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16. Abstract

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Evaluation of Express Lane Effectiveness in Freeway to Freeway Interchanges

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Research Concerning Operational Effects of Geometrics
Research Report 1232-14
Research Study Number 2-18-90/4-1232

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September 1992

METRIC (SI*) CONVERSION FACTORS

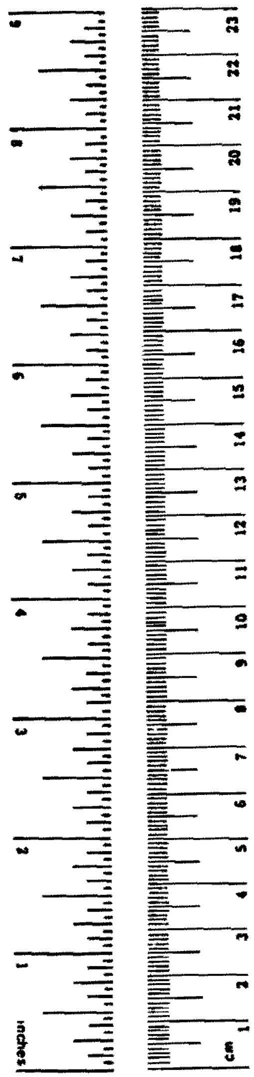
APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
	LENGTH			
in	inches	2.54	centimetres	cm
ft	feet	0.3048	metres	m
yd	yards	0.914	metres	m
mi	miles	1.61	kilometres	km
	AREA			
in^2	square inches	645.2	centimetres squared	cm^2
ft^2	square feet	0.0929	metres squared	m^2
yd^2	square yards	0.836	metres squared	m^2
mi^2	square miles	2.59	kilometres squared	km^2
ac	acres	0.395	hectares	ha
	MASS (weight)			
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
	VOLUME			
fl oz	fluid ounces	29.57	millilitres	mL
gal	gallons	3.785	litres	L
ft^3	cubic feet	0.0328	metres cubed	m^3
yd^3	cubic yards	0.0765	metres cubed	m^3

NOTE: Volumes greater than 1000 L shall be shown in m^3.

TEMPERATURE (exact)

Symbol	When You Know	Multiply By	To Find	Symbol
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

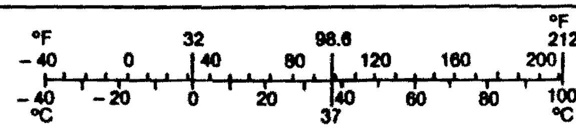


APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
	LENGTH			
mm	millimetres	0.039	inches	in
m	metres	3.28	feet	ft
m	metres	1.09	yards	yd
km	kilometres	0.621	miles	mi
	AREA			
mm^2	millimetres squared	0.0016	square inches	in^2
m^2	metres squared	10.764	square feet	ft^2
km^2	kilometres squared	0.39	square miles	mi^2
ha	hectores (10 000 m^2)	2.53	acres	ac
	MASS (weight)			
g	grams	0.0353	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams (1 000 kg)	1.103	short tons	T
	VOLUME			
mL	millilitres	0.034	fluid ounces	fl oz
L	litres	0.264	gallons	gal
m^3	metres cubed	35.315	cubic feet	ft^3
m^3	metres cubed	1.308	cubic yards	yd^3

TEMPERATURE (exact)

Symbol	When You Know	Multiply By	To Find	Symbol
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



These factors conform to the requirement of FHWA Order 5190.1A.

* SI is the symbol for the International System of Measurements

ABSTRACT

This research report focused on presenting three case studies and illustrating the process by which expresslane designs for freeway to freeway interchanges may be evaluated. The three case studies used for evaluation purposes were: 1) isolated interchanges 2) an isolated dual-route interchange, and 3) a system of connecting interchanges. The primary purpose of this research was to provide a method to determine the benefits that could be derived from implementing express lanes. The measure of effectiveness for this research was vehicle delay.

IMPLEMENTATION STATEMENT

To determine future highway needs and assist the Texas Department of Transportation in development of alternative designs, it is desirable to have methods of evaluating benefits of alternative designs. This report provides a method to evaluate freeway to freeway express lanes through urban interchanges. Information in this report should be of value in evaluating express lane designs.

DISCLAIMER

The contents of this report reflect the views of the authors who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Texas Department of Transportation or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation. In addition, this report is not intended for construction, bidding, or permit purposes. James W. Hanks, Jr. (Texas certification number 63299) prepared this research report.

SUMMARY

Urban congestion has become one of the largest concerns of the transportation community. This is a trend that will likely continue into and beyond the next century. Freeway interchanges are commonly a source or location of the more severe urban congestion. Because most urban interchanges were constructed some years ago, land development severely limits freeway expansion. This results in designers relying on innovative designs to improve traffic movement through the interchanges. Express lanes offer such an innovative design for alleviating congestion in urban interchanges.

Case Studies

Three case studies were conducted to evaluate the effects of express lane alternatives in different interchange configurations. Existing geometric and demand data were collected for each case study site. Operational characteristics were then determined by use of a microscopic freeway simulation (INTRAS) model. An express lane configuration was then developed for each case study and simulated with the model.

Overall, express lanes improved the existing traffic conditions in all the case studies. Using delay as the principal measure of effectiveness, improvements ranged between 15 and 56 percent reduction in delay.

Qualifications

Express lanes separate the through and interchanging movements. Before an interchange can be evaluated, detailed traffic and origin-destination data must be collected. In addition, the construction of elevated structures is extremely expensive, so right-of-way acquisition must be a major concern. Detailed origin-destination data is required to determine which travel directions have the greatest number of conflicts between through and interchanging traffic.

Disadvantages

The primary disadvantages to express lanes are the costs and signing. As previously discussed, elevated structures are costly and can only be justified by restrictive right-of-way. The signing problem becomes apparent because two routes exist for the same destination. The primary purpose of the express lane concept is to separate through and interchanging traffic; however, traffic can still remain within the existing interchange and travel through the interchange. If express lanes are implemented, care should be exercised in the signing of the facility.

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INTRODUCTION

Urban congestion has become a paramount concern of the transportation community. Freeway-to-freeway interchanges are commonly a source or location of the more severe urban congestion. This is not to say the initial interchange designs are flawed, but rather an indication of the demands placed on them by current traffic conditions. Many urban interchanges are operating over their design capacity. In addition, the majority of freeway-to-freeway interchanges have reached or are nearing their design life.

Several difficulties may be encountered in reconstructing urban freeway-to-freeway interchanges to increase their capacity. The most prominent factor is rights-of-way acquisition. Because most urban interchanges were constructed some years ago, land development severely restricts freeway expansion. Additional rights-of-way are extremely expensive to acquire. As a result, designers are required to rely on innovative designs to utilize existing resources, primarily right-of-way.

Purpose of Research

In 1987, TxDOT District 12 requested that the Texas Transportation Institute develop conceptual designs to alleviate congestion along IH-610W (West Loop). This project was a prime example of a freeway operating under excessive traffic demands with very restrictive right-of-way. The express lane concept was developed to alleviate congestion and improve the overall level-of-service while not acquiring additional right-of-way. While this particular application was purely site specific, the concept is a viable alternative for increasing freeway-to-freeway interchange capacity.

While the feasibility of implementing express lanes depends upon the specific interchange characteristics, this report outlines a general procedure to analyze this alternative. The procedure contained in this report documents three case studies and results from those analyses. This report is intended to outline the general considerations, required data, and modelling techniques used to evaluate the feasibility of implementing express lanes.

Research Methodology

The primary goal of an express lane is to provide a separation between through and interchanging movements that occur within an interchange. Removing the through traffic from areas that require weaving for interchanging movements allows optimum utilization of the additional capacity. Intuitively, adding capacity to a facility excluding weaving increases the throughput while decreasing delay and vehicular conflicts.

This research evaluates express lanes on the basis of reduced delay (vehicle-minutes) and level-of-service. The study design outlined in this report uses the Integrated Traffic Simulation (INTRAS) model to determine the amount of existing delay and the overall impact of the express lanes on the mainlanes. INTRAS estimates the vehicle-minutes of delay so that a benefit/cost analysis may be used to determine whether or not the construction of express lane is feasible.

Three types of express lane applications are evaluated in this report:

1) isolated interchanges
2) dual routes
3) multiple interchanges/systems

The three case studies represent three existing interchanges and were selected because of traffic data availability. In addition, these interchanges have significant through traffic movements. The through traffic volume is the primary indicator of whether express lanes will provide improved freeway operations. For these case studies, the TxDOT origin-destination (O-D) model (H-GRTS) provided the necessary data to determine the overall O-D pattern throughout the interchanges.

