

SCHOOL OF  
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JOINT HIGHWAY RESEARCH PROJECT

JHRP-90/14

Final Report

AN ELECTRONIC SURVEILLANCE AND  
CONTROL SYSTEM FOR TRAFFIC  
MANAGEMENT ON THE BORMAN  
EXPRESSWAY

Michael J. Cassidy

Kumares C. Sinha



PURDUE UNIVERSITY



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An Electronic Surveillance and Control System  
for Traffic Management on the Borman Expressway  
PART I

Final Report

TO: Harold L. Michael, Director  
Joint Highway Research Project  
November 12, 1990

FROM: Michael J. Cassidy, Asst. Professor  
Joint Highway Research Project  
Project: C-36-75A  
File: 8-9-1

Attached is the Final Report for the study titled "An Electronic Surveillance and Control System for Traffic Management on the Borman Expressway, PART I." The report details appropriate technologies and traffic management strategies for the proposed Borman Expressway freeway traffic management system. The research for this report was conducted by Professor Kumares C. Sinha and myself.

Respectfully submitted,



M. J. Cassidy  
Assistant Professor

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An Electronic Surveillance and Control System  
for Traffic Management on the Borman Expressway

by

Michael J. Cassidy  
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Joint Highway Research Project

Project No. C-36-75A

File No. 8-9-1

Prepared for an Investigation

Conducted by

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in cooperation with the

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The authors also wish to thank a number of people for their assistance in this study. We gratefully acknowledge the Borman Expressway Technical Advisory Committee for their help and support. We especially thank Mr. Daniel Shamo, INDOT LaPorte District, for his invaluable assistance throughout this study. We thank Messrs. James Poturalski and James Barr, INDOT Central Office, for their insights concerning this work.

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## 1. INTRODUCTION

The Borman Expressway (I80/94) in northwest Indiana has the highest average daily traffic volume of any roadway in the state. The expressway, which links Gary, Indiana to Chicago, Illinois, serves an average of over 140,000 vehicles each day. Overall volumes on the Borman remain fairly constant throughout the day. Moreover, a high proportion of trucks (approximately 30%) operate in the traffic stream.

The Indiana Department of Transportation (INDOT) has determined that an automated surveillance and control system is to be implemented on the Borman Expressway. The installation of such a freeway traffic management system will significantly reduce incident-induced operational problems which now occur regularly on the expressway. Such a system will also mitigate recurring congestion problems likely to occur in the future.

The purpose of this report is to detail technology options currently available (or soon to be available) in an effort to identify those systems which appear most promising for application on the Borman Expressway. The report also highlights potential traffic management strategies which can be employed. In this sense, the report represents a preliminary study for the overall project. Findings from this preliminary study should provide definite direction for the design and implementation of the Borman Expressway surveillance and control system.

### 1.1 Report Overview

This report is divided into several sections. Section 1 provides background information concerning the project and briefly summarizes those technologies and strategies which appear most promising. Section 2 of this report highlights available information on existing traffic flow conditions on the Borman Expressway. Section 2 also details certain operational aspects that can be improved through the application of technology and traffic management strategies. Section 3 details technology systems and operational strategies which could be implemented on

the Borman. Those systems which appear most promising are specifically identified in Section 3. Section 4 summarizes recommendations for the proposed Borman system and provides an implementation plan. Section 5 documents some of the estimated costs of those systems identified as being most promising. And finally, Section 6 of this report outlines future tasks required for system implementation.

## 1.2 Background

The proposed surveillance and control system is to be installed in a 12-mile section of the Borman Expressway. The "study site" extends from the I65 interchange to the Illinois/Indiana state boundary. Figure 1 illustrates the study area. The expressway currently experiences operational problems resulting from accidents, vehicle stalls and other incidents. The freeway traffic management system ultimately selected must have the capability to mitigate operating problems through the timely detection and removal of expressway incidents. Moreover, the freeway traffic management system must include control strategies for managing (and minimizing) congestion resulting from the incidents.

A wealth of technologies associated with freeway traffic surveillance and control currently exists. A number of U.S. metropolitan areas have implemented such technologies. A considerable amount of research related to surveillance and control technologies is being conducted at universities and research centers. And finally, a number of manufacturers and vendors currently offer advanced technology equipment for freeway traffic management. Thus, one of the primary objectives of this study is to synthesize available information so as to select technologies most appropriate for application in Indiana.

Toward this end, the tasks associated with this work included 1) a thorough literature review to identify completed and ongoing research in the area of freeway surveillance and control and 2) a study of operating conditions within the corridor and 3) meetings

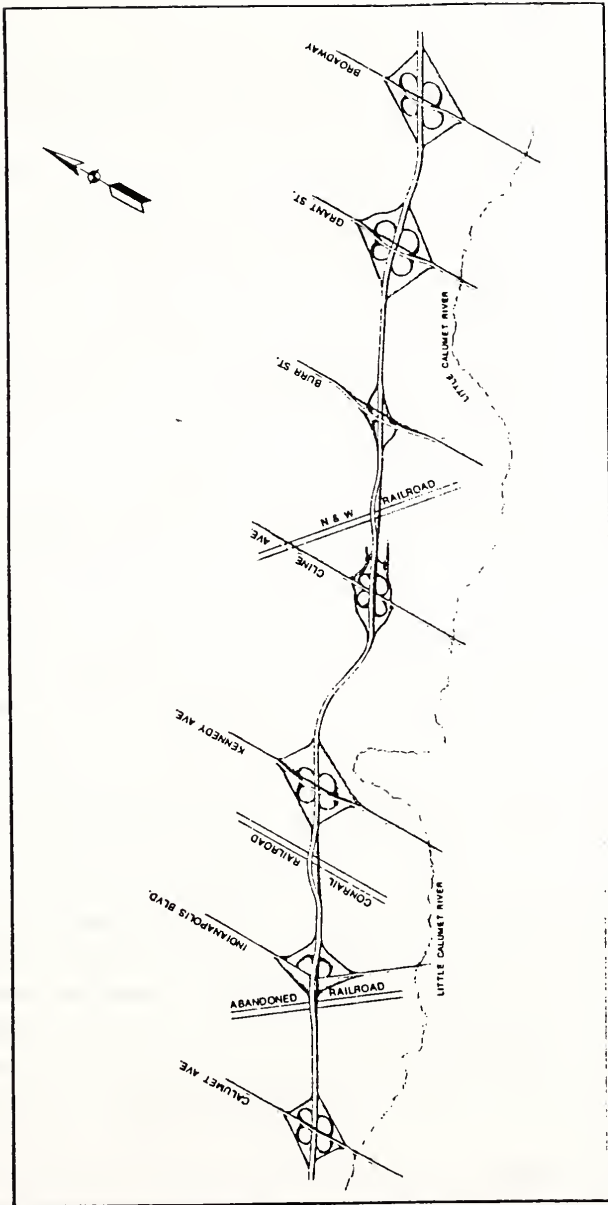


Figure 1  
Study Site

(Source: Reference 11)

and discussions with researchers and professional personnel who have experience in the design and implementation of freeway traffic management systems.

The objective of the overall project is to use advanced technologies for monitoring and managing traffic operations on the Borman. The system ultimately proposed must be implemented in the near future and must function in a "real world" environment. Thus, all elements of the surveillance and control system must be implementable and should not rely upon technologies which currently require significant additional development. This study has therefore sought to identify technology advancements which have proven to be effective and appropriate.

Researchers involved in this study subscribe to the belief that the appropriate design and implementation of a surveillance and control system on the Borman Expressway produces benefits which are two-fold. The first, and most obvious benefit, is improved operation on the expressway itself. Beyond this, however, the system chosen will serve as a pilot study for systems implemented at other locations in the future. In coming years, such systems may be called upon to monitor and control recurring congestion as well as incident-induced operating problems. The Borman surveillance and control system must therefore have the ability to "expand" and change. Moreover, advancements in technology could dictate the need for modifications or adjustments in the proposed system. The system should be capable of incorporating future technologies for the purpose of evaluation and testing. This, of course, means that the Borman surveillance system must be comprehensive. A comprehensive system facilitates maximum operating efficiency, and also provides the capabilities to measure and evaluate the impacts of implemented technologies.

### **1.3 Summary of Findings**

Based on findings from this study, it is recommended that the proposed freeway management system consist of three components. Each of these components could be implemented sequentially. The

duration of time between the implementation of each component would depend on the assessed need and/or urgency. Each would be designed with expansion in mind. The recommended elements comprising each of the three components are briefly summarized below:

#### **Component 1: Traffic Surveillance**

Traffic surveillance systems will provide real-time incident detection capability. The system should consist of 1) inductive loop detectors, 2) closed circuit television (CCTV), 3) additional milepost signs to provide location information to motorists "phoning-in" (i.e. reporting) congestion problems and 4) motorist service patrols. Through rapid detection, the surveillance system will greatly reduce delays and safety hazards resulting from incident-induced congestion. The system will also provide comprehensive information on freeway performance.

#### **Component 2: Motorist Information**

The motorist information system should provide highway users with information on incidents and other roadway problems by means of 1) changeable message signs (CMS), 2) highway advisory radio (HAR) and 3) traffic bulletins issued by local radio stations and other commercial media. The motorist information system should alert drivers to downstream traffic hazards. Under incident conditions, the system should provide motorists with opportunities to select alternate routes, thereby minimizing individual delays and reducing overall congestion in the corridor. The traffic surveillance system (component 1) will provide real-time roadway information required by the motorist information system.

#### **Component 3: Traffic Management**

Traffic management systems will serve to minimize traffic congestion resulting from incidents. Motorist service patrols serve a dual role of detecting and removing expressway incidents. To more effectively deal with incident occurrences, communication links with other agencies (e.g. local DOTs, police, fire) will be



implemented and emergency response strategies will be developed. In the future, ramp metering may be implemented to maintain acceptable expressway performance under incident conditions (or future recurring congestion). Ramp metering can also encourage alternate routing so as to create more balanced use of available corridor capacity. To accommodate route diversion, self-adaptive arterial signal systems should eventually be implemented.

The operation and coordination of these expressway systems will be controlled from a Traffic Operations Center (TOC). The TOC should be equipped with computing and communications equipment, T.V. monitors for the CCTV system, real-time traffic operations display maps and links to state police, local transportation agencies and the media. The TOC could also function as a visitor and information center for the public.

Ultimately, the TOC may centrally supervise the operation of all freeway traffic management systems in the state. Due to the proximity of the Borman Expressway, the TOC would likely be located in or near INDOT's LaPorte District. However, the option may also exist to initially manage the Borman Expressway surveillance system via the Illinois Department of Transportation (IDOT) Traffic Systems Center in Oak Park, Illinois.

## **2. BORMAN EXPRESSWAY OPERATING ENVIRONMENT**

All elements of the proposed surveillance and control system must be appropriate for the "operating environment" on the Borman Expressway. In response to the recent HNTB report (11), the FHWA's Regional Office of Engineering and Operations noted that reliable traffic count data are needed to support the levels of investment required for a freeway management system. Therefore, the present study has made a particular effort to identify traffic flow conditions occurring on the expressway. Data used in the report prepared by HNTB were used where appropriate, or where other data sources were not available. Additional main-line volume data were obtained from the Illinois DOT permanent count station located near the state boundary. And finally, peak period (and near peak period) main-line volumes were collected on the Borman just west of I65. There is an INDOT permanent count station located on I94 near the study site. However, this count station is located east of the I65 interchange. Therefore, INDOT count station volumes are of no real value for this study.

It should be noted that INDOT LaPorte District, is currently collecting volume data using temporary count stations installed at various locations along the Borman. In addition to this, Wilbur Smith & Associates are currently collecting traffic flow data as part of a corridor study. These data, which will be available shortly, will provide further insight into current operating conditions on the expressway. The currently-available count data presented in this report section do provide some indication of prevailing flow conditions. Moreover, these traffic volumes facilitate estimates of potential congestion problems on the Borman.

### **2.1 Borman Expressway Average Daily Traffic (ADT)**

Estimated 1988 ADTs on the Borman Expressway were available from the HNTB report (11). In an effort to approximate more current values, ADTs for January through September 1990 were obtained from the Illinois DOT's permanent count station on the

Kingery Expressway (near the state line). Differences between ADTs measured at the Illinois DOT count station and those (western-most) expressway ADTs documented by HNTB were used to compute adjustment factors. In an effort to determine reasonable estimates of 1990 ADTs for each main-line segment of the Borman, these adjustment factors were uniformly applied to the 1988 ADT values. These estimated 1990 ADTs are presented in Figure 2. The 1990 ADTs in the eastbound direction represent a 10 percent increase over 1988 values. Westbound 1990 ADTs increased by approximately 15 percent from 1988.

## **2.2 Borman Expressway Peak-Hour Volumes**

Identifying hourly volumes, particularly peak-hour volumes, is of significant importance when evaluating the need for, and the potential benefits derived from, a freeway traffic management system. Therefore, the present study has included efforts to identify main-line hourly volumes occurring on the Borman.

As part of the HNTB report, capacity analyses were performed on most "straight-pipe" freeway segments within the study area. The resulting computer outputs do document volumes used for each analysis. However, it is unclear where these volumes were obtained. Moreover, these volumes probably reflect 1988 conditions, and as such, may no longer be reliable. Efforts were therefore undertaken to obtain more reliable volume data for each straight-pipe link within the study site.

