Large Scale Traffic Modeling for Route-Guidance Evaluation: A Case Study

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LARGE-SCALE TRAFFIC MODELING
FOR ROUTE-GUIDANCE EVALUATION: A CASE STUDY

by R.L. Smith and K.E. Wunderlich
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Abstract

Through a case study of the Troy, Michigan roadway system we address the problem of creating and calibrating a realistic, large-scale model for dynamic traffic simulation. Topics include the generation of network topologies, origin-destination location, link and signalization characteristics, and origin-destination flow rates.

1: Introduction

The goal of the Troy network is to model a 36 square-mile region enclosing the city of Troy, Michigan for a single hour of morning rush hour traffic. Troy is a major Detroit suburb with a residential population of over 80,000 and a large industrial and commercial base. Because of the rapid growth of the city in the last ten years, traffic conditions are often some of the most congested in the Detroit metro area. Further, a major interstate highway, I-75, runs roughly diagonally across Troy from the northwest to the southeast, so there are a significant number of "drive-through" vehicles using the network for trips neither originating nor terminating within the Troy cordon area. The cordon area is defined as all roadways with segments bounded by 14 Mile Road on the south, Adams Road on the west, South Boulevard on the north, and Dequindre Road on the east. Dequindre Road forms the eastern boundary of Oakland County with Macomb County. The Troy area is the planned testing site for the FAST-TRAC experiment co-sponsored by Siemens, the Oakland County government, and the three major domestic auto manufacturers.

We chose the INTEGRATION traffic simulation to model the cordon area. INTEGRATION is a microscopic traffic simulation which models each vehicle individually and allows the dissemination of various types of route guidance information. The simulation requires five input files:

(1) **Network topology**: describes the geographic location and relationships between nodes and links.

(2) **Link characteristics:** describes each link (directed arc) in the network in terms of its length, free-flow speed, capacity, signalization, etc.

(3) **Signalization file:** describes the signal timing plans for nodes representing signalized intersections.

(4) **Dynamic origin-destination flow data**: describes the demand on the network in terms of the number of vehicles starting a trip from an origin to a destination at a particular time interval.

(5) **Incident descriptor:** describes the location, severity, and duration of accidents on the network.

2: Troy Model

Troy is modeled at an arterial level. This level of detail extends to the explicit modeling of every major roadway segment in the region, from freeway to major and secondary arterial roads. Small residential streets are not modeled explicitly. Particular attention has been paid to detailing major intersections. For example, every freeway intersection includes on- and off-ramp links with appropriate signalization. Major sources for the data used to generate the Troy model were the Southeastern Michigan Council of Governments (SEMCOG) regional planning authority and the city of Troy.

