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16. Abstract

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DEVELOPMENT OF PRELIMINARY CONGESTION INDICES FOR URBAN FREEWAYS IN TEXAS

by

Ronald W. Holder
Study Supervisor

Dennis L. Christiansen
Associate Research Engineer

and

Charles A. Fuhs
Research Assistant

Edited by

A. V. Fitzgerald
Assistant Research Specialist

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ABSTRACT

Traffic congestion on urban freeways in Texas is a growing concern; freeways in each of the five largest cities in Texas experience some degree of congestion every weekday, yet no quantitative measure of freeway congestion has been developed.

This report documents the results of an effort to develop a preliminary freeway congestion index. Elements of congestion are discussed, and measures of congestion which can be derived from available data are presented. Several candidate congestion indices are identified, and values for each are calculated and compared for nineteen selected freeways in five Texas cities. The study utilizes only readily available data; as a consequence, the results need to be viewed as preliminary, since data from a limited number of locations are used to describe an entire segment of roadway. Finally, recommendations are made of the best index to use for various applications.

Key words: Freeway Congestion, Traffic Congestion, Mass Transportation

SUMMARY

Traffic congestion on the urban freeways of Texas is a relatively new problem; most of the freeways were opened during the 1960's and did not begin to experience severe congestion until the 1970's.

The extent of the freeway congestion varies among different freeways in the same city and among freeways of different cities. Traditionally, freeway congestion has been a major indicator of the need for increases in effective roadway capacity; mass transportation represents a means of increasing that effective capacity. However, the extent or severity of congestion has never been quantified; hence, the need to develop a freeway congestion index.

The first step in developing such an index was to identify the elements of congestion, as viewed by both the individual driver and society as a whole. Those elements of congestion that were viewed from an individual driver's perspective included:

- Extent of speed reductions,
- Length of congested segments, and
- Duration of congestion.

From society's perspective, the aspects of congestion were identified as:

- Total costs to society (delay, pollution, fuel wasted, etc.) and
- Rate of increase in congestion.

The fact that the important elements of congestion differ with perspective suggested a need for two different indices of congestion -- an Individual Congestion Index (ICI) and a Societal Congestion Index (SCI). The Individual Congestion Index might be useful in correlating accident data or predicting park-and-ride patronage, while the Societal Congestion Index could prove valuable in evaluating the urgency for corrective action and allocating scarce funds.

Individual Congestion Index

In developing a congestion index, the first task was to identify appropriate data to be used to characterize each element. One source of data which was ideally suited for characterizing specific elements in the ICI is a speed contour map. However, the lack of available speed contour maps prevented their use as a primary data source for a congestion index. Three other sources, however, were identified:

- Travel Time Studies conducted periodically by the State Department of Highways and Public Transportation in the larger urban areas of Texas.
- Automatic Traffic Recorders (permanent traffic count stations) located at various places on the 70,000 miles of state-maintained highways in Texas, and
- Annual Traffic Volume Maps published by the State Department of Highways and Public Transportation (official State Traffic Map, published by Planning and Research Division, SDHPT).[1]

From these data sources, measures of delay time, annual average daily traffic (AADT) per lane, and average weekday traffic (AWT) during peak periods can be obtained which can be used to quantify the elements of congestion identified previously.[2]

Two candidate congestion indices were formulated to measure freeway congestion from an individual driver's perspective. The first was an Individual Congestion Index (ICI) which is defined as:

$$ICI = \frac{\text{Delay Time in min.}}{10''} + \frac{\text{AADT/Lane}}{20{,}000}$$

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[1] The AADT data are complicated by the fact that frontage road volumes are included in those data while they are not in the ATR data. This could result in a potential error of as much as 25 percent.

[2] The results of this quantification must be considered preliminary. Count data are available at only a very limited number of locations per freeway, and the Traffic Volume Map data are not from the same location as are the Automatic Traffic Recorder data.

The second index was a Commuter-Oriented Individual Congestion Index (CICI) and is defined as:

$$\text{CICI} = \frac{\text{Delay Time in min.}}{10''} + \frac{\text{AWT/Lane x P.M. Dir. Split}}{10{,}000}$$

A comparison of these two indices of freeway congestion for 19 selected freeways in five Texas cities revealed that the ICI and the CICI values are quite similar for each individual freeway, and the resulting relative ranking among these 19 freeways changes very little.

A check of the validity of the two candidate indices based on available Speed Contour Maps indicated that both indices appeared to provide a reasonably good measure of congestion.