SIMULATION MODEL

INTRAS, (1) which stands for INtegrated TRAffic Simulation, was developed by KLD Associates in 1974. INTRAS is a stochastic, microscopic model. Stochastic models yield outcomes that are not completely predictable for a given set of inputs because they depend upon one or more random variables whose values vary among runs. Microscopic models treat each vehicle as a separate unit. INTRAS is a very sophisticated vehicle specific, time stepping simulation. INTRAS contains several algorithms which mathematically execute complex behavior including car following, lane-changing, and crash avoidance maneuvers. A detailed evaluation of complicated and unusual traffic operations (such as a weaving area or an incident) of a freeway section or even an entire surrounding roadway network can be simulated. INTRAS is capable of producing an on-ramp metering scheme (optimization), simulating an incident, simulating on-freeway diversion to an alternative route and producing surveillance detector output.

The geometric representation of the roadway system in the INTRAS simulation model is accomplished by constructing a network of links and nodes. However, since INTRAS may be used to simulate an entire roadway network or system, links are defined as freeway, ramps, or surface streets. The INTRAS module used to simulate surface street operations (including sign and signal control) was adapted from the UTCS-1 simulation (the same as in the NETSIM model).

INTRAS is a very large program and is currently only available for execution on mainframe computers. The large quantities of input data required, along with the large amounts of computing time required to maintain the individual vehicles in memory, currently limits the widespread use of INTRAS. However, FHWA will be providing an updated version of INTRAS, called FRESIM which will be available on a microcomputer version in the near future.

INTRAS Input

INTRAS requires that data be coded into an 80-column format file, with each entry in a specific column and in a certain order. No data input manager exists for INTRAS, so the input data file must be constructed using a text editor or word processor. Due to the immense amount of data that may be necessary to execute an INTRAS simulation, the input has been divided into required and optional. Table 1 lists the input data required to produce a simulation of a simple freeway section simulation (no ramp metering, no diversion, no incidents and no surveillance output). Table 1 also lists the embedded data that may be changed by the user to calibrate the model for specific applications.

INTRAS Output

The INTRAS model produces many standard and optional output formats. The following describes a majority of the output formats. Summary tables of input parameters are provided for each simulation run. Freeway link statistics include: vehicles input and output, number of lane changes, current content, average content, vehicle miles, vehicle minutes, moving time, delay time, volume, speed and density. Ramp and surface street link statistics that are output include: vehicles input, vehicles output, current content, vehicle miles, vehicle minutes, speed, moving time, delay time, vehicle minutes/vehicle mile for total and delay, percent queue delay, average saturation percentage and cycle failures. Surveillance data for each detector by lane includes: mean speed, mean headway, percent of traffic at or below indicated speed and percent of traffic at or below indicated headway. The fuel consumption and emissions report contains (by link) gallons of fuel consumed by vehicle type, miles/gallon by vehicle type, HC by vehicle type, CO by vehicle type and NOx by vehicle type. Digital plots of vehicle time-space trajectories and contour maps of user specified MOE values may also be included in the output. Finally, output may also be generated containing simple comparisons and statistical tests of MOE values from separate simulation runs.

Table 1. Input Data for INTRAS Model

Required Input Data	Optional Input Data	Embedded Data
simulation duration time link length link type free flow speed grade number of through lanes exit reaction location type and length of auxiliary lanes lane number to which the auxiliary lanes is connected lane number to which the ramp lanes is connected ramp mean queue discharge headway percentage of vehicles turning each direction at each node type of sign control at on-ramp junction with mainlanes flow rates for ramps and mainlane entrance percentage of flow rates for each vehicle type percentage of vehicles assigned to each lane	curvature superelevation pavement type surface street man queue discharge headway turn pocket sizes fixed time signal control codes traffic actuated signal control codes background cycle length ramp metering initiation time type of ramp metering metering headway detector position speed threshold for metering acceptable gap for metering diversion initiation time percentage of traffic to be diverted nodes defining alternative paths for diversion surveillance detector type length and position of detectors distance between loops incident code by lane length of affected area duration of incident rubbernecking factor	probability of lead vehicle jumping at the beginning of the green phase speed of left turning vehicles speed of right turning vehicles maximum jerk for vehicle type 1 car length by vehicle types acceptable gap for stop sign traffic acceptable deceleration rates for driver types maximum deceleration for vehicle types acceptable gaps for unprotected left turning traffic percentage of mean speed by driver type sensitivity factor for driver type startup lost time of queued vehicles limiting speeds by vehicle type for grades vehicle acceleration profiles for vehicle types lane mean speed percentage pavement friction coefficients

Application

The INTRAS model is a highly complex system containing procedures for diagnostic testing, microscopic traffic simulation, output reporting, statistical analysis, detector output processing and digital plotting. Due to the large complex programming that INTRAS requires, storage limitations may limit its usage to small applications. To achieve meaningful results it may be necessary to segment the study freeway. Some of the applications for which INTRAS may be utilized are summarized below.

Freeway Geometric Features -- The INTRAS model may be used to simulate basic freeway sections, freeway to freeway connectors, ramps, connecting surface street operation or an entire urban network. Possible simulation applications include: lane additions and removals, ramp reconfigurations and changes in curvature or grade. Weaving sections may also be analyzed in detail due to INTRAS treating each vehicle as a separate unit.

Incident Simulation Capability -- A comprehensive freeway incident simulation procedure is included in INTRAS. Each incident may occur at any position along a freeway link for any given length of time. The severity of an incident may be changed with time.

Surveillance System Simulation -- INTRAS is capable of simulating "real world" information gathering (surveillance devices). Surveillance output, which depends upon the type of detector used, includes speed and time of actuation for each simulated vehicle, by detector.

On-Ramp Controls -- INTRAS contains four algorithm modules for simulating entrance metering. Clock time activated fixed metering, demand capacity metering, speed control metering or gap acceptance metering may be simulated at each on-ramp. All but the clock time activated fixed metering techniques require the use of mainlane and ramp detectors.

On-Freeway Diversion -- INTRAS contains two procedures for diverting freeway vehicles to parallel service facilities. Clock time diversion and least time path diversion are the two methods allowed in the program.

CASE STUDY EVALUATIONS

Three case studies were conducted to evaluate the effects of an express lane alternative for various geometric configurations. The case studies were intended to serve as typical examples of the geometric and demand characteristics of urban interchanges. The case studies presented in this report were selected based on a previous interchange study for TxDOT. Select interchanges in one of Texas' most congested urban areas were identified as possible locations where freeway express lanes might be a feasible improvement. The case studies focused on :

1) Isolated Interchange
2) Isolated Dual-Route Interchange
3) System of Connected Interchanges

Existing geometric and demand data were collected for each case study site. A microscopic freeway simulation (INTRAS) model was then used to produce operational characteristics. The demand volumes were then increased at a rate of 5% for each origin (volume input point) for 3 additional simulations. Freeway density (i.e. LOS) and total interchange delay were observed. An express lane configuration was developed, the network updated and additional INTRAS simulations were conducted. It was assumed that approximately 20% of the through volume would use the express lanes, and that demand on the express lanes would never exceed 2000 veh/hr/lane. Simulated operational information could then be used to quantify the effects of express lanes.