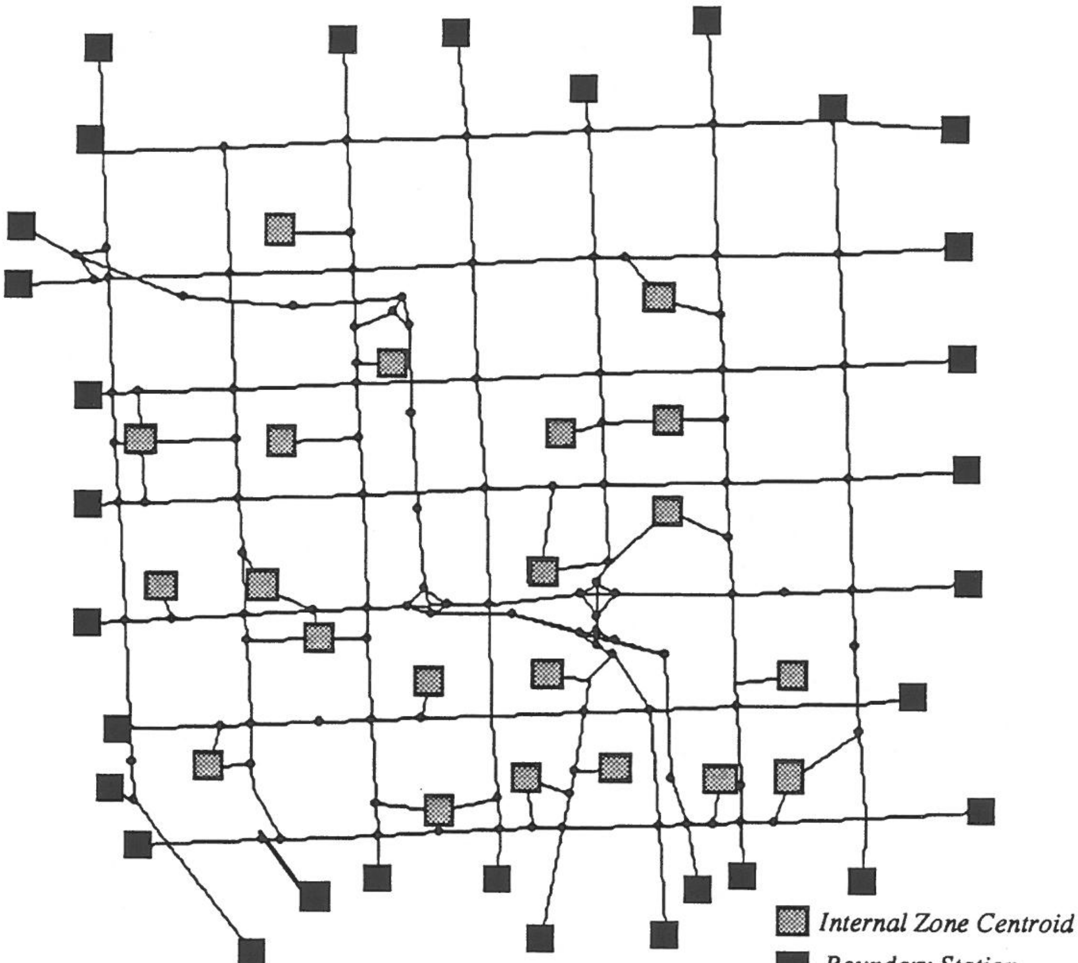

Fig.ure 1 The Troy Test Network

Network topology: (465 links, 170 nodes, 52 origins/destinations) The basic Troy network structure was generated from topology data used by regional planners for static, region-wide planning models. SEMCOG planners used standard transportation techniques to identify 1500 zones and corresponding zone centroids across its five-county jurisdiction as origins and destinations for regional travel. Of these 1500 zone centroids, twenty-one fell within the cordon area we defined above. These zone centroids were included in the Troy model as origins/destinations. Second, we identified all possible entry and exit points to the cordon area as boundary stations. These 21 stations comprise the second set of origins/destinations. Exit and entry points were only identified on the freeway and arterial links. Travel in or out of the cordon area on residential streets was not modeled.

Link characteristics: Link free-flow speed, length, and capacity data were all converted for use from the large planning model data. Additional links were added to some intersections to model freeway ramps and complicated major intersections. These additional links were capacitated to replicate characteristics of typical ramps and links in the SEMCOG data. Finally, zone centroid connectors were added to model the small networks of residential streets. These allow travel from zone centroids (which usually do not fall on arterials) to adjacent arterial links. Centroid connectors are assigned a length equal to the Euclidean distance from zone centroid to nearest arterial, and are characterized by slow speeds (30 kph) and large capacities. This results in the travel from arterial to zone centroid being generally slow, but less sensitive to congestion traffic. This helps model the fact that when vehicles leave the arterial network seeking destinations accessible only by residential streets, they are not all traveling together on a single link, but using a capillary network to reach various points within the zone.

