MACRO-LEVEL TRAFFIC SIMULATION AND CASE STUDY DEVELOPMENT FOR IVHS SYSTEM ARCHITECTURE EVALUATION

Karl E. Wunderlich, PhD
The MITRE Corporation
600 Maryland Avenue SW, Suite 755
Washington, DC 20024
Phone: (202) 488-5707
Fax: (202) 863-2988
e-mail: kwunderl@mitre.org

Michel Van Aerde, PhD, PE
Department of Civil Engineering
Queen's University
Kingston, Ontario
Canada K7L 3N6
Phone: (613) 547-5481
Fax: (613) 547-5481
e-mail: vanaerde@civl6000a.civil.queensu.ca

Bruce Hellinga, PhD
Department of Civil Engineering
Queen's University
Kingston, Ontario
Canada K7L 3N6
Phone: (613) 545-6000 ext. 5259
Fax: (613) 545-2128
e-mail: hellinga@civl6000a.civil.queensu.ca

John A. Harding
The MITRE Corporation
600 Maryland Avenue SW, Suite 755
Washington, DC 20024
Phone: (202) 488-5703
Fax: (202) 863-2988
e-mail: jharding@mitre.org

Abstract

As a part of the ongoing IVHS Systems Architecture effort sponsored by FHWA, contractor teams are using traffic and communication simulations in an effort to quantify impacts of implementing their proposed architectures. One aspect of this modeling effort has been the application and modification of a macro-level traffic simulation, INTEGRATION, to capture the effects of proposed evaluatory designs based on the architectures. A set of case studies have also been developed on which the contractor teams may base their evaluatory designs. These case studies correspond to scenarios from urban, inter-urban, and rural areas.

In this paper, the authors describe the approach taken in the modeling of architectural concepts within the INTEGRATION simulation. A description of the various vehicle types available in INTEGRATION is provided. These vehicle types are utilized within the study to represent the behavior of both guided and unguided vehicles, including the modeling of different levels of functionality in guided vehicles. In addition, specific model features which permit the consideration of vehicle probes as point sources of travel time information are described. The manner in which the presence and quality of alternative surveillance systems can be modeled is also discussed. Changeable message signs and beacons of various functionality levels are also modeled, as are high-occupancy vehicle facilities and restricted-acess links. Communication subsystem performance can also be reflected within the traffic simulation, including ATIS or ATMS updating intervals.

In the second part of this paper, the development of suitable input parameters detailing the selected scenarios is presented. The data was developed to provide a uniform test-bed for the evaluation of architectural designs. Topics include the generation of network topologies, link and signalization characteristics, and the construction of dynamic travel demand patterns. An overview of the three scenarios are presented, with a more detailed examination of input generation for the Urbansville network, a macro-level case study based on a subset of the Detroit, Michigan roadway network.

Topic keywords:
System Architecture Evaluation, Traffic and Transportation Modeling, Benefits

1.0 INTRODUCTION

One of the goals of the IVHS Systems Architecture research effort sponsored by the FHWA is the identification of a national architecture. The effort is comprised of two phases. Phase I (completed in January 1995) featured the evaluation of competing architectural approaches, while Phase II (beginning in 1995) features a consensus-building process to resolve incompatibilities among architectural approaches leading to the identification of a national standard. In either phase, the task of identifying and differentiating a promising IVHS architecture from alternative approaches necessitates the ability to quantitatively assess competing architectures over a range of issues.

Proposed architectures are evaluated against a set of criteria designated by the FHWA (1). These criteria range from cost, functionality, performance, benefits and risks to qualitative issues such as inter-jurisdictional cooperation, market potential, and societal priorities. McGurrin (2) provides an overview of the IVHS architecture assessment methodology identified for the research effort.

A subset of those criteria that are currently evaluated through modeling are detailed in Table 1. These criteria were selected for modeling because they were considered critical, sensitive to architectural approach, and because the state-of-the-art in modeling allowed for at least a first-cut quantitative approximation of these issues.

The criteria evaluated through modeling in the architecture effort center on capturing nuances of two distinct aspects of the proposed architecture implementation. The first aspect can be described as the effect of architecture implementation on traffic conditions and network mobility. The second aspect is described as the ability of the architecture to support the communications load placed on the system.

1.1 Traffic and Communication Modeling

Contractor teams selected by FHWA have developed candidate physical architectures. Since it is not possible to quantify the performance of a physical architecture, contractor teams also develop representative evaluatory system designs for a set of uniform scenarios, or case studies. Three scenarios have been developed for use in the architecture project, corresponding to representative urban, rural, and inter-urban geographic regions. Uniform scenario data, detailing scenario features such as roadway topology, travel demand patterns, demographic information, and terrain data, were developed and furnished as government-supplied baselines to all contractor teams.

The government-supplied scenario data provides a common baseline for the evaluation of evaluatory designs. A common set of traffic models were identified (2) to insure comparability of modeling results.

Traffic modeling and communication modeling are employed interactively by both the contractor teams and government evaluators for architecture evaluation. Traffic modeling provides a measure of the benefits accrued to the system because of the architecture's implementation, both in terms of system and user travel time reduction. Communication modeling justifies that the communication system proposed for the architecture has enough capacity to handle expected demands. Traffic modeling and communication modeling must be considered as interdependent for architecture evaluation. For example, the traffic model will use an update period and missed message rate supported by analysis from the communications model. In turn, data from the traffic model on localized flow conditions will be used to determine the demand on the communications system.

The overall traffic and communication modeling approach is illustrated in Figure 1. In the upper left of Figure 1 are government-defined data files describing a specific geographic region in terms of roadway networks, associated trip tables, and other data.