Videotape equipment was used to collect main-line flows just west of the I65 interchange. Mr. Daniel Shamo, INDOT LaPorte District, arranged to have INDOT personnel videotape the westbound direction from 8:00 to 9:00 am, Thursday, September 27, 1990. The time period of 8:00 to 9:00 am represents the hour immediately preceding the peak hour. Members of the Purdue research team videotaped the Borman eastbound direction during the peak hour of 4:00 to 5:00 pm later that same day. Purdue staff extracted count data directly from the video tapes.

Data from Illinois DOT's permanent count station located on

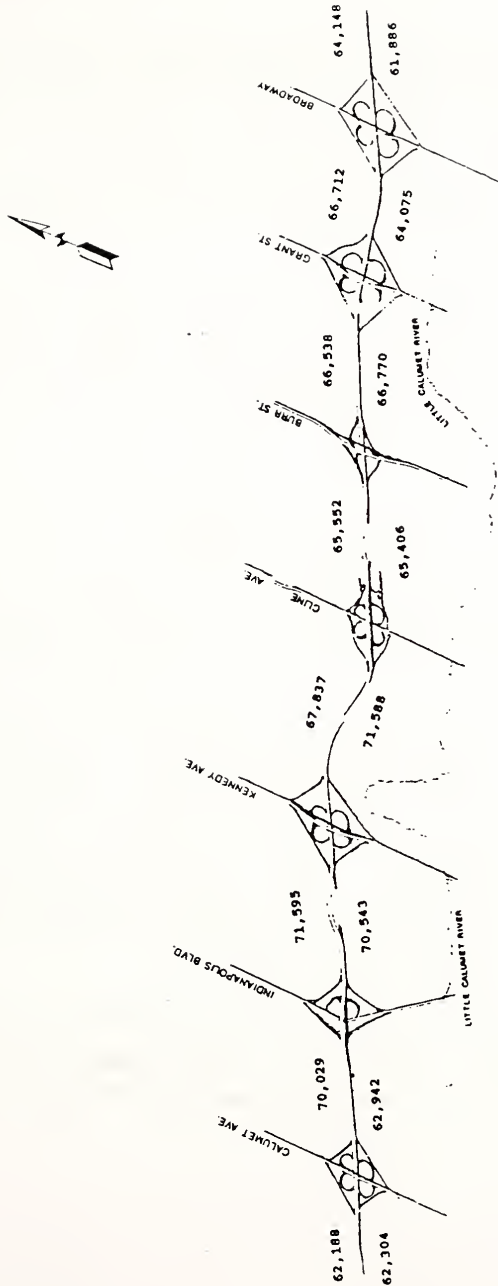


Figure 2  
Borman Expressway ADTs

the Kingery Expressway were used to determine hourly volumes at the west end of the Borman. Counts collected over numerous days were used to determine the average hourly volumes for westbound traffic from 8:00 to 9:00 am, and for eastbound traffic from 4:00 to 5:00 pm. From these efforts, reliable 60-minute volumes were obtained for each end of the study site.

Using 1985 ramp counts as a starting point, and knowing volumes on each end of the study site, hourly volumes for each straight-pipe segment of the Borman were estimated. These volumes, representing 8:00 to 9:00 am conditions for the westbound direction and 4:00 to 5:00 pm conditions for the eastbound direction, are illustrated in Figure 3.

### **2.3 Borman Expressway Potential Congestion Profiles**

Knowing hourly flows, estimates can be made concerning the potential impacts of incidents on the Borman Expressway. This report sub-section employs **queueing theory** to estimate expected delays and congestion profiles resulting from incidents occurring under current operating conditions. Queueing analysis is an analytical technique for evaluating the congestion phenomena occurring when traffic demands exceed roadway capacities. Specifically, queueing analysis compares the arrival process of vehicles approaching the bottleneck with the discharge rate of vehicles traversing the bottleneck. Thus, queueing techniques readily lend themselves to evaluating the effects of incidents, lane closures, roadway maintenance, and other causes of traffic flow interruption.

This report sub-section examines the negative impacts of three possible incident scenarios. Figure 1 of this report can be referred to for better visualization of the incident location for each scenario.

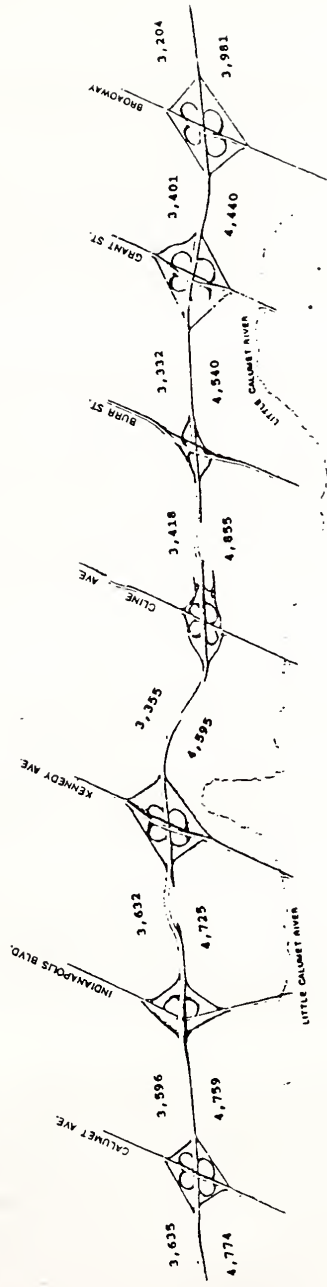


Figure 3  
Borman Expressway Hourly Volumes

**Scenario 1: A westbound stalled vehicle just east of the state boundary (8:00 am).**

Scenario 1 assumes a temporary closure of the shoulder lane.

- \* A 1982 study conducted by the Minnesota Department of Transportation (22) found that blockage in a single lane can reduce capacity of a 3-lane freeway by over 50 percent. A 50 percent capacity reduction is assumed in this analysis.
- \* The same Minnesota study found that it takes an average of 13 minutes for state patrols to arrive on the scene of a stalled vehicle once the incident has been reported. Data concerning the time required to detect incidents is not readily available. This analysis assumes an incident detection time of 12 minutes (which is rather optimistic given that no surveillance equipment currently exists on the Borman). It is also assumed that an additional 5 minutes is required to tow or push the stalled vehicle off the freeway via the nearest off-ramp. Thus, the vehicle blocks the shoulder lane for the time period extending from 8:00 to 8:30 am.
- \* Computations performed by HNTB (11) estimate that expressway capacity at the west end of the study site is 5,000 vehicles per hour (vph) during the am period. Thus, during the incident (30 minutes) capacity drops to 2,500 vph (50% reduction). This analysis optimistically assumes that full freeway capacity (i.e. 5,000 vph) is obtainable during the presence of traffic congestion resulting from the incident.

The queueing diagram developed for this analysis is contained in Appendix A of this report. Relevant calculations are also included. Delay estimates resulting from the incident described in Scenario 1 are listed in Table 1 below.

Total Duration of Congestion	55 minutes
Total Number of Vehicles Delayed	3,344 vehicles
Maximum Queue Length	568 vehicles
Maximum Individual Delay	13.6 minutes
Total Delay	261 vehicle-hours
Average Delay per Vehicle	5 minutes

**Table 1  
Delay Resulting From Scenario 1**



It should be noted that, although congestion appearing in Scenario 1 is significant, conditions prevailing in this scenario do not reflect peak-period demand. Obviously, incidents occurring during peak periods will produce greater overall delays (refer to Scenarios 2 and 3).

**Scenario 2: Eastbound stalled vehicle between Cline Ave. and Burr St. (4:00 pm).**

- \* This analysis assumes an incident identical to Scenario 1 (i.e. a stalled vehicle blocks the shoulder lane for 30 minutes).
- \* HNTB estimated capacity for the subject straight-pipe segment is 5,200 vph for the pm period. Thus, capacity during the presence of the stalled vehicle is 2,600 vph.
- \* Based on the Illinois DOT count station data, this analysis assumes that traffic demand drops by 10 percent each hour.

The queueing diagram and accompanying calculations are listed in Appendix A. Resulting delay estimates are listed in Table 2.

Total Duration of Congestion	2.1 hours
Total Number of Vehicles Delayed	9,618 vehicles
Maximum Queue Length	1,128 vehicles
Maximum Individual Delay	26 minutes
Total Delay	1,349 vehicle-hours
Average Delay per Vehicle	8.4 minutes

**Table 2  
Delay Resulting From Scenario 2**

Scenario 2 demonstrates the significant congestion problems that can occur during peak periods. Note, however, that incidents described in Scenarios 1 and 2 were fairly minor. Larger incidents create considerably higher vehicle delay values (refer to Scenario 3).



**Scenario 3: An eastbound major incident between Cline Ave. and Burr St. (4:00 pm).**

- \* Scenario 3 assumes a major incident blocking both the shoulder and middle lanes for a total of 60 minutes.

The queueing diagram and accompanying calculations are again listed in Appendix A. Resulting delay estimates are listed in Table 3.

Total Duration of Congestion	3.9 hours
Total Number of Vehicles Delayed	16,242 vehicles
Maximum Queue Length	3,205 vehicles
Maximum Individual Delay	1.9 hours
Total Delay	6,644 vehicle-hours
Average Delay per Vehicle	25 minutes

**Table 3  
Delays Resulting From Scenario 3**

Vehicle delays created by the incident described in scenario 3 are significant. Note that if the Scenario 3 incident had blocked all three expressway lanes for any portion of time, delays would have been even more dramatic.

The previous three incident scenarios demonstrate the significant amount of motorist delays resulting from "typical" incidents. These example incidents clearly illustrate the importance of rapid detection and removal of roadway problems. In addition, the example congestion profiles suggest that sizable benefit can be obtained by employing additional strategies for congestion management during incidents.

### **3. POTENTIAL TECHNOLOGY SYSTEMS AND MANAGEMENT STRATEGIES**

Section 3 of this report outlines potential technologies and traffic management strategies appropriate for inclusion in the Borman Expressway surveillance and control system. This study has classified the proposed freeway traffic management system into three components.

- 1) Traffic Surveillance
- 2) Motorist Information
- 3) Traffic Management

Section 3 outlines the functions of each component and discusses the technology systems which can execute these functions. System recommendations are also documented in this report section.

#### **3.1 Traffic Surveillance**

The obvious function of the freeway surveillance system is to detect and verify congestion problems caused by incidents (or other capacity constraints). This information is used not only for incident response purposes, but also to supply input data to motorist information and traffic management systems. Beyond this, the surveillance system measures and extracts relevant performance parameters such as traffic speed, flow and density/occupancy. In this way, the surveillance system monitors roadway performance and/or measures the resulting impacts of traffic control strategies. Moreover, data collected by the surveillance system can be used for highway planning purposes.

A number of technologies and techniques are available for performing freeway surveillance. This report sub-section lists those systems which appear to be most feasible.

##### **3.1.1 Artificial Vision**

Machine vision now appears to be a viable option for performing freeway surveillance. Application of artificial vision for roadway surveillance has been ongoing in Europe and Japan. In the U.S., the "Autoscope" system, developed at the University of

Minnesota (2), can reliably monitor traffic operations. The Autoscope is an advanced wide area detection and automatic surveillance device. The system accepts input from video cameras overlooking the roadway and simultaneously detects traffic in real time at multiple points on the roadway.

#### **Advantages of Artificial Vision**

As a surveillance system, the Autoscope offers several distinct advantages:

- \* Detection points can be installed at user-specified (and movable) locations through interactive graphics. Traffic detectors can be located and re-located at any point on the video monitor. Thus, detection points are flexible and variable.
- \* The Autoscope system facilitates both numerical and visual performance monitoring. The same video image used for measuring traffic performance characteristics can be used by operations personnel for observing roadway conditions. Thus, the same system performs incident detection and verification.
- \* As the Autoscope system does not rely on detectors physically placed on the roadway surface, the system can be implemented without seriously disturbing traffic operations. This, of course, leads to reduced installation and maintenance costs.
- \* Performance reliability of the Autoscope system may be at least comparable to accuracies associated with inductive loops.

#### **Potential Concerns with Artificial Vision**

There are some concerns and/or uncertainties associated with using a wide area detection system. Such a surveillance system is yet to be used as part of a "working" freeway traffic management system in the U.S. Questions concerning system appropriateness may as of yet be unanswered. For example, system performance under inclement weather conditions and/or darkness may be a concern (despite claims to the contrary made by the manufacturer). The Minnesota DOT has recently undertaken a pilot study in which several Autoscope cameras are to be installed on I35W. The

experience gained from this Minnesota study may provide insight into the future feasibility of machine vision.

The more pressing concern related to the Autoscope is that of cost efficiency. Purchase price of the Autoscope's 386 supervisor computer is \$12,000. The cost of the Autoscope detection box is \$20,000. The detection box is required for each camera installed in the field. The Autoscope system does not currently provide for automatic calibration of detection points when the camera focus is changed. For this reason, it should probably be assumed that a single Autoscope camera has a detection zone of 0.5 miles. A purchase cost of \$20,000 for a 0.5-mile detection area is considerably higher than the purchase and installation costs of inductive loops. Moreover, costs of implementing a "traditional" closed circuit television system should be less expensive than the Autoscope camera costs.