Societal Congestion Index

A number of candidate formulas for a congestion index to represent society's perspective were developed and evaluated. The two indices identified below were considered to be the best candidates for further consideration and use. These formulas were developed by taking the congestion indices developed from an individual's perspective and multiplying them by a measure for the total number of individuals involved. The resulting two indices, a Societal Congestion Index (SCI) and a Commuter-Oriented Societal Congestion Index (CSCI) are as follows:

$$\text{SCI} = \text{ICI} \times \frac{\text{ADT}}{100{,}000}$$

$$\text{CSCI} = \text{CICI} \times \frac{\text{200th Hourly Volume x P.M. Directional Split}}{6{,}000}$$

A comparison of the two societal congestion indices for the 19 freeways selected previously revealed that, although the magnitude of the index values were different in some cases, the resulting rankings were not drastically different. Again, however, limited count data are being used to characterize the operation of an entire freeway.

In conclusion, analyses of the Individual Congestion Index and the Societal Congestion Index, as applied to various freeways in Texas, indicate that at least six of the 19 freeways have critical congestion problems and at least seven more have severe problems. Even given the error range in the data evaluated, this conclusion would appear to remain valid. A need for further study of applicable priority treatments exists.

DISCLAIMER

IMPLEMENTATION STATEMENT

Many of the urban freeways in Texas have been experiencing severe traffic congestion problems in recent years. However, traffic engineers and transportation planners currently do not have a generally accepted method of quantifying the severity of that congestion. It was, therefore, desirable to develop a measure of the severity of freeway congestion -- a freeway congestion index. The entire thrust of this report and the primary use of the data and information are implementation.

This report documents the development of two freeway congestion indices, both of which should prove useful to decision-makers and officials of Texas in establishing the relative urgency for implementing mass transit service along various freeway corridors. Other potential uses for these indices include:

- A predictor for potential transit ridership along a specific corridor,
- Correlation with accident data,
- A measure of societal costs due to congestion that can be used in cost/benefit studies, and
- A method for determining priorities for the allocation of construction and operations funds.

In addition, the congestion indices presented in this report appear to be applicable to any urban freeway located in any urban area. These indices are, however, due to data deficiencies, preliminary only.

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INTRODUCTION

Traffic congestion is not a new problem; however, traffic congestion on urban freeways in Texas is a relatively new problem. Most of the urban freeways in Texas were opened during the 1960's and did not begin to experience severe congestion until the 1970's. Today, however, the freeway system in each of the five largest cities in Texas experiences some congestion problems every working day.

The extent of the freeway congestion varies among different freeways in the same city and among freeways in different cities. Stop-and-go traffic conditions may last only twenty minutes in one location while another freeway may be clogged for more than two hours. Certainly, there are degrees of severity for freeway congestion, but, thus far, no quantitative measure of congestion has been developed that can be easily determined and utilized. When asked to describe the severity of congestion on a specific freeway, the general public will respond with terms such as bad, horrible, indescribable, or numerous other unprintable descriptors. Obviously a more precise measure of the severity of freeway congestion is needed.

Mass transportation, or more specifically, techniques for identifying a need for providing mass transportation in Texas cities, has been the focus of this research study (Study #2-10-74-205) since its inception in 1974. Freeway congestion is a major indicator of the potential utilization of mass transportation. Hence, it seemed appropriate for an effort to develop a preliminary freeway congestion index to be conducted as a part of this study.

Initially, the primary usefulness of a congestion index was thought to be an aid in establishing the relative urgency for implementing mass transportation service along various freeway corridors. Numerous other potential uses for a freeway congestion index have become apparent. These include: 1) a predictor for potential transit ridership along the corridor; 2) correlation with accident data; 3) a measure of societal costs due to congestion that can be used in benefit/cost studies; and 4) a method for determining the appropriate allocation of limited construction and operations funds.

This report documents the results of an effort to develop a usable freeway congestion index. Measures of congestion that might be derived from available data are discussed and candidate congestion indices are identified. Limitations in application do result due to the limited data available. Values for each of the candidate congestion indices are calculated and compared for each of 19 freeways in five Texas cities. Finally, recommendations are made as to the best index to use for various applications.

The congestion indices presented in this report were all correlated using the rather limited data available from Texas freeways. However, the resulting indices appear to be applicable to any urban freeway regardless of geographic location. Hopefully, the congestion indices presented in this report will prove useful in all of the applications listed above and will apply to urban freeways in any city. These preliminary indices at least provide a starting point for more intensive evaluations.

MEASURES OF CONGESTION

One of the ground rules for this effort was that only normally available data be used in the resulting congestion indices. Naturally, data that were collected for another purpose are not ideally suited for a congestion index. Thus, one of the major tasks in selecting appropriate measures of congestion is an evaluation of the suitability of available data. Much of the discussion in this chapter relates to the limitations or suitability of specific data as measures of congestion.