Contractor team deliverables are indicated in the upper right of Figure 1. The contractor teams supply evaluatory design plans for each scenario. These plans describe the location and function of all system components. The contractor teams then alter input parameters to the traffic and communications models, selecting and justifying values which best represent their architectural approach.

1.2 Role of Macro-Level Traffic Modeling

Traffic modeling within the architecture effort entails both macro-level and micro-level modeling. Macro-level traffic modeling for architecture evaluation focuses on what has been termed as strategic architectural modeling analysis. *Strategic* analysis focuses on a larger geographic area with less detail. Strategic analysis will also deal with relatively large numbers of vehicles (tens of thousands) in the system. Most traveling is done on highways and major arterials. A key analysis done at the strategic level is measuring the benefit of route guidance, coupled ATIS and ATMS strategies, and trip planning technology.

In order to facilitate macro-level modeling within the architecture effort, two key tasks were undertaken. First, a suitable traffic simulation needed to be identified or developed. Second, a set of data for the simulation derived from the identified scenarios had to be generated. This paper presents the approach taken by the authors in these two areas. Section 2 of the paper describes model features and modifications employed in macro-level modeling to reflect aspects of architectural design. Section 3 of the paper presents the development of the macro-level traffic modeling case study data for the enhanced traffic simulation program.

A review of state-of-the-art traffic modeling capabilities (3), indicated that no single traffic simulation satisfied all the requirements for architectural evaluation. Desired modeling functionality included the ability to evaluate alternative route guidance strategies, model large-scale mixed freeway and arterial networks, and allow for the differentiation of communication system-specific architectural attributes such as point source versus broadcast-based approaches. Two traffic models were identified with enhancements for the architecture effort: INTEGRATION (4) for macro-level modeling and THOREAU (5) for micro-level modeling.

The INTEGRATION simulation model required modification to meet the functionality required for architecture evaluation. In Section 2, these architecture-related enhancements are detailed. Suggestions for model enhancements came from several sources. Initial modifications to the model were implemented with respect to the requirements identified before the start of Phase I . Ongoing development during Phase I also included the suggestions for model features made by contractor teams.

2.0 MODEL DEVELOPMENT

The INTEGRATION model is a microscopic network traffic simulation model that has been under continuous development since 1985. It has been applied by the model developers and others to a wide range of hypothetical and actual networks (6, 7). The model's capabilities and structure make it well-suited for the evaluation of IVHS systems and control strategies. Since more general descriptions of the model appear elsewhere in the literature (8, 9), the model description provided in this paper is limited to the presentation of enhancements to five representative model capabilities that are particularly relevant for the evaluation of IVHS system architectures.

First, a set of vehicle routing strategies supported by the model is presented. The modeling of surveillance systems and the flow of surveillance data from the field to the traffic management center (TMC) and from the TMC to the field are presented. The model's ability to represent probe vehicles and the data that are available from these vehicles are described. Next, the changeable message sign (CMS) and ATIS beacon modeling capabilities of the INTEGRATION model are presented. Finally, some of the input parameters which may be varied in relation to communication subsystem capabilities are presented.

2.1 Driver Classes and ATIS Functionality Choices

The different driver classes that can be modeled with INTEGRATION refer to the capability to represent different routing behavior or different access privileges to travel time information for each class of drivers. For each driver class, the user may specify the type, the quality, and the update frequency of any traffic information that is available to the driver, and how these data are used by the driver to choose their routes.

For Phase 1 of the Architecture Study, only four driver/vehicle classes were modeled, each class with pre-defined routing capabilities. For Phase II, the INTEGRATION model has been generalized to permit the user to assign one or more routing characteristics from a comprehensive menu of choices to each one of seven driver classes. This flexibility not only provides the user with the ability to model a larger number of driver classes within a variety of architecture frameworks, but also provides a greater flexibility in terms of how these features can be combined. Up to seven driver or vehicle classes may be modeled and evaluated simultaneously. For example, high-occupancy vehicles (HOV), commuter, unfamiliar driver, commercial traffic, transit, and vehicles equipped with route guidance systems (RGS-capable) may be concurrently modeled and travel time performance compared. Table 1 provides a summary of the driver class routing options currently available within the INTEGRATION model.

In addition, individual link access may be controlled by vehicle class. For example, HOV-only, transit-only or HAZMAT-restricted links might be designated in a network. Only vehicle classes with proper link access permissions will be allowed to traverse designated links during the simulation.

2.2 Surveillance Modeling Options

The INTEGRATION model is capable of representing a range of architectures in terms of alternative data paths from the field to the TMC, and from the TMC to equipped vehicles in the field. Typically, there exist two general sources of traffic data - field surveillance equipment, such as standard loop detectors, and vehicles equipped with the capability to directly transmit information to the TMC. These data sources provide traffic information, usually in the form of link travel times, to the TMC where the data are fused prior to the dissemination of these data from the TMC back to any equipped vehicles in the field.

The INTEGRATION model permits the user to specify which links in the network are under surveillance, and as such are tracked in a dynamic database at the TMC. Currently, for such links, travel time information is compiled in the TMC as an exponentially smoothed average. Each time a vehicle traverses a link under surveillance, its travel time is incorporated into the moving average. The reliability, importance, or weighting, that is placed on the travel time estimate obtained from a vehicle of a particular class can be user specified. Thus, it is possible to reflect the relative reliability with which different travel time data can be obtained from different driver classes. For example, vehicles equipped with the capability of directly broadcasting their travel times to the TMC, can be modeled to provide more reliable travel time information than vehicles that do not have this capability.

