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EVALUATION OF AASHTO RULES FOR IMPLEMENTATION OF CLIMBING LANES ON TWO-LANE HIGHWAYS

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EVALUATION OF AASHTO RULES FOR IMPLEMENTATION OF CLIMBING LANES ON TWO-LANE HIGHWAYS

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ABSTRACT

Lack of passing opportunities, due to limited sight distance and heavy oncoming traffic volumes in dense platoons, results in traffic operational issues on two-lane highways. Climbing lanes extend an opportunity for breaking traffic platoons on two-lane highway upgrades, thus potentially improving traffic operations on these segments. The American Association of State Highway and Transportation Officials promulgates guidelines to implement climbing lanes on two-lane highways that have remained unchanged over its last four editions of *"A policy on Geometric Design of Highways and Streets*". The guidelines do not account for the combination of variables known to determine specifically performance on two-lane highways by the current state-of-the-practice, in particular the opposing flow or the percentage of no-passing zone. Most state Departments of Transportation base their implementation decisions on climbing lanes on these old guidelines. They either refer to the AASHTO guidelines or interpret those directly as warrants. This research study evaluates the efficacy of the guidelines in the face of new research results on two-lane highway performance. The research deploys the Highway Capacity Software to evaluate the performance achieved with and without climbing lanes for two-lane highways for varied scenarios with randomly generated input values. The data serves to contrast the AASHTO recommendations for implementing climbing lanes with their necessity and sufficiency, thereby assessing their sampled efficacy. AASHTO recommendations only prove beneficial for 36% of the scenarios analyzed. Although certain study limitations apply, results point to a need to further research the study theme and potentially update the AASHTO guidelines.

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CHAPTER 1

INTRODUCTION

1.1 STATEMENT OF THE PROBLEM

Many of the traffic operational problems on rural two-lane highways result from the lack of passing opportunities due to limited sight distance and heavy oncoming traffic volumes in dense platoons. Drivers forcibly spend an uncertain amount of time following other vehicles and pass using the lane dedicated to the other travel direction through gaps in the opposing traffic. This might be dangerous due to the passing habits of drivers and dependent upon the presence of non-passing zones. Climbing lanes provide an effective method for improving traffic operations on upgrades on two-lane highways by extending additional passing opportunities at lower costs than would be required for the construction of a four-lane highway (Transportation Research Board, 2010).

This thesis will seek to evaluate parts of the guidelines for the implementation of climbing lanes on two-lane highways as promulgated by AASHTO, 2011. Evaluation will probe the necessity for, and the sufficiency of, climbing lanes when developed per the guidelines' recommendations. The thesis focuses only on Class I rural two-lane highways, with segment lengths that result in a 30-mph speed decrease on upgrades ranging from 6% to 10%, which connect to flat terrain on the grade's approach and departure. The study assumes for the most part uniformly distributed variables.

1.2 JUSTIFICATION OF THE STUDY

Climbing and passing lanes are introduced on two-lane highways in the aim of increasing their performance levels, breaking down platoons, enhancing travel speed and safety (Roess et al., 2011). In practice, most state Departments of Transportation (DOTs) base their decisions about implementing climbing lanes on old guidelines by the American Association of State Highway and Transportation Officials (AASHTO). These guidelines are a set of general conditions in which to consider a climbing lane. They have existed for over twenty years now and remained unchanged over at least four different editions of "A Policy on Geometric Design of Highways and Streets" (AASHTO, 1994, 2001, 2004, 2011). While these guidelines are useful, they do not account for the combination of variables known by the state-of-the-practice to determine specifically two-lane highway level of service (LOS).

This research shall determine if the AASHTO guidelines still apply in the face of enhanced methodologies to determine performance on two-lane highways or they need much improvement. If the guidelines prove questionable or inadequate, it is hoped that the research results may spur future research toward the development of enhanced guidelines for the implementation of climbing lanes on two-lane highways. Thus, resulting enhanced access to, and mobility of, goods and persons may promote enhanced economic, defense and transportation systems' performances. In addition, the resulting enhanced maneuverability may promote enhanced transportation system safety. If the guidelines prove to be adequate, then surely transportation operators, Departments of Transportation (DOTs) in particular, would benefit from enhanced confidence in their use.

1.3 ORGANIZATION OF THE RESEARCH

This thesis comprises five chapters. The first chapter gives a brief overview of the purpose and the goals of the study. The second is a brief review of the literature. It addresses the general performance of two-lane highways, as well as the effects of steep grades, no passing zones and heavy vehicles, such as trucks or agricultural vehicles, on performance. It also scrutinizes the design of climbing lanes and the nature of the factors affecting this design.

The third chapter further seeks to determine the distribution of performance and design setting variables, their averages and normal ranges, for simulation purposes within the universe of two-lane highways in the U.S. A random number generator simulates hypothetical two-lane highway input values for the HCS software given the assumed distribution of input variables. For the range of input simulated, performance is sought with and without a well-designed climbing lane. Then the methodology derives the validity of the AASHTO guidelines.

Chapter 4 analyzes the results from the experiments. Performance results achieved enable an assessment of the AASHTO guidelines for climbing lane implementation. Lastly, Chapter 5 summarizes the thesis, presents the limitations and outlines the study's conclusions and recommendations for future applications.

CHAPTER 2

REVIEW OF LITERATURE

2.1 CHARACTERISTICS OF TWO-LANE HIGHWAYS

This research addresses climbing lanes on rural two-lane highways. Rural two-lane highways are an essential element in the American highway system. Two-lane highways have a two-lane cross section, with one lane in each direction. For that reason, overtaking slower moving vehicles is only possible while using the opposing lane. Considering this limitation, sufficient sight distance or no-passing zones must be provided on two-lane highways (Transportation Research Board, 2010).

To ensure safety, every point on a highway must provide the safe stopping sight distance to drivers at the selected design speed. Passing sight distance constitutes the minimum sight distance required to perform safely a passing maneuver. Not every point on the highway needs provide the safe passing sight distance contrarily to stopping sight distance. Where passing sight distance is insufficient to allow for passing safely, passing should simply be disallowed. Especially two-lane highways rely on this safety measure, as passing maneuvers occur in the opposing traffic lane. Hence there must be "no-passing" zones or highway markings that prohibit passing where unsafe (Roess et al., 2011).

Effective methods to break down platoons, formed through lack of passing opportunities, or prevent their formations include turnouts, passing lanes at given intervals in each direction and climbing lanes on upgrades. To provide an exhaustive overview, the study revisits the fundamentals of the three methods, even though climbing lanes are the sole focus of this research.

Turnouts provide sufficient room for slower moving vehicles to pull out of the through traffic, and stop if necessary, to permit following vehicles to pass or provide room for emergency stops. The location of turnouts depends on the type of facility. They are mostly provided where passing opportunities are limited, a high frequency of slow-moving vehicles exists and cost for a full auxiliary lane would be inappropriate for the effect it causes (Washington State DOT, 2017). Turnouts are widened shoulder areas on two-lane highways, that are rather short, generally less than 625 ft (Transportation Research Board, 2010).

In general, climbing lanes allow for passing slow trucks through the provision of a short added lane to the right side of upgrades for the exclusive use of trucks. Climbing lanes are necessary, where slower moving vehicles like trucks or heavy, agricultural vehicles impede traffic flow as following drivers of faster vehicles have limited to no opportunities to overtake. In these situations, faster vehicles must follow closely behind slower ones until they are able to pass, resulting in platoon formations. In consequence, performance and safety may deteriorate (AASHTO, 2011; Polus and Reshetnik, 1987). Fig. 1 displays plan view examples of climbing lane designs on two-lane highways.

A passing lane is defined as an “additional lane on highways to facilitate the passing of all types of slow moving vehicles at locations other than sustained grades where passing opportunities are unavailable or very limited over a long stretch of highway” (Arizona DOT, 2015). Furthermore, a climbing lane is defined as an "additional lane on steep upgrades to facilitate the passing of trucks and slow moving vehicles whose speed drops because of the sustained grade rather than a lack of passing opportunity over a long stretch of highway" (Arizona DOT, 2015).

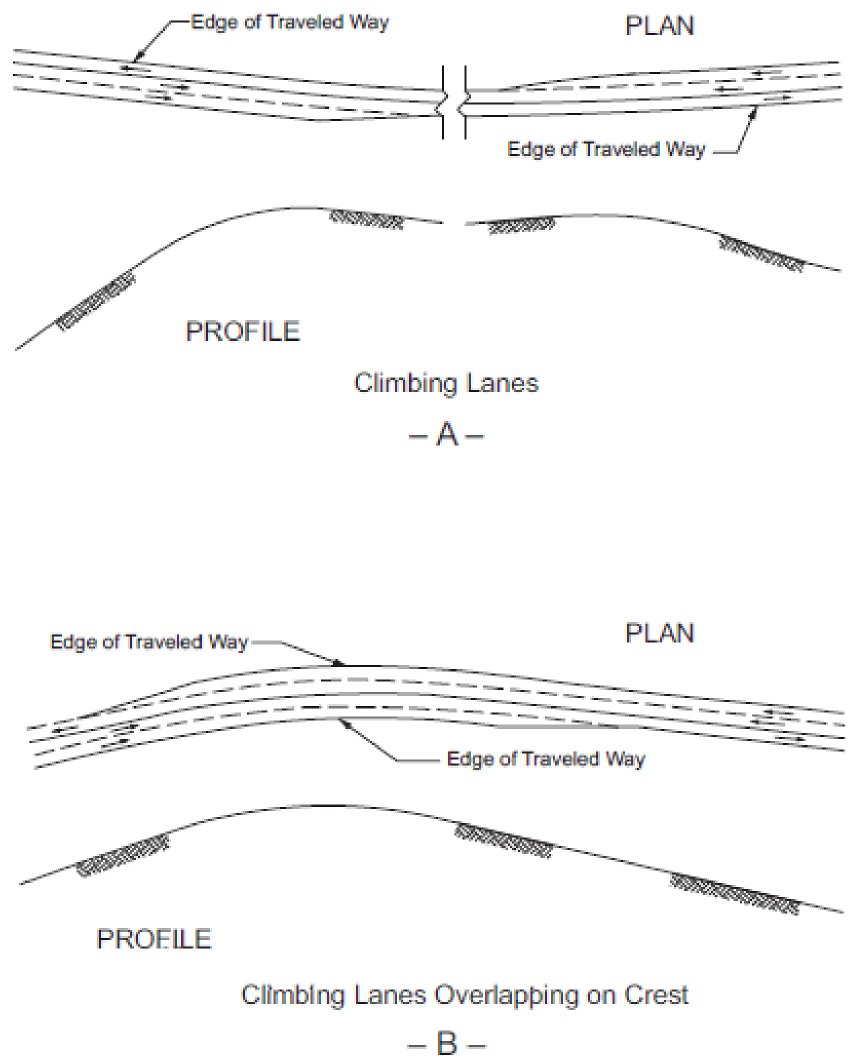

Figure 1: Design of a Two-Lane Highway with Added Climbing Lanes
Source: A Policy on Geometric Design of Highways and Streets, 2011, by the American Association of State Highways and Transportation Officials, Washington, D.C. Used with permission.

Climbing lanes increase the total number of lanes on a two-lane highway for a short travel segment, where the added lane shall be used by slower moving vehicles to allow faster moving vehicles to pass while staying in the normal lane. This is the main difference to a regular passing lane, in which faster vehicles move to the additional lane to overtake the slower moving vehicles, which stay in the normal lane (Transportation Research Board, 2010).

2.2 TWO-LANE HIGHWAY PERFORMANCE MEASURES

To convey the quality of traffic flow on two-lane highways, the Highway Capacity Manual's (HCM) Level of service (LOS) analysis incorporates three measures of effectiveness; *ATS* (the average travel speed), *PTSF* (the percent-time-spent-following) and *PFFS* (the percent free flow speed) (Transportation Research Board, 2010). In effect, the HCM conveys that travel speed and overall maneuverability, the both, can be indicators of highway performance or quality of service.

The HCM distinguishes between two classes of rural two-lane highways. Class I highways are relatively high-speed roads, arterials, primary highways that afford mobility. *ATS* and *PTSF* define the LOS of these highways. On Class II highways, drivers do not expect to travel at high speeds. These roads are access routes to Class I facilities or serve short trips. Only *PTSF* determines their LOS. The Florida Department of Transportation (FDOT) defines an additional class, Class III highways. They serve moderately developed areas and often have more limited passing options and much reduced speed limits to reflect higher activity level. For this class, *PFFS* determines the LOS (Transportation Research Board, 2010).

This research will investigate only the validity of the AASHTO guidelines for climbing lane implementation on rural Class I collector and arterial highways. Speed matters the most on these highway types and upgrades affect directly truck travel speeds. Considering that *ATS* and *PTSF* are the measures used for class I highways, the worse of the two determines the LOS.

New York State Department of Transportation (NYSDOT) provides 2 graphs for the determination of the prevailing LOS on two-lane highway segments in Appendix D1 and D2 of Chapter 5 of its highway design manual (New York State DOT, 2015). The graphs classify into LOS “C” or better, LOS “D” and LOS “E” or worse for undeveloped and developed segments, respectively. Per the definitions provided for undeveloped and developed segments, it is safe to conclude that they represent Class I and II HCS two-lane highways, respectively.

> “The undeveloped case applies to rural highways where relatively high speeds of travel are expected and that are major intercity routes, primary highways connecting major traffic generators, daily commuter routes, primary links in state/national highway networks or any facility that serves long-distance trips” (New York State DOT, 2015).

> “The developed case applies to all highways with an urban Functional Class. It also applies to some highways with a Functional Class of rural, but that serve developed areas (for example, a village), or a scenic or recreational area where speeds are expected to be lower” (New York State DOT, 2015).

NYSDOT does not consider the potentially negative impacts of unusually intense truck traffic on LOS; input variables to the graphs only include the AADT, expressed in vehicle per hour rather than passenger cars per hour, and the prevailing 85^{th} percentile flow speed.

2.3 AASHTO GUIDELINES FOR CLIMBING LANE IMPLEMENTATION

Per the guidelines, a consideration of climbing lanes on two-lane highways is justified by the below-stated conditions.

1. Traffic flow on the upgrade exceeds 200 veh/h,
2. Truck flow on the upgrade exceeds 20 trucks/h,
3. One or more of the following conditions apply:
    a. A 10 mph speed reduction of typical truck,
    b. LOS "E" or "F" on the upgrade without a climbing lane,
    c. A reduction of two or more LOS when driving between approach and grade.

In addition, crash frequencies may also justify a climbing lane, regardless of the grade or traffic flow. Therefore, safety considerations are another important aspect in the decision making on climbing lane implementation (AASHTO, 2011).

A cursory review of the AASHTO guidelines reveals their 3-conditional composition addressing flow, part 1 and 2, performance limits, part 3, as well as safety, the additional clause. Flow and performance conditions apply jointly while safety applies independently. If any independent condition of the guidelines proves ineffective then so do the overall guidelines. Further, the performance guidelines condition, Part 3, consists itself of three independent sub-conditions, applying/ firing independently.

Flow guideline conditions relate to vehicle interactions within a single direction of travel, the upgrade. Yet, flow interactions between both the travel directions, as dictated by volume distribution over travel lanes and percentage of no-passing zones are also known to impact on two-lane highway performance. If climbing lanes are meant to alleviate platoon creation and enhance performance, it seems logical that the opposing flow, or flow distribution, and the percentage of no-passing zones should also matter in their implementation guidelines.

The lack of opposing flow consideration seems remedied within the direct performance guidelines and mainly the last two, aimed directly at LOS or LOS reductions on the upgrade. In their lack of specificity on flow distribution and highway operation characteristics (no-passing zones percentage) or their interactions, latter guidelines withstand the test of time, even as procedures for the determination of LOS on two-lane highways vary and as long as LOS “E” and “F” continue to convey conditions near and beyond capacity, respectively. However, these conditions speak more of a need for enhanced performance levels. They do not ensure or guarantee their achievements through climbing lane provision on two-lane highways. AASHTO thus seems to assume automatically that well-designed climbing lanes always enhance two-lane highway performance from unacceptable to acceptable levels regardless of field conditions (i.e. flows, roadway geometries and operations).

Hypothetically, implementation of a climbing lane enhances significantly either performance or safety where a need for such enhancements exists. Reductions in the LOS letter grade capture the enhancements due to climbing lane implementation. Reliable software for two-lane highway performance prediction affords confirmation of gains in performance through climbing lane deployment. This capability should be enacted prior to actual field implementation. Performance enhancement need-based guidelines may fail to satisfy without ensuring that actual performance enhancement gains accrue.

2.4 STATE DEPARTMENT OF TRANSPORTATIONS' GUIDELINES FOR CLIMBING LANE IMPLEMENTATION

Several DOTs in the United States follow the AASHTO guidelines while making a decision on implementing climbing lanes on upgrades. These include the DOTs of Arizona (ADOT), California (CalTrans), Colorado (CDOT), Michigan (MDOT), Missouri (MoDOT), Montana (MDT), Nebraska (NDOT), New Jersey (NJDOT), Pennsylvania (PENNDOT), South Dakota (SDDOT) and Texas (TxDOT). NYSDOT views the AASHTO guidelines as warrants for climbing lanes on 2-lane highways. NYSDOT states, "However, other conditions may arise on low-volume highways where sufficient passing opportunities are not available where it might be advantageous to provide a climbing lane even though the warrants are not met" (New York State DOT, 2017b). Thus, NYSDOT hints to the AASHTO guidelines as not being exhaustive enough to capture the realm of possibilities that would justify developing climbing lanes. Unfortunately, NYSDOT does not spell out the exceptional conditions that may justify climbing lanes outside of the AASHTO guidelines. It only hints to these conditions being possibly related to the opportunity to pass and thus possibly, the opposing flow and the percentage of no passing zones.

MoDOT repeats the AASHTO guidelines but specifies that "(t)he Highway Capacity Manual and the AASHTO Green Book can also be used to determine the need for climbing lanes." Further, it construes the flow guidelines as economically inspired. “For low-volume roadways, only an occasional car is delayed, and a climbing lane may not be justified economically” (Missouri DOT, n.d.). The extent of delays sustained in total vehicle hours, rather than hours per vehicle, is thus a main motivator for implementing a climbing lane. Unfortunately, ATS or PTSF do not solely reflect this overall delay extent as incurred by traveling in platoons at slow speed. The total volume, *v*, of vehicles impacted matters as well.

Furthermore, Washington State DOT (WSDOT) interprets the AASHTO flow and speed performance guidelines as warrants. The first warrant relates to a speed reduction of 10 mph below the posted speed limit, AASHTO’s Guideline 3a. The second warrant combines two AASHTO guidelines. It relates to traffic volume on the upgrade, AASHTO’s Guideline 1, in excess of 200 vph and to truck volume on the same, AASHTO’s Guideline 2, in excess of 20 vph (Washington State DOT, 2017). In general, both these warrants must be met to justify a climbing lane. Under certain conditions, satisfaction of a single warrant may justify climbing lane implementation. “Either warrant may be waived if, for example, slow-moving traffic is causing an identified collision trend or congestion that could be corrected by the addition of a climbing lane” (Washington State DOT, 2017). Hence, WSDOT replaces “and” by “or” in the consideration of performance warrants, which become alternates. In addition, congestion (with platoon creation as possible manifestation) that may ensue from exceptional conditions, outside of warrants, may also serve as warrants. Unfortunately, as with NYSDOT, WSDOT does not specify these exceptional conditions.

In addition to following the AASHTO guidelines, CalTrans' Design Manual states that, in general, an investigation for climbing lane need should follow when the upgrade is greater than 2% and the total rise is greater than 250 ft (California DOT, 2017). Maryland DOT specifies that exceeding the critical length of grade, satisfaction of AASHTO's Guideline 3a, shall not solely be a warrant for climbing lanes. But rather, where the critical lengths of grade are exceeded and moderate to heavy traffic volumes exist, considerations for implementing a climbing lane should follow (Maryland DOT, n.d.).

In summary, most DOTs adopt the AASHTO guidelines verbatim for implementing climbing lanes on two-lane highways. Some DOTs, such as NYSDOT and WSDOT, may implement climbing lanes outside of the AASHTO guidelines where unspecified conditions mandate. WSDOT further considers the flow and performance guidelines independently as warrants. In addition, it drops from consideration the last two sub-conditions of the performance warrant. Finally, MoDOT refers to the possibility of leveraging the HCM to determine the need for climbing lane implementation.

2.5 CLIMBING LANE DESIGN CONSIDERATIONS

The following paragraphs will state the considerations about the design of climbing lanes by AASHTO and varied DOTs: ADOT, CDOT, Illinois (IDOT), Maryland (Maryland DOT), Michigan (Michigan DOT), MoDOT, MDT, NDOT, NJDOT, NYSDOT, SDDOT, TxDOT, Wisconsin (WisDOT) and WSDOT. To avoid any confusion in DOTs, the study spells out Maryland and Michigan DOTs given the same acronym utilized by the both. Table 1, below, gives a summary of the climbing lane design considerations by AASHTO and the state DOTs.

Climbing lane design	AASHTO	State DOTs
Startup Location	Where trucks' speeds are not tolerable anymore (critical length)	Per AASHTO
End Location	Beyond crest, where truck reaches a speed up to 40 mph or only varies up to 10 mph to surrounding traffic	Per AASHTO
Width	12 ft.	Per AASHTO
Entry Taper Length	At least 300 ft. with 25:1 ratio	150 – 500 ft with 25:1 ratio
Exit Taper Length	At least 600 ft given 50:1 ratio	Minimum of 200 ft with varying ratios depending on design speed (50:1, 60:1, 70:1)
Shoulder Width	Maintained for whole segment	Maintained, but may be reduced to 4 ft. If climbing lane width is 11 ft, shoulder width must be 5 ft wide

Table 1: Climbing Lane Design Considerations
Source: Based on AASHTO, 2011 and State DOTs

The startup location of the climbing lane depends on the trucks' speeds when approaching the grade and on the sight distance limitations at the approach. When conditions permit, a climbing lane can be introduced beyond the beginning of an upgrade if the speed of trucks will not immediately reduce to an intolerable speed for following drivers up the grade. Still, no sight distance restriction or other limitations to the speed must be at play (AASHTO, 2011).

The critical length is defined as "the maximum length of a specific upgrade on which a loaded truck can operate without an unreasonable reduction in speed" (Illinois DOT, 2016). If the length of the upgrade is longer than the critical length, trucks are at risk to attain speed reductions and operations that are unacceptable (AASHTO, 2011). Typically, drivers do not tolerate the speed reduction of trucks on an upgrade, when the critical length of grade is reached, i.e. truck operating speed is reduced about 10 mph (New York State DOT, 2017b).

SDDOT states in general that an upgrade should not exceed 2,000 ft to guarantee acceptable operations. SDDOT construes the critical length of grade to equal 2,000 ft, regardless of grade percentage. On grades longer than the critical length, consideration of an additional lane should be made (South Dakota DOT, n.d.).

"Fig. 2 shows the critical lengths of grades associated with varied upgrade slopes and for varied acceptable speed reductions given a representative truck of 200 lb/hp and a grade entry speed of 70 mph. The 10 mph speed-reduction graph needs to be paid special attention as this represents the general guideline for estimating critical length. In the past a speed reduction of 15 mph was used to determine this length of grade, however, the crash involvement of trucks experiences a significant increase when truck speed reduction is higher than 10 mph. This led to the recommendation to determine the critical length of grade by using the 10 mph curve" (AASHTO, 2011).

The chart for critical length of grade presented in Fig. 2, sourced from Fig. 3-63, AASHTO, 2011, considers a truck entry speed of 70 mph at the upgrade. Nevertheless, if the upgrade in question immediately follows a previous upgrade, the truck speed may already be lower than the design speed. In this case, the critical length of grade will be smaller. This consideration applies equally to an upgrade with an immediately approaching downgrade, where it is known that truck drivers will accelerate to get a "running start" at it. The critical length of grade will be longer than with a level entrance in that case (Harwood et al., 2003). This research will only focus on level terrain approaches and departures to upgrades.

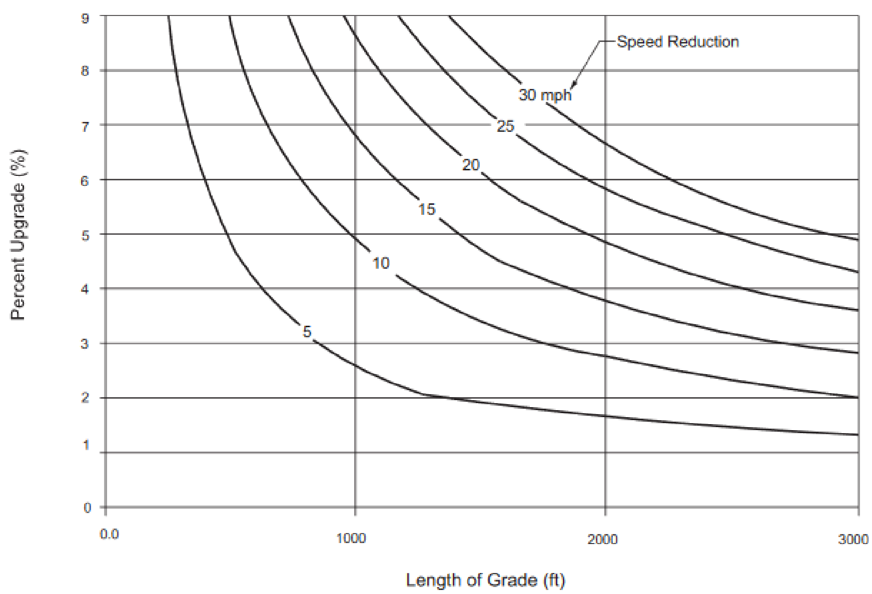

Figure 2: Critical Lengths of Grades Based on Truck Speed Reductions
Source: A Policy on Geometric Design of Highways and Streets, 2011, by the American Association of State Highways and Transportation Officials, Washington, D.C. Used with permission.

The critical length of grade is derived as the length of a tangent grade. An approximate equivalent length of tangent grade must be used where a vertical curve is part of a critical length of grade. When there are vertical curve tangents with only positive or only negative grades and the algebraic difference in grades is not too great, the measurement of critical length of grade is derived between the vertical points of intersection (VPI). Where vertical curves with positive and negative tangents are involved, particularly where the algebraic difference in grades is appreciable, about one-quarter of the vertical curve length may be considered as part of the grade under consideration (AASHTO, 2011). As this research will only consider grade connections to flat terrain, where the algebraic difference in grades will have an average to small value, the former measurements of critical length applies.

AASHTO recommends that the climbing lane should be developed through a tapered entry section with a ratio of 25:1 and a length of at least 300 ft (AASHTO, 2011). WSDOT, 2017, also affords a climbing lane taper at the 25:1 rate, given lane width and cross slope identical to those of the adjoining through lane. Thus, taper length would be at 300 ft, as per AASHTO, 2011, only for 12-ft lane highways and assuming stated conditions are met. Most DOTs demand the 25:1 ratio with a minimum entry taper length of 150 ft (Maryland DOT, n.d; Missouri DOT, n.d; Colorado DOT, 2005; New Jersey DOT, 2015; New York State DOT, 2017b; Texas DOT, 2018). NJDOT, NDOT and SDDOT require 300 ft, whereas Michigan DOT even requires 500 ft long entry tapers (South Dakota DOT, n.d; Michigan DOT, 2011; Nebraska DOT, 2011; New Jersey DOT, 2015).

To be effective, the full-width climbing lane itself, excluding the tapers, should be at least 1,000 ft long per IDOT (IDOT, 2016). SDDOT states that the length of the full-width climbing lane should at least be 0.5 mi, 2,640 ft, (South Dakota DOT, n.d.) and NDOT demands 1,200 ft (Nebraska DOT, 2011). A study from ADOT states that the majority of passing and climbing lanes on two-lane highways in the state of Arizona have a length of 0.5 mi to more than 1.0 mi (Arizona DOT, 2015).

AASHTO recommends that lane and shoulder widths be maintained for roadway segments with climbing lanes (AASHTO, 2011). Still, “Whenever possible, maintain a shoulder width equal to that of the adjacent roadway segments (preserve shoulder width continuity). On two-way two-lane highways, the shoulder may be reduced to 4 ft. If the shoulder width is reduced to 4 ft document the reasoning for the decision in the design parameter sheets. If the shoulder width is reduced to less than 4 ft, a design analysis is required." (Washington State DOT, 2017). NJDOT echoes the general sentiment of AAHSTO and WSDOT. The climbing lane should be as wide as the through lane, desirably 12 ft, with a shoulder width of 4 ft. If the climbing lane width is only 11 ft, the shoulder should be 5 ft wide (New Jersey DOT, 2015).

The cross slope of a two-lane highway with a climbing lane is handled in the same manner as the addition of a lane to a multilane highway (AASHTO, 2011). WSDOT further limits entrance speed for trucks to 60 mph, regardless of the posted speed limit, for assessing whether the AASHTO speed performance warrant is met (Washington State DOT, 2017). Trucks' approach speed at the grade should be estimated at 55 mph (Illinois DOT, 2016). WSDOT estimates approach speeds of 60 mph (Washington State DOT, 2017). AASHTO hints to the varied entry speeds as indicative of the variation in design speed for varied states.

Further, AASHTO legitimizes the practice of assuming varied entry speed to its critical length graphs, Fig. 2. Although Fig. 2 assumes a grade entry speed of 70 mph, it can be applied to any design speed (Montana DOT, 2007). The graphs can be viewed as entry speed insensitive and indicative only of speed reduction. Per AASHTO, if there is a difference in initial and minimum tolerable speeds because of a lower design speed, the critical length will still be the same for the 10 mph speed reduction with a design speed of 70 mph (AASHTO, 2011). Accordingly, a truck will travel the same critical length to experience a speed reduction of 10 mph, whether starting at 70 mph and ending at 60 mph or traveling at 60 mph and ending at 50 mph.

The climbing lane shall be extended beyond the crest, at which point trucks could gain a speed of at least 40 mph and that only varies up to 10 mph to the speed of the vehicles in the normal lane. As trucks need a long distance to accelerate to the desired speed, this scenario might not be practical in many cases. Hence the climbing lane could end where trucks can merge to the normal lane without interfering with other traffic. This could be where the sight distance becomes sufficient or when there is no oncoming traffic. Two hundred (200) ft beyond the crest of the curve is a recommended point to end the full width climbing lane (South Dakota DOT, n.d; AASHTO, 2011; Nebraska DOT, 2011; Texas DOT, 2018).