### **3.1.2 Inductive Loops**

Inductive loops, installed directly in the roadway pavement, have traditionally been the technology used for traffic surveillance. Such a detection system provides a reasonably cost efficient approach to monitoring roadway operation. For the most part, loops are a "tried and proven" technology for roadway surveillance and control. As INDOT embarks upon freeway traffic management, utilizing proven technologies may be advisable. Nonetheless, a number of issues exist concerning the appropriate design of a loop system.

### **Single vs. Paired Loop Detector Stations**

The HNTB report suggests primarily installing single loop stations on the expressway. Indeed, implementing single loop detector points will minimize capital costs. However, such a design will not result in an effective system, as single loop detection points can not reliably measure vehicle speeds. The equation for computing vehicle speeds based on occupancies measured by single detectors is as follows:

$$\dot{x}_n = (L_n + L_D) / (t_{occ})_n$$

where:

$\dot{x}_n$  = computed speed of vehicle n (ft/sec)

$L_n$  = length of vehicle n (ft) (this length is an assumed value reflecting the average vehicle length in the overall traffic stream)

$L_D$  = detector length (ft)

$(t_{occ})_n$  = measured occupancy of vehicle n (secs)

Clearly, the accuracy of the computed value for vehicle speed depends upon the reliability of the value used for vehicle length. As this value is unknown,  $L_n$  is typically some value thought to represent average length in the overall traffic stream. Under any traffic flow conditions, using an average vehicle length introduces considerable inaccuracies. Such inaccuracies would be even more pronounced given the traffic stream characteristics on the Borman.

The proportion of heavy vehicles (i.e. trucks) in the Borman traffic stream is high and rather varied from hour to hour. As an example, vehicle counts collected by videotape indicate that the proportion of trucks in the westbound traffic stream from 8:00 to 9:00 am is approximately 30 percent. In contrast, the proportion of trucks in the eastbound traffic stream from 4:00 to 5:00 pm is 20 percent. Moreover, trucks can vary dramatically in length. Overall then, using an average "default" value for vehicle length renders highly inaccurate speed computations.

However, where loop detectors are located in pairs, vehicle length is no longer an input variable. Paired loop stations consist of two loops (in the same lane) approximately 15 to 20 feet apart. Figure 4 illustrates such a tandem loop station. The equation for computing vehicle speed using paired loops is as follows:

$$\dot{x}_n = D / ((t_{on})_n)_B - ((t_{on})_n)_A$$

where:

$D$  = distance between the upstream edges of detection zone A to the upstream edge of detection zone B (ft) (refer to Figure 4)

$[(t_{on})_n]_B$  = time vehicle  $n$  enters detection zone B, the downstream detector (secs)

$[(t_{on})_n]_A$  = time vehicle  $n$  enters detection zone A, the upstream detector (secs)

With paired loop stations, assuming an average vehicle length is no longer necessary. Moreover, once vehicle speed is accurately measured, reliable information concerning vehicle classification can be derived. The equation is as follows:

$$L_n = \dot{x}_n[(t_{occ})_n]_A - [L_D]_A$$

Thus, tandem loops facilitate both accurate speed and vehicle classification measurements. Using paired loop stations does require that detector zone lengths be measured (i.e. calibrated). However, such calibrations are relatively simple and should only be needed once every several years.

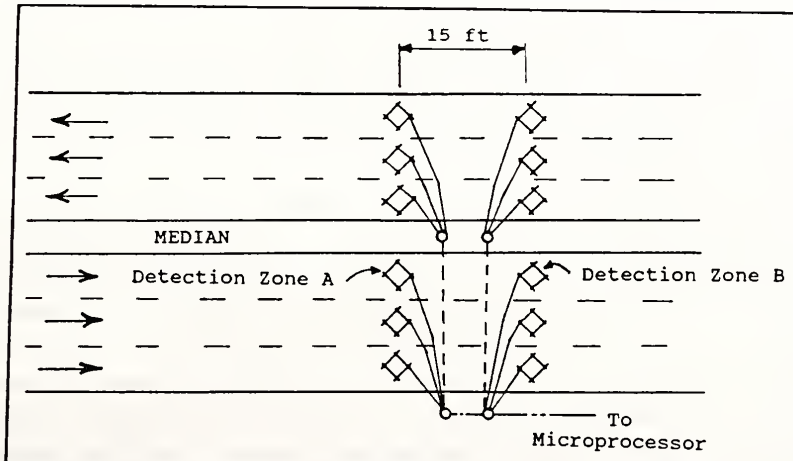


Figure 4  
Loop Station Configuration

The HNTB report does recommend that a portion of the Borman detector stations consist of paired loops. Specifically, HNTB suggests locating paired loop stations "for each direction at spacings of approximately 3 miles." These paired stations would measure speed and vehicle classification data and provide calibration data for neighboring single loop detector stations. In theory, such a design represents a reasonable compromise between capital cost and system reliability. However, the experience of the Ontario Ministry of Transportation dictates that "partial" paired loop stations are not sufficient. Toronto's freeway traffic management system in the Highway 401 corridor was designed with alternating single and paired loop stations. The Ministry found that such a design could not sufficiently measure crucial traffic performance characteristics. As a result, the Ministry has now adopted a policy of using only paired loop stations (in each travel lane). Based on the Toronto experience, the present study recommends that paired loops be used at all detector stations in all travel lanes of the Borman.

### **Detector Placement**

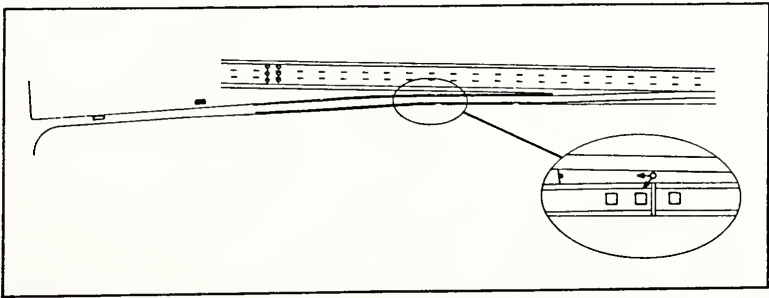
As implied in Figure 5.5 of the HNTB report (and Figure 4 of this report), loops should be installed in a diamond pattern, rather than square loops. Diamond loops reduce the problem of detecting vehicles in adjacent lanes and thus minimize "double counting."

The HNTB report recommends that detector stations be located at distance intervals of one-half mile. Half-mile intervals may reflect appropriate average spacings. However, the appropriate placement of individual detector stations depends on a number of factors (some of which can be rather arbitrary). Important considerations include the location of vehicle access and egress points as well as the location of utility access points along the expressway. The general objective behind locating detector stations is, of course, to achieve a balance between system performance and system cost. Thoughtful consideration will be



required to appropriately locate each detector station. Traffic volume data obtained from the Borman's temporary count stations and the Wilbur Smith study will provide insight toward locating detector stations.

Loops should also be installed at expressway on-ramps to facilitate the use of ramp metering in the future. (An extended discussion of ramp metering is contained in section 3.3.2 of this report). The ramp metering installation should generally consist of four loops at each ramp. Figure 5 illustrates the typical ramp installation. Two presence detectors, separated by approximately 10 ft, are located immediately upstream of the stop bar. A third loop is located several feet beyond the stop bar for use as an output and count detector. A fourth loop is located near the ramp entrance (i.e. far upstream of the stop bar). This upstream loop detects extended ramp queues. Where ramps have short tapers, an output loop can be installed near the merge point. When vehicles fail to enter the expressway, their presence on this merge detector will delay the meter's next green indication.



**Figure 5**  
**Loop Configuration for Ramps**  
(Source: Reference 6)

**Detection Algorithm**

Virtually all currently operating freeway traffic management systems use some form of the California algorithm for detecting



congestion on loops. The algorithm traditionally uses measured occupancy as a basis for detecting operational problems. For the Toronto surveillance system, the California algorithm was refined so that speed and volume, as well as occupancy, can be used for identifying congestion. Utilizing all three flow parameters could greatly increase the detection ability of the surveillance system. In a meeting with the Ontario Ministry of Transportation, Ministry personnel expressed considerable confidence in this algorithm. As the Toronto system comes into full operation in the coming weeks, the reliability of the algorithm can be readily studied. If necessary, additional refinements to the algorithm can be incorporated for implementation on the Borman Expressway.

#### **Processing Detector Data**

Essentially two options exist for processing traffic flow data measured by detectors. The Chicago Area Freeway Management System, for example, uses a telemetry based system. Raw data collected by the loop detectors are transmitted to the operations center. The data are then processed by the central computer. The advantage of such a system is that most of the electronic components are located in the operations center. Therefore, maintenance and troubleshooting become relatively simple. The disadvantage of using telemetry is that large amounts of (unprocessed) data must be transported over the communication links. Where leased (phone) lines are being employed, telemetry-based systems result in very high monthly communication costs. Much of the Borman communication system is likely to consist of leased lines. Thus, operating costs associated with a telemetry-based system might be prohibitive.

A second option for processing detector data is on-site microprocessors (as recommended in the HNTB report). Type 170 controllers (or the equivalent), located along the expressway, directly process detector data and transmit to the control center only those data which are relevant for freeway management. This results in significantly lower monthly communication costs. Processed data can also be sent directly from the roadside

microprocessors to other elements of the freeway traffic management system.

Determining the number of microprocessors required for the Borman system will depend upon the design of the detector stations. A single microprocessor can accommodate up to 40 magnetic loops. However, microprocessors should be located so as to minimize the length of communication cables. Thus, the number of loops connected to a given microprocessor will generally be well below 40. Lastly, microprocessors should be located in such a way as to protect them from possible vehicle collisions.

### **Loop Detector Summary**

Inductive loops are a reasonably effective and reliable means of detecting roadway congestion. However, past experience clearly indicates that loops alone can not provide a comprehensive surveillance system. The reliability of detected incidents versus false alarms varies as a function of operator-specified loop sensitivity. Moreover, loops become less effective at detecting incidents under low flow conditions. Where low traffic flows exist, differences in performance measures (e.g. occupancies) at successive detector stations are often not large enough to trigger "alarm" thresholds. As the effects of incidents are typically less disruptive at low flows, differences in traffic flow characteristics at successive loop stations are less marked. And lastly, the precise nature of individual incidents can not be ascertained using only loop detection.

Therefore, the proposed surveillance system should consist of additional components in order to achieve acceptable system performance. These additional surveillance components are described in the following pages of this report section.

#### **3.1.3 Closed Circuit Television**

Findings from this study suggest that the Borman system should be equipped with closed circuit television (CCTV). A CCTV system would provide improved incident detection, identification,

verification and management. When an incident is automatically detected by inductive loops, the CCTV cameras will be used by personnel in the traffic operations center to verify and identify the nature of the incident. In this way, the appropriate emergency responses can be executed in a timely manner. Moreover, CCTV will aid operations personnel in making adjustments to the Borman's automatic information and control elements (e.g. changeable message signs, ramp metering rates, etc.). And finally, CCTV will provide incident detection capabilities. Periodic scanning of the cameras can be used to locate operating problems. Thus, the CCTV system functions in concert with loop detectors. Under certain flow conditions (i.e. low flows), CCTV may prove to be the primary detection system.

### **Camera Placement**

Camera placement is an important consideration for controlling system cost and maximizing system effectiveness. Given the flat terrain and absence of horizontal curves on the Borman, and given the capabilities of the camera lens, a nominal camera spacing of approximately one-half mile to one mile would likely be sufficient. Cameras should be located so as to provide full view of the expressway, as well as a view of all ramps and critical changeable message signs. Each camera will have full pan, tilt and zoom capabilities, and will be remotely controlled by personnel in the Traffic Operations Center (TOC).

### **Camera Technology**

A number of options exist for selecting camera technology. The most desirable type of camera appears to be a "Silicon Intensified Tube" camera. (This technology is used in the military). Although the camera is black and white, this technology produces the best image during darkness and/or inclement weather conditions. Each camera would be housed in an environmentally protected casing. The camera housing includes a thermostat controlled fan and heater to provide suitable climate for the

equipment. The Camera housing should not include windshield wipers to remove raindrops from the glass window. Operating experience shows that windshield wipers often become "jammed" and obstruct the camera's view. The operator can remove raindrops from the housing's window by tilting and/or panning the camera.

Each camera would be mounted on a self-standing pole at a height of 40 to 50 feet above the surface of the expressway. Such a height would ensure that each camera has an adequate vantage point to capture roadway operation.

Cameras should be located so as to facilitate maintenance and repair. Because of the zoom capabilities, cameras would not have to be located in the median. However, all cameras must be located on the same side of the roadway to help orient operators in the TOC.

Initially, the television monitor configuration at the TOC would likely be one monitor per camera. In other words, each camera will have it's own monitor, although full switching capability will exist. As the proposed surveillance and control system expands to other roadway links adjacent to the Borman, the monitor/camera ratio will decrease from 1:1 to as low as 1:4. The system will have full remote control capability and the ability to display the image from any camera on any specified monitor.

#### **3.1.4 Service Patrols**

The report submitted by HNTB does not recommend using service patrols on the Borman Expressway. This is rather surprising given that the operating experience of numerous traffic management agencies indicates that such patrols are a very cost effective approach to identifying (and removing) incidents.