To provide greater flexibility in reflecting various architectures, individual links with the network may have vehicle specific weighting/reliability factors that are different from the network-wide default values. Thus, it is possible to reflect the situation in which travel time information cannot be obtained from RGS-equipped vehicles via radio broadcast due to, for example, the link being located in a canyon or otherwise being outside the direct radio broadcast region. These features permit the model to reflect the impact that communication equipment placement and coverage may have on the quality and quantity of travel time data available to the TMC.

2.3 Probe Vehicle Report Alternatives

The INTEGRATION model also permits the user to designate a portion of the traffic generated at any origin as probe vehicles. These probe vehicles do not possess any behavioral differences from their non-probe vehicle counterparts, however, they are considered to be capable of transmitting unique information back to the TMC. Information can be transmitted to the TMC each time a probe vehicle initiates its trip, reaches its destination, or traverses a link. The information provided by these probe reports includes the vehicle’s origin and destination zone, trip or link travel time, distance traveled, driver type, total fuel consumed, and total emissions of nitrous oxide, hydrocarbon, and carbon monoxide. These data records are provided in a structured output file and can be post-processed for user specific comparisons and aggregation.

2.4 ATIS Point Sources: Changeable Message Signs and ATIS Beacons

The INTEGRATION model incorporates the ability to model point sources of ATIS information, such as CMS and ATIS beacons, at network nodes. The designation of a node as an ATIS points source indicates that traffic data are provided to designated drivers when they pass by one of these locations.

Currently, the point sources are modeled such that drivers who are traveling through a network will temporarily receive updated travel time information, which they can use immediately to re-route themselves. This travel time information is refreshed each time a driver passes through one of these designated nodes. The spatially and temporally constrained characteristics of a point source may be captured as the user may specify the amount of time after a driver has passed a source, that the driver will receive updated travel time information. These times are location specific, such that different point sources may provide information to drivers for different lengths of time. Furthermore, the user may also reflect compliance rates by specifying, for each point source, the proportion of the traffic stream that will utilize the information that is provided.

The modeling of ATIS point sources is being made more flexible to provide for the representation of a greater range of architectures. The user will be able to define the characteristics of the source, in terms of the information being provided and/or received, the vehicle/driver classes that may communicate with the source, and the associated compliance rates. This feature also allows for the modeling of randomly-occurring "missed messages" or inadvertent driver routing error.

2.5 Interface with Communications Subsystem Modeling

To aid in the design and evaluation of communication subsystems, INTEGRATION provides a number of important parameters which can be readily imported into a standard communications modeling tool. For example, the user may identify the interval at which ATIS updating takes place.

3.0 CASE STUDY DEVELOPMENT

3.1 Introduction to Scenarios

Qualitative assessments of proposed architectural approaches are made with respect to a set of common baseline scenarios. Given the range of regional transportation characteristics encountered across the United States, the FHWA narrowed the focus of the system architecture study to a set of three representative scenarios: Urban, Inter-Urban, and Rural. The Urban scenario characterizes a transportation system serving an average size metropolitan environment. The Inter-Urban scenario depicts traffic characteristics between metropolitan areas. The Rural scenario describes a rural transportation environment.

This section provides an overview of the scenario development process. First, the scenario selection process is outlined and an overview of major features of the three scenarios provided. For the Urban scenario, a more detailed description of the development of inputs for the INTEGRATION simulation program is provided. Required inputs include roadway topology, signalization data, travel demand patterns, and incident data.

3.2 Scenario Development

The MITRE corporation was tasked by the FHWA to develop the three scenarios for the IVHS System Architecture analysis. The development of scenario data based on existing geographic entities was considered to be more realistic than a totally synthesized network. In an effort to properly approximate the characteristics of each scenario, a search was initiated for existing areas that could serve as foundations for the creation of each scenario. The creation of each scenario was initiated with a preliminary list of possible candidate sites. These sites were chosen based on there correlation to the individual scenario characteristics. The entries on this preliminary list were then rated according to how well there matched the characteristics of the subject scenario. The rating also took into account each candidate sites network complexity in advance of the construction of simulation input data.

Each site had different characteristics that exemplified its subject environment, however, each site did not contain every characteristic found in an ideal scenario for analysis. Therefore each candidate site was also rated against what characteristics it did not contain and how easy these missing characteristics could be added. From this ranking the preliminary list was cut down to a few candidate sites. The remaining candidates were then assesed with regard to data availability, the number of entities or agencies needed to coordinate in order to obtain all the required data, the media and format in which the data could be obtained, site willingness, and length of time it would take for the data to be prepared and transmitted. The above criteria identified a set of promising candidates from which data were obtained. Of the sites from which data were obtained, three were used as foundation for the scenarios. Data from other sites were used to estimate the incoporation of desired features not present in the selected sites.

The scenarios and their real-world counterparts selected for the system architecture effort are as follows:

Urban Scenario	Southeastern Michigan
Inter-Urban Scenario	The I-95 Corridor between Philadelphia, Pennsylvania and Trenton, New Jersey.
Rural Scenario	Lincoln County Montana

A description of the scenario its characteristics and modeling parameters were presented in a scenario guide and provided to each contractor team participating in the architecture study. A scenario may be represented by a maximum of three domains. The three domains cover different aspects of the scenario area as well as areas for individual analysis. The first of these areas is the region, a high level overview of the scope of the area of study and its demographics. The second area is the INTEGRATION simulation area. The INTEGRATION simulation area highlights a cordon area within the region for macroscopic modeling analysis. The third area is the THOREAU simulation area which is a detailed subset of the INTEGRATION simulation area.

The scenarios also span three time frames corresponding to 5-year, 10-year, and 20-years evolutionary snapshots. Each time frame represents different levels of population, employment and travel demand. The next three subsections present an overview of each scenario as presented in each scenario guide.