Signalization: Signal timing plans were supplied by the City of Troy. These plans included cycle time, offsets, and phase splits. There are over 100 signalized intersections in the cordon area. Signals on residential streets were not modeled. Even with these intersections removed, over two-thirds of all signals were included. Simulated cycle lengths for all signals closely approximate the timings provided. Except for freeway access and selected major intersections, signalized multi phase intersections have been approximated with two-phase signals. As there is no comprehensive real-time signal optimization in Troy, none is modeled. One can, however, test potential optimization algorithms using the model, for example, the method of Sampath, Sengupta and Lafortune[1].

Dynamic origin-destination flow data: No good single source of data existed for this file. SEMCOG provided data on the average number of trips between zone centroids over a typical 24-hour period, as well as 24-hour link counts for major roadway links. Further, SEMCOG studies estimate that roughly 8% of all traffic volume is seen in the peak morning rush hour period[2]. Using standard origin-destination recovery techniques like that of Willumsen[3], it is possible to produce stationary O-D flow data for the peak morning period. However, for these methods to be even reasonably accurate, a good 52 x 52 seed matrix had to be generated.

Recall that through the cordoning off of the Troy area from the regional network, we obtained 21 internal zone centroids and 31 boundary stations. Since the internal zone centroids in the Troy model correspond directly with SEMCOG zone data, we have a good first cut at the number of vehicles traveling between these zone centroids. The boundary stations, however, have no direct relationship with the remaining 1400 zones defined by SEMCOG outside the Troy cordon area. As shown in figure 2, all trips and link flows in our cordon area are of one of four types: Internal-Internal (II), External-Internal (EI), Internal-External (IE) , or External-External (EE). We have to estimate which of the boundary stations will be used in any IE, EI trip. Further, for EE trips, we have to estimate if any boundary stations will be used at all since EE trips may or may not traverse the cordon area. In order to make these determinations, we have to make some approximate routing choices for all the trips between the 1500 SEMCOG zone centroids.

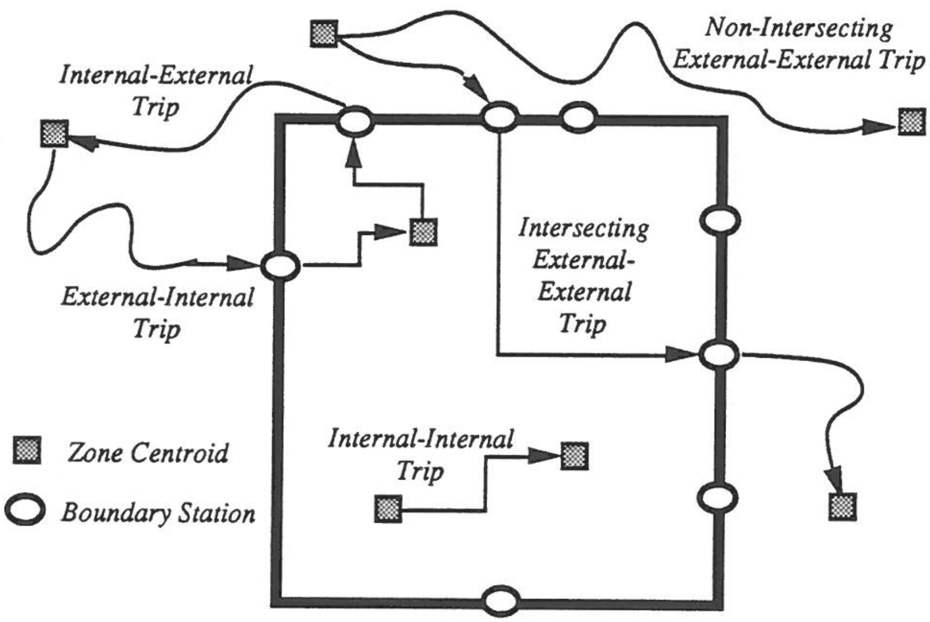

Figure 2 Trips In or Through the Troy Cordon Area

First, we assume that all trips between SEMCOG regional zone centroids follow a shortest free-flow path from origin to destination using the complete 14,000-link, 5,300-node regional network. To find shortest paths between all these zones would be a burdensome, if not impossible task. Additionally, accurate zone centroid location for all external zones was not available. The location of larger zoning entities for these external zones was available, however. These entities are districts (3-5 zones), super-districts (4-6 districts), and counties

