Building Urban Travel Demand Forecast Models in Michigan

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Outline of Presentation

What is a Travel Demand Forecast Model and Why are they Developed?

Purposes and Applications of the TDFM

Building a TDFM – 4-Step Process

Forecasting

Examples of TDFM Applications

MI Travel Counts - UMIP
What is a Travel Demand Forecasting Model?

A series of mathematical equations which are used to simulate observed traffic conditions.

**Forecasting** is the process of using a validated/calibrated model to predict travel into the future applying growth factors and data projections based on possible/anticipated changes in the study area.
Why Does MDOT Build Travel Demand Models?

Federal regulations require:

- **MPOs**: Urbanized Areas with populations over 50,000 are required to have a LRTP and an objective method to evaluate the federal aid road system.

- **TMAs**: Urbanized Areas with populations over 200,000 are required to have a model and staff knowledge on modeling.
Michigan TDF Model Area Boundaries
Purposes of Model

- **Forecasts**
  - How changes in Socio-Economic data (SE-data) effect traffic flows
  - Predict future traffic congestion
  - Test solutions

- **System wide analysis**
  - How changes in the network effect traffic flows
Purposes of Model

Air Quality Analysis

- 25 counties have non-attainment status

- Inputs to Air Quality Models:
  - Vehicle Miles Traveled (VMT)
  - Vehicle Hours Traveled (VHT)
  - Congested Speeds
Other Applications of TDFM

- Project Selection – Capacity Related
- Deficiency Analysis (Level of Service)
- Operational Analysis (Detours, Construction)
- Alternative Testing
- Congestion Management
Model Updates

The model inputs are developed, reviewed and approved by the MPO committee as part of their LRTP process.

Urban models are updated for each LRTP:
- Air quality non-attainment areas every 4 years
- Air quality attainment areas every 5 years
Building a TDFM

Model Inputs
1. Developing Road Network
2. Developing Traffic Analysis Zones (TAZs)
3. Gathering Socio-Economic Data

4 – Step Modeling Process
1. Trip Generation
2. Trip Distribution
3. Mode Choice/Split
4. Traffic Assignment
Development of Road Network

Creating Base Year Road Network

- Michigan Geographic Framework
  - Website: http://www.michigan.gov/cgi

  - Scaled, repositioned, length
  - Grade separation variables
  - National Functional Classification (NFC)
  - Road Name (with direction and type)
  - Physical Reference with beginning and ending mile point
  - County/Jurisdictional Boundaries
  - Federal Aid Roads (Version 5 and higher)
Framework “all roads” file
Framework w/ Model Road Network
Centroids

- Centroids represent the zones in model.
- Centroid connectors are special links which connect the centroids to the model network.
  - Represent the local roads
- Building centroid connectors
  - No intersections (or corners of zones)
  - No connectors crossing physical barriers (rivers)
  - Connect to road network where a local road exists
Purposes of Road Network Data

- Estimate capacity and model speeds of the roadway (see handout)
  - Road type, link type, NFC, through lanes, parking, lane width, percent commercial, area type, trunkline, etc.
  - Capacities for Level of service D
    - Capacities are measured either by a lookup table or a capacity calculator.
  - Free-flow and Posted Speeds are used as a starting point for determining final model speeds
Example of Road Segment

LENGTH = .2 miles
DIR_CD = 2
LINK_TYPE_CD = 3
TRAF_OP_CD = 3
THRU_LANES = 2
AREA_TYPE = 1
LANE WIDTH = 11
PARKING = 2
TRUNKLINE = Y
PER_COMM = 5%
POSTED SPEED = 25
FREE_FLOW SPEED = 28.28
TRAVEL TIME = .424
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Road Network Process

- **Skim network matrix**
  - Determines the travel time to get from each location to another within the network.

- **Connectivity of network**
  - Check to ensure that all links are connected at appropriate locations
  - Grade separation/crossing checks

- **Turn Penalties and/or Prohibitions**
Road Network Paths

Reasonable Paths

- Use Shortest Path tools
  - Shortest Path
  - K Shortest Path

Why

- Connectivity
- Travel Times
- Illogical travel patterns
Road Network Process

- Validate model volumes with Traffic Counts

  Traffic Counts for base year need to be coded
  - Modified raw counts
  - Average annual daily traffic (AADT)

- Where counts come from (sources)
  - MDOT
  - Local County Road Commissions
  - Local Cities and Planning Agencies
TAZ Network