In addition, an exit taper with an appropriate length needs to be provided to allow trucks to merge back into the normal lane. This exit taper should be at least 600 ft. long with a ratio of 50:1 (AASHTO, 2011). Most DOTs agree with this ratio, however, CDOT and Maryland DOT only require a minimum exit taper length of 200 ft (Maryland DOT, n.d; South Dakota DOT, n.d; Colorado DOT, 2005; Nebraska DOT, 2011). MDT states that the exit taper rate should vary, depending on the design speed. Hence, a 50 mph design speed would require a ratio of 50:1, a design speed of 60 mph would require a 60:1 ratio and a 70 mph design speed would require a 70:1 ratio for the exit taper (Montana DOT, 2007).

WSDOT recommends to "begin climbing lanes at the point where the speed reduction warrant is met, and end them where the warrant ends, for multilane highways, and 300 ft beyond for two-lane highways. Consider extending the auxiliary lane over the crest to improve vehicle acceleration and sight distance" (WSDOT, 2018).

2.6 PERFORMANCE ASSESSMENT OF TWO-LANE HIGHWAYS WITH CLIMBING LANES

To assess the impact of climbing lanes on the operation of two-lane highways, the HCS analysis proceeds as with a passing lane in level or rolling terrain. As major procedural differences, the adjustment factors, f_{pl}, for estimating *ATS* and *PTSF* within a climbing lane takes on different values and the distances, L_u, length upstream of climbing lane, and L_d, length downstream of climbing lane beyond its effective length, are set to zero. If the lane ends before the grade does, the L_{de}, effective segment length, is also set to zero (Transportation Research Board, 2010).

CHAPTER 3

METHODOLOGY

Data impacting two-lane highway performance will be randomly generated for varied scenarios, with or without climbing lanes, based on the below outlined experimental scenarios. Performance data for simulated scenarios will be collected using McTrans' Highway Capacity Software (HCS 7), which enacts the procedures defined in the Highway Capacity Manual (Transportation Research Board, 2010). Data analysis will determine whether the guidelines adequately predict the necessity and sufficiency of climbing lanes for the cases simulated given the HCS 7 predictions. To classify or interpret the performance enhancements reached due to the implementation of climbing lanes for simulated cases, the study gauges an acceptable LOS on two-lane highway, LOS "C". Furthermore, it assesses the efficacy of the guidelines by interpreting their classification rates of sampled scenarios for the necessity and sufficiency of climbing lanes in view of the HCS 7 performance gains they achieve.

3.1 DATA GENERATION

3.1.1 Highway Capacity Software (HCS 7)

For the generated scenarios, HCS 7 establishes the performance of hypothetical two-lane highways, with or without a climbing lane. The software, developed and maintained by the McTrans Center, University of Florida, utilizes input information about the terrain, traffic volumes and geometric characteristics for highway segments under study and provides the associated LOSs and additional data related to the operation of the facility.

3.1.2 HCS Default Values Utilized

Simulated scenarios utilize some default values, from HCS 7, as input variables. These include the default values for the recreational vehicle percentage, 4%, the access-point-density, 8 per mile, the lane width, 12 ft and the shoulder width, 6 ft. Cited lane and shoulder widths are common values for Class I two-lane highways (Transportation Research Board, 2010). The scenarios utilize the actual equivalents for trucks and RVs, E_T and E_R, as tabulated by HCS 7 for the both, *ATS* and *PTSF*. Peak hour factor, *PHF*, is set to a value 0.8, as the *PHF* in rural areas generally varies between 0.7 and 0.98 (Roess et al., 2011).

As stated earlier in the literature review, grade approach speeds on two-lane highways for trucks are assessed at 55 mph to 60 mph (IDOT, 2016; WSDOT, 2017) per the default value of HCS 7. Research scenarios thus assume a free-flow speed of 60 mph. Given this entry-speed assumption, the critical length can easily be estimated using Fig. 2, Chapter 2.5, for varied grade percentages as the projection on the distance axis of the intersection point of the curves for a 10 mph speed reduction and grade percentage. Even though the figure is based on a 70 mph entering speed, it can be used for different entry speeds as it is entry-speed insensitive (AASHTO, 2011).

For example, using Fig. 2, the critical lengths associated with 9% and 6% slopes, equal 500 ft and 775 ft respectively. The lengths obtain from Fig. 2 and not calculations. Grade values utilized in the study are not necessarily integers, but real values rounded up or down to a multiple of 0.5. Since HCS 7 only allows grade percentage values in the range between 3.0% and 9.9%, the highest percentage used in study equals 9.9%, even though displayed at times in the following tables at its rounded value of 10%.

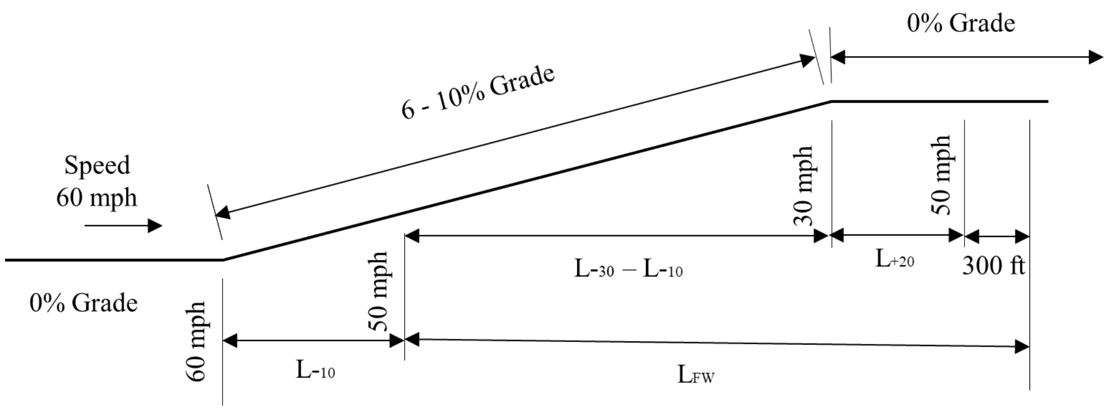

Figure 3: Illustration of relevant Lengths of Climbing Lanes
Source: Based on Wisconsin DOT, 2018

The length of grade is estimated to be the critical length associated with a 30 mph speed reduction, L_{-30}, per Fig 2. Consequently, there will be a different length of grade for each grade percentage analyzed. The critical length ranges between 1,230 ft for the highest upgrade considered in simulated scenarios, 10%, and 2,250 ft for the smallest upgrade considered, 6%. Table 2 displays the derived lengths of grade and climbing lane lengths associated with each value of scenario upgrade. Unfortunately, HCS 7 allows only grade length values in the range of 0.25 mi to 4.0 mi. Therefore, the lowest length of grade must be 0.25 mi, which equals 1,320 ft. The length of grade for 9.5% and 10% thus rounds up to 0.25 mi.

As outlined in the literature review, AASHTO and the DOTs have different standards for climbing lane design. The climbing lane should include entry and exit tapers of approximate lengths equal to 300 ft to 600 ft and 250 ft, respectively. The location, where the climbing lane should start, depends on the determination of critical grade length, typically associated with a 10 mph speed reduction on upgrades for a typical truck, L_{-10}. Thus, subtracting the critical length from the grade length derives the full-width climbing lane length on upgrade. This calculation repeats for every grade percentage analyzed. Given that the climbing lane should extend to a point 200 ft to 300 ft beyond the crest or where the truck has reached a speed that is only 10 mph below the speed of the surrounding vehicles, 3,200 ft, L_{+20}, shall be added to the climbing lane length. This length obtains from Figure 3-25, AASHTO (2011), as the projection on the distance axis of the intersection point of the 20 mph speed increase with the zero (0%) upgrade curve. In addition, 300 ft added to the climbing lane length account for the added distance afforded by AASHTO to deploy the exit taper.

The following equation, Eq. 1, sums up the stated considerations and derives the length of the full-width climbing lane. The full-width climbing lane, L_{FW}, should be at least 0.5 mi-, or 2,640 ft, long (AASHTO, 2011).

$$LFW = L_{-30} - L_{-10} + L_{+20} + 300$$

When considering the equation above and the values in the table below, the actual climbing lane length, L, for each grade can be calculated by adding the entry taper length, 300 ft, and the exit taper length, 250 ft. The following equation derives the total length of the climbing lane.

$$L = 300 + L_{FW} + 250$$

Table 2 presents this length in its last column. Regarding the recommendations from AASHTO, a minimum climbing lane length to consider equals about 0.66 mi (300 ft + 2,640 ft + 300 ft + 250 ft = 3,490 ft).

It can be observed that the derived climbing lane lengths are longer than the minimum climbing lane length recommended by AASHTO.

Grade %	**L_{-10} = Critical Grade Length,10 mph speed reduction**	**L_{-30} = Critical Grade Length, 30 mph speed reduction**		**L_{FW} = Full-width Climbing Lane Length**	**L = Climbing Lane Length**	
	in ft	in ft	in mi	in ft	in ft	in mi
6	775	2250	0.43	4975	5525	1.0
6.5	725	2062	0.39	4837	5387	1.0
7	650	1875	0.36	4725	5275	1.0
7.5	590	1745	0.33	4655	5205	1.0
8	575	1615	0.31	4540	5090	1.0
8.5	535	1500	0.28	4465	5015	0.9
9	500	1390	0.26	4390	4940	0.9
9.5	480	1310	0.25	4330	4880	0.9
10	460	1230	0.23	4270	4820	0.9

Table 2: Full-Width and Overall Climbing Lane Lengths
Source: Based on AASHTO, 2011

3.1.3 Input Variables

Main variables of interest to the software include slope, directional split, total flow, percentage of trucks and no passing zones. Table 3 below presents realistic ranges of these variables for US two-lane highways. To simulate the scenarios in the software, the values for these variables need be randomly generated and input in the software data panels. The study assumes a uniform distribution of variables. This distribution is not terribly realistic for flow. However, it helps generate data in all flow ranges as to more clearly pinpoint weakness regions for AASHTO's flow guidelines (anticipated in future studies).

Variables (Two-Lane Highway with Climbing Lane)	**Slope (%)**	**Total Flow (vph)**	***D-Factor***	**Truck Percentage (%)**	**No-Passing Zone Percentage (%)**
Lower limit	6	0	0.54	2	20
Upper limit	10	3200	0.85	20	100

Table 3: Range of Two-Lane Highway Input Variables Simulated
Source: Based on Transportation Research Board, 2010

The range of slopes on rural Class I two-lane collector and arterial highways in rolling terrain varies depending on the design speed. For the common travel speeds of 40 mph to 60 mph on these highways (New York State DOT, 2017a), the slope varies between 6% and 10%, where collector highways with grades of 10% represent the worst case scenario (AASHTO, 2011). The percentage of no-passing zones on two-lane highways, as linked with sight distance realized mostly on curves, varies between 20% and 100% (Transportation Research Board, 2010).

Flow on two-lane highways has a high variance, as high and low flows are combined into one distribution (Gerlough and Huber, 1975). The total flow, in both directions, on two-lane highways can reach up to 3,200 passenger cars per hour (pcph). Yet, the directional capacity reaches only 1,700 pcph with a maximum opposing flow of 1,500 pcph (Transportation Research Board, 2010).

The proportional factor between the opposed flows (*D-Factor*) sways usually the interval of 0.65 to 0.85 for two-lane highways (Roess et al., 2011). The truck percentage varies between 2%, the default value of the HCS, and 20% considered a high percentage by NYSDOT, 2017a, and representing the upper limit of the Highway Capacity Manual (Transportation Research Board, 2010).

3.1.4 Random Generation

A random number generator derives performance-impacting input variables for varied scenarios on two-lane highways. These probabilities combine with the known distributions of the input variables to identify them uniquely. Variables are generated singly assuming their independence and an input entry covariance matrix with zero (0) entries. Random number generation is the generation of a sequence of numbers that is uniformly distributed and cannot be predicted reasonably better than by a random chance. A simple example is simulating the toss of a die (Hoover and Perry, 1989).

Microsoft Excel has two functions to generate random numbers, the RAND( ) and RANDBETWEEN() function. These functions are uniform. The study deploys both the functions to generate input values for the experiments, per their ranges stated in Table 3. The RAND( ) function generates a random decimal number between 0 and 1 and is used for the values of the *D-Factor*, no-passing zone and slope percentage. To generate a *D-Factor* for instance, the RAND( ) function result leads to the specific *D-Factor* value not exceeded at this specific result value considered for probability value. Assuming a uniform distribution of *D-Factor* within the range [0.54, 0.85], the RAND( ) function results can be manipulated as follows: 0.54 + 0.31 * RAND ( ) to randomly generate them.

To generate random integers the RANDBETWEEN( ) function is used. It generates random integers (no decimal numbers) between two individually set boundaries (Easy Excel, 2018). The function =RANDBETWEEN (x; y) determines flow in the analysis direction and the truck percentage.

Table 6 in Appendix A presents a listing of all randomly generated values. The study randomly generates flow in pcph, as restrained to observe the directional and total capacity limits on two-lane highways. Total flow does not exceed 3,200 pcph and directional flow 1,700 pcph. In addition, for high values of total flow, opposing flow does not exceed 1,500 pcph. Yet, HCS 7 requires flow entries in vph. However, the conversion of directional flows from pcph to vph is not evident as it depends on the opposing flow already pre-expressed in vph. Conversion thus of directional flows from pcph to vph is a nonlinear process for two-lane highways.

Random flow generation starts with the derivation of directional flows, whether in the analysis direction, upgrade or its opposite direction, downgrade. Simulated flow values vary from 0 up to the directional capacity limit, 1,700 pcph. Opposite flow is derived using the simulated *D-factor* to deduct total flow and hence opposite flow, thereby dividing the analysis directional flow by the *D-Factor* and multiplying the result by the difference (1 - *D-Factor*). The range of values taken by the *D-Factor,* was adjusted to naturally restrain total flow to verify its capacity limits, or to values lesser than 3,200 pcph. The range of 0.54 to 0.85 was adopted, modifying the lower range limit from pre-cited literature (Roess et al., 2011), HCM capacity values permitting.

It may well be that the study artificially restrained the *D-Factor* to sway a limited range. However, the relevant literature duly references the range utilized, although the same documents other ranges that would not necessarily limit opposing flow to its upper bound.

Further, to bypass flow conversion, the analysis directly inputs generated flows in pcph, kept within their directional capacity limits, as HCS 7 flow entries in vph. Overshooting the required range of data input ensured its adequate coverage of the coveted range in pcph. Where generated flows within HCS 7, in pcph, exceed directional capacity within a scenario, the analysis eliminates this scenario and its results from further considerations. Table 8 in Appendix D documents every scenario's *ATS* and *PTSF* directional flows. Scenarios with flows exceeding the limits of 1,700 pcph in one direction or 1,500 pcph in the other (assuming higher opposite directional flows), or the total capacity of 3,200 pcph are marked with a "0" in the last column of Table 8, *Capacity Compliance*. Scenarios with flows within the capacity boundaries are marked with a "1".

Switching the direction of generated flow, upgrade versus downgrade, ensures that high flows are not limited to the analysis direction. Half of the software runs generate flows in the analysis direction and the other half in the opposite direction, leading to two different data streams. The analysis fused both the streams using a random scenario/record sorting method in Excel.

3.2 DESCRIPTIVE STATISTICS FOR GENERATED FLOW DATA

Flow input values to HCS 7 as randomly generated for the ATS analysis directional flows sway the range of 12 pcph to 1,697 pcph, with an average flow of 775 pcph. Fig. 4 shows a histogram of the ATS analysis directional flows.

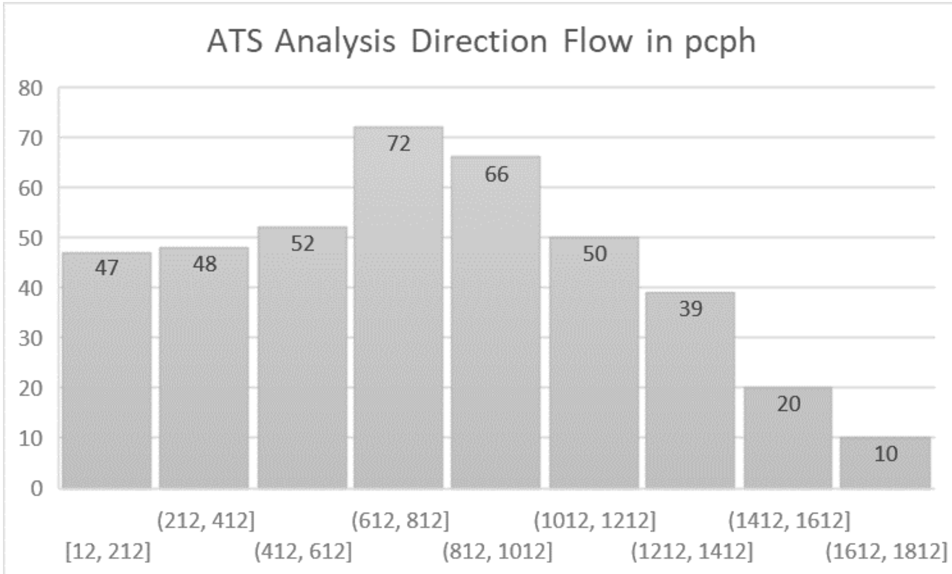

Figure 4: Histogram ATS Analysis Direction Flow in pcph

Total ATS flow sways the range of 14 pcph to 3,071 pcph, with an average of 1,353 pcph. Fig. 5 shows a histogram of the ATS total flows.

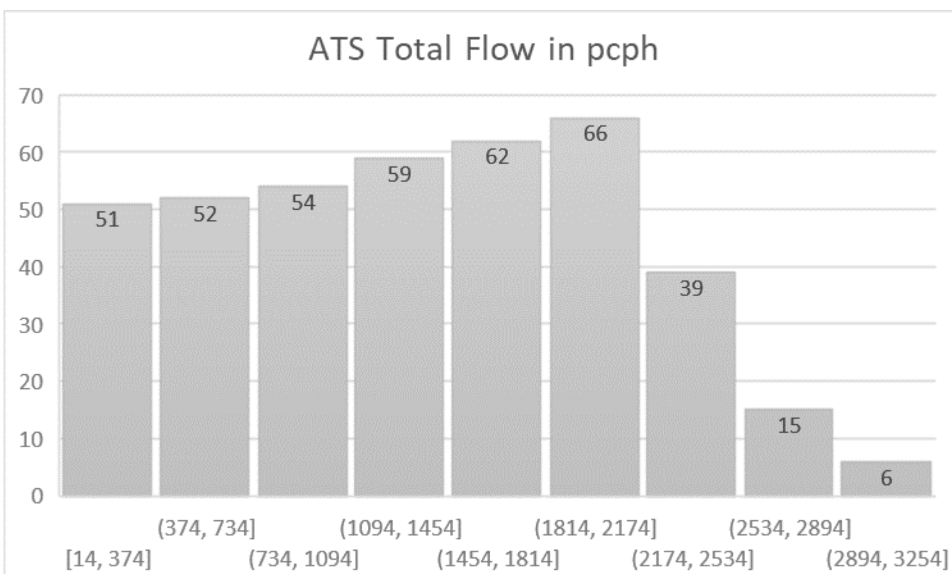

Figure 5: Histogram ATS Total Flow in pcph

3.3 DATA COLLECTION

The experiments deploy the HCS 7 from McTrans to determine the LOS of hypothetical two-lane highways with randomly simulated input variables. These runs are performed in United States Customary units. The following figure shows the *Input Data Panel* for the analysis direction on the upgrade.

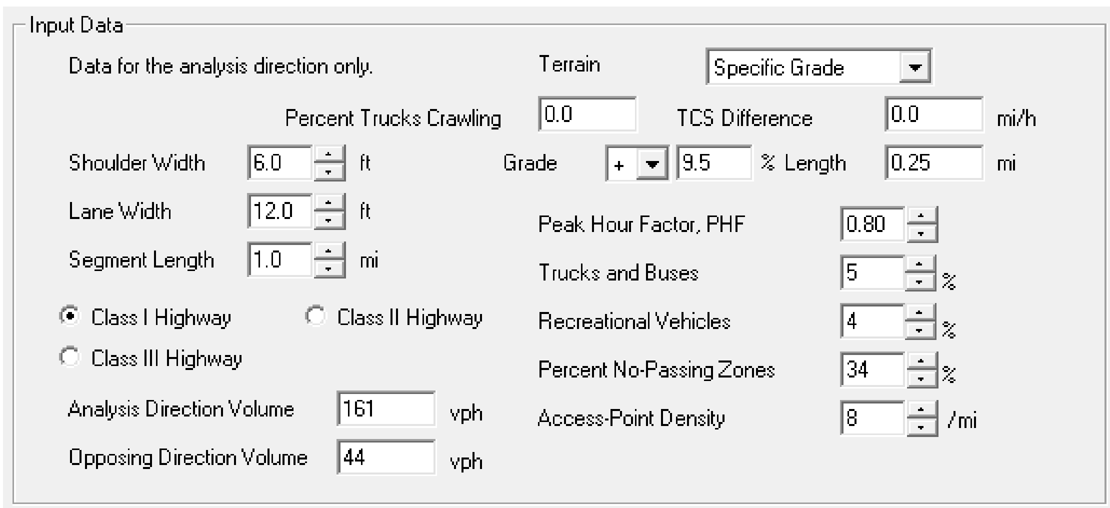

Figure 6: Input Data Panel in HCS 7
Source: HCS 7

Prior to the analysis, certain entry values need set in the *Input Data Panel* to their scenario values for both, the analysis and opposing directions of travel. This, in addition to using the HCS 7 default values cited in Section 3.1.2 above. The terrain must be set to "*Specific Grade"*, which will enable the functional buttons for "*grade percentage"* and "*length of slope"*. *PHF*, *truck percentage*, *no-passing zone percentage* and *Segment Length* need to be input. The study assumes that the climbing lane length is equal to the segment length, which is the length of the section analyzed. The segment lengths obtain from Table 2. Flows obtained for the analysis and opposing directions need also be set accordingly in the *Input Data Panel*. A listing of these values is enclosed in Table 7 in Appendix B.

Fig. 7 shows the *Passing Lane Analysis Panel*. For software runs that do not include a climbing lane, the "*No Passing Lane"* option needs to be selected in the *Input Data Passing Lane Analysis Panel* dropdown list. For software runs with an added climbing lane, the option "*Climbing Lane"* must be selected in the same. In this section the entry "*Length of Two-Lane Highway Upstream of the passing lane"* L_{u}, is automatically set to zero, "0", and the *"Length of Passing Lane Including Tapers"*, L_{pl}, to the segment length. Therefore, the segment length equals the climbing lane length.

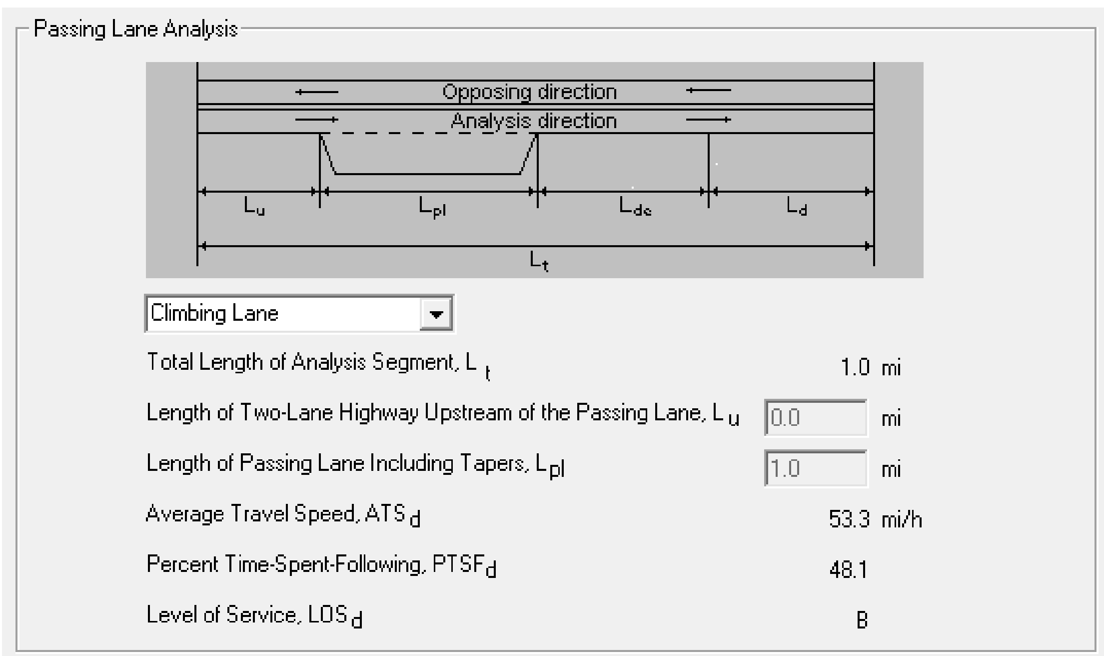

Figure 7: Input Data Panel Passing Lane Section
Source: HCS 7

Following data entry, the software automatically executes, and the LOS of the two-lane highway is attained (Transportation Research Board, 2010). Fig. 8 shows the result panel, *Level of Service and Other Performance Measures Panel*, for the analysis of a two-lane highway without climbing lane. A LOS "C" or better is satisfying.

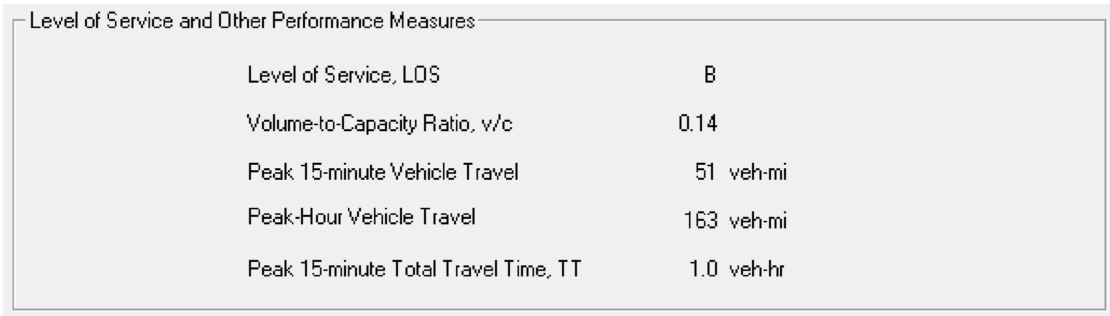

Figure 8: Level of Service and Other Performance Measures Panel
Source: HCS 7

Further execution results can be obtained from the *Free-Flow Speed Panel*, as displayed in Fig. 9. The average travel speed, *ATSd*, helps assess/confirm whether AASHTO's Guideline 3-a holds true.

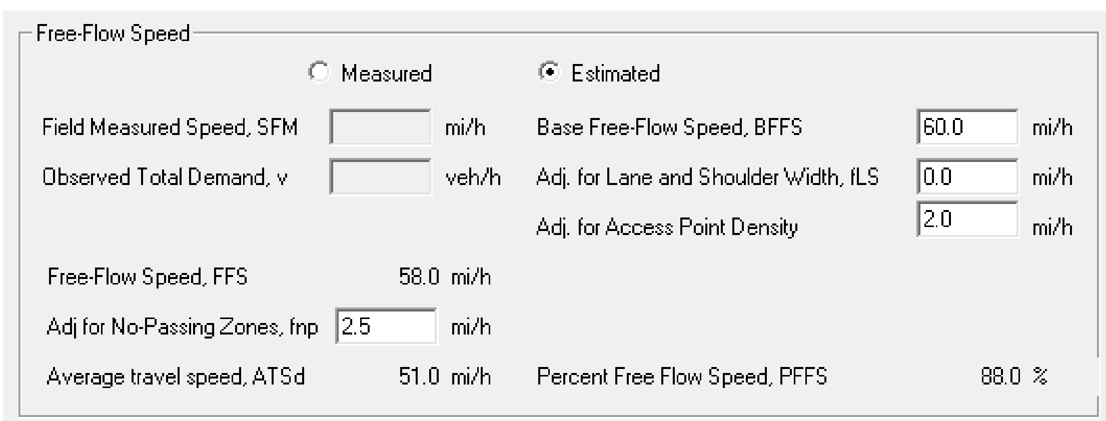

Figure 9: Free-Flow Speed Panel
Source: HCS 7

HCS 7 reports on the input data and results of software runs. Appendix C 1-5 show example reports for scenarios 68, 197, 307, 347 and 501.

3.4 DATA PROCESSING AND DATA ANALYSIS PROCEDURES

A preliminary review of the AASHTO guidelines on the implementation of climbing lanes (AASHTO, 2010) helps determine the logical clauses to test toward assessing their efficacy. If efficient, a climbing lane should be both, necessary and sufficient. Assuming necessity, for climbing lane implementation or non-implementation, then for a prevalence of cases the below logical clause should hold true.

1. If the guidelines are satisfied and no climbing lane exists, then unacceptable performance must prevail (proper classification).
2. If the guidelines are not satisfied and a climbing lane exists, then unacceptable performance must prevail (proper classification).

Further, sufficiency of the guidelines implies that the below logical clauses should hold true as well.

3. If the guidelines are satisfied and a climbing lane exists, then acceptable performance must prevail (proper classification).
4. If the guidelines are not satisfied and a climbing lane does not exist, then acceptable performance must prevail (proper classification).

Logical Clause 4 is not as restrictive as earlier clauses for conditions of low flows or given the violation of flow guidelines, as AASHTO considers the limited economic impact of engendered delays by such flows to advice against climbing lane implementation.

The analysis views the AASHTO guidelines as a scenario classifier for the efficacy of the implementation of a climbing lane. It tests logical clauses determining the necessity and the sufficiency of the AASHTO guidelines using the HCS 7 performance predictions for the quasi-representative sample scenarios earlier generated. If the clauses are untrue, the guidelines misguide and thus misclassify on the efficacy, necessity or sufficiency, of climbing lanes. If true, the guidelines classify correctly on the same. The analysis further determines a running percentage of the AASHTO guideline classification rates, proper classification and types I or II classification error rates, with large enough a sample size to stabilize the rates achieved. The extent of these rates bears witness to the efficacy, necessity and sufficiency, of the AASHTO guidelines taken verbatim as warrants, a rather typical DOT practice.

An acceptable level of service on two-lane highways must be gauged to classify or interpret the performance enhancements reached due to the implementation of climbing lanes for simulated cases. In this study, LOS “C” constitutes the minimum acceptable level for the research question.

Table 9 in Appendix E documents the results of the software experiments in a spreadsheet. Records relate to individual software run, hence scenario, results as numbered consecutively in Column 1, entitled *Scenario Number*. Column 19 and 20, *LOS (No Climbing Lane)* and *LOS (Climbing Lane)*, display the LOSs achieved for the scenarios without and with a climbing lane, respectively. Columns 21, 22, and 23 convey whether the scenarios per their traffic flow and performance conditions satisfy the AASHTO Guidelines 1, 2 and 3, *Guideline 1 Satisfied*, *Guideline 2 Satisfied* and *Guideline 3 Satisfied*, respectively. Entries of “0” and “1” in column 21, 22 and 23 point respectively to the dissatisfaction and to the satisfaction of the respective guideline.

