0.006	−6.813	−0.382	0.055	−7.403	−0.263	0.012	−6.977	−0.756
	March	0.017	−6.849	−0.066	0.008	−6.822	0.632	0.093	−7.399	−0.004	0.030	−6.837	−0.385	0.063	−7.282	−0.256	0.038	−6.946	−0.738
	April	0.032	−6.495	0.165	0.027	−6.493	1.755	0.104	−7.101	−0.004	0.061	−6.546	−0.419	0.076	−6.982	−0.253	0.061	−6.663	−0.731
	May	0.238	−5.894	0.354	0.240	−5.912	1.967	0.319	−6.685	−0.005	0.258	−5.929	−0.210	0.262	−6.563	−0.345	0.266	−6.145	−0.887
	June	0.080	−6.048	−0.182	0.074	−6.028	−0.045	0.142	−6.738	−0.005	0.093	−6.024	−0.642	0.107	−6.607	−0.321	0.089	−6.198	−0.722
	July	0.069	−6.248	−0.035	0.062	−6.198	1.425	0.130	−6.937	−0.005	0.083	−6.260	−0.505	0.097	−6.814	−0.302	0.080	−6.419	−0.805
	August	−0.081	−5.592	0.269	−0.083	−5.568	2.398	−0.031	−6.116	−0.003	−0.054	−5.696	−0.412	−0.047	−6.019	−0.198	−0.058	−5.819	−0.906
	September	−0.031	−5.736	0.113	−0.046	−5.691	1.849	0.076	−6.276	−0.004	−0.013	−5.780	−0.157	0.053	−6.156	−0.258	0.024	−5.858	−0.946
	October	−0.041	−5.435	0.344	−0.044	−5.415	2.626	0.033	−5.872	−0.002	−0.008	−5.576	−0.158	0.018	−5.787	−0.142	0.008	−5.645	−0.711
	November	−0.104	−5.912	0.513	−0.103	−5.872	4.359	−0.001	−6.352	−0.002	−0.045	−6.102	−0.167	−0.019	−6.274	−0.119	−0.040	−6.130	−0.451
	December	−0.037	−6.147	0.067	−0.070	−5.947	4.347	0.094	−6.831	−0.005	0.006	−6.255	−0.311	0.059	−6.686	−0.289	−0.004	−6.313	−0.779
2014	February	−0.028	−5.736	−0.046	−0.062	−5.581	3.025	0.075	−6.278	−0.003	0.036	−5.795	−0.370	0.050	−6.167	−0.215	−0.001	−5.827	−0.659
	March	−0.034	−5.985	−0.014	−0.049	−5.858	2.085	0.006	−6.474	−0.002	−0.001	−6.102	−0.472	−0.007	−6.376	−0.149	−0.021	−6.083	−0.414
	April	−0.033	−5.629	0.398	−0.036	−5.590	3.492	0.019	−6.033	−0.001	0.041	−5.921	−0.499	0.012	−5.982	−0.066	0.000	−5.851	−0.132
	May	0.007	−5.521	−0.062	−0.012	−5.413	2.052	0.072	−6.190	−0.004	0.044	−5.611	−0.553	0.041	−6.058	−0.250	0.016	−5.666	−0.587
	June	0.032	−5.265	0.160	0.008	−5.139	3.787	0.116	−6.026	−0.004	0.075	−5.433	−0.489	0.089	−5.921	−0.248	0.055	−5.477	−0.482
	July	0.009	−5.198	0.407	0.000	−5.054	4.917	0.068	−5.892	−0.003	0.057	−5.498	−0.590	0.053	−5.817	−0.175	0.032	−5.478	−0.261
	August	−0.015	−5.288	0.032	−0.032	−5.185	2.179	0.035	−5.723	−0.002	0.020	−5.377	−0.595	0.023	−5.655	−0.146	−0.001	−5.439	−0.425
	September	−0.015	−5.002	0.105	−0.037	−4.865	3.384	0.053	−5.594	−0.003	0.036	−5.141	−0.394	0.036	−5.503	−0.171	0.002	−5.172	−0.358

Appendix E: Detailed Examination of Uneconomical Managed Lane Trips

ML trips that did not save travel time compared to the alternative (GPL trip) even though a toll is paid are frequently observed in this dataset. In this appendix, these ML trips are defined as U-ML trips because the economic factors do not fully explain these ML trip choices. These U-ML trips account for about 11 percent (11.3 percent in 2012, 11.5 percent in 2013, and 10.8 percent in 2014) of total ML trips in the dataset. Exclusion of these U-ML trips in lane-choice models improved model results (see the "VOT and VOR Analysis" section in Appendix C), but there could be much more to learn from these trips. Therefore, this appendix examines these U-ML trips in more depth.

This appendix examines various factors that can be estimated from the dataset and might provide more insight into U-ML trips. These factors are classified into three categories:

- Trip characteristics.
- Time of travel.
- Traveler's familiarity with traffic condition on the freeway.

The traveler is defined as the one who made the U-ML trip. Each category includes diverse factors that help to describe the U-ML trips.

The *trip characteristics* category includes:

- Trip distance.
- Trip direction.
- Traveled ML section on the freeway.

The *time of travel* category includes:

- Time of day (peak, shoulder-peak, and off-peak hours).
- Hour of travel.
- Day of week.
- Month of travel.

The *traveler's familiarity with traffic condition on the freeway* category cannot be directly measured from the dataset. However, normally, the more a traveler travels on the freeway, the more likely he or she is to know the traffic conditions. The dataset enables researchers to estimate each traveler's total number of trips on the freeway during a year or any given time period. Thus, this section indirectly measures each traveler's familiarity with the traffic conditions as the total number of trips for a given period (one year or the past 30 days). The traveler's familiarity category therefore includes:

- The traveler's total number of trips on both GPLs and MLs in each year.
- The traveler's total number of trips on the MLs in each year.
- The traveler's total number of trips on both GPLs and MLs during the previous 30 days.
- The traveler's total number of trips on the MLs during the previous 30 days.

The total number of lane choices (trips) and the number of U-ML trips in the dataset are shown in Table 27. All three years show similar ratios of the U-ML trips to the total ML trips: about 11 percent. The following sections focus on these 11 percent of ML trips.

Table 27. Total Numbers of Trips on Each Lane and the Number of U-ML Trips.

Year	GPL Trips	ML Trips	Total Trips	U-ML Trips	U-ML/ML Trips (%)
2012	31,247,230	2,011,608	33,258,838	228,022	11.3%
2013	36,017,349	2,601,242	38,618,591	298,939	11.5%
2014	27,252,515	2,400,737	29,653,252	259,168	10.8%

Trip Characteristics of Uneconomical Trips

This section examines frequencies of U-ML trips depending on their trip characteristics, including trip distance, trip direction, and traveled ML section on the freeway.

Trip Distance

The study sections have distances of 26.61 miles in the eastbound section and 29.32 miles in the westbound section. The MLs are a 12-mile portion of this distance. Table 15 shows the number of ML trips and U-ML trips, and the proportion of U-ML trips depending on the trip distance. Trip distances are grouped by 4-mile interval. Compared to the average ratio in Table 14 (about 11 percent), the results indicate that ML trips where the total trip distance exceeds 20 miles result in a higher proportion of U-ML trips (see Table 28 and Figure 11).

