Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA/TX-00/1838-4		

4. Title and Subtitle	5. Report Date
PRESENTATION SLIDES FOR REVIEW MEETING ON AUGUST 19, 1999	September 1999
	6. Performing Organization Code
7. Author(s) Harikesh S. Nair, Huimin Zhao, and Chandra R. Bhat	8. Performing Organization Report No. 1838-4
9. Performing Organization Name and Address Center for Transportation Research The University of Texas at Austin 3208 Red River, Suite 200 Austin, TX 78705-2650	10. Work Unit No. (TRAIS) 11. Contract or Grant No. 0-1838
12. Sponsoring Agency Name and Address Texas Department of Transportation Research and Technology Transfer Section/Construction Division P.O. Box 5080 Austin, TX 78763-5080	13. Type of Report and Period Covered Research Report (9/98-8/99) 14. Sponsoring Agency Code

15. Supplementary Notes

Project conducted in cooperation with the Federal Highway Administration.

16. Abstract

This report presents the slide presentation of a meeting on August 19, 1999.

17. Key Words	18. Distribution Statement
Nonattainment areas, ozone, transportation control measures, emissions modeling, travel demand modeling	No restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161.

19. Security Classif. (of report)	20. Security Classif. (of this page)	21. No. of pages	22. Price
Unclassified	Unclassified	70	

PRESENTATION SLIDES FOR REVIEW MEETING ON AUGUST 19, 1999

by

Harikesh S. Nair, Huimin Zhao, and Chandra R. Bhat

Research Report 1838-4

Project Number 0-1838

Study Title: Transportation Control Effectiveness in Ozone Nonattainment Areas

Conducted for the

TEXAS DEPARTMENT OF TRANSPORTATION

in cooperation with the

U.S. DEPARTMENT OF TRANSPORTATION
Federal Highway Administration

by the

CENTER FOR TRANSPORTATION RESEARCH
Bureau of Engineering Research
THE UNIVERSITY OF TEXAS AT AUSTIN

September 1999

DISCLAIMERS

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ACKNOWLEDGMENTS

The researchers acknowledge the assistance provided by William Knowles (Austin District), TxDOT project director for this study. Also appreciated is the guidance provided by the other members of the project monitoring committee, which included George Reeves (DAL), Wayne Young (TNRCC), and Carol Nixon (HOU).

Prepared in cooperation with the Texas Department of Transportation and the U.S. Department of Transportation, Federal Highway Administration.

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SLIDES PRESENTED AT REVIEW MEETING ON AUGUST 19, 1999

TCM Evaluation for Ozone Non-attainment Areas

University of Texas, Austin

Broad Objectives

- Develop framework for analyzing TCM strategies
  - Refine travel demand models
  - Develop supplementary models for emissions modeling
  - Integrate all models within GIS architecture
- Validate Framework

Tasks completed at time of last meeting

- Reviewed Current NCTCOG Procedures
  - Travel Demand Modeling
  - Mobile Source Emissions Modeling
- Acquired Data
  - 1996 Activity Survey Data (NCTCOG)
  - 1996 Household Vehicle Survey Data (NCTCOG)
  - Vehicle registration data for Dallas, Tarrant, Collin, Denton and Rockwell counties (D-12 division of TxDoT)
- Cleaned and analyzed data

Tasks pursued since last meeting

- Developed improved models for Travel Demand Modeling
- Refined and developed improved models for Emissions Forecasting

- contd

Tasks pursued since last meeting - contd

- Collected Data
  - Annual 24-hour vehicle counts in D-FW from 1977-1993 (TxDOT Div 10, TxDOT RPO)
  - 1996 GIS road network coverage for D-FW (NCTCOG)
  - 1996 GIS zonal coverage for D-FW (NCTCOG)
  - 1996 GIS socioeconomic data for D-FW (NCTCOG)
  - 1996 zonal land use data (NCTCOG)
- Prepared reports on
  - NCTCOG's Travel Demand Modeling procedure
  - NCTCOG's Emissions Modeling procedure

Overview of rest of presentation

Part I : Travel Demand modeling

- New models developed
- Future Extensions

Part II : Emissions Forecasting

- New models developed
- Future Extensions

Part I. Travel Demand Modeling

Tasks Undertaken On Travel Demand Modeling

- Trip Generation
  - Focused only on trip productions.
  - Prepared and assembled data for estimation.
  - Estimated cross-classification and ordered response models.

Tasks Undertaken On Travel Demand Modeling

- Trip Distribution
  - Determines fraction of productions at each zone attracted to each attraction zone.
  - Prepared and assembled data for estimation.
  - Initiated development of computer code for Trip Distribution Model estimation.

