U.S. Department
of Transportation

**Federal Highway
Administration**

Detroit Corridor Evaluation Plan

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EXECUTIVE SUMMARY

In October 1996, the Michigan Department of Transportation (MDOT) proposed the 'Detroit Freeway Corridor Congestion Relief Project' to address metropolitan region issues regarding (1) the efficacy of their existing ITS facilities, and (2) the existence of motorists' resolute preference for freeways (termed freeway bias). The Project was initiated jointly in June 1997 with MDOT, the Federal Highway Intelligent Transportation Systems Joint Programs Office (ITS JPO), and Mitretek Systems. This report, prepared by Mitretek System, presents the plan to achieve the goals of the Project. The report provides a project context, describes the study region, specifies the evaluation methodology, outlines the data sources, and identifies the expected outcomes.

Project Overview

The goals of this project are to (1) measure the impacts from installing the existing ITS facilities, (2) determine whether motorists' exhibit a bias toward freeways, (3) calculate the impact of freeway bias, (3) identify operational strategies that improve corridor throughput, and (5) evaluate the real-world impact of the proposed strategies.

A two-phase methodology of simulation and field evaluation is proposed to meet project goals. First, a simulation evaluation will quantify current ITS impacts. This is not feasible through a field test as relevant pre-ITS data is unavailable. Simulation also provides an opportunity to 'game out' and fine-tune ITS strategies. Provided that in simulation ITS operational strategies improve performance, MDOT, the ITS JPO, and Mitretek Systems will select a subset of the strategies for field implementation. Mitretek expects to generate field-measured impacts by deploying and subsequently monitoring the simulation-successful strategies.

Study Region

Simulation capability, data manageability, and staff time constraints limit the project scope to a corridor of the Detroit metropolitan region, rather than the entire region. Corridor selection is based on the presence of freeway congestion, the existence of viable alternate paths, the availability of corridor monitoring systems, and the existence of motorist information systems. These four criteria are necessary conditions to achieve real-time freeway diversion benefits. An 8.0-km long corridor of the Lodge Freeway 2.5-km northwest of the central business district was selected for the study. There are approximately 220 signalized and 30 unsignalized intersections in the study area. ITS elements in the study area include 16 ramp meters, 5 changeable message sings, a highway advisory radio facility, and mainline detectors on M-10 every 0.50 miles.

Phase 1: Simulation Evaluation

As the greatest concern in corridor transportation performance is during peak periods, simulation will be conducted for a peak period time interval. Representation of corridor flow and freeway bias will be accomplished through an iterative process of demand estimation, simulation, and 'perceived speed' updating. QueensOD, a synthetic demand generation software, was selected to generate an estimate of corridor demand. INTEGRATION Ver. 2.0 was selected for simulation use in this study. Measures of corridor performance generated by INTEGRATION include time-based link, vehicle, trip, and system statistics on speed, travel time, queues, and throughput.

A primary project goal is to evaluate the effectiveness of alternative ITS strategies (referred to as alternatives) in mitigating congestion. Five classes of alternatives have been selected for evaluation. These include existing ITS, no ITS, existing ITS with ramp meter coordination, existing ITS with signal coordination, and existing ITS with signal and ramp meter coordination. The effectiveness of specific alternatives varies by type of capacity-reducing factor such as construction or incident (referred to as scenarios). The dimensions used to define the scenarios include traffic volume patterns, weather, major freeway incidents, and minor system-wide accidents. Fifteen scenario options are proposed for evaluation.

Annual impact, or measure of effectiveness, for an alternative would be derived from aggregating weighted scenario impacts. The scenario weight represents the probability of occurrence of that scenario over a one year time period. However, for this study, Mitretek is not generating annualized benefits estimates because of the data and time constraints in estimating scenario weights. Impacts will be presented by un-weighted scenario type.

Phase 2: Field Evaluation

The set of feasible strategies for field implementation is constrained to options that do not require physical infrastructure investments. Currently, promising actions include signal system retiming, ramp metering adjustments, and CMS operations. The process for field implementation will be further specified at the completion of the simulation evaluation phase of the project.

Data Sources and Constraints

Three types of data are required for micro-simulation models: network geometry, calibration, and validation data. Network geometry data defines the connectivity and right of way for vehicle progression. Calibration data define model reactionary components that parallel corridor driver behavior and traffic flow characteristics. Validation data is used to verify model output. Additional network information on the location and operation of loop detector, CMS, and HAR is also required to accurately represent the corridor. To represent scenarios, data on location and frequency of atypical demand, incidents, and poor weather conditions is necessary.

The primary sources for data included MDOT, Michigan State University, the Southeast Michigan Council of Governments, the City of Detroit, the City of Highland Park, Etak, Inc, and field observations. For circumstances where data was unavailable industry estimates are used.

Project Outputs

Successful completion of this study will yield three significant outputs. The first is a measure of the benefit from implementation of the current ITS system. The second is a measure of the potential for improvement in corridor performance through operational changes in the system. The third is a field-measured impact of operations changes is in ITS system. In addition, comparisons in simulation will quantify the impacts of any existing freeway bias. Furthermore, comparisons between field measured and simulation impacts of operational changes will yield reliability statistics on the ability of the simulation model to adequately represent corridor operation.

1. INTRODUCTION

This document presents the Mitretek Evaluation Plan for the Detroit Freeway Corridor Congestion Relief Project. The project, proposed by the Michigan Department of Transportation (MDOT), was initiated jointly in June 1997 by MDOT, the Federal Highway Intelligent Transportation Systems Joint Program Office (FHWA ITS JPO), and Mitretek Systems. The project is performed in cooperation with MDOT, Michigan State University, the Southeast Michigan Council of Governments (SEMCOG), the City of Detroit and the FHWA ITS JPO.

The purpose of this plan is to describe the evaluation methodology, the data collection process, and expected outputs. The specific objectives of this document are to detail the corridor selection process; specify the evaluation components and methodologies; outline data requirements and collection procedures; and identify evaluation outputs.

Toward these objectives various field experiments and research studies were reviewed. These included evaluation documents pertaining to the Smart Corridor [1], the Pathfinder Study [2], TravTek [3], INFORM [4], and the ADVANCE Project [5]. Of these, INFORM (INformation FOR Motorists) and TravTek (Travel Technology) projects provided the most insight toward the task of evaluation planning. The former performed a field evaluation of a 40 mi. long highway corridor in Long Island, NY with an Advanced Traffic Management System (ATMS) and Advanced Traveler Information System (ATIS) of integrated electronic traffic monitoring, variable message signs (VMS), and ramp metering. The latter performed a modeling and simulation evaluation of the downtown Orlando area with various levels of ATIS market penetration. The evaluation plan is constructed to meet the specific evaluation needs of MDOT and includes processes for assessment of network performance, ATMS/ATIS operational effectiveness, and motorist response impacts.

This section continues with an overview of the project background and objectives, and a description of the two-phase evaluation plan for meeting project objectives. Section 2 details the criteria for selecting the study corridor and describes the study area. Section 3, Model Selection and Description, outlines the basis for selection of an evaluation model and explains key features of the selected model. Section 4 describes the components of Phase One —Simulation Evaluation. Phase One evaluation components include the tasks of alternative and scenario generation; freeway bias definition and measurement; and simulation representation and validation. Section 5 provides a brief description of Phase Two —Field Evaluation. Section 6 lists data requirements, constraints, and sources. Section 7 concludes the document with an explanation of the expected measures of effectiveness and outputs.

1.1 Project Background

MDOT, in cooperation with local and federal agencies, has implemented an array of Intelligent Transportation Systems (ITS) in an effort to better meet motorists' needs. The existing Detroit Metropolitan ITS system includes 32 miles of freeway managed by a traffic monitoring system of 24 television monitors, 11 television cameras, 14 changeable message signs, 49 ramp meters, 4 highway advisory radios, and over 1200 inductive vehicle detectors [6]. An expansion is underway to extend the current ITS system an additional 148 miles. The freeway and major roadway facilities within the Detroit region are shown in Figure 1.