Table 28. Number of U-ML Trips and Total ML Trips by Trip Distance.

Trip Distance (Miles)	2012			2013			2014			Total
	U-ML	ML	U-ML/ ML	U-ML	ML	U-ML/ ML	U-ML	ML	U-ML/ ML	U-ML/ ML
≤4	33,179	228,552	14.5%	36,704	286,273	12.8%	26,867	253,335	10.6%	12.6%
4–8	124,821	1,015,196	12.3%	161,605	1,307,409	12.4%	137,813	1,192,329	11.6%	12.1%
8–12	21,006	286,477	7.3%	32,639	410,496	8.0%	29,570	360,381	8.2%	7.9%
12–16	17,863	238,928	7.5%	25,221	297,978	8.5%	24,482	290,913	8.4%	8.2%
16–20	15,720	152,716	10.3%	20,594	182,634	11.3%	20,788	190,364	10.9%	10.9%
20+	15,433	89,739	17.2%	22,176	116,452	19.0%	19,648	113,415	17.3%	17.9%

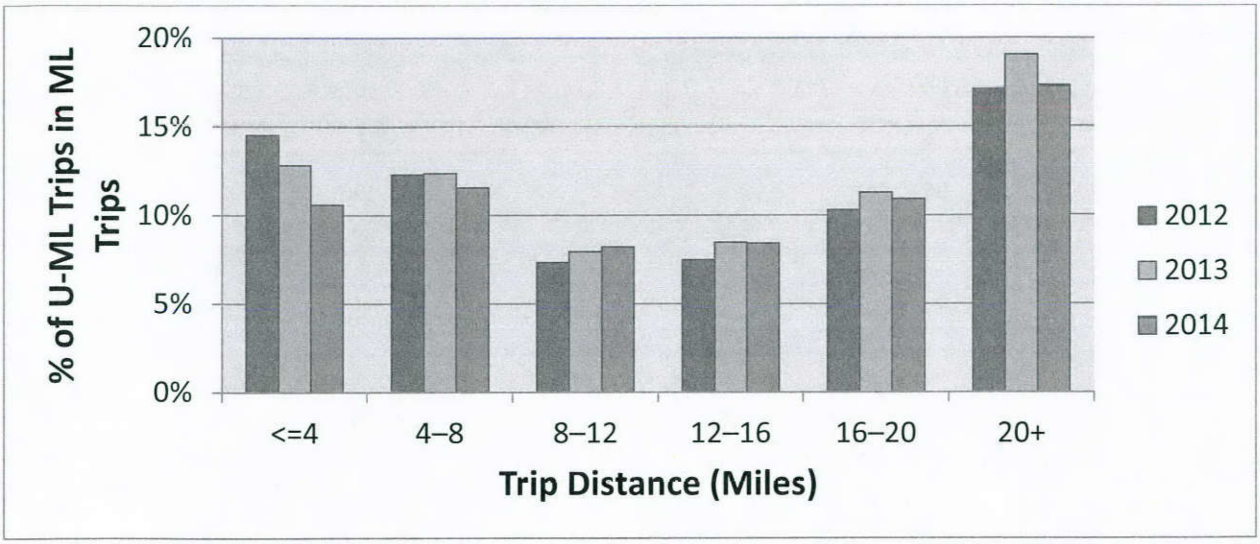


Figure 11. Percentage of U-ML Trips by Trip Distance.

Trip Direction

Katy Freeway connects the city of Katy in the west to downtown Houston in the east. Therefore, more eastbound trips are work-bound trips, and more westbound trips are homebound trips. This difference in trip purpose results in different traffic conditions on the freeway. For example, traffic congestion in the eastbound direction is worse in the morning due to commuting travelers. Table 29 shows the number of ML trips and U-ML trips and the proportion of U-ML trips depending on the trip direction. There were more U-ML trips in the westbound direction than in the eastbound direction.

Table 29. Number of U-ML Trips and Total ML Trips by Trip Direction.

Trip Direction	2012			2013			2014			Total
	U-ML	ML	U-ML/ ML	U-ML	ML	U-ML/ ML	U-ML	ML	U-ML/ ML	U-ML/ ML
Eastbound	101,445	1,030,967	9.8%	140,130	1,394,653	10.0%	134,386	1,378,945	9.7%	9.9%
Westbound	126,577	980,641	12.9%	158,809	1,206,589	13.2%	124,782	1,021,792	12.2%	12.8%

Traveled ML Section of the Freeway

The location of the U-ML trips was examined. In Table 5, the traveled ML sections are classified by the toll plazas that the ML trips passed. For example, the traveled ML section A-B implies that a ML trip was detected only at the toll plazas A and B. A indicates the toll plaza at Eldridge, B indicates the toll plaza at Wilcrest, and C indicates the toll plaza at Wirt. The ML trips that only passed toll plaza A or C in both directions include a higher proportion of U-ML trips (see Figure 12, Figure 13, and Table 30).

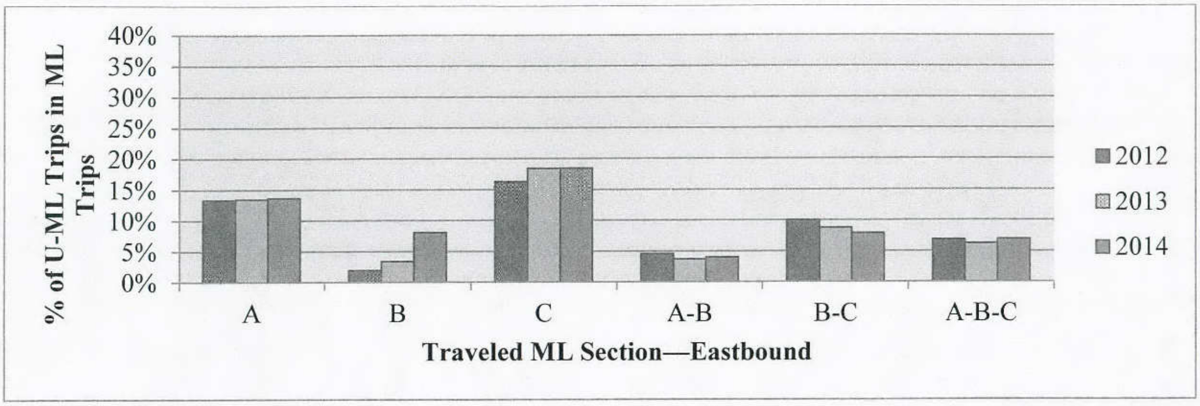


Figure 12. Percentage of U-ML Trips by Traveled ML Section (Eastbound).