3.3 The Urban Scenario

The Urban Scenario was designated Urbansville. The information to create Urbansville was based on the Southeast Michigan metropolitan area. The City of Detroit and portions of Wayne County, Oakland County and Macomb County constitute the area of Urbansville. However, selected facilities and characteristics do not correspond exactly with the Detroit area. Some facilities and characterizations have been altered to allow for the inclusion of typical facilities not found in the Detroit area. For example, toll and HOV facilities are modeled in the 2012 Urbansville scenario, but are not currently implemented in the Detroit area.

The area is traversed by an array of transportation facilities (Figure 2). The urban region represented here is approximately 800 square miles and contains a population of 3.7 million persons. The City of Detroit, Wayne, Oakland and Macomb Counties have approximate areas of 170, 200, 265, and 165 square miles respectively.

The INTEGRATION simulation area, or INTEGRATION domain, covers approximately 90 square miles. The area is illustrated in Figure 2 by the area cordoned off by the thick black lines. To the west, the outer cordon line corresponds to Southfield Freeway and extends between 11 Mile Road to the north and Plymouth Road to the south. The inner western boundary corresponds to Wyoming Avenue and extends between Plymouth Road to the north and Michigan Avenue to the south. The outer eastern boundary uses Mound Avenue to approximate a cordon line from 8 Mile Road to Michigan Avenue. The inner boundary on the east side of the cordon area corresponds to Dequindre Avenue and extends between 11 Mile Road and 8 Mile Road. The simulation area's roadway network is based on portions of the City of Detroit's, Wayne County's, and Oakland County's roadway network, however as indicated previously, some facilities have added, deleted or altered. The INTEGRATION domain of the Urbansville area was used in a number of case studies to model traffic conditions occurring in the morning peak period and mid-day period.

The network for the THOREAU domain for the Urbansville area is modeled after the downtown central business district (CBD) of Detroit, Michigan. Using the street network of Detroit as a guide, the THOREAU network roughly extends from Jefferson Avenue to the south; Warren Avenue to the north; Cass Avenue to the west; and Brush Street to the east. This is a north-south corridor surrounding Woodward Avenue and the central business district as illustrated in Figure 2 by the small darkly shaded area located in the bottom right hand corner of the INTEGRATION domain.

3.4 The Inter-Urban Scenario

The Inter-Urban Scenario has been designated Thruville due the characteristic through traffic identified in inter-urban corridors. The Thruville scenario is represented by two domains the regional domain and the INTEGRATION domain. The Thruville scenario was based on information from the Delaware Valley Regional Planning Commission

(DVRPC). The regional area depicted consists of a portion of the I-95 corridor from the Delaware/Pennsylvania state line to the I-95/I-295 junction in New Jersey, Figure 3. Included in this area are portions of three Pennsylvania counties and four New Jersey counties that contain the corridor and various complementary facilities. The names of the counties have been slightly altered to avoided confusion with the actual counties and additionally indicate that the counties in the scenario do not directly correspond to the actual counties in the DVRPC area. Certain modifications have been made to enhance the depiction of this inter-urban scenario, Thruville, for use in the IVHS system architecture study. The regional domain is estimated to cover 1375 square miles of fairly level terrain. The corridor is approximately 38 miles long.

The INTEGRATION domain covers roughly 415 square miles of the regional domain and is represented as the area enclosed by the dashed line on Figure 3. The INTEGRATION network includes I-95 to the west and north, I-295 as a northern boundary, the New Jersey Turnpike is the approximate eastern boundary. The network is comprised of the freeways, expressways, principal arterials, and some other minor roadways to complete connection between the major roadways. The INTEGRATION domain consists mainly of the parallel roadways that run the length of the domain and facilitate the northbound and southbound travel through the corridor. The network is enhanced with facilities that run east and west providing connections between the various parallel north/south facilities.

3.5 The Rural Scenario

The Rural Scenario, Mountainville, was based on Lincoln County in Montana. Lincoln County is a mountainous region located in the northwestern corner of Montana. Data was obtained from county and state data in the 1990 Census Transportation Planning Package (10) distributed by the Bureau of Transportation Statistics. Most of the data presented in this guide is consistent with the actual data that depicts the characteristics of Lincoln County. However, various roadway characteristics have been altered in order to create Mountainville, the rural scenario.

The Mountainville scenario is currently represented by one domain with the option to quickly create files for any modeling that may be initiated in phase two of the architecture study. The regional domain of the Mountainville scenario, depicted in Figure 4, roughly covers 3500 square miles of mountainous terrain.

3.6 The Construction of Urbansville Case Studies for Macro-Level Modeling

One aspect of the creation of Urbansville entailed the creation of data files that depicted the network and traffic demand with respect to the INTEGRATION simulation. The creation of these files typify the process that have been conducted in the creation of other data files for the other scenarios. The files that were created contain information on the nodes and links that depict the simulated network, the timing and phasing of signals, the depiction of travel demand patterns, and information depicting the effects of an incident on the system.

3.6.1 Nodes and Links

The nodes and links for the Urbansville network were extracted for Southeastern Michigan Council of Governments (SEMCOG) Transportation Systems Management database (TSM). The TSM file is an expanded link file database that contains information on many link and node attributes. This database was used to create SEMCOG's link files used to depict the regional planning model network. To obtain the network of Urbansville a computer program was written to extract certain link records by node location using their x-y coordinates and by link type. This extraction provided a base network to transform into Urbansville. To complete the network, time was spent locating and entering missing nodes and links. Also, certain nodes at major interchanges were modified to separate the traffic movements to enhance the simulations approximation of real world traffic characteristics. In an effort to cover many of the characteristics of an urban traffic network, an High Occupancy Vehicle (HOV) facility was added as well as toll facilities to the Southeastern Michigan network in its transformation to Urbansville. This activity culminated in the creation of the node file and link file used in the INTEGRATION simulation, which define a network of roughly 1,950 links and 875 nodes. The network also contains more than 90 signalized intersections.

