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Memorandum

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Re: French Broad River Metropolitan Planning Organization (FBRMPO) – Planning-Level Safety Models

Overview

The purpose of this memo is to describe how VHB developed and applied a series of areawide models applied to support a comprehensive regional transportation safety plan. Areawide models predict average crash frequency, by crash type and severity, for a defined area (rather than a single intersection or road corridor). For example, a defined area may include:

- Census tracts
- Traffic analysis zones (TAZ)
- Counties

Areawide safety models use inputs that characterize the broader area for which the models apply and may include:

- Demographic characteristics
- Socioeconomic characteristics
- Urban/rural area
- Land use

WHERE CAN TRANSPORTATION DECISIONS BE MOST EFFECTIVE AS THE COMMUNITY CHANGES?
Areawide models are most effective at predicting changes in crashes for places where people (will) live, work, and play, and before design details are known – in other words, lane widths, median types, shoulder presence and width, etc. This safety analysis approach can help localities proactively address severe safety outcomes through land use and community decisions.

Using the 2015/2045 French Broad River Metropolitan Planning Organization (FBRMPO) travel demand model (TDM) version 1.1 outputs, VHB compiled data at the TAZ-level for the base year, 2015, and the plan year, 2045. This data includes centerline, National Highway System (NHS) designation, and intersections from the North Carolina Department of Transportation (NCDOT's) open data portal, as well as TDM data including the FBRMPO TDM loaded network mileage, TAZ-level demographic data such as median household income, total population, total employment, commuters by mode, and total commuting population age 16-64, and transit stops. VHB used the final layers to predict future crashes based on the projections in the region's travel demand model.

Data Reduction

Roadway, intersection, and transit stop data are aggregated at the zonal level using GIS geoprocessing. For roadways, data are assigned according to the road's geographic location. This includes roadway centerlines that are completely contained within a TAZ, as well as roadways that comprise a boundary of two or more TAZs. Intersections are also separated into interior and boundary intersections. Interior intersections are assigned to the TAZ they intersect. Boundary intersections are applied to all adjoining TAZs (i.e., a boundary intersection is counted multiple times in the complete dataset). The duplication provides accurate metrics of street connectivity (i.e., intersection density) and reflect that intersection's influence area extends to all TAZs it touches. Transit stops differ in that they are assigned to

TAZs based on the exact location of the stop (i.e., wherever the point is located relative to TAZ boundaries). Transit stops located along boundary roads are only assigned to one TAZ.

Obtaining Centerline Mileage and VMT

For this project, VHB determined centerline mileage, NHS mileage, and TDM loaded network mileage for each TAZ for 2015 and 2045 based on the 2015/2045 FBRMPO travel demand model (TDM) version 1.1. As stated above, VHB identified interior segments and boundary segments using various GIS geoprocessing tools. VHB calculated vehicle miles traveled (VMT) by taking the interior roadway length and multiplying it by the segment AADT. For example, an interior roadway that is 1.5 miles long and has an AADT of 100, the assigned VMT would be 150. For boundary segments derived from the recommended process in NCHRP Research Report 1044[1], VMT are assigned evenly between all adjoining TAZs. For example, if a boundary segment, touching two TAZs, is 2 miles long and has an AADT of 400, the VMT for each TAZ would be half the segment length multiplied by half the AADT. In this example, the VMT for each TAZ would be 200. Once VHB assigned all segments centerline mileage and VMT, VHB summed all values based on the unique identifier for each TAZ.

Geoprocessing Tool Breakdown

- **Identity:** Computes a geometric intersection of input features and identity features. For this VHB used the tool to break centerline segments at TAZ boundaries. It was also used to break segments that fell within the 50ft boundary buffer. Identity creates multipart outputs.
- **Multipart to Singlepart:** Breaks multipart features into unique continuous segments.
- **Select by Location:** Finds centerlines that have their center within 45ft of the boundary buffer.
- **Calculate Field:** Populates flag field to differentiate interior and boundary segments. This tool was also used to calculate the split segment lengths for the assignment of segment length, AADT, and VMT for boundary segments.
- **Select by Attribute:** Selects records with desired attributes based on a specified query.
- **Export Features:** Exports selected features to a new feature class.
- **Spatial Join:** Assigns TAZ ID to centerline segments, intersections, and transit stops. Used to refine interior and boundary segments
- **Append:** Adds data from one feature class to another. This tool changes the input feature class. VHB used this tool to add interior segments from the spatial join back to the originally exported interior segments.
- **Summary Statistics:** Provides statistics on desired fields based on values in another field. To get centerline mileage, VHB took the sum of the split segment length for boundary segments based on the Left TAZID then Right TAZID and added it to the interior segment length is based on TAZID. This tool is also used to get counts of intersections and transit stops.
- **Join Field:** This geoprocessing tool joins data from one table to another based on a shared field value. It was used to connect the total centerline milage, NHS mileage, FBR Loaded Network mileage, intersection counts, and transit stops back to the 2015 and 2045 TAZ layers.