Case Study - Isolated Interchange

The interchange shown in Figure 1 was selected to evaluate the effectiveness of an express lane alternative for an isolated interchange. The interchange that was selected is a typical fully directional, 4-leg interchange. This particular interchange is one in a series of freeway-to-freeway interchanges on a circumferential freeway system. A three-leg directional interchange lies approximately one mile north, and a four-leg directional interchange is one and one-half miles south. The network (roadway representation) that was coded for use in the

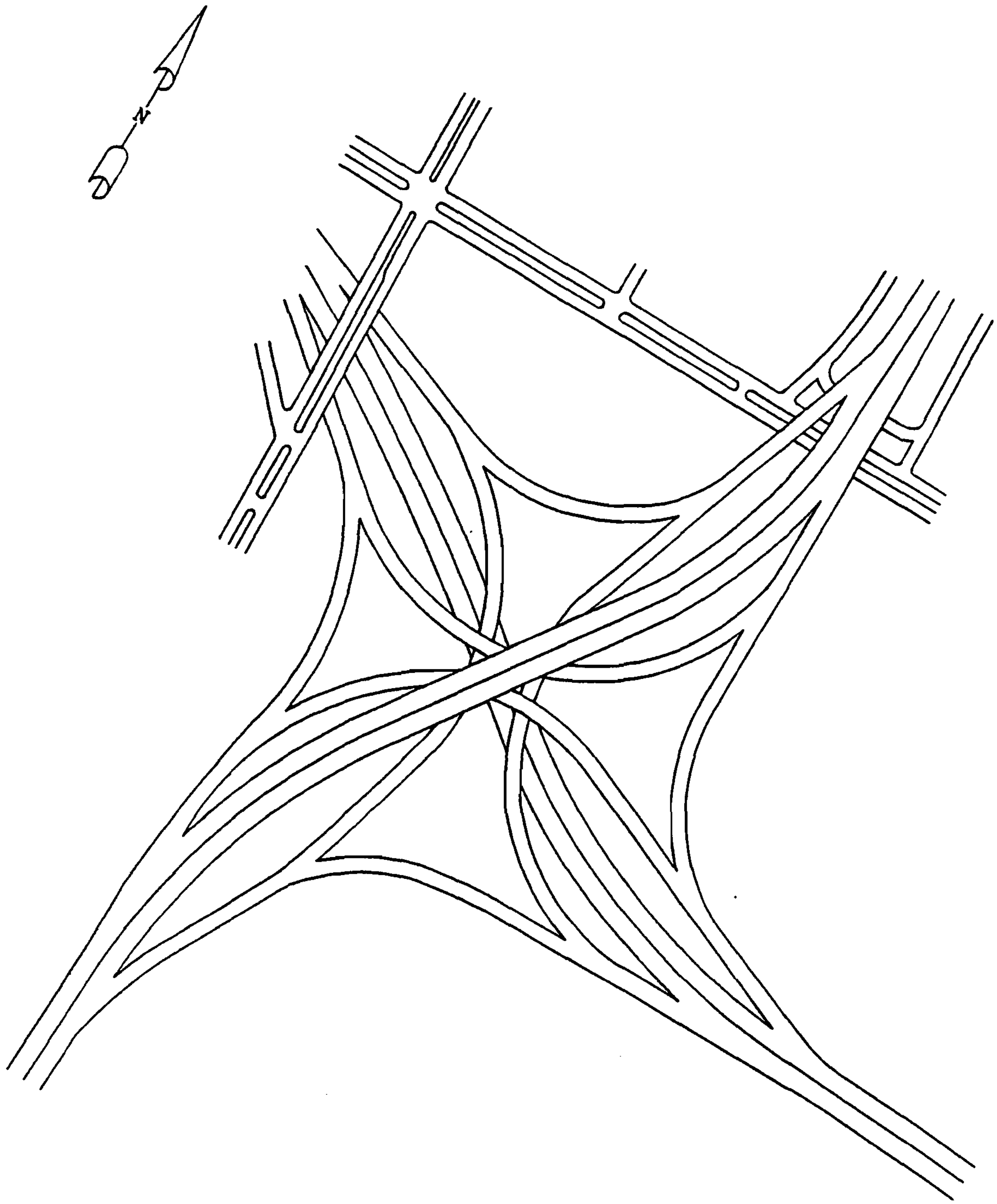

Figure 1. Case Study - Isolated Interchange

INTRAS computer model included all four freeway approaches and all of the directional connecting ramps between the freeways. The simulation of the existing geometric configuration and peak hour demand produced the levels-of-service (LOS) shown in Figure 2. Ramp operations are not shown since INTRAS computes densities (i.e. LOS) for freeway links only. Table 2 shows some of the output for the interchange from the INTRAS simulations for the peak hour using the existing configuration and demands. Also shown in the table are successive simulation results with an increased demand of 5% per simulation. The existing volume to capacity ratio for the freeway mainlanes (1.01) is derived from the entering mainlane volume per lane and a freeway capacity of 2200 vphpl. The V/C ratio is shown to illustrate the existing level of congestion and to serve as a comparative basis for recommendations.

Table 2. INTRAS Peak Hour Results for Existing Configuration of Isolated Interchange

V/C Ratio	Input Volume Veh/Hr.	Vehicle-Miles	Total Delay Veh.-Min.
1.01	29871	43524	54452

Two express lane alternatives were developed, Figures 3 and 4. First, to improve the east-west traffic movement to and from the CBD, a two lane exit was added upstream of the east-west approaches of the interchange, connecting to a two lane express lane that extended through the interchange and reconnected to the mainlanes downstream of the interchange with a two lane entrance ramp. The results from the INTRAS simulations for the east-west express lane alternative for existing demand and successive 5% demand increases is shown in Table 3. The existing mainlane volumes and additional expresslane capacity resulted in improved operations (decrease in V/C ratio from 1.01 to .80).