It must again be restated that the proposed Borman surveillance and control system should consist of as many information sources as possible to obtain a "clear picture" of traffic conditions. Service patrols provide additional visual detection. (Personnel at the Chicago Area Freeway Management System estimate that their "Emergency Traffic Patrols" are the

primary source for detecting incidents). Service patrols also detect operating problems by monitoring C.B. radios and other traffic data sources. In addition, service patrols verify and assess the response needed to remedy a given incident.

Perhaps most importantly, service patrols manage and control operational problems by removing incidents. An extended discussion of service patrols, and in particular their role in incident management, is contained in section 3.3.1 of this report. Important considerations associated with establishing and operating service patrols are also included in section 3.3.1.

### **3.1.5 Motorist "Location Information" and Emergency Phone Numbers**

Cellular phones are a rapidly emerging technology. Recognizing that car-phones are becoming increasingly commonplace, this technology should be exploited for the purpose of freeway surveillance. Personnel at a number of freeway operations centers verify that incidents are commonly reported via personal car phones. A significant problem, however, is that locations reported for these incidents are often incorrect. Apparently, motorists may not always be certain of their location at any specific point along their designated route.

To help remedy this problem, "location" signs can be installed along the Borman at distance intervals of one-half mile (or less). These signs should clearly display freeway number designation (i.e. I80/94), travel direction and milepost. An emergency phone number could also be displayed on these location signs. A public awareness/education program could accompany installation of the location signs.

Implementing such a surveillance system would require relatively little capital expenditure. The only appreciable cost would stem from monitoring and managing the emergency phone number. Eventually, such operations might be turned over to the state police or service patrol agency.

It is our understanding that INDOT's LaPorte district is currently installing information signs which display emergency

phone numbers for reporting Borman incidents. Implementing this system is commendable. Such signs should be placed throughout the study site. Given the relatively low cost, such signs could also be installed on freeway sections adjacent to the Borman.

Employing such a system could significantly improve incident detection capabilities. Beyond this, such "high profile" traffic management publicly demonstrates INDOT's commitment to safe and efficient highway operation.

### **3.1.6 Roadside Call Boxes**

Call boxes have been a traditional means of identifying operational problems, particularly stalled vehicles. However, by encouraging motorists to exit their vehicles, emergency phones do pose certain safety hazards. Such hazards might be particularly pronounced on the Borman given the frequent absence of wide shoulders. For this reason, it is not recommended that call boxes be installed along the expressway.

As an alternative, emergency phones could be located near junctions of off-ramps and city streets. Ideally, a motorist having car problems would guide his or her vehicle off the expressway and to the emergency phone. (Information signs could be located just upstream of the off-ramp). However, motorists who were unable to maneuver their vehicle off the expressway might be encouraged to exit their vehicle and walk to the nearest emergency phone. Moreover, phones located along city streets would be susceptible to vandalism. Overall, call boxes may not be an appropriate approach to traffic surveillance on the Borman.

### **3.1.7 Aircraft Patrol**

Two radio stations presently operate aircraft patrol on Chicago Area freeways during peak periods. As part of an effort to share Borman traffic information with the media, these radio stations might be willing to include the expressway as part of their patrol area.



### 3.2 Motorist Information

As the name clearly implies, the objective behind motorist information systems is to provide drivers with real-time information concerning prevailing traffic conditions. Alerting motorists to highway congestion (or other operating problems) essentially serves three functions:

- 1) **Improved Safety:** By informing motorists of downstream roadway problems (e.g. queued vehicles, highway maintenance, icy roads) drivers are likely to approach the problem location with greater caution. This clearly minimizes the accident risk created when motorists encounter safety hazards. A comprehensive motorist information system can therefore significantly reduce the occurrence of secondary accidents.
- 2) **Improved Operation:** In addition to alerting drivers to problems, a properly implemented motorist information system can provide drivers with reliable and understandable alternate routes. By selecting these alternate routes, motorists avoid delays caused by congestion and thereby minimize individual travel times. Perhaps more importantly, by diverting traffic from incidents and other bottlenecks, resulting congestion and system delays are kept to a minimum and corridor capacity is used more effectively.
- 3) **Improved Public Opinion:** A motorist information system is readily apparent to the driving public. Thus, motorist information systems publicly display the highway agency's efforts toward improving roadway safety and performance. When implemented appropriately, such systems are perceived as being of true benefit by the users. As a result, the highway agency benefits from positive public opinion.

As in the case of freeway surveillance, a number of technology options exist for implementing a motorist information system.

Section 3.2 outlines those technology options which appear most appropriate for the proposed Borman Expressway surveillance and control system.

### **3.2.1 Changeable Message Signs**

The changeable message sign (CMS) is an effective means of providing information to motorists. The recent report by HNTB does recommend implementation of a CMS system. However, the suggested technology is questionable. The disk-matrix CMS, recommended by HNTB, appears to require significant maintenance and repair. The individual disks, which pivot to display messages are highly susceptible to becoming "stuck" or "jammed."

#### **CMS Technology**

A more reliable technology is a "rotating drum" CMS. This type of CMS typically consists of three lines of six-sided rotating drums. Each of the drum's six sides displays a fixed message. In theory then, over 200 pre-established messages are possible (although not all text combinations would result in appropriate messages). Text lines can be manually replaced with new messages when appropriate.

Like the disk-matrix technology, the rotating drum CMS requires relatively little power to operate. Once the drum is rotated to the desired message, no additional power is required to sustain the message. The Rotating drum CMS has a relatively low capital cost (i.e. less expensive than the disk-matrix CMS) and is enclosed in a walk-in cabinet for easy maintenance.

The Minnesota Department of Transportation (MnDOT) has used rotating drum signs for a number of years. MnDOT has found this technology results in simple yet effective changeable message signs. The rotating drum CMS does appear to be a more appropriate technology than the somewhat more traditional disk-matrix sign.

Light Emitting Diode (LED) technology is another option for changeable message signs. This technology provides superior



flexibility and legibility. A typical LED CMS would accommodate three lines of text. Text messages could be typed in directly by operators. However, limiting input capabilities to an established "library" would prevent the display of inappropriate or ambiguous messages, spelling errors, etc. LED signs have graphics capabilities. Such graphics, which include moving arrows and icons, can typically be displayed on either side of text messages. LED messages and graphics can be displayed in different colors and LED intensity automatically adjusts for sunlight and nightfall conditions.

Although LED technology offers unsurpassed flexibility and effectiveness, such technology is not without costs. Beyond the relatively high capital costs, LED signs require continuous power to operate. Electricity costs would therefore be significant. LED maintenance and repair requirements are not yet truly known. However, the Toronto freeway management system has implemented LED changeable message signs. In the coming months, Toronto's operating experience will provide better insight into the costs and benefits associated with LED technology.

In summary, it appears that either the simple rotating drum CMS or the more advanced LED CMS represent the most appropriate technology for the Borman Expressway. Final technology selection for the CMS system should perhaps not be made before further study and deliberation.

### **CMS Location**

Regardless of technology selected, the precise location of each CMS is an important consideration. Messages (which can be automatically displayed by the system or manually "overridden" by operations personnel) can be used to alert motorists to downstream operating problems as well as provide useful detour information. Thus, the strategic placement of all signs is crucial.

Real-time traffic data collected by the Borman's proposed surveillance system (i.e. inductive loops) would provide considerable insight into appropriate sign placement. Beyond this,

changeable message signs should be installed 3,000 ft to 4,000 ft upstream of off-ramps accessing alternate routes (i.e. detour roadways). CMS locations should therefore be established only after corridor operating conditions have been carefully evaluated and diversion roadways have been established. Signs should be installed on the expressway and its key access facilities.

### 3.2.2 Highway Advisory Radio

Other technologies can be cost-effectively employed to supplement motorist information provided by the CMS system. One such technology is highway advisory radio (HAR). Like the CMS system, HAR broadcasts alert motorists to operating problems and provide detour information.

A number of strategies exist for implementing and operating an HAR system. For example, a so-called "leaky" (coaxial) cable can be installed in the Borman's median barrier. This cable would broadcast low-power AM band traffic information to motorists monitoring the appropriate radio channel. However, such a system is expensive to install and may not be particularly effective. If "leaky" cable was to be installed on the Borman, vehicles traveling on nearby roadways (e.g. I65, I90) would not receive HAR broadcasts. Indeed, broadcasts are of such low power that even vehicles traveling in the Borman's outside lanes may not receive clear broadcasts.

The Minnesota DOT uses a local public radio station (owned by the Minneapolis Public School System) to broadcast frequent (but not continuous) traffic information. Because the radio station is publicly owned and not concerned about commercial sponsorship, much of the broadcast time can be dedicated to traffic bulletins. Minnesota DOT reports that these HAR broadcasts are well received by local motorists.

Perhaps a more effective means of broadcasting HAR information would be to internally operate a low-power AM band radio channel. In this way traffic conditions could be broadcast continuously during peak and off-peak time periods. The Federal Communications

Commission has recently announced that the AM band will be expanding (i.e. adding radio channels) in the coming year. This provides INDOT with the opportunity of exclusively obtaining an AM radio channel.

Messages could be pre-recorded and automatically and/or manually broadcast as appropriate. Under very unusual operating conditions, HAR broadcasts could be transmitted "live" from the traffic operations center (TOC). HAR operation would be managed at the TOC and could be broadcast throughout the Borman corridor.

### **3.2.3 Commercial Radio Broadcasts**

Traffic reports broadcast via commercial AM radio is an additional means of providing information to the driving public. Virtually all functioning freeway traffic management systems have direct links to local radio stations. As real-time operational problems are detected, this information is provided to the radio station(s), who in turn, broadcast advisories. These radio "traffic updates" appear to be a reasonably effective way of informing motorists en route as well as those who have yet to begin their trip.

As part of the present study, discussions have been held with traffic-reporting personnel at WBBN radio, Chicago. These reporters welcome the opportunity to broadcast Borman real-time traffic bulletins to their listeners. Providing communication links from the TOC to the radio station(s) could be done at minimal cost and effort. (In all likelihood, the radio station(s) would consent to cover all costs). Thus, commercial radio traffic broadcasts would be a simple and reasonably effective means of providing information to motorists.

### **3.2.4 Additional Information Technologies**

Once the proposed traffic management system is implemented on the Borman, additional driver information systems can be tested as they become available. As an example, with the growing popularity

of cable television, perhaps a local cable station can be dedicated exclusively to broadcasting real-time traffic information. Such information could help motorists plan their trips before leaving home.

More significantly, the popularity of in-vehicle navigation systems is likely to increase in coming years. Currently, these on-board systems provide static map and/or directional information to motorists. Using the cellular phone system (or related technology) real time operating data could be transmitted to individual on-board navigators. The real-time data would be used by the navigating systems to display optimal routing strategies to motorists. Such experiments are currently on-going in the U.S. and Europe.

### **3.3 Traffic Management**

Beyond detecting and informing motorists of roadway problems, a number of technologies and strategies can be employed to manage corridor operations during incident conditions. By minimizing congestion and delays caused by incidents, these management techniques improve roadway safety and performance. Section 3.3 outlines feasible traffic management strategies for the Borman Expressway.

#### **3.3.1 Service Patrols - Incident Response**

In addition to detecting roadway incidents, service patrols are an effective means of managing traffic at incident locations. Service patrols, particularly mobile service patrols, reduce the times required to respond to incidents. In many instances, the incident (e.g. disabled vehicle, spilled debris or other potential hazard) can be removed by the patrol operator.

Where a major incident has occurred, the trained patrol operator can assess the situation and quickly determine appropriate response (e.g. tow truck, ambulance, etc.). The patrol operator can work as part of a team in removing major incidents. In

addition, patrol personnel are prepared to manage the incident scene (e.g. direct traffic, help establish alternate routes, provide emergency medical treatment, etc). Employing service patrols therefore minimizes incident duration and restores the roadway to full capacity in a timely manner.

### **Service Patrol Implementation**

To implement service patrols, a variety of issues must be resolved. The number and composition of vehicle types in the service patrol fleet must be established. For example, the California DOT operates a mobile service patrol consisting of tow trucks during peak periods on the Oakland-San Francisco Bay Bridge. Many other patrol fleets consist of standard pick-up trucks equipped with push bumpers capable of pushing average-size vehicles off the roadway. The Chicago Area patrol fleet includes large tow vehicles capable of removing diesel rigs.

The high cost of large tow vehicles would probably preclude their incorporation into the Borman patrol fleet (initially). The fleet could consist of pick-up and/or light tow trucks. Agreements on the use of larger tow vehicles for emergency situations could be sought from the Illinois DOT.

Due to the absence of sufficient shoulder widths, disabled vehicles would be completely removed from the expressway via the nearest off-ramp. Once removed from the Borman, motorists would be required to independently seek further assistance. Small amounts of gasoline could be provided to the motorist where needed.

Several options exist for operating the proposed service patrol. Operations could be carried out internally as part of a division within INDOT (or the state police). Or, independent operators could be contracted to perform the required services. Regardless of the approach ultimately adopted, all patrol operators must be carefully trained and monitored to insure proper performance of duties. The proper implementation of a service patrol will result in improved highway operation and benefit INDOT's public image.