Column 24, *Guidelines Satisfied (overall)*, conveys the general satisfaction or dissatisfaction of the AASHTO guidelines. For simplicity of analysis and owing to the "OR" consideration for the performance conditions of the guidelines, guideline satisfaction is verified at its minimal acceptation. For instance, Guideline 3b does not have to necessarily be checked, if Guideline(s) 1, 2 and 3a are satisfied. And Guideline 3c needs not be checked if Guidelines 1 and 2, plus one of the Guideline(s) 3a or 3b are satisfied.

In Column 25, *Acceptable Performance (No Climbing Lane)*, and 26 *Acceptable Performance (Climbing Lane)*, entries denote the acceptability of scenario LOSs without and with a climbing lane. LOS grades of "C" or better are considered acceptable and thus entail column entries of "1". Lower LOS grades relate to unacceptable performances and generate "0" entries.

Four spreadsheet columns, Columns 27, 28, 29 and 30, *Logical Clause 1 Valid*, *Logical Clause 2 Valid*, *Logical Clause 3 Valid* and *Logical Clause 4 Valid*, convey for each scenario the satisfaction of the Logical Clause(s) 1, 2, 3 and 4 earlier specified, Section 3.3, which establish the necessity and the sufficiency of a climbing lane. As with Guidelines 1, 2 and 3, entries of "0" and "1" convey the dissatisfaction and the satisfaction of a logical clause, respectively. Satisfaction of Logical Clause 1 entails

1) the satisfaction of overall AASHTO guidelines (“1” entry, Column 24) AND
2) an unacceptable performance without a climbing lane (“0” entry, Column 25).

Scenarios that satisfy Logical Clause 1 generate an entry of “1” in Column 27. Otherwise “0” entry registers in this column. Further, the satisfaction of Logical Clause 2 entails

3) the lack of satisfaction of overall AASHTO guidelines (“0” entry, Column 24) AND
4) an unacceptable performance with a climbing lane (“0” entry, Column 26).

Scenarios that satisfy Logical Clause 2 generate an entry of “1” in Column 28. Otherwise a “0” entry registers in this column. Further, the satisfaction of Logical Clause 3 entails

1) the satisfaction of overall AASHTO guidelines (“1” entry, Column 24) AND
2) an acceptable performance with a climbing lane (“1” entry, Column 26).

Scenarios that satisfy Logical Clause 3 generate an entry of “1” in Column 29. Otherwise a “0” entry registers in this column. Finally, satisfaction of Logical Clause 4 entails

1) the lack of satisfaction of the overall AASHTO guidelines (“0” entry, Column 24) AND

2) an acceptable performance without a climbing lane (“1” entry, Column 25)

Scenarios that satisfy Logical Clause 4 generate an entry of “1” in Column 30. Otherwise a “0” entry registers in this column.

Lastly, the efficacy of implementing a climbing lane per the AASHTO guidelines must be gauged for the scenarios simulated. Using the data generated, a climbing lane is determined as necessary or sufficient for a simulated scenario if this specific scenario satisfies the both, necessity, *Logical Clause(s) 1* and *2*, and sufficiency, *Logical Clause(s) 3* and *4*,. The efficacy of the AASHTO guidelines relates to their proper classifications of the performance benefits realized by scenarios through climbing lane implementation. Thus, the classification rates of the scenario sample results point directly to this efficacy. Following paragraphs endeavor to compute proper and false classification rates using the scenario sample results as validation data.

Proper scenario classification ensues from recommendations for climbing lane implementation that lead to beneficial impacts for upgrade segment performance. Assuming the satisfaction of the AASHTO guidelines (“1” entry, *Guidelines Satisfied (overall)*, Column 24), then a climbing lane implementation must be

1) necessary (“1” entry, *Logical Clause 1 Valid*, Column 27), AND
2) sufficient (“1” entry, *Logical Clause 3 Valid*, Column 29),

AND, Assuming the lack of satisfaction of the AASHTO guidelines (“0” entry, *Guidelines Satisfied (overall),* Column 24), then the non-implementation of a climbing lane must be

3) not necessary (“1” entry, *Logical Clause 2 Valid*, Column 28), AND
4) not sufficient (“1” entry, *Logical Clause 4 Valid*, Column 30).

The proper classification rate thus equals the ratio of the number of scenarios that satisfy logical clause 1 and 3, when the guidelines are satisfied, plus the number that satisfy logical clauses 2 and 4, when the guidelines are not satisfied to the total number of scenarios analyzed.

Assuming the satisfaction of the AASHTO guidelines (“1” entry, *Guidelines Satisfied (overall)*, Column 24), a Type I classification error occurs, when a climbing lane implementation is

1) not necessary, “0” entry, *Logical Clause* 1, Column 27, OR
2) not sufficient, “0” entry, *Logical Clause* 3, Column 29.

The type I classification error rate thus equals the ratio of the total number of scenarios for which AASHTO recommends a climbing lane AND that do not satisfy *Logical Clause*(s) 1 OR 3 to the total number of scenarios simulated. Column 36 *Type I Error Rate* displays a running computed value of Type I classification error rate, up to the scenario under consideration.

Assuming the lack of satisfaction of AASHTO guidelines ("0" entry, *Guidelines Satisfied (overall)*, Column 24), a Type II classification error occurs when the non-implementation of a climbing lane is

1) not necessary, "0" entry, *Logical Clause 2*, Column 28, OR
2) not sufficient, "0" entry, *Logical Clause 4,* Column 30.

The type II classification error rate thus equals the ratio of the total number of scenarios for which AASHTO does not recommend a climbing lane AND that do not satisfy *Logical Clause*(s) 2 OR 4 to the total number of scenarios simulated. Column 39 *Type II Error Rate* displays a running computed value of Type II classification error rate, up to the scenario under consideration.

CHAPTER 4

FINDINGS / RESULTS

To assess the efficacy of the AASHTO guidelines, the HCS 7 was run 601 times with the randomly generated scenarios of Table 7 in Appendix B. In 197 scenarios, the flows exceed two-lane highway capacity, which leaves 404 scenarios to analyze. The wording "total number of studied scenarios" refers in the following to these 404 scenarios. Table 9 in Appendix E presents a summary of the LOS results achieved for the 404 scenarios without and with a climbing lane. In addition, the table points to the applicable AASHTO guidelines for each scenario. Thus, table entries enable a direct assessment of whether AASHTO recommends a climbing lane and of the acceptability of the scenario segment performances with and without a climbing lane. Lastly, it displays the classification of the scenarios per the four logical clauses and enhancement in LOS due to a climbing lane. Table 10, in Appendix F, displays the proper classification rate, as well as the type I and type II classification error rates achieved.

4.1 AASHTO GUIDELINES AND NECESSITY OF CLIMBING LANE IMPLEMENTATION

Two hundred and fourteen (214) scenarios satisfy the guidelines, an equivalent to 53% of the total number of studied scenarios, 404. Out of the 214 scenarios, 196 or 49% of total studied scenarios, satisfy *Logical Clause* 1, Column 27, which indicates that a climbing lane is necessary. For these scenarios, unacceptable performance, LOS "C", prevails without a climbing lane. For the remaining 18 out of 214 scenarios that satisfy the guidelines, representing 4% of total studied scenarios, acceptable performance prevails without a climbing lane **(Type I errors)**. Table 4, below, displays these scenarios, where acceptable performance prevails without a climbing lane, even though AASHTO would suggest climbing lane implementation given guidelines' satisfaction.

1	3	4	5	10	11	12	13	14	15	19	20
Scenario Number	**Analysis Direction Flow vpn**	**Opposing Direction Flow vpn**	**Sum Flows**	**ATS analysis directon pcph**	**ATS opposing direction pcph**	**Total ATS Flow**	**PTSF anaylsis direction pcph**	**PTSF opposing direction pcph**	**Total PTSF Flow**	**LOS (no Climbing Lane)**	**LOS (Climbing Lane)**
15	214	378	592	742	487	1229	267	472	739	C	B
38	320	73	393	1024	104	1128	400	93	493	C	B
54	257	126	383	823	178	1001	321	160	481	C	B
171	351	547	898	793	689	1482	439	684	1123	C	B
256	262	350	612	839	462	1301	327	437	764	C	B
277	290	362	652	781	464	1245	362	452	814	C	B
319	647	336	983	267	444	711	80	420	500	B	B
321	231	48	279	677	65	742	289	61	350	C	A
324	243	410	653	732	527	1259	304	512	816	C	B
372	252	315	567	726	407	1133	315	398	713	C	B
375	289	55	344	1180	81	1261	361	70	431	C	B
377	279	156	435	852	209	1061	349	198	547	C	B
449	212	285	497	591	368	959	265	360	625	C	B
463	218	646	864	643	819	1462	272	807	1079	C	B
488	344	77	421	812	107	919	430	97	527	C	A
507	228	90	318	918	130	1048	285	114	399	C	A
531	244	544	788	774	688	1462	305	680	985	C	B
589	268	364	632	902	472	1374	335	455	790	C	B

Table 4: Scenarios with Satisfied Guidelines and Acceptable Performance without Climbing Lane

One hundred ninety (190) scenarios do not satisfy the overall guidelines, or approximately 47% of the total number of studied ones. In 41 of these scenarios, representing 10% of total studied scenarios, a climbing lane is necessary to achieve an acceptable level of service (**Type II errors**). HCS 7 outputs for these 41 scenarios point to necessity; with LOS “D” or worse achieved on their upgrade segments without climbing lanes. Table 5 displays these scenarios. (Further analysis shows that the truck percentage is very low in most of these scenarios resulting in a flow of less than 20 trucks per hour, hence Guideline 2 is not satisfied. The lack of satisfaction of Guideline 2 engenders the lack of satisfaction of the overall guidelines.) In 149 scenarios, representing 37% of total studied scenarios, AASHTO does not recommend climbing lane implementations when indeed unnecessary. In summary, for an impressive 86% of simulated scenarios, the AASHTO guidelines point correctly to the necessity or non-necessity of climbing lanes.

1	3	4	5	7	8	19	20
Scenario Number	**Analysis Direction Flow vpn**	**Opposing Direction Flow vpn**	**Sum Flows**	**Truck%**	**Sum Trucks**	**LOS (no Climbing Lane)**	**LOS (Climbing Lane)**
19	1016	1263	2279	2	20	E	E
32	635	848	1483	3	19	D	C
45	192	833	1025	15	29	D	C
51	402	904	1306	5	20	D	C
122	897	651	1548	2	18	E	C
137	418	745	1163	3	13	D	B

151	669	946	1615	2	13	E	C
161	580	396	976	3	17	D	B
199	717	392	1109	2	14	E	B
234	272	1238	1510	3	8	D	D
236	359	120	479	3	11	D	A
240	200	992	1192	16	32	D	C
241	910	294	1204	2	18	E	C
243	258	748	1006	6	15	D	B
250	183	1025	1208	8	15	D	C
266	854	648	1502	2	17	E	C
275	232	1081	1313	8	19	D	C
276	392	253	645	4	16	D	B
286	249	895	1144	5	12	D	C
313	485	724	1209	3	15	D	B
327	474	862	1336	2	9	D	C
328	898	1194	2092	2	18	E	D
351	687	922	1609	2	14	E	C
387	390	1095	1485	3	12	D	C
388	432	1274	1706	4	17	E	D
391	440	574	1014	2	9	D	B
396	638	136	774	3	19	E	B
410	273	853	1126	4	11	D	B
423	354	74	428	4	14	D	A
450	711	165	876	2	14	E	B
456	476	209	685	3	14	D	B
458	490	936	1426	2	10	D	C
465	290	1113	1403	6	17	D	C
477	491	840	1331	3	15	D	C
517	491	157	648	2	10	D	A
545	448	265	713	4	18	D	B
549	474	130	604	3	14	D	B
559	399	912	1311	3	12	D	C
567	412	902	1314	3	12	D	C
573	781	156	937	2	16	E	B
584	226	1118	1344	6	14	D	C

Table 5: Scenarios with Non-Satisfied Guidelines and Unacceptable Performance without Climbing Lane

4.2 AASHTO GUIDELINES AND SUFFICIENCY OF CLIMBING LANE IMPLEMENTATION

Of the 214 scenarios that satisfy the AASHTO guidelines, 166 scenarios, or approximately 41% of the total studied scenarios, also satisfy Logical Clause 3, Column 29, which indicates that climbing lanes are indeed sufficient. HCS 7 outputs for these 166 scenarios point to sufficiency; with LOS “C” or better achieved on their upgrade segments with climbing lanes. Thus, in 41% of scenarios, the AASHTO guidelines identify properly the sufficiency of a climbing lane implementation. For the remaining 48 scenarios, out of 214 that satisfy the guidelines, representing 12% of total studied scenarios, unacceptable performance still prevails with implemented climbing lanes (**Type I errors**). Thus, in these scenarios the AASHTO suggested implementation of climbing lanes is not sufficient.

Out of the 190 scenarios that do not satisfy the overall guidelines, 149 scenarios, approximately 37% of the total studied, verify Logical clause 4, Column 30, which indicates the sufficiency of the non-implementation of a climbing lane. HCS 7 outputs for these 166 scenarios point to sufficiency; with LOS “C” or better achieved on their upgrade segments without climbing lanes. Thus, in 37% of scenarios, the AASHTO guidelines identify properly the non-sufficiency of a climbing lane to achieve an acceptable level of service. For the remaining 41 scenarios, out of 190 that do not satisfy the guidelines, representing 10% of the total scenarios, unacceptable performance prevails per HCS 7 when the AASHTO guidelines do not recommend a climbing lane (**Type II errors**). Thus in 10% of total scenarios the AASHTO suggested non-implementation of climbing lanes is not sufficient. In summary, for

78% of simulated scenarios, the AASHTO guidelines point correctly to the sufficiency or non-sufficiency of climbing lanes.

4.3 PERFORMANCE WITH AND WITHOUT A CLIMBING LANE

Further, the analysis of the 404 scenarios shows that in 167 scenarios, approximately 41% of studied scenarios, acceptable performances prevail and yet no climbing lane exists. The remaining 59%, or 237 scenarios, experience unacceptable performance with a LOS “D” or worse given no climbing lane.

When analyzing the performance of two-lane highways with implemented climbing lanes, in 352 scenarios, or approximately 87% of the total scenarios studied, performance is better or equal to LOS “C” and therefore acceptable. Of the remaining 52 scenarios, 48 scenarios, approximately 12% of the total scenarios analyzed, continue to have unacceptable performance per HCS 7 even though the guidelines are satisfied, and a climbing lane exists (**Type I error**). The remaining 4 scenarios, approximately 1% of the total scenarios studied, do not satisfy the guidelines and have unacceptable performance. In summary, the implementation of climbing lanes does enhance performance in the majority of scenarios studied.

4.4 CLASSIFICATION RATES AND GUIDELINES’ EFFICACY

The classification errors hinted above in Section 4.1 and 4.2 do not encompass those resulting from the interplay of necessity and sufficiency. Although AASHTO guidelines predict adequately necessity and sufficiency, it is not evident that they can predict their interplay successfully. To do so, the analysis derives proper and erroneous classification rates. Table 10 in Appendix F displays the derived proper, type I error and type II error classification rates. **Fehler! Verweisquelle konnte nicht gefunden werden.** illustrates the extents of these classification rates in decimal values of a whole.

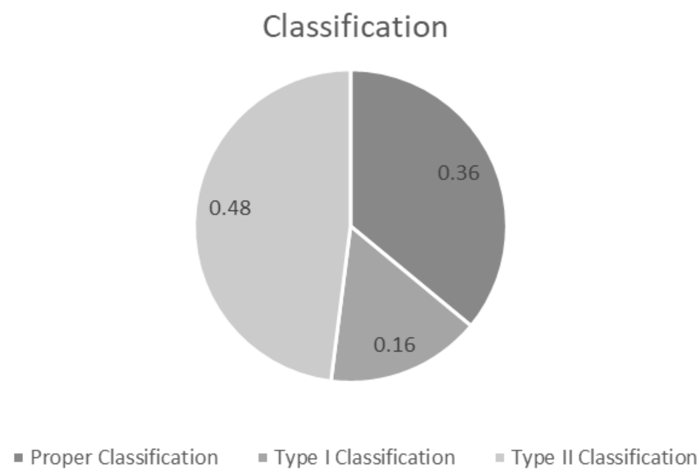

Figure 10: Proportions of Classification Rates

One hundred forty-eight (148) scenarios have a proper classification per Column 32, *"Proper Classification Count"*. Column 33, "*Proper Classification Rate"*, displays a computed running value of the proper classification rate, up to the scenario under consideration. This rate stabilizes around the 331st scenario (actual scenario 489 given that 158 prior scenarios were not analyzed for being over-capacity) at the value of 0.36. The analysis of studied scenarios points to only 36% of the total amount of scenarios analyzed, 404, as classified properly, and thus to 64% as classified erroneously. Figure 11 displays the stabilization course of the proper classification rate.

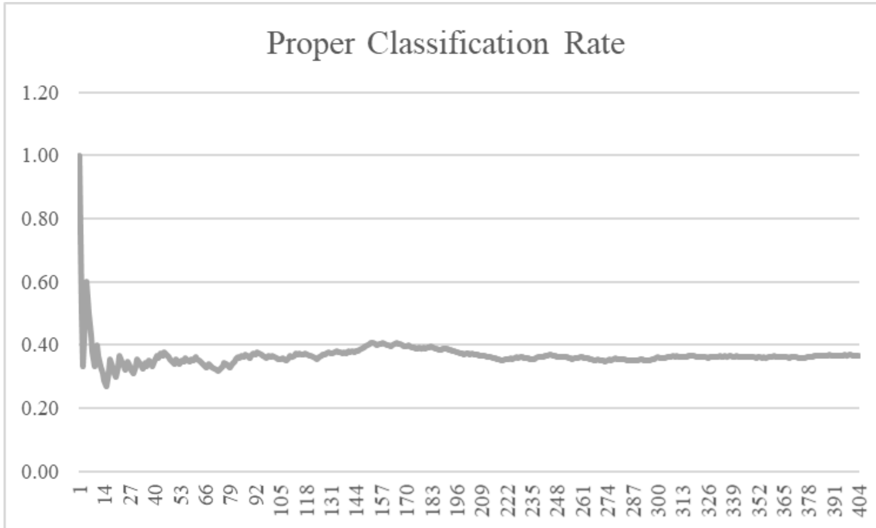

Figure 11: Proper Classification Rate

Sixty-six (66) scenarios have type I classification errors. Column 36, *Type I Error Rate*, displays a computed running value of the Type I classification error rate, up to the scenario under consideration. This rate stabilizes/converges around the 348th valid scenario (actual scenario 509 given that the analysis ignored 161 prior scenarios for being over-capacity) at the value of 0.16. For 16% of the total number of analyzed scenarios, the AASHTO guidelines recommend the implementation of a climbing lane when it is not necessary or not sufficient. Figure 12 displays the stabilization course of the type I error rate.

Figure 12: Type I Error Rate

One hundred ninety (190) scenarios display type II classification errors. Column 39, *Type II Error Rate*, displays a computed running value of the Type II classification error rate, up to the scenario under consideration. This rate stabilizes/converges around the 354th valid scenario (actual scenario 521 given that the analysis ignored 167 prior scenarios for being over-capacity) at the value of 0.48. For 48% of all scenarios, the AASHTO guidelines do not suggest implementation of a climbing lane while non-implementation is not necessary or not sufficient. Figure 13 displays the stabilization course of the type II error rate.

Figure 13: Type II Error Rate

CHAPTER 5

CONCLUSIONS

5.1 SUMMARY

This study evaluates the flow and performance parts of the AASHTO guidelines on climbing lane implementation for rural two-lane highways to determine their continued applicability in the face of new research on these facilities' performance. The evaluation targets the necessity and the sufficiency of the guidelines for upgrade segment lengths that cause a 30 mph speed decrease assuming flat terrain at their approaches and departures.

Chapter 1 presents the study purpose and justification. Although the guidelines seek to enhance performance on upgrade segments of cited highways, they have remained unchanged in the face of recent research development on this performance and do not reflect the state-of-the-practice on the same. For instance, they do not account for the variables known to determine specifically two-lane highway LOS, mainly opposing flow and percentage of no-passing zones. Still, most state DOTs base their decisions on implementing climbing lanes on these old guidelines. Questions about their efficacy seem valid and the study seeks to apprehend this efficacy. Study results could positively benefit the implementation practice of climbing lanes at varied DOTs.

Chapter 2 reviews the relevant literature and provides a detailed overview of the characteristics of two-lane highways, their performance measures, the AASHTO guidelines for climbing lane implementation as well as the state DOT's practices and considerations about climbing lane design. The guidelines consist of three parts, with two that apply jointly and one independently. If any independent guideline part can be proven inefficient, the guidelines themselves can be so proven. The study focused on the evaluation of the AASHTO flow and performance guidelines.

Chapter 3 describes the methodology utilized. The study views the set of AASHTO guidelines as a classifier of scenarios into the interplay of necessity and sufficiency, or efficacy, of an eventual climbing lane implementation. The methodology describes 1) the means of assessing the necessity and the sufficiency of the AASHTO guidelines, 2) the derivation of scenario analysis data, and 3) the data processing techniques toward the guidelines' evaluation. Logical clauses enable assessment of the necessity and/or sufficiency of the guidelines. Random scenarios to analyze generate from the simulation of random variables of interest using random number generators. For these scenarios, performance is determined with and without climbing lanes using HCS 7 to assess the enhancement afforded by a climbing lane implementation or negated without it. The performance achieved for simulated scenarios, assuming the satisfaction or the non-satisfaction of the AASHTO guidelines, leads to the computation of the guidelines' classification rates.

Chapter 4 presents the findings and results from the study. For 86% of simulated scenarios, the AASHTO guidelines point correctly to the necessity or non-necessity of climbing lanes and for 78% of simulated scenarios, the AASHTO guidelines point correctly to the sufficiency or non-sufficiency of climbing lanes. In addition, the analysis shows that the implementation of climbing lanes does enhance performance in the majority of scenarios studied. The proper classification rate achieved, 0.36, points to a poor performance by the guideline parts studied. In essence, for the cases studied and given the study assumptions, the guidelines seem wanting of revisions. The study thus points to a need for its own extension to be more representative of field conditions, such as upgrade segment lengths engendering smaller speed decreases and to remove some study limitations that restrict applicability. Finally, for scenarios with severe drops in travel speed and flat terrain on approaches and departures, the study points to the need for a new classifier into the efficacy of climbing lane implementation. It may be noted that highway flows, and all variables simulated in general, were assumed uniformly distributed in the study. This distribution assumption may have introduced some biases in study results. Field recorded flows on rural highways tend to be low.

LIMITATIONS

Some study limitations apply. Firstly, this study only addresses Class I rural two-lane highways for upgrade segment lengths that result in a 30-mph speed decrease given an entry speed of 60 mph. The speed reduction graph on upgrades utilized relates to an upgrade entry speed of 70 mph, assuming a typical 200 lb/hp, and admittedly applicable to 60 mph hour entry speeds as well (AASHTO, 2011). The study uses numerous HCS 7 entry default values and scenarios abide to HCS 7 data limitations. For instance, the software only allows grade percentages in the range of 3.0% to 9.9%. Higher grades could not be studied. Similarly, HCS 7 accepts only grade length values in the range of 0.25 mi to 4.0 mi. Therefore, the lowest scenario length of grade must be set to 0.25 mi or 1,320 ft. Overall, variables simulated were assumed uniformly distributed and independent. It is well known that flow distributions in particular are non-uniform. The independence of variables led to a covariance with zero entries. This assumption afforded the independent generation of variables rather than their joint generation using a joint probability distribution.

However, as stated in the literature review, total flow on two-lane highways can reach up to 3,200 pcph while the directional capacity reaches as much as 1,700 pcph in one direction given a maximum opposing flow of 1,500 pcph. Thus there exist some dependencies, at least toward their upper limits, between directional flows. To abide by this constraint, still assuming no direct dependence, the study focused on analysis directional flow and *D-factor* to derive opposing flow. *D-Factor* range was made to sway a prescribed interval to naturally constrain opposite flow within its ascribed capacity limits per HCM, 2010.

5.2 RESULTS AND FUTURE WORK

The proper classification rate, outlined in chapter 4, implies that the AASHTO guidelines only classify correctly 36% of the 404 scenarios analyzed. In addition, in 16% of all scenarios the implementation of a climbing lane is recommended by the AASHTO guidelines, even though it is either unnecessary or insufficient. In 47% of the scenarios the lack of recommendation to implement a climbing lane is not necessary or nor sufficient. These results indicate that the AASHTO guidelines are not effective enough as implementation warrants of climbing lanes for scenarios of the type studied. Further research could improve on the AASHTO guidelines by designing classifiers for the necessity and sufficiency of the implementation of climbing lanes. In addition, future studies could simulate realistic distributions of two-lane highway characteristics, as this study used mostly uniform distributions. Short of using realistic distributions, sensitivity analysis of study results to flow ranges can be conducted and could inform on the proper range of application of the guidelines viewed as warrants, if any. Furthermore, this study only investigates upgrade segments with slopes that extend to the point where typical trucks experience a 30 mph speed reduction. Due to this limitation, this research does not considered shorter or longer lengths of slopes whereas future studies could. An investigation into the different lengths of slope might provide insights valuable for proper classifier design.

APPENDICES

Appendix A:

Table 6: Randomly Generated Input Values

D-Factor	Analysis Direction Flow in vph	Slope in %	Trucks in %	No-Passing Zone in %
0.551	538	7.5	6	49
0.557	122	7.5	12	54
0.783	60	7.5	4	22
0.668	1660	9.5	4	57
0.740	278	6.5	17	55
0.570	1258	7.5	6	77
0.607	591	6.5	12	77
0.579	249	7.5	4	85
0.543	1179	9	14	81
0.558	1124	7	8	24
0.756	1581	6	4	45
0.561	17	8	3	57
0.768	1691	7	3	39
0.722	1390	8	7	30
0.638	214	6	15	46
0.713	592	8	11	68
0.619	69	8.5	5	44
0.555	394	9.5	19	82
0.554	1016	6	2	47
0.848	1194	7.5	14	35
0.753	429	8	7	35
0.756	326	8	20	38
0.807	1351	8.5	3	26
0.593	62	7	11	74
0.677	121	9.5	14	83
0.829	1370	9.5	3	60
0.839	1608	9.5	19	72
0.733	847	6.5	5	44
0.736	369	7.5	7	77
0.681	777	7	16	71
0.675	211	8.5	8	65
0.572	635	9.5	3	24
0.763	61	8.5	10	36

0.652	400	9.5	12	55
0.834	1510	9.5	17	48
0.827	785	9	3	84
0.645	928	6.5	8	90
0.813	320	6	16	38
0.593	925	8	7	53
0.729	1453	7.5	19	52
0.778	599	8	19	37
0.566	1188	7.5	10	45
0.569	1644	7.5	8	49
0.771	1228	9	2	85
0.812	192	10	15	85
0.615	172	9.5	2	24
0.655	489	9.5	9	26
0.608	455	8	17	60
0.776	133	8.5	7	39
0.553	6	7.5	8	78
0.692	402	9.5	5	47
0.841	924	10	16	33
0.698	626	7	10	76
0.672	257	10	19	77
0.617	347	8	9	72
0.680	329	9	3	24
0.809	135	7.5	19	44
0.756	348	8	9	68
0.821	440	9	5	73
0.675	1555	10	19	51
0.541	649	6.5	20	76
0.665	315	8.5	14	69
0.605	899	6.5	2	53
0.788	392	7	17	59
0.700	483	9	13	38
0.578	460	6.5	15	38
0.756	420	6.5	8	37
0.674	27	7	5	29
0.838	66	6.5	10	29
0.642	166	10	15	86
0.653	718	6	20	70
0.750	426	9.5	17	26
0.590	532	8.5	4	45
0.700	67	6.5	7	36
0.558	1013	9.5	18	32
0.785	10	8.5	8	34

0.736	1276	8.5	7	71
0.703	718	8	2	38
0.829	479	8	8	82
0.701	3	8	16	50
0.743	532	7	9	26
0.717	27	6.5	3	52
0.676	704	6.5	16	41
0.547	83	7.5	7	45
0.613	822	8	5	61
0.760	1193	6	7	62
0.821	80	9.5	14	51
0.822	260	9.5	9	56
0.783	83	6.5	19	35
0.710	165	9	17	27
0.803	16	7.5	20	80
0.605	634	8.5	13	53
0.671	603	7	6	42
0.689	233	8.5	3	52
0.803	135	7.5	3	80
0.615	435	9	17	59
0.656	1061	8.5	6	35
0.833	1345	9.5	3	30
0.821	190	9.5	14	51
0.557	82	9.5	3	70
0.802	171	9	6	53
0.676	64	9	17	79
0.688	501	8	14	60
0.766	917	7	16	86
0.611	711	7	11	47
0.729	548	8	9	35
0.848	209	9	18	61
0.608	1055	9.5	8	58
0.707	110	9.5	18	56
0.543	34	9.5	18	28
0.671	839	8	3	76
0.690	616	9.5	16	29
0.652	480	6.5	15	34
0.779	1481	8.5	15	22
0.656	803	7.5	2	42
0.799	1498	7	16	55
0.648	1436	7.5	3	41
0.591	919	9	6	41
0.625	589	10	9	63

0.641	1333	6.5	2	67
0.573	1663	9.5	14	82
0.579	897	7.5	2	70
0.674	499	10	7	77
0.679	1606	6.5	17	28
0.691	593	7.5	17	50
0.546	1650	7	11	43
0.776	1278	6.5	10	53
0.680	362	8.5	12	71
0.728	1152	8	8	49
0.702	445	7.5	20	34
0.830	58	9.5	20	36
0.706	314	9.5	7	44
0.688	378	7.5	14	54
0.811	25	10	6	66
0.617	236	6.5	20	85
0.640	61	8	8	80
0.641	418	9.5	3	73
0.600	567	10	18	28
0.687	680	8	13	73
0.809	107	8	20	73
0.756	1631	7	20	45
0.784	1152	10	16	56
0.672	526	7	12	43
0.764	1155	9.5	17	39
0.779	520	9	6	68
0.544	1112	7	9	29
0.797	1692	9.5	4	59
0.726	1086	8.5	18	68
0.841	78	7.5	12	58
0.841	208	7.5	18	79
0.586	669	6.5	2	36
0.564	1283	6.5	6	75
0.641	1264	9.5	12	42
0.572	80	9.5	8	45
0.773	440	9.5	18	88
0.721	25	7.5	5	68
0.825	266	6.5	16	83
0.764	1161	9.5	16	31
0.651	1318	6.5	15	24
0.636	482	9.5	15	47
0.595	580	9	3	46
0.816	21	7	14	66

