Montana Department of Transportation

TRANSPORTATION REGIONAL ECONOMIC DEVELOPMENT

# TRED

THEODORE ROOSEVELT EXPRESSWAY

## Working Paper #5: Level of Service and Safety

Final

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# TABLE OF CONTENTS

# 1 INTRODUCTION

## Overview

Safety and Level of Service are the two key issues that transportation planners and decision-makers at federal, state, and local levels aim at addressing. While level of service rating relates the overall efficiency of the roadway in facilitating the flow of traffic, overall accident rate or fatal accident rate of the roadway represents the safety performance of the roadway.

The level of service rating of a roadway relates how well the roadway is performing its primary function, allowing motorists to travel to their destinations in a timely and efficient manner. When level of service is high, traffic flows freely and without congestion, but as the level of service declines, vehicular interactions increase and traffic speeds decline due to the addition of traffic congestion.

In rural areas, congestion is not a major factor and therefore the focus is mainly on the safety of the roadways. Safety issues in rural areas can range from geometry related-issues which affect visibility (horizontal and vertical alignment), intersections, side slope conditions, clear zones, lack of passing lanes, truck volumes and speed differential.

There are many options available to address safety issues on rural highways. Each roadway segment can be analyzed to determine the appropriate treatment to improve safety. Some of the treatments can be improving the horizontal and vertical alignment of the roadway, providing flatter side slopes, providing clear zone, providing wider shoulders, providing auxiliary turn lanes where needed, providing passing lanes where needed, and expanding a two-lane facility to a four-lane facility where justified based on capacity and/or safety.

This paper addresses the capacity and safety issues as it relates to the TRED corridor. Given the findings, stated in Working Paper #4, pertaining to the projected high percentage of truck traffic in the next twenty years. The capacity analysis used the truck percentage of thirty.

# 2 LEVEL OF SERVICE

This section provides an overview of level of service (LOS), TRED level of service planning goals, and the existing capacity and level of service in the study area. Traffic volumes for the TRED corridor are compared with capacities to determine the current quality of service on the highway.

## 2.1 Levels of Service

### 2.1.1 Categories

Level of service is a method of measuring the vehicle capacity in an area. When the capacity of a roadway is exceeded, this condition results in congestion and a poor level of service. Six levels of service ranging from A to F are used to define congestion and the operating conditions on roadways, with LOS A representing the best operating conditions (free-flowing traffic) and LOS F the worst operating conditions (extremely congested, stop-and-go traffic). Table 1 illustrates the level of service for a two-lane, Class I highway (primary arterials connecting major traffic generators/daily commuter routes/primary links to state or national highway networks) according to highway capacity standards.

**Table 1: Level of Service Criteria for Two-Lane Highways in Class I**

| Level of Service (LOS) | Level of Service Definitions | Percent of Time Spent Following Other Vehicles | Average Vehicle Speed (mph) |
|---|---|---|---|
| A | Motorists can travel at their desired speed. No more than 35% of the time is spent following other vehicles. | 35% | 55 |
| B | Average speed of 50–55 mph. Demand for passing is high. 50% of the time is spent following other vehicles. | 35–50% | 50–55 |
| C | Average speed of 45–50 mph. Noticeable increase in following traffic with reduction in passing opportunities. | 50–65% | 45–50 |
| D | Unstable traffic flow. Passing demand is high but passing opportunities approach zero. Vehicle following length of 5 to 10 vehicles and average speeds of 40–45 mph. | 65–80% | 40–45 |
| E | Average speed below 40 mph. 80% of the time is spent following other vehicles. Passing is virtually impossible. | 80% | 40 |

| Level of Service (LOS) | Level of Service Definitions | Percent of Time Spent Following Other Vehicles | Average Vehicle Speed (mph) |
|---|---|---|---|
| LOS F applies whenever the number of vehicles traveling on the highway exceeds the roadway capacity. | | | |
| Average Vehicle Speed assumes a free-flow speed of 60 mph. | | | |
| Source: Transportation Research Board 2000 | | | |

### 2.1.2 Planning Goals

According to Table 1 above, level of service on two-lane rural highways is defined by speed and percent of time spent following other vehicles. As traffic levels increase, particularly with the presence of trucks and heavy vehicles, the amount of time vehicles spend following other vehicles increases. Speeds begin to decline slightly, the freedom to maneuver within the traffic stream is more noticeably limited, and drivers often experience reduced physical and psychological comfort. This decrease in speed and increase in time spent following other vehicles leads to both a decreased level of service and a possible increase in accident rates as drivers seek opportunities to pass.

Consistent with the Federal Highway Administration's functional classification criteria, the TRED corridor is a rural principal arterial, which applies to the highways that typically provide high travel speeds and the longest trip movements. A highway’s functional classification determines which geometric design standards are applied for that facility. MDT’s Road Design Manual contains geometric design and level of service guidelines for roads, based on functional classification. As a general design consideration, designers should strive for the highest level of service that is practical and is consistent with anticipated conditions. For principal arterials in level terrain, such as the TRED corridor, MDT has set a level of service objective of “B”.