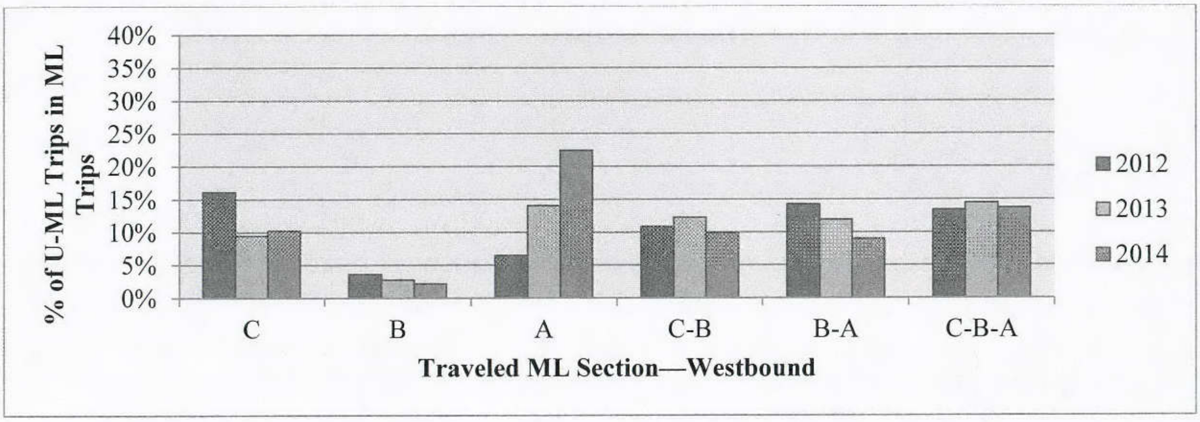


Figure 13. Percentage of U-ML Trips by Traveled ML Section (Westbound).

Table 30. Number of U-ML Trips and Total ML Trips by Traveled ML Section.

Traveled ML Section		2012			2013			2014			Total
		U-ML	ML	U-ML/ML	U-ML	ML	U-ML/ML	U-ML	ML	U-ML/ML	U-ML/ML
Eastbound	A*	10,468	78,493	13.3%	12,649	94,235	13.4%	12,025	88,146	13.6%	13.5%
	B*	30	1,563	1.9%	35	1,035	3.4%	63	781	8.1%	3.8%
	C*	36,927	226,539	16.3%	62,248	338,361	18.4%	53,579	289,963	18.5%	17.9%
	A-B	4,248	92,464	4.6%	3,590	96,943	3.7%	4,325	108,175	4.0%	4.1%
	B-C	17,811	177,708	10.0%	25,468	290,329	8.8%	23,431	297,699	7.9%	8.7%
	A-B-C	28,287	412,099	6.9%	31,919	511,711	6.2%	40,342	586,146	6.9%	6.7%
Westbound	C	8,229	51,125	16.1%	9,664	102,401	9.4%	8,802	86,110	10.2%	11.1%
	B	403	11,206	3.6%	289	10,517	2.7%	367	16,763	2.2%	2.8%
	A	3,172	48,861	6.5%	6,966	49,715	14.0%	9,845	43,900	22.4%	14.0%
	C-B	13,734	126,507	10.9%	18,354	150,251	12.2%	14,640	148,047	9.9%	11.0%
	B-A	24,141	169,906	14.2%	26,854	226,053	11.9%	16,273	180,765	9.0%	11.7%
	C-B-A	76,617	572,285	13.4%	96,430	666,717	14.5%	74,579	545,187	13.7%	13.9%

* A = the toll plaza at Eldridge, B = the toll plaza at Wilcrest, and C = the toll plaza at Wirt.

Time of Travel

This section examines the frequency of U-ML trips depending on time of travel, including time of day, hour of travel, day of the week, and month of travel, using the ratio of U-ML trips to total ML trips.

Time of Day

Depending on the time of day (off-peak, shoulder, or peak period), the traffic conditions on the freeway vary significantly. Researchers compared the frequency of the U-ML trips depending on the time of day. The results indicate that there were more U-ML trips during the off-peak period (see Table 5 for time periods) than other times of day (see Table 31).

Table 31. Number of U-ML Trips and Total ML Trips by Time of Day.

Time of Day	2012			2013			2014			Total
	U-ML	ML	U-ML/ ML	U-ML	ML	U-ML/ ML	U-ML	ML	U-ML/ ML	U-ML/ ML
Off-peak	136,628	807,019	16.9%	186,284	1,250,544	14.9%	171,622	1,322,072	13.0%	14.6%
Shoulder	29,913	439,720	6.8%	37,021	471,319	7.9%	27,803	389,150	7.1%	7.3%
Peak	61,481	764,869	8.0%	75,634	879,379	8.6%	59,743	689,515	8.7%	8.4%

Hour of Travel

A more detailed analysis of the U-ML trip frequency depending on the time of day was conducted. The highest proportion of U-ML trips occurred between midnight and 6 a.m. The next highest percentage of U-ML trips occurred between 10 p.m. and midnight, and then between 10 a.m. and 3 p.m. The lowest percentage occurred during the peak periods (see Figure 14 and Table 32).

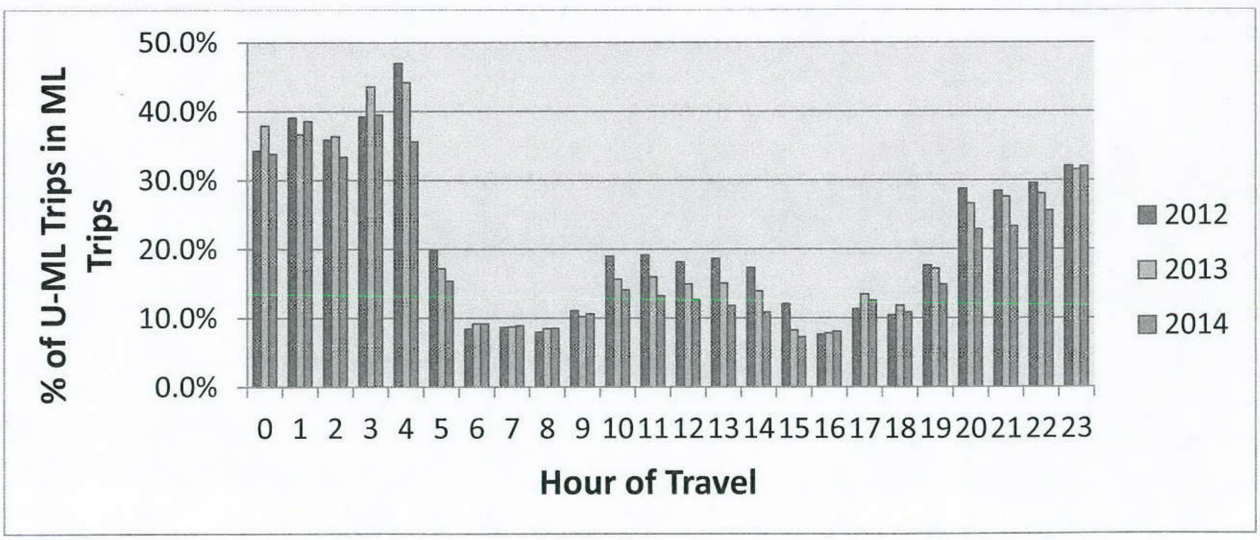


Figure 14. Percentage of U-ML Trips by Hour of Travel.