(5-8 super-districts). In order to provide computational tractability, the 1500 SEMCOG zones were grouped into 127 aggregate zones using the following scheme, graphically illustrated in figure 3:

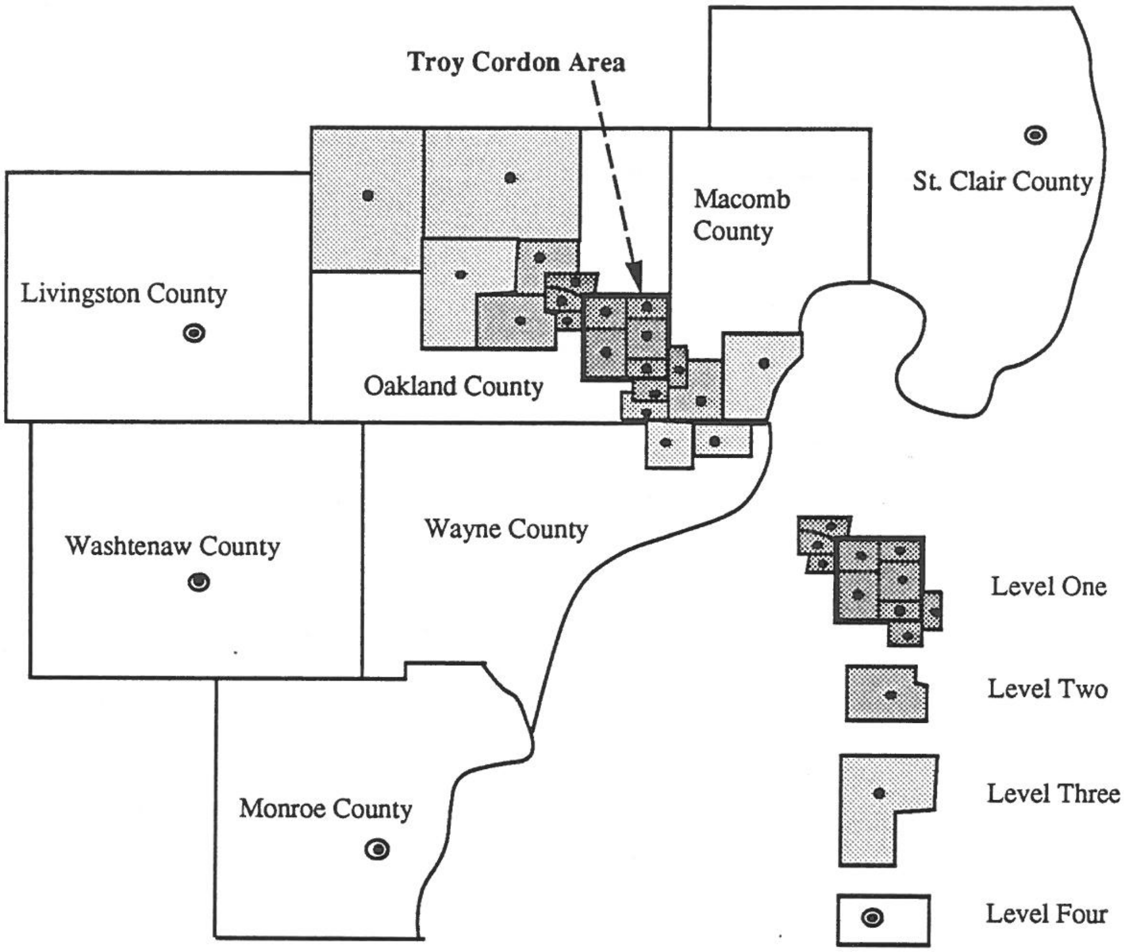

Figure 3 Aggregation Scheme for Regional Shortest Path Calculation

Level One:	All internal zone centroids and zones adjacent to the cordon area are not aggregated, i.e., assign each of these to their own unique aggregates.
Level Two:	Group by district zones contained in districts adjacent to level one aggregates.
Level Three:	For the all zones not yet assigned to level-one or level-two aggregates in Oakland, Macomb, and Wayne counties, group by super-district into aggregate zones.
Level Four:	Group by county all zones in Washtenaw, Livingston, Monroe, or St. Clair counties.