3.6.2 Signals

Actual signal timing plans that specify cycle length and phasing were obtained from the State of Michigan, Wayne, Oakland, and Macomb Counties, and the City Of Detroit. Signal cycle time and phasing were developed using the actual timings specified in the plans. However, many of the phasing schemes' complexity surpassed the limitations of representing the phasing in INTEGRATION. In the cases were the complexity of the phasing could not actually be represented in INTEGRATION, an alternated phasing that could be coded in INTEGRATION was developed that closely resembled the actual phasing. Arterial signal progressions were based on actual field progressions, however, due to elimination of signals on cross streets not included in the network and adjustments to signal phasing, progression adjustments were made to simulate a progression on arterials. Throughout the construction of the signal timing plan for the Urbansville network, the signals' cycle lengths and phasings specified in the signal timing plans were used to represent the signals in the INTEGRATION simulation. In an attempt to portray realistic network conditions, no signal optimization analyses were conducted to improve the operation of the signals by altering cycle length or phasing.

3.6.3 Travel Demand Pattern Characteristics

The travel patterns for the Urbansville INTEGRATION domain were directly developed from the origin-destination demand levels contained within the SEMCOG regional planning model. The process began by using the SEMCOG regional planning model and extracting a subarea that represented the INTEGRATION domain area. Through this extraction process a file specifying origin-destination demands for the subarea were output. This origin-destination information was then compressed to correspond to the INTEGRATION origin-destination zone structure and the origin-destination demands were converted into directional trip rates for the morning peak period (from 7:00 a.m. to 9:30 a.m.) and an off-peak mid-day period (11:00 a.m. - 2:00 p.m.). Over 200,000 vehicles are modeled in the morning peak period case. The dynamic variation in network inflow rates for the morning peak period is illustrated in Figure 5.

In Phase I, travel demand patterns were developed which described the expected, or mean, travel pattern. In Phase II, these travel demand patterns have been enhanced to include day-to-day and intra-day variation in demand. This data facilitates more accurate modeling of commuter traffic, which through experience may have a relatively accurate estimate of average conditions, but receives no real-time updates on current traffic congestion.

3.6.4 Modeling Incidents

The INTEGRATION simulation has the capability of simulating the effect of incidents on traffic flow. The INTEGRATION simulation requires an incident be identified in terms of the link on which the incidents occurs, the effective number of lanes the incident will block, and the time the incident occurs and ends. To create the incidents the General Estimates System 1991 (11), and the Federal Accident Reporting System 1991 (12) were consulted. Statistics relating to severity, number of vehicles involved, and crash location helped formulate the expected effect on link characteristics and the values of the parameters entered into and input file of the INTEGRATION simulation. Different parameter values were developed to simulate a severe, moderate, or limited impact incident type.

4.0 SUMMARY

This paper describes some of the efforts undertaken to enable macro-level traffic modeling to be employed for IVHS system architecture evaluation. The role of macro-level traffic simulation within a larger modeling evaluation effort including communication and micro-level traffic simulation is presented. Architectural modeling and its application *vis a vis* the capabilities of an enhanced version of the INTEGRATION traffic simulation is described, along with the development of suitable case study data based on realistic, uniform scenarios. This model and case study development has allowed contractor teams within the IVHS system architecture effort to evaluate architectural approaches without the independent development of these resources. At the same time, it has provided the FHWA with a uniform test bed in which to differentiate between architectural approaches.

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REFERENCES

[1] FHWA, *Solicitation for Intelligent Vehicle Highway System Architecture Development*, RFP#DTFH61-93-R-00065, **Commerce Business Daily**, PSA-0783, Federal Highway Administration, Februrary 16, 1993.

[2] McGurrin, Michael, **IVHS Architecture Assessment Methodologies,** IVHS Review, Winter/Spring 1994, Washington, DC, IVHS America, 1994.

[3] Koch, Brian, Wunderlich, Karl, and Yablonski, Anne, **Modeling Analysis for IVHS Architecture Evaluation**, MITRE WP#93W0000160, The MITRE Corporation, McLean, VA, December, 1993.

[4] Van Aerde, M. (1985) **Modeling of Traffic Flows, Assignment and Queuing in Integrated Freeway/Traffic Signal Networks.** Ph.D. Dissertation, Department of Civil Engineering, University of Waterloo, Ontario, Canada.

[5] Codelli, D., Niedringhaus, R., Wang, P., and Young, B. **User's Manual for Traffic and Highway Objects for REsearch Analysis, and Understanding (THOREAU)**, Volume II, Revision 1, The MITRE Corporation, McLean, VA, October, 1993.

[6] Hellinga, B. and Van Aerde, M. (1994) *An Overview of a Simulation Study of the Highway 401 Freeway Traffic Management System.* **Canadian Journal of Civil Engineering**, Volume 21.

[7] Gardes, Y., May, A.D., and Van Aerde, M. (1993) *Evaluation of IVHS Strategies on the Smart Corridor*. **ITE Annual Meeting**, The Hague, Netherlands.

[8] Van Aerde, M. and Yagar, S. (1990) *Combining Traffic Management and Driver Information in Integrated Traffic Networks*. **Third International Conference on Road Traffic Control**, IEE Conference Publication Number 320, London.

[9] Rakha, H., Van Aerde, M., and Wang, J. (1993) *A Comparison of Two Alternative Traffic Simulation Models: TRANSYT vs. INTEGRATION*. **Proceeding of the Canadian Institute of Civil Engineers**, Edmonton, Alberta.