[1] https://nap.nationalacademies.org/catalog/27125/development-and-application-of-quantitative-macro-level-safety-prediction-models

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Obtaining Intersection and Transit Stop Counts

For intersections, VHB performed a spatial join between the intersection layer and TAZ layer, with a join setting of one-to-many, intersecting within 1 ft. From there, VHB computed summary statistics to obtain a count of keyintersectionIDs, with the TAZ identifier serving as the case field. This count was then joined back to the TAZ layer, enhancing the data with intersection count information.

For transit stops, VHB dissolved the 2015 and 2045 layers based on NODEID and then spatially joined these new layers to their respective 2015 or 2045 TAZ layers. Like the intersections, the summary statistics tool obtained a count of transit stops within each TAZ.

Crash Prediction

Areawide models use a negative binomial count regression model approach to predict crashes. Negative binomial regression is a commonly used method in transportation safety as it applies to over-dispersed count data (i.e., the variance exceeds the mean of the observed data). The dependent variable in the model is the number of crashes, making a count model appropriate for the data. The functional form of the negative binomial regression model is shown in Figure 1.[2]

$$\lambda_i = e^{\beta X_i + \varepsilon_i}$$

Figure 1. Equation. Negative Binomial Regression Functional Form

Where:

$e^{\varepsilon i}$ = gamma distributed error term, where $e^{\varepsilon i}$ is gamma-distributed with a mean equal to one and variance equal to α.

λi = expected number of crashes at location i.

β = vector of estimated parameters.

Xi = vector of independent variables that characterize location i and influence crash frequency.

VHB applied five areawide crash prediction models for the FBRMPO planning area.

1. Total fatal (K) crashes.
2. Total fatal and serious injury (KA) crashes.
3. Total fatal and injury (KABC) crashes.
4. Total (KABCO) crashes.
5. Total pedestrian and bicycle fatal and serious injury (KA) crashes.
6. Total pedestrian and bicycle (KABCO) crashes.

The inputs for each model are as follows and are the same used in NCHRP Research Report 1044 (Table 1):

Table 1. MPO Models; estimate and (standard error).

[2] Lord, D., Mannering, F., 2010. The Statistical Analysis of Crash-Frequency Data: A Review and Assessment of Methodological Alternatives. Transp. Res. Part A Policy Pract. 44 5 , 291–305. doi:10.1016/j.tra.2010.02.001

	Total Crashes				Bicycle/ Pedestrian	
Input	**KABCO**	**KABC**	**KA**	**K**	**KABCO**	**KA**
Intercept	-3.4647 (0.0988)	-4.9512 (0.1096)	-4.6008 (0.1379)	-8.6210 (0.2223)	-8.0810 (0.2339)	-8.7022 (0.3584)
Natural Log of VMT	0.6220 (0.0079)	0.6513 (0.0088)	0.5063 (0.0112)	0.6354 (0.0219)	0.2354 (0.0157)	0.3091 (0.0256)
Median Household Income ($1,000's)	-0.0027 (0.0002)	-0.0041 (0.0002)	-0.0051 (0.0003)	-0.0085 (0.0008)	-0.0055 (0.0004)	-0.0077 (0.0007)
Total Intersections	0.0040 (0.0003)	0.0036 (0.0003)	0.0026 (0.0004)	0.0066 (0.0006)	-	-
Inverse Area Variable	0.9574 (0.0468)	0.8187 (0.0508)	-0.5955 (0.0600)	-	1.3179 (0.0873)	0.7229 (0.1359)
Proportion of Non-Motorized Commuters	-	-	-	-	1.9517 (0.1610)	1.4637 (0.2495)
Transit Stop Density	-	-	-	-	0.0076 (0.0006)	0.0071 (0.0010)
Natural Log of Population Plus Employment	-	-	-	-	0.5674 (0.0271)	0.4400 (0.0413)
Overdispersion, k	0.2413	0.2606	0.2408	0.3140	0.3549	0.3762

Using the Crash Predictions

The models used in the FBRMPO results are not calibrated to local conditions; in other words, the models are not based on North Carolina crash data. These models are pulled directly from the NCHRP 1044 research. As such, **the crash estimates (i.e., number of predicted crashes per year in 2015 and 2045) should not be used directly by planners. The best uses of these models are:**

- **Comparing one TAZ to another (i.e., one TAZ has 50 percent more crashes than another)**
- **The percent change in crashes for a TAZ between 2015 and 2045 (i.e., the models estimate a 50 percent increase in crashes per year between 2015 and 2045).**