**MoDOT’s Work Zone Impact Analysis Spreadsheet with HCM 2010 Program Directions**

The following steps will describe the process of running the capacity program and review the output information (located in Excel worksheet titled *HCM 2010 Program*). The *Total Capacity for Spreadsheet* capacity is entered in the *MoDOT’s Work Zone Impact Analysis Spreadsheet*.

**Highway Capacity Manual 2010 Program**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Work Location | Travel Lane Width (ft) | Capacity of Work Zone Before Trucks (pc/h/ln) | Percent of Trucks\* | ET - Equivalent Truck\* | Lane Width Factor (fLW) | Capacity (w/Trucks) veh/lane/hr | Number of Lanes Open | Total Capacity for Spreadsheet (veh/hr) |
| Workers & equipment less than 4-feet from travel lane | > 11.5 | 1440 | 30.0 | 1.5 | 1.000 | 1252 | 1 | 1252 |
| 10 - 11.5 | 1440 | 30.0 | 1.5 | 0.910 | 1139 | 1 | 1139 |
| <10  | 1440 | 30.0 | 1.5 | 0.860 | 1077 | 1 | 1077 |
| Workers & equipment greater than 4-feet from travel lane | > 11.5 | 1600 | 30.0 | 1.5 | 1.000 | 1391 | 1 | 1391 |
| 10 - 11.5 | 1600 | 30.0 | 1.5 | 0.910 | 1266 | 1 | 1266 |
| <10  | 1600 | 30.0 | 1.5 | 0.860 | 1197 | 1 | 1197 |
| Barrier located less than 2-feet from travel lane | > 11.5 | 1500 | 30.0 | 1.5 | 1.000 | 1304 | 1 | 1304 |
| 10 - 11.5 | 1500 | 30.0 | 1.5 | 0.910 | 1187 | 1 | 1187 |
| <10  | 1500 | 30.0 | 1.5 | 0.860 | 1122 | 1 | 1122 |
| Barrier located greater than 2-feet from travel lane | > 11.5 | 1600 | 30.0 | 1.5 | 1.000 | 1391 | 1 | 1391 |
| 10 - 11.5 | 1600 | 30.0 | 1.5 | 0.910 | 1266 | 1 | 1266 |
| <10  | 1600 | 30.0 | 1.5 | 0.860 | 1197 | 1 | 1197 |
| Ramp (used as bypass) | > 11.5 | 1680 | 30.0 | 1.5 | 1.000 | 1530 | 1 | 1530 |
| 10 - 11.5 | 1680 | 30.0 | 1.5 | 0.910 | 1393 | 1 | 1393 |
| <10  | 1680 | 30.0 | 1.5 | 0.860 | 1316 | 1 | 1316 |
| Crossover on Divided Highway | > 11.5 | 1760 | 30.0 | 1.5 | 1.000 | 1530 | 1 | 1530 |
| 10 - 11.5 | 1760 | 30.0 | 1.5 | 0.910 | 1393 | 1 | 1393 |
| <10  | 1760 | 30.0 | 1.5 | 0.860 | 1316 | 1 | 1316 |
| \* Percent of Trucks and ET - Equivalent Truck located in the below chart. |  |  |  |

*Work Location -* The relative location of workers and/or equipment to the traveling public has been shown to affect the capacity of the travel lane through the work area.

*Travel Lane Width* - At times the travel lane width may be reduced due to the type of operation, size of work equipment, etc. Restricting travel lane width has shown in studies that free-flow speed is reduced, which in turn will decrease the capacity.

*Capacity of Work Zone Before Trucks* – The Highway Capacity Manual 2010 states the base value capacity for the travel lane is approximately 1600 passenger cars per hour per lane for “normal” work zone activity. If the work area is located close to the travel lane, the capacity is adjusted as much as 10% due to closeness of vehicles and people, rubbernecking, etc. If the work area is located some distance from the travel lane, the capacity may increase as much as 10% due to less activity along the travel lane.