[10] DOT, **1990 Census Transportation Planning Package**, BTS-CD-02-12, Bureau of Transportation Statistics. 1992.

[11] DOT, **Fatal Accident Repository System 1991**, HS 807 954, National Highway Traffic Safety Administration, March 1993.

[12] DOT, **General Estimates System 1991**, National Highway Traffic Safety Administration. 1993.

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Table 2 Summary of Driver Class Routing Options in INTEGRATION

Routing Option	Example Use	Description
1a	Commuter traffic	Time series of Frank-Wolfe based static user-equilibrium assignments resulting in a time series of multipath routes
1b	Drivers unfamiliar with the network area (i.e. tourists)	Minimum paths computed on the basis of free speed travel times
1c	Drivers familiar with average historical conditions	Minimum paths computed on the basis of externally specified expected average traffic conditions
1d	Drivers familiar with time varying historical conditions	Minimum paths computed on the basis of a time series of externally specified expected traffic conditions
2a	RGS equipped drivers	Minimum paths computed on the basis of most recently available TMC data
2b	Anticipatory RGS drivers	Minimum paths computed on the basis of most recently available TMC data and anticipated traffic conditions
3	Drivers with fixed routes (i.e. buses, CVO)	Externally specified multipath routes
4	Drivers with access to restricted links (i.e. HOV, transit)	Minimum paths computed with the consideration that access to specialized links is available