### **3.3.2 Emergency Response Strategies**

Strategies should be developed for responding to major incidents in the Borman corridor. Pre-planned techniques for dealing with all foreseeable incident scenarios should be created. Such emergency response schemes would clearly reduce safety hazards and other operational problems associated with incidents.

Developing emergency response plans would involve local DOTs, police and other emergency services. Thus, cooperation and coordination should be sought from all relevant agencies. The proposed Borman system would consist of communication links between INDOT and these relevant agencies.

### **3.3.3 Ramp Metering**

In the past, ramp metering has been a primary technique for managing congested freeway operations. The vast majority of existing freeway traffic management systems rely to some degree on ramp metering. The simple objective behind ramp metering is to prevent freeway demand from exceeding capacity by regulating the input of vehicles onto the "mainline." Metering can generally meet this objective. Some studies even suggest that freeway capacity under uncongested conditions is higher than the discharge rate of vehicles departing from queues. Thus, if ramp metering can prevent freeway breakdown from occurring, metering may actually promote higher capacities.

There are some concerns which have historically been associated with ramp metering. One such concern is that of equity. Ramp metering does indeed promote improved mainline operation - but at the expense of the on-ramp vehicles. Mainline motorists traveling through the system experience uncongested operation. Motorists wishing to enter the system via a metered on-ramp experience delays resulting from the metering process. Beyond this, ramp queues formed by metering often extend onto city streets thereby creating unsafe and inefficient street operation.

However, operating conditions in the Borman corridor appear to be conducive to ramp metering. In the initial years of operation,

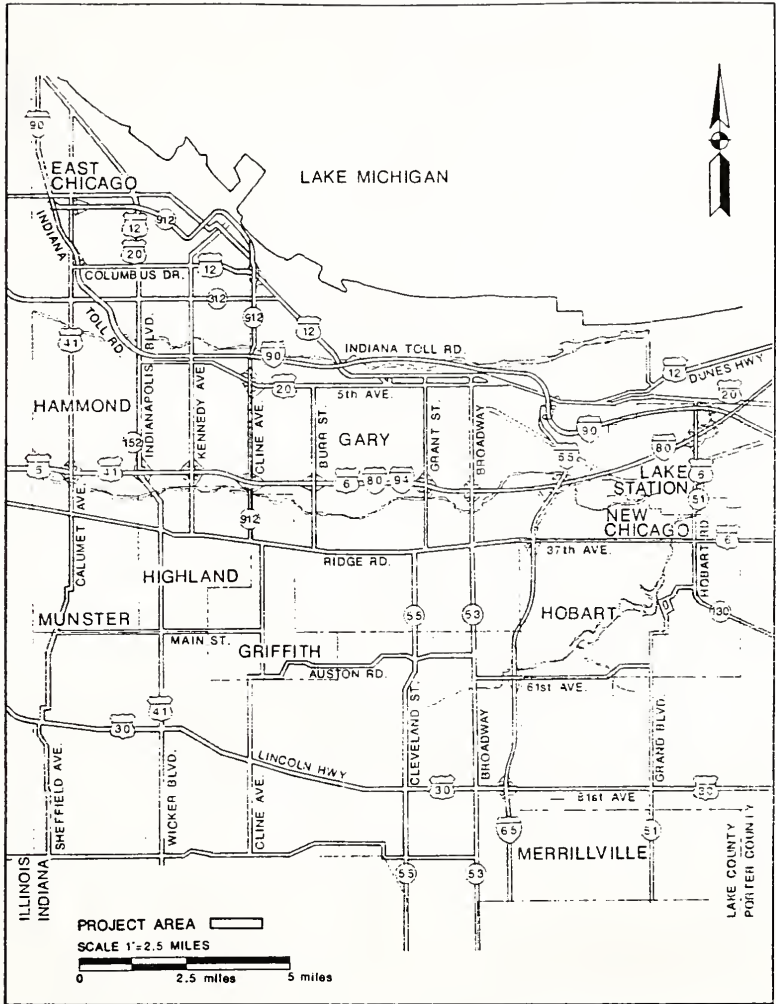


traffic management strategies on the Borman will be implemented only during incident conditions. (Ramp metering is currently unnecessary under non-incident conditions). Under incident operations, delay is likely to be incurred by all motorists. Ramp metering might therefore serve to minimize system delays somewhat evenly. On-ramp motorists wishing to avoid delays created by metering do have alternate routes available to them. The proposed Borman motorist information system will help provide drivers with the ability to make informed route selections.

It should be noted that origin - destination studies conducted by HNTB indicate that a large proportion of Borman traffic enter and exit the expressway within the limits of the study area. This is precisely the type of expressway traffic (i.e. motorists making short trips) which should be minimized - particularly during incidents. Short-trip motorists may well be encouraged to use alternate surface streets rather than incur on-ramp delays caused by metering. It should also be noted that ramp metering would only be activated on those on-ramps upstream of incident locations.

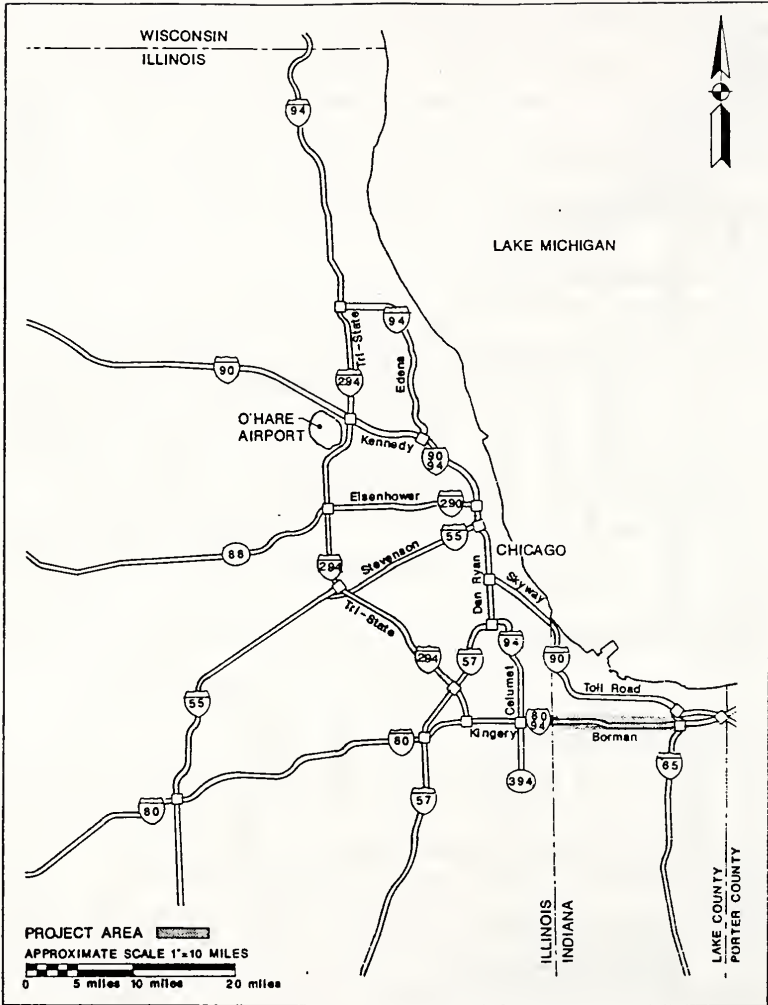
### **3.3.3 Trip Diversion/Alternate Routes**

The potential benefits of motorist information systems and ramp metering include trip diversion. A study of the corridor has indicated that a number of alternate routes do exist near the expressway. Figure 6 illustrates major roadways within the Borman Corridor. Figure 7 illustrates major routes (in Lake County and the Chicago Area) linking to the Borman Expressway itself. Many of the roadway facilities shown in Figures 6 and 7 could be used effectively under incident conditions to mitigate congestion on the Borman.



**Figure 6**  
**Major Routes Within the Borman Corridor**  
 (Source: Reference 11)





**Figure 7**  
**Major Routes Linking to Borman Expressway**  
 (Source: Reference 11)

### **I90, the Indiana East - West Toll Road:**

The toll road runs parallel to, and approximately two miles to the north of, the Borman Expressway (refer to Figures 6 and 7). At the west end of the study site (near Route 152) the toll road extends in a north-south direction to the Chicago Skyway. Under a number of incident scenarios, traffic wishing to travel westbound on the Borman could be diverted to the toll facility. Likewise, traffic traveling outbound from the Downtown Chicago Area could be directed to the toll road. A number of north-south roadways within the corridor appear to have sufficient capacity to accommodate traffic diverting between the toll road and the Borman Expressway. These roadways include routes 41, 152, 912, 53 and I65. The actual north - south roadways used for any given diversion strategy would depend on incident location and the ultimate destination of the individual motorist.

Detouring traffic to a toll facility does present certain practical and policy problems. Motorists being diverted to I90 might resent, or even refuse to pay tolls. Moreover some diverted motorists may not be carrying cash. Management strategies can be developed for dealing effectively with such conditions.

Agreements could be sought to remove tolls during incident conditions. Removing toll collection would increase capacity on the toll facility itself, as well as eliminate the problem of detoured motorists who are unable or unwilling to pay tolls. Should such agreements prove impossible to obtain, other operating schemes could be employed. Diverted motorists not carrying cash could be issued invoices for later payment by mail. In the future, perhaps automatic vehicle identification, in conjunction with a direct billing system, could be implemented on the toll road. Motorists who simply refuse to pay tolls could be informed (via on-site motorist information systems) not to divert to I90. These motorists would either remain on the Borman (and suffer the incident-induced delay) or detour to another facility (e.g. U.S. 20).

### **U.S. Highway 20:**

U.S. Route 20, running parallel to and just south of the toll road, is another potential diversion facility. Much of U.S. 20 presently operates as a closed-loop signal system. This interconnected signal system could be used to provide additional green times to accommodate the influx of diverted traffic. Moreover, a substantial portion of U.S. 20 is directionally separated. Thus, additional capacity (i.e. green times) could be provided to the major directional flow without impacting opposing movements. Upon intersecting Route 152 at the west end of the study site, U.S. 20 proceeds in a north - south direction and eventually links to Lake Shore Drive near the Downtown Chicago Area. Motorists not wishing to travel in this direction could divert from U.S. 20 to the toll road or back to the Borman (downstream of the congestion).

An unfortunate consideration associated with using U.S. 20 as a detour facility is that a portion of the highway traverses through an economically depressed area of Gary, Indiana. This could, in some instances, create personal safety concerns among detoured motorists. However, the opportunity will generally exist to divert from U.S. 20 to the toll road or back to the Borman Expressway prior to entering those areas likely to be perceived as unsafe.

As U.S. 20 is a state operated highway, public opposition to using it as a detour facility will probably be minimal. Moreover, education programs informing the community of the importance and benefits of such traffic diversion may promote public acceptance.

### **Highway 30:**

Highway 30 runs parallel to, and several miles south of the Borman Expressway. The facility, having two lanes in each direction and a relatively small number of signalized intersections, has sufficient capacity to accommodate a significant amount of diverted traffic. Specifically, Route 30 would be an appropriate detour facility for eastbound traffic wishing to

eventually travel southbound on I65, and for traffic traveling northbound on I65 and wishing to proceed westbound on the Borman. Several high-capacity north-south roadways (i.e. route 41, Torrence Avenue and the Calumet Expressway) link Highway 30 with the Borman. Thus, suitable access exists between the two facilities. The actual north-south facility used for any given diversion strategy would depend largely upon incident location.

As Route 30 is a state operated highway, designating the facility as a diversion route should be feasible. Traffic signals on the roadway could ultimately be interconnected to better respond to diverted traffic demands.

#### **Ridge Road:**

Although not an ideal diversion facility, Ridge Road might service limited amounts of detoured traffic. Ridge Road has limited capacity and lies largely within residential areas. Thus, there may be some public opposition to diversion on Ridge Road. However, the facility offers the only suitable detour for traffic originating south of Downtown Chicago and wishing to travel eastbound on I80 (toward Porter County). A number of north-south facilities link the Borman with Ridge Road. Therefore, the possibility of limited short-distance diversion on Ridge Road might be worth exploring. For example, diverting eastbound Borman traffic on Ridge Road between Routes 152 and 912 could effectively mitigate certain incident scenarios.

The proposed Borman traffic management system could compensate for the absence of an outstanding eastbound diversion facility by "stepping-up" incident response for eastbound problems.

#### **Example Diversion Scenarios**

The following example scenarios are presented in the effort to better illustrate some of the potential diversion options. Figures 6 and 7 may be used for better visualization of detour strategies.

**Scenario 1:** Borman incident in the westbound direction just east of the I65 interchange.

If incident-induced congestion is spilling back onto the northbound I65, northbound I65 motorists wishing to eventually travel westbound can be diverted onto Highway 30. Detoured motorists wishing to travel toward Downtown Chicago can be re-connected with the Borman (downstream of congestion) via several possible north-south roadways (e.g. Routes 53, 55, 912, 41). The north-south route(s) actually used would depend upon incident location and on which routes are ultimately designated as diversion facilities.

If incident-induced congestion is not impacting operation on I65, motorists whose destinations lie south of Downtown Chicago could be re-routed to Highway 30 (and then possibly returned to the Borman). Motorists traveling into the Downtown Chicago Area could be directed to the toll road or U.S. 20 via I65 north.