Trip Production Modeling

- Estimated new model with 1996 activity survey data
- Used three trip purposes: home-based work trips, home-based non-work trips and non-home-based trips
- Developed models for disaggregate trip purposes

Trip Production Modeling

- Developed and compared Cross Classification Model and Ordered Response Probit Model.
- Used four income quartile and six household size categories as in current NCTCOG model.
- Income quartiles based on 1996 U.S. census data.
- Will present home-based non-work trip estimation results.

Sample for Analysis

- 4641households in “raw” activity survey file.

- 3561 households remain after data cleaning and screening.

- 186 households (5.2%) did not make any trip during the survey day.

Data Description

0	1150	32.29%
1	548	15.39%
2	1138	31.96%
3	234	6.57%
4	356	10.00%
>=5	135	3.79%

Data Description

0	675	18.96%
1	325	9.13%
2	725	20.36%
3	227	6.37%
4	438	12.30%
5	141	3.96%
6	257	7.22%
7	123	3.45%
8	180	5.05%
9	74	2.08%
10	102	2.86%
>=11	294	8.26%

Data Description

0	1192	33.47%
1	441	12.38%
2	470	13.20%
3	316	8.87%
4	311	8.73%
5	189	5.31%
6	185	5.20%
7	121	3.40%
8	80	2.25%
9	70	1.97%
>=10	186	5.22%

Ordered Response Model: Theory

- The number of trips made by each household is discrete.
- The trip-making behavior has definite order. The second trip has to be made after the first trip.
- Continuous exogenous variables can be accommodated.

Modeling Results (for HBNW Trips)

Cross-classification Model:

	HH1	HH2	HH3	HH4	HH5	HH>=6
LOW	1.589	3.109	5.024	6.839	8.641	6.300
LOW-MEDIAN	1.615	3.318	5.705	6.710	8.793	10.737
HI-MEDIAN	1.486	3.253	4.762	7.000	10.672	13.964
HIGH	2.217	3.101	4.884	7.498	9.646	11.000

$R^2 = 0.331$

Probabilistic Prediction Results from ORP:

	HH1	HH2	HH3	HH4	HH5	HH>=6
LOW	1.816	3.155	4.921	6.504	8.324	5.876
LOW-MEDIAN	1.828	3.345	5.721	6.596	7.863	9.679
HI-MEDIAN	1.679	3.283	4.686	6.883	10.167	11.942
HIGH	2.348	3.133	4.814	7.193	8.814	9.657

Modeling Results (for HBNW Trips)

Ordered Response Probit Model Results:

- Households with more individuals tend to make more trips.

- Higher income households do not necessarily make more trips compared to lower income households.

Other Important Variables Affecting Trip Production

- Age structure
- Race
- Education Level
- Employment status
- Student
- License

Models On Disaggregate Trip Purposes

- Re-defined six trip purposes:
  - community
  - grocery shopping
  - other shopping
  - personal business
  - recreational
  - social.
- Will provide recommendations regarding trip purpose categories for use in Trip Generation.

Dissaggregate Trip Attraction-end Model

- Replaces the aggregate trip attraction and distribution models currently in use.
- Randomly selected six candidate attraction zones along with the actual chosen attraction zone for model estimation.
- Development of computer code is progressing.

Formulation of Ordered Response Probit Model

The random index function is:

$$I_n = \beta \mathbf{X_n} + \varepsilon_n$$

where I_n represents the degree of preference of one option over another for household n. ε_n is an error term distributed Normal with mean of zero and variance of one.

Formulation of Ordered Response Probit Model (Cont.)

A set of threshold value μ_i is also estimated:

if $I_n < \mu_0$, $T_n = 0$

if $\mu_{i-1} < I_n < \mu_i$, $T_n = i$ (for I = 1, 2,…, M-1)

if $I_n > \mu_{M-1}$, $T_n = M$

where T_n is predicted trips made by household n, M is the maximum trip rate in the choice set.

Deterministic and Probabilistic Prediction Methods

- Two methods to predict the trips made by households are used and compared.
- The deterministic method is formulated as followings:

$$\text{if } \beta \mathbf{X_n} < \mu_0,\ T_n = 0$$

$$\text{if } \mu_{i-1} < \beta \mathbf{X_n} < \mu_i,\ T_n = i \qquad \text{(for } i = 1, 2, \ldots, M\text{-}1)$$

$$\text{if } \beta \mathbf{X_n} > \mu_{M-1},\ T_n = M.$$

Deterministic and Probabilistic Prediction Methods (Cont.)