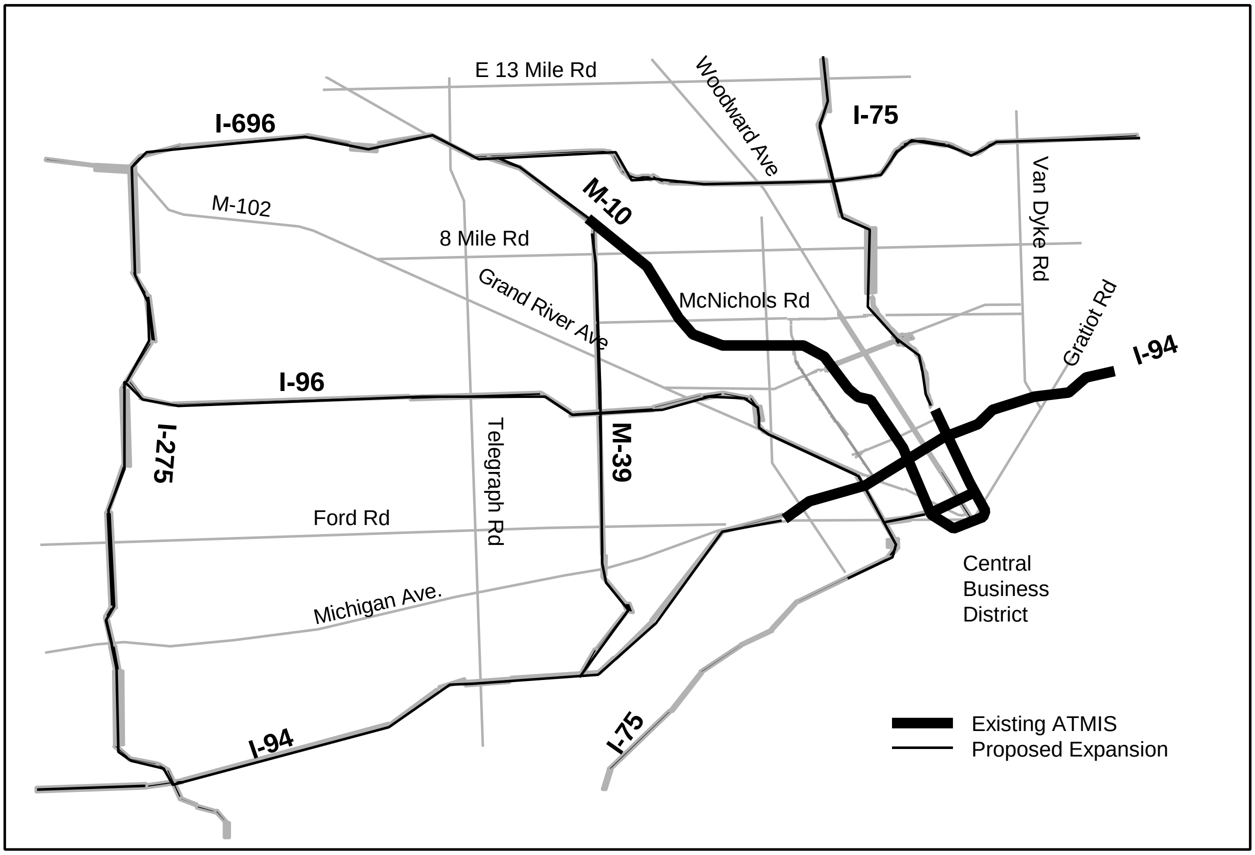

Figure 1. Detroit Metropolitan Road Infrastructure

The aim of ATMS and ATIS is to improve transportation system efficiency. This is particularly important in the face of unexpected travel demand or changes in system capacity. ATMS technologies can be used to identify unexpected conditions such as incidents, and can subsequently modify ramp metering and signal coordination to meet corridor capacity changes. ATIS technologies can then be used to notify motorists of atypical delays on their present route, prompting a shift to paths with excess capacity. Through this process, queues are reduced and overall corridor throughput is improved.

Figure 2 illustrates this phenomenon measured by the aggregate directional corridor flow of freeway and arterial facilities along the length of the corridor. During an incident the capacity of the corridor is reduced along the section where the event occurred. Without diversion, queue spill back occurs upstream of the incident, reducing overall flow. With diversions, queue spill back occurs, but with lesser intensity as drivers are moving away from the reduced capacity roadway. Consequently, with diversion, the flow reduction is not as significant in magnitude and does not progress as far upstream of the incident. The shaded region identifies the increase in overall corridor flow along the length of the corridor attributable to ITS activities promoting diversion.

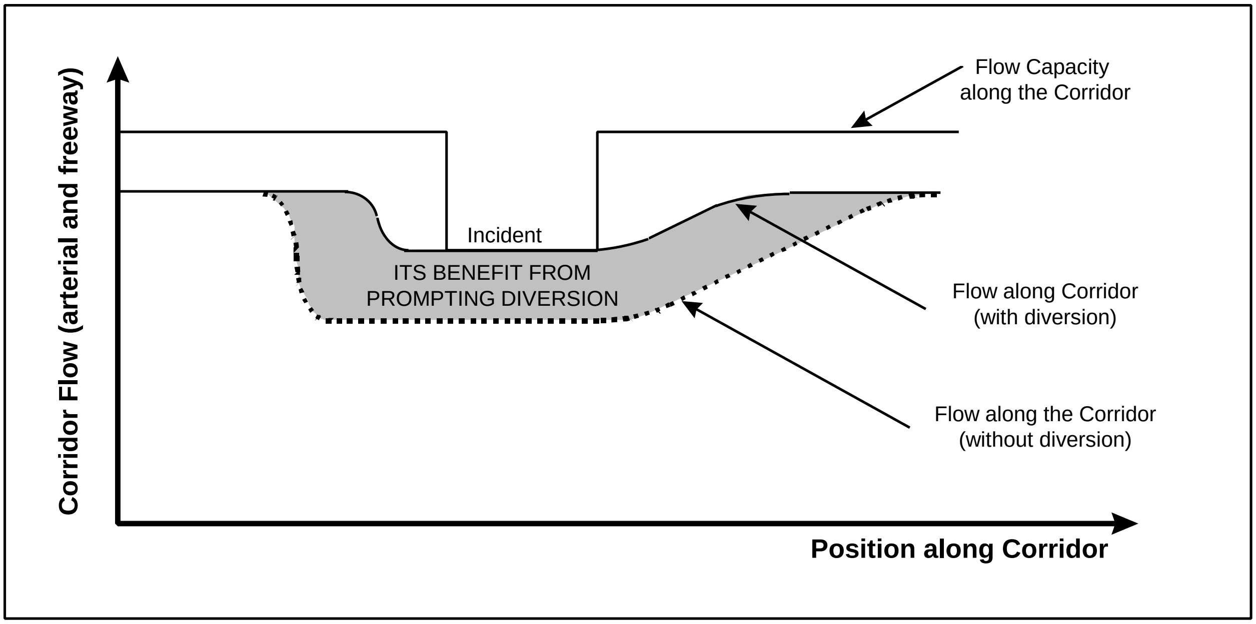

Figure 2. Impact of Diversions on Corridor Flow

MDOT postulates that within the Detroit metropolitan region “freeways are excessively crowded during the morning and evening ‘rush’ hours while the major surface streets are greatly under used.” [7] The preference by motorists toward freeway travel regardless of better time-based paths is termed ‘freeway bias.’ The Detroit Freeway Corridor Congestion Relief Project is an initiative to measure the level of this freeway bias within a corridor of Detroit, and to investigate the options for promoting spatial equilibration using ATMS and ATIS strategies.

Within the Detroit metropolitan area approximately 20 major arterial roadways are parallel to ATMS/ATIS equipped freeway facilities. MDOT anticipates that the current ATMS/ATIS system has prompted some level of route diversions from freeway to arterial facilities; however, additional diversion would improve overall system performance. This project was initiated to address these transportation issues within a subset of the Detroit region and to address the national issues of ITS effectiveness in promoting more efficient transportation systems.

1.2 Project Objectives

The goals of this project are to measure current corridor performance, to calculate the existing ITS system benefit, to identify strategies for improved corridor performance, and to evaluate the effectiveness of such strategies. Specific queries to be addressed by this project include:

- For the current state of ATMS/ATIS:
  - What is the magnitude of freeway bias within the study corridor?
  - What is the experience of freeway detour users, non-users, and arterial users?
  - What is the system impact of detours by motorists?
  - In the event of incident, how many motorists detour in response to the current ATIS system versus pre ATMS/ATIS implementation?

- Prior to ATMS/ATIS system implementation, what was the magnitude of freeway bias within the study corridor?
- For each set of integrated/modified ATMS/ATIS strategies:
  - What impacts do the strategies have on system performance by type and delivery system?
  - Which strategies are worthy of implementation?
  - What corridor operating situations (unexpected demand change, incident, etc.) are most benefited by specific strategies?
  - In the event of freeway incidents, how many motorists will detour in response to integrated/modified ATMS/ATIS strategies versus baseline detour behavior?
- In the absence of freeway bias, or if freeway bias can be eliminated, what system performance level can be expected?

The following section describes the process by which the above objectives and queries are met. Activity responsibility and schedule are discussed in the following section. The section concludes with a Gantt chart and explanation of project activities.

1.3 Project Plan and Schedule

To answer the questions of interest, an integrated modeling and field study approach is proposed. Figure 3 presents an overview of the entire project and expected outcomes, with activities distributed by between Mitretek and MDOT. The benefits from the existing ATMS/ATIS system can be estimated through simulation of the corridor. This is not feasible with field-testing as corridor performance data prior to ATMS/ATIS implementation is not available. Moreover, the use of models provides an opportunity to ‘game out’ and fine-tune strategies to increase ATMS/ATIS effectiveness in the corridor. Equally important, the deployment and subsequent monitoring of model-successful strategies permit the assessment of actual field impacts and comparison of field and model outcomes. Data generation and acquisition tasks are the primary responsibility of MDOT along with project scope and direction. Mitretek is primarily responsible for data processing, simulation, and evaluation tasks.

The project is divided into two phases of implementation: simulation and field evaluation. The principal implementation activities for each phase as well as the scheduled and actual completion time for each activity is presented in Figure 4. The critical task in completion of activities is the time required for generation and transmission of data by MDOT. At this point, Mitretek is in the midst of completing the simulation phase. Mitretek has acquired network and signal control data, generated a corridor simulation model, and is currently conducting model validation activities.

Prior to implementation of either phase, was the task of selecting the study corridor. This decision and factors affecting the decision are presented in Section 2. Phase One of the study is evaluation through modeling. The form and specific requirements of the evaluation model are outlined in Section 3. The remainder of this document focuses in detail on Phase One activities. These activities include generating modeling options, representing corridor operation, and incorporating freeway bias.