Elements of Congestion

The first step in an effort to develop congestion indices is appropriately an identification of the elements of congestion. Discussions concerning this point led to a realization that important elements of congestion differed according to the perspective from which they are viewed. For example, an individual driver trying to negotiate a congested freeway every day in traveling between home and work is concerned about certain specific aspects of congestion. Society in general, on the other hand, when considering the severity of a congestion problem and possible remedial actions is concerned about somewhat different aspects of congestion. The elements of congestion that were identified for use in this study are as follows:

From an individual driver's perspective

1. Extent of speed reductions,
2. Length of congested segments, and
3. Duration of congestion.

From society's perspective

1. Total costs to society (delay, pollution, fuel wasted, etc.), and

2. Rate of increase in congestion.

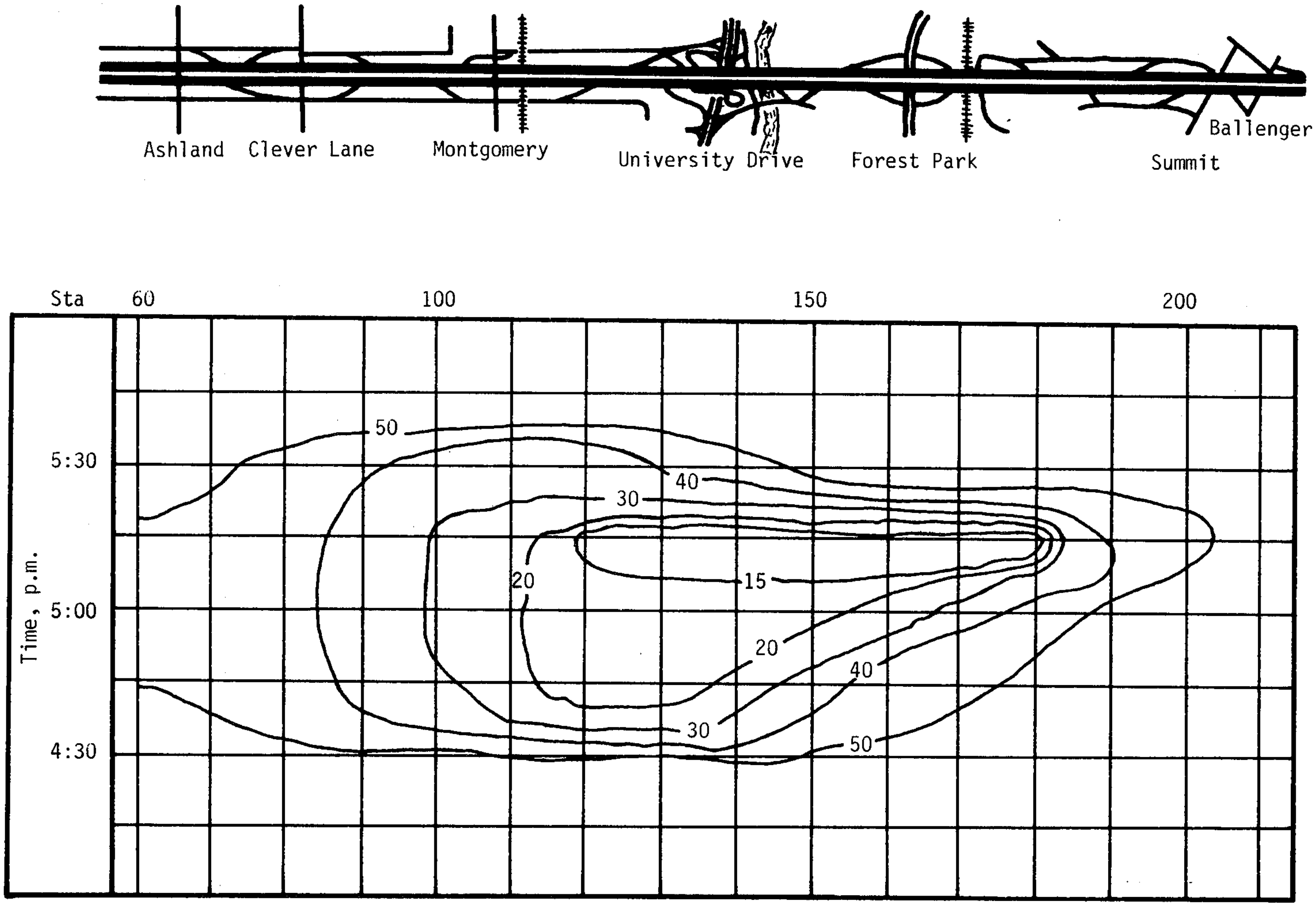
The fact that the important elements of congestion differ with perspective suggests a possible need for two different indices of congestion — an Individual Congestion Index (ICI) and a Societal Congestion Index (SCI). The ICI might be more appropriate for correlation with accident data and as a predictor of potential users of a park-and-ride lot at a specific location. The SCI, on the other hand, seems more appropriate for use in establishing relative urgencies between freeways and allocating funds.