*Percent of Trucks* – The percentage of trucks is a comparison between number of trucks and the total number of vehicles.

*ET – Equivalent Truck* – Large trucks, buses, and RV’s in traffic cannot be compared with passenger vehicles (cars/small trucks) because of the length and weight of the trucks/buses/RVs. Trucks/buses/RVs are normally calculated as equivalent trucks. In the below table, trucks/buses/RVs are measured as a *number of passenger vehicles* that would be equal to a truck/bus/RV based on length of grade, percent of grade, and percentage of truck/bus/RV.

*Lane Width Factor* – The percentage of capacity based on the narrowness of the travel way.

*Capacity (w/Trucks)* – The travel lane capacity for one lane open to the traveling public.

*Number of Lanes Open* – Number of travel lanes that will be open to the traveling public.

*Total Capacity for Spreadsheet* – Capacity of the travel lane multiplied by the number of open lanes.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Passenger - Car Equivalents for Trucks on Upgrades** |  |  |  |  |  |  |  |  |  |  |
| Climbing Grade (%)\* | Length (mi) | ET - Passenger - Car Equivalents for Trucks on Upgrades |
| Percentage of Trucks |
| 2 | 4 | 5 | 6 | 8 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
| < 2 |   | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 |
| >2-3 | 0 - 0.49 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 |
| 0.50 - 1.00 | 2.0 | 2.0 | 2.0 | 2.0 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 |
| >1.00 | 3.0 | 3.0 | 2.5 | 2.5 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| >3-4 | 0 - 0.49 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 |
| 0.50 - 1.00 | 3.0 | 3.0 | 2.5 | 2.5 | 2.5 | 2.5 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| >1.00 | 4.0 | 3.5 | 3.0 | 3.0 | 3.0 | 3.0 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 |
| >4-5 | 0 - 0.49 | 3.0 | 2.5 | 2.5 | 2.5 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 0.50 - 1.00 | 4.0 | 3.5 | 3.5 | 3.5 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 |
| >1.00 | 5.0 | 4.0 | 4.0 | 4.0 | 3.5 | 3.5 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 |
| >5-6 | 0 - 0.49 | 4.5 | 4.0 | 3.5 | 3.0 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 |
| 0.50 - 1.00 | 5.5 | 5.0 | 4.5 | 4.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 |
| >1.00 | 6.0 | 5.0 | 5.0 | 4.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 |
| >6 | 0 - 0.49 | 5.0 | 4.5 | 4.0 | 4.0 | 3.5 | 3.0 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 |
| 0.50 - 1.00 | 6.0 | 5.5 | 5.0 | 5.0 | 4.5 | 4.0 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 |
| >1.00 | 7.0 | 6.0 | 5.5 | 5.5 | 5.0 | 4.5 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 | 4.0 |
| \*Climbing Grade can be located anywhere throughout the entire work zone project. |  |  |  |  |  |  |  |  |

Interstate, freeway, and multi-lane roadways with a continuous climbing grade may reduce the work zone roadway capacity, especially when large percentages of heavy vehicles (trucks, buses, RV, etc.) are present. If the grades are steep and long enough, the heavier vehicles speed may be reduce to a “crawl” speed. To help identify equivalent trucks; this table was developed to easily estimate the Highway Capacity Manual calculations. The necessary data needed for the table are climbing grades, length of the grade, and percent of trucks.

An example of the table is shown above. To locate the Equivalent Truck value (Green) with the following criteria: grade of 3.5%, length is less than ½ mile, and 30% trucks (located in blue).

**MoDOT’s Work Zone Impact Analysis Spreadsheet Directions**

The following steps will describe the process of running the program and review the output information (located in Excel worksheet titled WZ Impact Analysis Spreadsheet).