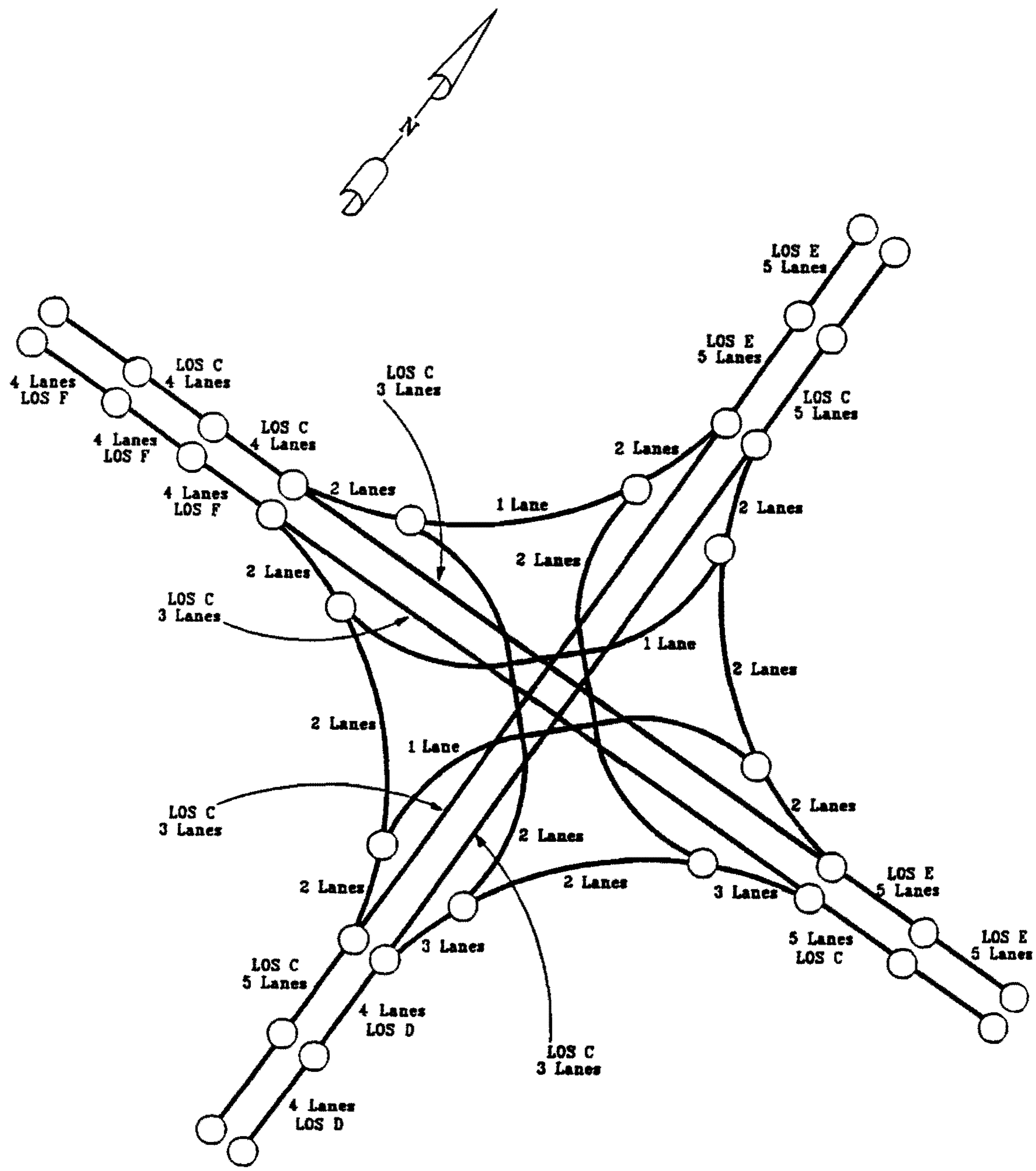

Figure 2. Existing Level of Service for Isolated Interchange Case Study

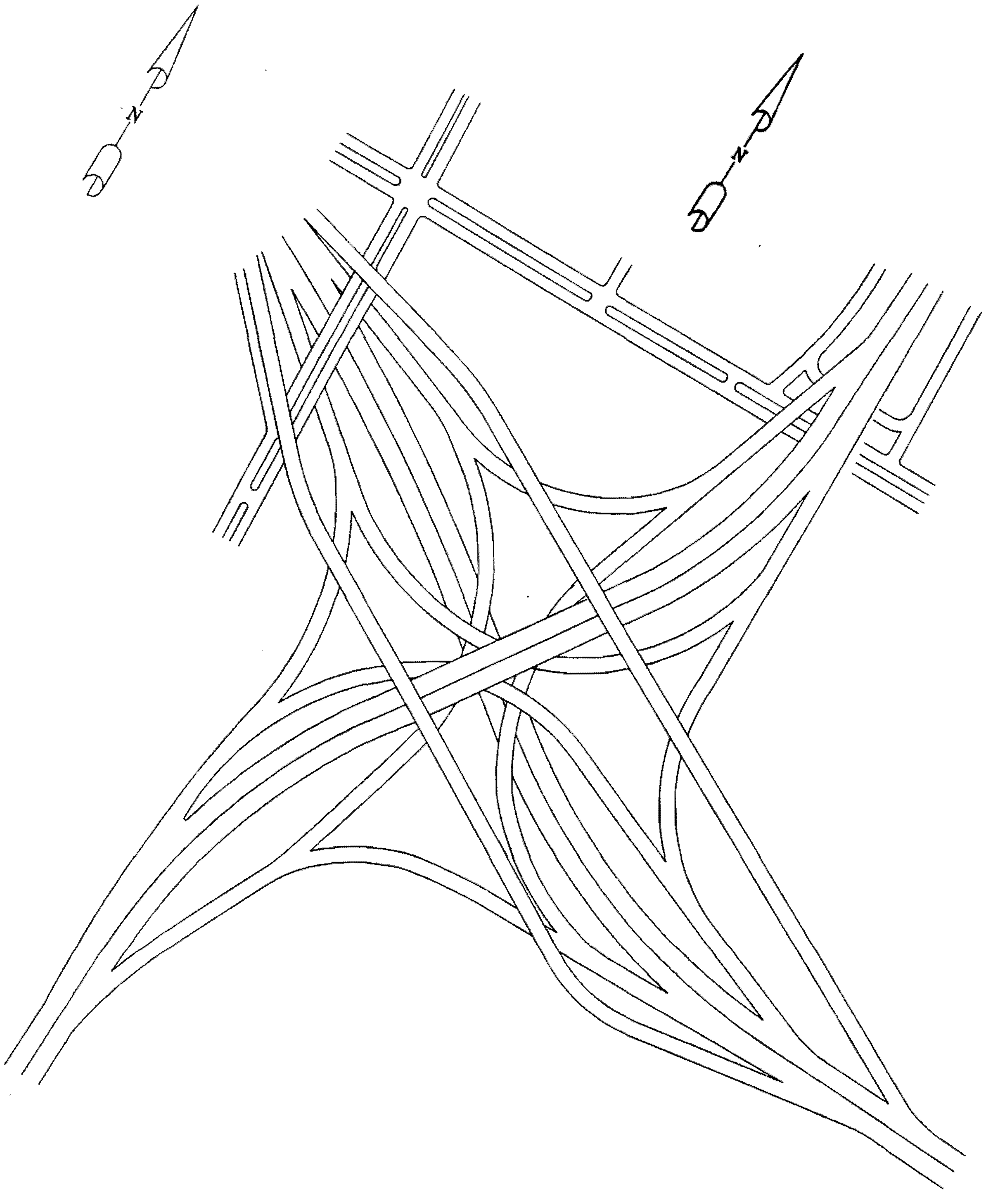

Figure 3. East-West Expresslane Alternative for Isolated Interchange

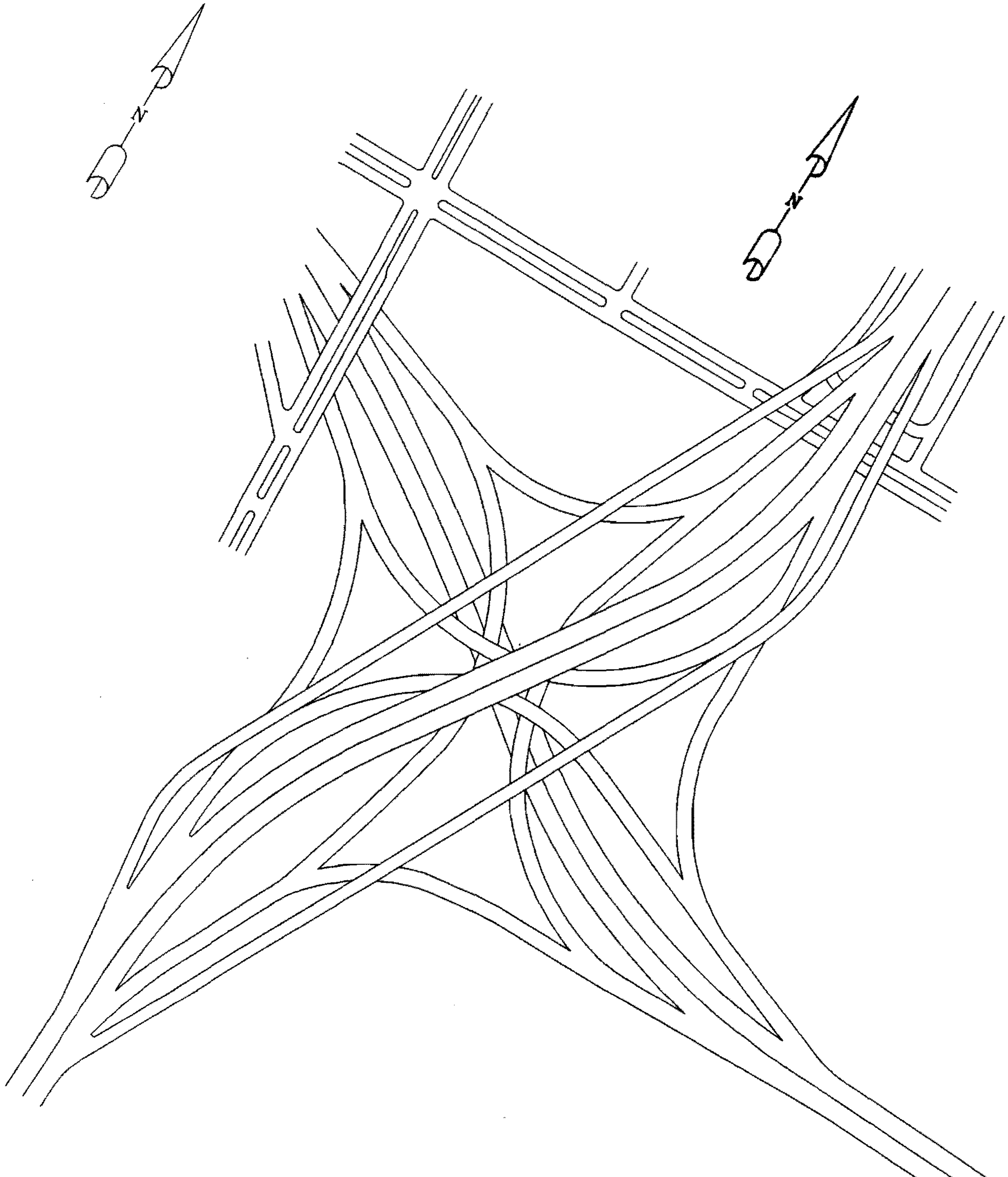

Figure 4. North-South Expresslane Alternative for Isolated Interchange

Table 3. INTRAS Peak Hour Results for East-West Express lane Configuration of Isolated Interchange

V/C Ratio	Input Volume Veh/Hr.	Vehicle-Miles	Total Delay Veh.-Min.
.80	29871	48424	37706
.84	31360	49948	42506
.88	32854	50328	47540
.92	34348	50680	52770

A north-south express lane alternative through the interchange was developed and modelled. The results of the INTRAS simulations are shown in Table 4.