Traffic Analysis Zones (TAZs)
- Small geographic subdivisions of the study area
- Developed according to Census Blocks with similar land use and zoning characteristics

Size and Boundary Delineation
- Size is based on model application
- Boundaries: road network, physical features, political jurisdictions and census geography
TAZ Network

- Census Geography
  - Socio-economic Data

Transportation and Land Use (Direct Link)
  - Can’t plan one without addressing the other
Model Inputs - TAZs

Area Type: (see handout)

1. Central Business District
2. Urban
3. Suburban
4. Fringe
5. Rural
The traffic analysis zones contain population, household and employment information. Centroids are points representing:

- Aggregated population, HH and employment
- All local residents and businesses within a zone
SE Data Methods

Population and Households (Trip Productions)

- 2000 Census Blocks containing
  - Population (in households vs. group quarters)
  - # of Households (Occupied vs. Vacant dwelling units)
  - Persons/HH (persons in HH/Occupied DUs)

- 2000 Census Block Groups containing
  - Average Income/HH
  - Auto Availability: # of HH with 0,1,2,3+ Autos
SE Data Methods

Employment Types (Trip Attractions)
- Retail Employment
- Service Employment
- Other (Non-Service, Non-Retail) Employment

Employment Databases
- MESA (2005)
- Claritas (2008)
- Hoovers (2008)
Four-Step TDFM Process

- **Trip Generation**
  - Who is making the trip and why are they making the trip (what purpose)?

- **Trip Distribution**
  - Where are they going?

- **Mode Choice/Mode Split**
  - How are they getting there (by car, walk, bus)?

- **Traffic Assignment**
  - What route are they taking to get there?
Trip Generation

- Socio-Economic data by TAZ to generate productions and attractions

- Based on NCHRP 365 or Modified 365
  - Population range 50-199k, 200-500k, 500k+
  - Based on auto per household or income
  - External – internal, internal – external
  - Special generators
Production Variables

Cross Classification Method
- Total Households
- Autos per household
- Household size

Other factors to consider
- Household Income
- Area Type of the zone
- HH make-up
  - Presence of Children, Retirees, etc.
### Cross Classification Table

Based on Average Autos and Average HH Size

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## Cross Classification Table

Based on Area Type & Autos Per HH and Persons Per HH

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Trip Purposes

- Home
- Work
- Home Based Work
- Non-Home Based
- Retail Mall
- Home Based Other
Current Purposes

- Home-Based Work (HBW)
- Home-Based Other (HBO)
- Non-Home-Based (NHB)

Additional Purposes being considered

- Home-Based Retail (HBR) – shopping
- Home-Based School/University (HBSU)
- Non-Home Based Work (NHBW)
- Non-Home Based Other (NHBO)
Attraction Variables

- Linear regression equations by trip purpose
  - Total households
  - Retail employment
  - Service employment
  - Other (non retail or service) employment
  - Area type
Balancing of Trip Table: Productions and Attractions

- HBW and HBO purposes are set to productions
- NHB trips are set to attractions
- I-E/E-I trips are factored by trip purpose
  - HBW = 0.20, HBO = 0.57, NHB = 0.23
- Trips balanced
- Final product: Productions & attractions by purpose for each TAZ
Calibration and Reasonableness Checks – Trip Generation

- Review SE data for mistakes and anomalies
- Average person trips per household
- Percentage of overall trips by purpose
- Average Person Trips per Vehicle
  - 3.5 to 4.0
- Production/Attraction Ratio
  - 0.90 to 1.10
### Calibration and Reasonableness Checks – Trip Generation

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Trip Distribution

**Trip Distribution**: where are people going?

- Uses trip ends from trip generation and the network skim matrix to link trip ends to TAZs

**Gravity Model**
- Based on Newton’s 3rd law of Gravity
- Interaction Level between two TAZs
  - Directly related to the TAZ size (measured by number of trips)
  - Inversely related to distance (travel time)
Gravity Model

- 10 Homes
- 15 Homes
- 300 Employees
- 75 Homes
- 400 Homes
- 15 Employees
Trip Distribution: Friction Factors

- Measure of one’s perception of distance.
- NCHRP 365: Length of Average Trip by Purpose
- Express effect of spatial separation or accessibility on travel patterns
- Function of Impedance of travel from P to A, measured in terms of travel time and cost
Trip Distribution: Friction Factors

![Graph showing friction factors over travel time]

- HBW
- HBO
- NHB
## Trip Distribution: Friction Factors

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</table>
Trip Distribution - Outputs