Table 32. Number of U-ML Trips and Total ML Trips by Hour of Travel.

Hour	2012			2013			2014			Total
	U-ML	ML	U-ML/ML	U-ML	ML	U-ML/ML	U-ML	ML	U-ML/ML	U-ML/ML
0	375	1,095	34.2%	627	1,655	37.9%	547	1,618	33.8%	35.5%
1	229	586	39.1%	306	835	36.6%	314	815	38.5%	38.0%
2	248	692	35.8%	305	839	36.4%	257	771	33.3%	35.2%
3	191	487	39.2%	307	705	43.5%	214	542	39.5%	41.1%
4	953	2,029	47.0%	1,162	2,632	44.1%	1,036	2,911	35.6%	41.6%
5	4,731	23,924	19.8%	6,019	35,090	17.2%	5,596	36,460	15.3%	17.1%
6	11,642	138,463	8.4%	13,321	145,301	9.2%	11,141	121,786	9.1%	8.9%
7	18,837	217,970	8.6%	21,575	246,654	8.7%	19,032	214,522	8.9%	8.8%
8	14,808	185,947	8.0%	18,094	214,041	8.5%	16,547	193,933	8.5%	8.3%
9	7,918	71,508	11.1%	9,558	93,302	10.2%	10,038	94,785	10.6%	10.6%
10	6,739	35,555	19.0%	8,126	51,952	15.6%	8,168	57,974	14.1%	15.8%
11	8,503	44,399	19.2%	10,822	67,774	16.0%	10,354	78,300	13.2%	15.6%
12	8,821	48,686	18.1%	11,530	77,196	14.9%	11,241	88,982	12.6%	14.7%
13	10,762	57,844	18.6%	13,662	90,546	15.1%	12,109	102,877	11.8%	14.5%
14	10,433	60,376	17.3%	13,150	94,598	13.9%	11,022	101,657	10.8%	13.5%
15	15,872	131,784	12.0%	15,656	190,010	8.2%	13,230	181,877	7.3%	8.9%
16	24,861	327,152	7.6%	32,731	419,079	7.8%	29,320	363,538	8.1%	7.8%
17	43,068	380,327	11.3%	64,048	475,825	13.5%	49,964	398,494	12.5%	12.5%
18	21,366	205,185	10.4%	32,458	274,882	11.8%	25,121	232,063	10.8%	11.1%
19	7,502	42,557	17.6%	11,732	68,345	17.2%	10,775	72,284	14.9%	16.4%
20	4,497	15,647	28.7%	6,145	23,104	26.6%	5,890	25,784	22.8%	25.6%
21	3,037	10,697	28.4%	3,893	14,121	27.6%	3,607	15,474	23.3%	26.2%
22	1,860	6,299	29.5%	2,511	8,949	28.1%	2,404	9,407	25.6%	27.5%
23	769	2,399	32.1%	1,201	3,807	31.5%	1,241	3,883	32.0%	31.8%

Day of Week

Next, each ML trip was classified by the day of the week when the ML trip was made. The ratios of U-ML trips to total ML trips are similar during weekdays (see Table 20). However, there is a difference in the ratios between weekdays and weekends. There was a higher percentage of U-ML trips during weekends than during weekdays (see Table 33 and Figure 15).

Table 33. Number of U-ML Trips and Total ML Trips by Day of Week.

Day of Week	2012			2013			2014			Total
	U-ML	ML	U-ML/ ML	U-ML	ML	U-ML/ ML	U-ML	ML	U-ML/ ML	U-ML/ ML
Mon.	39,290	330,035	11.9%	45,242	432,121	10.5%	41,321	386,673	10.7%	11.0%
Tues.	41,479	385,863	10.7%	66,289	495,521	13.4%	51,260	431,302	11.9%	12.1%
Wed.	40,297	385,675	10.4%	52,636	495,068	10.6%	48,349	441,697	10.9%	10.7%
Thurs.	42,012	400,573	10.5%	54,056	498,585	10.8%	48,321	464,205	10.4%	10.6%
Fri.	38,789	370,672	10.5%	47,897	468,804	10.2%	35,930	416,310	8.6%	9.8%
Sat.	16,075	84,626	19.0%	18,610	131,455	14.2%	18,451	161,427	11.4%	14.1%
Sun.	10,080	54,164	18.6%	14,209	79,688	17.8%	15,536	99,123	15.7%	17.1%

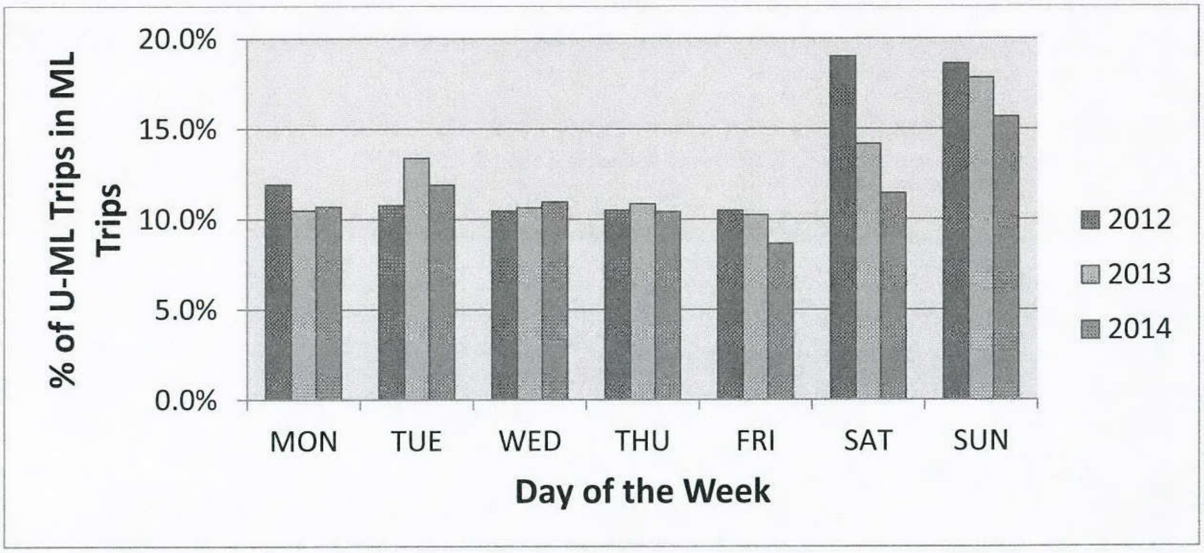


Figure 15. Percentage of U-ML Trips by Day of Week.

Month of Travel

Traffic conditions can have seasonal or monthly variation. Researchers classified each ML trip by month when the ML trip was made. The results indicate that the ratio is similar every month except May 2012, August 2012, and May 2013 (see Table 34 and Figure 16) where it increases to over 15 percent.

Table 34. Number of U-ML Trips and Total ML Trips by Month of Travel.