Table 4. INTRAS Peak Hour Results for North-South Express lane Configuration of Isolated Interchange

V/C Ratio	Input Volume Veh/Hr.	Vehicle-Miles	Total Delay Veh.-Min.
.67	29871	46688	46368
.70	30465	47688	49384
.74	31062	48480	54620
.77	31659	49948	55856

Case Study - Isolated Dual-Route Interchange

The interchange shown in Figure 5 was selected to evaluate the effectiveness of express lanes for an isolated dual-route interchange. A dual-route interchange implies the two route designations occupy the same right-of-way at some point. In this case study the interchange is located in the CBD of a major urban area and right-of-way is extremely limited. A north-south freeway intersects with an east-west freeway with direct connectors for all movements. The two freeways overlap along a north-south orientation for approximately 3000 feet. The resulting simulation operations and existing number of lanes for the interchange segments are shown on

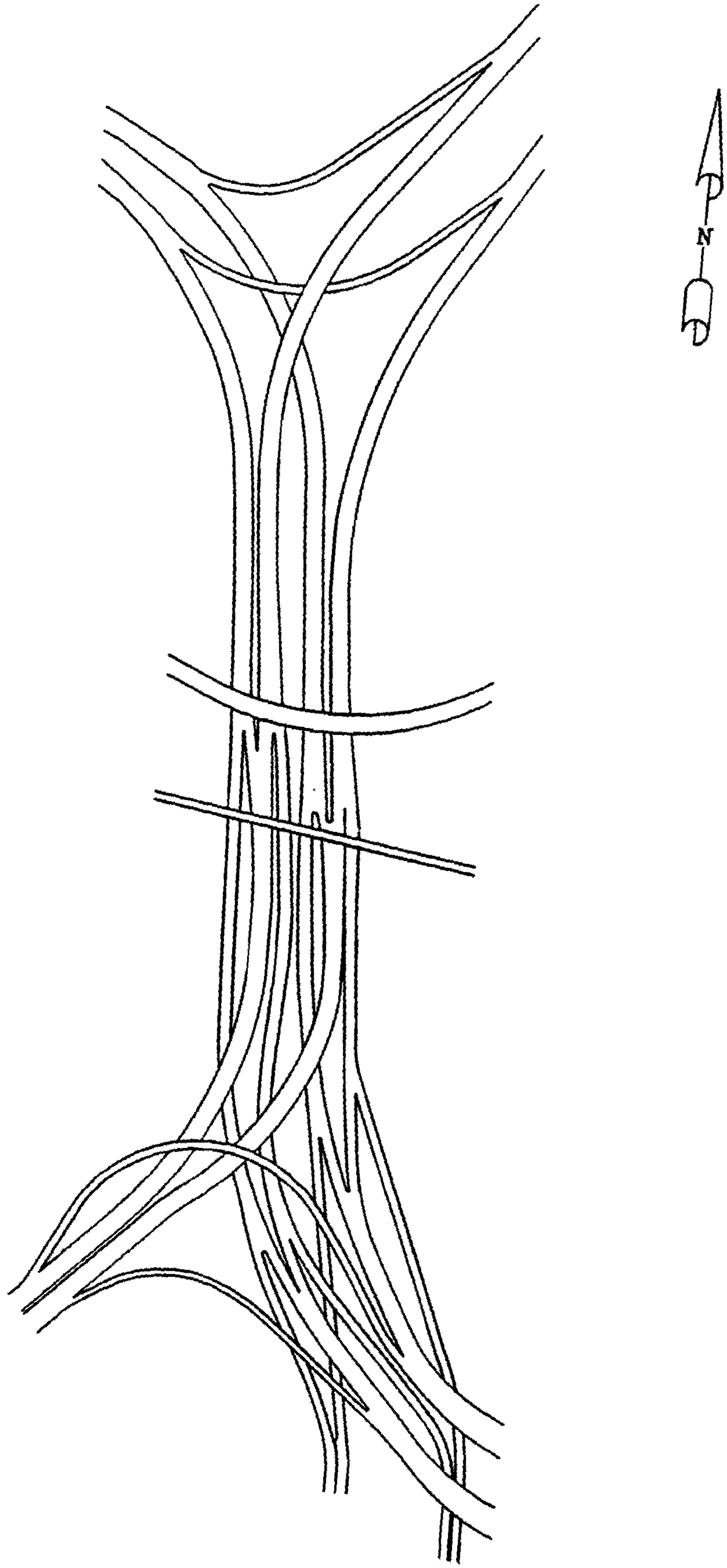

Figure 5. Case Study - Isolated Dual-Route Interchange

the network drawing, Figure 6. Table 5 shows additional interchange operating characteristics output from the INTRAS simulation for various demand levels.

Table 5. INTRAS Peak Hour Results for the Existing Configuration of Dual-Route Interchange

V/C Ratio	Input Volume Veh/Hr.	Vehicle-Miles	Total Delay Veh.-Min.
.90	24662	16748	34036
.95	25895	17136	34940
.99	27130	17876	38808
1.03	28362	18808	37328

An express lane design was developed for this interchange, Figure 7. A two-lane exit was added prior to the interchange on all four freeway approaches and connected to two express lanes northbound and two southbound. The expressway terminated downstream of the interchange using two lane ramps which fed the four departing freeways. The results from the INTRAS simulations of the express lane alternative for the dual-route interchange are shown in Table 6.

Table 6. INTRAS Peak Hour Results for Express lane Configuration of Dual-Route Interchange

V/C Ratio	Input Volume Veh/Hr.	Vehicle-Miles	Total Delay Veh.-Min.
.76	24662	23936	15020
.80	25895	24852	19772
.84	27130	25848	22248
.88	28362	26884	25000