**Scenario 2:** Borman incident in the eastbound direction near Kennedy Avenue.

Motorists traveling southbound on the Dan Ryan Expressway and Chicago Skyway near the downtown area could be informed of congestion in advance. These motorists whose destinations lie east along I80 could be diverted to the toll road or U.S. 20. All motorists wishing to travel south on I65 could be detoured to Highway 30 via the Calumet Expressway. Motorists originating south of Downtown Chicago and wishing to travel eastbound on I80 would, to some degree, be forced to endure congestion on the Borman. This congestion would be reduced, however, due to the aforementioned detour strategies. Moreover, some limited diversion might be possible on Ridge Road.

Effectively diverting traffic from the Borman Expressway to the appropriate neighboring facilities is not a trivial task. Reliable and easily understood detour information must be provided

to the motorist. Only in this way can drivers make appropriate detour choices. Moreover, the motorist information system must be designed in such a way as to prevent all drivers from using any single alternate route. A single diversion facility will generally not accommodate all origin-destination patterns. More importantly, diverting all Borman traffic to a single roadway would simply create congestion on the detour facility itself. Diverted motorists must be evenly disbursed across the entire corridor network based on driver destination choices and capacity constraints of the detour facilities. This means that all elements of the proposed motorist information system must work in concert to present appropriate detour information to all motorists. A comprehensive motorist information system (as described in Section 3.2) is vital.

#### **Arterial Optimization**

Beyond providing motorist information, techniques must be employed to insure acceptable operation on diversion facilities. At present, the potential detour roadways appear to generally operate at sufficient service levels during peak and off-peak periods.

Thus, additional traffic volumes arriving as a result of route diversion could generally be accommodated. However, traffic system management techniques must be implemented to handle the influx of diverted vehicles. Specifically, traffic signals must be capable of adapting to increased demands. A self-adaptive signal control system similar to the one used by the Los Angeles City DOT could be implemented. In such a signal system, traffic performance is measured at each signalized intersection approach using loop detectors buried in the pavement. Based on measured performance parameters (e.g. volume, delay. etc.), appropriate signal timing strategies are automatically selected by the system's computer(s). The appropriate timing strategies are chosen from a library of pre-planned control schemes which have been developed off-line using simulation (e.g. TRANSYT 7F).



Like surveillance and control strategies on the Borman, arterial signal operations would be supervised from the TOC. Any signal control scheme automatically implemented by the system could be manually modified or completely "overridden" by TOC personnel.

Implementing the recommended arterial control system is not a minor task. Signal surveillance and control hardware must be installed on all surface streets which have been designated as diversion facilities. (Several of these potential roadways already operate as "closed loop" signal systems). Timing strategies and other operating schemes must be developed and tested. Information systems must be implemented to guide motorists through detour routes. Beyond this, operating agreements must be made between all involved state and local agencies (e.g. INDOT, state police, cities and towns in the region, etc.). Transportation agencies in Los Angeles California have recently established such joint operating agreements. Their experiences can serve as examples in developing inter-agency management schemes for the Borman corridor.

Due to the complexities associated with arterial control systems, it is not necessarily suggested that such control schemes be implemented in the initial stages of the proposed Borman management system. Rather, trip diversion represents a somewhat long-term goal toward improving operation within the corridor. As traffic demands grow in coming years, route diversion may not only be desirable, but in fact a crucial element in maintaining acceptable roadway performance. Only through trip diversion can all available capacity within the corridor can be used effectively. And as demands grow, more sophisticated technologies (e.g. arterial signals controlled by expert systems) can be employed to facilitate balanced roadway utilization.

This report section does not provide detailed design options for a comprehensive route diversion plan. Considerably more analysis is required to develop such a strategy. Instead, the discussion in this report section is intended to point-out that route diversion within the Borman corridor is feasible.

### **3.4 Traffic Operations Center**

Operation within the Borman corridor will be supervised and managed from a single remote Traffic Operations Center (TOC). Specifically, the TOC will serve to 1) monitor traffic operations, 2) supervise and control traffic management strategies and 3) issue information on operating conditions to neighboring transportation agencies, emergency response agencies and the media. In addition, the TOC could serve as an information and visitor's center to the public.

#### **TOC Operation**

Trained personnel within the TOC would monitor traffic and roadway conditions using information collected from loop detectors, CCTV, two-way radio reports issued by service patrols and other emergency response agencies, cellular phone reports and any other surveillance system implemented in the corridor. Clearly then, the TOC must be equipped with instrumentation to aid personnel in monitoring the corridor.

Operating experience suggests that TOC personnel have a natural tendency to monitor system operations by viewing CCTV images. Such a monitoring technique might be acceptable where a system is relatively small and only a few CCTV monitors are required to capture the entire corridor. However, experience gained from the Detroit surveillance system indicates that, for larger freeway systems, the ratio of camera to monitor rises above 1:1. Remote switching of cameras is therefore required to view all freeway areas. This can become a tedious task. Moreover, natural biases of monitoring personnel can result in unintentional neglect of certain freeway areas.

CCTV can indeed be a very effective means of monitoring traffic and roadway performance. CCTV is particularly appropriate for verifying suspected incident locations. To most effectively supervise a freeway system however, CCTV should work in conjunction with other surveillance systems - rather than becoming the primary or exclusive monitoring mode. Equipment in the TOC can be used to



promote a coordinated monitoring scheme. Real-time traffic and roadway conditions can be graphically presented on corridor maps. These maps, which can be displayed on computer terminals and even on a large-screen television monitor, will identify any operational problem locations - generally by means of color code designations. Monitoring personnel can, in turn, access detailed information about any specific location (e.g. operational problem area). This detailed information would include real-time volumes, average vehicle speeds and occupancies measured by the loop detector stations.

Processed loop data can be transmitted from the on-site microprocessors where they will be managed and evaluated by a "master" computer located at the TOC. Loop station measurements can be taken as often as sixty times per second. Measured flow parameters are typically aggregated over 30 to 60 second time intervals. TOC map displays are typically updated once or twice every minute. Note that all information is to be managed and transmitted via the master computer. A freeway traffic management system might typically employ a second "stand-by" computer to automatically "take-over" during master computer malfunctions.

Virtually all of the technologies used for motorist information and traffic management can be implemented automatically by means of the master computer. Thus, options for ramp metering rates, CMS messages, HAR broadcasts and arterial signal timings consist of pre-planned responses accommodating the range of expected operating conditions. Based on traffic flow measures extracted by the loop detectors, the appropriate information and management schemes are automatically set into place. Computer terminals in the TOC will enable monitoring personnel to supervise and, if appropriate, override any system-generated response.

And finally, personnel in the TOC can manage and coordinate communication between appropriate outside agencies. As examples, TOC communication staff might 1) manage service patrols and cellular phone reports, 2) supervise HAR broadcasts, 3) notify emergency response agencies where appropriate and 4) provide

information to local news media.

The TOC facility itself would require something on the order of 10,000 square feet of operating space. Short-term alternate power sources should be available to automatically respond to power drops and to provide "graceful degradation" of the system during extended power failures.

Incidents can, of course, occur during any hour of the day or night. However, it is unrealistic to expect that budget constraints will allow 24-hour staffing of the TOC. As a compromise, TOC personnel should be present for much of the day as possible. Typical hours of TOC operation might extend from 5:30 am to 7:30 pm Monday through Friday. TOC staff would be on duty during special events, and should be available for service during emergency situations.

#### **TOC Location**

Ultimately, INDOT will require its own TOC facility. Perhaps the facility could be constructed as part of the new LaPorte district building. However, in the initial stages of system implementation, the possibility may exist to use the Illinois DOT's Traffic Systems Center located in Oak Park, Illinois. Traffic flow information measured from detectors could be transmitted to the Chicago Area Systems Center where it would be processed. Monitoring operation on the Borman Expressway could then be accomplished in one of two ways. An INDOT employee would work in the Illinois DOT Systems Center and supervise Borman operations from Oak Park. Or, processed data could be transmitted from Oak Park to a computer terminal located in Indiana (e.g. the LaPorte district office). This latter arrangement would probably prohibit the transmission of video images from a CCTV system. Regardless of the arrangement made, it might not be realistic to expect that traffic management strategies could be implemented through the Oak Park Systems Center.

Nonetheless, using the existing Chicago Area System Center might provide an appropriate "start-up" for the proposed Borman

system. Such an arrangement would provide INDOT personnel the opportunity to gain experience in freeway traffic management before investing large capital into the Borman system. At this time, it is uncertain if use of the Oak Park facility by INDOT is actually feasible. A number of cost-sharing and working agreements would have to be reached by the two state transportation agencies. The option might be worth investigating.

### 3.5 Communication Linkages

In determining the most appropriate technology for transmitting information between the field (i.e. the Borman Expressway) and the TOC, several factors should be considered.

1. At this time, it is uncertain precisely where the TOC will be located.
2. Initially, surveillance data might be transmitted to the Illinois DOT Systems Center. A permanent INDOT TOC would be established later.
3. Regardless of location selected, the INDOT TOC may likely be many miles from the Borman itself.

Due to these factors, leasing phone company utility lines appears to be the most cost-effective manner of transmitting information. Leased lines can accommodate all data transmissions associated with the proposed Borman system. Moreover, leasing lines provides the flexibility to change communication routing strategies in the event that the TOC location is changed. Transmission service can be canceled at any time should alternate communication strategies become available in the future.

Additional monthly communication costs would be associated with leased lines. However, surveillance data collected from detector stations could be processed using on-site microprocessors before being transmitted to the TOC. This would reduce communication costs. Moreover, leasing lines eliminates the high costs of installing dedicated cable between the TOC and the Borman itself.

Linkages from inductive loops and changeable message signs to the on-site microprocessors can be accomplished using traditional coaxial cable or twisted wire. However, fiber optic cables should be used for all trunk lines. Fiber optic lines are less susceptible to deterioration and require less maintenance. Most importantly, the added transmission capacity provided by fiber optic cable can better accommodate information sent by the CCTV system.

Fiber optic cable is relatively expensive and will require specially trained personnel for installation and maintenance. Transceivers will also be required to convert electronic pulses to optical pulses.

### **Satellite Communication**

Satellite technology is emerging as an option for data transmission. Information can be relayed between the freeway site and the TOC by means of Vary Small Aperture Terminals (installed along the roadside), a satellite transponder (in space), and a satellite hub (located at the TOC and other appropriate agency offices). Currently, satellite technology is being used in freeway traffic management on a somewhat experimental basis. For example, the Los Angeles district office of the California DOT is currently working with Huges Aircraft to transmit compressed video images via satellite. The Illinois DOT is also considering satellite technology for transmitting information for the Chicago Area surveillance system.

Using satellite communication does offer distinct advantages. Where a freeway traffic management system is located great distance from the TOC, satellite transmission greatly reduces communication costs. Conceivably, traffic management systems for an entire state could be supervised from a single TOC. Beyond this, satellite technology provides "video conferencing" capabilities. As such, INDOT may wish to consider satellite communications in the future.

The associated costs of satellite technology are not small. In addition to the costs of the satellite transponder and hubs,

Vary Small Aperture Terminals must be installed at distance intervals of approximately one mile along the roadside.

The opportunity may exist to initially use satellite communication as part of a pilot study. Purdue University can acquire use of a satellite transponder and a hub. One or more Vary Small Aperture Terminals could be installed at the Borman. Real-time traffic data could then be transmitted from the expressway to the Purdue campus. Conducting such a pilot study would offer several benefits:

- 1) A test of the effectiveness of satellite communications for freeway traffic surveillance and control.
- 2) Provide ready access of real-time data to Purdue researchers so as to evaluate the effects of various traffic management and control strategies.
- 3) Create a laboratory for university instruction and thereby stimulate student interest in traffic engineering in general, and INDOT in particular. The lab would also serve as a training facility for INDOT personnel.

#### **4. SYSTEM RECOMMENDATIONS & IMPLEMENTATION STRATEGY**

As the title implies, the purpose of Section 4 is to 1) summarize recommended technologies and traffic management strategies for the proposed Borman system and 2) present a potential implementation plan for these recommended elements. It is recommended that the Borman system consist of three components. Each of the three components should be implemented sequentially. Sequential implementation is suggested for several reasons. In some cases, information gained from the installation of a given system will provide insight to better design and implement additional systems. Beyond this, sequential implementation facilitates the evaluation of the benefits derived from the installation of each system. This is important given that the proposed Borman project is likely to serve as a pilot study for future traffic management systems in the state. The time duration between the implementation of each level of the proposed plan is somewhat variable - depending largely on funding availability and the assessed need for each system element.

In addition, proposed reconstruction and geometric improvements of the Borman Expressway will influence the installation of system elements. Clearly, construction activities must be coordinated with implementation of the proposed surveillance and control system.

Lastly, it should be recognized that the Borman Expressway functions as a single link in a much larger roadway network - with much of this network existing in the Chicago area. Thus, to the extent possible, surveillance and control systems implemented on the Borman should be coordinated with Chicago traffic management efforts. Moreover, any given element implemented as part of the Borman system should be evaluated on a system-wide basis.

##### **4.1 Component 1: Traffic Surveillance**

By providing real-time incident detection capability, traffic surveillance elements would serve as the "backbone" of the Borman system. The recommended surveillance system consists of several



elements - each coordinated so as to provide comprehensive detection and performance monitoring capabilities.