## 2.2 Existing and Future Level of Service

For the analysis of the level of service conditions on the TRED corridor, the study area was divided into three segments:  MT 16 from the Port of Raymond to Plentywood, MT 16 from Plentywood to Culbertson, and US 2 from Culbertson to the North Dakota State line.

MDT has adopted the Highway Capacity Manual (HCM) as the standard methodology for calculating level of service. The HCM presents the nationwide criteria for performing capacity analyses for highway facilities. Included in Appendix A are the LOS calculation worksheets for the TRED corridor.  The existing lane configuration was used in our analysis for both the existing traffic volumes and proposed future traffic volumes in 2036. future traffic volumes used in the capacity analysis are those from Working Paper #4 that have a 10% chance of exceeding in 2036.

### 2.2.1 Existing Level of Service

The existing level of service analysis used traffic volume, large-truck percentage, percent of passing zones, the number of access points (driveways, roads, etc.) per mile, and lane and shoulder width information provided by MDT in the analysis. Other factors, such as the type of terrain or the directional traffic split (the amount of vehicle traveling in each direction) were determined from local observation or by applying default values from the HCM, which is consistent with the guidance in MDT's Road Design Manual.

### 2.2.2 Future Level of Service

The future level of service analysis was performed using the same assumptions for the existing conditions with some modifications to account for the future peak travel period.

Table 2 illustrates the results of the analysis of existing (2006) and future (2036) level of service conditions for each segment of the TRED corridor. As shown in Table 2, the existing and future levels of service meet the guidelines of LOS "B" for this type of facility.

**Table 2: TRED Corridor Current and Future Levels of Service**

| Segment | MDT LOS Guidelines | 2006 LOS | 2036 LOS[a] | Terrain |
|---|---|---|---|---|
| MT 16 from Port of Raymond to Plentywood | B | A | B | Level |
| MT 16 from Plentywood to Culbertson | B | A | B | Level |
| US 2 from Culbertson to the North Dakota State line | B | A | B | Level |

[a] The existing highway corridor was used with no improvements.

Table 2 above provides the level of service for the TRED corridor based on existing conditions and the year 2036, assuming no capacity-related improvements to the corridor. The future capacity analyses were performed using statistical median traffic volumes, as well as volumes for the 10-percent and 90-percent confidence intervals. As shown in Table 2, with the future traffic volumes for the 10-percent confidence interval (worst case scenario), the TRED corridor will operate at an acceptable LOS "B" in 2036 with no capacity related improvements.  As shown in the LOS worksheets in the appendix, the LOS is at the upper end of the "B" range and close to the "C" range.

# 3 SAFETY ANALYSIS

With over 42,000 fatalities occurring annually on America's highways, improving highway safety performance is central component of the Federal Highway Administration's mission, accordingly, FHWA's website states, "Safety on our highways is FHWA's top priority." Highway safety is also listed as one of the three Federal Highway Administration's "Vital Few Priorities," comprising safety, congestion mitigation, and environmental stewardship and streamlining. Consequently, it is clear that FHWA considers safety improvements to be of critical importance when determining the validity of highway improvement projects.

Likewise the Montana Department of Transportation takes into account the safety benefits of transportation projects it considers undertaking. The importance of improving the safety of Montana's roadways is apparent as safety is framed as one of the key elements of MDT's mission statement.

> "MDT's mission is to serve the public by providing a transportation system and services that emphasize quality, safety, cost effectiveness, economic vitality and sensitivity to the environment."

As government institutions charged with serving the public, increasing the safety performance of roadways is one of the primary methods that transportation agencies can use to increase the public welfare. It is because of this fact, that opportunities to improve the safety of the nation's roadways are a key consideration in transportation planning decisions.

The commitment to improving highway safety by both FHWA and MDT is evident by the central placement of safety within their mission statements. The importance of that commitment is clear; increasing the safety performance of roadways affects the public directly by reducing injuries, property damage, and fatalities. This reality is the motivation for this chapter's analysis.

## 3.1 Existing Research

An extensive search for the safety benefits of a 4-lane roadway compared to a 2-lane roadway was completed. However, no comparable routes to the TRED corridor were found. Therefore, conclusion from the studies in other corridors can not be used to draw conclusions in the TRED corridor.

## 3.2 Speed Limit Differential

The MT 16 and US 2 sections of the TRED corridor within the state of Montana are governed by dual speed limits; one limit for large trucks, and a 10 mph higher limit for passenger vehicles.

