Traffic assignment checking

# 1. Update VDF table

## A.Overview and updated VDF tables

In this section, we update the capacities of the links of different volume delay function (VDF) types under different peak periods. We also update the parameters “alpha and beta” in the BPR function. **Table 1** shows the original capacity values and parameters for the VDF. **Table 2** displays the updated version. We only update the values for freeways and arterials in CBD, outlying CBD, mixed urban area (VDF code: 101, 106, 201, 206, 301, and 306). However, the change of parameters for these VDF types will lead to indirect change for the volume and speed on the links of other VDF types.

**Table 1. Original VDF table**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| VDF\_TYPE | AM\_CAP | MD\_CAP | PM\_CAP | NT\_CAP | **ALPHA** | **BETA** |
| 101 | 4979 | 8438 | 6873 | 8438 | **0.87** | **5** |
| 106 | 1692 | 3158 | 2469 | 3158 | **1.5** | **1.5** |
| 201 | 5223 | 8851 | 7210 | 8851 | **0.75** | **4** |
| 206 | 1713 | 3197 | 2500 | 3197 | **1.2** | **2** |
| 301 | 5113 | 8665 | 7058 | 8665 | **0.71** | **3.47** |
| 306 | 2014 | 3758 | 2938 | 3758 | **1.8** | **2.1** |

**Table 2. Updated VDF table**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| VDF\_TYPE | AM\_CAP | MD\_CAP | PM\_CAP | NT\_CAP | **ALPHA** | **BETA** |
| 101 | 4449.882 | 8311.58 | 5595.469 | 9268.15 | **0.57** | **5.09** |
| 106 | 1454.091 | 2302.182 | 1854.864 | 3158 | **0.96** | **2.08** |
| 201 | 5067.163 | 9135.226 | 6728.819 | 12207.72 | **0.8** | **4.9** |
| 206 | 2163.321 | 3781.588 | 2917.493 | 3197 | **1.37** | **1.96** |
| 301 | 5457.626 | 9926.645 | 7973.731 | 12784.14 | **0.18** | **6.77** |
| 306 | 1966.081 | 3339.914 | 2641.501 | 3758 | **0.76** | **2.21** |

We use the following two-step method to calculate the period capacity and the parameters.

**Step 1:** We calibrate the **ultimate capacity**  which is the hourly lane capacity **and cut-off speed ,** by using the traffic stream model (S3).

**Step 2:** We calculate the PHF **for different VDF types**. Remarkably, the estimation of capacity is based on the following assumption of the Hour-to-period factor (PHF). For each link, we can obtain a PHF base on the following formula.

We can also calculate period capacity for all links of a VDF type that is expressed by . Based on the above formula, we reformulate the speed-flow fundamental diagram as an estimation problem with speeds as a monotonically decreasing function of *v*\*/*c* ratios. To convert hourly ultimate capacity to period capacity , we use the following formula to obtain the period capacity

|  |  |
| --- | --- |
|  |  |

**Step 3:** Calibrate relationship between and speed using the BPR function to obtain the alpha and beta

## B. Capacity estimation and PHF

Figure 1 and Table 3 show the estimated speed-volume fundamental diagrams of the six VDF types with their estimated cut-off speed and ultimate capacity (volume per lane per hour):



Figure 1 Calibrated speed-volume fundamental diagram with capacity and cut-off speed.