Output:

- Zone-to-Zone Person Trip Matrices
- Measured in terms of number of Productions and Attractions traveling to and from each zone.
Calibration and Reasonableness Checks – Trip Distribution

- Trip Length Frequency Distribution
- Validation Check: HBW Average Trip Length
  - 15-20 minutes
  - Compare with CTPP Journey-To-Work
- HBO and NHB Average Trip Length
  - 75-85% of HBW trip length
- Percent of Intrazonal Trips
  - Typically less than 5%
External to External Trips

- Traffic counts
- Percent of through trips
  - Statewide Model, professional judgments or Origin-Destination studies
  - Create number of through trips
- Create EE matrix for base year and future years
  - Growth factor method (TransCAD)
  - Check matrix sums
- Check matrix for reasonableness
Mode Choice / Split

**Mode Choice**
- TMAs are developing mode split logit models
- Small MPOs – Transit (not significant factor)

**Auto Occupancy**
- Trip Distribution = Person Trips
- Auto Occupancy factors are applied by trip purpose
- Person Trips → Vehicle Trips (HBW, HBO, NHB)
- NCHRP 365 values (sometimes modified due to heavy reliance on automobiles in MI)
## Auto Occupancy Rates

<table>
<thead>
<tr>
<th>NCHRP 365</th>
<th>Kalamazoo and Jackson</th>
<th>MI Travel Counts Small MPO</th>
</tr>
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<tbody>
<tr>
<td>HBW</td>
<td>1.11</td>
<td>1.1</td>
</tr>
<tr>
<td>HBO</td>
<td>1.67</td>
<td>1.3</td>
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<tr>
<td>NHB</td>
<td>1.66</td>
<td>1.37</td>
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</table>
Mode Choice / Split

Auto Occupancy

Productions and Attractions

Balance Matrix

Origins and Destinations
(Final Output Matrix)
Time of Day/Peak Periods

- **Peak Period Model**
  - AM Peak - 6am-9am
  - Mid-day Peak = 9am-3pm
  - PM Peak - 3pm-6pm
  - Off Peak - all other hours

- Apply factors prior to assignment
  - Percentage of trips
Traffic Assignment

- **Inputs:**
  - Final Total O&D Distribution Matrix by Vehicle Trips
  - Road Network using
    - Travel Time
    - 1-Way Capacity
Traffic Assignment

Methods

- **All or Nothing** – assigns all trips to shortest path (capacity is not a factor)
  - Statewide Model uses All or Nothing

- **User Equilibrium**
  - Uses capacity, and delay functions to address congestion impacts to travel time and route choice
  - Assigns all trips to shortest path until traffic volumes approach the capacity, and then distribute the remainder along alternative routes
  - Goes through a series of iterations until it reaches a level of convergence (.01 or .001)
Delay Function – BPR Curve

- An equation that tells the model how to adjust the speed of a link depending on the V/C ratio
  \[
  C_{\text{time}} = F_{\text{time}}(1 + a(v/c)b)
  \]
- Can be adjusted globally and on an individual link basis
BPR Curve

**TRAVEL SPEEDS**

<table>
<thead>
<tr>
<th>FACILITY</th>
<th>α</th>
<th>β</th>
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</thead>
<tbody>
<tr>
<td>70 mph</td>
<td>0.88</td>
<td>9.8</td>
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<tr>
<td>Freeways</td>
<td>0.83</td>
<td>5.5</td>
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<tr>
<td>50 mph</td>
<td>0.56</td>
<td>3.6</td>
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<tr>
<td>70 mph</td>
<td>1.00</td>
<td>5.4</td>
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<tr>
<td>Multilane</td>
<td>0.83</td>
<td>2.7</td>
</tr>
<tr>
<td>50 mph</td>
<td>0.71</td>
<td>2.1</td>
</tr>
</tbody>
</table>
Calibration and Reasonableness Checks – Traffic Assignment

Check Vehicle Miles Traveled (VMT)

- VMT per household
  - 30 to 40 miles per day for small urban
  - \( \frac{\text{Total volume} \times \text{miles}}{\text{Total Households}} \)

- VMT per person
  - 10 to 16 miles per day for small urban
  - \( \frac{\text{Total volume} \times \text{miles}}{\text{Total Persons}} \)
MDOT Validation Standards