Because of this disparity in speed limits, it was hypothesized that an inherent unsafe driving environment existed. A 2003 study and a 2006 follow-up both by Garber et al. examined states with dual speed limits and ones without to determine if the dual speed limit states showed increased crash rates. The studies looked at six states, three of which maintained a uniform speed limit during the 1990's, Arizona, Missouri, and North Carolina. Two of the states examined changed to a dual speed limit during this time period, Idaho and Arkansas. And one state changed from a differential speed limit to a uniform speed limit, Virginia. The authors conducted statistical tests across road segments within each state to determine if there were any statistically significant increases in the crash rates across the groups of states. They found no consistent link to increased crash rates within the states that had dual speed limits.

These studies, however, only considered multi-lane interstate sections, focusing on the expected safety hazard where slower moving trucks are traveling in the right lane and faster moving cars are passing the larger trucks while traveling in the left lane of the four-lane highway. Because of this fact, the results may not reflect the true safety ramifications along two-lane rural roadways, such as those comprising the study area corridor.

## 3.3 Montana Crash Data

Montana crash data for the MT 16 and US 2 sections of the TRED study area corridor and other comparable rural two-lane roadways is provided in Table 3. The sections of roadways outside the study area corridor were selected because they exhibit similar traffic volumes and have similar fractions of overall traffic composed of large trucks. Crash rates and severity rates for overall traffic and for large trucks are shown in Table 3.

**Table 3: Crash and Severity Rates for Various Rural Two-Lane and Four-Lane Montana Roadways 2001-2005 (Per Million VMT)**

| Roadway Segment | Milepost Start | Milepost End | Description | Segment AADT | Percent Trucks | Overall Crash Rate | Truck Crash Rate | Overall Severity Rate |
|---|---|---|---|---|---|---|---|---|
| **N-1 (US 2)** | **645** | **667** | **Culbertson to North Dakota Border** | **1186** | **10.7%** | **1.40** | **0.78** | **3.44** |
| **N-34 (MT 16)** | **0** | **15.4** | **Saskatchewan Border to Plentywood** | **731** | **12.7%** | **0.15** | **0.39** | **0.60** |
| **N-22 (MT 16)** | **42.3** | **88.5** | **Plentywood to Culbertson** | **1028** | **14.4%** | **0.63** | **0.88** | **1.63** |
| N-1 (US 2) | 383.7 | 428.5 | US-2 Havre to Fort Belknap | 2727 | 8.7% | 1.27 | 1.13 | 2.54 |
| N-62 (MT 16) | 0 | 36.6 | Culbertson to Sidney | 1142 | 12.1% | 0.91 | 1.00 | 1.56 |
| N-53 (MT 3) | 3.5 | 46.7 | Billings to Lavina | 2181 | 13.0% | 0.69 | 0.76 | 1.42 |
| N-14(MT 3) | 99 | 146 | Harlowton to Lavina | 1554 | 19.1% | 0.95 | 0.55 | 1.86 |
| N-8 (US 12) 4-lane | 32.5 | 40.5 | Helena to bottom of MacDonald Pass | 3944 | 9.0% | 2.07 | 0.93 | 2.75 |
| N-14 (MT 3)4-lane w/ TWLTL | 87.3 | 90.4 | Great Falls to Jct. S227/S228 | 6202 | 9.4% | 1.34 | 0.90 | 3.77 |

*Segments that comprise the Montana portion of the TRED corridor are highlighted in bold*

The crash and severity rates listed in the above table can be compared to the statewide averages for rural principal arterials on the National Highway System (NHS). The statewide average for the crash rate is 1.24 and for severity the rate is 2.88. As can be shown in the table above the only segment that is over the statewide average crash rate and severity rate is the segment of US 2 between Culbertson and the North Dakota Border.

The crashes were analyzed in more detail on the segments within the TRED corridor and the results are as follows:

| | Single Vehicle | Multiple Vehicle Turning Related | Multiple Vehicle Passing Related | Involves Trucks |
|---|---|---|---|---|
| US 2 Culbertson to North Dakota Border | 86.6% | 9.0% | 1.5% | 6% |
| MT 16 Saskatchewan Border to Plentywood | 100% | | | 33% |
| MT 16 Plentywood to Culbertson | 83.6% | 3.6% | 1.8% | 18% |

## 3.4 Projected Safety Conditions

The projected safety conditions were analyzed extensively in the US-2, Havre to Fort Belknap EIS for different lane configurations. The lane configurations analyzed were the No build, Improved 2-lane, Improved 2-lane with passing lanes, 4-lane undivided, and 4-lane divided. The US-2, Havre to Fort Belknap is a similar corridor to the TRED corridor as was shown in Table 3. The crash rate used in the EIS was for the years 1997 through 2001. The decrease in the crash rate with the above lane configurations are as follows:

| | Crash Rate | Change From Existing Condition | Incremental Change |
|---|---|---|---|
| No build | 1.51 | 0 | 0 |
| Improved 2-lane | 1.36 | 0.15 | 0.15 |
| Improved 2-lane with passing lanes | 1.26 | 0.25 | 0.10 |
| 4-lane undivided | 1.22 | 0.29 | 0.04 |
| 4-lane divided | 1.13 | 0.38 | 0.09 |

As can be shown above, the projected safety benefits for a 4-lane undivided facility is marginal over an improved 2-lane with passing lanes.