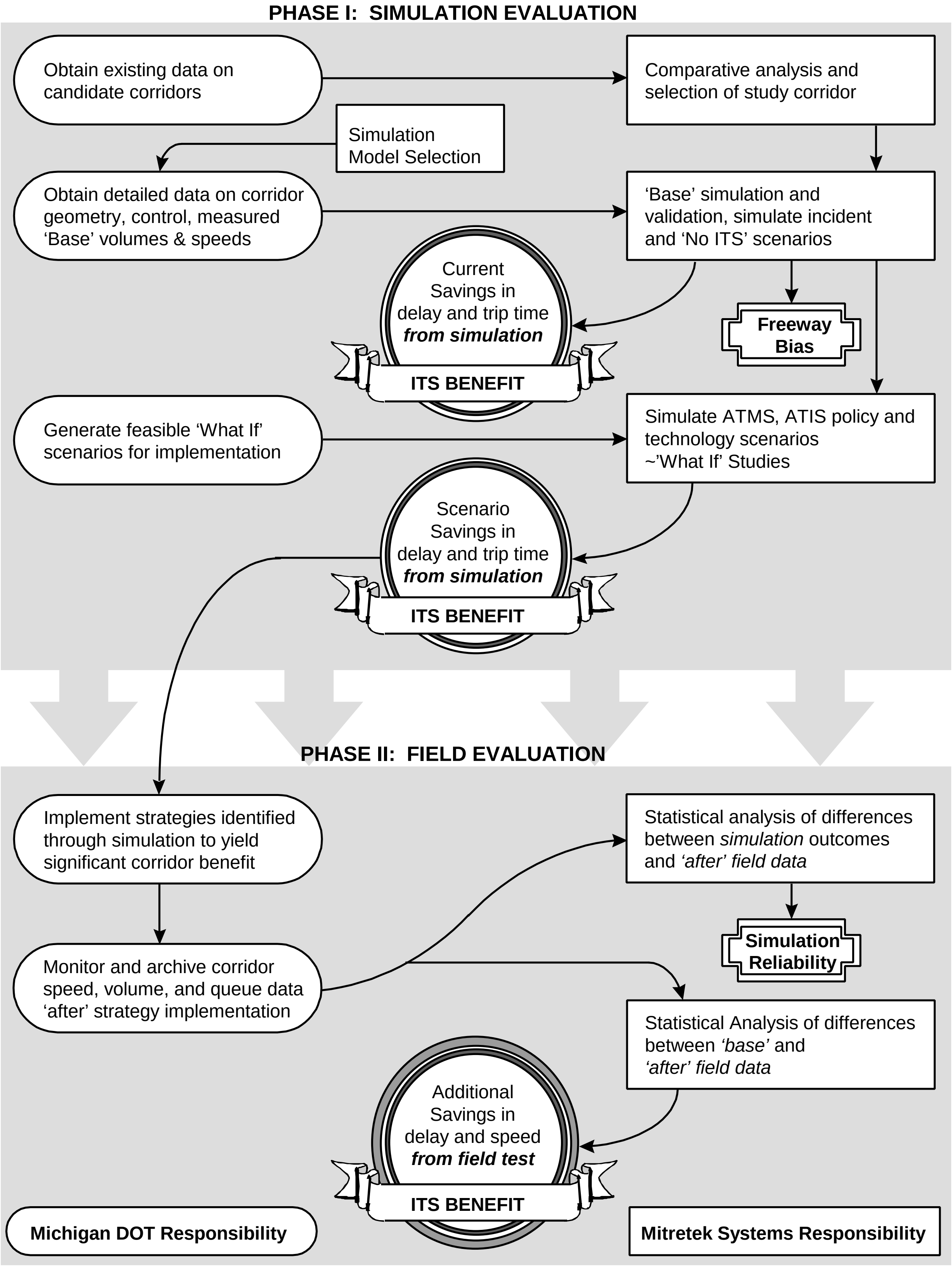

Figure 3. Overview of the Detroit Corridor Congestion Relief Project Implementation

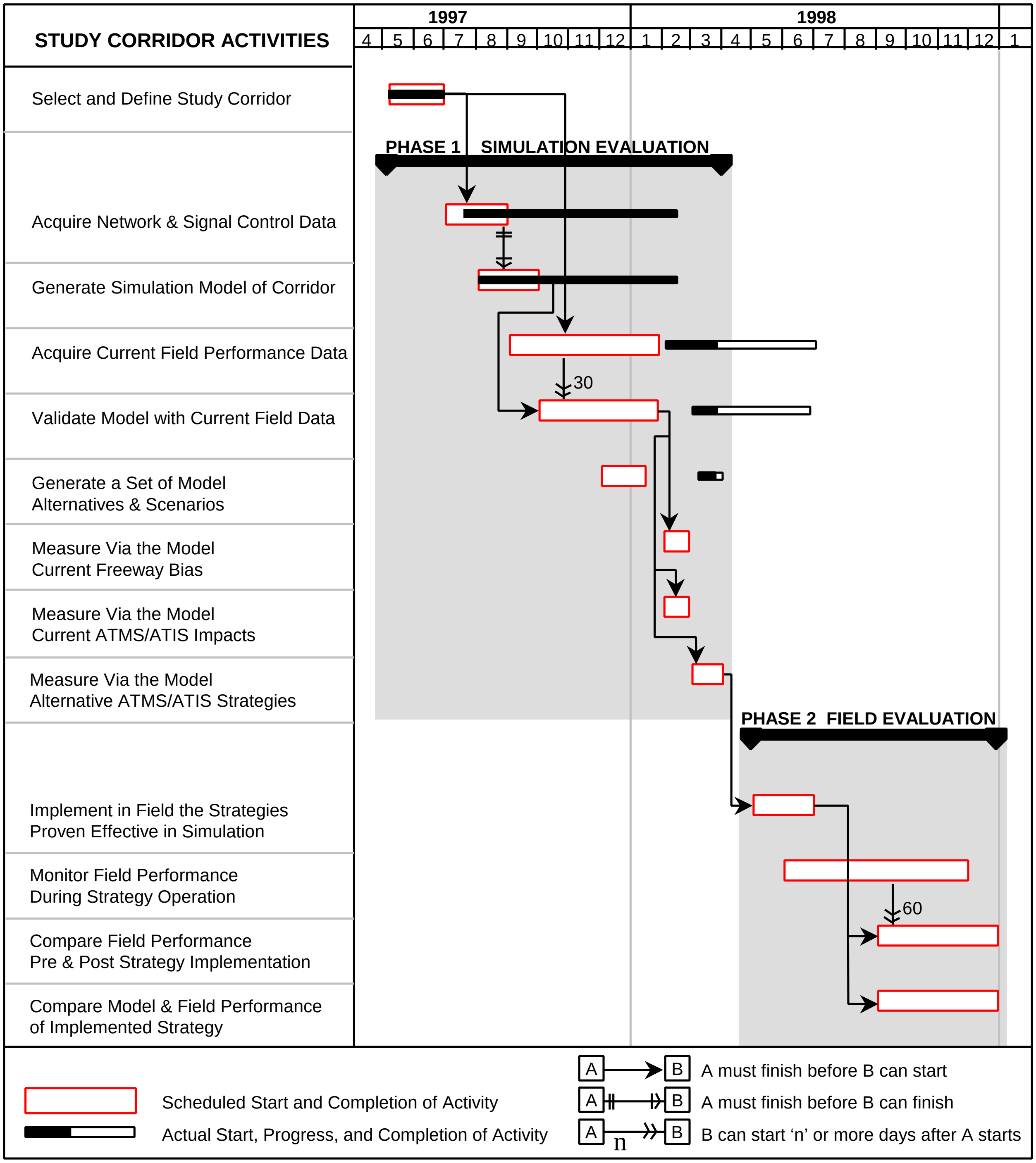

Figure 4. Chart of Project Activities' Duration and Progress

2. CORRIDOR SELECTION AND DESCRIPTION

Limitations in data availability, simulation capabilities, and staff time resources required the selection of a subset of the Metropolitan region with ATMS and ATIS. The following section outlines the criteria and decision process involved in selecting the study corridor. The subsequent section describes the transportation and land use characteristics of the study area.

2.1 Selection Criteria

The four necessary conditions to achieve real-time freeway diversion benefits are (1) freeway congestion, (2) the existence of viable alternate paths, (3) the availability of corridor monitoring systems, and (4) the existence of motorist information systems. The bases for these conditional requirements are described as follows. First, the absence of freeway congestion would eliminate the need for route diversion. As such, any consideration of diversion strategies must be for a corridor with congestion –be it recurrent or incident based. Second, given the presence of freeway congestion, if no alternate path exists, or if all alternate paths were equally congested, the benefit from route diversion would be minimal. Therefore, the availability of viable alternate paths is necessary for diversion benefits. Furthermore, real-time recognition and transmission of information about freeway congestion is required on the part of the corridor control authority to prompt significant motorist diversion. Thus, the availability of corridor monitoring and motorist information systems is required.

A simple cumulative scoring process was developed to identify acceptable freeway corridor options. For each freeway alternative, four scores are assigned, each associated with one of the necessary attributes for real-time freeway diversion benefits. Scores range in magnitude from 3, 2, 1, and 0 corresponding to ‘significant,’ ‘moderate,’ ‘minimal,’ and ‘none.’ The four scores are summed for each freeway alternative. Alternatives with higher cumulative score and no score less than one are identified as acceptable choices for the project. The final selection among acceptable alternatives was made based on the score of the alternative and the interests of MDOT.