0.712	1454	7.5	2	80
0.723	539	8.5	4	69
0.702	726	6.5	20	45
0.820	211	7.5	12	69
0.790	206	7	12	73
0.846	120	9	19	41
0.743	679	8.5	9	45
0.685	363	6	9	49
0.609	351	7	7	26
0.844	370	8.5	6	70
0.552	1315	7.5	12	49
0.650	536	10	17	64
0.735	1286	8.5	11	52
0.735	35	7.5	19	43
0.541	385	7	8	89
0.586	853	8	13	62
0.642	44	7	19	68
0.831	1686	9.5	14	32
0.697	19	9.5	9	39
0.648	725	6	20	40
0.806	8	7	13	81
0.664	200	7.5	12	27
0.817	70	9.5	4	59
0.736	444	7.5	12	67
0.688	1273	7	5	70
0.641	773	6.5	2	35
0.628	668	8.5	15	88
0.657	347	8	6	46
0.787	285	8	14	63
0.781	44	6	5	32
0.658	854	6.5	8	31
0.547	757	7.5	4	30
0.751	1223	6.5	6	89
0.684	1163	6	17	52
0.669	161	9	19	67
0.654	1364	6	2	44
0.647	717	9.5	2	70
0.565	523	8	16	87
0.580	1438	8.5	10	40
0.645	998	6.5	16	50
0.753	536	8	16	69
0.711	43	8.5	6	68
0.642	614	9	11	76

0.787	1161	7.5	3	87
0.806	229	9.5	20	38
0.716	526	9	15	42
0.733	1265	10	7	85
0.650	735	8	13	45
0.675	326	8.5	6	52
0.613	271	6.5	19	84
0.818	13	7.5	14	23
0.729	273	9.5	9	47
0.786	53	6.5	10	68
0.545	1376	10	11	30
0.845	262	9.5	7	74
0.685	427	10	10	56
0.666	776	6	6	88
0.750	453	10	11	35
0.839	448	8.5	17	31
0.804	501	6	13	40
0.849	1668	10	11	46
0.716	753	9	16	25
0.578	573	9	10	53
0.620	1317	9.5	6	88
0.779	1399	9	19	26
0.559	1440	6.5	11	74
0.726	487	9	9	29
0.795	419	9.5	10	63
0.728	107	7.5	20	39
0.814	85	9	2	36
0.837	1485	9	17	36
0.820	272	8	3	77
0.730	804	9.5	7	83
0.750	359	9	3	85
0.548	668	8.5	5	72
0.652	1245	7	4	86
0.685	1666	9	19	29
0.832	200	8.5	16	67
0.756	910	9	2	68
0.815	20	7.5	2	38
0.743	258	6.5	6	69
0.723	781	10	19	25
0.772	679	8.5	16	81
0.615	437	8	12	29
0.750	95	10	5	85
0.772	1595	7.5	5	89

0.633	334	10	6	49
0.849	183	8.5	8	31
0.817	241	9.5	2	27
0.649	1257	9.5	9	56
0.752	247	8	2	31
0.759	299	6	14	67
0.765	305	7	20	53
0.572	262	9.5	19	69
0.571	650	8	18	81
0.849	1645	7.5	9	75
0.567	181	10	18	76
0.566	1248	7.5	7	42
0.653	26	7	15	44
0.563	541	7.5	11	87
0.671	725	9.5	18	38
0.845	1441	6.5	11	50
0.566	1398	6.5	8	62
0.569	854	7	2	41
0.756	1021	9	3	81
0.824	92	8	8	76
0.742	1580	8.5	3	32
0.834	719	7	19	31
0.836	615	7	14	76
0.751	21	9	16	48
0.688	658	7	16	57
0.665	175	8.5	20	34
0.823	232	8.5	8	77
0.607	392	7.5	4	31
0.555	290	10	13	36
0.560	942	6	13	88
0.703	1129	7.5	16	28
0.753	43	8.5	11	66
0.601	351	8	10	54
0.557	1128	10	14	76
0.719	762	9.5	5	51
0.835	107	7.5	10	28
0.546	1027	10	9	49
0.782	249	8	5	86
0.672	910	7	13	38
0.590	139	7	8	76
0.662	218	9.5	4	59
0.597	1510	8.5	18	24
0.847	151	8	5	76

0.728	46	6	10	33
0.629	626	6.5	20	73
0.572	55	7.5	3	89
0.679	190	6	11	83
0.550	1587	10	18	32
0.671	1172	9	18	44
0.724	1363	7	14	73
0.716	819	8	20	75
0.558	1183	8	12	73
0.637	1267	10	14	46
0.630	1084	6.5	15	51
0.680	80	6.5	17	86
0.568	1020	8.5	13	72
0.825	1231	9	2	35
0.718	63	8	11	87
0.749	560	9.5	19	60
0.754	488	9	12	35
0.666	555	8.5	16	78
0.644	351	9	11	74
0.766	30	8.5	12	31
0.745	422	10	8	45
0.599	485	9	3	33
0.767	379	10	10	47
0.616	262	10	3	24
0.600	351	8	20	41
0.774	123	6.5	6	22
0.639	1537	9	13	55
0.658	647	9.5	19	74
0.721	502	7	9	39
0.827	231	7	9	62
0.611	871	8.5	17	37
0.576	125	7.5	12	29
0.628	243	8.5	14	22
0.697	428	8	17	32
0.663	825	8	11	65
0.645	474	9.5	2	20
0.571	898	7.5	2	41
0.598	550	6.5	20	69
0.635	759	10	18	77
0.608	488	6.5	15	52
0.634	139	9.5	3	58
0.714	888	10	18	54
0.582	622	8	11	41

0.617	906	7.5	10	35
0.845	938	6.5	12	50
0.750	543	7	6	82
0.548	1468	7	19	49
0.663	136	6	19	69
0.850	399	9	10	43
0.582	1416	8	6	76
0.645	735	8.5	13	65
0.694	654	7	15	44
0.824	92	7.5	5	67
0.815	1662	7.5	12	58
0.562	1549	8.5	17	75
0.695	350	7	18	49
0.700	538	9	9	79
0.787	46	8	7	42
0.788	68	6.5	19	68
0.573	687	7.5	2	26
0.775	54	7.5	19	50
0.795	176	7	7	37
0.541	687	9	3	60
0.559	1273	9	5	80
0.580	506	6.5	15	53
0.797	667	8.5	4	32
0.838	30	8	20	28
0.590	415	9	8	85
0.693	1076	7.5	5	62
0.609	937	6.5	12	32
0.589	576	9.5	10	76
0.704	317	9.5	11	67
0.556	1127	7	8	60
0.744	1444	7.5	20	89
0.792	823	7.5	5	58
0.680	4	9.5	7	52
0.727	169	8.5	18	57
0.686	521	9.5	16	42
0.823	922	6.5	16	30
0.757	47	6.5	10	57
0.556	252	8	11	22
0.631	248	9.5	8	73
0.573	707	8.5	5	56
0.841	289	6.5	20	42
0.551	875	7.5	19	45
0.641	279	8	14	27

0.677	185	6.5	10	78
0.731	64	6	18	40
0.732	996	7	12	69
0.599	113	6.5	7	67
0.634	951	10	9	50
0.769	735	7	14	66
0.789	123	8	3	27
0.802	802	9	11	82
0.765	472	6.5	18	73
0.737	390	9.5	3	90
0.747	432	7	4	78
0.805	41	9.5	17	25
0.653	1607	8.5	20	49
0.566	440	6.5	2	25
0.824	1534	6	6	42
0.710	1237	7.5	5	90
0.845	79	7.5	6	36
0.667	227	6.5	8	33
0.825	638	7.5	3	84
0.586	1021	6.5	11	83
0.762	5	7	18	89
0.546	1636	8	10	80
0.750	248	9.5	20	27
0.716	202	9	12	62
0.843	1199	6.5	5	89
0.551	854	10	3	77
0.708	89	10	14	84
0.677	28	8	17	79
0.739	513	6.5	3	25
0.621	786	9.5	7	83
0.549	387	9	14	81
0.657	1312	6	13	55
0.757	273	8	4	58
0.846	232	8	12	76
0.679	1544	8.5	6	27
0.603	395	8.5	14	62
0.573	117	9.5	9	28
0.701	1336	8	16	39
0.653	100	7.5	16	41
0.769	1653	9.5	18	38
0.687	528	9	13	44
0.831	77	10	11	79
0.811	169	9.5	19	87

0.779	337	8.5	13	80
0.801	50	6.5	5	65
0.828	354	7	4	43
0.747	287	8	20	21
0.788	78	6.5	16	56
0.790	52	9.5	11	32
0.732	621	6	4	34
0.846	1694	8	12	74
0.845	697	9	12	37
0.714	576	7.5	7	81
0.635	1314	6.5	17	75
0.626	571	6	12	53
0.591	1642	8	10	76
0.580	1161	9	12	87
0.591	110	10	2	66
0.615	1468	8.5	15	84
0.611	69	6.5	20	79
0.594	193	8.5	19	32
0.804	189	9	14	46
0.654	361	9	14	70
0.627	922	9	2	36
0.784	424	10	7	81
0.775	610	7	15	63
0.695	310	8.5	16	85
0.643	547	8.5	4	88
0.708	661	6.5	15	36
0.755	313	10	15	87
0.760	18	7.5	8	52
0.574	212	9	11	59
0.811	711	8	2	71
0.685	372	9.5	9	66
0.768	749	6.5	7	77
0.559	1231	9.5	6	48
0.553	602	9.5	6	81
0.624	748	8	19	46
0.695	476	9.5	3	58
0.624	748	10	11	27
0.656	490	8.5	2	34
0.787	379	8.5	8	47
0.685	644	9	12	88
0.822	446	6	6	34
0.696	48	10	9	25
0.748	218	9.5	14	42

0.745	255	9	6	20
0.794	290	6.5	6	51
0.819	245	9.5	16	49
0.728	402	8.5	11	33
0.621	1379	8	20	39
0.764	220	6.5	20	23
0.802	789	7	16	29
0.757	483	8	12	74
0.569	333	9.5	5	32
0.543	1311	6	19	29
0.690	59	8	10	57
0.552	904	10	12	25
0.702	77	6.5	7	58
0.631	491	8	3	81
0.576	897	6.5	12	57
0.688	450	9	6	38
0.585	292	8.5	3	39
0.728	1524	8	8	88
0.797	26	8.5	15	37
0.751	384	8.5	15	65
0.543	684	7.5	11	38
0.810	54	8.5	2	69
0.617	890	7	13	44
0.830	208	7.5	19	89
0.817	344	9.5	12	27
0.838	449	9	11	88
0.549	953	9	17	74
0.843	512	7	11	76
0.576	261	9	6	49
0.769	171	6.5	12	83
0.827	360	8	14	83
0.664	609	8	19	31
0.718	610	6	19	80
0.673	317	9.5	8	71
0.710	38	7	3	81
0.635	45	8	14	31
0.788	1282	9	7	37
0.551	178	7	13	31
0.739	772	8.5	4	26
0.734	216	6.5	3	71
0.694	420	7.5	19	34
0.697	945	6.5	8	47
0.803	395	6	13	46

0.718	228	6.5	17	21
0.772	81	9.5	12	89
0.569	1555	7	5	58
0.819	963	7	20	55
0.591	1514	7.5	4	59
0.823	879	8	8	56
0.746	198	7.5	8	50
0.668	131	9.5	10	62
0.556	1195	8	8	49
0.806	1515	8.5	5	62
0.758	491	9.5	2	37
0.689	726	9	17	30
0.674	822	9.5	16	44
0.660	213	7.5	4	72
0.709	488	8.5	8	34
0.722	345	9	18	90
0.541	1053	9.5	6	38
0.627	174	8	14	28
0.828	883	10	11	28
0.593	634	7.5	13	33
0.676	174	10	13	70
0.815	1697	7	17	78
0.573	600	8.5	12	64
0.614	114	7	6	30
0.691	244	7	12	73
0.569	1411	9	3	52
0.584	1100	6.5	18	24
0.789	160	9.5	3	65
0.664	376	7	18	54
0.599	1361	9	15	43
0.751	110	9	8	26
0.742	41	9.5	20	89
0.797	352	8	19	33
0.570	755	7.5	15	89
0.593	895	9	10	54
0.642	50	9.5	18	60
0.640	501	8.5	9	63
0.668	335	8	9	66
0.629	448	7.5	4	68
0.789	1313	7.5	20	86
0.664	1682	6.5	20	80
0.555	1210	7.5	11	66
0.785	474	8.5	3	80

0.728	1679	6	16	62
0.741	207	8.5	2	52
0.586	1007	9.5	10	23
0.576	817	7	11	66
0.700	69	8	9	40
0.820	215	9	13	54
0.649	813	10	13	81
0.663	1508	7	7	48
0.848	1238	8	10	69
0.696	399	7.5	3	23
0.692	744	6	20	67
0.649	521	7.5	10	42
0.836	335	10	11	87
0.609	1027	7	19	77
0.698	1646	10	18	83
0.550	596	9	7	60
0.715	616	7.5	14	51
0.686	412	7	3	82
0.716	603	7	14	88
0.556	959	8	13	26
0.850	127	9	8	69
0.596	1297	6.5	2	73
0.747	1301	8.5	12	67
0.834	781	8.5	2	58
0.643	762	8.5	14	74
0.696	266	7	17	73
0.687	364	7	13	69
0.609	1562	7.5	9	34
0.549	151	9	11	36
0.705	1624	7.5	2	41
0.580	1177	10	2	33
0.689	679	7	12	40
0.676	405	6	12	50
0.713	533	7	4	42
0.832	226	9.5	6	70
0.732	440	7.5	20	53
0.699	215	9.5	6	82
0.760	381	8.5	7	40
0.616	431	9.5	13	57
0.576	268	8.5	19	62
0.700	368	7.5	19	47
0.845	40	7	5	58
0.707	923	10	15	49

0.762	443	6.5	12	77
0.574	152	9	10	53
0.643	1392	10	19	56
0.580	942	9	5	31
0.632	882	9.5	13	85
0.723	173	8.5	7	23
0.604	733	8	14	29
0.719	1416	9.5	17	58
0.571	631	7	17	59

Appendix B:

Table 7: Input Parameters with Added Flows

Scenario Number	Analysis Direction Flow in vph	Opposing Direction Flow in vph	Slope in %	Trucks in %	Truck Flow on Upgrade	No-Passing Zone in %
1	538	438	7.5	6	32	49
2	122	154	7.5	12	15	54
3	60	217	7.5	4	2	22
4	1660	825	9.5	4	66	57
5	278	792	6.5	17	47	55
6	1258	951	7.5	6	75	77
7	591	382	6.5	12	71	77
8	249	342	7.5	4	10	85
9	1179	994	9	14	165	81
10	1124	1422	7	8	90	24
11	1581	509	6	4	63	45
12	17	13	8	3	1	57
13	1691	510	7	3	51	39
14	1390	536	8	7	97	30
15	214	378	6	15	32	46
16	592	1474	8	11	65	68
17	69	42	8.5	5	3	44
18	394	493	9.5	19	75	82
19	1016	1263	6	2	20	47
20	1194	215	7.5	14	167	35
21	429	1307	8	7	30	35
22	326	1009	8	20	65	38
23	1351	324	8.5	3	41	26
24	62	43	7	11	7	74
25	121	58	9.5	14	17	83
26	1370	282	9.5	3	41	60
27	1608	308	9.5	19	306	72
28	847	309	6.5	5	42	44
29	369	132	7.5	7	26	77
30	777	1657	7	16	124	71
31	211	439	8.5	8	17	65
32	635	848	9.5	3	19	24
33	61	197	8.5	10	6	36
34	400	749	9.5	12	48	55
35	1510	302	9.5	17	257	48

36	785	164	9	3	24	84
37	928	510	6.5	8	74	90
38	320	73	6	16	51	38
39	925	634	8	7	65	53
40	1453	540	7.5	19	276	52
41	599	171	8	19	114	37
42	1188	1547	7.5	10	119	45
43	1644	1243	7.5	8	132	49
44	1228	366	9	2	25	85
45	192	833	10	15	29	85
46	172	108	9.5	2	3	24
47	489	257	9.5	9	44	26
48	455	706	8	17	77	60
49	133	462	8.5	7	9	39
50	6	8	7.5	8	1	78
51	402	904	9.5	5	20	47
52	924	175	10	16	148	33
53	626	1446	7	10	63	76
54	257	126	10	19	49	77
55	347	558	8	9	31	72
56	329	698	9	3	10	24
57	135	574	7.5	19	26	44
58	348	1078	8	9	31	68
59	440	96	9	5	22	73
60	1555	750	10	19	295	51
61	649	550	6.5	20	130	76
62	315	159	8.5	14	44	69
63	899	1376	6.5	2	18	53
64	392	1460	7	17	67	59
65	483	1128	9	13	63	38
66	460	631	6.5	15	69	38
67	420	1303	6.5	8	34	37
68	27	55	7	5	1	29
69	66	340	6.5	10	7	29
70	166	297	10	15	25	86
71	718	1351	6	20	144	70
72	426	1279	9.5	17	72	26
73	532	765	8.5	4	21	45
74	67	156	6.5	7	5	36
75	1013	803	9.5	18	182	32
76	10	35	8.5	8	1	34
77	1276	458	8.5	7	89	71
78	718	1698	8	2	14	38

79	479	99	8	8	38	82
80	3	1	8	16	0	50
81	532	184	7	9	48	26
82	27	68	6.5	3	1	52
83	704	1467	6.5	16	113	41
84	83	100	7.5	7	6	45
85	822	519	8	5	41	61
86	1193	377	6	7	84	62
87	80	368	9.5	14	11	51
88	260	1206	9.5	9	23	56
89	83	300	6.5	19	16	35
90	165	67	9	17	28	27
91	16	66	7.5	20	3	80
92	634	970	8.5	13	82	53
93	603	1229	7	6	36	42
94	233	105	8.5	3	7	52
95	135	33	7.5	3	4	80
96	435	695	9	17	74	59
97	1061	557	8.5	6	64	35
98	1345	270	9.5	3	40	30
99	190	41	9.5	14	27	51
100	82	103	9.5	3	2	70
101	171	691	9	6	10	53
102	64	31	9	17	11	79
103	501	1103	8	14	70	60
104	917	281	7	16	147	86
105	711	453	7	11	78	47
106	548	204	8	9	49	35
107	209	1167	9	18	38	61
108	1055	679	9.5	8	84	58
109	110	265	9.5	18	20	56
110	34	40	9.5	18	6	28
111	839	412	8	3	25	76
112	616	1372	9.5	16	99	29
113	480	257	6.5	15	72	34
114	1481	419	8.5	15	222	22
115	803	1533	7.5	2	16	42
116	1498	378	7	16	240	55
117	1436	780	7.5	3	43	41
118	919	637	9	6	55	41
119	589	980	10	9	53	63
120	1333	746	6.5	2	27	67
121	1663	1238	9.5	14	233	82

122	897	651	7.5	2	18	70
123	499	242	10	7	35	77
124	1606	758	6.5	17	273	28
125	593	1328	7.5	17	101	50
126	1650	1373	7	11	182	43
127	1278	368	6.5	10	128	53
128	362	767	8.5	12	43	71
129	1152	429	8	8	92	49
130	445	1045	7.5	20	89	34
131	58	12	9.5	20	12	36
132	314	756	9.5	7	22	44
133	378	172	7.5	14	53	54
134	25	108	10	6	2	66
135	236	381	6.5	20	47	85
136	61	108	8	8	5	80
137	418	745	9.5	3	13	73
138	567	851	10	18	102	28
139	680	1494	8	13	88	73
140	107	455	8	20	21	73
141	1631	527	7	20	326	45
142	1152	318	10	16	184	56
143	526	1075	7	12	63	43
144	1155	357	9.5	17	196	39
145	520	148	9	6	31	68
146	1112	1328	7	9	100	29
147	1692	430	9.5	4	68	59
148	1086	411	8.5	18	195	68
149	78	412	7.5	12	9	58
150	208	1095	7.5	18	37	79
151	669	946	6.5	2	13	36
152	1283	1662	6.5	6	77	75
153	1264	708	9.5	12	152	42
154	80	60	9.5	8	6	45
155	440	1496	9.5	18	79	88
156	25	64	7.5	5	1	68
157	266	1251	6.5	16	43	83
158	1161	359	9.5	16	186	31
159	1318	708	6.5	15	198	24
160	482	842	9.5	15	72	47
161	580	396	9	3	17	46
162	21	92	7	14	3	66
163	1454	588	7.5	2	29	80
164	539	1404	8.5	4	22	69

165	726	308	6.5	20	145	45
166	211	962	7.5	12	25	69
167	206	775	7	12	25	73
168	120	657	9	19	23	41
169	679	235	8.5	9	61	45
170	363	789	6	9	33	49
171	351	547	7	7	25	26
172	370	68	8.5	6	22	70
173	1315	1620	7.5	12	158	49
174	536	994	10	17	91	64
175	1286	464	8.5	11	141	52
176	35	97	7.5	19	7	43
177	385	454	7	8	31	89
178	853	1208	8	13	111	62
179	44	25	7	19	8	68
180	1686	344	9.5	14	236	32
181	19	43	9.5	9	2	39
182	725	1334	6	20	145	40
183	8	2	7	13	1	81
184	200	395	7.5	12	24	27
185	70	312	9.5	4	3	59
186	444	1242	7.5	12	53	67
187	1273	577	7	5	64	70
188	773	1381	6.5	2	15	35
189	668	395	8.5	15	100	88
190	347	181	8	6	21	46
191	285	1050	8	14	40	63
192	44	158	6	5	2	32
193	854	443	6.5	8	68	31
194	757	912	7.5	4	30	30
195	1223	405	6.5	6	73	89
196	1163	538	6	17	198	52
197	161	80	9	19	31	67
198	1364	720	6	2	27	44
199	717	392	9.5	2	14	70
200	523	680	8	16	84	87
201	1438	1040	8.5	10	144	40
202	998	548	6.5	16	160	50
203	536	176	8	16	86	69
204	43	105	8.5	6	3	68
205	614	1099	9	11	68	76
206	1161	314	7.5	3	35	87
207	229	953	9.5	20	46	38

208	526	1328	9	15	79	42
209	1265	462	10	7	89	85
210	735	396	8	13	96	45
211	326	676	8.5	6	20	52
212	271	428	6.5	19	51	84
213	13	58	7.5	14	2	23
214	273	732	9.5	9	25	47
215	53	14	6.5	10	5	68
216	1376	1151	10	11	151	30
217	262	1429	9.5	7	18	74
218	427	196	10	10	43	56
219	776	1550	6	6	47	88
220	453	151	10	11	50	35
221	448	86	8.5	17	76	31
222	501	122	6	13	65	40
223	1668	296	10	11	183	46
224	753	298	9	16	120	25
225	573	784	9	10	57	53
226	1317	806	9.5	6	79	88
227	1399	397	9	19	266	26
228	1440	1134	6.5	11	158	74
229	487	184	9	9	44	29
230	419	1621	9.5	10	42	63
231	107	40	7.5	20	21	39
232	85	375	9	2	2	36
233	1485	290	9	17	252	36
234	272	1238	8	3	8	77
235	804	298	9.5	7	56	83
236	359	120	9	3	11	85
237	668	810	8.5	5	33	72
238	1245	665	7	4	50	86
239	1666	767	9	19	317	29
240	200	992	8.5	16	32	67
241	910	294	9	2	18	68
242	20	86	7.5	2	0	38
243	258	748	6.5	6	15	69
244	781	299	10	19	148	25
245	679	201	8.5	16	109	81
246	437	697	8	12	52	29
247	95	285	10	5	5	85
248	1595	472	7.5	5	80	89
249	334	577	10	6	20	49
250	183	1025	8.5	8	15	31

251	241	54	9.5	2	5	27
252	1257	680	9.5	9	113	56
253	247	749	8	2	5	31
254	299	942	6	14	42	67
255	305	994	7	20	61	53
256	262	350	9.5	19	50	69
257	650	866	8	18	117	81
258	1645	294	7.5	9	148	75
259	181	238	10	18	33	76
260	1248	1629	7.5	7	87	42
261	26	49	7	15	4	44
262	541	698	7.5	11	60	87
263	725	1478	9.5	18	131	38
264	1441	263	6.5	11	159	50
265	1398	1071	6.5	8	112	62
266	854	648	7	2	17	41
267	1021	329	9	3	31	81
268	92	432	8	8	7	76
269	1580	549	8.5	3	47	32
270	719	144	7	19	137	31
271	615	121	7	14	86	76
272	21	62	9	16	3	48
273	658	299	7	16	105	57
274	175	349	8.5	20	35	34
275	232	1081	8.5	8	19	77
276	392	253	7.5	4	16	31
277	290	362	10	13	38	36
278	942	1200	6	13	122	88
279	1129	478	7.5	16	181	28
280	43	14	8.5	11	5	66
281	351	527	8	10	35	54
282	1128	896	10	14	158	76
283	762	298	9.5	5	38	51
284	107	542	7.5	10	11	28
285	1027	1234	10	9	92	49
286	249	895	8	5	12	86
287	910	444	7	13	118	38
288	139	200	7	8	11	76
289	218	426	9.5	4	9	59
290	1510	1020	8.5	18	272	24
291	151	27	8	5	8	76
292	46	17	6	10	5	33
293	626	1063	6.5	20	125	73

294	55	73	7.5	3	2	89
295	190	403	6	11	21	83
296	1587	1299	10	18	286	32
297	1172	575	9	18	211	44
298	1363	520	7	14	191	73
299	819	324	8	20	164	75
300	1183	938	8	12	142	73
301	1267	722	10	14	177	46
302	1084	636	6.5	15	163	51
303	80	38	6.5	17	14	86
304	1020	1340	8.5	13	133	72
305	1231	261	9	2	25	35
306	63	25	8	11	7	87
307	560	1667	9.5	19	106	60
308	488	1497	9	12	59	35
309	555	1105	8.5	16	89	78
310	351	194	9	11	39	74
311	30	9	8.5	12	4	31
312	422	1232	10	8	34	45
313	485	724	9	3	15	33
314	379	1247	10	10	38	47
315	262	420	10	3	8	24
316	351	234	8	20	70	41
317	123	36	6.5	6	7	22
318	1537	870	9	13	200	55
319	647	336	9.5	19	123	74
320	502	1296	7	9	45	39
321	231	48	7	9	21	62
322	871	1368	8.5	17	148	37
323	125	92	7.5	12	15	29
324	243	410	8.5	14	34	22
325	428	985	8	17	73	32
326	825	1626	8	11	91	65
327	474	862	9.5	2	9	20
328	898	1194	7.5	2	18	41
329	550	818	6.5	20	110	69
330	759	436	10	18	137	77
331	488	755	6.5	15	73	52
332	139	80	9.5	3	4	58
333	888	355	10	18	160	54
334	622	865	8	11	68	41
335	906	1456	7.5	10	91	35
336	938	172	6.5	12	113	50

337	543	1628	7	6	33	82
338	1468	1210	7	19	279	49
339	136	267	6	19	26	69
340	399	71	9	10	40	43
341	1416	1019	8	6	85	76
342	735	404	8.5	13	96	65
343	654	1481	7	15	98	44
344	92	431	7.5	5	5	67
345	1662	378	7.5	12	199	58
346	1549	1208	8.5	17	263	75
347	350	795	7	18	63	49
348	538	1252	9	9	48	79
349	46	169	8	7	3	42
350	68	253	6.5	19	13	68
351	687	922	7.5	2	14	26
352	54	16	7.5	19	10	50
353	176	681	7	7	12	37
354	687	583	9	3	21	60
355	1273	1005	9	5	64	80
356	506	367	6.5	15	76	53
357	667	170	8.5	4	27	32
358	30	157	8	20	6	28
359	415	288	9	8	33	85
360	1076	477	7.5	5	54	62
361	937	1458	6.5	12	112	32
362	576	401	9.5	10	58	76
363	317	754	9.5	11	35	67
364	1127	899	7	8	90	60
365	1444	496	7.5	20	289	89
366	823	216	7.5	5	41	58
367	4	8	9.5	7	0	52
368	169	448	8.5	18	30	57
369	521	1140	9.5	16	83	42
370	922	198	6.5	16	148	30
371	47	147	6.5	10	5	57
372	252	315	8	11	28	22
373	248	424	9.5	8	20	73
374	707	949	8.5	5	35	56
375	289	55	6.5	20	58	42
376	875	713	7.5	19	166	45
377	279	156	8	14	39	27
378	185	88	6.5	10	19	78
379	64	174	6	18	12	40

380	996	364	7	12	120	69
381	113	76	6.5	7	8	67
382	951	1646	10	9	86	50
383	735	221	7	14	103	66
384	123	459	8	3	4	27
385	802	198	9	11	88	82
386	472	145	6.5	18	85	73
387	390	1095	9.5	3	12	90
388	432	1274	7	4	17	78
389	41	10	9.5	17	7	25
390	1607	852	8.5	20	321	49
391	440	574	6.5	2	9	25
392	1534	329	6	6	92	42
393	1237	506	7.5	5	62	90
394	79	433	7.5	6	5	36
395	227	456	6.5	8	18	33
396	638	136	7.5	3	19	84
397	1021	720	6.5	11	112	83
398	5	16	7	18	1	89
399	1636	1362	8	10	164	80
400	248	743	9.5	20	50	27
401	202	80	9	12	24	62
402	1199	223	6.5	5	60	89
403	854	1048	10	3	26	77
404	89	217	10	14	13	84
405	28	13	8	17	5	79
406	513	1454	6.5	3	15	25
407	786	480	9.5	7	55	83
408	387	318	9	14	54	81
409	1312	685	6	13	171	55
410	273	853	8	4	11	58
411	232	1272	8	12	28	76
412	1544	729	8.5	6	93	27
413	395	260	8.5	14	55	62
414	117	87	9.5	9	11	28
415	1336	571	8	16	214	39
416	100	53	7.5	16	16	41
417	1653	497	9.5	18	298	38
418	528	240	9	13	69	44
419	77	16	10	11	8	79
420	169	727	9.5	19	32	87
421	337	1190	8.5	13	44	80
422	50	200	6.5	5	2	65