# 4 CONCLUSION

## Concluding Remarks

- An improved 2-lane would provide the necessary capacity for this corridor to function adequately.

- With 30% trucks and the associated speed differential, a four-lane facility will help with the passing conflicts throughout the entire segment.

- US 2 from Culbertson to the North Dakota state line has an average crash rate and severity rate exceeding statewide averages.

- As the corridor approaches the design year traffic volumes, the corridor will be approaching LOS "C" conditions.

- With increasing traffic volumes, passing conflicts will increase.

- All options (Improved 2-lane, Improved 2-lane with passing lanes, 4-lane undivided, and a 4-lane divided) will reduce the crash rate, however, the incremental benefits of a 4-lane undivided improvement over an improved 2-lane with passing lanes are minimal.

# 5 APPENDIX: LEVEL OF SERVICE CALCULATIONS

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_                  HCS2000: Two-Lane Highways Release 4.1c

Phone:                                  Fax:
E-Mail:

___________________Two-Way Two-Lane Highway Segment Analysis__________________

Analyst                 Danielle Bolan
Agency/Co.              MDT
Date Performed          10/14/2006
Analysis Time Period
Highway                 US 2
From/To                 Culbertson to ND State Line
Jurisdiction            MDT
Analysis Year           2006
Description  TRED Corridor

___________________________________Input Data_________________________________

Highway class  Class 1
Shoulder width       2.5     ft     Peak-hour factor, PHF       0.88
Lane width           12.0    ft     % Trucks and buses          7       %
Segment length       22.5    mi     % Recreational vehicles     4       %
Terrain type         Level          % No-passing zones          31      %
Grade:  Length               mi     Access points/mi            5       /mi
        Up/down              %

Two-way hourly volume, V    190     veh/h
Directional split       60  /   40  %

____________________________Average Travel Speed______________________________

Grade adjustment factor, fG                        1.00
PCE for trucks, ET                                 1.7
PCE for RVs, ER                                    1.0
Heavy-vehicle adjustment factor,                   0.953
Two-way flow rate,(note-1) vp                      226     pc/h
Highest directional split proportion (note-2)      136     pc/h

Free-Flow Speed from Field Measurement:
Field measured speed, SFM                           -      mi/h
Observed volume, Vf                                 -      veh/h
Estimated Free-Flow Speed:
Base free-flow speed, BFFS                         62.0    mi/h
Adj. for lane and shoulder width, fLS              2.6     mi/h
Adj. for access points, fA                         1.2*    mi/h

Free-flow speed, FFS                               58.2    mi/h

Adjustment for no-passing zones, fnp               1.2     mi/h
Average travel speed, ATS                          55.2    mi/h

__________________________Percent Time-Spent-Following________________________

Grade adjustment factor, fG                                      1.00
PCE for trucks, ET                                               1.1
PCE for RVs, ER                                                  1.0
Heavy-vehicle adjustment factor, fHV                             0.993
Two-way flow rate,(note-1) vp                                    217    pc/h
Highest directional split proportion (note-2)                    130
Base percent time-spent-following, BPTSF                         17.4   %
Adj.for directional distribution and no-passing zones, fd/np     11.8
Percent time-spent-following, PTSF                               29.2   %

________________Level of Service and Other Performance Measures_______________

Level of service, LOS                                            A
Volume to capacity ratio, v/c                                    0.07
Peak 15-min vehicle-miles of travel, VMT15                       1214    veh-mi
Peak-hour vehicle-miles of travel, VMT60                         4275    veh-mi
Peak 15-min total travel time, TT15                              22.0    veh-h

Notes:
1. If vp >= 3200 pc/h, terminate analysis-the LOS is F.
2. If highest directional split vp >= 1700 pc/h, terminate
   analysis-the LOS is F.
                  HCS2000: Two-Lane Highways Release 4.1c

Phone:                                  Fax:
E-Mail:

___________________Two-Way Two-Lane Highway Segment Analysis__________________

Analyst                 Danielle Bolan
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```
Agency/Co.              MDT
Date Performed          10/14/2006
Analysis Time Period    design hour
Highway                 US 2
From/To                 Culbertson to ND State Line
Jurisdiction            MDT
Analysis Year           2036 - 90% Confidence
Description  TRED Corridor

___________________________________Input Data_________________________________

Highway class  Class 1
Shoulder width       2.5     ft     Peak-hour factor, PHF       0.88
Lane width           12.0    ft     % Trucks and buses          30      %
Segment length       22.5    mi     % Recreational vehicles     4       %
Terrain type         Level          % No-passing zones          31      %
Grade:  Length               mi     Access points/mi            5       /mi
        Up/down              %