Figure 1. Traffic and Communication Modeling for IVHS Architecture Evaluation

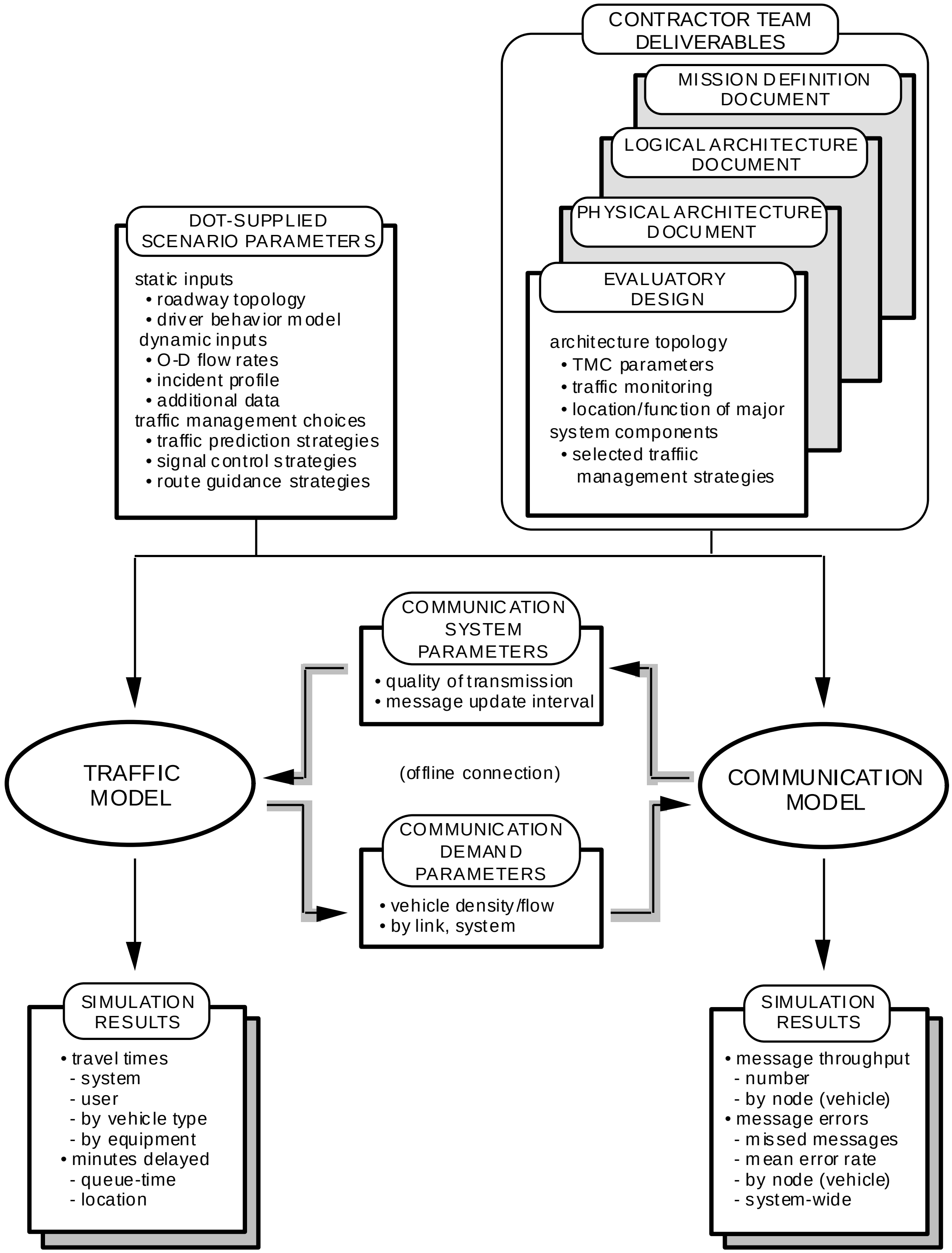

Figure 2.
The Urban Scenario

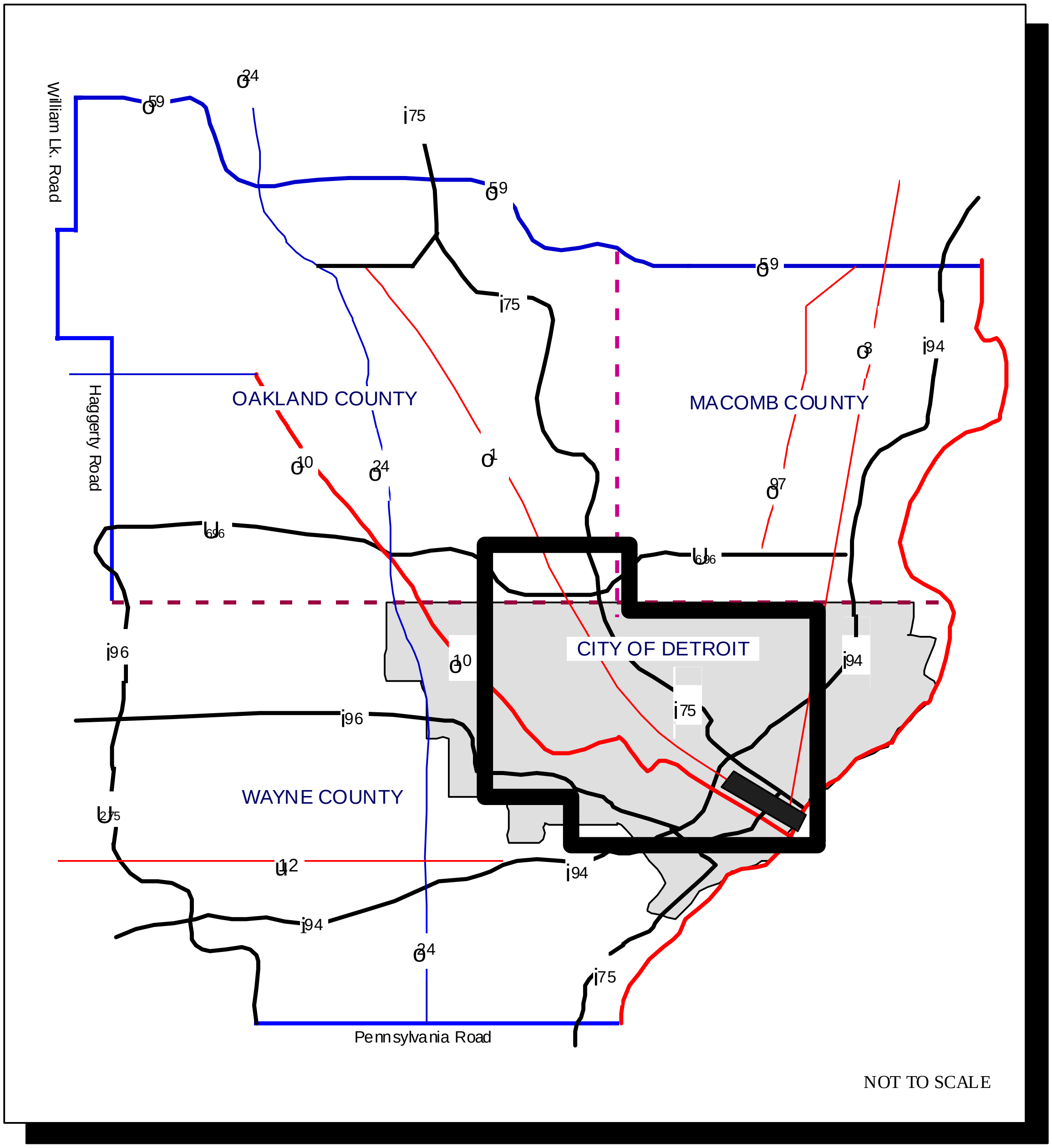