#### **4.1.1 Loop Detection**

Inductive loop detectors are recommended for inclusion in the Borman system. Detector stations should consist of paired loops located in all travel lanes at distance intervals of one-half to one mile. As loops measure traffic performance as well as detect incidents, loop detectors should be the first element installed on the Borman. In this way, the benefits of succeeding elements can be empirically evaluated.

Developing a detailed design for the proposed loop system will require careful study. Traffic volume data now being collected from Borman temporary count stations and the Wilbur Smith study should provide valuable insights into appropriate loop location. Beyond this, detector stations should be located downstream of access and egress points and at any locations where empirical data suggest that operational problems are likely (e.g. bottlenecks).

Data measured by detectors would be processed by on-site microprocessors before being transmitted to the TOC for evaluation.

#### **4.1.2 Closed Circuit Television (CCTV)**

CCTV should serve to augment the automatic detection capabilities provided by inductive loops. CCTV can not only verify detected incidents, but will also enable monitoring personnel to evaluate the extent of operating problems. At times (particularly low flow conditions), CCTV would likely serve as the primary detection mechanism.

The recommended CCTV system would consist of approximately 24 cameras mounted on self-standing poles approximately 45 ft high and spaced at distance intervals of roughly one-half mile along the roadway.

#### **4.1.3 Motorist "Location Information" & Emergency Phone Numbers**

The emerging popularity of cellular mobile phones should be

exploited for the purpose of freeway surveillance. An emergency phone number could be made available (and publicized) to motorists wishing to phone-in and report incidents. To aid these drivers in identifying incident locations, "mile-post" signs should be installed at fairly short intervals along the expressway. To some extent, such a surveillance system is currently being implemented on the Borman.

#### **4.1.4 Service Patrols**

Service patrols provide additional visual detection of roadway operating problems. Service patrols are perhaps most valuable for the traffic management and control capabilities they provide. In implementing a service patrol system, a number of options and considerations must be resolved (e.g. fleet size and composition of vehicles in the fleet). As the Borman Expressway is a relatively small facility (approximately 12 miles in length), the initial fleet size could be small. Perhaps two or three standard pick-up trucks, operated by trained personnel, would be sufficient for peak-period operation. These vehicles could also service neighboring facilities (i.e. I65 and the toll road).

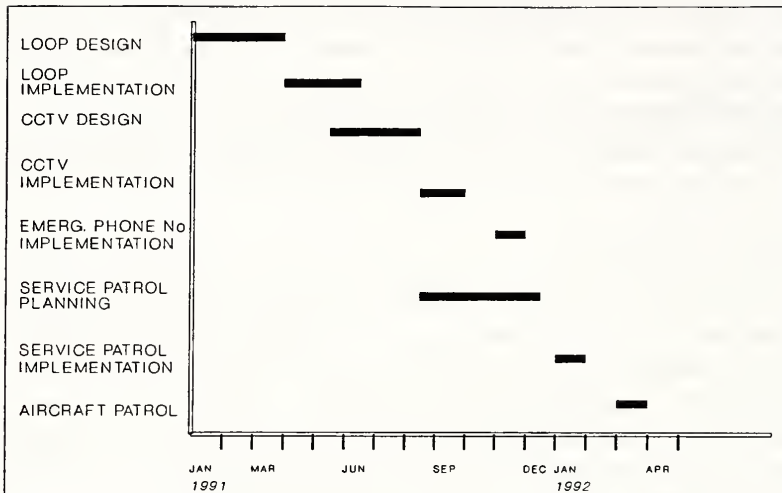
#### **4.1.5 Aircraft Patrol**

The feasibility of utilizing aircraft patrol already existing in the region should be examined.

#### **4.1.6 Implementation of Proposed Surveillance Elements**

Figure 8 illustrates a possible implementation plan for each element of the surveillance system. The time lag between installation of each element permits evaluation of the operational benefits resulting from each element.





**Figure 8**  
**Implementation Plan for Proposed Surveillance System**

#### **4.2 Component 2: Motorist Information**

The capability of providing motorists with real-time roadway information is an important aspect of the proposed Borman system. Section 4.2 summarizes those motorist information elements recommended for the project.

##### **4.2.1 Commercial Radio Broadcasts**

Relaying real-time traffic information to local news media is a relatively simple task. As such, commercial radio broadcasts should perhaps be the first motorist information element implemented.

##### **4.2.2 Changeable Message Signs**

A changeable message sign (CMS) can inform motorists of

downstream roadway problems as well as provide detour information. Before a CMS system can be implemented, two major issues must be resolved:

- 1) A determination of the technology to be used for the CMS must be made.
- 2) Appropriate locations for each CMS must be identified.

Two feasible options appear to exist for a choice of CMS technology: The simple drum-type CMS or the more advanced LED CMS. A careful study on the operating experiences of both technologies can be undertaken to identify sign technology most appropriate for the Borman. Determining sign location is a somewhat more complicated matter. Decisions must be made as to the extent to which the proposed CMS system is to be relied upon. For example, if the sole purpose of the CMS is to merely alert motorists of downstream congestion, then signs can be located at fixed intervals throughout the expressway (and upstream of any known bottlenecks). Conversely, if efforts are to be directed toward diverting traffic under incident conditions, than CMS placement will require careful study. Routes which are to serve as diversion facilities must be identified so that signs can be installed 3,000 ft to 4,000 ft upstream of detour route access points.

Moreover, each CMS should be viewable by CCTV cameras. Thus, designing of the CCTV and CMS systems must, to some extent, be coordinated.

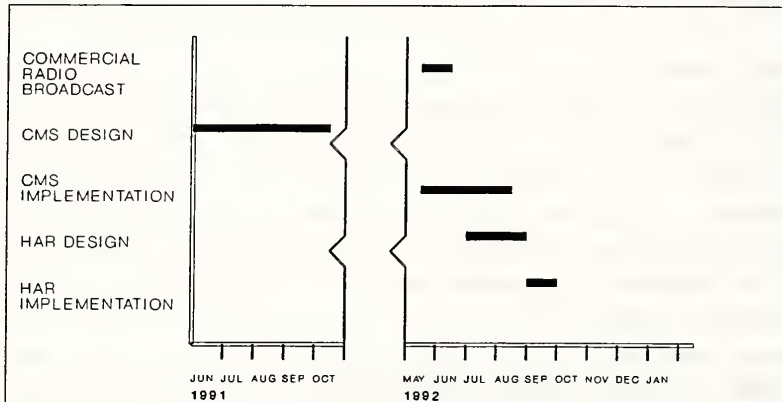
#### **4.2.3 Highway Advisory Radio (HAR)**

A HAR system consisting of pre-recorded messages should be implemented for the Borman Corridor. The HAR system would also have the capability of broadcasting "live" roadway reports when necessary.

#### **4.2.4 Implementation of Proposed Motorist Information Elements**

Figure 9 illustrates a possible implementation strategy for

each recommended element of the motorist information system.



**Figure 9**  
**Implementation Plan for Proposed Motorist Information System**

### 4.3 Level 3: Traffic Management

Installation of the traffic management system represents the final level of the proposed implementation plan. These elements improve roadway safety and performance by managing corridor operations during incident occurrences. INDOT may elect not to install some of the elements associated with traffic management during the initial implementation stages of the Borman system. However, all elements discussed in section 4.3 represent features which should be considered for eventual implementation.

#### 4.3.1 Service Patrols

In addition to detecting incidents, service patrols provide a cost-effective means of managing traffic at the incident location.

#### **4.3.2 Emergency Response Strategies**

Emergency response plans should be established to conduct traffic management under major incident conditions. Such a task would require joint efforts from INDOT, local cities and counties and emergency service agencies (i.e. police, fire, etc).

#### **4.3.3 Ramp Metering**

Metering Borman on-ramps would be an effective strategy for mitigating main-line congestion and encouraging surface street diversion under incident conditions.

#### **4.3.4 Trip Diversion**

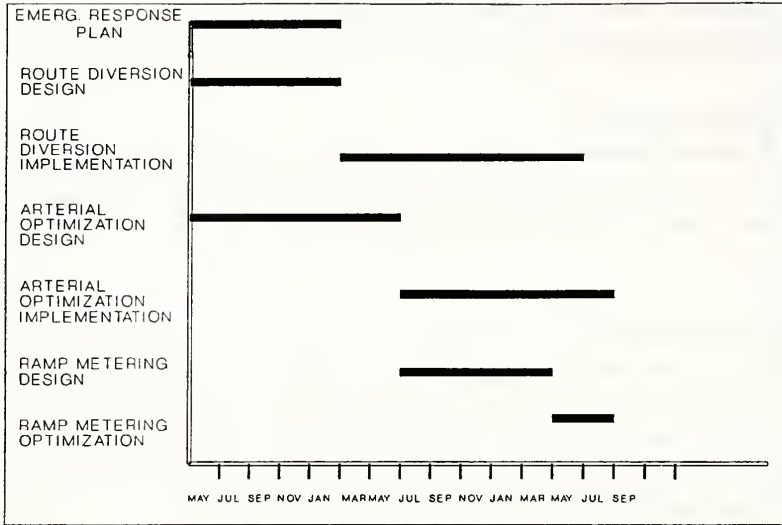
Within the Borman corridor, a number of roadway facilities could be used for route diversion during incident occurrence on the expressway. Developing a comprehensive diversion strategy would require certain roadway geometric improvements, self-adaptive signal systems and an effective motorist information system.

#### **4.3.5 Arterial Optimization**

If, during incidents, motorists are to be diverted from the expressway to surface streets, traffic signals must be capable of accommodating increased traffic demands. A signal control system must eventually be implemented. The signal system would consist of loop detectors to monitor changing traffic demands, and have the capability of automatically responding to these demand changes.

#### **4.3.6 Implementation of Proposed Traffic Management Elements**

Figure 10 illustrates a possible implementation strategy for each recommended element of the traffic management system.



**Figure 10**  
**Implementation Plan for Proposed Traffic Management System**

## 5. ESTIMATED COSTS

This report section documents costs associated with the purchase and installation of key items in the proposed freeway traffic management system. Detailed cost estimates for the overall project are not possible until final designs for each element are completed.

As an approximation, a total cost for the design and implementation of a comprehensive freeway management system can be estimated as \$1 million per mile (both directions). This estimate includes all costs associated with system development, communications, and construction and instrumentation of the TOC. Thus, the estimated total costs for the 12-mile project section would be approximated at \$12 million. Annual operating costs (including the costs of service patrols) can be estimated as ten percent of the total system cost.

### 5.1 Traffic Surveillance

Loop with amplifier (purchase & installation)	\$700/loop
Estim. cost of total loop system (includ. ramps)	\$237,000
Controllers	\$2,500/unit
Controller cabinet	\$5,000/unit
Estim controller costs for loop detection	\$52,500
CCTV camera (purchase & installation)	\$20,000/unit
CCTV monitors	\$1,000/unit
Estim. cost for CCTV system (24 cameras)	\$504,000

## 5.2 Motorist Information

CMS (Drum-type)	\$100,000/unit
CMS (LED)	\$300,000/unit
CMS structure (includ. installation)	\$75,000/unit
CMS controllers	\$60,000
Estim. cost for CMS system (assume 8 initial installations) Drum-type CMS	\$1.4 million
LED CMS	\$3 million

## 5.3 Traffic Management

Ramp metering	\$15,000/ramp
Estim. cost of ramp control (25 ramps)	\$375,000
Arterial optimization	\$90,000/intersection

## 5.4 Communications

Fiber optic cable (purchase & installed)	\$300,000/mile
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## 6. CONCLUSIONS AND FUTURE DIRECTIONS

The objective of this report has been to identify feasible technologies and management strategies for the proposed Borman Expressway surveillance and control system. In particular, the report has sought to determine those technologies and strategies which appear to be most appropriate for the operating environment within the Borman corridor.

As this report represents a feasibility study, considerably more work remains prior to implementation of the final freeway management system. For example, each system element recommended in this report serves a vital role in the overall surveillance and control scheme. Yet, one could argue that not all elements are of equal importance. Thus, each technology and strategy which is to be implemented in the overall system must first be agreed upon by the Borman Expressway Technical Advisory Committee. And clearly, the complexities associated with freeway corridor management dictate that a number of further studies and design refinements be undertaken. This section of the report seeks to identify additional efforts required for system implementation.

### 6.1 System Design Needs

Significant complexities are associated with each element of the overall Borman system. The operating experiences of existing freeway traffic management systems suggest that a "generic" surveillance and control system should not be "blindly" applied to any given corridor. Design of each system element must be done with careful study. Final designs should be a function of 1) desired objectives of the overall system and the individual system element and 2) the operating environment in the corridor.

Much of the design work could be performed by consultants - with supervision by INDOT and Purdue staff. In some instances, designs of each system element should be done sequentially - recognizing that information resulting from the installation of one element might be used to better design subsequent elements. Moreover, a sequential design process would likely promote more



careful consideration of individual surveillance and control elements.

The following list documents some of the more important tasks which have yet to be undertaken. These tasks are vital to the success of the proposed Borman system.