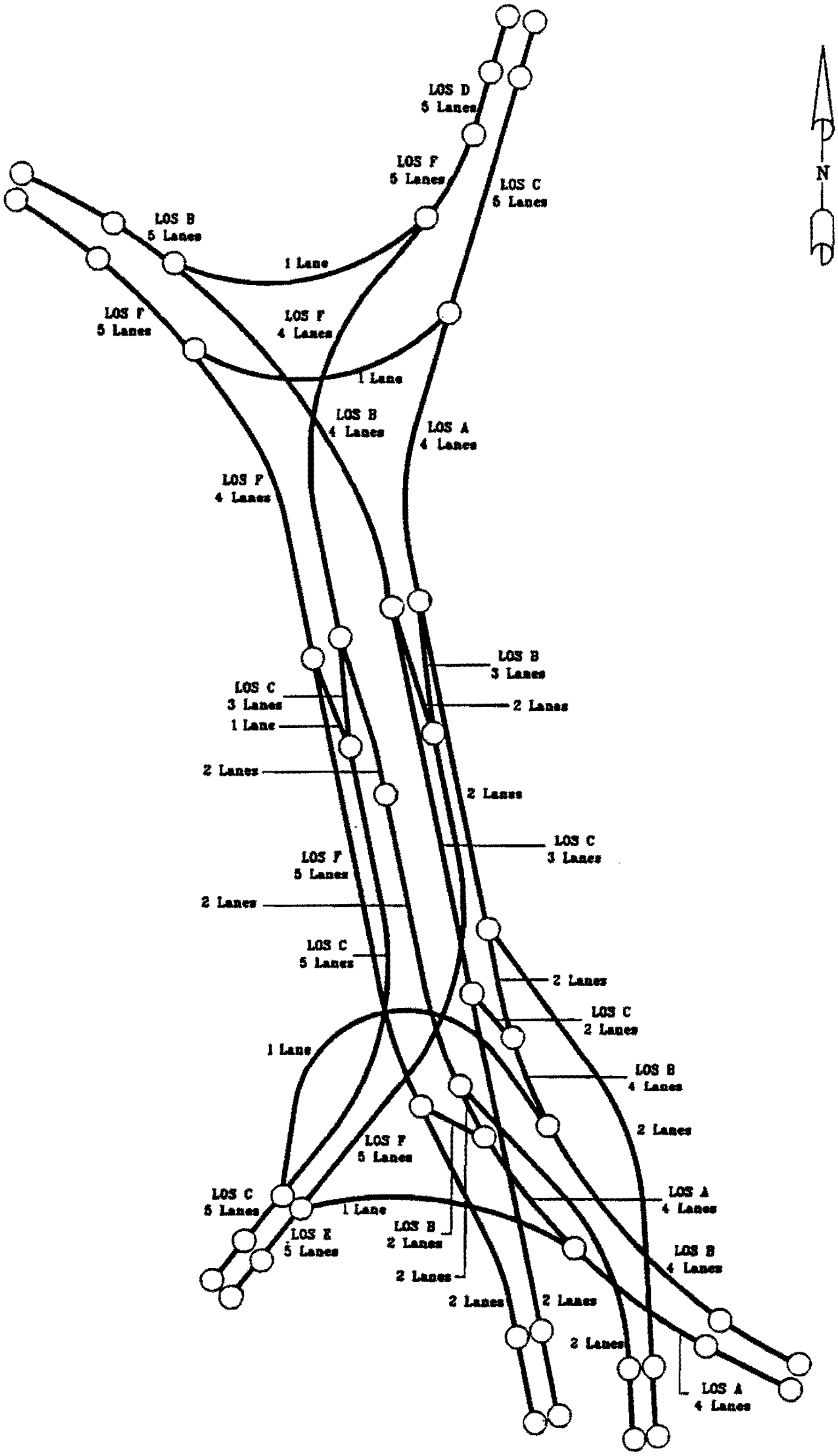

Figure 6. Existing Level of Service for Isolated Dual-Route Interchange

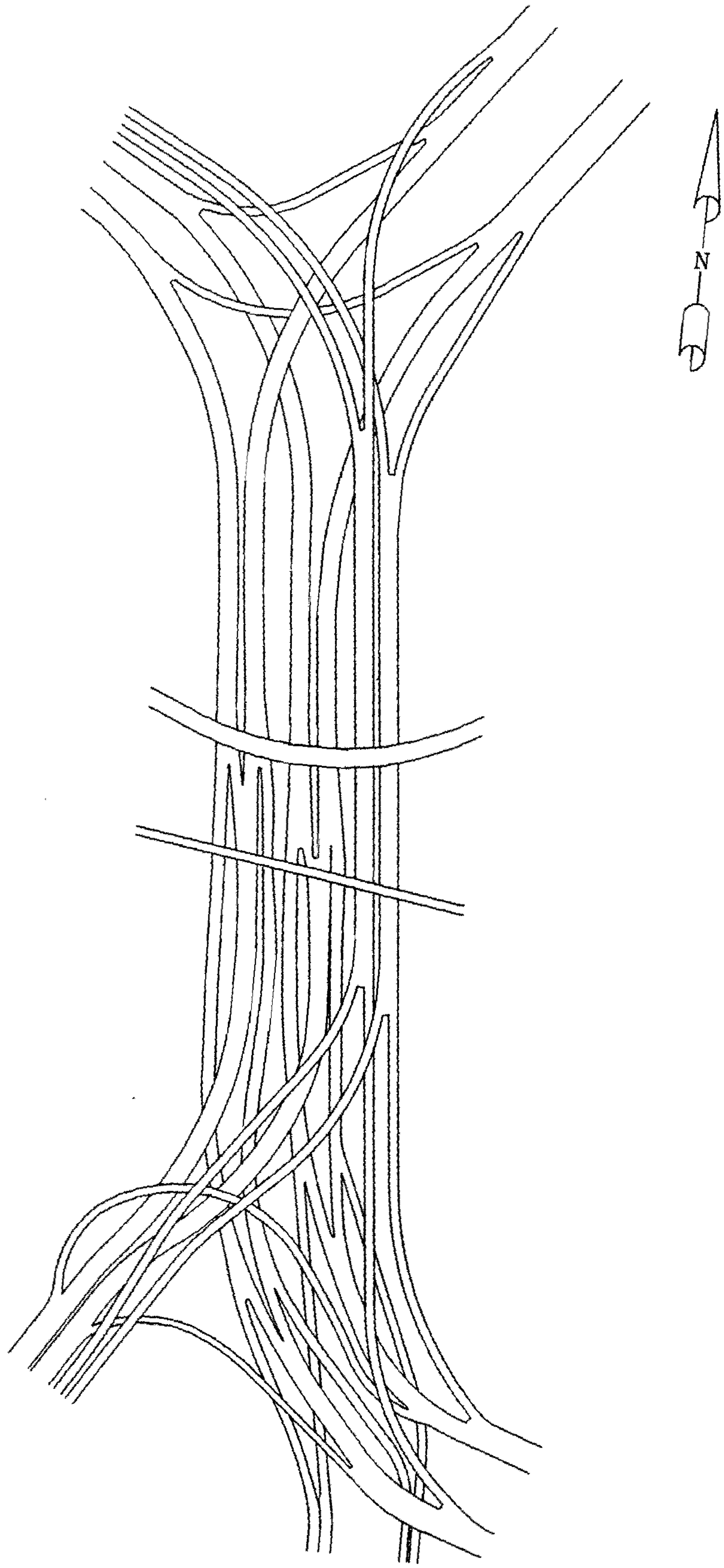

Figure 7. Expresslane Alternative for Isolated Dual-Route Interchange

Case Study - System of Connected Interchanges

The freeway system shown in Figure 8 was chosen to evaluate the effectiveness of an extended interchange expressway alternative. This particular system is part of an urban circumferential freeway. This case study system is approximately 4 1/2 miles long and includes two diamond interchanges, two partial diamonds, and two fully directional freeway to freeway interchanges. The northern end of the system contains the fully directional interchange depicted in the isolated interchange case-study.

As simulation work on this case study began, it became apparent that the microscopic aspect of the INTRAS model would actually become a limiting factor in this large system. The model could not keep track of the inordinately large number of vehicles and links required to model the entire system. Therefore, the network used in the simulations for this system did not include the east-west freeways for the two fully directional interchanges. The network representation and resulting levels-of-service for the existing configuration and existing volumes for the peak hour are shown in Figure 9. Operating characteristics for the existing system for current and increased volumes are shown in Table 7. An express lane alternative was developed, Figure 10, which consisted of a two lane expressway for both north and southbound vehicles. The express lanes connected to the mainlanes by two lane entrance and exit ramps north of the northern system interchange and south of the southern most interchange. The resulting express lane alternative operations for this system are shown in Table 8.

Table 7. INTRAS Peak Hour Results for Existing Configuration of a System of Interchanges

V/C Ratio	Input Volume Veh/Hr.	Vehicle-Miles	Total Delay Veh.-Min.
.83	36451	59832	31476
.88	38271	61536	36660
.92	40095	61944	34308
.96	41916	63216	39732
1.00	43730	63288	41580