**Step 1: Number of Lanes, Truck Percentage, Work Zone Capacity, and User Cost.**

|  |  |
| --- | --- |
| MoDOT WORK ZONE IMPACT ANALYSIS SPREADSHEET  |   |
|   |   |   |   |   |   |   |   |   |   |
|  | **TOTAL NUMBER OF LANES** | **2** | **NUMBER OF LANES OPEN** | **1**  |   |   |   |   |
|  | **TRUCK PERCENTAGE** | **25** | **OPEN LANE CAPACITY** | **1600**  |   |   |   |   |
|   |   |   |   |   |   |   |   |   |   |
|  | **TOTAL CAPACITY OF WORKZONE**  | **1240** |  |  |  |  |  |
|  | **(The capacity value is consistent with MoDOT's recommended value for the chosen lane configuration)**  |   |
|   |   |   |   |   |   |   |   |   |   |   |
|  | **USER** | **TRUCKS**  | **$22.70**  |  |  |  |  |  |   |
|  | **COST** | **CARS** | **$10.30**  |   |   |   |   |   |   |   |   |   |   |

The information in the blue section is required for the spreadsheet. The *Total Number of Lanes* and *Number of Lanes Open* fields are filled in with the appropriate number of lanes. The *Truck Percentage* is a comparison between number of trucks and the total number of vehicles *Open Lane Capacity* is normally consider free-flow with a capacity of 1600 vehicles/hr/lane.

The *Total Capacity of Work Zone* value is the calculated capacity based on the *Highway Capacity Manual 2010 Program* (see above directions).

The *User Cost* is currently the Missouri rates. The *User Cost* field may be adjusted to better represent user cost for a specific area or state.

**Step 2: Hourly Volume**

The *DEMAND* field is a blue required field. The demand information is the hourly volume, which is based on vehicles per hour per lane. The *Demand* information is normally populated from the Transportation Management System (TMS) database. Data from the TMS is calculated from field data and updated every 1-3 yrs, dependent on roadway type. The *Demand* field can be populated by actual field data.

*TOTAL ARRIVALS* field is a running count of the number of vehicles entering the work zone.

*TOTAL DEPARTURES* field is a running count of the number of vehicles that leave the work zone based on the maximum capacity.

*QUEUED VEHICLES* are the difference of vehicle arriving versus departures. This work zone has a capacity of 1,240 vehicles/hour. At 7:00 a.m., 1,371 vehicles arrive, but only 1,240 vehicles can travel through the work zone. There are 131 vehicles that cannot enter the work zone for that particular hour and must wait their turn. If the number of arriving vehicles is greater than the capacity of the work zone lane closures, then the work zone will see a queue and delay.

*QUEUE LENGTH* field calculates the length (miles) of the queue based on the percentage of passenger vehicles and trucks. The length of vehicles for this example is 25 feet for passenger vehicles and 50 feet for trucks.

For example at 7:00 a.m. there are 131 queued vehicles of which 25 percent (0.25) are trucks. (131 vehicles)\*(0.75 percent cars)\*(25 feet per passenger vehicles) + (131 vehicles)\*(0.25 percent trucks)\*(50 feet per trucks) = (2,456.25 feet + 1,637.5 feet) / (2 lanes of open lane) \* (5,280 feet/mile) = 0.39 mile queue.