Month	2012			2013			2014		
	U-ML	ML	U-ML/ ML	U-ML	ML	U-ML/ ML	U-ML	ML	U-ML/ ML
Jan.	14,079	152,268	9.2%	18,242	179,241	10.2%	23,472	217,066	10.8%
Feb.	15,699	167,391	9.4%	21,128	192,408	11.0%	30,954	242,103	12.8%
March	18,377	179,256	10.3%	20,167	193,632	10.4%	30,081	256,947	11.7%
April	18,730	178,853	10.5%	23,393	222,154	10.5%	29,957	272,716	11.0%
May	32,044	206,048	15.6%	37,497	239,337	15.7%	26,276	271,215	9.7%
June	17,839	181,893	9.8%	26,758	219,242	12.2%	26,761	279,973	9.6%
July	17,694	171,510	10.3%	21,995	213,303	10.3%	27,104	276,423	9.8%
Aug.	33,990	216,286	15.7%	29,061	239,166	12.2%	29,418	290,015	10.1%
Sept.	22,183	183,380	12.1%	28,311	231,610	12.2%	35,145	294,279	11.9%
Oct.	19,967	201,235	9.9%	29,767	250,322	11.9%	NA	NA	NA
Nov.	17,420	173,488	10.0%	22,782	218,884	10.4%	NA	NA	NA
Dec.	NA	NA	NA	19,838	201,943	9.8%	NA	NA	NA

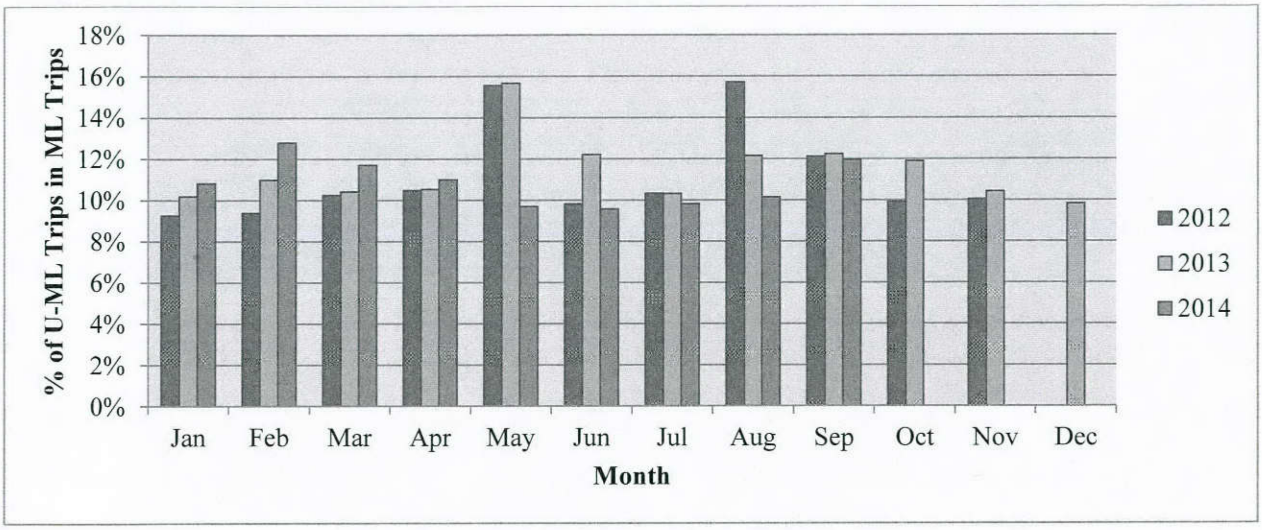


Figure 16. Percentage of U-ML Trips by Month of Travel.

Traveler's Familiarity with Traffic Conditions

This section examines the frequencies of U-ML trips depending on travelers' frequency of travel on Katy Freeway. Each traveler's total number of trips for a given period (the past year or past 30 days) was used as a measure of his or her familiarity with traffic conditions on the freeway.

Total Number of Trips on both GPLs and MLs in Each Year

Each ML traveler was grouped by the total number of trips on both the GPLs and MLs made by that traveler during a year. The total number of trips in 2012 is the total number of trips from January to November 2012, and the total number of trips in 2014 is the total number of trips from January to September 2014. There is a slight decrease in the percentage of U-ML trips made as travelers use the freeway more—except for the most frequent travelers (see Table 35 and Figure 17). From these results, a traveler's familiarity with Katy Freeway appears to slightly reduce his or her U-ML choices (trips).

Table 35. Number of U-ML Trips and Total ML Trips by Traveler's Total Trips in Each Year.

Total Trips in Each Year	2012			2013			2014			Total
	U-ML	ML	U-ML/ ML	U-ML	ML	U-ML/ ML	U-ML	ML	U-ML/ ML	U-ML/ ML
1–20	35,566	265,219	13.4%	42,215	335,162	12.6%	46,243	398,293	11.6%	12.4%
21–40	22,714	180,205	12.6%	27,376	223,978	12.2%	30,405	262,399	11.6%	12.1%
41–60	19,622	162,212	12.1%	23,553	199,050	11.8%	25,471	220,075	11.6%	11.8%
61–80	17,083	146,566	11.7%	22,133	188,550	11.7%	21,636	197,102	11.0%	11.4%
81–100	16,507	147,435	11.2%	19,571	170,854	11.5%	20,237	178,854	11.3%	11.3%
101–120	14,928	132,586	11.3%	18,294	161,039	11.4%	17,134	162,227	10.6%	11.0%
121–140	13,495	126,873	10.6%	16,306	153,079	10.7%	16,676	161,698	10.3%	10.5%
141–160	12,382	117,741	10.5%	16,001	145,885	11.0%	15,355	152,668	10.1%	10.5%
161–180	11,424	110,148	10.4%	15,194	136,333	11.1%	13,977	135,593	10.3%	10.6%
181–200	10,488	102,041	10.3%	13,921	124,726	11.2%	11,744	118,838	9.9%	10.5%
201–220	9,045	91,058	9.9%	12,582	119,626	10.5%	9,650	103,910	9.3%	9.9%
221–240	8,333	86,379	9.6%	12,204	109,460	11.1%	7,661	84,105	9.1%	10.1%
241–260	7,091	72,462	9.8%	10,466	95,857	10.9%	6,559	71,749	9.1%	10.0%
261–280	6,068	62,429	9.7%	9,121	86,625	10.5%	5,033	53,285	9.4%	10.0%
281–300	4,632	48,562	9.5%	8,680	80,500	10.8%	3,484	35,864	9.7%	10.2%
300+	18,644	159,692	11.7%	31,322	270,518	11.6%	7,903	64,077	12.3%	11.7%