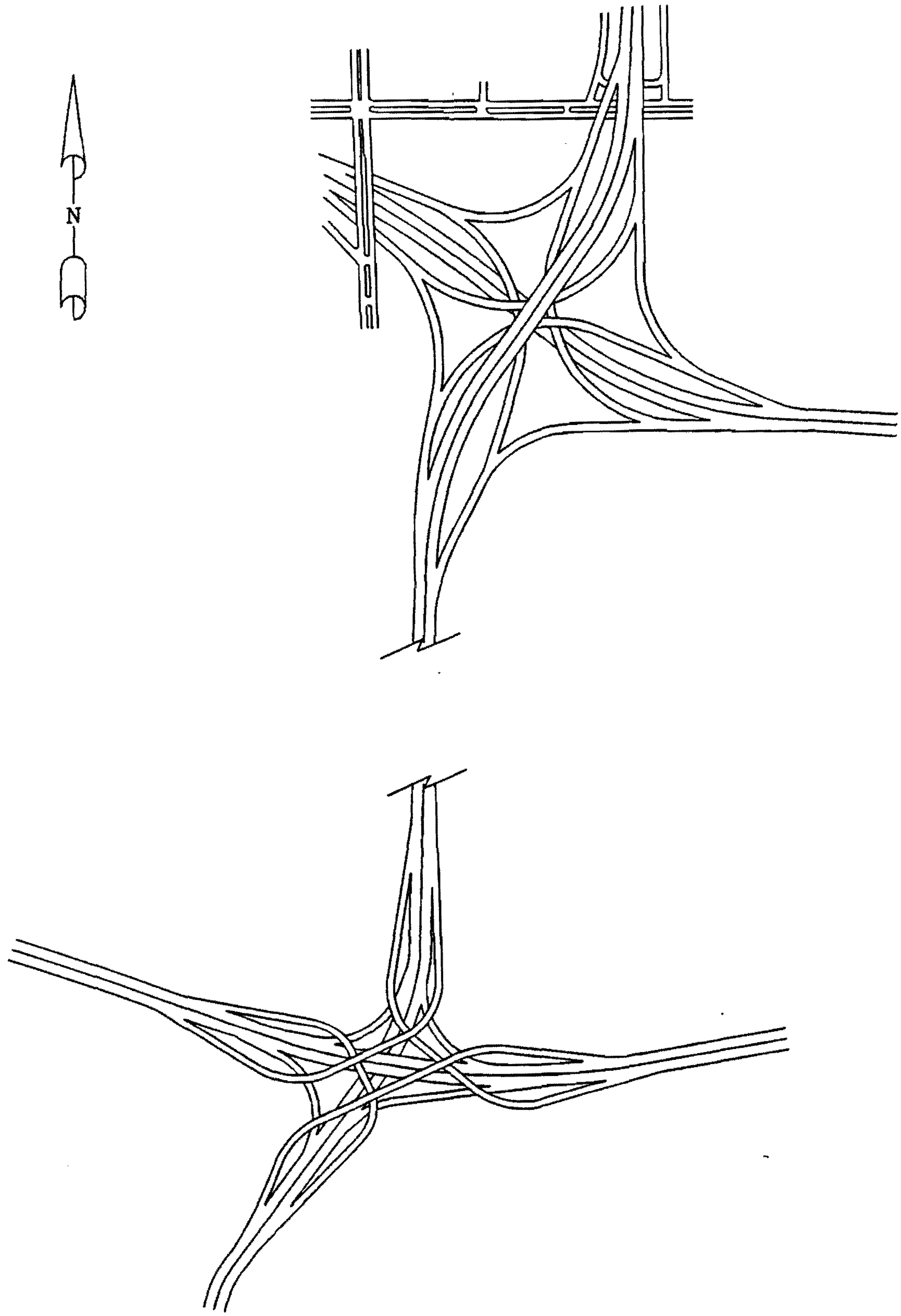

Figure 8. Case Study - System of Connecting Interchanges

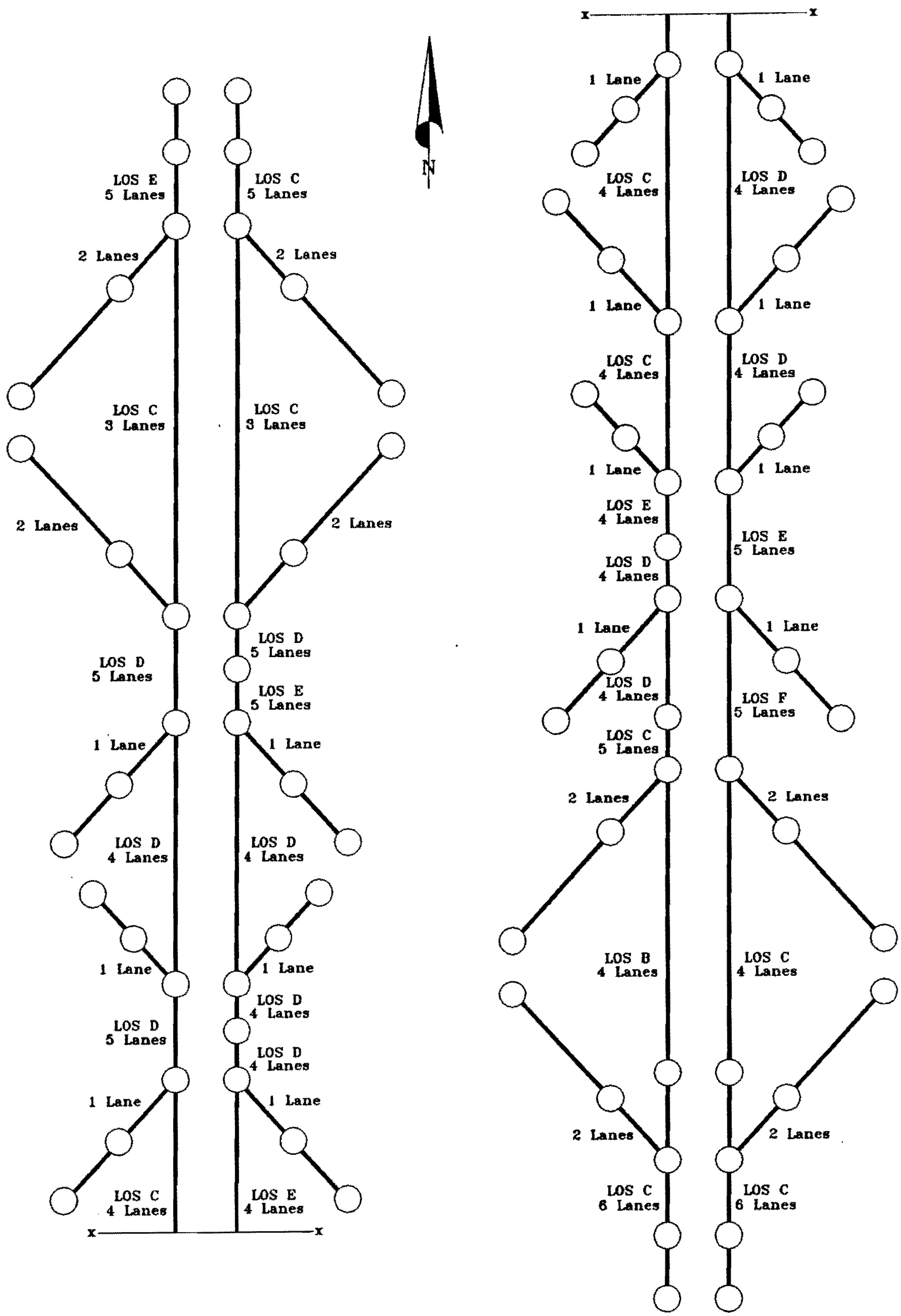

Figure 9. Existing Level of Service for System of Connecting Interchanges

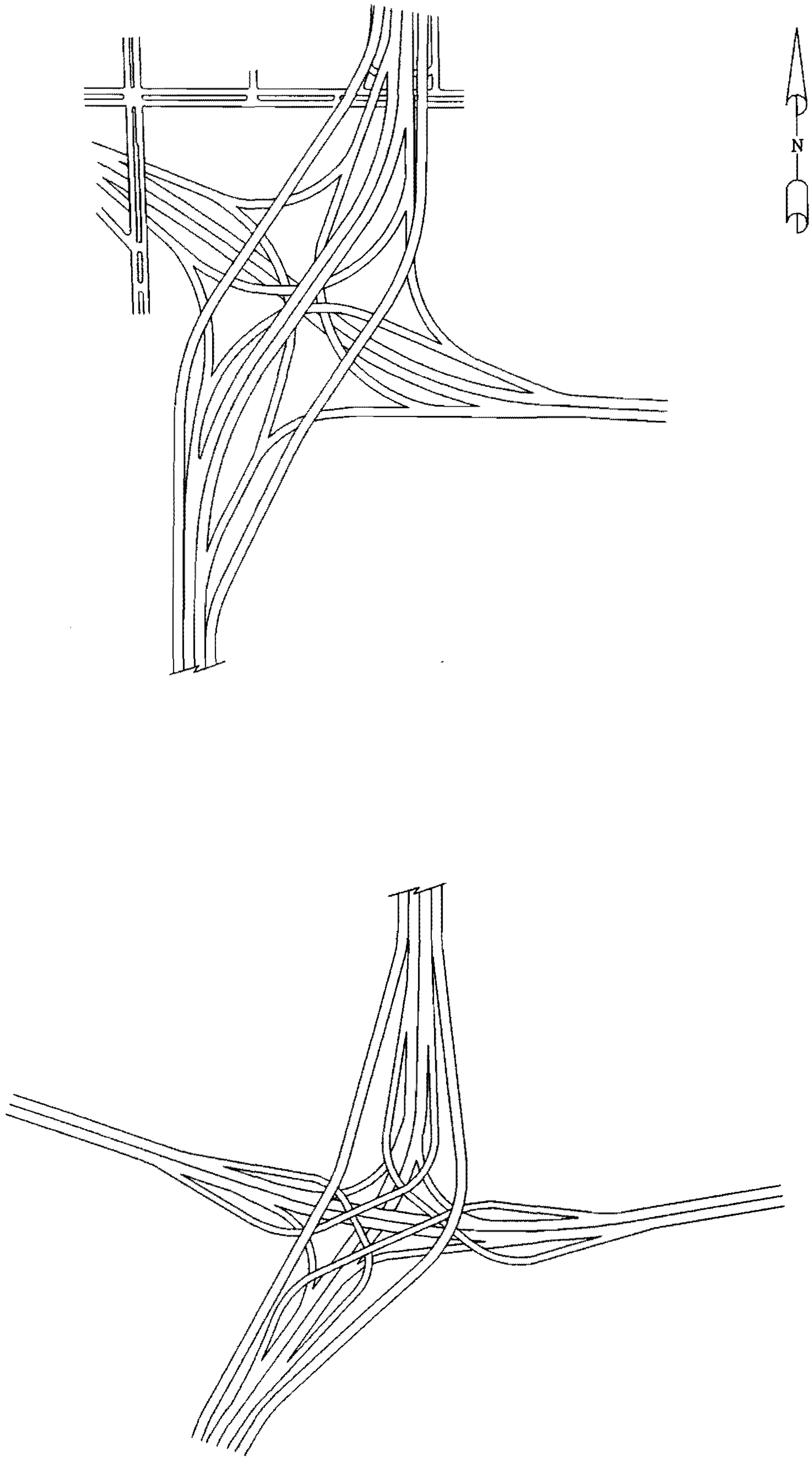

Figure 10. Expresslane Alternative for System of Connecting Interchanges

Table 8. INTRAS Peak Hour Results for the Express lane Configuration of a System of Interchanges