- (1) A careful study of main-line volumes and congestion profiles should be undertaken. This information will be available from the temporary count stations now being installed on the Borman Expressway. Traffic data collected from these count stations will provide information for better designing proceeding system elements.
- (2) Roadways adjacent to the Borman should be further evaluated in the effort to identify alternate routes to be used during incidents. Alternate facilities should be selected so as to satisfy origin-destination patterns. Existing geometric conditions and "unused" capacities on potential diversion facilities must also be considered.
- (3) Results from tasks (1) and (2) will aid in determining appropriate locations for each changeable message sign (CMS).
- (4) A study of CMS technologies should be undertaken to determine if the drum-type or LED CMS is most appropriate for application on the Borman Expressway.
- (5) An assessment should be made concerning the feasibility (and desirability) of using the Illinois DOT Transportation Systems Center in Oak Park, Illinois during the initial stages of system operation on the Borman.
- (6) A determination must be made on how service patrols are to be implemented. For example, service patrols can be operated as part of an INDOT unit, or the service can be contracted to private interests. In either event, hiring strategies, training programs, and a scheme for monitoring the performance of individual service patrol operators must be devised.
- (7) Operating agreements must be established between INDOT and local news media.
- (8) Strategies must be established for coordinating traffic management and motorist information between the Chicago Area freeway traffic management system and the proposed Borman system.

- (9) The formulation of emergency response plans for major incidents. This would first require the development of working agreements between INDOT and all relevant agencies.
- (10) Once detailed traffic information is obtained from the Borman's proposed loop detection system, these data can be used as input for detailed evaluation of a variety of traffic management strategies.

## 6.2 Conclusions

The recommended technologies and management strategies described in this report will produce an effective surveillance and control system for the Borman Expressway. Such a system would facilitate improved traffic operation and highway safety under incident conditions as well as serve to mitigate recurring congestion problems likely to occur in the future. By implementing the comprehensive traffic management system recommended in this report, the operational benefits of individual system elements can be carefully evaluated. Such information would be valuable when implementing future systems elsewhere in the state.

Given the significance of the proposed system, and the complex considerations surrounding the project, initial tasks associated with system design must be thoughtfully orchestrated. Recommendations made in this report are the results of 1) a study of completed and ongoing traffic management research, 2) an evaluation of operating conditions within the Borman corridor and 3) discussions with professionals experienced in the area of freeway traffic management. It is the firm belief of researchers involved in this project that the proposed system described in this report represents the most appropriate approach toward traffic management on the Borman. Moreover, it is hoped that this report will provide definite direction for system implementation.

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**APPENDIX A**  
Delay Calculations

**Scenario 1:** Westbound stalled vehicle just east of the state boundary (8:00 am)

Volume at 8:00 am: 3,635 vehicles per hour (Figure 3)

Total Duration of Congestion, T:

$3635 \text{ vph (T)} = 2500 \text{ vph (0.5 hr)} + 5000 \text{ vph (T - 0.5 hr)}$

$T = 0.92 \text{ hr} = 55 \text{ minutes}$

Total Number of Vehicles Delayed:

$3635 \text{ vph (0.92 hr)} = 3,344 \text{ vehicles}$

Maximum Queue Length (occurs at 8:30 am):

$3635 \text{ vph (0.5 hr)} - 2500 \text{ vph (0.5 hr)} = 568 \text{ vehicles}$

Maximum Individual Delay,  $D_M$ :

$2500 \text{ vph} = 568 \text{ veh}/D_M$

$D_M = 0.23 \text{ hr} = 13.6 \text{ minutes}$

Total Delay, TD:

TD = AREA

$1/2 (0.92 \text{ hr}) (568 \text{ veh}) = 261 \text{ vehicle-hours}$

Average Delay per Vehicle:

$261/3344 = 0.08 \text{ hr} = 5 \text{ minutes}$

**Refer to Figure A1**

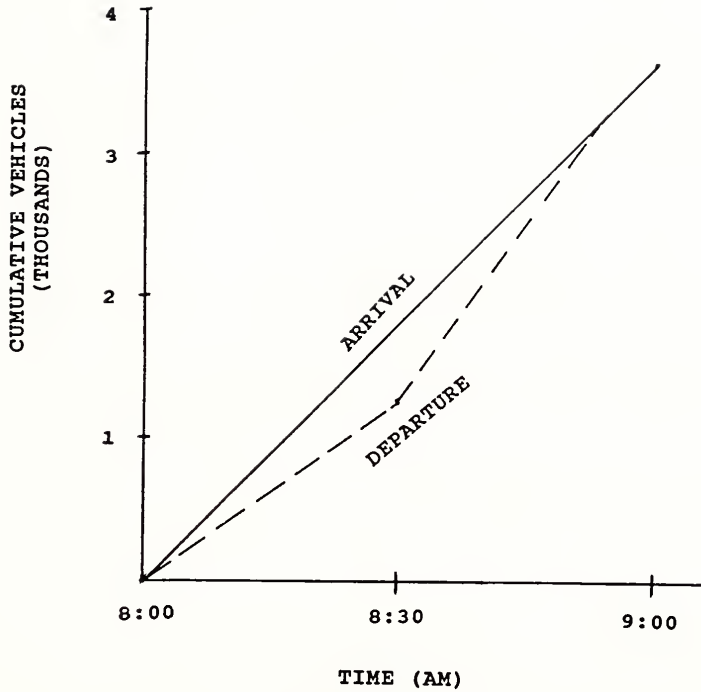


Figure A1  
Queueing Diagram for Scenario 1

**Scenario 2:** Eastbound stalled vehicle between Cline Ave and Burr St (4:00 pm)

Volume at 4:00 pm: 4,855 vehicles per hour (Figure 3)

Volume at 5:00 pm:  $4855 (0.9) = 4,370$  vph (10 % reduction)

Volume at 6:00 pm:  $4370 (0.9) = 3,933$  vph

Total Duration of Congestion, T:

$4855 \text{ vph (1 hr)} + 4370 \text{ vph (1 hr)} + 3933 \text{ vph (t)} =$

$2600 \text{ vph (0.5 hr)} + 5200 \text{ vph (t + 1.5 hr)}$

$t = 0.1 \text{ hr}$

$T = 2.1 \text{ hr}$

Total Number of Vehicles Delayed:

$4855 \text{ vph (1 hr)} + 4370 \text{ vph (1 hr)} + 3933 (0.1 \text{ hr}) = 9,618 \text{ vehicles}$

Maximum Queue Length (occurs at 4:30 pm):

$4855 \text{ vph (0.5 hr)} - 2600 \text{ vph (0.5 hr)} = 1,128 \text{ vehicles}$

Maximum Individual Delay,  $D_M$ :

$2600 \text{ vph} = 1,128 \text{ veh}/D_M$

$D_M = 0.43 \text{ hr} = 26 \text{ minutes}$

Total Delay, TD:

TD = AREA

Queue at 5:00 pm:  $4855(1) - [2600(0.5) + 5200(0.5)] = 955 \text{ vehs}$

Queue at 6:00 pm:  $4855 + 4370 - [2600(0.5) + 5200(1.5)] = 125 \text{ vehs}$

$1/2 (0.5 \text{ hr}) (1128 \text{ veh}) + 1/2 (1128 \text{ veh} + 955 \text{ veh}) (0.5 \text{ hr}) +$

$1/2 (955 \text{ veh} + 125 \text{ veh}) (1 \text{ hr}) + 1/2 (0.1 \text{ hr}) (125 \text{ veh}) =$

**1,349 vehicle-hours**

Average Delay per Vehicle:

$1349/9618 = 0.14 \text{ hr} = 8.4 \text{ minutes}$

**Refer to Figure A2**



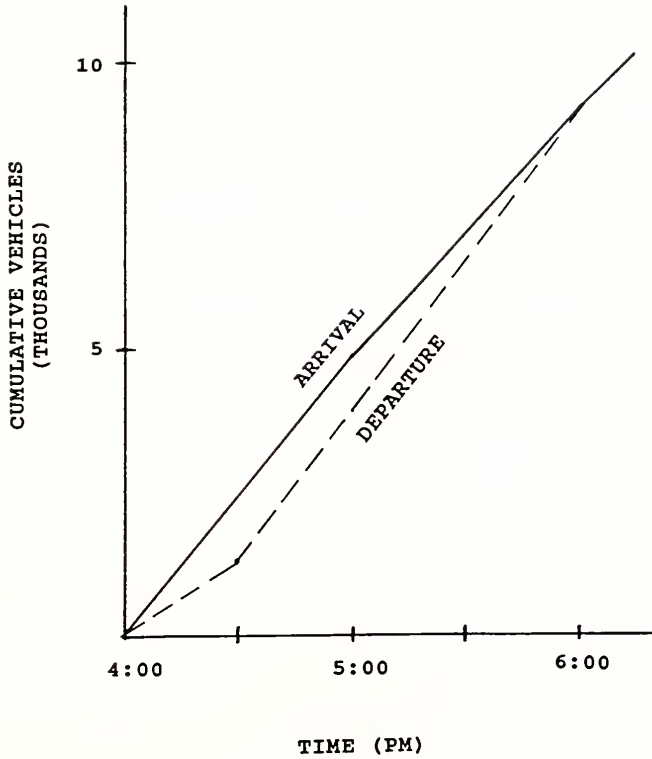


Figure A2  
 Queuing Diagram for Scenario 2

**Scenario 3: Eastbound major incident between Cline Ave and Burr St (4:00 pm)**

Assume Capacity is 1,650 vph during presence of incident  
1 lane available

20% trucks ( $f_{HV} = 0.88$ )

Incident creates lateral obstruction ( $f_w = 0.94$ )

Volume at 4:00 pm: 4,855 vehicles per hour (Figure 3)

Volume at 5:00 pm: 4,370 vph

Volume at 6:00 pm: 3,933 vph

Volume at 7:00 pm: 3,545 vph (10 % reduction)

Total Duration of Congestion, T:

$4855 \text{ vph (1 hr)} + 4370 \text{ vph (1 hr)} + 3933 \text{ vph (1 hr)} + 3545 \text{ vph (t)}$   
 $= 1650 \text{ vph (1 hr)} + 5200 \text{ vph (t + 2 hr)}$

$t = 0.9 \text{ hr}$

**T = 3.9 hr**

Total Number of Vehicles Delayed:

$4855 \text{ vph (1 hr)} + 4370 \text{ vph (1 hr)} + 3933 \text{ (1 hr)} + 3545 \text{ (0.9)} =$   
**16,242 vehicles**

Maximum Queue Length (occurs at 5:00 pm):

$4855 \text{ vph (1 hr)} - 1650 \text{ vph (1 hr)} = \mathbf{3,205 \text{ vehicles}}$

Maximum Individual Delay,  $D_M$ :

$1650 \text{ vph} = 3205 \text{ veh}/D_M$

**$D_M = 1.9 \text{ hr}$**

Total Delay, TD:

**TD = AREA**

Queue at 6:00 pm:  $4855(1) + 4370 (1) - [1650(1) + 5200(1)] = 2375$

Queue at 7:00 pm:  $4855 + 4370 + 3933 - [1650(1) + 5200(2)] = 125$

$1/2 (1 \text{ hr}) (3205 \text{ veh}) + 1/2 (3205 \text{ veh} + 2375 \text{ veh}) (1 \text{ hr}) +$   
 $1/2 (2375 \text{ veh} + 1138 \text{ veh}) (1 \text{ hr}) + 1/2 (0.9 \text{ hr}) (1138 \text{ veh}) =$   
**6,644 vehicle-hours**

Average Delay per Vehicle:

$6644/1626 = 0.41 \text{ hr} = 25 \text{ minutes}$

Refer to Figure A3

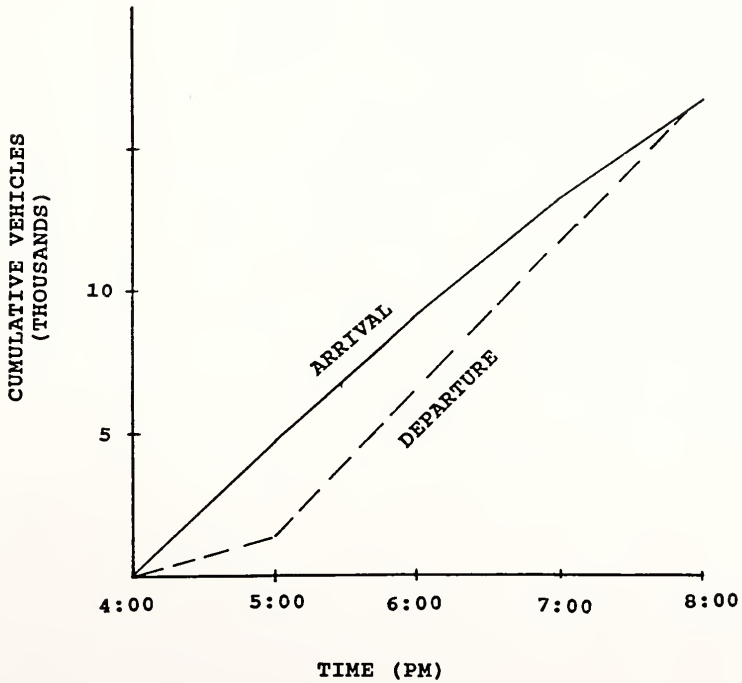


Figure A3  
Queuing Diagram for Scenario 3



COVER DESIGN BY ALDO GIORGINI