- The probability for household n making i trips is:

$$\begin{aligned} Pr_{ni} &= Pr(T_n = i) = Pr(\mu_{i-1} < \beta \mathbf{X_n} + \varepsilon_n < \mu_i) \\ &= Pr(\mu_{i-1} - \beta \mathbf{X_n} < \varepsilon_n < \mu_i - \beta \mathbf{X_n}) \\ &= \Phi(\mu_i - \beta \mathbf{X_n}) - \Phi(\mu_{i-1} - \beta \mathbf{X_n}) \end{aligned}$$

The expected trip rate combines all the choice (trip rate) possibilities which could be made by household n. It is formulated as:

$$T_n = \sum_{i=0}^{M} i * \Pr_{ni}$$

Part II
Emissions Modeling

Introduction

- 50% of ozone precursor emissions and about 90% of CO emissions originate from mobile source emissions
- Accurate and reliable emissions forecasting needed to
  - Demonstrate regional adherence to NAAQS
  - Conform to emissions budgets established in the State Implementation Plans (SIPs)
- More improvements need to be made to the emissions modeling process

Current Areas of Focus

- VMT Mix Ratio
- Intra-Zonal Trip Length
- Operating Mode Fractions
  - Hot stabilized vs Cold transient modes
  - Hot starts vs Cold starts

VMT Mix Ratio

Background

- VMT = Vehicle Miles Traveled
- VMT Mix = Fraction of V.M.T accrued by a particular vehicle type
- EPA Vehicle types based on weight/fuel type - other classification schemes exist
- Emission Factor models take VMT mix as input

State of the Practice

- Accept aggregate Mobile5 national default values
  - VMT mix sensitive to regional variations
- Use 24-hour vehicle classification counts
  - Aggregate level values applied to lower-level road types
  - Variations exists even after controlling for roadway class

Proposed Methodology

- Model VMT Mix as a function of several link and zonal characteristics
- Use a Fractional Split model

Data Sources

- 24-hour Local Vehicle Classification counts by the TxDot R.P.O and the TxDot D-10 division, spanning 16 years (1979-1995)
- 1990 Dallas-Fortworth roadway and zonal G.I.S networks from NCTCOG
- 1990 Landuse disaggregation from NCTCOG
- 1990 Disaggregate Zonal level information from NCTCOG

Data Preparation

- Geocode vehicle count locations to the 1990 D-FW roadway and zonal G.I.S networks
  - Overlay road and zonal coverages within GIS environment
  - Query location in the road coverage to get link id using
    - a) the name of the street
    - b) names of the cross streets at the end nodes
  - Query location in zonal network coverage to get id of TSZ
- Map land-use characteristics and link characteristics using link and TSZ identifiers
- Convert data into "case-alt" format for estimation - fraction of VMT accumulated by each vehicle class is the dependant variable

Data Characteristics

- Number of Observations = 243
- Six vehicle classifications
  - Passenger Cars
  - Pickups and Vans
  - Sports Utility Vehicles
  - Heavy Trucks (3-ax,4-ax & 6-ax Combos)
  - Buses-2 axles and 3 axles
  - Motorcycles

Exogenous Variables

- Link Functional Classification
  - Freeways
  - Major Arterials
  - Minor Arterials
  - Collectors/Local Residential streets
- Link Physical Attributes
  - Number of lanes
  - Is Road Divided?
- Link Free Speed
  - Low Speed (0-30 mph)
  - Medium Speed (31-40 mph)
  - High Speed (55- mph)

Exogenous Variables - contd

- Degree of Urbanization in zone
  - Central Business District
  - Urban
  - Sub-Urban/Rural
- Zonal Attributes
  - Total area in Retail, Office and Hotel/motel
  - Total area in Manufacturing Plants & Warehouses
  - Presence of Airport-related infrastructure
  - Presence of institutional facilities

Model Results

- Link Functional Classification
  - More PUVs and MC on arterials
  - PUVs and MC highest on collector/local streets
  - Buses low Collectors/Local Residential streets
- Link Physical Attributes
  - Number of lanes - decrease in bus and trucks
  - Divided roads - less buses and more trucks
- Link Free Speed
  - PUVs and SUVs more prevalent on higher speed links
  - Buses most prevalent on low-speed links

Model Results - contd

- Degree of Urbanization in zone
  - Lesser trucks in CBDs and Urban areas

- Zonal Attributes
  - More autos in zones with greater area in Retail, Office and Hotel/motel
  - More non-auto/non-motorcycle modes in zones having more manufacturing plants & warehouses
  - More PUVS in zones with airport-related infrastructure
  - More autos in zones with institutional facilities

Conversion to EPA vehicle classes

- Use county specific Local Registration data
- Use TEDB default gasoline-diesel split
  - Passenger cars
  - Light Duty Trucks