423	354	74	7	4	14	43
424	287	847	8	20	57	21
425	78	21	6.5	16	12	56
426	52	197	9.5	11	6	32
427	621	1695	6	4	25	34
428	1694	310	8	12	203	74
429	697	128	9	12	84	37
430	576	1439	7.5	7	40	81
431	1314	754	6.5	17	223	75
432	571	341	6	12	69	53
433	1642	1137	8	10	164	76
434	1161	839	9	12	139	87
435	110	76	10	2	2	66
436	1468	919	8.5	15	220	84
437	69	108	6.5	20	14	79
438	193	132	8.5	19	37	32
439	189	774	9	14	26	46
440	361	191	9	14	51	70
441	922	1551	9	2	18	36
442	424	1533	10	7	30	81
443	610	177	7	15	92	63
444	310	709	8.5	16	50	85
445	547	304	8.5	4	22	88
446	661	1599	6.5	15	99	36
447	313	964	10	15	47	87
448	18	58	7.5	8	1	52
449	212	285	9	11	23	59
450	711	165	8	2	14	71
451	372	811	9.5	9	33	66
452	749	227	6.5	7	52	77
453	1231	1562	9.5	6	74	48
454	602	745	9.5	6	36	81
455	748	1243	8	19	142	46
456	476	209	9.5	3	14	58
457	748	450	10	11	82	27
458	490	936	8.5	2	10	34
459	379	1400	8.5	8	30	47
460	644	1400	9	12	77	88
461	446	97	6	6	27	34
462	48	21	10	9	4	25
463	218	646	9.5	14	30	42
464	255	745	9	6	15	20
465	290	1113	6.5	6	17	51

466	245	1107	9.5	16	39	49
467	402	1075	8.5	11	44	33
468	1379	843	8	20	276	39
469	220	715	6.5	20	44	23
470	789	195	7	16	126	29
471	483	1505	8	12	58	74
472	333	252	9.5	5	17	32
473	1311	1559	6	19	249	29
474	59	26	8	10	6	57
475	904	733	10	12	108	25
476	77	182	6.5	7	5	58
477	491	840	8	3	15	81
478	897	1219	6.5	12	108	57
479	450	204	9	6	27	38
480	292	412	8.5	3	9	39
481	1524	569	8	8	122	88
482	26	101	8.5	15	4	37
483	384	1162	8.5	15	58	65
484	684	812	7.5	11	75	38
485	54	229	8.5	2	1	69
486	890	1433	7	13	116	44
487	208	1017	7.5	19	40	89
488	344	77	9.5	12	41	27
489	449	87	9	11	49	88
490	953	782	9	17	162	74
491	512	95	7	11	56	76
492	261	354	9	6	16	49
493	171	570	6.5	12	21	83
494	360	75	8	14	50	83
495	609	1203	8	19	116	31
496	610	1556	6	19	116	80
497	317	654	9.5	8	25	71
498	38	92	7	3	1	81
499	45	26	8	14	6	31
500	1282	345	9	7	90	37
501	178	218	7	13	23	31
502	772	273	8.5	4	31	26
503	216	78	6.5	3	6	71
504	420	954	7.5	19	80	34
505	945	411	6.5	8	76	47
506	395	97	6	13	51	46
507	228	90	6.5	17	39	21
508	81	275	9.5	12	10	89

509	1555	1176	7	5	78	58
510	963	213	7	20	193	55
511	1514	1048	7.5	4	61	59
512	879	189	8	8	70	56
513	198	68	7.5	8	16	50
514	131	65	9.5	10	13	62
515	1195	1494	8	8	96	49
516	1515	364	8.5	5	76	62
517	491	157	9.5	2	10	37
518	726	1611	9	17	123	30
519	822	398	9.5	16	132	44
520	213	110	7.5	4	9	72
521	488	1190	8.5	8	39	34
522	345	133	9	18	62	90
523	1053	1240	9.5	6	63	38
524	174	103	8	14	24	28
525	883	183	10	11	97	28
526	634	434	7.5	13	82	33
527	174	363	10	13	23	70
528	1697	386	7	17	288	78
529	600	447	8.5	12	72	64
530	114	182	7	6	7	30
531	244	544	7	12	29	73
532	1411	1070	9	3	42	52
533	1100	1542	6.5	18	198	24
534	160	43	9.5	3	5	65
535	376	742	7	18	68	54
536	1361	912	9	15	204	43
537	110	330	9	8	9	26
538	41	119	9.5	20	8	89
539	352	1380	8	19	67	33
540	755	1003	7.5	15	113	89
541	895	1305	9	10	90	54
542	50	28	9.5	18	9	60
543	501	892	8.5	9	45	63
544	335	672	8	9	30	66
545	448	265	7.5	4	18	68
546	1313	351	7.5	20	263	86
547	1682	850	6.5	20	336	80
548	1210	1508	7.5	11	133	66
549	474	130	8.5	3	14	80
550	1679	628	6	16	269	62
551	207	72	8.5	2	4	52

552	1007	1427	9.5	10	101	23
553	817	1110	7	11	90	66
554	69	160	8	9	6	40
555	215	979	9	13	28	54
556	813	441	10	13	106	81
557	1508	766	7	7	106	48
558	1238	223	8	10	124	69
559	399	912	7.5	3	12	23
560	744	1673	6	20	149	67
561	521	281	7.5	10	52	42
562	335	66	10	11	37	87
563	1027	659	7	19	195	77
564	1646	712	10	18	296	83
565	596	488	9	7	42	60
566	616	1547	7.5	14	86	51
567	412	902	7	3	12	82
568	603	240	7	14	84	88
569	959	1200	8	13	125	26
570	127	22	9	8	10	69
571	1297	878	6.5	2	26	73
572	1301	442	8.5	12	156	67
573	781	156	8.5	2	16	58
574	762	1370	8.5	14	107	74
575	266	607	7	17	45	73
576	364	799	7	13	47	69
577	1562	1004	7.5	9	141	34
578	151	184	9	11	17	36
579	1624	679	7.5	2	32	41
580	1177	1624	10	2	24	33
581	679	1505	7	12	82	40
582	405	194	6	12	49	50
583	533	1324	7	4	21	42
584	226	1118	9.5	6	14	70
585	440	1199	7.5	20	88	53
586	215	500	9.5	6	13	82
587	381	1206	8.5	7	27	40
588	431	269	9.5	13	56	57
589	268	364	8.5	19	51	62
590	368	858	7.5	19	70	47
591	40	219	7	5	2	58
592	923	383	10	15	138	49
593	443	138	6.5	12	53	77
594	152	205	9	10	15	53

595	1392	773	10	19	264	56
596	942	1302	9	5	47	31
597	882	1515	9.5	13	115	85
598	173	453	8.5	7	12	23
599	733	1119	8	14	103	29
600	1416	554	9.5	17	241	58
601	631	473	7	17	107	59

Appendix C-1: Details for Software run 68

HCS7: Two-Lane Highways Release 7.3

________Directional Two-Lane Highway Segment Analysis________

Analyst:	Luisa Schuelke
Agency/Co.:	University of Rhode Island
Date Performed:	07/28/2018
Highway:	Hypothetical Two-Lane Highway
Analysis Year:	2018
Description:	68

________Input Data________

Highway class:	Class 1		Peak hour factor, PHF:	0.80	
Shoulder width:	6.0	ft	% Trucks and buses:	5	%
Lane width:	12.0	ft	% Trucks crawling:	0.0	%
Segment length:	1.0	mi	Truck crawl speed:	0.0	mi/hr
Terrain type:	Specific Grade		% Recreational vehicles:	4	%
Grade: Length	0.35	mi	% No-passing zones	29	%
Up/down	7.0	%	Access point density:	8	/mi

Analysis direction volume, Vd	27	veh/h
Opposing direction volume, Vo	55	veh/h

________Average Travel Speed________

Direction	Analysis(d)	Opposing (o)
PCE for trucks, ET	6.2	1.9
PCE for RVs, ER	1.6	1.0
Heavy-vehicle adj. factor,(note-5) fHV	0.779	0.957
Grade adj. factor,(note-1) fg	0.50	1.00

Directional flow rate,(note-2) vi 87 pc/h 72 pc/h

Free-Flow Speed from Field Measurement:

Field measured speed,(note-3) S FM - mi/h

Observed total demand,(note-3) V - veh/h

Estimated Free-Flow Speed:

Base free-flow speed,(note-3) BFFS 60.0 mi/h

Adj. for lane and shoulder width,(note-3) fLS 0.0 mi/h

Adj. for access point density,(note-3) fA 2.0 mi/h

Free-flow speed, FFSd 58.0 mi/h

Adjustment for no-passing zones, fnp 1.0 mi/h

Average travel speed, ATSd 55.8 mi/h

Percent Free Flow Speed, PFFS 96.1 %

________Percent Time-Spent-Following________

Direction	Analysis(d)	Opposing (o)
PCE for trucks, ET	1.0	1.1
PCE for RVs, ER	1.0	1.0
Heavy-vehicle adjustment factor, fHV	1.000	0.995
Grade adjustment factor,(note-1) fg	1.00	1.00
Directional flow rate,(note-2) vi	34 pc/h	69 pc/h

Base percent time-spent-following,(note-4) BPTSFd 4.2 %

Adjustment for no-passing zones, fnp 33.4

Percent time-spent-following, PTSFd 15.2 %

________Level of Service and Other Performance Measures________

Level of service, LOS A

Volume to capacity ratio, v/c 0.02

Peak 15-min vehicle-miles of travel, VMT15 8 veh-mi

Peak-hour vehicle-miles of travel, VMT60 27 veh-mi

Peak 15-min total travel time, TT15 0.1 veh-h

Capacity from ATS, CdATS 1374 veh/h

Capacity from PTSF, CdPTSF 1700 veh/h

Directional Capacity 1374 veh/h

________Passing Lane Analysis_________

Total length of analysis segment, Lt 1.0 mi

Length of two-lane highway upstream of the passing lane, Lu 0.0 mi

Length of passing lane including tapers, Lpl 1.0 mi

Average travel speed, ATSd (from above) 55.8 mi/h

Percent time-spent-following, PTSFd (from above) 15.2

Level of service, LOSd (from above) A

________Average Travel Speed with Passing Lane________

Downstream length of two-lane highway within effective length of passing lane for average travel speed, Lde 0.00 mi

Length of two-lane highway downstream of effective length of the passing lane for average travel speed, Ld 0.00 mi

Adj. factor for the effect of passing lane on average speed, fpl 1.02

Average travel speed including passing lane, ATSpl 56.9

Percent free flow speed including passing lane, PFFSpl 98.0 %

________Percent Time-Spent-Following with Passing Lane________

Downstream length of two-lane highway within effective length of passing lane for percent time-spent-following, Lde 0.00 mi

Length of two-lane highway downstream of effective length of the passing lane for percent time-spent-following, Ld 0.00 mi

Adj. factor for the effect of passing lane on percent time-spent-following, fpl 0.20

Percent time-spent-following including passing lane, PTSFpl 3.0 %

______Level of Service and Other Performance Measures with Passing Lane ______

Level of service including passing lane, LOSpl	A
Peak 15-min total travel time, TT15	0.1 veh-h

________ Bicycle Level of Service ________

Posted speed limit, Sp	55
Percent of segment with occupied on-highway parking	0
Pavement rating, P	3
Flow rate in outside lane, vOL	33.8
Effective width of outside lane, We	39.57
Effective speed factor, St	4.79
Bicycle LOS Score, BLOS	-2.29
Bicycle LOS	A

Notes:

1. Note that the adjustment factor for level terrain is 1.00, as level terrain is one of the base conditions. For the purpose of grade adjustment, specific downgrade segments are treated as level terrain.

2. If vi (vd or vo) >= 1,700 pc/h, terminate analysis-the LOS is F.

3. For the analysis direction only and for v>200 veh/h.

4. For the analysis direction only.

5. Use alternative Exhibit 15-14 if some trucks operate at crawl speeds on a specific downgrade.

Appendix C-2: Details for Software run 197

HCS7: Two-Lane Highways Release 7.3

________Directional Two-Lane Highway Segment Analysis________

Analyst:	Luisa Schuelke
Agency/Co.:	University of Rhode Island
Date Performed:	07/28/2018
Highway:	Hypothetical Two-Lane Highway
Analysis Year:	2018
Description:	197

________Input Data________

Highway class:	Class 1		Peak hour factor, PHF:	0.80	
Shoulder width:	6.0	ft	% Trucks and buses:	19	%
Lane width:	12.0	ft	% Trucks crawling:	0.0	%
Segment length:	0.9	mi	Truck crawl speed:	0.0	mi/hr
Terrain type:	Specific Grade		% Recreational vehicles:	4	%
Grade: Length	0.26	mi	% No-passing zones	67	%
Up/down	9.0	%	Access point density:	8	/mi

Analysis direction volume, Vd	161	veh/h
Opposing direction volume, Vo	397	veh/h

________Average Travel Speed________

Direction	Analysis(d)	Opposing (o)
PCE for trucks, ET	5.2	1.2
PCE for RVs, ER	1.4	1.0
Heavy-vehicle adj. factor,(note-5) fHV	0.551	0.963
Grade adj. factor,(note-1) fg	0.64	1.00

Directional flow rate,(note-2) vi 571 pc/h 515 pc/h

Free-Flow Speed from Field Measurement:

Field measured speed,(note-3) S FM - mi/h

Observed total demand,(note-3) V - veh/h

Estimated Free-Flow Speed:

Base free-flow speed,(note-3) BFFS 60.0 mi/h

Adj. for lane and shoulder width,(note-3) fLS 0.0 mi/h

Adj. for access point density,(note-3) fA 2.0 mi/h

Free-flow speed, FFSd 58.0 mi/h

Adjustment for no-passing zones, fnp 2.1 mi/h

Average travel speed, ATSd 47.5 mi/h

Percent Free Flow Speed, PFFS 81.9 %

________Percent Time-Spent-Following________

Direction	Analysis(d)		Opposing (o)	
PCE for trucks, ET	1.0		1.0	
PCE for RVs, ER	1.0		1.0	
Heavy-vehicle adjustment factor, fHV	1.000		1.000	
Grade adjustment factor,(note-1) fg	1.00		1.00	
Directional flow rate,(note-2) vi	201	pc/h	496	pc/h

Base percent time-spent-following,(note-4) BPTSFd 27.1 %

Adjustment for no-passing zones, fnp 38.6

Percent time-spent-following, PTSFd 38.2 %

________Level of Service and Other Performance Measures________

Level of service, LOS C

Volume to capacity ratio, v/c 0.20

Peak 15-min vehicle-miles of travel, VMT15 45 veh-mi

Peak-hour vehicle-miles of travel, VMT60 145 veh-mi

Peak 15-min total travel time, TT15 0.9 veh-h

Capacity from ATS, CdATS 1017 veh/h

Capacity from PTSF, CdPTSF 1700 veh/h

Directional Capacity 1017 veh/h

________Passing Lane Analysis_________

Total length of analysis segment, Lt 0.9 mi

Length of two-lane highway upstream of the passing lane, Lu 0.0 mi

Length of passing lane including tapers, Lpl 0.9 mi

Average travel speed, ATSd (from above) 47.5 mi/h

Percent time-spent-following, PTSFd (from above) 38.2

Level of service, LOSd (from above) C

________Average Travel Speed with Passing Lane________

Downstream length of two-lane highway within effective length of passing lane for average travel speed, Lde 0.00 mi

Length of two-lane highway downstream of effective length of the passing lane for average travel speed, Ld 0.00 mi

Adj. factor for the effect of passing lane on average speed, fpl 1.07

Average travel speed including passing lane, ATSpl 50.8

Percent free flow speed including passing lane, PFFSpl 87.7 %

________Percent Time-Spent-Following with Passing Lane________

Downstream length of two-lane highway within effective length of passing lane for percent time-spent-following, Lde 0.00 mi

Length of two-lane highway downstream of effective length of the passing lane for percent time-spent-following, Ld 0.00 mi

Adj. factor for the effect of passing lane on percent time-spent-following, fpl 0.20

Percent time-spent-following including passing lane, PTSFpl 7.6 %

______Level of Service and Other Performance Measures with Passing Lane ______

Level of service including passing lane, LOSpl B

Peak 15-min total travel time, TT15 0.9 veh-h

________ Bicycle Level of Service ________

Posted speed limit, Sp	55
Percent of segment with occupied on-highway parking	0
Pavement rating, P	3
Flow rate in outside lane, vOL	201.3
Effective width of outside lane, We	24.00
Effective speed factor, St	4.79
Bicycle LOS Score, BLOS	9.82
Bicycle LOS	F

Notes:

1. Note that the adjustment factor for level terrain is 1.00, as level terrain is one of the base conditions. For the purpose of grade adjustment, specific downgrade segments are treated as level terrain.

2. If vi (vd or vo) >= 1,700 pc/h, terminate analysis-the LOS is F.

3. For the analysis direction only and for v>200 veh/h.

4. For the analysis direction only.

5. Use alternative Exhibit 15-14 if some trucks operate at crawl speeds on a specific downgrade.

Appendix C-3: Details for Software run 307

HCS7: Two-Lane Highways Release 7.3

________Directional Two-Lane Highway Segment Analysis________

Analyst:	Luisa Schuelke
Agency/Co.:	University of Rhode Island
Date Performed:	07/28/2018
Highway:	Hypothetical Two-Lane Highway
Analysis Year:	2018
Description:	307

________Input Data________

Highway class:	Class 1		Peak hour factor, PHF:	0.80	
Shoulder width:	6.0	ft	% Trucks and buses:	19	%
Lane width:	12.0	ft	% Trucks crawling:	0.0	%
Segment length:	0.9	mi	Truck crawl speed:	0.0	mi/hr
Terrain type:	Specific Grade		% Recreational vehicles:	4	%
Grade: Length	0.25	mi	% No-passing zones	60	%
Up/down	9.5	%	Access point density:	8	/mi

Analysis direction volume, Vd	560	veh/h
Opposing direction volume, Vo	1667	veh/h

________Average Travel Speed________

Direction	Analysis(d)	Opposing (o)
PCE for trucks, ET	4.7	1.0
PCE for RVs, ER	1.0	1.0
Heavy-vehicle adj. factor,(note-5) fHV	0.587	1.000
Grade adj. factor,(note-1) fg	0.92	1.00

Directional flow rate,(note-2) vi 1296 pc/h 2084 pc/h

Free-Flow Speed from Field Measurement:

Field measured speed,(note-3) S FM - mi/h

Observed total demand,(note-3) V - veh/h

Estimated Free-Flow Speed:

Base free-flow speed,(note-3) BFFS 60.0 mi/h

Adj. for lane and shoulder width,(note-3) fLS 0.0 mi/h

Adj. for access point density,(note-3) fA 2.0 mi/h

Free-flow speed, FFSd 58.0 mi/h

Adjustment for no-passing zones, fnp 0.7 mi/h

Average travel speed, ATSd 31.1 mi/h

Percent Free Flow Speed, PFFS 53.6 %

________Percent Time-Spent-Following________

Direction	Analysis(d)		Opposing (o)	
PCE for trucks, ET	1.0		1.0	
PCE for RVs, ER	1.0		1.0	
Heavy-vehicle adjustment factor, fHV	1.000		1.000	
Grade adjustment factor,(note-1) fg	1.00		1.00	
Directional flow rate,(note-2) vi	700	pc/h	2084	pc/h

Base percent time-spent-following,(note-4) BPTSFd 73.0 %

Adjustment for no-passing zones, fnp 11.7

Percent time-spent-following, PTSFd 75.9 %

________Level of Service and Other Performance Measures________

Level of service, LOS F

Volume to capacity ratio, v/c 0.68

Peak 15-min vehicle-miles of travel, VMT15 157 veh-mi

Peak-hour vehicle-miles of travel, VMT60 504 veh-mi

Peak 15-min total travel time, TT15 5.0 veh-h

Capacity from ATS, CdATS 1034 veh/h

Capacity from PTSF, CdPTSF 1700 veh/h

Directional Capacity 1034 veh/h

________Passing Lane Analysis_________

Total length of analysis segment, Lt 0.9 mi

Length of two-lane highway upstream of the passing lane, Lu 0.0 mi

Length of passing lane including tapers, Lpl 0.9 mi

Average travel speed, ATSd (from above) 31.1 mi/h

Percent time-spent-following, PTSFd (from above) 75.9

Level of service, LOSd (from above) F

________Average Travel Speed with Passing Lane________

Downstream length of two-lane highway within effective length of passing lane for average travel speed, Lde 0.00 mi

Length of two-lane highway downstream of effective length of the passing lane for average travel speed, Ld 0.00 mi

Adj. factor for the effect of passing lane on average speed, fpl 1.14

Average travel speed including passing lane, ATSpl 35.5

Percent free flow speed including passing lane, PFFSpl 61.1 %

________Percent Time-Spent-Following with Passing Lane________

Downstream length of two-lane highway within effective length of passing lane for percent time-spent-following, Lde 0.00 mi

Length of two-lane highway downstream of effective length of the passing lane for percent time-spent-following, Ld 0.00 mi

Adj. factor for the effect of passing lane on percent time-spent-following, fpl 0.23

Percent time-spent-following including passing lane, PTSFpl 17.5 %

______Level of Service and Other Performance Measures with Passing Lane ______

Level of service including passing lane, LOSpl E

Peak 15-min total travel time, TT15 4.4 veh-h

________ Bicycle Level of Service ________

Posted speed limit, Sp

Percent of segment with occupied on-highway parking 0

Pavement rating, P 3

Flow rate in outside lane, vOL 700.0

Effective width of outside lane, We 24.00

Effective speed factor, St 4.79

Bicycle LOS Score, BLOS 10.45

Bicycle LOS F

Notes:

1. Note that the adjustment factor for level terrain is 1.00, as level terrain is one of the base conditions. For the purpose of grade adjustment, specific downgrade segments are treated as level terrain.

2. If vi (vd or vo) >= 1,700 pc/h, terminate analysis-the LOS is F.

3. For the analysis direction only and for v>200 veh/h.

4. For the analysis direction only.

5. Use alternative Exhibit 15-14 if some trucks operate at crawl speeds on a specific downgrade.

Appendix C-4: Details for Software run 347

HCS7: Two-Lane Highways Release 7.3

________Directional Two-Lane Highway Segment Analysis________

Analyst:	Luisa Schuelke
Agency/Co.:	University of Rhode Island
Date Performed:	07/28/2018
Highway:	Hypothetical Two-Lane Highway
Analysis Year:	2018
Description:	347

________Input Data________

Highway class:	Class 1		Peak hour factor, PHF:	0.80	
Shoulder width:	6.0	ft	% Trucks and buses:	18	%
Lane width:	12.0	ft	% Trucks crawling:	0.0	%
Segment length:	1.0	mi	Truck crawl speed:	0.0	mi/hr
Terrain type:	Specific Grade		% Recreational vehicles:	4	%
Grade: Length	0.35	mi	% No-passing zones	49	%
Up/down	7.0	%	Access point density:	8	/mi

Analysis direction volume, Vd 350 veh/h

Opposing direction volume, Vo 795 veh/h

________Average Travel Speed________

Direction	Analysis(d)	Opposing (o)
PCE for trucks, ET	6.1	1.0
PCE for RVs, ER	1.0	1.0
Heavy-vehicle adj. factor,(note-5) fHV	0.523	1.000
Grade adj. factor,(note-1) fg	0.74	1.00

Directional flow rate,(note-2) vi 1130 pc/h 994 pc/h

Free-Flow Speed from Field Measurement:

Field measured speed,(note-3) S FM - mi/h

Observed total demand,(note-3) V - veh/h

Estimated Free-Flow Speed:

Base free-flow speed,(note-3) BFFS 60.0 mi/h

Adj. for lane and shoulder width,(note-3) fLS 0.0 mi/h

Adj. for access point density,(note-3) fA 2.0 mi/h

Free-flow speed, FFSd 58.0 mi/h

Adjustment for no-passing zones, fnp 0.8 mi/h

Average travel speed, ATSd 40.8 mi/h

Percent Free Flow Speed, PFFS 70.3 %

________Percent Time-Spent-Following________

Direction Analysis(d) Opposing (o)

PCE for trucks, ET 1.0 1.0

PCE for RVs, ER 1.0 1.0

Heavy-vehicle adjustment factor, fHV 1.000 1.000

Grade adjustment factor,(note-1) fg 1.00 1.00

Directional flow rate,(note-2) vi 437 pc/h 994 pc/h

Base percent time-spent-following,(note-4) BPTSFd 53.1 %

Adjustment for no-passing zones, fnp 19.0

Percent time-spent-following, PTSFd 58.9 %

________Level of Service and Other Performance Measures________

Level of service, LOS D

Volume to capacity ratio, v/c 0.48

Peak 15-min vehicle-miles of travel, VMT15 109 veh-mi

Peak-hour vehicle-miles of travel, VMT60 350 veh-mi

Peak 15-min total travel time, TT15 2.7 veh-h

Capacity from ATS, CdATS 916 veh/h

Capacity from PTSF, CdPTSF 1700 veh/h

Directional Capacity 916 veh/h

________Passing Lane Analysis_________

Total length of analysis segment, Lt 1.0 mi

Length of two-lane highway upstream of the passing lane, Lu 0.0 mi

Length of passing lane including tapers, Lpl 1.0 mi

Average travel speed, ATSd (from above) 40.8 mi/h

Percent time-spent-following, PTSFd (from above) 58.9

Level of service, LOSd (from above) D

________Average Travel Speed with Passing Lane________

Downstream length of two-lane highway within effective length of passing lane for average travel speed, Lde 0.00 mi

Length of two-lane highway downstream of effective length of the passing lane for average travel speed, Ld 0.00 mi

Adj. factor for the effect of passing lane on average speed, fpl 1.14

Average travel speed including passing lane, ATSpl 46.5

Percent free flow speed including passing lane, PFFSpl 80.1 %

________Percent Time-Spent-Following with Passing Lane________

Downstream length of two-lane highway within effective length of passing lane for percent time-spent-following, Lde 0.00 mi

Length of two-lane highway downstream of effective length of the passing lane for percent time-spent-following, Ld 0.00 mi

Adj. factor for the effect of passing lane on percent time-spent-following, fpl 0.21

Percent time-spent-following including passing lane, PTSFpl	12.4	%

______Level of Service and Other Performance Measures with Passing Lane ______

Level of service including passing lane, LOSpl	C	
Peak 15-min total travel time, TT15	2.3	veh-h

________ Bicycle Level of Service ________

Posted speed limit, Sp	55
Percent of segment with occupied on-highway parking	0
Pavement rating, P	3
Flow rate in outside lane, vOL	437.5
Effective width of outside lane, We	24.00
Effective speed factor, St	4.79
Bicycle LOS Score, BLOS	9.63
Bicycle LOS	F

Notes:

1. Note that the adjustment factor for level terrain is 1.00, as level terrain is one of the base conditions. For the purpose of grade adjustment, specific downgrade segments are treated as level terrain.

2. If vi (vd or vo) >= 1,700 pc/h, terminate analysis-the LOS is F.

3. For the analysis direction only and for v>200 veh/h.

4. For the analysis direction only.

5. Use alternative Exhibit 15-14 if some trucks operate at crawl speeds on a specific downgrade.

Appendix C-5: Details for Software run 501

HCS7: Two-Lane Highways Release 7.3

________Directional Two-Lane Highway Segment Analysis________

Analyst:	Luisa Schuelke
Agency/Co.:	University of Rhode Island
Date Performed:	07/28/2018
Highway:	Hypothetical Two-Lane Highway
Analysis Year:	2018
Description:	501

________Input Data________

Highway class:	Class 1		Peak hour factor, PHF:	0.80	
Shoulder width:	6.0	ft	% Trucks and buses:	13	%
Lane width:	12.0	ft	% Trucks crawling:	0.0	%
Segment length:	1.0	mi	Truck crawl speed:	0.0	mi/hr
Terrain type:	Specific Grade		% Recreational vehicles:	4	%
Grade: Length	0.35	mi	% No-passing zones	31	%
Up/down	7.0	%	Access point density:	8	/mi

Analysis direction volume, Vd	178	veh/h
Opposing direction volume, Vo	218	veh/h

________Average Travel Speed________

Direction	Analysis(d)	Opposing (o)
PCE for trucks, ET	6.2	1.4
PCE for RVs, ER	1.4	1.0
Heavy-vehicle adj. factor,(note-5) fHV	0.593	0.951
Grade adj. factor,(note-1) fg	0.60	1.00

Directional flow rate,(note-2) vi 625 pc/h 287 pc/h

Free-Flow Speed from Field Measurement:

Field measured speed,(note-3) S FM - mi/h

Observed total demand,(note-3) V - veh/h

Estimated Free-Flow Speed:

Base free-flow speed,(note-3) BFFS 60.0 mi/h

Adj. for lane and shoulder width,(note-3) fLS 0.0 mi/h

Adj. for access point density,(note-3) fA 2.0 mi/h

Free-flow speed, FFSd 58.0 mi/h

Adjustment for no-passing zones, fnp 2.0 mi/h

Average travel speed, ATSd 48.9 mi/h

Percent Free Flow Speed, PFFS 84.3 %

________Percent Time-Spent-Following________

Direction	Analysis(d)		Opposing (o)	
PCE for trucks, ET	1.0		1.1	
PCE for RVs, ER	1.0		1.0	
Heavy-vehicle adjustment factor, fHV	1.000		0.987	
Grade adjustment factor,(note-1) fg	1.00		1.00	
Directional flow rate,(note-2) vi	222	pc/h	276	pc/h

Base percent time-spent-following,(note-4) BPTSFd 25.5 %

Adjustment for no-passing zones, fnp 43.4

Percent time-spent-following, PTSFd 44.8 %

________Level of Service and Other Performance Measures________

Level of service, LOS C

Volume to capacity ratio, v/c 0.21

Peak 15-min vehicle-miles of travel, VMT15 56 veh-mi

Peak-hour vehicle-miles of travel, VMT60 178 veh-mi

Peak 15-min total travel time, TT15 1.1 veh-h

Capacity from ATS, CdATS 1051 veh/h

Capacity from PTSF, CdPTSF 1700 veh/h

Directional Capacity 1051 veh/h

________Passing Lane Analysis_________

Total length of analysis segment, Lt 1.0 mi

Length of two-lane highway upstream of the passing lane, Lu 0.0 mi

Length of passing lane including tapers, Lpl 1.0 mi

Average travel speed, ATSd (from above) 48.9 mi/h

Percent time-spent-following, PTSFd (from above) 44.8

Level of service, LOSd (from above) C

________Average Travel Speed with Passing Lane________

Downstream length of two-lane highway within effective length of passing lane for average travel speed, Lde 0.00 mi

Length of two-lane highway downstream of effective length of the passing lane for average travel speed, Ld 0.00 mi

Adj. factor for the effect of passing lane on average speed, fpl 1.14

Average travel speed including passing lane, ATSpl 55.8

Percent free flow speed including passing lane, PFFSpl 96.1 %

________Percent Time-Spent-Following with Passing Lane________

Downstream length of two-lane highway within effective length of passing lane for percent time-spent-following, Lde 0.00 mi

Length of two-lane highway downstream of effective length of the passing lane for percent time-spent-following, Ld 0.00 mi

Adj. factor for the effect of passing lane on percent time-spent-following, fpl: 0.20

Percent time-spent-following including passing lane, PTSFpl: 9.0 %

______Level of Service and Other Performance Measures with Passing Lane ______

Level of service including passing lane, LOSpl	A	
Peak 15-min total travel time, TT15	1.0	veh-h

________ Bicycle Level of Service ________

Posted speed limit, Sp	55
Percent of segment with occupied on-highway parking	0
Pavement rating, P	3
Flow rate in outside lane, vOL	222.5
Effective width of outside lane, We	24.00
Effective speed factor, St	4.79
Bicycle LOS Score, BLOS	6.69
Bicycle LOS	F

Notes:

1. Note that the adjustment factor for level terrain is 1.00, as level terrain is one of the base conditions. For the purpose of grade adjustment, specific downgrade segments are treated as level terrain.