Individual Congestion Index

Once the appropriate elements of congestion are identified, the next step in developing a congestion index is to identify appropriate data to be used to characterize each element[3]. One source of data that is ideally suited for characterizing the specific elements in the ICI (i.e., speed reductions, length of congestion, and duration of congestion) is a speed contour map. An example of a speed contour map developed for the West Freeway (I-30W) in Fort Worth is shown in Figure 1.

Referring to Figure 1, the contour lines denote the speeds that prevail, the horizontal axis measures the length of freeway over which reduced speeds occur, and the vertical axis measures the extent of time (duration) during which reduced speeds occurred. The area bounded by the 20 mph contour denotes the number of hour-miles over which speeds of 20 mph or less are encountered. Thus, by measuring the area bounded by each speed contour, curves can be plotted that

[3] Refer to footnotes 1 and 2, page iv.



Source: State Department of Highways and Public Transportation, Fort Worth Office.

Figure 1: Speed Contours of West Freeway (I-30W) in Fort Worth

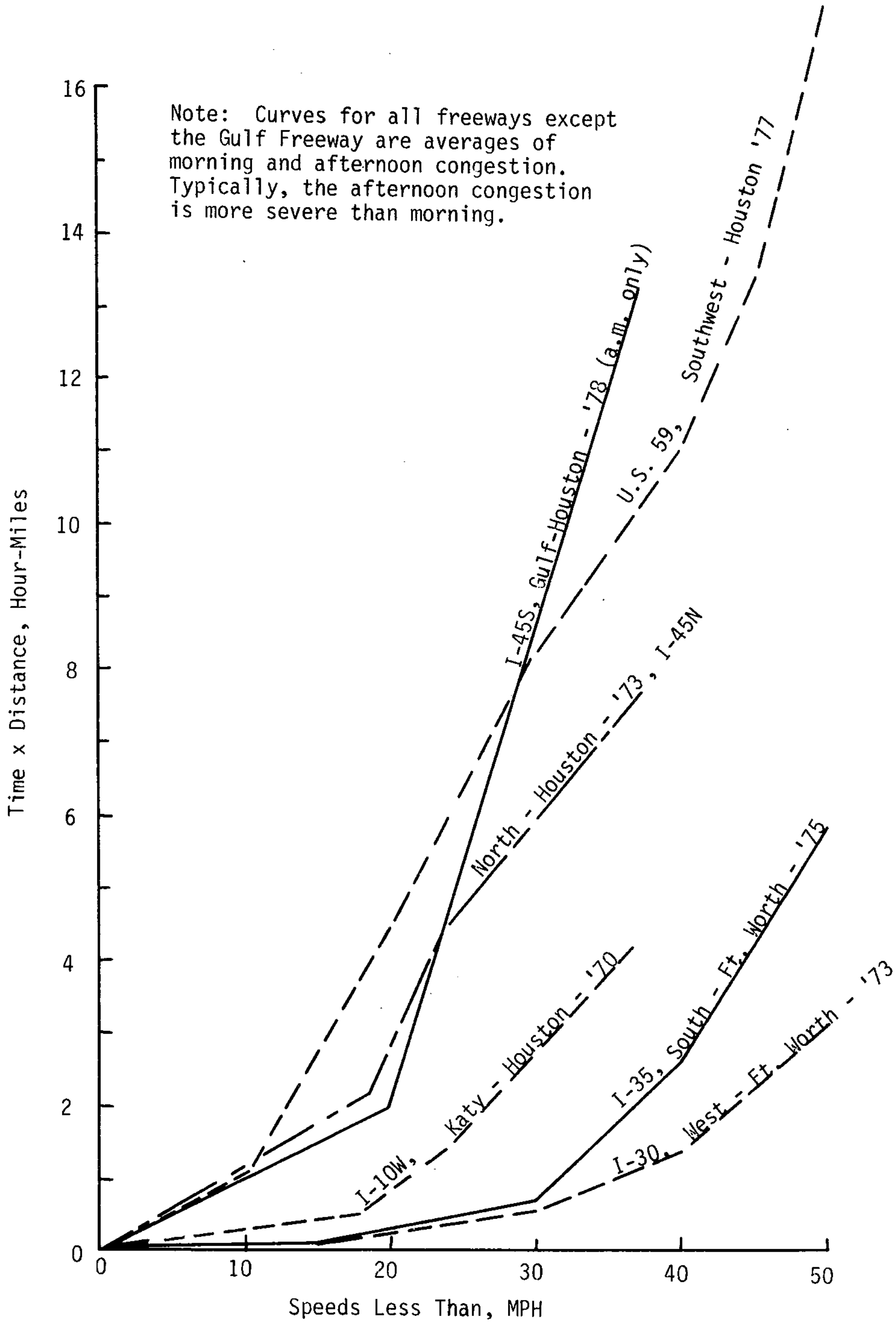
Westbound with All Ramps Open

totally characterize the congestion on a specific freeway as viewed by an individual driver.