**Table 3** Calibrated cut-off speed and ultimate capacities

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| VDF\_TYPE | assignment period | CUT\_OFF\_SPD (mile/hour) | ULT\_CAP (vehicle per lane per hour) | peak\_factor | period capacity |
| 101 | 0600\_0900 | 51.53 | 1,687.71 | 2.64 | 4,449.88 |
| 101 | 0900\_1400 | 51.53 | 1,687.71 | 4.92 | 8,311.58 |
| 101 | 1400\_1800 | 51.53 | 1,687.71 | 3.32 | 5,595.47 |
| 101 | 1800\_0600 | 51.53 | 1,687.71 | 5.49 | 9,268.15 |
| 201 | 0600\_0900 | 51.39 | 1,850.81 | 2.74 | 5,067.16 |
| 201 | 0900\_1400 | 51.39 | 1,850.81 | 4.94 | 9,135.23 |
| 201 | 1400\_1800 | 51.39 | 1,850.81 | 3.64 | 6,728.82 |
| 201 | 1800\_0600 | 51.39 | 1,850.81 | 6.60 | 12,207.72 |
| 301 | 0600\_0900 | 57.86 | 1,985.72 | 2.75 | 5,457.63 |
| 301 | 0900\_1400 | 57.86 | 1,985.72 | 5.00 | 9,926.64 |
| 301 | 1400\_1800 | 57.86 | 1,985.72 | 4.02 | 7,973.73 |
| 301 | 1800\_0600 | 57.86 | 1,985.72 | 6.44 | 12,784.14 |
| 106 | 0600\_0900 | 20.59 | 493.40 | 2.95 | 1,454.09 |
| 106 | 0900\_1400 | 20.59 | 493.40 | 4.67 | 2,302.18 |
| 106 | 1400\_1800 | 20.59 | 493.40 | 3.76 | 1,854.86 |
| 106 | 1800\_0600 | 20.59 | 493.40 | 9.76 | 4,817.09 |
| 206 | 0600\_0900 | 17.63 | 741.03 | 2.92 | 2,163.32 |
| 206 | 0900\_1400 | 17.63 | 741.03 | 5.10 | 3,781.59 |
| 206 | 1400\_1800 | 17.63 | 741.03 | 3.94 | 2,917.49 |
| 206 | 1800\_0600 | 17.63 | 741.03 | 7.27 | 5,387.37 |
| 306 | 0600\_0900 | 22.82 | 666.34 | 2.95 | 1,966.08 |
| 306 | 0900\_1400 | 22.82 | 666.34 | 5.01 | 3,339.91 |
| 306 | 1400\_1800 | 22.82 | 666.34 | 3.96 | 2,641.50 |
| 306 | 1800\_0600 | 22.82 | 666.34 | 7.04 | 4,688.70 |

Our method is based on the key insights to distinguish volume and demand: (a) **Volume** is defined as the flow rate of vehicles during a time interval. (b) **Demand** includes the queue discharge rate at the bottleneck and vehicles in the queue, which is termed as **queued demand** in this paper. Both freeways and intersections have recurring bottlenecks where the discharge rate is constrained and queuing occurs upstream of bottlenecks during rush hours. To characterize the oversaturation degree of a peak period, we can only focus on a “peak hour” within the period. In the existing studies, a peak hour is defined as the hour with the highest volume during a peak period. However, we define the peak hour as the hour containing the lowest speed during the peak period. In the example illustrated in **Fig. 2(a)**, the peak period AM is from 6:00 to 9:00. The lowest speed happens within 8:00-8:15. The peak hour is from 7:45 to 8:45 including data collected from 7:45-8:00, 8:00-8:15, 8:15-8:30, and 8:30-8:45. We denote the volume within the peak hour as . Next, we consider a **congestion period** from and **containing** the peak hour. The total volume within the congestion period is viewed as the queued demand for the peak hour’s capacity under oversaturated conditions, which implies when , and becomes the **queued demand** for the peak hour. Conversely, is served as the demand.

There are different ways to define the congestion period. We provide two ways to define queue demand.

**Def. 1.** We find the lowest speed and then extend both to , until the speed of both and are larger than the calibrated cut-off speed (see **Fig. 2 (b))**

**Def. 2.** We find the lowest speed and then extend , until the speed of is larger than the calibrated cut-off speed. The is the start time of the peak hour. (See **Fig. 2 (c)**)