2. If vi (vd or vo) >= 1,700 pc/h, terminate analysis-the LOS is F.

3. For the analysis direction only and for v>200 veh/h.

4. For the analysis direction only.

5. Use alternative Exhibit 15-14 if some trucks operate at crawl speeds on a specific downgrade.

Appendix D:

Table 8: Directional Flows in pcph and Capacity Compliance

Scenario Number	Analysis Direction Flow vpn	Opposing Direction Flow vpn	Sum Flows	ATS analysis directon pcph	ATS opposing direction pcph	Total ATS Flow	PTSF anaylsis direction pcph	PTSF opposing direction pcph	Total PTSF Flow	Capacity Compliance
1	538	438	976	969	554	1523	672	547	1219	1
2	122	154	276	440	204	644	152	195	347	1
3	60	217	277	183	276	459	75	272	347	1
4	1660	825	2485	2356	1031	3387	2075	1031	3106	0
5	278	792	1070	1060	990	2050	347	990	1337	1
6	1258	951	2209	1996	1189	3185	1572	1189	2761	0
7	591	382	973	1323	489	1812	739	477	1216	1
8	249	342	591	576	433	1009	311	427	738	1
9	1179	994	2173	2203	1242	3445	1474	1242	2716	0
10	1124	1422	2546	1941	1777	3718	1405	1777	3182	0
11	1581	509	2090	2372	639	3011	1976	636	2612	0
12	17	13	30	49	17	66	21	16	37	1
13	1691	510	2201	2416	639	3055	2114	637	2751	0
14	1390	536	1926	2251	675	2926	1737	670	2407	0
15	214	378	592	742	487	1229	267	472	739	1
16	592	1474	2066	1166	1842	3008	740	1842	2582	0
17	69	42	111	203	55	258	86	53	139	1
18	394	493	887	976	628	1604	492	616	1108	1
19	1016	1263	2279	1397	1579	2976	1270	1579	2849	1
20	1194	215	1409	2431	284	2715	1492	273	1765	0
21	429	1307	1736	810	1634	2444	536	1634	2170	1
22	326	1009	1335	1108	1261	2369	407	1261	1668	1
23	1351	324	1675	1883	409	2292	1689	405	2094	0
24	62	43	105	247	59	306	77	54	131	1
25	121	58	179	409	82	491	151	74	225	1
26	1370	282	1652	1888	356	2244	1712	354	2066	0
27	1608	308	1916	3306	407	3713	2010	392	2402	0
28	847	309	1156	1340	392	1732	1059	388	1447	1

29	369	132	501	781	172	953	461	166	627	1
30	777	1657	2434	1710	2071	3781	971	2071	3042	0
31	211	439	650	554	558	1112	264	549	813	1
32	635	848	1483	877	1060	1937	794	1060	1854	1
33	61	197	258	211	259	470	76	249	325	1
34	400	749	1149	827	936	1763	500	936	1436	1
35	1510	302	1812	2977	397	3374	1887	384	2271	0
36	785	164	949	1085	208	1293	981	206	1187	1
37	928	510	1438	1652	643	2295	1160	637	1797	1
38	320	73	393	1024	104	1128	400	93	493	1
39	925	634	1559	1498	798	2296	1156	792	1948	1
40	1453	540	1993	3363	688	4051	1816	675	2491	0
41	599	171	770	1444	234	1678	749	218	967	1
42	1188	1547	2735	2152	1934	4086	1485	1934	3419	0
43	1644	1243	2887	2792	1554	4346	2055	1554	3609	0
44	1228	366	1594	1643	459	2102	1535	457	1992	1
45	192	833	1025	591	1041	1632	240	1041	1281	1
46	172	108	280	363	137	500	215	135	350	1
47	489	257	746	906	333	1239	611	324	935	1
48	455	706	1161	1151	882	2033	569	882	1451	1
49	133	462	595	375	582	957	166	577	743	1
50	6	8	14	21	11	32	7	10	17	1
51	402	904	1306	680	1130	1810	502	1130	1632	1
52	924	175	1099	1782	236	2018	1155	222	1377	0
53	626	1446	2072	1197	193	1390	782	184	966	1
54	257	126	383	823	178	1001	321	160	481	1
55	347	558	905	808	704	1512	434	697	1131	1
56	329	698	1027	624	872	1496	411	872	1283	1
57	135	574	709	582	731	1313	169	717	886	1
58	348	1078	1426	811	1347	2158	435	1347	1782	1
59	440	96	536	737	125	862	550	121	671	1
60	1555	750	2305	3197	937	4134	1944	937	2881	0
61	649	550	1199	1697	701	2398	811	687	1498	1
62	315	159	474	896	213	1109	394	202	596	1
63	899	1376	2275	1243	1720	2963	1124	1720	2844	0
64	392	1460	1852	1093	1825	2918	490	1825	2315	0
65	483	1128	1611	1004	1410	2414	604	1410	2014	1
66	460	631	1091	1230	801	2031	575	789	1364	1
67	420	1303	1723	898	1629	2527	525	1629	2154	1
68	27	55	82	87	72	159	34	69	103	1
69	66	340	406	272	438	710	82	425	507	1
70	166	297	463	528	388	916	207	377	584	1
71	718	1351	2069	1795	1689	3484	897	1689	2586	0

72	426	1279	1705	981	1599	2580	532	1599	2131	1
73	532	765	1297	859	956	1815	665	956	1621	1
74	67	156	223	247	202	449	84	196	280	1
75	1013	803	1816	2042	1004	3046	1266	1004	2270	0
76	10	35	45	32	47	79	12	44	56	1
77	1276	458	1734	2019	577	2596	1595	572	2167	0
78	718	1698	2416	973	2122	3095	897	2122	3019	0
79	479	99	578	922	132	1054	599	125	724	1
80	3	1	4	13	1	14	4	1	5	1
81	532	184	716	1092	240	1332	665	232	897	1
82	27	68	95	84	87	171	34	85	119	1
83	704	1467	2171	1627	1834	3461	880	1834	2714	0
84	83	100	183	278	132	410	104	126	230	1
85	822	519	1341	1244	652	1896	1027	649	1676	1
86	1193	377	1570	2012	478	2490	1491	471	1962	0
87	80	368	448	296	473	769	100	460	560	1
88	260	1206	1466	644	1507	2151	325	1507	1832	1
89	83	300	383	451	396	847	104	382	486	1
90	165	67	232	558	97	655	206	85	291	1
91	16	66	82	81	97	178	20	84	104	1
92	634	970	1604	1207	1212	2419	792	1212	2004	1
93	603	1229	1832	1975	2035	4010	1536	2035	3571	0
94	233	105	338	506	134	640	291	132	423	1
95	135	33	168	346	42	388	169	41	210	1
96	435	695	1130	1013	869	1882	544	869	1413	1
97	1061	557	1618	1629	700	2329	1326	696	2022	0
98	1345	270	1615	1854	342	2196	1681	339	2020	0
99	190	41	231	579	58	637	237	52	289	1
100	82	103	185	217	132	349	102	129	231	1
101	171	691	862	423	864	1287	214	864	1078	1
102	64	31	95	258	45	303	80	39	119	1
103	501	1103	1604	1142	1379	2521	626	1379	2005	1
104	917	281	1198	2016	368	2384	1145	357	1502	0
105	711	453	1164	1355	572	1927	889	566	1455	1
106	548	204	752	1066	264	1330	685	257	942	1
107	209	1167	1376	698	1459	2157	261	1459	1720	1
108	1055	679	1734	1678	856	2534	1319	849	2168	1
109	110	265	375	417	355	772	137	337	474	1
110	34	40	74	139	58	197	42	51	93	1
111	839	412	1251	1181	518	1699	1049	515	1564	1
112	616	1372	1988	1233	1715	2948	770	1715	2485	0
113	480	257	737	1266	341	1607	600	326	926	1
114	1481	419	1900	2911	539	3450	1851	524	2375	0

115	803	1533	2336	1093	1916	3009	1004	1916	2920	0
116	1498	378	1876	3297	488	3785	1872	472	2344	0
117	1436	780	2216	2037	975	3012	1795	975	2770	0
118	919	637	1556	1392	801	2193	1149	796	1945	1
119	589	980	1569	1028	1225	2253	736	1225	1961	1
120	1333	746	2079	1843	932	2775	1666	932	2598	0
121	1663	1238	2901	3066	1547	4613	2079	1547	3626	0
122	897	651	1548	1221	815	2036	1121	814	1935	1
123	499	242	741	873	311	1184	624	305	929	1
124	1606	758	2364	3817	947	4764	2007	947	2954	0
125	593	1328	1921	1411	1660	3071	741	1660	2401	1
126	1650	1373	3023	3144	1716	4860	2062	1716	3778	0
127	1278	368	1646	2446	469	2915	1597	460	2057	0
128	362	767	1129	853	959	1812	452	959	1411	1
129	1152	429	1581	1925	545	2470	1440	536	1976	0
130	445	1045	1490	1258	1306	2564	556	1306	1862	1
131	58	12	70	248	18	266	72	15	87	1
132	314	756	1070	693	945	1638	392	945	1337	1
133	378	172	550	975	230	1205	472	218	690	1
134	25	108	133	74	141	215	31	136	167	1
135	236	381	617	1015	495	1510	295	476	771	1
136	61	108	169	210	144	354	76	136	212	1
137	418	745	1163	661	931	1592	522	931	1453	1
138	567	851	1418	1268	1064	2332	709	1064	1773	1
139	680	1494	2174	1320	1867	3187	850	1867	2717	0
140	107	455	562	479	580	1059	134	569	703	1
141	1631	527	2158	3982	672	4654	2039	659	2698	0
142	1152	318	1470	2222	417	2639	1440	404	1844	0
143	526	1075	1601	1190	1344	2534	657	1344	2001	1
144	1155	357	1512	2277	469	2746	1444	446	1890	0
145	520	148	668	879	192	1071	650	186	836	1
146	1112	1328	2440	1986	1660	3646	1390	1660	3050	0
147	1692	430	2122	2403	542	2945	2115	537	2652	0
148	1086	411	1497	2289	532	2821	1357	514	1871	0
149	78	412	490	316	527	843	97	515	612	1
150	208	1095	1303	785	1369	2154	260	1369	1629	1
151	669	946	1615	934	1182	2116	836	1182	2018	1
152	1283	1662	2945	2113	2077	4190	1604	2077	3681	0
153	1264	708	1972	2225	885	3110	1580	885	2465	0
154	80	60	140	250	80	330	100	76	176	1
155	440	1496	1936	1035	1870	2905	550	1870	2420	0
156	25	64	89	80	84	164	31	80	111	1
157	266	1251	1517	1001	1564	2565	332	1564	1896	1

158	1161	359	1520	2240	470	2710	1451	449	1900	0
159	1318	708	2026	2958	885	3843	1647	885	2532	0
160	482	842	1324	1041	1052	2093	602	1052	1654	1
161	580	396	976	859	498	1357	725	495	1220	1
162	21	92	113	92	128	220	26	117	143	1
163	1454	588	2042	1980	736	2716	1817	735	2552	0
164	539	1404	1943	861	1755	2616	674	1755	2429	0
165	726	308	1034	1871	408	2279	907	393	1300	0
166	211	962	1173	673	1202	1875	264	1202	1466	1
167	206	775	981	679	969	1648	257	969	1226	1
168	120	657	777	462	837	1299	150	821	971	1
169	679	235	914	1142	304	1446	849	296	1145	1
170	363	789	1152	830	986	1816	454	986	1440	1
171	351	547	898	793	689	1482	439	684	1123	1
172	370	68	438	716	90	806	462	86	548	1
173	1315	1620	2935	2529	2025	4554	1644	2025	3669	0
174	536	994	1530	1199	1242	2441	670	1242	1912	1
175	1286	464	1750	2280	586	2866	1607	580	2187	0
176	35	97	132	172	140	312	44	124	168	1
177	385	454	839	833	572	1405	481	567	1048	1
178	853	1208	2061	1651	1510	3161	1066	1510	2576	0
179	44	25	69	221	37	258	55	32	87	1
180	1686	344	2030	3108	448	3556	2107	430	2537	0
181	19	43	62	61	58	119	24	54	78	1
182	725	1334	2059	1812	1667	3479	906	1667	2573	0
183	8	2	10	34	3	37	10	3	13	1
184	200	395	595	648	506	1154	250	494	744	1
185	70	312	382	192	395	587	87	392	479	1
186	444	1242	1686	1012	1552	2564	555	1552	2107	1
187	1273	577	1850	1969	725	2694	1591	721	2312	0
188	773	1381	2154	1069	1726	2795	966	1726	2692	0
189	668	395	1063	1319	509	1828	835	494	1329	1
190	347	181	528	729	233	962	434	228	662	1
191	285	1050	1335	870	1312	2182	356	1312	1668	1
192	44	158	202	135	202	337	55	198	253	1
193	854	443	1297	1521	558	2079	1067	554	1621	1
194	757	912	1669	1116	1140	2256	946	1140	2086	1
195	1223	405	1628	2014	512	2526	1529	506	2035	0
196	1163	538	1701	2687	684	3371	1454	672	2126	0
197	161	80	241	571	515	1086	201	496	697	1
198	1364	720	2084	1876	900	2776	1705	900	2605	0
199	717	392	1109	958	492	1450	896	490	1386	1
200	523	680	1203	1258	864	2122	654	850	1504	1

201	1438	1040	2478	2483	1300	3783	1797	1300	3097	0
202	998	548	1546	2306	696	3002	1247	685	1932	0
203	536	176	712	1275	238	1513	670	224	894	1
204	43	105	148	131	138	269	54	132	186	1
205	614	1099	1713	1113	1374	2487	767	1374	2141	1
206	1161	314	1475	1647	396	2043	1451	394	1845	1
207	229	953	1182	777	1191	1968	286	1191	1477	1
208	526	1328	1854	1138	1660	2798	657	1660	2317	1
209	1265	462	1727	1957	582	2539	1581	577	2158	0
210	735	396	1131	1422	508	1930	919	495	1414	1
211	326	676	1002	703	850	1553	407	845	1252	1
212	271	428	699	1094	555	1649	339	535	874	1
213	13	58	71	56	82	138	16	74	90	1
214	273	732	1005	667	915	1582	341	915	1256	1
215	53	14	67	219	19	238	66	18	84	1
216	1376	1151	2527	2363	1439	3802	1720	1439	3159	0
217	262	1429	1691	612	1786	2398	327	1786	2113	0
218	427	196	623	826	257	1083	534	247	781	1
219	776	1550	2326	1261	1937	3198	970	1937	2907	0
220	453	151	604	897	199	1096	566	191	757	1
221	448	86	534	1080	124	1204	560	109	669	1
222	501	122	623	1148	166	1314	626	154	780	1
223	1668	296	1964	2864	382	3246	2085	374	2459	0
224	753	298	1051	1473	390	1863	941	378	1319	1
225	573	784	1357	1062	980	2042	716	980	1696	1
226	1317	806	2123	1981	1007	2988	1646	1007	2653	0
227	1399	397	1796	2924	515	3439	1749	496	2245	0
228	1440	1134	2574	2848	1417	4265	1800	1417	3217	0
229	487	184	671	909	240	1149	609	232	841	1
230	419	1621	2040	820	2026	2846	524	2026	2550	0
231	107	40	147	498	59	557	134	51	185	1
232	85	375	460	217	471	688	106	469	575	1
233	1485	290	1775	258	1856	2114	80	1856	1936	0
234	272	1238	1510	583	1547	2130	340	1547	1887	1
235	804	298	1102	1244	380	1624	1005	375	1380	1
236	359	120	479	629	152	781	449	150	599	1
237	668	810	1478	996	1012	2008	835	1012	1847	1
238	1245	665	1910	1853	835	2688	1556	831	2387	0
239	1666	767	2433	3482	959	4441	2082	959	3041	0
240	200	992	1192	661	1240	1901	250	1240	1490	1
241	910	294	1204	1218	370	1588	1137	368	1505	1
242	20	86	106	56	109	165	25	108	133	1
243	258	748	1006	687	935	1622	322	935	1257	1

244	781	299	1080	1606	395	2001	976	381	1357	1
245	679	201	880	1371	267	1638	849	255	1104	1
246	437	697	1134	966	871	1837	546	871	1417	1
247	95	285	380	260	362	622	119	358	477	1
248	1595	472	2067	2440	593	3033	1994	590	2584	0
249	334	577	911	680	726	1406	417	721	1138	1
250	183	1025	1208	489	1281	1770	229	1281	1510	1
251	241	54	295	482	69	551	301	68	369	1
252	1257	680	1937	2051	858	2909	1571	850	2421	0
253	247	749	996	515	936	1451	309	936	1245	1
254	299	942	1241	928	1177	2105	374	1177	1551	1
255	305	994	1299	1140	1242	2382	381	1242	1623	1
256	262	350	612	839	462	1301	327	437	764	1
257	650	866	1516	1438	1082	2520	812	1082	1894	1
258	1645	294	1939	2888	377	3265	2056	371	2427	0
259	181	238	419	609	319	928	226	303	529	1
260	1248	1629	2877	2050	2036	4086	1560	2036	3596	0
261	26	49	75	117	70	187	32	62	94	1
262	541	698	1239	1151	872	2023	676	872	1548	1
263	725	1478	2203	1462	1847	3309	906	1847	2753	0
264	1441	263	1704	2850	343	3193	1801	332	2133	0
265	1398	1071	2469	2489	1339	3828	1747	1339	3086	0
266	854	648	1502	1169	812	1981	1067	810	1877	1
267	1021	329	1350	1412	415	1827	1276	411	1687	1
268	92	432	524	304	549	853	115	540	655	1
269	1580	549	2129	2202	688	2890	1975	686	2661	0
270	719	144	863	1712	201	1913	899	183	1082	0
271	615	121	736	1346	166	1512	769	153	922	1
272	21	62	83	83	89	172	26	79	105	1
273	658	299	957	1470	392	1862	822	380	1202	1
274	175	349	524	659	462	1121	219	436	655	1
275	232	1081	1313	599	1351	1950	290	1351	1641	1
276	392	253	645	694	321	1015	490	318	808	1
277	290	362	652	781	464	1245	362	452	814	1
278	942	1200	2142	1943	1500	3443	1177	1500	2677	0
279	1129	478	1607	2425	607	3032	1411	597	2008	0
280	43	14	57	153	19	172	54	18	72	1
281	351	527	878	844	665	1509	439	659	1098	1
282	1128	896	2024	2080	1120	3200	1410	1120	2530	0
283	762	298	1060	1114	378	1492	952	374	1326	1
284	107	542	649	376	684	1060	134	677	811	1
285	1027	1234	2261	1676	1542	3218	1284	1542	2826	0
286	249	895	1144	586	1119	1705	311	1119	1430	1

287	910	444	1354	1841	562	2403	1137	555	1692	0
288	139	200	339	437	258	695	174	252	426	1
289	218	426	644	478	537	1015	272	532	804	1
290	1510	1020	2530	3183	1275	4458	1887	1275	3162	0
291	151	27	178	396	35	431	189	34	223	1
292	46	17	63	171	23	194	57	21	78	1
293	626	1063	1689	1674	1329	3003	782	1329	2111	1
294	55	73	128	161	94	255	69	92	161	1
295	190	403	593	589	515	1104	237	504	741	1
296	1587	1299	2886	3200	1624	4824	1984	1624	3608	0
297	1172	575	1747	2398	732	3130	1465	719	2184	0
298	1363	520	1883	2840	659	3499	1704	650	2354	0
299	819	324	1143	1885	429	2314	1024	405	1429	0
300	1183	938	2121	2227	1172	3399	1479	1172	2651	0
301	1267	722	1989	2336	902	3238	1584	902	2486	0
302	1084	636	1720	2433	807	3240	1355	795	2150	0
303	80	38	118	412	55	467	100	48	148	1
304	1020	1340	2360	1906	1675	3581	1275	1675	2950	0
305	1231	261	1492	1647	329	1976	1539	327	1866	1
306	63	25	88	239	34	273	79	32	111	1
307	560	1667	2227	1296	2084	3380	700	2084	2784	0
308	488	1497	1985	989	1871	2860	610	1871	2481	0
309	555	1105	1660	1258	1381	2639	694	1381	2075	1
310	351	194	545	813	256	1069	439	245	684	1
311	30	9	39	110	12	122	37	11	48	1
312	422	1232	1654	772	1540	2312	527	1540	2067	1
313	485	724	1209	751	905	1656	606	905	1511	1
314	379	1247	1626	781	1559	2340	474	1559	2033	1
315	262	420	682	535	528	1063	327	525	852	1
316	351	234	585	1110	316	1426	439	298	737	1
317	123	36	159	394	47	441	154	45	199	1
318	1537	870	2407	2805	1087	3892	1921	1087	3008	0
319	647	336	983	267	444	711	80	420	500	1
320	502	1296	1798	1042	1620	2662	627	1620	2247	1
321	231	48	279	677	65	742	289	61	350	1
322	871	1368	2239	1794	1710	3504	1089	1710	2799	0
323	125	92	217	451	126	577	156	116	272	1
324	243	410	653	732	527	1259	304	512	816	1
325	428	985	1413	1085	1231	2316	535	1231	1766	1
326	825	1626	2451	1510	2032	3542	1031	2032	3063	0
327	474	862	1336	707	1077	1784	592	1077	1669	1
328	898	1194	2092	1223	1492	2715	1122	1492	2614	1
329	550	818	1368	1631	1022	2653	687	1022	1709	1

330	759	436	1195	1530	565	2095	949	545	1494	1
331	488	755	1243	1287	944	2231	610	944	1554	1
332	139	80	219	326	103	429	174	100	274	1
333	888	355	1243	1790	468	2258	1110	444	1554	0
334	622	865	1487	1182	1081	2263	777	1081	1858	1
335	906	1456	2362	1641	1820	3461	1132	1820	2952	0
336	938	172	1110	1919	228	2147	1172	218	1390	0
337	543	1628	2171	989	2035	3024	678	2035	2713	0
338	1468	1210	2678	3495	1512	5007	1835	1512	3347	0
339	136	267	403	573	359	932	170	340	510	1
340	399	71	470	798	97	895	499	90	589	1
341	1416	1019	2435	2218	1274	3492	1770	1274	3044	0
342	735	404	1139	1373	518	1891	919	505	1424	1
343	654	1481	2135	1421	1851	3272	817	1851	2668	0
344	92	431	523	280	544	824	115	539	654	1
345	1662	378	2040	3196	484	3680	2077	472	2549	0
346	1549	1208	2757	3190	1510	4700	1936	1510	3446	0
347	350	795	1145	1130	994	2124	437	994	1431	1
348	538	1252	1790	993	1565	2558	672	1565	2237	1
349	46	169	215	153	219	372	57	213	270	1
350	68	253	321	370	340	710	85	322	407	1
351	687	922	1609	936	1152	2088	859	1152	2011	1
352	54	16	70	266	23	289	67	20	87	1
353	176	681	857	505	851	1356	220	851	1071	1
354	687	583	1270	951	731	1682	859	729	1588	1
355	1273	1005	2278	1872	1256	3128	1591	1256	2847	0
356	506	367	873	1335	473	1808	632	459	1091	1
357	667	170	837	963	217	1180	834	213	1047	1
358	30	157	187	145	216	361	37	200	237	1
359	415	288	703	774	369	1143	519	363	882	1
360	1076	477	1553	1646	599	2245	1345	596	1941	1
361	937	1458	2395	1917	1822	3739	1171	1822	2993	0
362	576	401	977	1046	511	1557	720	501	1221	1
363	317	754	1071	786	942	1728	396	942	1338	1
364	1127	899	2026	1946	1124	3070	1409	1124	2533	0
365	1444	496	1940	3425	632	4057	1805	620	2425	0
366	823	216	1039	1259	275	1534	1029	271	1300	1
367	4	8	12	12	11	23	5	10	15	1
368	169	448	617	607	570	1177	211	560	771	1
369	521	1140	1661	1140	1425	2565	651	1425	2076	1
370	922	198	1120	2130	267	2397	1152	251	1403	0
371	47	147	194	194	195	389	59	186	245	1
372	252	315	567	726	407	1133	315	398	713	1

373	248	424	672	597	538	1135	310	530	840	1
374	707	949	1656	1052	1186	2238	884	1186	2070	1
375	289	55	344	1180	81	1261	361	70	431	1
376	875	713	1588	2025	891	2916	1094	891	1985	0
377	279	156	435	852	209	1061	349	198	547	1
378	185	88	273	617	120	737	231	111	342	1
379	64	174	238	304	237	541	80	221	301	1
380	996	364	1360	1958	466	2424	1245	455	1700	0
381	113	76	189	384	101	485	141	96	237	1
382	951	1646	2597	1552	2057	3609	1189	2057	3246	0
383	735	221	956	1531	292	1823	919	280	1199	1
384	123	459	582	314	575	889	154	574	728	1
385	802	198	1000	1392	261	1653	1002	250	1252	1
386	472	145	617	1374	201	1575	590	185	775	1
387	390	1095	1485	632	1369	2001	487	1369	1856	1
388	432	1274	1706	762	1592	2354	540	1592	2132	1
389	41	10	51	163	14	177	51	13	64	1
390	1607	852	2459	3537	1065	4602	2009	1065	3074	0
391	440	574	1014	726	719	1445	550	717	1267	1
392	1534	329	1863	2493	419	2912	1917	411	2328	0
393	1237	506	1743	1893	636	2529	1546	632	2178	0
394	79	433	512	261	548	809	99	541	640	1
395	227	456	683	680	575	1255	284	570	854	1
396	638	136	774	915	173	1088	797	171	968	1
397	1021	720	1741	2019	900	2919	1276	900	2176	0
398	5	16	21	24	23	47	6	20	26	1
399	1636	1362	2998	2909	1702	4611	2045	1702	3747	0
400	248	743	991	812	929	1741	310	929	1239	1
401	202	80	282	580	111	691	252	101	353	1
402	1199	223	1422	1897	284	2181	1499	280	1779	0
403	854	1048	1902	1177	1310	2487	1067	1310	2377	1
404	89	217	306	323	286	609	111	275	386	1
405	28	13	41	126	19	145	35	17	52	1
406	513	1454	1967	857	1817	2674	641	1817	2458	0
407	786	480	1266	1216	604	1820	982	600	1582	1
408	387	318	705	884	414	1298	484	403	887	1
409	1312	685	1997	2706	856	3562	1640	856	2496	0
410	273	853	1126	609	1066	1675	341	1066	1407	1
411	232	1272	1504	704	1590	2294	290	1590	1880	1
412	1544	729	2273	2371	911	3282	1930	911	2841	0
413	395	260	655	910	343	1253	494	330	824	1
414	117	87	204	344	118	462	146	110	256	1
415	1336	571	1907	2797	725	3522	1670	714	2384	0

416	100	53	153	428	76	504	125	67	192	1
417	1653	497	2150	3333	632	3965	2066	621	2687	0
418	528	240	768	1086	316	1402	660	304	964	1
419	77	16	93	263	22	285	96	20	116	1
420	169	727	896	592	909	1501	211	909	1120	1
421	337	1190	1527	876	1487	2363	421	1487	1908	1
422	50	200	250	170	255	425	62	251	313	1
423	354	74	428	710	96	806	442	93	535	1
424	287	847	1134	1024	1059	2083	359	1059	1418	1
425	78	21	99	391	30	421	97	27	124	1
426	52	197	249	178	260	438	65	249	314	1
427	621	1695	2316	954	2119	3073	776	2119	2895	0
428	1694	310	2004	3189	401	3590	2117	392	2509	0
429	697	128	825	1245	173	1418	871	162	1033	1
430	576	1439	2015	1038	1799	2837	720	1799	2519	0
431	1314	754	2068	3123	942	4065	1642	942	2584	0
432	571	341	912	1235	442	1677	714	426	1140	1
433	1642	1137	2779	2920	1421	4341	2052	1421	3473	0
434	1161	839	2000	2067	1049	3116	1451	1049	2500	0
435	110	76	186	261	97	358	137	95	232	1
436	1468	919	2387	2885	1149	4034	1835	1149	2984	0
437	69	108	177	386	157	543	86	138	224	1
438	193	132	325	697	184	881	241	168	409	1
439	189	774	963	582	967	1549	236	967	1203	1
440	361	191	552	881	255	1136	451	242	693	1
441	922	1551	2473	1234	1939	3173	1152	1939	3091	0
442	424	1533	1957	753	1916	2669	530	1916	2446	0
443	610	177	787	1389	238	1627	762	225	987	1
444	310	709	1019	928	886	1814	387	886	1273	1
445	547	304	851	874	385	1259	684	382	1066	1
446	661	1599	2260	1504	1999	3503	826	1999	2825	0
447	313	964	1277	862	1205	2067	391	1205	1596	1
448	18	58	76	64	78	142	22	73	95	1
449	212	285	497	591	368	959	265	360	625	1
450	711	165	876	964	208	1172	889	207	1096	1
451	372	811	1183	755	1014	1769	465	1014	1479	1
452	749	227	976	1284	292	1576	936	286	1222	1
453	1231	1562	2793	1852	1952	3804	1539	1952	3491	0
454	602	745	1347	952	931	1883	752	931	1683	1
455	748	1243	1991	1685	1554	3239	935	1554	2489	0
456	476	209	685	735	264	999	595	262	857	1
457	748	450	1198	1284	569	1853	935	562	1497	1
458	490	936	1426	744	1170	1914	612	1170	1782	1