Curves representing congestion developed from speed contour maps for several freeways in Texas are presented in Figure 2. The Gulf Freeway (I-45S) and the Southwest Freeway (US 59) in Houston are the most congested freeways included in this comparison. However, it should be noted that the speed contour maps for each freeway were developed in different years (from 1970 to 1978). Therein lies the problem in trying to use speed contour maps as a data source for a congestion index — the process of acquiring a speed contour map is so expensive that it is rarely done. Hence, speed contour maps are not an available source of data on which to base a congestion index for all freeways.

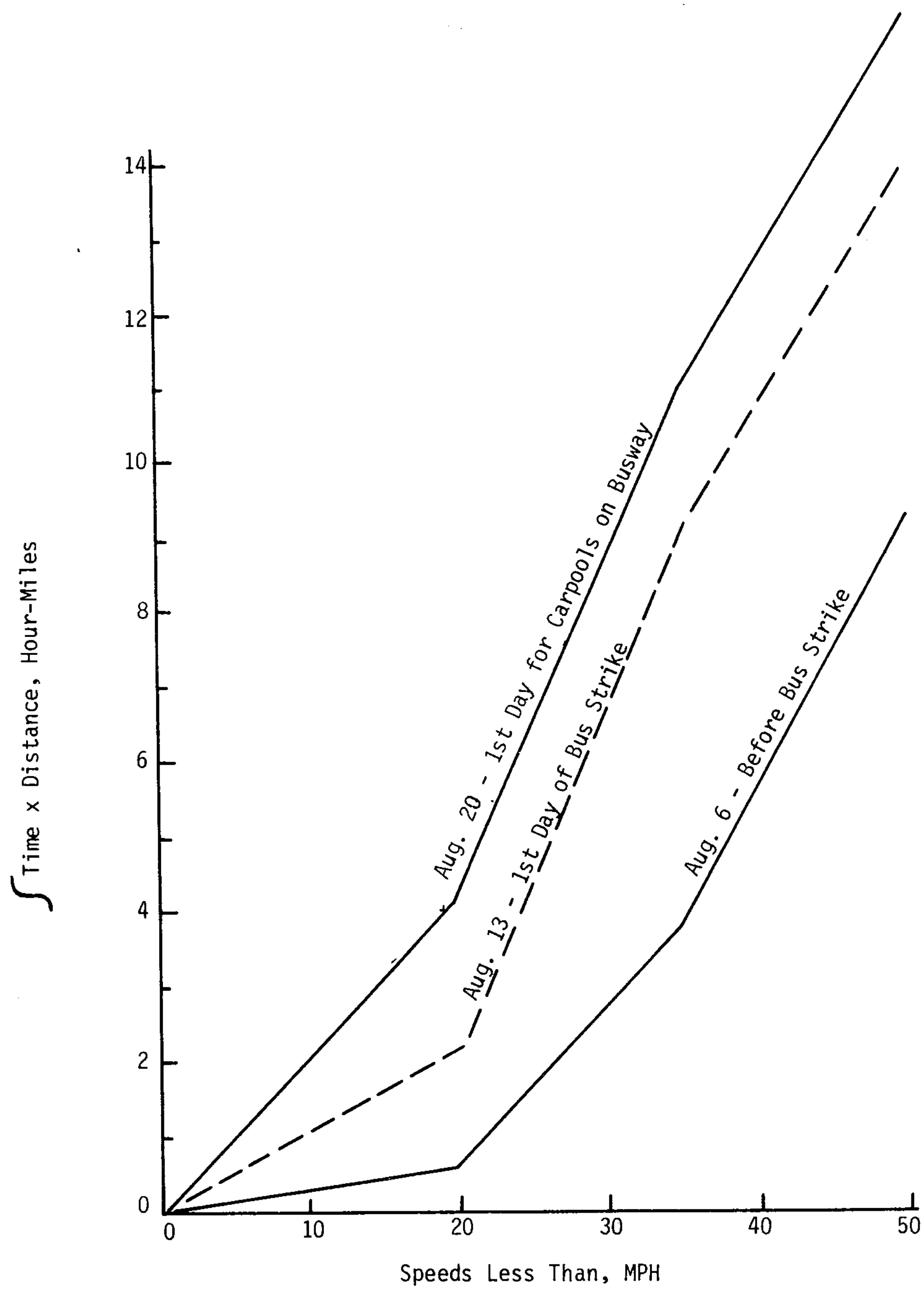
Even though the lack of available speed contour maps prevents their use as a data source for a congestion index, they do appear to offer the most precise characterization of congestion available. Therefore, the data presented in Figure 2 are used as a basis for evaluating the validity of other data sources discussed subsequently.