V/C Ratio	Input Volume Veh/Hr.	Vehicle-Miles	Total Delay Veh.-Min.
.67	36451	70764	16956
.70	38271	74856	22740
.74	40095	77388	30804
.77	41916	79212	32256
.80	43730	80628	32928

FINDINGS

Isolated Interchange

The isolated interchange selected for study was a typical 4-leg fully directional type, Figure 1. Existing operational characteristics are illustrated in Figure 2 and Table 2. From Table 2, the existing V/C ratio indicates that the interchange is operating at capacity during the peak-hour.

Table 9 summarizes the information of Tables 2, 3, and 4. The isolated interchange evaluated currently experiences 908 vehicle-hours of delay during the peak-hour which equates to approximately 1.8 million vehicle-hours of delay annually. Also shown in Table 9 are the two alternative express lane designs. From this evaluation, the East-West alternative has the most pronounced effect on interchange congestion. The East-West expressway alternative will allow traffic volumes to increase by 15 percent while maintaining lower V/C and delay values than currently exist. The North-South expressway alternative will produce operations nearly identical to the existing conditions for a volume increase of 10%.

Table 9. Express Lane Effects on Isolated Interchange

	Existing	East-West Express Lanes	North-South Express Lanes
V/C Ratio	1.01	0.92	0.74
Total Delay Peak-Hour (veh-hrs)	908	879	910
Annual Delay (million veh-hrs)	1.8	1.8	1.8
Growth (%)	0	15	10

Under current conditions the following results can be derived from Tables 2, 3, and 4.

1) The East-West express lane would reduce delay by 31 percent and reduce the V/C ratio from 1.01 to 0.80.
2) The North-South express lane alternative reduces delay by 15 percent and the V/C ratio to 0.67.

Isolated Dual-Route Interchange

The interchange selected for this case study is shown in Figure 3. This dual-route interchange is located near the CBD with extremely limited rights-of-way. Existing interchange operations are illustrated in Table 5 and Figure 4. Table 5 indicates that with 15 percent growth of traffic demands, the interchange will be operating at capacity during the peak-hour.

The express lane alternative for this interchange provided two-lane connector ramp up and down stream of the interchange to remove the through traffic from the interchange. Table 10 summarizes the effects of the express lane design on the interchange. With 15 percent growth in traffic volumes the interchange would have a V/C ratio of 1.03 and experience 622 vehicle-hours of delay during the peak-hour. Implementing the express lane alternative, the V/C ratio would be reduced to 0.88 and delay reduced by 33 percent to 416 vehicle-hours. Tables 5 and 6 indicate that under current volumes, the V/C ratio would be reduced from 0.90 to 0.76 and delays by 56 percent with the express lane alternative.

Table 10. Express Lane Effects on Isolated Dual-Route Interchanges

	Existing	Express Lane
V/C Ratio	1.03	0.88
Total Delay Peak-Hour (veh-hrs)	622	416
Annual Delay (million veh-hrs)	1.3	0.9
Growth (%)	15	15

System of Connected Interchanges

Figure 5 illustrates the freeway system chosen for this case study. The system selected is 4.5 miles long and contains two major freeway to freeway interchanges. Table 7 and Figure 6 illustrate the existing freeway operations through the system. From Table 7, the system of interchanges currently operates with a V/C ratio of 0.83, and with 20 percent growth in traffic volumes the V/C ratio will increase to 1.0 during the peak-hour.

The express lane design for this case study provided two-lane connectors upstream of the northern most interchange and downstream of the southern most interchange. Table 11 summarizes the effects of the express lane design with 20 percent growth in traffic volumes. The V/C ratio would be reduced from 1.0 to 0.8 with a 21 percent reduction in delay. Tables 7 and 8 show that at the current traffic volumes the V/C ratio would be decreased from 0.83 to 0.67 with a 46 percent reduction in delay with the implementation of express lanes through this section.

Table 11. Express Lane Effects on a System of Connecting Interchanges

	Existing	Express Lane
V/C Ratio	1.00	0.80
Total Delay Peak-Hour (veh-hrs)	693	548
Annual Delay (million veh-hrs)	1.4	1.1
Growth (%)	20	20

Qualifications

Express lanes separate the through and interchanging movements. Before an interchange can be evaluated, detailed traffic and origin-destination data must be collected. In addition, the construction of elevated structures is extremely expensive, so right-of-way acquisition must be a major concern. Detailed origin-destination data is required to determine which travel directions have the greatest number of conflicts between through and interchanging traffic.

Disadvantages

The primary disadvantages to express lanes are the costs and signing. As previously discussed, elevated structures are extremely costly and can only be justified by restrictive right-of-way. The signing problem becomes apparent because two routes exist for the same destination. The primary purpose of the express lane concept is to separate through and interchanging traffic; however, through traffic is not restricted to the express lanes. If express lanes are implemented, care should be exercised in the signing of the facility.

Benefit/Cost Analysis

INTRAS calculates the benefits of the express lane alternatives through V/C ratio, additional capacity, and reduction in delay. For the purpose of this benefit/cost analysis, existing V/C and delay values will be compared to the corresponding volumes with express lanes addressed. Assuming a construction cost of $55 per square foot and an express lane configuration of two 10-foot shoulders and two 12-foot travel lanes, the construction cost is $12.8 million per express lane mile. Table 12 summarizes the construction cost of each case study. The annual costs assume a discount rate of 10 percent and a service life of 25 years.

Table 12. Alternative Design Construction Costs

Alternative	Length	Cost ($ Millions)	Annual Cost ($ Millions)
Isolated (both)	4.1 miles	52.4	5.8
Dual Route	6.3 miles	80.5	8.9
System	10.4 miles	132.9	14.6

The benefits of constructing express lanes in the isolated interchange case study can be derived from Tables 2, 3, and 4. Using existing interchange volumes, Table 13 shows the reduction in delay. A vehicle and driver cost of $13.10 per hour was assumed.

Table 13. Isolated Interchange Benefits by Implementation of Express Lanes

Configuration	V/C Ratio	Total Delay (Veh-min)	Annual Reduction in Delay (Veh-hrs)	Annual Benefits ($ Millions)
Existing	1.01	54452	0	0
East-West	0.80	37706	558200	7.3
North-South	0.67	46368	269466	3.5

Tables 14 and 15 utilize the same method to determining benefits for dual route and system express lane configurations.

Table 14. Dual Route Benefits by Implementation of Express Lanes

Configuration	V/C Ratio	Total Delay (Veh-min)	Annual Reduction in Delay (Veh-hrs)	Annual Benefits ($ Millions)
Existing	0.90	34036	0	0
Express Lane	0.76	15020	660000	10.4

Table 15. System of Connected Interchange Benefits by Implementation of Express Lanes

Configuration	V/C Ratio	Total Delay (Veh-min)	Annual Reduction in Delay (Veh-hrs)	Annual Benefits ($ Millions)
Existing	0.83	31476	0	0
Express Lane	0.67	16956	504000	7.9

Table 16 combines Tables 12 through 15 to analyze the effectiveness of implementing express lanes in each case study.

Table 16. Benefits of Express Lane Implementation

Alternative	Annual		B/C ratio
	Cost	Benefits	
Isolated (E-W)	5.8	7.3	1.3
Isolated (N-S)	5.8	3.5	0.6
Dual	8.9	10.4	1.2
System	14.6	7.9	0.5

From Table 16, constructing express lanes in the isolated east-west alternative and the dual route case studies would be beneficial and cost effective. The other case studies show that the annual benefits cannot offset the construction costs of the express lane alternative.

REFERENCES

1. Wicks, D.A. and Lieberman, E.B., "Development and Testing of INTRAS, A Microscopic Freeway Simulation Model," FHWA, August 1977.