459	379	1400	1779	763	1750	2513	474	1750	2224	0
460	644	1400	2044	1155	1750	2905	805	1750	2555	0
461	446	97	543	816	127	943	557	122	679	1
462	48	21	69	155	28	183	60	26	86	1
463	218	646	864	643	819	1462	272	807	1079	1
464	255	745	1000	580	931	1511	319	931	1250	1
465	290	1113	1403	749	1391	2140	362	1391	1753	1
466	245	1107	1352	742	1384	2126	306	1384	1690	1
467	402	1075	1477	770	1344	2114	502	1344	1846	1
468	1379	843	2222	3174	1054	4228	1724	1054	2778	0
469	220	715	935	961	894	1855	275	894	1169	1
470	789	195	984	1736	263	1999	986	248	1234	0
471	483	1505	1988	1052	1881	2933	604	1881	2485	0
472	333	252	585	665	321	986	416	317	733	1
473	1311	1559	2870	3194	1949	5143	1639	1949	3588	0
474	59	26	85	217	35	252	74	33	107	1
475	904	733	1637	1592	916	2508	1130	916	2046	1
476	77	182	259	284	235	519	96	229	325	1
477	491	840	1331	791	1050	1841	614	1050	1664	1
478	897	1219	2116	1835	1524	3359	1121	1524	2645	0
479	450	204	654	778	261	1039	562	257	819	1
480	292	412	704	593	518	1111	365	515	880	1
481	1524	569	2093	2547	717	3264	1905	711	2616	0
482	26	101	127	103	141	244	32	128	160	1
483	384	1162	1546	931	1452	2383	480	1452	1932	1
484	684	812	1496	1280	1015	2295	855	1015	1870	1
485	54	229	283	124	289	413	67	287	354	1
486	890	1433	2323	1800	1791	3591	1112	1791	2903	0
487	208	1017	1225	806	1271	2077	260	1271	1531	1
488	344	77	421	812	107	919	430	97	527	1
489	449	87	536	898	120	1018	561	110	671	1
490	953	782	1735	1906	977	2883	1191	977	2168	0
491	512	95	607	1122	129	1251	640	120	760	1
492	261	354	615	593	450	1043	326	442	768	1
493	171	570	741	623	721	1344	214	712	926	1
494	360	75	435	949	106	1055	450	95	545	1
495	609	1203	1812	1450	1504	2954	761	1504	2265	1
496	610	1556	2166	1554	1945	3499	762	1945	2707	0
497	317	654	971	721	824	1545	396	817	1213	1
498	38	92	130	112	118	230	47	115	162	1
499	45	26	71	186	37	223	56	33	89	1
500	1282	345	1627	1998	440	2438	1602	431	2033	0
501	178	218	396	625	287	912	222	276	498	1

502	772	273	1045	1112	347	1459	965	343	1308	1
503	216	78	294	524	100	624	270	98	368	1
504	420	954	1374	1161	1192	2353	525	1192	1717	1
505	945	411	1356	1683	522	2205	1181	514	1695	1
506	395	97	492	948	134	1082	494	123	617	1
507	228	90	318	918	130	1048	285	114	399	1
508	81	275	356	284	360	644	101	348	449	1
509	1555	1176	2731	2406	1470	3876	1944	1470	3414	0
510	963	213	1176	2351	288	2639	1204	272	1476	0
511	1514	1048	2562	2232	1310	3542	1892	1310	3202	0
512	879	189	1068	1469	246	1715	1099	238	1337	1
513	198	68	266	563	91	654	247	86	333	1
514	131	65	196	390	89	479	164	82	246	1
515	1195	1494	2689	1997	1867	3864	1494	1867	3361	0
516	1515	364	1879	2254	460	2714	1894	455	2349	0
517	491	157	648	732	198	930	614	197	811	1
518	726	1611	2337	1452	2014	3466	907	2014	2921	0
519	822	398	1220	1586	513	2099	1027	497	1524	1
520	213	110	323	512	142	654	266	138	404	1
521	488	1190	1678	909	1487	2396	610	1487	2097	1
522	345	133	478	969	184	1153	431	169	600	1
523	1053	1240	2293	1584	1550	3134	1316	1550	2866	0
524	174	103	277	589	143	732	217	131	348	1
525	883	183	1066	1516	241	1757	1104	231	1335	1
526	634	434	1068	1277	557	1834	792	542	1334	1
527	174	363	537	517	466	983	217	454	671	1
528	1697	386	2083	3836	499	4335	2121	482	2603	0
529	600	447	1047	1166	565	1731	750	559	1309	1
530	114	182	296	351	234	585	142	229	371	1
531	244	544	788	774	688	1462	305	680	985	1
532	1411	1070	2481	1951	1337	3288	1764	1337	3101	0
533	1100	1542	2642	2686	1927	4613	1375	1927	3302	0
534	160	43	203	357	55	412	200	54	254	1
535	376	742	1118	1119	927	2046	470	927	1397	1
536	1361	912	2273	2605	1140	3745	1701	1140	2841	0
537	110	330	440	327	422	749	137	412	549	1
538	41	119	160	175	170	345	51	152	203	1
539	352	1380	1732	1072	1725	2797	440	1725	2165	0
540	755	1003	1758	1578	1254	2832	944	1254	2198	1
541	895	1305	2200	1514	1631	3145	1119	1631	2750	0
542	50	28	78	204	41	245	62	36	98	1
543	501	892	1393	951	1115	2066	626	1115	1741	1
544	335	672	1007	814	848	1662	419	840	1259	1

545	448	265	713	765	337	1102	560	333	893	1
546	1313	351	1664	3114	465	3579	1641	439	2080	0
547	1682	850	2532	4335	1062	5397	2102	1062	3164	0
548	1210	1508	2718	2261	1885	4146	1512	1885	3397	0
549	474	130	604	747	166	913	592	163	755	1
550	1679	628	2307	3775	798	4573	2099	785	2884	0
551	207	72	279	439	92	531	259	90	349	1
552	1007	1427	2434	1687	1784	3471	1259	1784	3043	0
553	817	1110	1927	1557	1387	2944	1021	1387	2408	1
554	69	160	229	245	209	454	86	202	288	1
555	215	979	1194	633	1224	1857	269	1224	1493	1
556	813	441	1254	1466	558	2024	1016	551	1567	1
557	1508	766	2274	2513	957	3470	1885	957	2842	0
558	1238	223	1461	2201	290	2491	1547	282	1829	0
559	399	912	1311	671	1140	1811	499	1149	1648	1
560	744	1673	2417	1860	2091	3951	930	2091	3021	0
561	521	281	802	1075	362	1437	651	355	1006	1
562	335	66	401	792	91	883	419	83	502	1
563	1027	659	1686	2445	839	3284	2445	839	3284	0
564	1646	712	2358	3319	890	4209	2057	890	2947	0
565	596	488	1084	989	614	1603	745	610	1355	1
566	616	1547	2163	1319	1934	3253	770	1934	2704	0
567	412	902	1314	696	1127	1823	515	1127	1642	1
568	603	240	843	1336	317	1653	754	304	1058	1
569	959	1200	2159	1856	1500	3356	1199	1500	2699	0
570	127	22	149	365	29	394	159	28	187	1
571	1297	878	2175	1793	1097	2890	1621	1097	2718	0
572	1301	442	1743	2371	559	2930	1626	552	2178	0
573	781	156	937	1051	197	1248	976	195	1171	1
574	762	1370	2132	1461	1712	3173	952	1712	2664	0
575	266	607	873	962	772	1734	332	759	1091	1
576	364	799	1163	980	999	1979	455	999	1454	1
577	1562	1004	2566	2742	1255	3997	1952	1255	3207	0
578	151	184	335	452	243	695	189	233	422	1
579	1624	679	2303	2211	850	3061	2030	849	2879	0
580	1177	1624	2801	1572	2030	3602	1471	2030	3501	0
581	679	1505	2184	1337	1881	3218	849	1881	2730	0
582	405	194	599	931	257	1188	506	245	751	1
583	533	1324	1857	907	1655	2562	666	1655	2321	1
584	226	1118	1344	530	1397	1927	282	1397	1679	1
585	440	1199	1639	1244	1499	2743	550	1499	2049	1
586	215	500	715	505	629	1134	269	625	894	1
587	381	1206	1587	742	1507	2249	476	1507	1983	1

588	431	269	700	901	354	1255	539	341	880	1
589	268	364	632	902	472	1374	335	455	790	1
590	368	858	1226	1115	1072	2187	460	1072	1532	1
591	40	219	259	128	279	407	50	275	325	1
592	923	383	1306	1743	493	2236	1154	479	1633	0
593	443	138	581	1091	185	1276	554	175	729	1
594	152	205	357	435	266	701	190	259	449	1
595	1392	773	2165	2862	966	3828	1740	966	2706	0
596	942	1302	2244	1385	1627	3012	1177	1627	2804	1
597	882	1515	2397	1591	1894	3485	1102	1894	2996	0
598	173	453	626	455	570	1025	216	566	782	1
599	733	1119	1852	1457	1399	2856	916	1399	2315	1
600	1416	554	1970	2792	704	3496	1770	692	2462	0
601	631	473	1104	1466	601	2067	789	591	1380	1

Appendix E:

Table 9: Results from HCS 7 Runs

1	19	20	21	22	23	24	25	26	27	28	29	30
Scenario Number	**LOS (no Climbing Lane)**	**LOS (Climbing Lane)**	**Guideline1**	**Guideline2**	**Guideline3**	**Guidelines Satisfied (overall)**	**Acceptable Performance (No Climbing Lane)**	**Acceptable Performance (Climbing Lane)**	**Logical Clause 1 Valid**	**Logical Clause 2 Valid**	**Logical Clause 3 Valid**	**Logical Clause 4 Valid**
1	D	B	1	1	1	1	0	1	1	0	1	0
2	C	B	0	0	1	0	1	1	0	0	0	1
3	B	B	0	0	0	0	1	1	0	0	0	1
5	D	C	1	1	1	1	0	1	1	0	1	0
7	E	C	1	1	1	1	0	1	1	0	1	0
8	C	B	1	0	1	0	1	1	0	0	0	1
12	A	A	0	0	0	0	1	1	0	0	0	1
15	C	B	1	1	1	1	1	1	0	0	1	0
17	B	B	0	0	0	0	1	1	0	0	0	1
18	D	C	1	1	1	1	0	1	1	0	1	0
19	E	E	1	0	1	0	0	0	0	1	0	0
21	E	D	1	1	1	1	0	0	1	0	0	0
22	E	D	1	1	1	1	0	0	1	0	0	0
24	B	B	0	0	0	0	1	1	0	0	0	1
25	C	A	0	0	0	0	1	1	0	0	0	1
28	E	C	1	1	1	1	0	1	1	0	1	0
29	D	B	1	1	1	1	0	1	1	0	1	0
31	C	B	1	0	1	0	1	1	0	0	0	1
32	D	C	1	0	1	0	0	1	0	0	0	0
33	B	B	0	0	0	0	1	1	0	0	0	1
34	D	C	1	1	1	1	0	1	1	0	1	0
36	E	B	1	1	1	1	0	1	1	0	1	0
37	E	D	1	1	1	1	0	0	1	0	0	0
38	C	B	1	1	1	1	1	1	0	0	1	0
39	E	D	1	1	1	1	0	0	1	0	0	0
41	D	C	1	1	1	1	0	1	1	0	1	0

44	E	D	1	1	1	1	0	0	1	0	0	0
45	D	C	0	1	1	0	0	1	0	0	0	0
46	B	A	0	0	0	0	1	1	0	0	0	1
47	D	B	1	1	1	1	0	1	1	0	1	0
48	D	C	1	1	1	1	0	1	1	0	1	0
49	C	B	0	0	1	0	1	1	0	0	0	1
50	A	A	0	0	0	0	1	1	0	0	0	1
51	D	C	1	0	1	0	0	1	0	0	0	0
53	D	C	1	1	1	1	0	1	1	0	1	0
54	C	B	1	1	1	1	1	1	0	0	1	0
55	D	B	1	1	1	1	0	1	1	0	1	0
56	C	B	1	0	1	0	1	1	0	0	0	1
57	C	B	0	1	1	0	1	1	0	0	0	1
58	D	C	1	1	1	1	0	1	1	0	1	0
59	D	A	1	1	1	1	0	1	1	0	1	0
61	E	D	1	1	1	1	0	0	1	0	0	0
62	D	B	1	1	1	1	0	1	1	0	1	0
65	E	D	1	1	1	1	0	0	1	0	0	0
66	D	C	1	1	1	1	0	1	1	0	1	0
67	E	D	1	1	1	1	0	0	1	0	0	0
68	A	A	0	0	0	0	1	1	0	0	0	1
69	B	B	0	0	0	0	1	1	0	0	0	1
70	C	B	0	1	1	0	1	1	0	0	0	1
72	E	D	1	1	1	1	0	0	1	0	0	0
73	D	C	1	1	1	1	0	1	1	0	1	0
74	B	B	0	0	0	0	1	1	0	0	0	1
76	A	A	0	0	0	0	1	1	0	0	0	1
79	D	B	1	1	1	1	0	1	1	0	1	0
80	A	A	0	0	0	0	1	1	0	0	0	1
81	D	B	1	1	1	1	0	1	1	0	1	0
82	B	A	0	0	0	0	1	1	0	0	0	1
84	B	B	0	0	0	0	1	1	0	0	0	1
85	E	C	1	1	1	1	0	1	1	0	1	0
87	B	B	0	0	0	0	1	1	0	0	0	1
88	D	C	1	1	1	1	0	1	1	0	1	0
89	C	B	0	0	1	0	1	1	0	0	0	1
90	B	A	0	1	0	0	1	1	0	0	0	1
91	B	B	0	0	0	0	1	1	0	0	0	1
92	E	D	1	1	1	1	0	0	1	0	0	0
94	C	B	1	0	0	0	1	1	0	0	0	1
95	C	A	0	0	0	0	1	1	0	0	0	1
96	D	C	1	1	1	1	0	1	1	0	1	0
99	C	B	0	1	0	0	1	1	0	0	0	1

100	B	B	0	0	0	0	1	1	0	0	0	1
101	C	B	0	0	1	0	1	1	0	0	0	1
102	B	B	0	0	0	0	1	1	0	0	0	1
103	E	D	1	1	1	1	0	0	1	0	0	0
105	E	C	1	1	1	1	0	1	1	0	1	0
106	D	B	1	1	1	1	0	1	1	0	1	0
107	D	C	1	1	1	1	0	1	1	0	1	0
108	E	D	1	1	1	1	0	0	1	0	0	0
109	C	B	0	0	1	0	1	1	0	0	0	1
110	A	A	0	0	0	0	1	1	0	0	0	1
111	E	C	1	1	1	1	0	1	1	0	1	0
113	D	C	1	1	1	1	0	1	1	0	1	0
118	E	C	1	1	1	1	0	1	1	0	1	0
119	E	C	1	1	1	1	0	1	1	0	1	0
122	E	C	1	0	1	0	0	1	0	0	0	0
123	D	B	1	1	1	1	0	1	1	0	1	0
125	E	E	1	1	1	1	0	0	1	0	0	0
128	D	C	1	1	1	1	0	1	1	0	1	0
130	E	D	1	1	1	1	0	0	1	0	0	0
131	B	A	0	0	0	0	1	1	0	0	0	1
132	D	B	1	1	1	1	0	1	1	0	1	0
133	D	B	1	1	1	1	0	1	1	0	1	0
134	B	B	0	0	0	0	1	1	0	0	0	1
135	D	B	1	1	1	1	0	1	1	0	1	0
136	B	B	0	0	0	0	1	1	0	0	0	1
137	D	B	1	0	1	0	0	1	0	0	0	0
138	E	D	1	1	1	1	0	0	1	0	0	0
140	C	B	0	1	1	0	1	1	0	0	0	1
143	E	D	1	1	1	1	0	0	1	0	0	0
145	D	B	1	1	1	1	0	1	1	0	1	0
149	C	B	0	0	1	0	1	1	0	0	0	1
150	D	C	1	1	1	1	0	1	1	0	1	0
151	E	C	1	0	1	0	0	1	0	0	0	0
154	B	B	0	0	0	0	1	1	0	0	0	1
156	B	A	0	0	0	0	1	1	0	0	0	1
157	E	D	1	1	1	1	0	0	1	0	0	0
160	D	C	1	1	1	1	0	1	1	0	1	0
161	D	B	1	0	1	0	0	1	0	0	0	0
162	B	B	0	0	0	0	1	1	0	0	0	1
166	D	C	1	1	1	1	0	1	1	0	1	0
167	D	B	1	1	1	1	0	1	1	0	1	0
168	C	B	0	1	1	0	1	1	0	0	0	1
169	E	B	1	1	1	1	0	1	1	0	1	0

170	D	C	1	1	1	1	0	1	1	0	1	0
171	C	B	1	1	1	1	1	1	0	0	1	0
172	D	A	1	1	1	1	0	1	1	0	1	0
174	E	D	1	1	1	1	0	0	1	0	0	0
176	B	B	0	0	0	0	1	1	0	0	0	1
177	D	B	1	1	1	1	0	1	1	0	1	0
179	B	B	0	0	0	0	1	1	0	0	0	1
181	A	A	0	0	0	0	1	1	0	0	0	1
183	B	A	0	0	0	0	1	1	0	0	0	1
184	C	B	0	1	1	0	1	1	0	0	0	1
185	B	B	0	0	0	0	1	1	0	0	0	1
186	E	D	1	1	1	1	0	0	1	0	0	0
189	E	C	1	1	1	1	0	1	1	0	1	0
190	D	B	1	1	1	1	0	1	1	0	1	0
191	D	C	1	1	1	1	0	1	1	0	1	0
192	B	B	0	0	0	0	1	1	0	0	0	1
193	E	C	1	1	1	1	0	1	1	0	1	0
194	E	C	1	1	1	1	0	1	1	0	1	0
197	C	B	0	1	1	0	1	1	0	0	0	1
199	E	B	1	0	1	0	0	1	0	0	0	0
200	D	C	1	1	1	1	0	1	1	0	1	0
203	D	C	1	1	1	1	0	1	1	0	1	0
204	B	B	0	0	0	0	1	1	0	0	0	1
205	E	D	1	1	1	1	0	0	1	0	0	0
206	E	D	1	1	1	1	0	0	1	0	0	0
207	D	C	1	1	1	1	0	1	1	0	1	0
208	E	D	1	1	1	1	0	0	1	0	0	0
210	E	C	1	1	1	1	0	1	1	0	1	0
211	C	B	1	0	1	0	1	1	0	0	0	1
212	D	C	1	1	1	1	0	1	1	0	1	0
213	A	A	0	0	0	0	1	1	0	0	0	1
214	D	B	1	1	1	1	0	1	1	0	1	0
215	B	B	0	0	0	0	1	1	0	0	0	1
218	D	B	1	1	1	1	0	1	1	0	1	0
220	D	B	1	1	1	1	0	1	1	0	1	0
221	D	B	1	1	1	1	0	1	1	0	1	0
222	D	B	1	1	1	1	0	1	1	0	1	0
224	E	C	1	1	1	1	0	1	1	0	1	0
225	D	C	1	1	1	1	0	1	1	0	1	0
229	D	B	1	1	1	1	0	1	1	0	1	0
231	B	A	0	1	0	0	1	1	0	0	0	1
232	B	B	0	0	0	0	1	1	0	0	0	1
234	D	D	1	0	1	0	0	0	0	1	0	0

235	E	C	1	1	1	1	0	1	1	0	1	0
236	D	A	1	0	1	0	0	1	0	0	0	0
237	E	C	1	1	1	1	0	1	1	0	1	0
240	D	C	0	1	1	0	0	1	0	0	0	0
241	E	C	1	0	1	0	0	1	0	0	0	0
242	A	A	0	0	0	0	1	1	0	0	0	1
243	D	B	1	0	1	0	0	1	0	0	0	0
244	E	C	1	1	1	1	0	1	1	0	1	0
245	E	C	1	1	1	1	0	1	1	0	1	0
246	D	C	1	1	1	1	0	1	1	0	1	0
247	B	B	0	0	0	0	1	1	0	0	0	1
249	C	B	1	0	1	0	1	1	0	0	0	1
250	D	C	0	0	1	0	0	1	0	0	0	0
251	C	A	1	0	0	0	1	1	0	0	0	1
253	C	C	1	0	1	0	1	1	0	0	0	1
254	D	C	1	1	1	1	0	1	1	0	1	0
255	E	D	1	1	1	1	0	0	1	0	0	0
256	C	B	1	1	1	1	1	1	0	0	1	0
257	E	D	1	1	1	1	0	0	1	0	0	0
259	C	B	0	1	1	0	1	1	0	0	0	1
261	B	A	0	0	0	0	1	1	0	0	0	1
262	D	C	1	1	1	1	0	1	1	0	1	0
266	E	C	1	0	1	0	0	1	0	0	0	0
267	E	C	1	1	1	1	0	1	1	0	1	0
268	C	B	0	0	1	0	1	1	0	0	0	1
271	D	C	1	1	1	1	0	1	1	0	1	0
272	B	A	0	0	0	0	1	1	0	0	0	1
273	E	C	1	1	1	1	0	1	1	0	1	0
274	C	B	0	1	1	0	1	1	0	0	0	1
275	D	C	1	0	1	0	0	1	0	0	0	0
276	D	B	1	0	1	0	0	1	0	0	0	0
277	C	B	1	1	1	1	1	1	0	0	1	0
280	B	A	0	0	0	0	1	1	0	0	0	1
281	D	B	1	1	1	1	0	1	1	0	1	0
283	E	B	1	1	1	1	0	1	1	0	1	0
284	C	B	0	0	1	0	1	1	0	0	0	1
286	D	C	1	0	1	0	0	1	0	0	0	0
288	C	B	0	0	1	0	1	1	0	0	0	1
289	C	B	1	0	1	0	1	1	0	0	0	1
291	C	A	0	0	0	0	1	1	0	0	0	1
292	A	A	0	0	0	0	1	1	0	0	0	1
293	E	E	1	1	1	1	0	0	1	0	0	0
294	B	B	0	0	0	0	1	1	0	0	0	1

295	C	B	0	1	1	0	1	1	0	0	0	1
303	B	A	0	0	0	0	1	1	0	0	0	1
305	E	C	1	1	1	1	0	1	1	0	1	0
306	B	B	0	0	0	0	1	1	0	0	0	1
309	E	D	1	1	1	1	0	0	1	0	0	0
310	D	B	1	1	1	1	0	1	1	0	1	0
311	A	A	0	0	0	0	1	1	0	0	0	1
312	E	D	1	1	1	1	0	0	1	0	0	0
313	D	B	1	0	1	0	0	1	0	0	0	0
314	E	D	1	1	1	1	0	0	1	0	0	0
315	C	B	1	0	1	0	1	1	0	0	0	1
316	D	B	1	1	1	1	0	1	1	0	1	0
317	B	A	0	0	0	0	1	1	0	0	0	1
319	B	B	1	1	1	1	1	1	0	0	1	0
320	E	D	1	1	1	1	0	0	1	0	0	0
321	C	A	1	1	1	1	1	1	0	0	1	0
323	B	A	0	0	0	0	1	1	0	0	0	1
324	C	B	1	1	1	1	1	1	0	0	1	0
325	E	D	1	1	1	1	0	0	1	0	0	0
327	D	C	1	0	1	0	0	1	0	0	0	0
328	E	D	1	0	1	0	0	0	0	1	0	0
329	E	D	1	1	1	1	0	0	1	0	0	0
330	E	C	1	1	1	1	0	1	1	0	1	0
331	E	C	1	1	1	1	0	1	1	0	1	0
332	C	A	0	0	0	0	1	1	0	0	0	1
334	E	C	1	1	1	1	0	1	1	0	1	0
339	C	B	0	1	1	0	1	1	0	0	0	1
340	D	A	1	1	1	1	0	1	1	0	1	0
342	E	C	1	1	1	1	0	1	1	0	1	0
344	C	B	0	0	1	0	1	1	0	0	0	1
347	D	C	1	1	1	1	0	1	1	0	1	0
348	E	D	1	1	1	1	0	0	1	0	0	0
349	B	B	0	0	0	0	1	1	0	0	0	1
350	C	B	0	0	1	0	1	1	0	0	0	1
351	E	C	1	0	1	0	0	1	0	0	0	0
352	B	B	0	0	0	0	1	1	0	0	0	1
353	C	B	0	0	1	0	1	1	0	0	0	1
354	E	C	1	1	1	1	0	1	1	0	1	0
356	D	C	1	1	1	1	0	1	1	0	1	0
357	D	B	1	1	1	1	0	1	1	0	1	0
358	B	B	0	0	0	0	1	1	0	0	0	1
359	D	B	1	1	1	1	0	1	1	0	1	0
360	E	D	1	1	1	1	0	0	1	0	0	0

362	E	C	1	1	1	1	0	1	1	0	1	0
363	D	C	1	1	1	1	0	1	1	0	1	0
366	E	C	1	1	1	1	0	1	1	0	1	0
367	A	A	0	0	0	0	1	1	0	0	0	1
368	C	B	0	1	1	0	1	1	0	0	0	1
369	E	D	1	1	1	1	0	0	1	0	0	0
371	B	B	0	0	0	0	1	1	0	0	0	1
372	C	B	1	1	1	1	1	1	0	0	1	0
373	C	B	1	0	1	0	1	1	0	0	0	1
374	E	C	1	1	1	1	0	1	1	0	1	0
375	C	B	1	1	1	1	1	1	0	0	1	0
377	C	B	1	1	1	1	1	1	0	0	1	0
378	C	A	0	0	1	0	1	1	0	0	0	1
379	B	B	0	0	0	0	1	1	0	0	0	1
381	B	A	0	0	0	0	1	1	0	0	0	1
383	E	C	1	1	1	1	0	1	1	0	1	0
384	C	B	0	0	1	0	1	1	0	0	0	1
385	E	C	1	1	1	1	0	1	1	0	1	0
386	D	C	1	1	1	1	0	1	1	0	1	0
387	D	C	1	0	1	0	0	1	0	0	0	0
388	E	D	1	0	1	0	0	0	0	1	0	0
389	A	A	0	0	0	0	1	1	0	0	0	1
391	D	B	1	0	1	0	0	1	0	0	0	0
394	B	B	0	0	0	0	1	1	0	0	0	1
395	C	B	1	0	1	0	1	1	0	0	0	1
396	E	B	1	0	1	0	0	1	0	0	0	0
398	B	A	0	0	0	0	1	1	0	0	0	1
400	D	B	1	1	1	1	0	1	1	0	1	0
401	C	B	1	1	0	0	1	1	0	0	0	1
403	E	D	1	1	1	1	0	0	1	0	0	0
404	C	B	0	0	1	0	1	1	0	0	0	1
405	B	A	0	0	0	0	1	1	0	0	0	1
407	E	C	1	1	1	1	0	1	1	0	1	0
408	D	B	1	1	1	1	0	1	1	0	1	0
410	D	B	1	0	1	0	0	1	0	0	0	0
411	E	C	1	1	1	1	0	1	1	0	1	0
413	D	B	1	1	1	1	0	1	1	0	1	0
414	B	A	0	0	0	0	1	1	0	0	0	1
416	B	A	0	0	0	0	1	1	0	0	0	1
418	D	B	1	1	1	1	0	1	1	0	1	0
419	B	B	0	0	0	0	1	1	0	0	0	1
420	C	C	0	1	1	0	1	1	0	0	0	1
421	E	D	1	1	1	1	0	0	1	0	0	0

422	B	B	0	0	0	0	1	1	0	0	0	1
423	D	A	1	0	0	0	0	1	0	0	0	0
424	D	C	1	1	1	1	0	1	1	0	1	0
425	B	A	0	0	0	0	1	1	0	0	0	1
426	B	B	0	0	0	0	1	1	0	0	0	1
429	D	B	1	1	1	1	0	1	1	0	1	0
432	D	C	1	1	1	1	0	1	1	0	1	0
435	B	B	0	0	0	0	1	1	0	0	0	1
437	B	B	0	0	0	0	1	1	0	0	0	1
438	C	A	0	1	1	0	1	1	0	0	0	1
439	C	C	0	1	1	0	1	1	0	0	0	1
440	D	B	1	1	1	1	0	1	1	0	1	0
443	E	C	1	1	1	1	0	1	1	0	1	0
444	D	C	1	1	1	1	0	1	1	0	1	0
445	D	B	1	1	1	1	0	1	1	0	1	0
447	D	C	1	1	1	1	0	1	1	0	1	0
448	B	A	0	0	0	0	1	1	0	0	0	1
449	C	B	1	1	1	1	1	1	0	0	1	0
450	E	B	1	0	1	0	0	1	0	0	0	0
451	D	C	1	1	1	1	0	1	1	0	1	0
452	E	C	1	1	1	1	0	1	1	0	1	0
454	D	C	1	1	1	1	0	1	1	0	1	0
456	D	B	1	0	1	0	0	1	0	0	0	0
457	E	C	1	1	1	1	0	1	1	0	1	0
458	D	C	1	0	1	0	0	1	0	0	0	0
461	D	A	1	1	1	1	0	1	1	0	1	0
462	A	A	0	0	0	0	1	1	0	0	0	1
463	C	B	1	1	1	1	1	1	0	0	1	0
464	C	C	1	0	1	0	1	1	0	0	0	1
465	D	C	1	0	1	0	0	1	0	0	0	0
466	D	C	1	1	1	1	0	1	1	0	1	0
467	D	C	1	1	1	1	0	1	1	0	1	0
469	D	C	1	1	1	1	0	1	1	0	1	0
472	C	A	1	0	1	0	1	1	0	0	0	1
474	B	B	0	0	0	0	1	1	0	0	0	1
475	E	D	1	1	1	1	0	0	1	0	0	0
476	B	B	0	0	0	0	1	1	0	0	0	1
477	D	C	1	0	1	0	0	1	0	0	0	0
479	D	B	1	1	1	1	0	1	1	0	1	0
480	C	B	1	0	1	0	1	1	0	0	0	1
482	B	A	0	0	0	0	1	1	0	0	0	1
483	E	D	1	1	1	1	0	0	1	0	0	0
484	E	C	1	1	1	1	0	1	1	0	1	0