Nine alternative freeway relief corridors within the Detroit metropolitan region were introduced in the *Freeway Relief Corridors Discussion Paper* [8]. These include the John C. Lodge Freeway (M-10), Edsel Ford Freeway (I-94), Southfield Freeway (M-39), Chrysler Freeway (I-75 & I-375), Fisher Freeway (I-75), Davison Freeway (M-8), Reuther Freeway (I-696), I-275 Freeway, and Jeffries Freeway (I-96). Table 1 lists the individual and cumulative scores for the nine freeway alternatives. The table was completed by engineers at the Michigan Intelligent Transportation Systems (MITS) Center, the hub of the Detroit Metropolitan area ITS operations. Upon a review of the top three alternatives (I-94, M-10, and I-75) the M-10 alternative was selected for its relatively greater number of alternative paths which included a freeway facility (Chrysler Freeway). The Edsel Ford Freeway was not selected for study as long-term facility construction and rehabilitation plans would interfere in performance measurements.

Concomitant to the freeway selection decision was the selection of corridor study boundaries. Criteria for boundary selection include location of freeway diversion opportunities, location of alternative routes, location of motorist advisory information, data availability, and resource constraints (staff time, data collection costs, etc.). Corridor boundaries are selected to include ‘natural’ points of freeway diversion choice and locations where motorist information would be received. Definition of corridor boundaries was based on the aforementioned factors and the interests of MDOT. Boundaries include McNichols Avenue to the north, Chrysler Freeway to the east, Forest Avenue to the south, and Linwood Avenue to the west. The following section describes the selected corridor.

	Guage of Freeway Corridor Aceeptability for Study				
Freeway Alternatives	Congestion Presence	Uncongested Alternative(s)	Corridor Surveillance	Motorist Information	TOTAL SCORE
Edsel Ford Freeway (I-94)	3	1	3	2	9
John C. Lodge Freeway (M-10)	2	3	2	1	8
Fisher Freeway (I-75)	3	2	1	2	8
Chrysler Freeway (I-75/I-375)	3	2	1(3)	1(3)	6
I-275 Freeway	3	2	0(1)	0(2)	5
Reuther Freeway (I-696)	3	2	0(2)	0(2)	5
Jeffries Freeway (I-96)	2	2	0(2)	0(2)	4
Southfield Freeway (M-39)	2	1	0 (1)	0(2)	3
Davison Freeway (M-8)	0	2	0	0	2

cell entry options/scores: 3 = significant 1 = minimal
2 = moderate 0 =none
Number in brackets is expected conditions upon ATMS/ATIS expansion.

Table 1. Corridor Options and Attractiveness Rating

2.2 Description of Study Corridor

The study corridor (Figure 5) is located 2.5 km north and west of the Detroit Central Business District (CBD). It is approximately rectangular, 8 km long by 4 km wide, bordered on the east by the Chrysler Freeway and on the west by Linwood Avenue. McNichols Street and Forest Avenue form its northern and southern boundaries, respectively. As mentioned earlier, data availability and simulation constraints affect the size of the corridor model. A number of potential alternate arterials to the west of Linwood were not included.

The study area encompasses two north/south freeways, the Lodge (M-10) and Chrysler (I-75), and two east/west freeways, the Ford (I-94) and Davison. The Lodge, Chrysler, and Ford Freeways link the Detroit suburbs with the CBD. Parallel to Lodge and Chrysler are a number of arterial streets that provide alternative access to the downtown areas. Woodward Avenue, the primary arterial, is a 4-lane undivided facility midway between the Lodge and Chrysler Freeways. To the west of the Lodge Freeway is Linwood Avenue, which is 4-lane street through most of the corridor, and links to Grand River for access to the downtown area. In addition, there are a number of one-way arterial pairs that could serve as alternatives to both Lodge and Chrysler through the corridor section. These are (west to east): 14th/Rosa Parks (12th) Avenues, 3rd/2nd Avenues, and John R/Brush Avenues. In addition, Hamilton and Oakland Avenues provide partial alternatives to Lodge and Chrysler respectively.

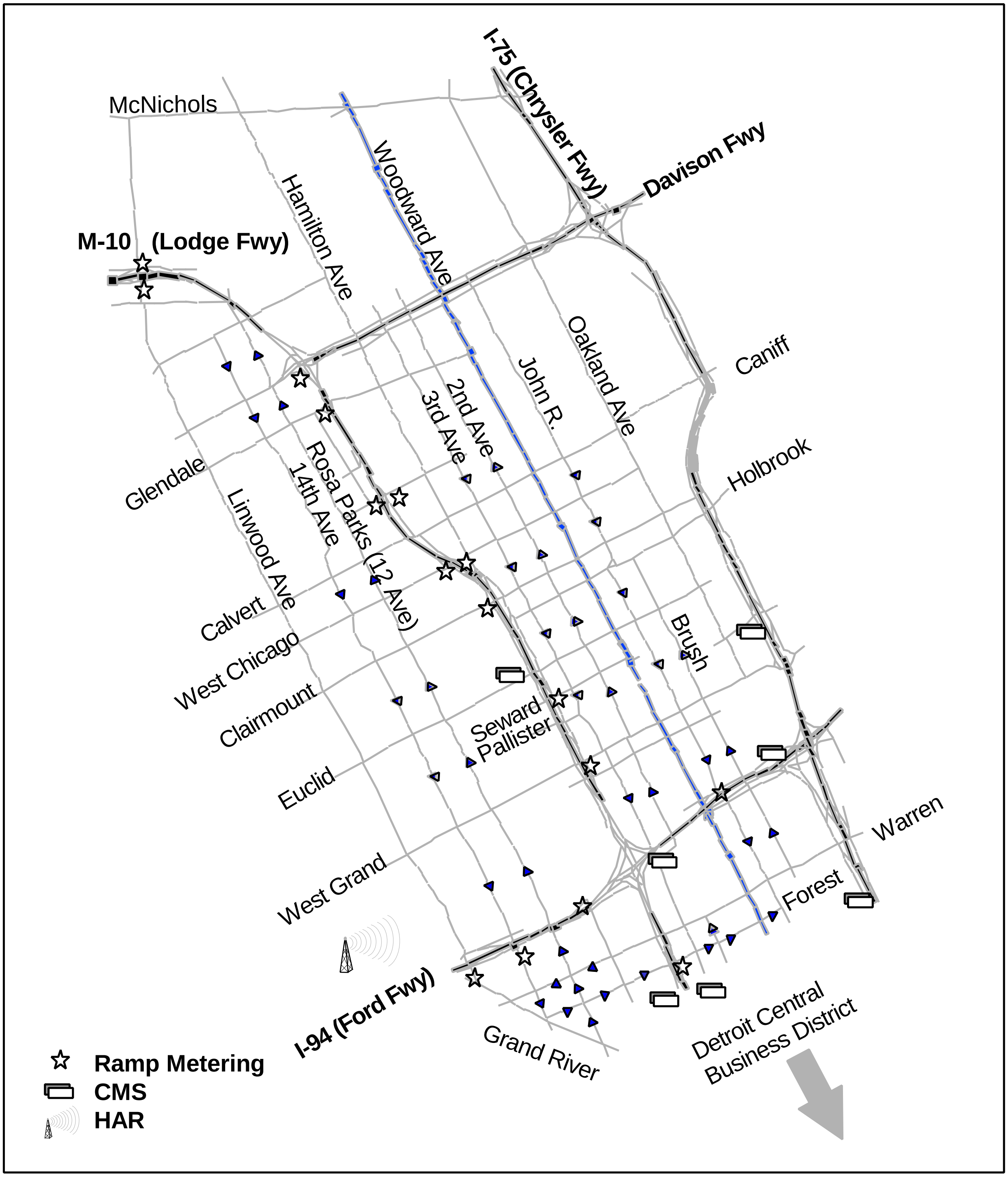

Figure 5. Detroit Study Corridor Roadway and ITS Infrastructure

Land use throughout the corridor is light industrial, small business/office, and residential. Business and office space, along with museums and Wayne State University occupy the southern portion of the corridor (south of West Grand Boulevard), while residential areas and a few downsized automotive plants dominate the northern section.

2.2.1 Conventional Traffic and ITS Elements

Within the study area are approximately 220 signalized and 30 unsignalized intersections. Signal control is non-homogeneous, with no centralized traffic control system. Signal timing is predominantly fixed-time, operating in a.m., p.m., and off-peak plans. Most intersections are 2-phase operations, though a number of locations implement protected or protected/permitted phasing.

The set of ITS elements existing within the Detroit study area includes ramp metering, CMS, HAR, CCTV, and mainline detectors. Location and operation of each device is described in this section.

Ramp metering is operated Monday to Friday from 6 a.m. to 10 a.m. and from 3 p.m. to 7 p.m. on the Lodge and Ford Freeways. Ramp metering is also operated during major incidents in the off-peak times. The metering rate is based on a demand responsive system using main line loop detectors to activate/deactivate meters when thresholds are met. Metering signals operate at a step-wise rate with a minimum of 10 vehicles per minute and a maximum rate of 15 vehicles per minute. The rate increase from a minimum rate is triggered by an occupancy value of 20%. Sixteen ramps within the study area are metered. Motorist information systems in the corridor include five CMS within study boundaries, and two just outside the southern boundary. In addition, CMS is located along the Lodge Freeway five miles northwest of the corridor. A HAR and an Internet site also transmit traveler information. The location of ramp meters, CMS, and HAR are shown in Figure 5.

Corridor freeway surveillance includes a series of detector stations and CCTV cameras along the Chrysler, Lodge, and Ford freeways. The detector stations consist of magnetic loops placed in each lane at an interval of approximately 0.50 miles along the Lodge and Ford freeways. These stations collect volume, occupancy, and speed data in 30 second blocks, and transmit the data to the MITS center located in the Detroit CBD.