*DELAY* field is the calculation of the queued vehicles, capacity, and conversion from hours to minutes. For 7:00 a.m. example, (131 vehicles)\*(60 minutes/hour)/(1,240 vehicles/hour) = 6.34 minutes.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| SATURDAY  |    | TIME  | DEMAND  | CAPACITY  | TOTAL ARRIVALS  | TOTAL DEPARTURES  | QUEUED VEHICLES  | QUEUE LENGTH  | DELAY  |
|   |   |   |   |   |   |   |   |   |   |
| 0  | AM  | 0:00  | 364  | 1240  | 364  | 364  | 0  | 0.00  | 0.00  |
| 1  |   | 1:00  | 331  | 1240  | 695  | 695  | 0  | 0.00  | 0.00  |
| 2  |   | 2:00  | 296  | 1240  | 991  | 991  | 0  | 0.00  | 0.00  |
| 3  |   | 3:00  | 337  | 1240  | 1328  | 1328  | 0  | 0.00  | 0.00  |
| 4  |   | 4:00  | 395  | 1240  | 1723  | 1723  | 0  | 0.00  | 0.00  |
| 5  |   | 5:00  | 621  | 1240  | 2344  | 2344  | 0  | 0.00  | 0.00  |
| 6  |   | 6:00  | 1024  | 1240  | 3368  | 3368  | 0  | 0.00  | 0.00  |
| 7  |   | 7:00  | 1371  | 1240  | 4739  | 4608  | 131  | 0.39  | 6.34  |
| 8  |   | 8:00  | 1331  | 1240  | 6070  | 5848  | 222  | 0.66  | 10.74  |
| 9  |   | 9:00  | 1095  | 1240  | 7165  | 7088  | 77  | 0.23  | 3.73  |
| 10  |   | 10:00  | 1238  | 1240  | 8403  | 8328  | 75  | 0.22  | 3.63  |
| 11  |   | 11:00  | 1196  | 1240  | 9599  | 9568  | 31  | 0.09  | 1.50  |
| 12  | PM  | 12:00  | 1276  | 1240  | 10875  | 10808  | 67  | 0.20  | 3.24  |
| 13  |   | 13:00  | 1216  | 1240  | 12091  | 12048  | 43  | 0.13  | 2.08  |
| 14  |   | 14:00  | 1317  | 1240  | 13408  | 13288  | 120  | 0.36  | 5.81  |
| 15  |   | 15:00  | 1326  | 1240  | 14734  | 14528  | 206  | 0.61  | 9.97  |
| 16  |   | 16:00  | 1310  | 1240  | 16044  | 15768  | 276  | 0.82  | 13.35  |
| 17  |   | 17:00  | 1222  | 1240  | 17266  | 17008  | 258  | 0.76  | 12.48  |
| 18  |   | 18:00  | 1091  | 1240  | 18357  | 18248  | 109  | 0.32  | 5.27  |
| 19  |   | 19:00  | 847  | 1240  | 19204  | 19204  | 0  | 0.00  | 0.00  |
| 20  |   | 20:00  | 859  | 1240  | 20063  | 20063  | 0  | 0.00  | 0.00  |
| 21  |   | 21:00  | 695  | 1240  | 20758  | 20758  | 0  | 0.00  | 0.00  |
| 22  |   | 22:00  | 601  | 1240  | 21359  | 21359  | 0  | 0.00  | 0.00  |
| 23  |    | 23:00  | 492  | 1240  | 21851  | 21851  | 0  | 0.00  |  0.00   |

**Step 3: Work Duration and Calculated Data**

When calculating, a start time and duration of closure is required. The above example starts at 12:00 midnight and operates all day or a 24-hour operation. The start time and duration cannot total more than a 24-hour day. For example, start time is 8:00 a.m. and the longest duration can only be 16-hour duration.

The results from the spreadsheet are tabulated as the following: *MAX DELAY* – maximum delay in minutes, *AVE DELAY* – average delay in minutes, *COST ($)* – total user cost for the vehicle (passenger vehicle and truck), and *MAX QUEUE LENGTH* – maximum queue length in miles.

|  |  |
| --- | --- |
| **Start Time**  | **0**  |
| **Duration of closure**  | **24**  |
|   |   |
| count  | 24  |
| short  | 0  |
|   |   |
| **MAX DELAY**  | 13.35  |
|   |   |
| **AVE DELAY**  | 4.43  |
|   |   |
| **COST ($)**  | $5,813.65  |
|   |   |
| **MAX QUEUE LENGTH**  | 0.82   |

**Step 4: Work Zone Queue Length and Delay Graphs**

The final product of the spreadsheet is a graphical representation of the queue and delay of the work zone. The entire week is graphed to see the trends of the work zone concerns of queue and delay.