Two-way hourly volume, V    317     veh/h
Directional split       60  /   40  %

____________________________Average Travel Speed______________________________

Grade adjustment factor, fG                       1.00
PCE for trucks, ET                                1.7
PCE for RVs, ER                                   1.0
Heavy-vehicle adjustment factor,                  0.826
Two-way flow rate,(note-1) vp                     436     pc/h
Highest directional split proportion (note-2)     262     pc/h

Free-Flow Speed from Field Measurement:
Field measured speed, SFM                          -      mi/h
Observed volume, Vf                                -      veh/h
Estimated Free-Flow Speed:
Base free-flow speed, BFFS                        62.0    mi/h
Adj. for lane and shoulder width, fLS             2.6     mi/h
Adj. for access points, fA                        1.2*    mi/h

Free-flow speed, FFS                              58.2    mi/h

Adjustment for no-passing zones, fnp              2.2     mi/h
Average travel speed, ATS                         52.6    mi/h

__________________________Percent Time-Spent-Following________________________

Grade adjustment factor, fG                                    1.00
PCE for trucks, ET                                             1.1
PCE for RVs, ER                                                1.0
Heavy-vehicle adjustment factor, fHV                           0.971
Two-way flow rate,(note-1) vp                                  371     pc/h
Highest directional split proportion (note-2)                  223
Base percent time-spent-following, BPTSF                       27.8    %
Adj.for directional distribution and no-passing zones, fd/np 11.8
Percent time-spent-following, PTSF                             39.6    %

________________Level of Service and Other Performance Measures_______________

Level of service, LOS                                          B
Volume to capacity ratio, v/c                                  0.14
Peak 15-min vehicle-miles of travel, VMT15                     2026    veh-mi
Peak-hour vehicle-miles of travel, VMT60                       7133    veh-mi
Peak 15-min total travel time, TT15                            38.5    veh-h

Notes:
1. If vp >= 3200 pc/h, terminate analysis-the LOS is F.
2. If highest directional split vp >= 1700 pc/h, terminate
   analysis-the LOS is F.                          HCS2000: Two-Lane Highways Release 4.1c

Phone:                                  Fax:
E-Mail:

___________________Two-Way Two-Lane Highway Segment Analysis__________________

Analyst                 Danielle Bolan
Agency/Co.              MDT
Date Performed          10/14/2006
Analysis Time Period    design hour
Highway                 US 2
From/To                 Culbertson to ND State Line
Jurisdiction            MDT
Analysis Year           2036 - Median
Description  TRED Corridor
```

```
___________________________________Input Data_________________________________

Highway class  Class 1
Shoulder width       2.5     ft     Peak-hour factor, PHF       0.88
Lane width           12.0    ft     % Trucks and buses          30      %
Segment length       22.5    mi     % Recreational vehicles     4       %
Terrain type         Level          % No-passing zones          31      %
Grade:  Length               mi     Access points/mi            5       /mi
        Up/down              %

Two-way hourly volume, V    374     veh/h
Directional split       60  /   40  %

____________________________Average Travel Speed______________________________

Grade adjustment factor, fG                      1.00
PCE for trucks, ET                               1.7
PCE for RVs, ER                                  1.0
Heavy-vehicle adjustment factor,                 0.826
Two-way flow rate,(note-1) vp                    514     pc/h
Highest directional split proportion (note-2)    308     pc/h

Free-Flow Speed from Field Measurement:
Field measured speed, SFM                         -      mi/h
Observed volume, Vf                               -      veh/h
Estimated Free-Flow Speed:
Base free-flow speed, BFFS                       62.0    mi/h
Adj. for lane and shoulder width, fLS            2.6     mi/h
Adj. for access points, fA                       1.2*    mi/h

Free-flow speed, FFS                             58.2    mi/h

Adjustment for no-passing zones, fnp             2.1     mi/h
Average travel speed, ATS                        52.1    mi/h

__________________________Percent Time-Spent-Following________________________

Grade adjustment factor, fG                                    1.00
PCE for trucks, ET                                             1.1
PCE for RVs, ER                                                1.0
Heavy-vehicle adjustment factor, fHV                           0.971
Two-way flow rate,(note-1) vp                                  438    pc/h
Highest directional split proportion (note-2)                  263
Base percent time-spent-following, BPTSF                       32.0   %
Adj.for directional distribution and no-passing zones, fd/np 14.1
Percent time-spent-following, PTSF                             46.0   %

________________Level of Service and Other Performance Measures_______________

Level of service, LOS                                          B
Volume to capacity ratio, v/c                                  0.16
Peak 15-min vehicle-miles of travel, VMT15                     2391    veh-mi
Peak-hour vehicle-miles of travel, VMT60                       8415    veh-mi
Peak 15-min total travel time, TT15                            45.9    veh-h

Notes:
1. If vp >= 3200 pc/h, terminate analysis-the LOS is F.
2. If highest directional split vp >= 1700 pc/h, terminate
   analysis-the LOS is F.
           HCS2000: Two-Lane Highways Release 4.1c