2.2.2 Traveler Demand Characteristics

Travel demand is primarily thru-travel between suburbs and the CBD. Morning peak period demand is predominantly southbound with relatively equal demand east and west bound. Morning congestion starts at 7:00 a.m. and subsides by 9:00 a.m., with demand peaking between 7:30 to 8:00 a.m. Approximately 40,000 motorists traverse the corridor from 7:00 to 9:00. Evening congestion starts at 3:00 p.m. and subsides by 6:30 p.m., with approximately 45,000 motorists traversing the corridor during the evening peak. Demand estimates are scaled for the 1997-1998 year and are based on observed flow and SEMCOG planning data. Construction activities have been ongoing on Ford Freeway throughout the data acquisition phase, and are expected to continue for some years to come. As such, demand is influenced by motorist response to construction within and outside the corridor.

3. MODEL SELECTION AND DESCRIPTION

This section outlines the requirements for an evaluation model, identifies the applicability of currently available models, and describes the model selected for use in this project. Specific details on representing the corridor and various traffic conditions are discussed in Section 4.3.

3.1 Modeling Requirements

From a brief review of various model types such as econometric, mathematical and simulation, it was apparent that the appropriate direction was simulation modeling. In selecting the appropriate simulation model, three model review documents were surveyed: “Smartest: Review of Micro-Simulation Models,” “A Simulation Laboratory for Evaluation of Dynamic Traffic Management Systems,” and “Modeling Requirements for Emerging Transportation Systems Operating Environments.” [9,10,11] In addition, various studies using simulation models were reviewed.

Specific simulation capability requirements for this study include modeling of:

- interactions between arterial and freeway facilities;
- dynamic traffic management problems caused by incidents, road work, and events;
- adaptive and coordinated traffic signal controls;
- traffic phenomenon such as queue spill back, lane weaving, and freeway merging; and
- technologies such as loop detectors, ramp metering, dynamic route guidance, and HAR.

The simulation model should also be able to generate specific measures of performance. These include time-based link, vehicle, OD, and system statistics for speed, travel time, queue length, and throughput. The suitability of simulation models is also a function of the size of the networks, in terms of computation time and model building capabilities. Selection of a specific model should take into consideration the above criteria.

3.2 Model Description

A review of commercially available micro-simulation models identified a small set with the ability to both quantify the benefits of ITS technologies and represent combined urban/freeway networks. This model set includes INTEGRATION, AIMSUM2, FLEXSYT II, PARAMICS, and VISSIM. Of these, INTEGRATION has been identified as most widely used. [9] Moreover, it is the only with the ability to model networks of the size required by this project, and support the simulation platforms available for the study. Thus, INTEGRATION Version 2.0 was selected for the simulation task.

INTEGRATION models the progress of individual vehicles as they traverse a network of links from various origins to various destinations. An aggregate time-variant demand matrix externally specifies the number of vehicles from each origin to each destination. The aggregate demand is parsed into a series of individual vehicles that enter the network when the simulation clock reaches the vehicle’s scheduled departure time. The desired travel speed of the vehicle is determined by the characteristics of the link upon which it is traveling. The actual speed of the vehicle, subsequent to entering the network, is based on the distance headway between it and the vehicle immediately preceding it. Lane changing decision and speed updates are performed every 0.10 seconds for each vehicle in this micro-simulation model.

A vehicle's decision to traverse one of many links is based on a path table that indicates the appropriate next link, given that vehicle's present location and final destination. Various path tables are created and periodically updated based on historical or prevailing network conditions. Each path table corresponds to a specific vehicle class. Through this process the INTEGRATION model provides for static and dynamic multi-path routing. A vehicle progress toward its specified destination is a result of its desired speed as well as network controls or constraints such as traffic signals, ramp meters, speed limits, and queue formation.

In addition to the demand matrix specification, input on network composition is required. The primary network input components include node, link, lane striping, signal control, and incident files. Nodes can be of an origin and/or destination type, or of a link connector type. A link is specified to be a segment of roadway characterized by homogeneity in factors such as the number of lanes, roadway geometry, speed limit, capacity, and lane restrictions. The lane striping file indicates what turning movements are acceptable from each lane. The signal control file specifies the existing signal timing plans of all signalized intersections within the network as well as cycle length boundaries for signal optimization search processes. The incident file lists location, duration, and severity of incidents to be modeled through simulation.

Measures of performance generated by the INTEGRATION model include vehicle statistics on trip time, trip distance, and number of stops. Link statistics on total flow, average travel time, maximum queue size, maximum vehicle density, average speed, average occupancy, average volume to capacity ratio, and average effective green duration can also be generated.

As with most micro-simulation models, INTEGRATION uses random number streams in its modules. The simulation should be executed for an array of random number streams to verify that differences in alternatives are not attributed to the random stream. The random number stream introduces variability in the vehicle path and time trajectory; therefore, precise agreement between the micro-simulation model and real world data is unlikely. Validation of the model should be based on similarities in mean and variance of field observed and modeled characteristics. Two ideal comparable characteristics are link flow and trip time.

4. PHASE ONE EVALUATION: SIMULATION MODELING

The absence of detailed traffic data prior to the installation of ATMS and ATIS within the Detroit Metropolitan region precludes field measurement of changes in the performance of the transportation system. However, by comparing simulations of existing performance with simulations without ITS, the transportation performance of the corridor ITS infrastructure can be gauged. This section describes the set of options that will be modeled; defines the concept of freeway bias; and outlines the process for demand and freeway bias estimation.

4.1 Alternatives and Scenarios

A primary goal of this study is to quantify freeway bias within the study corridor. Assuming the absence of this bias, the task is to identify and evaluate a number of alternative ITS solutions or strategies (referred to as alternatives) that could address recurrent or non-recurrent congestion. The effectiveness of specific alternatives is related to the source of system variability, be it an accident, or a demand change (referred to as scenarios). This section provides insight into the alternative and scenario development process, and defines the set of alternatives and scenarios to be studied. Current estimates are that each alternative - scenario combination will be modeled four to six times corresponding to different random number streams to verify that differences in models are not attributable to the random number stream used.

4.1.1 Corridor Alternatives

The guiding principles for the alternatives selected for this study can be summarized as follows:

- Include No Action (No Build) as an explicitly considered alternative (comprised of existing infrastructure/services)
- Consider only alternatives that are improvements to or expansions of existing systems
- Ensure that each alternative is distinct from the others
- Refine each alternative to optimize its capabilities
- Keep the number of alternatives manageable
- Ensure that the alternatives address the study goals and objectives

All alternatives considered are of the “no-build” variety in the traditional Major Investment Study sense. Solutions will involve improvements and/or expansions to currently installed systems. They will not require geometric modifications such as additional lanes or left-turn bays. Following are the five classes of alternatives that will be evaluated through simulation:

4.1.1.1 Existing (some ITS)

This is the baseline scenario. It models the current transportation systems, infrastructure, and services within the corridor, and will be calibrated to approximate existing traffic patterns. The corridor currently has ITS elements that by definition will be included in the alternative.

4.1.1.2 No ITS

This alternative will model the ‘existing’ corridor without ITS. In this way we hope to demonstrate the beneficial impact of ITS (baseline scenario) when compared to this alternative.

4.1.1.3 Existing with Signal Coordination

Signals within the corridor are coordinated on a local basis; i.e. little consideration has been given to signal timing impacts relative to overall network performance. In addition, no consideration has been given to signal optimization in circumstances of additional freeway diversion. Successful diversion strategies will require optimized coordination along the surface arterials.

4.1.1.4 Existing with Ramp Metering Coordination

Ramp meter operation currently is independent of up stream or down stream ramp meters. Coordination of ramp meters can regulate freeway entry to promote smooth freeway flow.

4.1.1.5 Existing with Signal Coordination and Ramp Metering Coordination

This alternative is an implementation of an Integrated Traffic Management System (ITMS) to coordinate traffic control within the corridor. ITMS integrates hardware and software elements, traffic signal systems, freeway management systems, and traveler information systems. An FHWA study entitled "Coordinated Operation of Ramp Metering and Adjacent Traffic Signal Control Systems [12]" developed operating strategies and control tactics to address the problem of congestion in corridors. Four strategies were devised:

- Local Coordinated Strategy: Used when freeway demand does not require integrated ramp control. Ramp meter rates and traffic signal timings at each interchange are selected and adjusted based on local conditions. Primarily applies to non-peak, non-incident conditions.
- Area-wide Integrated Strategy: Used when freeway is in traffic-responsive area control mode. Ramp metering rates and traffic signal timing plans are set according to corridor flow optimization rather than local conditions at interchanges. Applies once local management begins to affect non-local freeway operations.
- Diversion Strategy: Used to handle freeway incidents. Special timing plans are assigned for both arterial signals and ramp meters at locations affected by the selected diversion routes. Applies to freeway incident and maintenance conditions.
- Congestion Strategy: Used when traffic demand exceeds capacity in corridor sub-area. If traffic demand exceeds the sub-area capacity, traffic control objectives change to manage the spread of congestion rather than handle demand.

This alternative is primarily concerned with mitigating freeway congestion by taking advantage of unused capacity on local arterials. Consequently, management tactics will involve a fusion of the Diversion and Congestion strategies, a combination of diverting traffic from the freeway and optimizing ramp-metering and local signal coordination to accommodate the additional demand.

4.1.2 Corridor Scenarios

ITS strategies are expected to be most effective under high-variability conditions. Three factors causing variability in corridor performance are demand, weather, and incident. Figure 6 presents these three factors in a three-dimensional coordinate area. The center is representative of average demand, weather, and no incidents generating typical corridor performance. The extreme in poor performance is characterized by block 1(Figure 6) which represents a simultaneous occurrence of high demand, very poor weather, and a large incident. Although the occurrence of such an event is extremely rare, a significant portion of ITS benefit may be derived from mitigating the single extreme event.