Figure 3. The Inter-Urban Scenario Wunderlich, Van Aerde, Hellinga, Harding

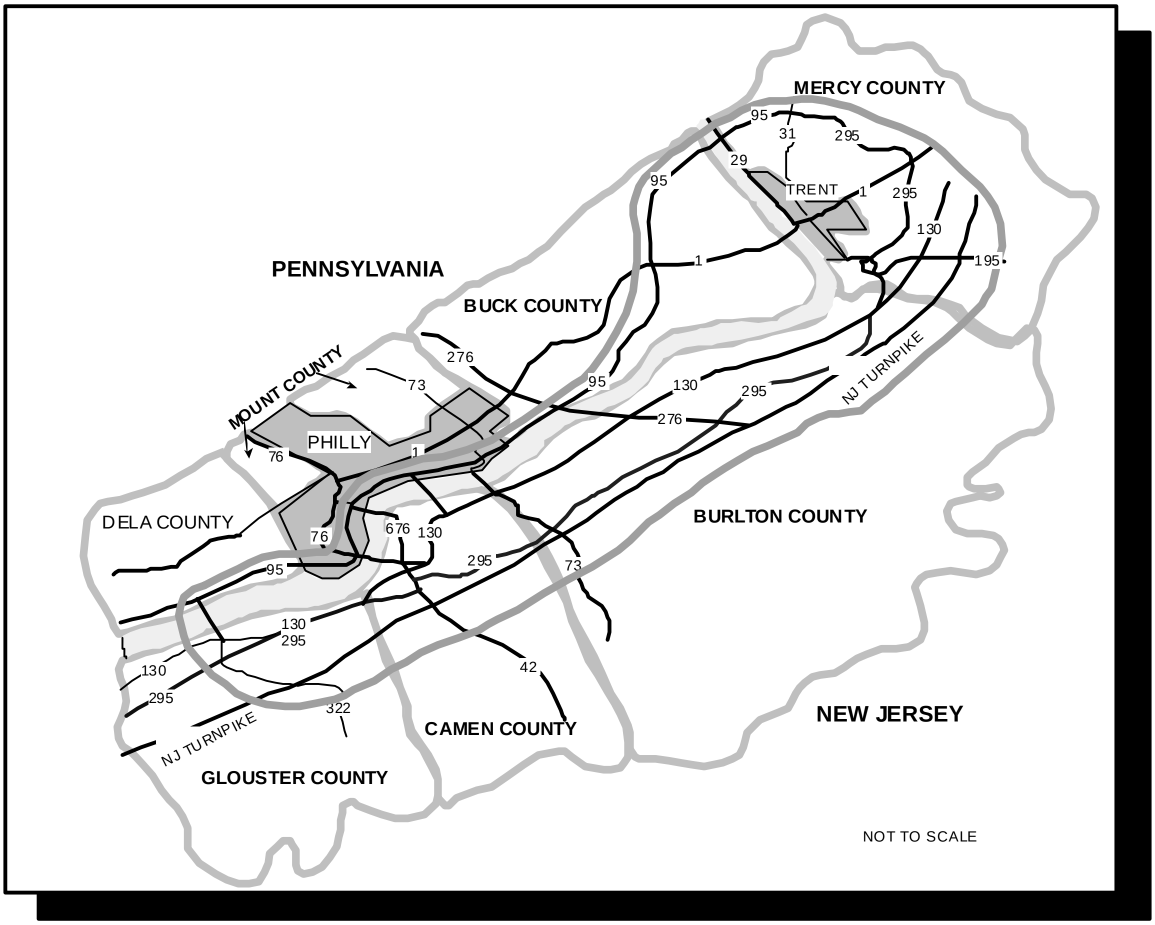

Figure 4 The Rural Scenario

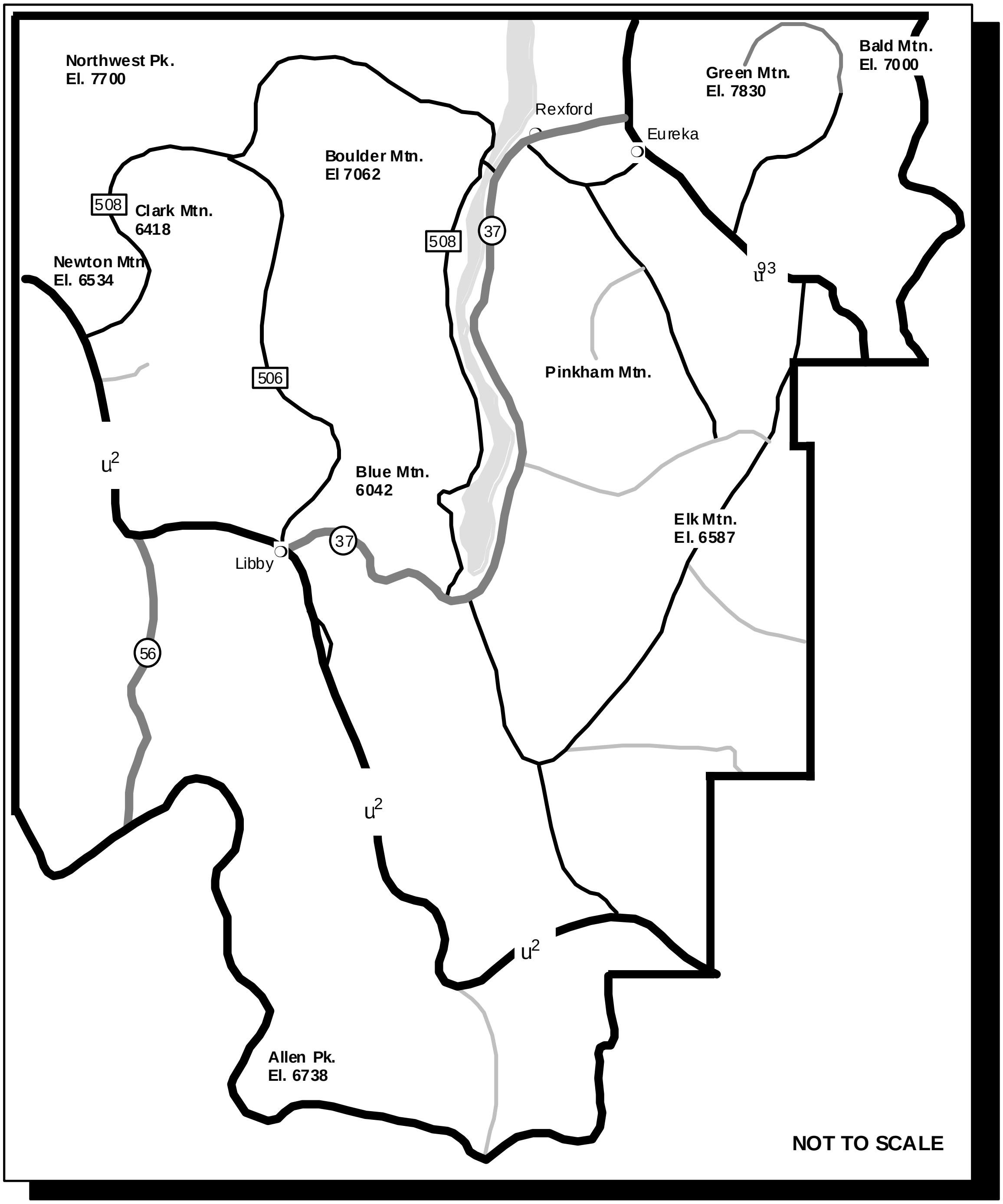

Figure 5. A.M. Peak Period Demand Pattern (Urbansville)