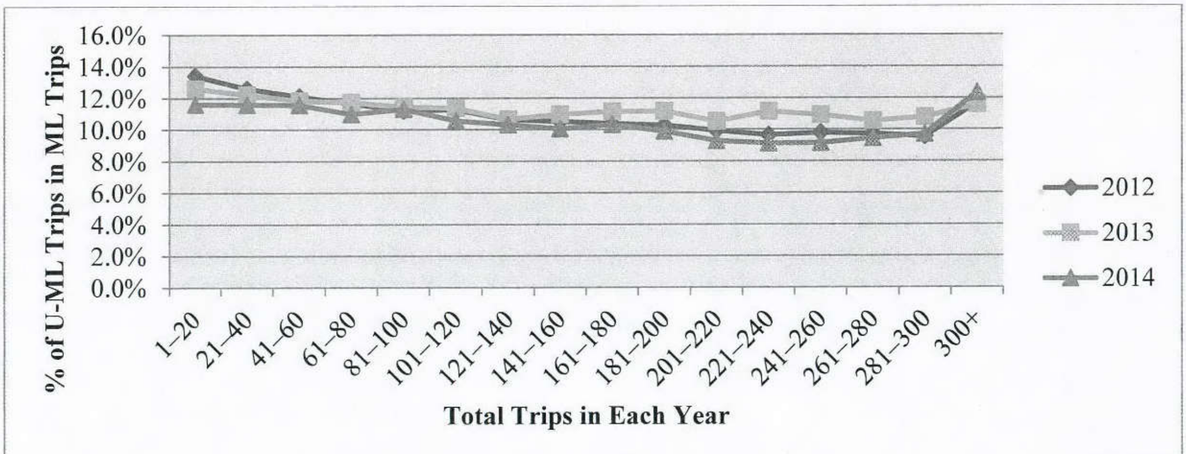


Figure 17. Percentage of U-ML Trips by Traveler's Total Trips in Each Year.

Total Number of Trips on the MLs in Each Year

The ML users were classified by the total number of trips they took on the MLs during a year. There was no clear trend in the ratio of U-ML trips to total ML trips (see Table 36 and Figure 18). From these results, whether the traveler's familiarity of travel on the MLs reduces making U-ML choices is uncertain. For the previous factor, the familiarity a traveler has with Katy Freeway (as measured by the total number of trips on both the GPLs and MLs) slightly reduces the proportion of U-ML trips. For this factor, the effect of the familiarity measured by the total number of trips on the MLs is unclear. Thus, for the next factors, different measurements of familiarity were tested.

Table 36. Number of U-ML Trips and Total ML Trips by the Traveler's Total ML Trips per Year.

Total ML Trips in Each Year	2012			2013			2014			Total
	U-ML	ML	U-ML/ ML	U-ML	ML	U-ML/ ML	U-ML	ML	U-ML/ ML	U-ML/ ML
1–20	95,755	747,386	12.8%	116,050	936,678	12.4%	109,537	956,051	11.5%	12.2%
21–40	33,323	296,910	11.2%	41,694	359,024	11.6%	39,677	354,992	11.2%	11.3%
41–60	21,573	202,883	10.6%	27,924	257,179	10.9%	26,265	241,547	10.9%	10.8%
61–80	16,811	160,194	10.5%	22,281	203,051	11.0%	19,147	185,830	10.3%	10.6%
81–100	13,181	125,997	10.5%	16,467	157,254	10.5%	16,718	158,888	10.5%	10.5%
101–120	9,212	97,773	9.4%	14,970	140,356	10.7%	13,427	134,233	10.0%	10.1%
121–140	7,549	77,931	9.7%	11,121	109,895	10.1%	9,509	98,658	9.6%	9.8%
141–160	6,972	69,763	10.0%	10,171	94,033	10.8%	6,979	75,026	9.3%	10.1%
161–180	5,067	55,415	9.1%	7,661	76,784	10.0%	5,227	59,683	8.8%	9.4%
181–200	3,475	36,512	9.5%	6,598	62,224	10.6%	3,210	35,180	9.1%	9.9%
201–220	3,360	35,881	9.4%	5,184	48,451	10.7%	2,213	28,729	7.7%	9.5%
221–240	2,047	23,385	8.8%	3,785	38,183	9.9%	2,086	25,775	8.1%	9.1%
241–260	2,021	22,426	9.0%	2,922	23,802	12.3%	1,245	14,532	8.6%	10.2%
261–280	1,077	15,745	6.8%	1,762	17,580	10.0%	994	10,508	9.5%	8.7%
281–300	794	9,612	8.3%	2,098	18,242	11.5%	744	8,115	9.2%	10.1%
300+	5,805	33,795	17.2%	8,251	58,506	14.1%	2,190	12,990	16.9%	15.4%

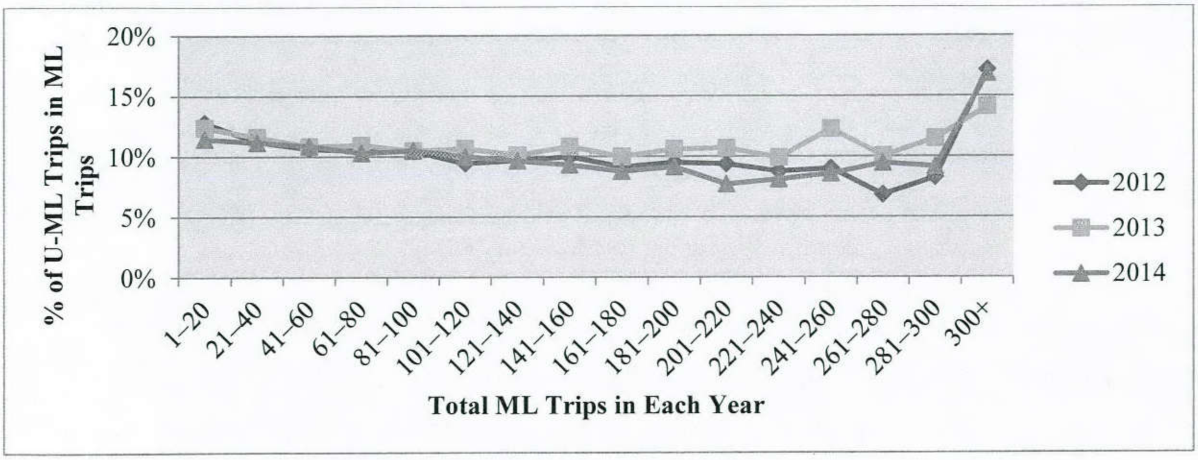


Figure 18. Percentage of U-ML Trips by Traveler's Total ML Trips in Each Year.

Total Number of Trips on both the GPLs and MLs during the Previous 30 Days

Each traveler's familiarity with traffic conditions was measured by his or her total number of trips on both GPLs and MLs during the previous 30 days. January 2012 data were excluded since December 2011 data were not part of the dataset. Also, the dataset does not include all trip records in December 2012. Thus, to calculate the total number of trips for all ML trips in January 2013, researchers used trip records from November 2012 instead.

Each ML traveler was classified by his or her total number of trips on both the GPLs and MLs during the previous 30 days. In general, there is a slight decrease in the percentage of U-ML trips as the number of trips increases, except for those who traveled Katy Freeway more than 30 times during the previous 30 days (see Table 37 and Figure 19).

Table 37. Number of U-ML Trips and Total ML Trips by Traveler's Total Trips during the Previous 30 Days.