The objective in scenario definition is to select a small set of representative events that will both reflect the varying conditions and differences in each alternative's responses. The constraints to the scenario set size are computation, data storage and staff effort.

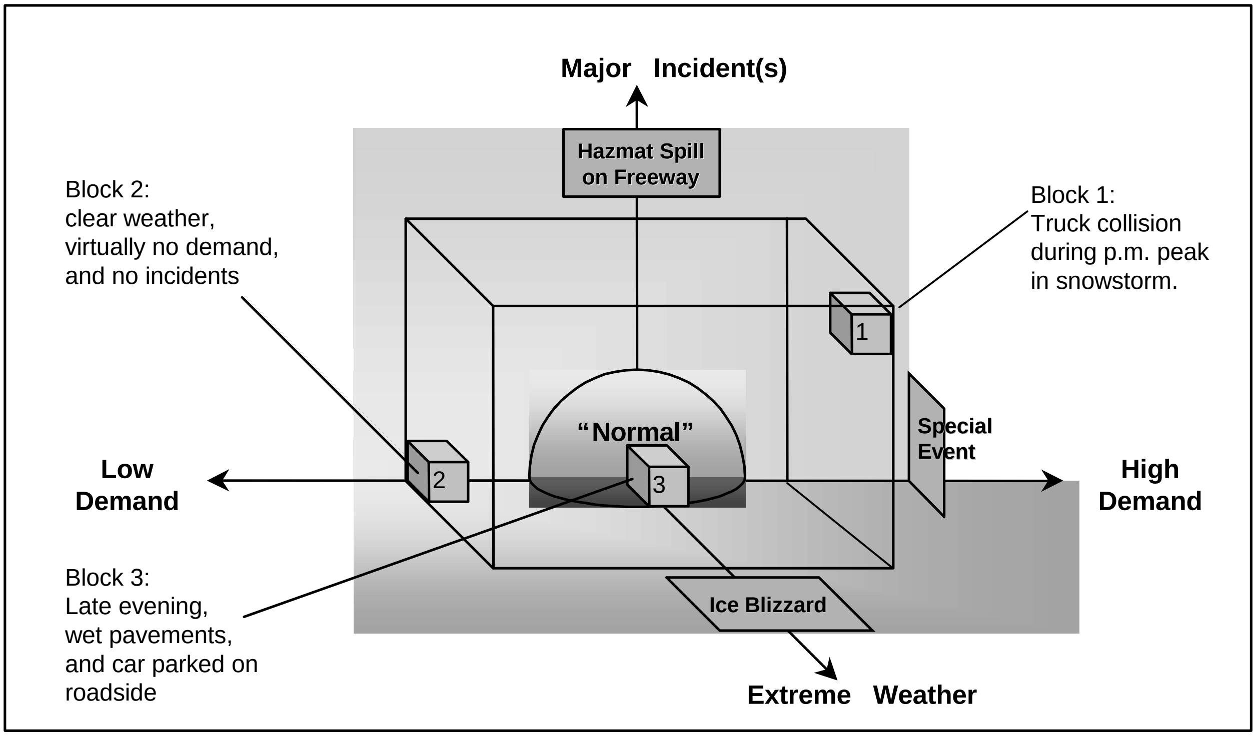

Figure 6. Factors Contributing to Corridor Variability

Annual impact, or measure of effectiveness, for an alternative would be derived from aggregating weighted scenario impacts. The scenario weight would represent the probability of occurrence of that scenario over a one year time period. However, for this study, we are not generating annualized benefits estimates because of the data and time constraints in estimating scenario weights. Impacts will be presented by un-weighted scenario type.

The dimensions used to define the scenarios include traffic volume pattern, weather, major freeway incident, and minor system-wide accident. The location, duration, and severity of any system perturbation also define the scenario. The location, duration, and severity of events will be based on historic frequency of occurrences of such events. Fifteen scenario options, defined in Table 2, will be evaluated through simulation. The first of these fifteen is a simulation with average demand, no incidents, and good weather.

The set of selected scenarios will be run for circumstances of existing motorist bias and the absences of motorist bias. Comparison of simulation outcomes will indicate the degradation impact of bias under capacity and demand changes. The set of fifteen scenarios with two levels of freeway bias will be modeled for each of the five alternatives yielding a total of 150 (5 alternatives x 15 scenarios x 2 bias levels) unique simulation cases. The 150 cases will be run four to six times, each time with a different random number stream. This will identify whether performance differences are attributable to the case or the random number stream. Thus, the total number of simulations ranges from 600 to 900.

SCENARIO OPTION SET FOR SIMULATION

Characteristics	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6	Option 7	Option 8	Option 9	Option 10	Option 11	Option 12	Option 13	Option 14	Option 15
high demand											✓	✓	✓	✓	
average demand	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓					
low demand															✓
no incident	✓	✓	✓								✓				
multiple minor incidents				✓	✓	✓				✓		✓	✓		✓
major incident(s)							✓	✓	✓	✓				✓	
good weather	✓			✓			✓					✓			
wet/rain		✓			✓			✓		✓				✓	
frozen/snow			✓			✓			✓				✓		✓

Table 2. Description of Scenario Options

4.2 Freeway Bias

A corridor is defined to be at user equilibrium when no motorist can achieve a better travel time through the corridor by changing to an alternate route. In the absence of unusual travel demand or system capacity changes, a corridor system is expected to exist near user equilibrium. This is because seasoned motorists are expected to have tested feasible paths for their commute and have selected alternatives with minimal travel time for an average day of traffic. Under certain circumstances, however, a motorist population may have preferences for a path despite the existence of alternate shorter time-based paths.

Freeway bias can be shown to exist when an arterial route provides a significantly better travel time than a parallel freeway route whose performance is degraded by recurrent congestion. This bias may be attributed to the complexity of arterial paths, greater variability in arterial travel time, unfamiliarity with arterial paths, or safety concerns related to arterial environments. Figure 7 demonstrates freeway bias during a peak and its manifestation via demand and travel time imbalance among parallel routes.

Freeway bias can also be observed in circumstances of capacity reducing events on the freeway. For example, during queue spillback resulting from a freeway incident, motorists may choose to remain on the queued freeway rather than divert to a parallel arterial with lower travel time.

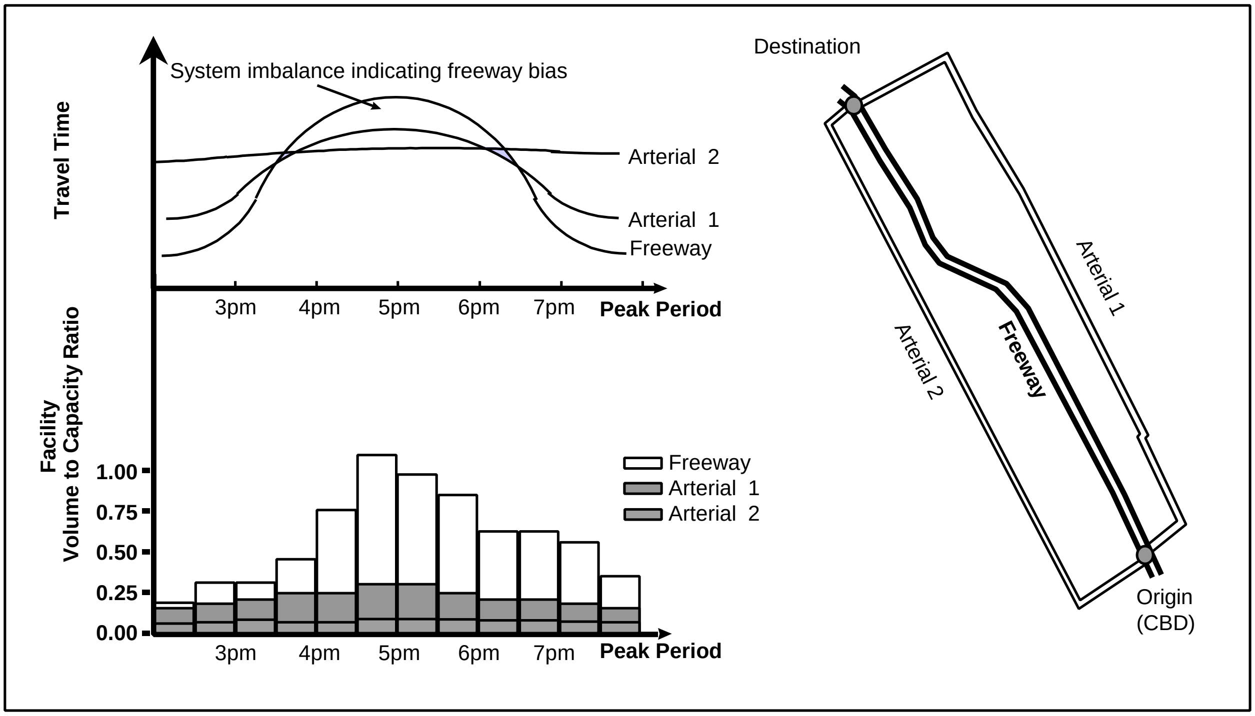

Figure 7. Occupancy and Traversal Time Relationship for Freeway Biased Facilities

Two processes will address the MDOT hypothesis that Detroit commuters have a bias toward freeways: simulation modeling of the freeway corridor, and statistical analyses of field data. Assuming the existence of freeway bias, commuter would select a freeway route although another route may provide a better travel time. A comparison of field data on travel time for the freeway and any parallel arterial during expected traffic conditions would reveal the existence and magnitude of freeway bias. In the absence of travel time data, field data on point speeds may be used to derive travel time. Furthermore in the absence of point speed data, volume data along with macroscopic speed-flow relationships may be used to estimate speed and consequently travel time. The macroscopic speed-flow relationship is based on the Highway Capacity Manual [13] and is characterized by four parameters: free-flow speed, speed at capacity, flow at capacity, and jam density. At a lower bound of free flow demand, vehicular speed is expected to be at or above the posted speed limit on the road facility.