	LDGV	LDDV	LDGT1	LDGT2	LDDT	HDGV	HDDV	MC
Autos	98.8	1.2	-	-	-	-	-	-
PUVs	-	-	95.16	2.72	2.12	-	-	-
SUVs	-	-	95.16	2.72	2.12	-	-	-
Trucks	-	-	-	-	-	35.43	64.57	-
Buses	-	-	-	-	-	20.90	79.91	-
MCs	-	-	-	-	-	-	-	100

TXDot to EPA vehicle conversion factors for Dallas County

Future Extensions

- Integrate model within TransCAD
- Extend model to account for seasonal and temporal variation in VMT mix - data constraints

Areas of focus

- VMT Mix Ratio
- **Intra-Zonal Trip Length**
- Operating Mode Fractions
  - Hot stabilized vs Cold transient modes
  - Hot starts vs Cold starts

Intra-zonal Trip length

Background

- VMT Estimation on Local roads
  - Local roads not included in road network
  - Use parameter representing average intra-zonal trip length
- Present practice
  - Estimate Intra-zonal Trip length Parameter as a function of area of zone

Proposed Approach

- Use a log-linear regression model
  - Assume speed of 20 m.p.h on local roads and model duration of intra-zonal trips

- Estimate Intra-zonal trip duration parameter as a function of various zonal characteristics

Data sources and Preparation

- Use 1996 Activity Survey data for Intra-zonal trips
  - TAP level aggregation
- Extract details of <u>*intra*</u>*-zonal* <u>*vehicle*</u> trips from activity file
  - trips using a vehicle made by two or more persons, counted as separate *person* trips
  - eliminate repeated trips

Exogenous Variables

- Trip Purpose
  - home based (base)
  - non-home based
  - work (base)
  - shopping
  - personal-business
  - social-recreational
  - school trips
- Zonal Characteristics

Model Application

Given zonal characteristics, the Intra-zonal trip length parameter is given by:

20 * Intra-zonal trip duration

Local VMT = Vehicle trips (from trip generation)
* Intra-zonal trip length

Areas of focus

- VMT Mix Ratio
- Intra-Zonal Trip Length
- **Operating Mode Fractions**
  - Hot stabilized vs Cold transient modes
  - Hot starts vs Cold starts

Operating Mode Fractions

Part A: Hot stabilized vs Cold transient trips for local roads

Background

- Cold Transient Operating Mode: first 505 s of operation of vehicle
- Hot Stabilized mode: remainder of use of vehicle
- Emissions factor models take operating mode fractions as an input to estimate pollutant-specific emission factors

State of Present practice

- Ellis's (1976) methodology used
  - local roads not included in (DFWRTM) network
  - apply same fractions as developed for higher level road types
- No documented method exists to obtain operating modes for local roads

Proposed methodology and application

- Estimate trip duration distribution from log-regression model for intra-zonal trip duration
- Obtain the share of cold-transient trips as the proportion of trips of duration less than 505 seconds

Part B: Hot vs Cold starts for local roads

Background

- Hot start: start of a vehicle within 1 hour of last-use
- Cold start: start of a vehicle after more than 1 hour of last-use
- Cold starts emit more NOx => important for Ozone non-attainment areas
- Most cold starts take place on local roads (first-starts in residential areas)
- The proportion of hot and cold starts is an input for calculating emission factors

Proposed Methodology

- Model whether a trip is a first start or not, as a function of trip purpose, zonal characteristics
- Assume that all first starts are cold-starts
- For all non-first starts, use a linear regression model of the logarithm of soak-time on zonal characteristics and trip purpose
  - Determine share of hot vs cold starts within set of trips with non-first starts

Data preparation and Model application

- Calculate soak-time for each household vehicle from details of intra-zonal *vehicle* trips in the 1996 activity survey
- Given zonal characteristics, estimate proportion of cold starts within the zone, as

  Fraction of first-starts + Fraction of non-first starts that are cold starts

Next Tasks

- Travel Demand modeling side
  - Complete linking of network impedance files with other files for estimation of travel models
  - Complete specification and interpretation of trip generation and trip distribution models
  - Develop recommendations for trip purpose classification and explanatory variables for use in trip generation and trip distribution
  - Initiate specification and estimation of travel mode choice and departure time models
- Emissions Modeling side
  - Complete estimation of models of intra-zonal trip length and soak time duration for intra-zonal trips
  - Integrate all GIS files and introduce all estimated models VMT mix model into TransCAD

Acknowledgements

- Arnold Breeden, TxDot
- Ken Cervenka, NCTCOG
- Ken Kirkpatrick, NCTCOG
- Gustavo Baez, NCTCOG
- Chris Klaus, NCTCOG