Total Trips during the Previous 30 Days	2012			2013			2014			Total
	U-ML	ML	U-ML/ ML	U-ML	ML	U-ML/ ML	U-ML	ML	U-ML/ ML	U-ML/ ML
0	77,812	588,304	13.2%	112,858	878,190	12.9%	95,889	808,916	11.9%	12.6%
1–5	39,065	308,397	12.7%	54,156	455,175	11.9%	48,706	430,555	11.3%	11.9%
6–10	25,813	229,308	11.3%	35,882	318,264	11.3%	32,242	294,576	10.9%	11.2%
11–15	21,766	209,227	10.4%	29,975	279,286	10.7%	26,440	255,622	10.3%	10.5%
16–20	17,920	185,686	9.7%	24,720	245,079	10.1%	21,217	222,891	9.5%	9.8%
21–25	12,951	142,003	9.1%	17,705	185,073	9.6%	15,140	168,324	9.0%	9.2%
26–30	8,513	95,716	8.9%	11,228	119,317	9.4%	9,439	109,742	8.6%	9.0%
30+	10,103	100,699	10.0%	12,415	120,858	10.3%	10,095	110,111	9.2%	9.8%

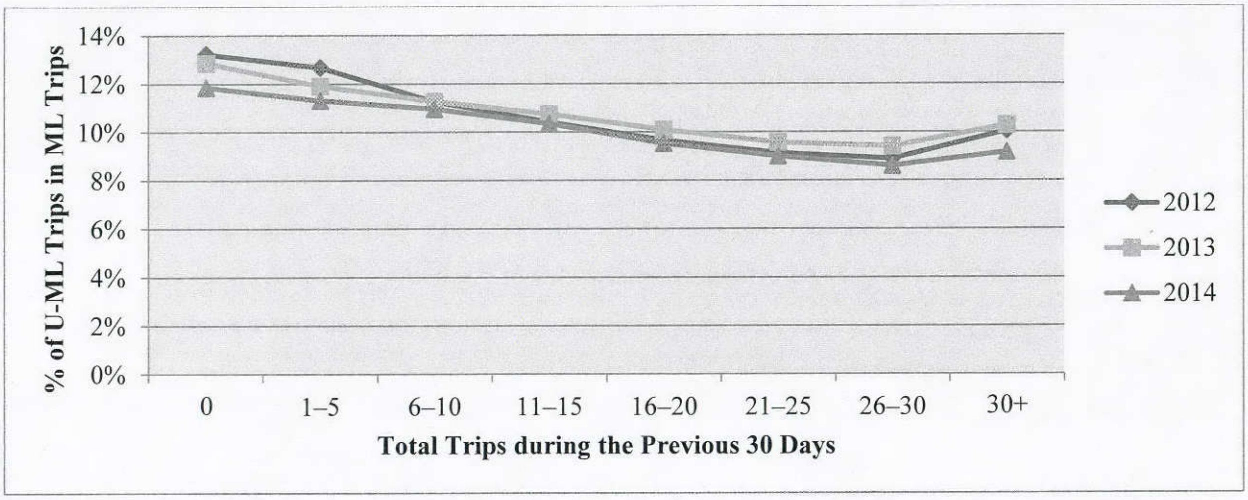


Figure 19. Percentage of U-ML Trips by Traveler's Total Trips during the Previous 30 Days.

Total Number of Trips on the MLs during the Previous 30 Days

Each traveler's familiarity with traffic conditions was measured by his or her total number of trips on the MLs during the previous 30 days. Travelers who are familiar with the MLs are hypothesized to make fewer U-ML trips. For all ML trips during January 2012 and January 2013, the same method for the previous factor was used to calculate the total number of ML trips. There is an obvious decrease in the percentage of U-ML trips because the number of ML trips increases (see Table 38 and Figure 20). Thus, travelers who frequently traveled on the MLs generally make fewer U-ML choices (trips).

Table 38. Number of U-ML Trips and Total ML Trips by Traveler's Total ML Trips during the Previous 30 Days.

Total ML Trips during the Previous 30 Days	2012			2013			2014			Total
	U-ML	ML	U-ML/ ML	U-ML	ML	U-ML/ ML	U-ML	ML	U-ML/ ML	U-ML/ ML
0	103,027	781,404	13.2%	145,359	1,146,587	12.7%	123,003	1,051,715	11.7%	12.5%
1	18,738	148,708	12.6%	24,651	208,630	11.8%	22,083	196,344	11.2%	11.8%
2	12,732	104,881	12.1%	16,869	144,210	11.7%	15,142	135,691	11.2%	11.6%
3	9,354	82,523	11.3%	12,764	111,348	11.5%	11,452	104,833	10.9%	11.2%
4	7,671	69,599	11.0%	10,434	93,703	11.1%	9,338	86,251	10.8%	11.0%
5	6,512	60,573	10.8%	8,715	80,567	10.8%	7,981	74,572	10.7%	10.8%
6	5,678	54,465	10.4%	7,746	71,891	10.8%	7,064	66,177	10.7%	10.6%
7	5,126	49,544	10.3%	6,807	64,943	10.5%	6,202	60,199	10.3%	10.4%
8	4,496	45,382	9.9%	6,205	60,047	10.3%	5,475	55,534	9.9%	10.0%
9	4,058	42,001	9.7%	5,679	55,812	10.2%	5,126	51,523	9.9%	10.0%
10	3,821	38,898	9.8%	5,342	52,486	10.2%	4,709	48,327	9.7%	9.9%
10+	32,730	381,362	8.6%	48,368	511,018	9.5%	41,593	469,571	8.9%	9.0%

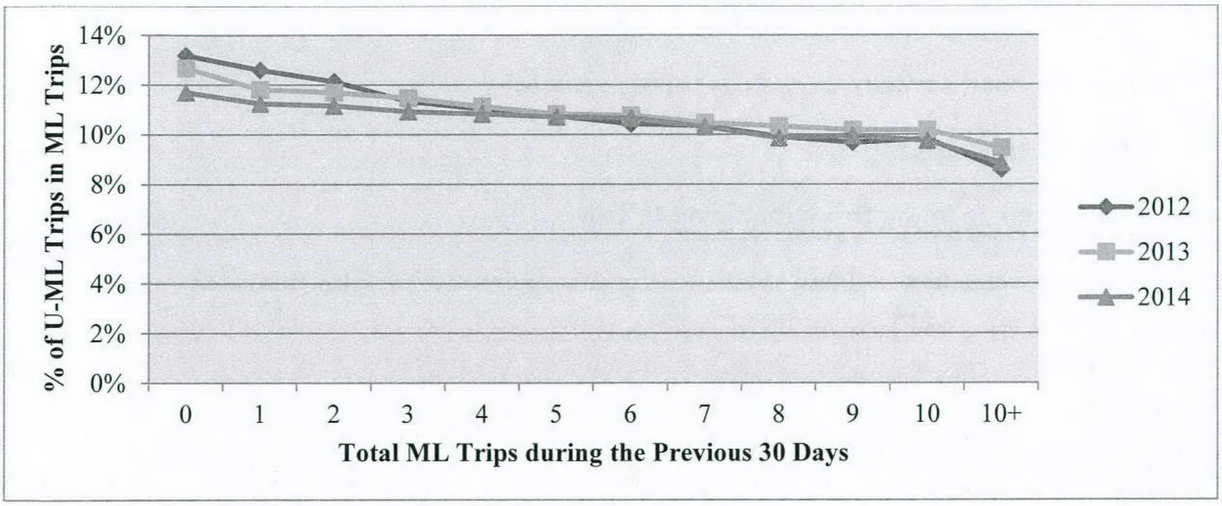


Figure 20. Percentage of U-ML Trips by Traveler's Total ML Trips during the Previous 30 Days.