Since the primary focus of this research study (Number 2-10-74-205) is on mass transportation, it seems appropriate to include some data that dramatically demonstrate the potential effects that mass transportation can have on freeway congestion. The El Monte Busway runs along the San Bernardino Freeway in Los Angeles. During the Summer of 1974, an average of 5600 persons rode buses on the busway each day. Speed contour maps were developed for various days prior to and during a bus strike — resulting congestion curves are presented in Figure 3. As can be seen, the cessation of bus service during the strike had a tremendous impact on congestion. Prior to the strike, the degree of congestion on the main lanes was almost precisely equal to that recorded on Houston's Katy Freeway (I-10W) in 1970. During the strike, even with a special carpool



Sources of Data: Various Speed Contour Maps developed by the State Department of Highways and Public Transportation

Figure 2: Comparison of Freeway Congestion Using Speed Contour Map Data



Source: California Department of Transportation, Traffic Volume and Occupancy Data -- Santa Monica Freeway Peak Periods. October 1976.

Figure 3: Congestion on San Bernardino Freeway in Los Angeles (1974 Bus Strike)

program, congestion on the San Bernardino Freeway was approximately equivalent to that measured on Houston's Southwest Freeway (US 59) in 1977. These data dramatically demonstrate that mass transportation, at least in some situations, can be an effective way to counteract the growing freeway congestion problems in Texas--except during periods of bus strikes.

Returning now to the question of suitable measures to be used in a congestion index, three primary sources of relevant data were identified. These are:

1. Travel Time Studies conducted periodically by the State Department of Highways and Public Transportation in the larger cities in Texas,
2. Automatic Traffic Recorders (permanent count stations) located at various places on the 70,000 miles of state-maintained highways in Texas, and
3. Annual Traffic Volume Maps published by the State Department of Highways and Public Transportation.

Each of these sources offer some special data not available in the others, but they also have special limitations.

For example, travel time studies are conducted only periodically. The most recent available data on travel times in the five largest cities in Texas for use in this analysis are as follows:

Dallas/Fort Worth - 1974-1975,

Houston - 1976,

San Antonio - 1977, and

El Paso - 1978.

Automatic Traffic Recorders (ATR) provide information on the directional split of traffic during peak hours, traffic volumes for specific hours, days, etc., and other useful data. However, many urban freeways in Texas do not have an ATR; on other freeways the ATR is not in the best location. The Traffic Volume

Maps, on the other hand, provide annual average daily traffic counts for virtually every segment of freeway, but they provide no data on peaking characteristics or directional splits. Also, they are not located at the same place as are the ATR data, and they include frontage road volumes which the ATR data do not. That, alone, might cause as much as a 25% difference in calculations using the different freeway volume data.

Despite these limitations, some measures were identified from these data sources that appear to be reasonably good proxies for the elements of congestion. These measures are identified in Table 1 and discussed in greater detail in the following paragraphs.

Table 1: Measures for Elements of Congestion

Elements	Measure	Data Source
1. Extent of Speed Reductions 2. Length of Congestion	Delay Time	Travel Time Studies
3. Duration of Congestion	AADT/Lane or AWT/Lane x P.M. Dir. Split	Traffic Maps or ATR

Note: AADT = Annual Average Daily Traffic
AWT = Average Weekday Traffic

Delay Time

Delay time, the additional time required to traverse a segment of freeway due to congestion during peak hours as opposed to off-peak travel time, should be a reasonably good measure of the combined effects of the extent of speed reductions and the length of freeway over which reduced speeds occur. Values of delay times for selected freeways in Texas are shown in Table 2. (Note: The specific freeways included in this listing are limited to those that have