**WE ADOPT DEFINITION 2 TO CALCULATE THE QUEUED DEMAND.** Both methods are based on the assumption that the speed evolution only has one dip during the peak period. In these cases, is the summation of all volumes under the cut-off speed including both discharges and queues during the peak period. Then means the congestion duration to service all vehicles if the system has discharge rate. When is the ultimate capacity of the link, is the **lower bound** of the congestion duration, because the actual queue discharge rates are less than the ultimate capacity. To achieve the mapping from regime B to regime C, we define the **highest** speed **within the peak hour** as . Then we can define the queued demand as follows:

|  |  |
| --- | --- |
|  |  |



**Table 3** also shows the obtained PHF for different assignment periods and VDF types. It should be noted that some arterials have low queued demand during the night based on our assumption, which implies a higher PHF. The higher PHFs might overestimate the period capacity of peak period NT. As a result, we do not update the capacity of NT\_CAP in the table. Now we compare the capacity, alpha, and beta between the original and updated version. The changes in the values are shown in Table 4 (The change is zero in the column NT\_CAP, row 106, 206, and 306).

**Table 4. Comparison of capacity, alpha, and beta (updated VDF – original VDF)**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| VDF\_TYPE | AM\_CAP | MD\_CAP | PM\_CAP | NT\_CAP | ALPHA | BETA |
| 101 | -529.118 | -126.42 | -1277.531 | 830.15 | -0.3 | 0.09 |
| 106 | -237.909 | -855.818 | -614.136 | 0 | -0.54 | 0.58 |
| 201 | -155.837 | 284.226 | -481.181 | 3356.72 | 0.05 | 0.9 |
| 206 | 450.321 | 584.588 | 417.493 | 0 | 0.17 | -0.04 |
| 301 | 344.626 | 1261.645 | 915.731 | 4119.14 | -0.53 | 3.3 |
| 306 | -47.919 | -418.086 | -296.499 | 0 | -1.04 | 0.11 |

# 2. Validation of volume

After the traffic assignment using TRANSCAD based on the GISDK script and excel spreadsheet provided by the MAG team. We get the following validation results (see Table 5 and 6).Here, we only conduct the traffic assignment of the four-step method using OD tables sent to ASU from the MAG team with the new alpha, beta, and capacities. Further, we consider the length factor in the script.

**Table 5. Validation table before updating (provided by the MAG team, ABM\_0902\_2020)**



**Table 6, Validation results after updating VDF table (considering length factor)**

## A. Summary Table

The comparison between the two tables is displayed using Table 7. We use the following three indicators to compare the validation results for different peak periods.

1. Updated R^2 – Original R^2
2. Updated RMSE% – Original RMSE%
3. |Updated Diff%| – |Original Diff %|

The important finds are as follows:

1. The updated VDF table can improve RMSE% of our validation results. **Average RMSE% decreases by 0.6%.**

**2.** The updated version also decreases the Diff% which implies that the assigned volumes on links are close to the observations for validation. **Average Diff% decreases by 0.84%.**

2. The updated VDF table outstandingly improves the quality of the RMSE% on freeway and CBD areas from 52.9% to 43%. The overall RMSE% of PM decreases by 3.57%

3. The R^2 becomes worse after updating the VDF table. However, the change in R^2 is usually minor. Average R^2 only decreases by 0.0019

**Table 7 Summary table of the comparison of volume (with length factors)**



In summary, we obtain the following finds

**AM:**

1. Overall, the RMSE% is reduced from 33.4% to 32%. Diff% is reduced from 0.5% to 0.4%. However, R^2 becomes worse slightly from 0.943 to 0.942.
2. The RMSE% decreases greatly in CBD area from 40.2% to 35.2%
3. The RMSE% and Diff% are also reduced in outlying CBD areas from 22.6% to 20.7%

**MD:**

1. Overall, RMSE% and Diff% are slightly increased (from 28.2% to 29.1%; from 1.1% to 1.6%)
2. RMSE%, in the CBD, is changed from 22.4% to 22.3 %. However, in other areas, the RMSE% is slightly increased, for example, outlying CBD, from 23.8% to 24.4 %, mixed urban: from 28.5% to 30.6 %

Suburban, from 36.2% to 37.1 %, and rural area from 43.7% to 43.9 %.