Researchers identified some of the characteristics of the U-ML trips in the dataset. Specifically, trip characteristics where the U-ML trips are frequently observed, time of travel when the U-ML trips are frequently made, and travelers who frequently make U-ML trips were identified (based on their frequency of travel). The findings are summarized as follows:

- Long-distance (more than 20 miles) ML trips have a higher percentage of U-ML trips.
- Westbound ML trips have a higher percentage of U-ML trips.
- ML trips that passed only the Eldridge toll plaza or Wirt toll plaza (either direction) have a higher percentage of U-ML trips.
- ML trips that were made during the off-peak period have a higher percentage of U-ML trips, particularly from midnight to 6 a.m.
- The percentage of U-ML trips is higher during weekends than on weekdays.

- ML trips during May 2012, August 2012, and May 2013 have a higher percentage of U-ML trips.
- Travelers who traveled less frequently on the MLs during the previous 30 days have a higher percentage of U-ML trips.

Identifying Characteristics of Travelers Who Made the U-ML Trips

The previous factor identified the cases where the U-ML trips were more frequently observed. However, if the MLs were frequently slower than the GPLs, travelers might often make U-ML choices regardless of their intention. Therefore, an examination of the percentage of time the MLs were slower than the GPLs was undertaken.

First, four cases where U-ML trips were frequently observed were selected:

- Off-peak hours (from midnight to 6 a.m.).
- Specific months (May 2012, August 2012, and May 2013).
- The westbound direction.
- Long-distance (more than 20 miles) ML trips.

Then, the average speeds of all ML trips and all GPL trips for every 10-minute interval in each direction were compared to determine if the MLs provided faster travel than the GPLs during that 10-minute period. Since there are a large number of 10-minute intervals in each case, those comparisons are summarized as the percentage of 10-mintue intervals when the MLs were slower. This clearly shows how often the MLs were slower than the GPLs. Despite a large number of trips in the dataset, not all 10-minute intervals had trips in both the MLs and GPLs, and thus some intervals could not be included. Finally, the percentage of the U-ML trips was compared to the percentage of 10-mintue intervals when the MLs were slower.

Table 39 compares the percentage of U-ML trips that were made between midnight and 6 a.m. with the percentage of 10-minute intervals when the MLs were slower than the GPLs during the same time of day. In 2012, a total of 28,813 ML trips between midnight and 6 a.m. were identified in the dataset, and 23.3 percent (6,727 trips) of the ML trips were U-ML trips. In the same year, a total of 6,550 (10-minute) intervals between midnight and 6 a.m. had the data needed to compare average speeds of ML and GPL trips, and 31.2 percent (2,045 intervals) of the 10-minute intervals contained slower ML trips than GPL trips. This means that, during 31.2 percent of time between midnight and 6 a.m. in 2012, the MLs were slower than the GPLs. If travelers had chosen to travel in the ML at random, then the percentage of U-ML trips would be closer to 31.2 percent. The other years also showed similar results. Therefore, travelers were somewhat selective in choosing the ML to avoid U-ML trips.

Table 39. Comparison of the Percentage of U-ML Trips and the Percentage of 10-Minute Intervals When the MLs Were Slower than the GPLs between Midnight and 6 a.m.

Year	Number of Trips			Number of 10-Minute Intervals		
	U-ML	ML	U-ML/ML	MLs Were Slower	Total	MLs Were Slower/Total
2012	6,727	28,813	23.3%	2,045	6,550	31.2%
2013	8,726	41,756	20.9%	2,397	8,163	29.4%
2014	7,964	43,117	18.5%	1,720	6,745	25.5%
Total	23,417	113,686	20.6%	6,162	21,458	28.7%

Table 40 compares the percentage of U-ML trips that were made in May 2012, August 2012, and May 2013 with the percentage of 10-minute intervals when the MLs were slower than the GPLs during the same month. In this case, a much higher percentage of travelers are making U-ML trips than if they had simply chosen the MLs at random.

Table 40. Comparison of the Percentage of U-ML Trips and the Percentage of 10-Minute Intervals When the MLs Were Slower than the GPLs in May 2012, August 2012, and May 2013.

Month	Number of Trips			Number of 10-Minute Intervals		
	U-ML	ML	U-ML/ML	MLs Were Slower	Total	MLs Were Slower/Total
May 2012	32,044	206,048	15.6%	532	6,123	8.7%
August 2012	33,990	216,286	15.7%	531	6,138	8.7%
May 2013	37,497	239,337	15.7%	430	6,190	6.9%

Table 41 compares the percentage of U-ML trips that were made in the westbound direction with the percentage of 10-minute intervals when the MLs were slower than the GPLs in the westbound direction. Again, there are more travelers choosing the MLs during periods when the MLs are slower than if they simply chose the MLs at random.

Table 41. Comparison of the Percentage of U-ML Trips and the Percentage of 10-Minute Intervals When the MLs Were Slower than the GPLs in the Westbound Direction.

Year	U-ML and ML Trips			Number of 10-Minute Intervals		
	U-ML	ML	U-ML/ML	GPL Faster	Total	GPL Faster/Total
2012	126,577	980,641	12.9%	4,069	36,306	11.2%
2013	158,809	1,206,589	13.2%	3,927	41,254	9.5%
2014	124,782	1,021,792	12.2%	2,597	31,639	8.2%
Total	410,168	3,209,022	12.8%	10,593	109,199	9.7%

Next, long-distance trips (over 20 miles) were examined. To calculate average speeds on the MLs and the GPLs, only long-distance (more than 20 miles) trips were used. Again, a much higher percentage of travelers made U-ML trips than if they had just randomly chosen to travel on the MLs.

Table 42. Comparison of the Percentage of U-ML Trips and the Percentage of 10-Minute Intervals When the MLs Were Slower than the GPLs for Long-Distance Trips.

Year	Number of Trips			Number of 10-Minute Intervals		
	U-ML	ML	U-ML/ML	MLs Were Slower	Total	MLs Were Slower/Total
2012	15,433	89,739	17.2%	4,219	31,557	13.4%
2013	22,176	116,452	19.0%	4,891	38,933	12.6%
2014	19,648	113,415	17.3%	4,157	36,343	11.4%
Total	57,257	319,606	17.9%	13,267	106,833	12.4%

This examination of U-ML trips revealed several instances where the proportion of travelers making U-ML trips is greater than the proportion of the time the MLs are slower than the GPLs. Thus, there are clearly other factors influencing travelers' choice of the MLs other than travel time, toll, and travel time reliability.

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