Table 2: Average Delay Time Due to Congestion

During Peak Hours

Freeway	Value in Minutes	Rank	Ratio (10 = 1.0)
HOUSTON (1976 Data)			
Southwest (US 59 South)	11	6	1.10
Katy (I-10 West)	15	2	1.50
North (I-45 North)	15	2	1.50
Eastex (US 59 North)	11	6	1.10
East (I-10 East)	5	11	0.50
Gulf (I-45 South)	15	2	1.50
West Loop (I-610)	8	9	0.80
DALLAS (1974-75 Data)			
Stemmons (I-35E North)	5	11	0.50
N. Central (US 75 North)	18	1	1.80
Thornton East (I-30 East)	15	2	1.50
Thornton South (I-35E South)	1	18	0.10
LBJ on North Side (I-635)	2	17	0.20
SAN ANTONIO (1977 Data)			
S. PanAm (I-35 South)	4	13	0.40
I-10 West	9	8	0.90
N. PanAm (I-35 North)	3	14	0.30
FORT WORTH (1974-75 Data)			
West (I-30 West)	8	9	0.80
South (I-35 South)	3	14	0.30
EL PASO (1978 Data)			
I-10 East	3	14	0.30
I-10 West	0	19	0

Source of Data: Various Travel Time Studies performed by the State Department of Highways and Public Transportation.

permanent ATR stations on them so that the same freeways can be compared for all measures.)

The specific value of delay time shown in Table 2 is the added time required to drive the total length of the congested portions of the freeway during the peak-hour versus off-peak periods. North Central (US 75) in Dallas has the largest delay time recorded at 18 minutes. Several other freeways show a delay time of 15 minutes. The ranking assigned to each freeway is only an indication of its standing among these 19 freeways.

Each parameter included in this study was "normalized" by dividing the actual value by a par value. The par values were selected so that they would be near the median value for these 19 freeways and also be high enough to indicate a problem on any freeway that exceeds the par value. In the case of the delay time, a par value of 10 minutes was selected. Using a normalized ratio permits various parameters to be combined into indices with equal weighting.

Measures of Duration of Congestion

Two different measures were identified that might be used to indicate the duration of congestion on a specific freeway. The Average Annual Daily Traffic per lane was determined using the Traffic Volume Maps and a knowledge of the freeway cross section to determine the highest value of AADT/Lane that occurs along a freeway (see Table 3).[4] An alternative measure of duration of congestion utilizes the average weekday traffic (Monday-Friday) per lane recorded at permanent ATR stations multiplied by the typical directional split measured during the afternoon peak (see Table 4).

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[4] This highest AADT count is not at the same location as the ATR counts. This accounts for part of the difference in the congestion indices developed in this report.

Table 3: Average Annual Daily Traffic per Lane

(from Traffic Volume Maps)

Freeway	AADT/Lane*	Rank	Ratio (20,000 = 1.0)
HOUSTON			
Southwest (US 59)	22,852	6	1.1
Katy (I-10)	22,035	8	1.1
North (I-45)	23,106	5	1.2
Eastex (US 59)	20,452	10	1.0
East (I-10)	22,655	7	1.1
Gulf (I-45)	25,251	2	1.3
West Loop (I-610)	23,765	4	1.2
DALLAS			
Stemmons (I-35E)	15,749	14	0.8
N. Central (US 75)	27,795	1	1.4
Thornton - East (I-30)	13,072	17	0.7
Thornton - South (I-35E)	12,469	18	0.6
LBJ - north side (I-635)	17,311	12	0.9
SAN ANTONIO			
S. PanAm (I-35)	20,785	9	1.0
Northwest (I-10)	24,032	3	1.2
N. PanAm (I-35)	18,012	11	0.9
FORT WORTH			
West (I-30)	14,157	16	0.7
South (I-35W)	14,912	15	0.7
EL PASO			
I-10 East	15,871	13	0.8
I-10 West	6,295	19	0.3

*Maximum value of AADT/Lane noted on each freeway. This does not necessarily occur at the same location as does the highest AADT.

Table 4: Average Weekday Traffic per Lane

Modified by Directional Split

Freeway	ATR Sta. #	# of Lanes	$\frac{\text{AWT}}{\text{Lane}}$ x P.M. Dir. Split	Rank	Ratio (10,000 = 1.0)
HOUSTON					
Southwest (US 59)	S-140	9	12,471	4	1.2
Katy (I-10W)	S-141	7*	11,840	5	1.2
North (I-45N)	S-142	8	10,527	8	1.1
Eastex (US 59)	S-124	8	8,712	13	0.9
East (I-10E)	S-154	8	9,116	11	0.9
Gulf (I-45S)	S-089	7*	12,891	2	1.3
W. Loop (I-610)	S-156	8	12,684	3	1.3
DALLAS					
Stemmons (I-35)	S-126	10	7,136	17	0.7
N. Central (US 75)	S-169	6	8,618	14	0.9
Thornton East (I-30)	S-147	8	9,933	9	1.0
Thornton South (I-30E)	S-148	8	9,315	10	0.9
LBJ North (I-635)	S-170	8	9,032	12	0.9
SAN ANTONIO					
South PanAm (I-35S)	S-106	4	10,888	6	1.1
Northwest (I-10)	S-094	4	12,927	1	1.3
North PanAm (I-35N)	S-108	4	8,558	15	0.9
FORT WORTH					
West (I-20)	S-130	4	10,693	7	1.1
South (I-35S)	S-109	6	7,619	16	0.8
EL PASO					
I-10 East	S-162	10	5,020	18	0.5
I-10 West	S-123	4	2,220	19	0.2

*Note: These ATR's are located immediately adjacent to where the freeway widens from 6 lanes to 8 lanes, an average width of 7 lanes was used.