- **Area wide VMT**: +/- 5% (Assignment/count)
- **AREA TYPE**: +/- 10%
  - CBD, Urban, Suburban, Fringe, Rural
- **Screenline**: +/- 5%
- **Cutline**: +/- 10%
# Validation Standards

<table>
<thead>
<tr>
<th>LINK TYPE</th>
<th>MDOT Standards</th>
<th>FHWA Standards</th>
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<tbody>
<tr>
<td>Freeway</td>
<td>+/- 6%</td>
<td>+/- 7%</td>
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<tr>
<td>Ramps</td>
<td>NO STANDARD</td>
<td>NO STANDARD</td>
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<tr>
<td>Trunkline</td>
<td>+/- 6%</td>
<td>NO STANDARD</td>
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<td>Major Arterial</td>
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<td>Minor Arterial</td>
<td>+/- 10%</td>
<td>+/- 20%</td>
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<tr>
<td>Collector</td>
<td>+/- 20%</td>
<td>+/- 25%</td>
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</table>
**VOLUME GROUP Validation Standards**

Individual link targets (percent deviation of assignment/count volumes on a link-by-link basis)

<table>
<thead>
<tr>
<th>Volume Group</th>
<th>MDOT Standards</th>
<th>FHWA Standards</th>
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<tbody>
<tr>
<td>&lt; 1,000</td>
<td>+/- 200%</td>
<td>+/- 60%</td>
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<tr>
<td>1,000 to 2,500</td>
<td>+/- 100%</td>
<td>+/- 47%</td>
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<tr>
<td>2,500 to 5,000</td>
<td>+/- 50%</td>
<td>+/- 36%</td>
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<td>5,000 to 10,000</td>
<td>+/- 25%</td>
<td>+/- 29%</td>
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<td>10,000 to 25,000</td>
<td>+/- 20%</td>
<td>+/- 25%</td>
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<td>25,000 – 50,000</td>
<td>+/- 15%</td>
<td>+/- 22%</td>
</tr>
<tr>
<td>&gt; 50,000</td>
<td>+/- 10%</td>
<td>+/- 21%</td>
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</table>
Calibration and Validation

To find out more about calibration & validation check the following:

"Model Validation and Reasonableness Checking Manual" June 2001- TMIP (Travel Model Improvement Program)

http://tmip.fhwa.dot.gov/clearinghouse/docs/mvrcm/
Forecasting

The model can assist in planning out projects in the short- and long-term future.

Population, Household, and Employment data are projected out to future years based on various forecasting models (REMI, Woods and Poole, etc.)

The forecasted data is then placed onto a build or no-build network to establish deficiencies in the future.
Examples of Model Applications

- New US-31 Freeway Alternative in Berrien County near Benton Harbor, MI
- I-475 freeway closure and lane reductions work zone analysis in Flint, MI
Example 1: US-31 Berrien County

**Situation:** Proposed completion between Napier Avenue and I-94

**Task:** Study travel characteristics in 2035 with and without the freeway

**Analysis:** Study both the local impacts (using the TwinCATS Urban Model) and the regional/statewide impacts (using Statewide Model)
Example 1: US-31 Berrien County
Example 1: US-31 Berrien County
Example 1: US-31 Berrien County
Example 1: US-31 Freeway – Urban Model Results
Example 1: US-31 Freeway – Statewide Model Results
Example 2: I-475 in southern Genesee County

**Situation:** Proposed Closure of Freeway in 2010 for reconstruction

**Task:** Study impacts to network and study likely detour routes.

**Analysis:** Develop diversion map depicting what routes that vehicles will be diverted to during time of construction (see map on wall)
Example 2: I-475 in Genesee County
Example 2: I-475 in Genesee County
Household Travel Survey Data

- The seven sampling areas
  1. SEMCOG (S.E. Michigan & Detroit)
  2. TMA areas (200,000+ population)
  3. Small Urban Model areas (50,000 – 200,000 population)
  4. Small Cities (5,000-50,000 population)
  5. Rural Upper Peninsula
  6. Rural Northern Lower Peninsula
  7. Rural Southern Lower Peninsula

- Randomly selecting households within the seven sampling areas
Urban Model Improvement Program (UMIP)

- Contract to improve models.
- Develop localized model factors for four-step model
- Develop a single model framework for all SUMAs
- Develop a model development and application guide
- Evaluate current and State-of-the-Practice modeling techniques
Revise calibration and validation standards for MI models.

Add additional components to existing models
  - Peak Period/Time-of-day
  - Truck
  - Mode Choice/Transit
What Were We Not Clear About?

Questions?