Phone:                                   Fax:
E-Mail:

___________________Two-Way Two-Lane Highway Segment Analysis__________________

Analyst                 Danielle Bolan
Agency/Co.              MDT
Date Performed          10/14/2006
Analysis Time Period    design hour
Highway                 US 2
From/To                 Culbertson to ND State Line
Jurisdiction            MDT
Analysis Year           2036 - 10% Confidence
Description  TRED Corridor

___________________________________Input Data_________________________________

Highway class  Class 1
Shoulder width       2.5     ft     Peak-hour factor, PHF       0.88
Lane width           12.0    ft     % Trucks and buses          30      %
Segment length       22.5    mi     % Recreational vehicles     4       %
Terrain type         Level          % No-passing zones          31      %
Grade:  Length               mi     Access points/mi            5       /mi
```

```
        Up/down              %

Two-way hourly volume, V    427     veh/h
Directional split       60  /   40  %

____________________________Average Travel Speed______________________________

Grade adjustment factor, fG                        1.00
PCE for trucks, ET                                 1.7
PCE for RVs, ER                                    1.0
Heavy-vehicle adjustment factor,                   0.826
Two-way flow rate,(note-1) vp                      587     pc/h
Highest directional split proportion (note-2)      352     pc/h

Free-Flow Speed from Field Measurement:
Field measured speed, SFM                           -      mi/h
Observed volume, Vf                                 -      veh/h
Estimated Free-Flow Speed:
Base free-flow speed, BFFS                         62.0    mi/h
Adj. for lane and shoulder width, fLS              2.6     mi/h
Adj. for access points, fA                         1.2*    mi/h

Free-flow speed, FFS                               58.2    mi/h

Adjustment for no-passing zones, fnp               2.1     mi/h
Average travel speed, ATS                          51.6    mi/h

__________________________Percent Time-Spent-Following________________________

Grade adjustment factor, fG                                      1.00
PCE for trucks, ET                                               1.1
PCE for RVs, ER                                                  1.0
Heavy-vehicle adjustment factor, fHV                             0.971
Two-way flow rate,(note-1) vp                                    500    pc/h
Highest directional split proportion (note-2)                    300
Base percent time-spent-following, BPTSF                         35.6   %
Adj.for directional distribution and no-passing zones, fd/np     13.9
Percent time-spent-following, PTSF                               49.4   %

________________Level of Service and Other Performance Measures_______________

Level of service, LOS                                            B
Volume to capacity ratio, v/c                                    0.18
Peak 15-min vehicle-miles of travel, VMT15                       2729    veh-mi
Peak-hour vehicle-miles of travel, VMT60                         9608    veh-mi
Peak 15-min total travel time, TT15                              52.9    veh-h

Notes:
1. If vp >= 3200 pc/h, terminate analysis-the LOS is F.
2. If highest directional split vp >= 1700 pc/h, terminate
   analysis-the LOS is F.
                        HCS2000: Two-Lane Highways Release 4.1c

Phone:                                  Fax:
E-Mail:

___________________Two-Way Two-Lane Highway Segment Analysis__________________

Analyst                 Danielle Bolan
Agency/Co.              MDT
Date Performed          10/14/2006
Analysis Time Period
Highway                 MT 16
From/To                 Culbertson to Raymond
Jurisdiction            MDT
Analysis Year           2006
Description  TRED Corridor

___________________________________Input Data_________________________________

Highway class  Class 1
Shoulder width       3.1     ft     Peak-hour factor, PHF       0.88
Lane width           12.0    ft     % Trucks and buses          8       %
Segment length       62.4    mi     % Recreational vehicles     4       %
Terrain type         Level          % No-passing zones          32      %
Grade:  Length               mi     Access points/mi            3       /mi
        Up/down              %

Two-way hourly volume, V    184     veh/h
Directional split       60  /   40  %

____________________________Average Travel Speed______________________________

Grade adjustment factor, fG                        1.00
```

```
PCE for trucks, ET                              1.7
PCE for RVs, ER                                 1.0
Heavy-vehicle adjustment factor,                0.947
Two-way flow rate,(note-1) vp                   221     pc/h
Highest directional split proportion (note-2)   133     pc/h

Free-Flow Speed from Field Measurement:
Field measured speed, SFM                        -      mi/h
Observed volume, Vf                              -      veh/h
Estimated Free-Flow Speed:
Base free-flow speed, BFFS                      62.0    mi/h
Adj. for lane and shoulder width, fLS           2.6     mi/h
Adj. for access points, fA                      1.2*    mi/h

Free-flow speed, FFS                            58.2    mi/h

Adjustment for no-passing zones, fnp            1.2     mi/h
Average travel speed, ATS                       55.3    mi/h