**PM:**

1. Overall, RMSE% is decreased from 37%🡪33.4% (-3.6%)
2. RMSE% and Diff% are outstandingly improved in CBD/Outlying CBD area
   1. CBD: 52.9% 🡪43.0 %
   2. Outlying CBD 29.1% 🡪27.3%
3. RMSE% and Diff% are slightly increased in other area types, for example, mixed urban, from 25.1% to 25.3 %, Suburban, from 33.8% to 35.3 %, and rural area from 39% to 40 %.

**NT:**

1. Overall, RMSE% is decreased from 33.6%🡪33.2% (-0.4%)

## B. Impact of the length factor

Length factors help restrict the volumes on long-distance links (usually arterials) and transfer the volume from the arterials to freeways. This section attempts to explore the impacts of the length factor. Thus, we revise the code of the TRANSCAD GIDDK script provided by the MAG team as follows:

*Line 710-733*

*// Populate the LTERM fields as relevant (AD February 2015)*

*query = "Select \* where [AB ALPHA]<>NULL"*

*n = SelectByQuery("Populate\_AB\_LTERM", "Several", query,)*

*if n > 0 then do*

*vw\_set = link\_lyr + "|Populate\_AB\_LTERM"*

*lenvector= GetDataVector(vw\_set, "[AB Length]",)*

*tollvector= GetDataVector(vw\_set, "[AB Toll]",)*

*//lencost=lenvector\*1.4*

*//lencost=lenvector\*1.0+ tollvector*

*lencost=(lenvector****\*1.4\*0****+ tollvector)*

*SetDataVector(vw\_set, "[AB LTERM]", lencost,)*

*end*

*query = "Select \* where [BA ALPHA]<>NULL"*

*n = SelectByQuery("Populate\_BA\_LTERM", "Several", query,)*

*if n > 0 then do*

*vw\_set = link\_lyr + "|Populate\_BA\_LTERM"*

*lenvector= GetDataVector(vw\_set, "[BA Length]",)*

*tollvector= GetDataVector(vw\_set, "[BA Toll]",)*

*//lencost=lenvector\*1.4*

*//lencost=lenvector\*1.0+ tollvector*

*lencost=lenvector\*****1.4\*0****+ tollvector*

*SetDataVector(vw\_set, "[BA LTERM]", lencost,)*

*end*

Then we get the validation results shown in Table 8. We further compare the original validation results with the updated version. The comparative results are shown in Table 9.

**Table 8 Validation results after updating VDF table (do not consider length factors**)

**Table 9 Summary table of the comparison of volume (without length factors)**



Compared with the version with length factors, in the AM, MD, PM, the improvement of the validation results seems weaker. For example, average RMSE% decreases only -0.28% compared to -0.6% previously. Similar results can also be found in each peak period, i.e. AM, MD, and PM.

1. AM: increasing 1.19% (without length factors) vs. decreasing -1.33% (with length factors)
2. MD: increasing 1.54% (without length factors) vs. decreasing 1.54% (with length factors)
3. PM: decreasing -1.32% (without length factors) vs. decreasing -3.57% (with length factors)

Interestingly, if we do not use the length factor during night periods, we will distinguishedly improve our performance. Overall, RMSE% decrease by -4.15%.

# 3. Comparison of speed

## A. Summary Table

**Table 10** summarizes the previous speed estimation and the updated version considering the length factor. We first calculate the absolute difference between the estimated speed and observation speed. Then, we further compare the differences to measure the improvement of our updating. Generally, the speed estimation becomes better after our updating. **Table 11** also compares the results after we neglect the length factors. The conclusions are similar to what we found when validating volume. In the AM, MD, and PM, if we do not consider the length factors, we will obtain a result with less improvement. However, without the length factors, we obtain better speed estimation in the NT period, as shown in **Table 11**.

**Table 10 Difference between previous speed and currently updated speed (with length factors)**



**Table 11 Difference between previous speed and currently updated speed (without length factors)**



# 4. Recommendation

We can use the length factors when we conduct traffic assignments in AM, MD, and PM periods, and do not use the factor in the NT period.