Ideally, we would then have identified aggregate-zone centroids by computing the center of population. However, given a lack of complete data on population density, the location of these centroids was approximated.

For each of the 127 aggregates, a shortest free-flow path tree on the regional network was generated. If any of these paths crossed a boundary station or terminated at an internal zone centroid, 8% of the 24-hour count for trips between the aggregates was entered into a corresponding estimated 52 x 52 estimated O-D trip matrix for the peak hour. Finally, this seed matrix was used to generate O-D demand data through synthetic origin-destination estimation.

Analysis of the results above indicate that in a 24-hour period, 833,355 trips pass through the Troy cordon area, which is 6.53% of all trips in southeastern Michigan. Trips through the cordon area are 20% II trips, 52% IE or EI trips, and 28% EE trips.

Incident descriptor: No incidents are used in this model.

3: Calibration

Although the Troy model is a closely detailed model of a real-world system, in order to reflect accurately traffic conditions in the city of Troy, MI it will have to be calibrated against measured empirical data. The simulation is not exact and the generation of our input files only approximates existing conditions. We plan to calibrate the model by matching experienced travel times for selected origin-destinations pairs in the simulation under 100% background traffic with measured travel times between their corresponding intersections on the actual roadway system. So far, we have identified two methods of calibrating the model.

First, we may adjust link capacities. For each link in the network, the capacity of the links converted from SEMCOG files is the midblock capacity. This is a flow measure of the number of vehicles that can traverse the link in one hour at an average speed of 115% of free-flow travel time. In INTEGRATION, capacity is interpreted in the impedance function as the number of vehicles physically on the link when experienced travel time for vehicles just entering the link is 200% free-flow travel time.[4] This subtle but important distinction in the nature of link capacity has important ramifications for the traffic modeler.

Second, since we are using 100% background traffic to calibrate the model, the methods by which we route background vehicles must be closely examined. There are several schemes that can be used to model background drivers behavior, including fastest free-flow path, shortest geographic-distance path, and more complicated multipath assignment methods like that of Underwood, Chou, Takriti.[5] The viability of these schemes can be measured by calibrating against measured travel times.

We plan to obtain this data through results from the FAST-TRAC project, or if needed, by performing limited point-to-point timings in the network ourselves.

4: Conclusions

The Troy model case study presents methods of translating existing static traffic data into inputs for a dynamic traffic simulation of a realistic roadway network. We consider in particular detail the generation of accurate origin-destination flow data using a regional travel analysis. When calibrated, the Troy model can serve as an important case in the evaluation of different route-guidance technologies.

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[1] Sampath M., Sengupta R., and Lafortune S. (1992) *Real-time Traffic Signal Control Using the Dynamical Systems Model.* University of Michigan IVHS Program (in progress).

[2] *Survey of Regional Traffic Volume Patterns in Southeast Michigan,* SEMCOG technical report, September 1985.

[3] Willumsen, L.G. (1984) "Estimating Time-Varying Trip Matrices from Traffic Counts." *Proceedings of the Ninth International Symposium on Transportation and Traffic Theory.* pp 397-411.

[4] Van Aerde, M., Voss, J., and McKinnon, G. (1989) *Integration Simulation Model User's Guide Version 1.1.* Department of Civil Engineering, Queen's University, Kingston, Canada.

[5] Underwood S., Chou Y., and Takriti S. (1991) *Behavioral Modeling of Network Traffic: Integrating Route Choice and Traffic Assignment.* University of Michigan IVHS Program (in progress).