485	B	B	0	0	0	0	1	1	0	0	0	1
487	D	C	1	1	1	1	0	1	1	0	1	0
488	C	A	1	1	1	1	1	1	0	0	1	0
489	D	B	1	1	1	1	0	1	1	0	1	0
491	D	B	1	1	1	1	0	1	1	0	1	0
492	C	B	1	0	1	0	1	1	0	0	0	1
493	C	B	0	1	1	0	1	1	0	0	0	1
494	D	B	1	1	1	1	0	1	1	0	1	0
495	E	E	1	1	1	1	0	0	1	0	0	0
497	D	B	1	1	1	1	0	1	1	0	1	0
498	B	B	0	0	0	0	1	1	0	0	0	1
499	A	A	0	0	0	0	1	1	0	0	0	1
501	C	A	0	1	1	0	1	1	0	0	0	1
502	E	B	1	1	1	1	0	1	1	0	1	0
503	C	B	1	0	0	0	1	1	0	0	0	1
504	E	D	1	1	1	1	0	0	1	0	0	0
505	E	D	1	1	1	1	0	0	1	0	0	0
506	D	B	1	1	1	1	0	1	1	0	1	0
507	C	A	1	1	1	1	1	1	0	0	1	0
508	C	B	0	0	1	0	1	1	0	0	0	1
512	E	C	1	1	1	1	0	1	1	0	1	0
513	C	B	0	0	0	0	1	1	0	0	0	1
514	C	A	0	0	0	0	1	1	0	0	0	1
517	D	A	1	0	1	0	0	1	0	0	0	0
519	E	C	1	1	1	1	0	1	1	0	1	0
520	C	B	1	0	1	0	1	1	0	0	0	1
521	E	D	1	1	1	1	0	0	1	0	0	0
522	D	B	1	1	1	1	0	1	1	0	1	0
524	B	B	0	1	0	0	1	1	0	0	0	1
525	E	C	1	1	1	1	0	1	1	0	1	0
526	D	C	1	1	1	1	0	1	1	0	1	0
527	C	B	0	1	1	0	1	1	0	0	0	1
529	E	C	1	1	1	1	0	1	1	0	1	0
530	B	B	0	0	0	0	1	1	0	0	0	1
531	C	B	1	1	1	1	1	1	0	0	1	0
534	C	A	0	0	0	0	1	1	0	0	0	1
535	D	C	1	1	1	1	0	1	1	0	1	0
537	B	B	0	0	0	0	1	1	0	0	0	1
538	B	B	0	0	0	0	1	1	0	0	0	1
540	E	D	1	1	1	1	0	0	1	0	0	0
542	B	B	0	0	0	0	1	1	0	0	0	1
543	D	C	1	1	1	1	0	1	1	0	1	0
544	D	B	1	1	1	1	0	1	1	0	1	0

545	D	B	1	0	1	0	0	1	0	0	0	0
549	D	B	1	0	1	0	0	1	0	0	0	0
551	C	A	1	0	0	0	1	1	0	0	0	1
553	E	E	1	1	1	1	0	0	1	0	0	0
554	B	B	0	0	0	0	1	1	0	0	0	1
555	D	C	1	1	1	1	0	1	1	0	1	0
556	E	C	1	1	1	1	0	1	1	0	1	0
559	D	C	1	0	1	0	0	1	0	0	0	0
561	D	B	1	1	1	1	0	1	1	0	1	0
562	D	A	1	1	1	1	0	1	1	0	1	0
565	E	B	1	1	1	1	0	1	1	0	1	0
567	D	C	1	0	1	0	0	1	0	0	0	0
568	E	C	1	1	1	1	0	1	1	0	1	0
570	C	A	0	0	0	0	1	1	0	0	0	1
573	E	B	1	0	1	0	0	1	0	0	0	0
575	D	C	1	1	1	1	0	1	1	0	1	0
576	D	C	1	1	1	1	0	1	1	0	1	0
578	B	B	0	0	0	0	1	1	0	0	0	1
582	D	B	1	1	1	1	0	1	1	0	1	0
583	E	D	1	1	1	1	0	0	1	0	0	0
584	D	C	1	0	1	0	0	1	0	0	0	0
585	E	D	1	1	1	1	0	0	1	0	0	0
586	C	B	1	0	1	0	1	1	0	0	0	1
587	E	C	1	1	1	1	0	1	1	0	1	0
588	D	B	1	1	1	1	0	1	1	0	1	0
589	C	B	1	1	1	1	1	1	0	0	1	0
590	D	C	1	1	1	1	0	1	1	0	1	0
591	B	B	0	0	0	0	1	1	0	0	0	1
593	D	B	1	1	1	1	0	1	1	0	1	0
594	C	B	0	0	1	0	1	1	0	0	0	1
596	E	E	1	1	1	1	0	0	1	0	0	0
598	C	B	0	0	1	0	1	1	0	0	0	1
599	E	D	1	1	1	1	0	0	1	0	0	0
601	E	C	1	1	1	1	0	1	1	0	1	0

Appendix F:

Table 10: Classification and Error Rates

1	31	32	33	34	35	36	37	38	39
Scenario Number	**Proper Classification**	**Proper Classification Count**	**Proper Classification Rate**	**Type I Classification Error**	**Type I Error Count**	**Type I Error Rate**	**Type II Classification Error**	**Type II Error Count**	**Type II Error Rate**
1	1	1	1.00	0	0	0.00	0	0	0.00
2	0	1	0.50	0	0	0.00	1	1	0.50
3	0	1	0.33	0	0	0.00	1	2	0.67
5	1	2	0.50	0	0	0.00	0	2	0.50
7	1	3	0.60	0	0	0.00	0	2	0.40
8	0	3	0.50	0	0	0.00	1	3	0.50
12	0	3	0.43	0	0	0.00	1	4	0.57
15	0	3	0.38	1	1	0.13	0	4	0.50
17	0	3	0.33	0	1	0.11	1	5	0.56
18	1	4	0.40	0	1	0.10	0	5	0.50
19	0	4	0.36	0	1	0.09	1	6	0.55
21	0	4	0.33	1	2	0.17	0	6	0.50
22	0	4	0.31	1	3	0.23	0	6	0.46
24	0	4	0.29	0	3	0.21	1	7	0.50
25	0	4	0.27	0	3	0.20	1	8	0.53
28	1	5	0.31	0	3	0.19	0	8	0.50
29	1	6	0.35	0	3	0.18	0	8	0.47
31	0	6	0.33	0	3	0.17	1	9	0.50
32	0	6	0.32	0	3	0.16	1	10	0.53
33	0	6	0.30	0	3	0.15	1	11	0.55
34	1	7	0.33	0	3	0.14	0	11	0.52
36	1	8	0.36	0	3	0.14	0	11	0.50
37	0	8	0.35	1	4	0.17	0	11	0.48
38	0	8	0.33	1	5	0.21	0	11	0.46
39	0	8	0.32	1	6	0.24	0	11	0.44
41	1	9	0.35	0	6	0.23	0	11	0.42
44	0	9	0.33	1	7	0.26	0	11	0.41

45	0	9	0.32	0	7	0.25	1	12	0.43
46	0	9	0.31	0	7	0.24	1	13	0.45
47	1	10	0.33	0	7	0.23	0	13	0.43
48	1	11	0.35	0	7	0.23	0	13	0.42
49	0	11	0.34	0	7	0.22	1	14	0.44
50	0	11	0.33	0	7	0.21	1	15	0.45
51	0	11	0.32	0	7	0.21	1	16	0.47
53	1	12	0.34	0	7	0.20	0	16	0.46
54	0	12	0.33	1	8	0.22	0	16	0.44
55	1	13	0.35	0	8	0.22	0	16	0.43
56	0	13	0.34	0	8	0.21	1	17	0.45
57	0	13	0.33	0	8	0.21	1	18	0.46
58	1	14	0.35	0	8	0.20	0	18	0.45
59	1	15	0.37	0	8	0.20	0	18	0.44
61	0	15	0.36	1	9	0.21	0	18	0.43
62	1	16	0.37	0	9	0.21	0	18	0.42
65	0	16	0.36	1	10	0.23	0	18	0.41
66	1	17	0.38	0	10	0.22	0	18	0.40
67	0	17	0.37	1	11	0.24	0	18	0.39
68	0	17	0.36	0	11	0.23	1	19	0.40
69	0	17	0.35	0	11	0.23	1	20	0.42
70	0	17	0.35	0	11	0.22	1	21	0.43
72	0	17	0.34	1	12	0.24	0	21	0.42
73	1	18	0.35	0	12	0.24	0	21	0.41
74	0	18	0.35	0	12	0.23	1	22	0.42
76	0	18	0.34	0	12	0.23	1	23	0.43
79	1	19	0.35	0	12	0.22	0	23	0.43
80	0	19	0.35	0	12	0.22	1	24	0.44
81	1	20	0.36	0	12	0.21	0	24	0.43
82	0	20	0.35	0	12	0.21	1	25	0.44
84	0	20	0.34	0	12	0.21	1	26	0.45
85	1	21	0.36	0	12	0.20	0	26	0.44
87	0	21	0.35	0	12	0.20	1	27	0.45
88	1	22	0.36	0	12	0.20	0	27	0.44
89	0	22	0.35	0	12	0.19	1	28	0.45
90	0	22	0.35	0	12	0.19	1	29	0.46
91	0	22	0.34	0	12	0.19	1	30	0.47
92	0	22	0.34	1	13	0.20	0	30	0.46
94	0	22	0.33	0	13	0.20	1	31	0.47
95	0	22	0.33	0	13	0.19	1	32	0.48
96	1	23	0.34	0	13	0.19	0	32	0.47
99	0	23	0.33	0	13	0.19	1	33	0.48
100	0	23	0.33	0	13	0.19	1	34	0.49

101	0	23	0.32	0	13	0.18	1	35	0.49
102	0	23	0.32	0	13	0.18	1	36	0.50
103	0	23	0.32	1	14	0.19	0	36	0.49
105	1	24	0.32	0	14	0.19	0	36	0.49
106	1	25	0.33	0	14	0.19	0	36	0.48
107	1	26	0.34	0	14	0.18	0	36	0.47
108	0	26	0.34	1	15	0.19	0	36	0.47
109	0	26	0.33	0	15	0.19	1	37	0.47
110	0	26	0.33	0	15	0.19	1	38	0.48
111	1	27	0.34	0	15	0.19	0	38	0.48
113	1	28	0.35	0	15	0.19	0	38	0.47
118	1	29	0.35	0	15	0.18	0	38	0.46
119	1	30	0.36	0	15	0.18	0	38	0.46
122	0	30	0.36	0	15	0.18	1	39	0.46
123	1	31	0.36	0	15	0.18	0	39	0.46
125	0	31	0.36	1	16	0.19	0	39	0.45
128	1	32	0.37	0	16	0.18	0	39	0.45
130	0	32	0.36	1	17	0.19	0	39	0.44
131	0	32	0.36	0	17	0.19	1	40	0.45
132	1	33	0.37	0	17	0.19	0	40	0.44
133	1	34	0.37	0	17	0.19	0	40	0.44
134	0	34	0.37	0	17	0.18	1	41	0.45
135	1	35	0.38	0	17	0.18	0	41	0.44
136	0	35	0.37	0	17	0.18	1	42	0.45
137	0	35	0.37	0	17	0.18	1	43	0.45
138	0	35	0.36	1	18	0.19	0	43	0.45
140	0	35	0.36	0	18	0.19	1	44	0.45
143	0	35	0.36	1	19	0.19	0	44	0.45
145	1	36	0.36	0	19	0.19	0	44	0.44
149	0	36	0.36	0	19	0.19	1	45	0.45
150	1	37	0.37	0	19	0.19	0	45	0.45
151	0	37	0.36	0	19	0.19	1	46	0.45
154	0	37	0.36	0	19	0.18	1	47	0.46
156	0	37	0.36	0	19	0.18	1	48	0.46
157	0	37	0.35	1	20	0.19	0	48	0.46
160	1	38	0.36	0	20	0.19	0	48	0.45
161	0	38	0.36	0	20	0.19	1	49	0.46
162	0	38	0.35	0	20	0.19	1	50	0.46
166	1	39	0.36	0	20	0.18	0	50	0.46
167	1	40	0.36	0	20	0.18	0	50	0.45
168	0	40	0.36	0	20	0.18	1	51	0.46
169	1	41	0.37	0	20	0.18	0	51	0.46
170	1	42	0.37	0	20	0.18	0	51	0.45

171	0	42	0.37	1	21	0.18	0	51	0.45
172	1	43	0.37	0	21	0.18	0	51	0.44
174	0	43	0.37	1	22	0.19	0	51	0.44
176	0	43	0.37	0	22	0.19	1	52	0.44
177	1	44	0.37	0	22	0.19	0	52	0.44
179	0	44	0.37	0	22	0.18	1	53	0.45
181	0	44	0.37	0	22	0.18	1	54	0.45
183	0	44	0.36	0	22	0.18	1	55	0.45
184	0	44	0.36	0	22	0.18	1	56	0.46
185	0	44	0.36	0	22	0.18	1	57	0.46
186	0	44	0.35	1	23	0.19	0	57	0.46
189	1	45	0.36	0	23	0.18	0	57	0.46
190	1	46	0.37	0	23	0.18	0	57	0.45
191	1	47	0.37	0	23	0.18	0	57	0.45
192	0	47	0.37	0	23	0.18	1	58	0.45
193	1	48	0.37	0	23	0.18	0	58	0.45
194	1	49	0.38	0	23	0.18	0	58	0.45
197	0	49	0.37	0	23	0.18	1	59	0.45
199	0	49	0.37	0	23	0.17	1	60	0.45
200	1	50	0.38	0	23	0.17	0	60	0.45
203	1	51	0.38	0	23	0.17	0	60	0.45
204	0	51	0.38	0	23	0.17	1	61	0.45
205	0	51	0.38	1	24	0.18	0	61	0.45
206	0	51	0.37	1	25	0.18	0	61	0.45
207	1	52	0.38	0	25	0.18	0	61	0.44
208	0	52	0.37	1	26	0.19	0	61	0.44
210	1	53	0.38	0	26	0.19	0	61	0.44
211	0	53	0.38	0	26	0.18	1	62	0.44
212	1	54	0.38	0	26	0.18	0	62	0.44
213	0	54	0.38	0	26	0.18	1	63	0.44
214	1	55	0.38	0	26	0.18	0	63	0.44
215	0	55	0.38	0	26	0.18	1	64	0.44
218	1	56	0.38	0	26	0.18	0	64	0.44
220	1	57	0.39	0	26	0.18	0	64	0.44
221	1	58	0.39	0	26	0.18	0	64	0.43
222	1	59	0.40	0	26	0.17	0	64	0.43
224	1	60	0.40	0	26	0.17	0	64	0.43
225	1	61	0.40	0	26	0.17	0	64	0.42
229	1	62	0.41	0	26	0.17	0	64	0.42
231	0	62	0.41	0	26	0.17	1	65	0.42
232	0	62	0.40	0	26	0.17	1	66	0.43
234	0	62	0.40	0	26	0.17	1	67	0.43
235	1	63	0.40	0	26	0.17	0	67	0.43

236	0	63	0.40	0	26	0.17	1	68	0.43
237	1	64	0.41	0	26	0.16	0	68	0.43
240	0	64	0.40	0	26	0.16	1	69	0.43
241	0	64	0.40	0	26	0.16	1	70	0.44
242	0	64	0.40	0	26	0.16	1	71	0.44
243	0	64	0.40	0	26	0.16	1	72	0.44
244	1	65	0.40	0	26	0.16	0	72	0.44
245	1	66	0.40	0	26	0.16	0	72	0.44
246	1	67	0.41	0	26	0.16	0	72	0.44
247	0	67	0.40	0	26	0.16	1	73	0.44
249	0	67	0.40	0	26	0.16	1	74	0.44
250	0	67	0.40	0	26	0.15	1	75	0.45
251	0	67	0.40	0	26	0.15	1	76	0.45
253	0	67	0.39	0	26	0.15	1	77	0.45
254	1	68	0.40	0	26	0.15	0	77	0.45
255	0	68	0.40	1	27	0.16	0	77	0.45
256	0	68	0.39	1	28	0.16	0	77	0.45
257	0	68	0.39	1	29	0.17	0	77	0.44
259	0	68	0.39	0	29	0.17	1	78	0.45
261	0	68	0.39	0	29	0.16	1	79	0.45
262	1	69	0.39	0	29	0.16	0	79	0.45
266	0	69	0.39	0	29	0.16	1	80	0.45
267	1	70	0.39	0	29	0.16	0	80	0.45
268	0	70	0.39	0	29	0.16	1	81	0.45
271	1	71	0.39	0	29	0.16	0	81	0.45
272	0	71	0.39	0	29	0.16	1	82	0.45
273	1	72	0.39	0	29	0.16	0	82	0.45
274	0	72	0.39	0	29	0.16	1	83	0.45
275	0	72	0.39	0	29	0.16	1	84	0.45
276	0	72	0.39	0	29	0.16	1	85	0.46
277	0	72	0.39	1	30	0.16	0	85	0.45
280	0	72	0.38	0	30	0.16	1	86	0.46
281	1	73	0.39	0	30	0.16	0	86	0.46
283	1	74	0.39	0	30	0.16	0	86	0.45
284	0	74	0.39	0	30	0.16	1	87	0.46
286	0	74	0.39	0	30	0.16	1	88	0.46
288	0	74	0.38	0	30	0.16	1	89	0.46
289	0	74	0.38	0	30	0.15	1	90	0.46
291	0	74	0.38	0	30	0.15	1	91	0.47
292	0	74	0.38	0	30	0.15	1	92	0.47
293	0	74	0.38	1	31	0.16	0	92	0.47
294	0	74	0.37	0	31	0.16	1	93	0.47
295	0	74	0.37	0	31	0.16	1	94	0.47

303	0	74	0.37	0	31	0.16	1	95	0.48
305	1	75	0.37	0	31	0.15	0	95	0.47
306	0	75	0.37	0	31	0.15	1	96	0.48
309	0	75	0.37	1	32	0.16	0	96	0.47
310	1	76	0.37	0	32	0.16	0	96	0.47
311	0	76	0.37	0	32	0.16	1	97	0.47
312	0	76	0.37	1	33	0.16	0	97	0.47
313	0	76	0.37	0	33	0.16	1	98	0.47
314	0	76	0.37	1	34	0.16	0	98	0.47
315	0	76	0.36	0	34	0.16	1	99	0.47
316	1	77	0.37	0	34	0.16	0	99	0.47
317	0	77	0.36	0	34	0.16	1	100	0.47
319	0	77	0.36	1	35	0.17	0	100	0.47
320	0	77	0.36	1	36	0.17	0	100	0.47
321	0	77	0.36	1	37	0.17	0	100	0.47
323	0	77	0.36	0	37	0.17	1	101	0.47
324	0	77	0.36	1	38	0.18	0	101	0.47
325	0	77	0.35	1	39	0.18	0	101	0.47
327	0	77	0.35	0	39	0.18	1	102	0.47
328	0	77	0.35	0	39	0.18	1	103	0.47
329	0	77	0.35	1	40	0.18	0	103	0.47
330	1	78	0.35	0	40	0.18	0	103	0.47
331	1	79	0.36	0	40	0.18	0	103	0.46
332	0	79	0.35	0	40	0.18	1	104	0.47
334	1	80	0.36	0	40	0.18	0	104	0.46
339	0	80	0.36	0	40	0.18	1	105	0.47
340	1	81	0.36	0	40	0.18	0	105	0.46
342	1	82	0.36	0	40	0.18	0	105	0.46
344	0	82	0.36	0	40	0.18	1	106	0.46
347	1	83	0.36	0	40	0.17	0	106	0.46
348	0	83	0.36	1	41	0.18	0	106	0.46
349	0	83	0.36	0	41	0.18	1	107	0.46
350	0	83	0.36	0	41	0.18	1	108	0.47
351	0	83	0.36	0	41	0.18	1	109	0.47
352	0	83	0.35	0	41	0.18	1	110	0.47
353	0	83	0.35	0	41	0.17	1	111	0.47
354	1	84	0.36	0	41	0.17	0	111	0.47
356	1	85	0.36	0	41	0.17	0	111	0.47
357	1	86	0.36	0	41	0.17	0	111	0.47
358	0	86	0.36	0	41	0.17	1	112	0.47
359	1	87	0.36	0	41	0.17	0	112	0.47
360	0	87	0.36	1	42	0.17	0	112	0.46
362	1	88	0.36	0	42	0.17	0	112	0.46

363	1	89	0.37	0	42	0.17	0	112	0.46
366	1	90	0.37	0	42	0.17	0	112	0.46
367	0	90	0.37	0	42	0.17	1	113	0.46
368	0	90	0.37	0	42	0.17	1	114	0.46
369	0	90	0.36	1	43	0.17	0	114	0.46
371	0	90	0.36	0	43	0.17	1	115	0.46
372	0	90	0.36	1	44	0.18	0	115	0.46
373	0	90	0.36	0	44	0.18	1	116	0.46
374	1	91	0.36	0	44	0.18	0	116	0.46
375	0	91	0.36	1	45	0.18	0	116	0.46
377	0	91	0.36	1	46	0.18	0	116	0.46
378	0	91	0.36	0	46	0.18	1	117	0.46
379	0	91	0.36	0	46	0.18	1	118	0.46
381	0	91	0.36	0	46	0.18	1	119	0.46
383	1	92	0.36	0	46	0.18	0	119	0.46
384	0	92	0.36	0	46	0.18	1	120	0.47
385	1	93	0.36	0	46	0.18	0	120	0.46
386	1	94	0.36	0	46	0.18	0	120	0.46
387	0	94	0.36	0	46	0.18	1	121	0.46
388	0	94	0.36	0	46	0.18	1	122	0.47
389	0	94	0.36	0	46	0.17	1	123	0.47
391	0	94	0.36	0	46	0.17	1	124	0.47
394	0	94	0.35	0	46	0.17	1	125	0.47
395	0	94	0.35	0	46	0.17	1	126	0.47
396	0	94	0.35	0	46	0.17	1	127	0.48
398	0	94	0.35	0	46	0.17	1	128	0.48
400	1	95	0.35	0	46	0.17	0	128	0.48
401	0	95	0.35	0	46	0.17	1	129	0.48
403	0	95	0.35	1	47	0.17	0	129	0.48
404	0	95	0.35	0	47	0.17	1	130	0.48
405	0	95	0.35	0	47	0.17	1	131	0.48
407	1	96	0.35	0	47	0.17	0	131	0.48
408	1	97	0.35	0	47	0.17	0	131	0.48
410	0	97	0.35	0	47	0.17	1	132	0.48
411	1	98	0.35	0	47	0.17	0	132	0.48
413	1	99	0.36	0	47	0.17	0	132	0.47
414	0	99	0.35	0	47	0.17	1	133	0.48
416	0	99	0.35	0	47	0.17	1	134	0.48
418	1	100	0.36	0	47	0.17	0	134	0.48
419	0	100	0.35	0	47	0.17	1	135	0.48
420	0	100	0.35	0	47	0.17	1	136	0.48
421	0	100	0.35	1	48	0.17	0	136	0.48
422	0	100	0.35	0	48	0.17	1	137	0.48

423	0	100	0.35	0	48	0.17	1	138	0.48
424	1	101	0.35	0	48	0.17	0	138	0.48
425	0	101	0.35	0	48	0.17	1	139	0.48
426	0	101	0.35	0	48	0.17	1	140	0.48
429	1	102	0.35	0	48	0.17	0	140	0.48
432	1	103	0.35	0	48	0.16	0	140	0.48
435	0	103	0.35	0	48	0.16	1	141	0.48
437	0	103	0.35	0	48	0.16	1	142	0.48
438	0	103	0.35	0	48	0.16	1	143	0.49
439	0	103	0.35	0	48	0.16	1	144	0.49
440	1	104	0.35	0	48	0.16	0	144	0.49
443	1	105	0.35	0	48	0.16	0	144	0.48
444	1	106	0.36	0	48	0.16	0	144	0.48
445	1	107	0.36	0	48	0.16	0	144	0.48
447	1	108	0.36	0	48	0.16	0	144	0.48
448	0	108	0.36	0	48	0.16	1	145	0.48
449	0	108	0.36	1	49	0.16	0	145	0.48
450	0	108	0.36	0	49	0.16	1	146	0.48
451	1	109	0.36	0	49	0.16	0	146	0.48
452	1	110	0.36	0	49	0.16	0	146	0.48
454	1	111	0.36	0	49	0.16	0	146	0.48
456	0	111	0.36	0	49	0.16	1	147	0.48
457	1	112	0.36	0	49	0.16	0	147	0.48
458	0	112	0.36	0	49	0.16	1	148	0.48
461	1	113	0.36	0	49	0.16	0	148	0.48
462	0	113	0.36	0	49	0.16	1	149	0.48
463	0	113	0.36	1	50	0.16	0	149	0.48
464	0	113	0.36	0	50	0.16	1	150	0.48
465	0	113	0.36	0	50	0.16	1	151	0.48
466	1	114	0.36	0	50	0.16	0	151	0.48
467	1	115	0.36	0	50	0.16	0	151	0.48
469	1	116	0.37	0	50	0.16	0	151	0.48
472	0	116	0.36	0	50	0.16	1	152	0.48
474	0	116	0.36	0	50	0.16	1	153	0.48
475	0	116	0.36	1	51	0.16	0	153	0.48
476	0	116	0.36	0	51	0.16	1	154	0.48
477	0	116	0.36	0	51	0.16	1	155	0.48
479	1	117	0.36	0	51	0.16	0	155	0.48
480	0	117	0.36	0	51	0.16	1	156	0.48
482	0	117	0.36	0	51	0.16	1	157	0.48
483	0	117	0.36	1	52	0.16	0	157	0.48
484	1	118	0.36	0	52	0.16	0	157	0.48
485	0	118	0.36	0	52	0.16	1	158	0.48

487	1	119	0.36	0	52	0.16	0	158	0.48
488	0	119	0.36	1	53	0.16	0	158	0.48
489	1	120	0.36	0	53	0.16	0	158	0.48
491	1	121	0.36	0	53	0.16	0	158	0.48
492	0	121	0.36	0	53	0.16	1	159	0.48
493	0	121	0.36	0	53	0.16	1	160	0.48
494	1	122	0.36	0	53	0.16	0	160	0.48
495	0	122	0.36	1	54	0.16	0	160	0.48
497	1	123	0.36	0	54	0.16	0	160	0.47
498	0	123	0.36	0	54	0.16	1	161	0.48
499	0	123	0.36	0	54	0.16	1	162	0.48
501	0	123	0.36	0	54	0.16	1	163	0.48
502	1	124	0.36	0	54	0.16	0	163	0.48
503	0	124	0.36	0	54	0.16	1	164	0.48
504	0	124	0.36	1	55	0.16	0	164	0.48
505	0	124	0.36	1	56	0.16	0	164	0.48
506	1	125	0.36	0	56	0.16	0	164	0.48
507	0	125	0.36	1	57	0.16	0	164	0.47
508	0	125	0.36	0	57	0.16	1	165	0.48
512	1	126	0.36	0	57	0.16	0	165	0.47
513	0	126	0.36	0	57	0.16	1	166	0.48
514	0	126	0.36	0	57	0.16	1	167	0.48
517	0	126	0.36	0	57	0.16	1	168	0.48
519	1	127	0.36	0	57	0.16	0	168	0.48
520	0	127	0.36	0	57	0.16	1	169	0.48
521	0	127	0.36	1	58	0.16	0	169	0.48
522	1	128	0.36	0	58	0.16	0	169	0.48
524	0	128	0.36	0	58	0.16	1	170	0.48
525	1	129	0.36	0	58	0.16	0	170	0.48
526	1	130	0.36	0	58	0.16	0	170	0.47
527	0	130	0.36	0	58	0.16	1	171	0.48
529	1	131	0.36	0	58	0.16	0	171	0.48
530	0	131	0.36	0	58	0.16	1	172	0.48
531	0	131	0.36	1	59	0.16	0	172	0.48
534	0	131	0.36	0	59	0.16	1	173	0.48
535	1	132	0.36	0	59	0.16	0	173	0.48
537	0	132	0.36	0	59	0.16	1	174	0.48
538	0	132	0.36	0	59	0.16	1	175	0.48
540	0	132	0.36	1	60	0.16	0	175	0.48
542	0	132	0.36	0	60	0.16	1	176	0.48
543	1	133	0.36	0	60	0.16	0	176	0.48
544	1	134	0.36	0	60	0.16	0	176	0.48
545	0	134	0.36	0	60	0.16	1	177	0.48

549	0	134	0.36	0	60	0.16	1	178	0.48
551	0	134	0.36	0	60	0.16	1	179	0.48
553	0	134	0.36	1	61	0.16	0	179	0.48
554	0	134	0.36	0	61	0.16	1	180	0.48
555	1	135	0.36	0	61	0.16	0	180	0.48
556	1	136	0.36	0	61	0.16	0	180	0.48
559	0	136	0.36	0	61	0.16	1	181	0.48
561	1	137	0.36	0	61	0.16	0	181	0.48
562	1	138	0.36	0	61	0.16	0	181	0.48
565	1	139	0.36	0	61	0.16	0	181	0.48
567	0	139	0.36	0	61	0.16	1	182	0.48
568	1	140	0.37	0	61	0.16	0	182	0.48
570	0	140	0.36	0	61	0.16	1	183	0.48
573	0	140	0.36	0	61	0.16	1	184	0.48
575	1	141	0.37	0	61	0.16	0	184	0.48
576	1	142	0.37	0	61	0.16	0	184	0.48
578	0	142	0.37	0	61	0.16	1	185	0.48
582	1	143	0.37	0	61	0.16	0	185	0.48
583	0	143	0.37	1	62	0.16	0	185	0.47
584	0	143	0.37	0	62	0.16	1	186	0.48
585	0	143	0.36	1	63	0.16	0	186	0.47
586	0	143	0.36	0	63	0.16	1	187	0.48
587	1	144	0.37	0	63	0.16	0	187	0.47
588	1	145	0.37	0	63	0.16	0	187	0.47
589	0	145	0.37	1	64	0.16	0	187	0.47
590	1	146	0.37	0	64	0.16	0	187	0.47
591	0	146	0.37	0	64	0.16	1	188	0.47
593	1	147	0.37	0	64	0.16	0	188	0.47
594	0	147	0.37	0	64	0.16	1	189	0.47
596	0	147	0.37	1	65	0.16	0	189	0.47
598	0	147	0.37	0	65	0.16	1	190	0.47
599	0	147	0.36	1	66	0.16	0	190	0.47
601	1	148	0.37	0	66	0.16	0	190	0.47

Appendix G: Permission Letter from American Association of State Highway and Transportation Officials

AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS

AASHTO

JOHN SCHROER, PRESIDENT
COMMISSIONER, TENNESSEE DEPARTMENT OF TRANSPORTATION

BUD WRIGHT, EXECUTIVE DIRECTOR

444 NORTH CAPITOL STREET NW, SUITE 249, WASHINGTON, DC 20001
(202) 624-5800 • FAX: (202) 624-5806 • WWW.TRANSPORTATION.ORG

May 25, 2018

Luisa Schülke
14 Penobscot Trail
Narragansett, RI 02882

Dear Ms. Schülke:

This is in response to your recent email requesting permission to reproduce Figures 3-28 and 3-30 from the 2011 edition of the AASHTO publication *A Policy on Geometric Design of Highways and Streets* and include both of those figures in your master's thesis at the University of Rhode Island.

You have AASHTO's permission to use both of the aforementioned excerpts. Please note that this authorization applies only to your master's thesis. In addition, please insert the following language or something similar with each excerpt:

From *A Policy on Geometric Design of Highways and Streets*, 2011, by the American Association of State Highway and Transportation Officials, Washington, D.C. Used with permission.

If you have any questions about this letter, please do not hesitate to contact me at bcullen@aashto.org or 202-624-8918.

Sincerely,

Robert Cullen
Information Resource Manager

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