__________________________Percent Time-Spent-Following________________________

Grade adjustment factor, fG                                   1.00
PCE for trucks, ET                                            1.1
PCE for RVs, ER                                               1.0
Heavy-vehicle adjustment factor, fHV                          0.992
Two-way flow rate,(note-1) vp                                 211    pc/h
Highest directional split proportion (note-2)                 127
Base percent time-spent-following, BPTSF                      16.9   %
Adj.for directional distribution and no-passing zones, fd/np 11.8
Percent time-spent-following, PTSF                            28.7   %

________________Level of Service and Other Performance Measures_______________

Level of service, LOS                                         A
Volume to capacity ratio, v/c                                 0.07
Peak 15-min vehicle-miles of travel, VMT15                    3262    veh-mi
Peak-hour vehicle-miles of travel, VMT60                      11482   veh-mi
Peak 15-min total travel time, TT15                           59.0    veh-h
___________________________
Notes:
1. If vp >= 3200 pc/h, terminate analysis-the LOS is F.
2. If highest directional split vp >= 1700 pc/h, terminate
   analysis-the LOS is F.
HCS2000: Two-Lane Highways Release 4.1c

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E-Mail:

___________________Two-Way Two-Lane Highway Segment Analysis__________________

Analyst                 Danielle Bolan
Agency/Co.              MDT
Date Performed          10/14/2006
Analysis Time Period    design hour
Highway                 MT 16
From/To                 Culbertson to Raymond
Jurisdiction            MDT
Analysis Year           2036 - 90% Confidence
Description  TRED Corridor

___________________________________Input Data_________________________________

Highway class  Class 1
Shoulder width       3.1     ft     Peak-hour factor, PHF       0.88
Lane width           12.0    ft     % Trucks and buses                  %
Segment length       62.4    mi     % Recreational vehicles     4       %
Terrain type         Level          % No-passing zones          32      %
Grade:  Length               mi     Access points/mi            3       /mi
        Up/down              %

Two-way hourly volume, V    305     veh/h
Directional split       60  /   40  %

____________________________Average Travel Speed______________________________

Grade adjustment factor, fG                     1.00
PCE for trucks, ET                              1.7
PCE for RVs, ER                                 1.0
Heavy-vehicle adjustment factor,                0.790
Two-way flow rate,(note-1) vp                   439     pc/h
Highest directional split proportion (note-2)   263     pc/h

Free-Flow Speed from Field Measurement:
Field measured speed, SFM                        -      mi/h
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Observed volume, Vf                               -      veh/h
Estimated Free-Flow Speed:
Base free-flow speed, BFFS                       62.0    mi/h
Adj. for lane and shoulder width, fLS            2.6     mi/h
Adj. for access points, fA                       1.2*    mi/h

Free-flow speed, FFS                             58.2    mi/h

Adjustment for no-passing zones, fnp             2.3     mi/h
Average travel speed, ATS                        52.5    mi/h

__________________________Percent Time-Spent-Following________________________

Grade adjustment factor, fG                                    1.00
PCE for trucks, ET                                             1.1
PCE for RVs, ER                                                1.0
Heavy-vehicle adjustment factor, fHV                           0.963
Two-way flow rate,(note-1) vp                                  360    pc/h
Highest directional split proportion (note-2)                  216
Base percent time-spent-following, BPTSF                       27.1   %
Adj.for directional distribution and no-passing zones, fd/np 11.8
Percent time-spent-following, PTSF                             38.9   %

________________Level of Service and Other Performance Measures_______________

Level of service, LOS                                          B
Volume to capacity ratio, v/c                                  0.14
Peak 15-min vehicle-miles of travel, VMT15                     5407    veh-mi
Peak-hour vehicle-miles of travel, VMT60                       19032   veh-mi
Peak 15-min total travel time, TT15                            102.9   veh-h
______________________________________________
Notes:
1. If vp >= 3200 pc/h, terminate analysis-the LOS is F.
2. If highest directional split vp >= 1700 pc/h, terminate
   analysis-the LOS is F.
                    HCS2000: Two-Lane Highways Release 4.1c

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E-Mail:

___________________Two-Way Two-Lane Highway Segment Analysis__________________

Analyst                 Danielle Bolan
Agency/Co.              MDT
Date Performed          10/14/2006
Analysis Time Period    design hour
Highway                 MT 16
From/To                 Culbertson to Raymond
Jurisdiction            MDT
Analysis Year           2036 - Median
Description  TRED Corridor

___________________________________Input Data_________________________________

Highway class  Class 1
Shoulder width       3.1     ft     Peak-hour factor, PHF       0.88
Lane width           12.0    ft     % Trucks and buses          32      %
Segment length       62.4    mi     % Recreational vehicles     4       %
Terrain type         Level          % No-passing zones          32      %
Grade:  Length               mi     Access points/mi            3       /mi
        Up/down              %