Travel time on a facility may vary within a peak period and between days. Given that necessary data is provided by MDOT, tests will be performed to determine whether average travel time on the freeway facility is significantly different from that of parallel arterial routes. For these comparisons, a two-tailed t-test for means and differences will be performed.

After identifying bias, simulation modeling can quantify the degradation in performance resulting from the freeway bias for a range of corridor demand and capacity characteristics. The process of representing of freeway bias within the simulation model is described in the section 4.3.3.

4.3 Simulation Representation

For this study, INTEGRATION 2.0 is being utilized for modeling the corridor and evaluating ITS strategies. It permits modeling of ITS strategies such as ATIS (CMS, HAR) and ATMS (signal coordination techniques, freeway surveillance). INTEGRATION utilizes a vehicle class function, where up to 5 vehicle classes can be defined (e.g., bus, HOV, ATIS-enabled). Vehicles of a particular class use similar information sources to select a shortest time-based travel path. Information types include free flow speeds, peak period speeds, real-time speeds, and variants of these. Subsequent entries within the various input files define how these vehicles interact.

In modeling the corridor system three primary tasks are necessary: representing the physical and operations infrastructures; representing the alternatives and scenarios; and calibrating the demand and traveler response components. The method of demand and freeway bias calibration incorporates a validation of model performance against observed system performance. These activities are described in the following three sections.

4.3.1 Traditional Physical Infrastructure and Control Representation

Representing the physical traffic network in INTEGRATION requires the creation of four separate input files: node, link, lane striping, and signal. These files transform the corridor of roads, intersections, and controls into a network representation of links, and nodes with operational characteristics (Figure 8). The following sections detail the four input files.

4.3.1.1 Nodes

Nodes define points in the network where vehicles originate from or are destined to (OD Nodes), locations where roads intersect or connect, and where roadway characteristics, such as number of lanes, speed or geometry, change. Each node is defined by rectangular coordinates, and while the INTEGRATION model does not require the node placement to correspond to real-world locations, doing so makes network implementation/representation much simpler. Link lengths are defined specifically in the link file, rather than derived from node coordinates. The node file is primarily for link connection, vehicle origin/destinations specification, and graphical simulation purposes.

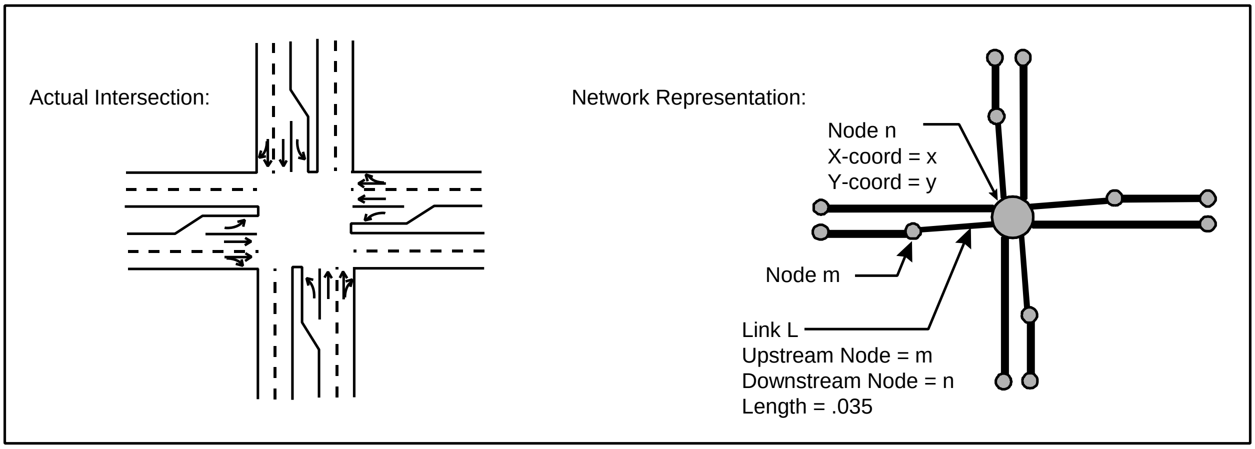

Figure 8. Intersection with Link-Node Representation

4.3.1.2 Links

Roadway sections are represented by links in the simulation model. Each link is defined by a number of characteristics, which include:

- upstream and downstream nodes
- speed-flow parameters
- traffic signal reference and phase information
- opposing traffic information
- length
- capacity
- number of lanes
- level of real-time surveillance

The link file therefore defines the substance of the network, i.e. which links connect to which links, how long the link is, and the characteristics of traffic flow along that link. Other characteristics include vehicle prohibition (no through trucks, for example). Network calibration primarily involves this file.

4.3.1.3 Lane Striping

The lane striping file is used to designate lane utilization on specific links; e.g. left-turn only bays, through only lanes, etc. In addition, specific vehicle classes can be prohibited from using certain lanes; e.g. bus only lanes, HOV lanes, etc.

4.3.1.4 Signals

Signal control in INTEGRATION is defined in both the link and signal timing files. Contained in the link file is phase information specific to each signalized link, i.e. on what phases a specific movement is permitted. Each signalized link also references a specific signal contained in the signal timing file. The signal timing file lists for each signal the following:

- minimum/maximum cycle lengths for optimization
- effective green and lost time for each phase interval
- cycle length
- offset

The lost time in the signal file represents the amber and all red time following a green time. The signal file can contain multiple timing plans for some or all signals. Intersection approach controls such as stop or yield signs are designated in the link file as a link end attribute.

4.3.2 Scenario and ITS Alternative Representation

Incident, adverse weather, and demand change options are represented through the incident, link, and demand files respectively. The incident file specifies the links upon which incidents occur, the start and duration of each incident, and the severity of each incident in terms of percentage of lanes blocked. Weather conditions are modeled by their impact on system capacity. Within the link file, a percentage network capacity reduction can be specified corresponding to factors such as wet/icy road conditions. Directional or aggregate changes in demand are represented by modifications of the demand file.

The representation of ITS technologies in INTEGRATION is achieved through a variety of techniques. Ramp metering is modeled via the signal file by generating a signal with very short cycle length. Loop detectors operation is represented in an optional file wherein location and operation characteristics such as accuracy and lane coverage are specified.

CMS are not explicitly modeled in INTEGRATION; thus, a multi-step process is generated to represent CMS and its impacts. CMS is modeled through a binary nodal attribute --information availability. Vehicles traversing a node with information available will temporarily be transformed to a CMS vehicle type corresponding to CMS routing. The CMS-routed vehicles will base their path on a travel time input file. This input file consists of travel times associated with the vehicles normal routing information when CMS is inactive. When the CMS is active, the file will supply a travel time that is significantly larger than normal travel time on the link with incident, causing vehicles to use alternate routes. The percentage of motorists who adhere to the CMS must also be specified in the node file. HAR is modeled in a similar process as CMS with information available at a set of nodes rather than one node.

In addition, other ITS elements can be modeled using INTEGRATION. These include pre-trip planning, en-route diversions, advanced signal control, and mode shift (though the study corridor does not lend itself to this). Motorists representing pre-trip or en-route planners are modeled as vehicle types with network entry route based on real-time link statistics. The pre-trip planners adhere to the best path identified at trip start. En-route planners re-evaluate and modify their path at specified time intervals to take the shortest path to destination given their present position and corridor congestion. Signal control and ramp metering may be optimized internally for a static or dynamic signal strategy by the INTEGRATION model.

4.3.3 Demand and Freeway Bias Estimation

INTEGRATION models demand based on a matrix of origins and destinations (OD elements). Each OD has associated with it a demand rate (vehicles per hour), a time span for which this demand rate is valid, and a percentage breakdown of demand by vehicle type. A software preprocessor then constructs path(s) for each vehicle type represented in the origin-destination-time (ODT) specific demand rate.

Demand data is usually unavailable at the required level of detail, and costly to acquire. Therefore, a synthetic OD generation software, QueensOD [14], will be used to generate a time-based OD demand file. Synthetic generation techniques require an initial estimate of origin-destination demand, field observations of time-variant flows, and intersection turning movements.

Given that the corridor may exhibit freeway bias and that network flows reflect this bias; the OD demand would be influenced by this bias. Consequently, although the OD demand may vary from corridor demand, it will adequately represent existing flow patterns. In addition, within the simulation assignment process, path choice based on actual trip times would neglect any existing freeway bias. Thus, perceived trip times, a function of actual trip time multiplied by freeway bias constants, may be generated for the traffic assignment module within INTEGRATION. Depending of the existence of time based bias the set of freeway bias constants may vary temporally and spatially. The relationships between OD generation, freeway bias estimation, simulation output and field data is presented in Figure 9.

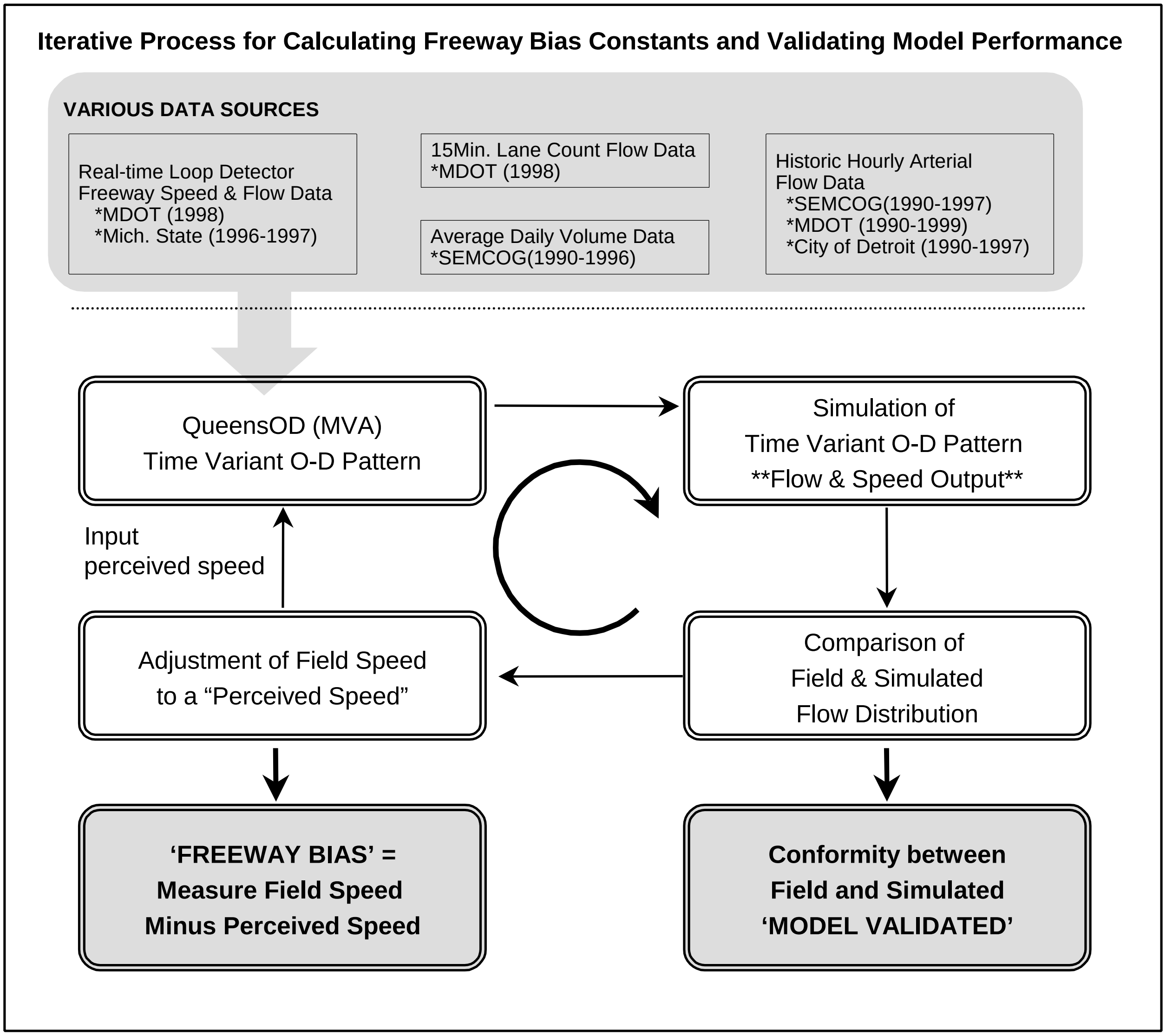

Figure 9. Demand/Freeway Bias Estimation and Model Validation

The interactive effect of the OD demand and freeway bias constants should result in simulation output that is validated by field observation. Points of validation include link flow, link speed, and OD travel time data. Given simulation network geometry parallels the actual corridor, and that link flows and speeds parallel those observed in the field within a specified confidence interval, the simulation network is stated to be validated.

The expectation is that strategies applied to the network will influence route choice. Thus, flows and turning movements on links will change by scenario and alternative. These strategies; however, will not significantly effect the departure time or rate of demand made from each OD element. Thus, the ODT flow values generated by QueensOD remain valid.

5. PHASE TWO: FIELD IMPLEMENTATION

Given that simulation exercises successfully identify corridor operational changes that enhance system performance, Mitretek, MDOT and the ITS JPO will select a subset of the operational changes for field implementation. The set of feasible strategies for field implementation is constrained to options that do not require physical infrastructure investments. Currently, promising actions include signal system retiming, ramp metering adjustments, and CMS operations. The time schedule for field implementation will be agreed upon by Mitretek, MDOT and the ITS JPO upon Phase One completion.

After field implementation MDOT is expected to archive loop detector information on freeways and maintain arterial observations for a two to six month time period. Time-of-day and day-of-week average statistics will be calculated and compared to corresponding loop detector data collected prior to operational implementation. Atypical corridor conditions such as incident or poor weather will also be compared prior to and after operational implementation. This set of comparisons will determine the magnitude of impact observed from the operational changes.

The set of observed flow and speed characteristics will also be compared to simulation to determine the level of agreement with simulation and observed impacts. This comparison will indicate the degree of accuracy with which the simulation model formulates outcomes.

6. DATA REQUIREMENTS

Three types of data are required for micro-simulation models: network geometry, calibration, and validation data. Network geometry data defines the connectivity and right of way for vehicle progression. Types of geometric and right of way data include:

- nodal coordinate (x, y) values
- road lengths
- number of lanes per segment
- lane prohibited movements
- facility or lane use restrictions
- directionality restrictions
- ramp length and configuration
- signal locations
- signal controller type
- signal cycle length and phase operation
- ramp meter location
- ramp meter hours of operation
- ramp meter control type
- stop and yield sign locations

Additional network information on loop detector, CMS, and HAR location and operation is also required for accurate network model representation.

Calibration data define model reactionary components that parallel corridor driver behavior and traffic flow characteristics. Driver behavior characteristics are modeled via car following, gap acceptance, and overtaking rules. These represent desired headway, reaction times, acceleration rates, aggressiveness, and awareness of drivers. The difficulty in direct measurement of these attributes coupled with resource and staff time constraints precluded specification of Detroit-specific driver behavior characteristic. As such, behavioral characteristics specified as defaults in the INTEGRATION simulation model were adopted. Traffic flow characteristics follow the Highway Capacity Manual (HCM) speed, flow, and density relationship. This relationship is defined by free flow speed, speed at capacity, jam density, and saturation flow rate. These variables are generated to match observed flow and speed relationships for freeway facilities. HCM estimates are used to represent arterial traffic flow characteristics.

Validation data is used to verify model output. The specific measures of comparison for this study are link flow and link speed statistics on roadway sections for a given time duration. Travel time for specific OD pairs will also be used for model validation.

To meet representation, calibration, and validation data needs various data sources were contacted. Data on system variability pertaining to incident conditions were also obtained. The following lists sources of data and accompanying metadata:

- Etak, Inc --Latitude and longitudinal coordinates of roadways profiles with a resolution of 0.05 miles. Data are transformed to generate node coordinates and link lengths.
- Michigan DOT Plans of Proposed Traffic Signals for the City of Detroit & Highland Park – Intersection layout plan views with lane striping (1997).
- Michigan DOT Detroit Area Freeway Surveillance, Control & Driver Information System General Plans -Loop detector location, ramp merge profiles, and number of lanes (1980).
- City of Detroit, Department of Transportation Signal Timing Plans –Signal cycle, phase, and offset data for existing signal operation (1952-1998).
- City of Highland Park, Department of Transportation Signal Timing Plans –Signal cycle, phase, and offset data for existing signal operation (1952-1998).
- SEMCOG Traffic Study Volume Reports –Hourly directional volume counts (1992-1998).
- Michigan State University Filtered Loop Detector Counts –Volume, speed, and occupancy measurements by minute intervals from freeway loop detectors (1996-1997).
- Michigan ITS Center Loop Detector Counts –Volume, speed, and occupancy measurements by 15-minute intervals from freeway loop detectors (1998).
- Michigan ITS Center (MITSC) Arterial Lane Counts –Counts by 15-minute intervals (1998).
- GPS Odograph Roadway Profiles --Arterial and freeway speed and travel time profiles conducted by Mitretek Systems (1997-1998).
- MDOT-MITSC MALI Incident Database – Incident history data for freeway and arterial streets (1991-1995, 1997).

Field observations were also made to acquire facility use, turning movement, and signal location data where the above data sources were insufficient. CMS location and operation data was provided by the MITSC center.

7. MEASURES OF EFFECTIVENESS AND OUTPUTS

Successful completion of this study will yield three significant outputs. The first is a measure of the benefit from implementation of the current ITS system. The second is a measure of the potential for improvement in corridor performance through operational changes in the system. The third is a field-measured impact of operations changes is in ITS system. In addition, comparisons in simulation will quantify the impacts of any existing freeway bias. Furthermore, comparisons between field measured and simulation impacts of operational changes will yield reliability statistics on the ability of the simulation model to adequately represent corridor operation.

Strategies fostering the dynamic balance traffic loads within a freeway corridor include demand actions of motorist information via CMS and HAR, and capacity actions of ramp metering and signal controls. Measures of corridor performance from these strategies include link and trip based statistics on the following:

<u>Link-based Statistics</u>

- stops per vehicle-kilometer
- average speed
- variance in speed

<u>Trip-based Statistics</u>

- Trip Time by motorist type
- Throughput in vehicles per hour
- Delay reduction in minutes

These statistics will provide measures of freeway bias, impacts of specific ATMS and ATIS strategies, and benefits from freeway bias reductions. The total number of vehicle stops is indicative of emissions output. The variance is speed is indicative of incident tendency.

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