Two-way hourly volume, V    360     veh/h
Directional split       60  /   40  %

____________________________Average Travel Speed______________________________

Grade adjustment factor, fG                      1.00
PCE for trucks, ET                               1.7
PCE for RVs, ER                                  1.0
Heavy-vehicle adjustment factor,                 0.817
Two-way flow rate,(note-1) vp                    501     pc/h
Highest directional split proportion (note-2)    301     pc/h

Free-Flow Speed from Field Measurement:
Field measured speed, SFM                         -      mi/h
Observed volume, Vf                               -      veh/h
Estimated Free-Flow Speed:
Base free-flow speed, BFFS                       62.0    mi/h
Adj. for lane and shoulder width, fLS            2.6     mi/h
Adj. for access points, fA                       1.2*    mi/h

Free-flow speed, FFS                             58.2    mi/h
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Adjustment for no-passing zones, fnp          2.2     mi/h
Average travel speed, ATS                     52.1    mi/h

__________________________Percent Time-Spent-Following________________________

Grade adjustment factor, fG                                 1.00
PCE for trucks, ET                                          1.1
PCE for RVs, ER                                             1.0
Heavy-vehicle adjustment factor, fHV                        0.969
Two-way flow rate,(note-1) vp                               422    pc/h
Highest directional split proportion (note-2)               253
Base percent time-spent-following, BPTSF                    31.0   %
Adj.for directional distribution and no-passing zones, fd/np 14.3
Percent time-spent-following, PTSF                          45.3   %

________________Level of Service and Other Performance Measures_______________

Level of service, LOS                                       B
Volume to capacity ratio, v/c                               0.16
Peak 15-min vehicle-miles of travel, VMT15                  6382    veh-mi
Peak-hour vehicle-miles of travel, VMT60                    22464   veh-mi
Peak 15-min total travel time, TT15                         122.4   veh-h
______________________________________________________________________________
Notes:
1. If vp >= 3200 pc/h, terminate analysis-the LOS is F.
2. If highest directional split vp >= 1700 pc/h, terminate
   analysis-the LOS is F.
                    HCS2000: Two-Lane Highways Release 4.1c

Phone:                                  Fax:
E-Mail:

___________________Two-Way Two-Lane Highway Segment Analysis__________________

Analyst                 Danielle Bolan
Agency/Co.              MDT
Date Performed          10/14/2006
Analysis Time Period    design hour
Highway                 MT 16
From/To                 Culbertson to Raymond
Jurisdiction            MDT
Analysis Year           2036 - 10% Confidence
Description  TRED Corridor

___________________________________Input Data_________________________________

Highway class  Class 1
Shoulder width       3.1     ft    Peak-hour factor, PHF        0.88
Lane width           12.0    ft    % Trucks and buses           38      %
Segment length       62.4    mi    % Recreational vehicles      4       %
Terrain type         Level         % No-passing zones           32      %
Grade:  Length               mi    Access points/mi             3       /mi
        Up/down              %

Two-way hourly volume, V    427    veh/h
Directional split       60  /  40  %

____________________________Average Travel Speed______________________________

Grade adjustment factor, fG                   1.00
PCE for trucks, ET                            1.2
PCE for RVs, ER                               1.0
Heavy-vehicle adjustment factor,              0.929
Two-way flow rate,(note-1) vp                 522     pc/h
Highest directional split proportion (note-2) 313     pc/h

Free-Flow Speed from Field Measurement:
Field measured speed, SFM                      -      mi/h
Observed volume, Vf                            -      veh/h
Estimated Free-Flow Speed:
Base free-flow speed, BFFS                    62.0    mi/h
Adj. for lane and shoulder width, fLS         2.6     mi/h
Adj. for access points, fA                    1.2*    mi/h

Free-flow speed, FFS                          58.2    mi/h

Adjustment for no-passing zones, fnp          2.2     mi/h
Average travel speed, ATS                     52.0    mi/h

__________________________Percent Time-Spent-Following________________________

Grade adjustment factor, fG                                 1.00
PCE for trucks, ET                                          1.1
PCE for RVs, ER                                             1.0
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Heavy-vehicle adjustment factor, fHV                          0.963
Two-way flow rate,(note-1) vp                                 504    pc/h
Highest directional split proportion (note-2)                 302
Base percent time-spent-following, BPTSF                      35.8   %
Adj.for directional distribution and no-passing zones, fd/np 14.0
Percent time-spent-following, PTSF                            49.8   %

________________Level of Service and Other Performance Measures_______________

Level of service, LOS                                         B
Volume to capacity ratio, v/c                                 0.16
Peak 15-min vehicle-miles of travel, VMT15                    7570    veh-mi
Peak-hour vehicle-miles of travel, VMT60                      26645   veh-mi
Peak 15-min total travel time, TT15                           145.6   veh-h

Notes:
1. If vp >= 3200 pc/h, terminate analysis-the LOS is F.
2. If highest directional split vp >= 1700 pc/h, terminate
   analysis-the LOS is F.
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