A comparison of the ranking of freeways in Tables 3 and 4 reveals some of the differences in these two measures. For example, North Central (US 75) in Dallas has the highest AADT/Lane (Table 3) but is ranked 14th in AWT/Lane x P.M. Directional Split (Table 4). This difference is primarily because the ATR station is located in one of the less critical places on North Central (US 75). This problem with locations of ATR stations also influences the ranking of Eastex Freeway (US 59).

The other differences in rankings of specific freeways on these two tables stem primarily from the differences in these two measures. The first, AADT/Lane, tends to emphasize those freeways that have reasonably balanced flow and heavy midday traffic. The second measure, AWT/Lane x P.M. Directional Split, places more emphasis on problems during normal commuter traffic. As a result, freeways that have significant commuter problems but little off-peak traffic, such as R. L. Thornton-East (I-30) in Dallas, are ranked higher on Table 4 than on Table 3. This difference in measures results in slight differences in the congestion indices formulated in the following paragraphs.

Candidate Indices

Two candidate congestion indices were formulated to measure freeway congestion from an individual driver's perspective. The first uses data from the Traffic Volume Maps and tends to emphasize those freeways that are heavily utilized throughout the day. The formula for this Individual Congestion Index is:

$$ICI = \frac{\text{Delay Time in min.}}{10''} + \frac{\text{AADT/Lane}}{20{,}000}$$

The second index formulated uses data from permanent ATR stations and tends to place greater emphasis on commuter-oriented problems. Again, the Traffic Volume Map data and the ATR data are from different locations along the freeway. This Commuter-Oriented Individual Congestion Index is calculated as follows:

$$\text{CICI} = \frac{\text{Delay Time in min.}}{10''} + \frac{\text{AWT/Lane x P.M. Directional Split}}{10{,}000}$$

These two indices are compared in Table 5. Perhaps the most surprising observation concerning this comparison is that there is very little difference between these two indices. The two index values are quite similar for each individual freeway, and the relative ranking among these 19 freeways changes very little. Of course, both indices have the same first term (delay time in min./10") so that the differences in their second terms are moderated somewhat.

Validation of Indices

Curves derived from Speed Contour Maps provide the most precise characterization of the elements of freeway congestion as viewed by the individual driver; however, the scarcity of Speed Contour Maps prohibits their use as the basis for a congestion index. The curves shown in Figure 2, page 7, were used, however, as a check of the validity of the two candidate congestion indices developed to model the same characteristics. The results of this validity check are shown in Figure 4, page 18.

The Speed Contour Index, used as the vertical axis for Figure 4, is the area under each curve on Figure 2 out to a speed of 35 mph divided by a par value of 70. The index values measured on the horizontal axis are calculated using the formulas for ICI and CICI but plugging in data for the appropriate year for each freeway shown on Figure 2.

Table 5: Comparison of Indices of Freeway Congestion from an Individual Driver's Perspective

Freeway	ICI Value	Rank	CICI Value	Rank
HOUSTON				
Southwest (US 59)	2.2	5	2.3	6
Katy (I-10W)	2.6	4	2.7	2
North (I-45N)	2.7	3	2.6	4
Eastex (US 59)	2.1	7	2.0	9
East (I-10E)	1.6	10	1.4	12
Gulf (I-45S)	2.8	2	2.8	1
W. Loop (I-610)	2.0	9	2.1	8
DALLAS				
Stemmons (I-35)	1.3	13	1.2	13
N. Central (US 75)	3.2	1	2.7	2
Thornton East (I-30)	2.2	5	2.5	5
Thornton South (I-30)	0.7	18	1.0	17
LBJ North (I-635)	1.1	15	1.1	15
SAN ANTONIO				
South PanAm (I-35S)	1.4	12	1.5	11
Northwest (I-10)	2.1	7	2.2	7
North PanAm (I-35N)	1.2	14	1.2	13
FORT WORTH				
West (I-20)	1.5	11	1.9	10
South (I-35S)	1.0	17	1.1	15
EL PASO				
I-10 East	1.1	15	0.8	18
I-10 West	0.4	19	0.3	19

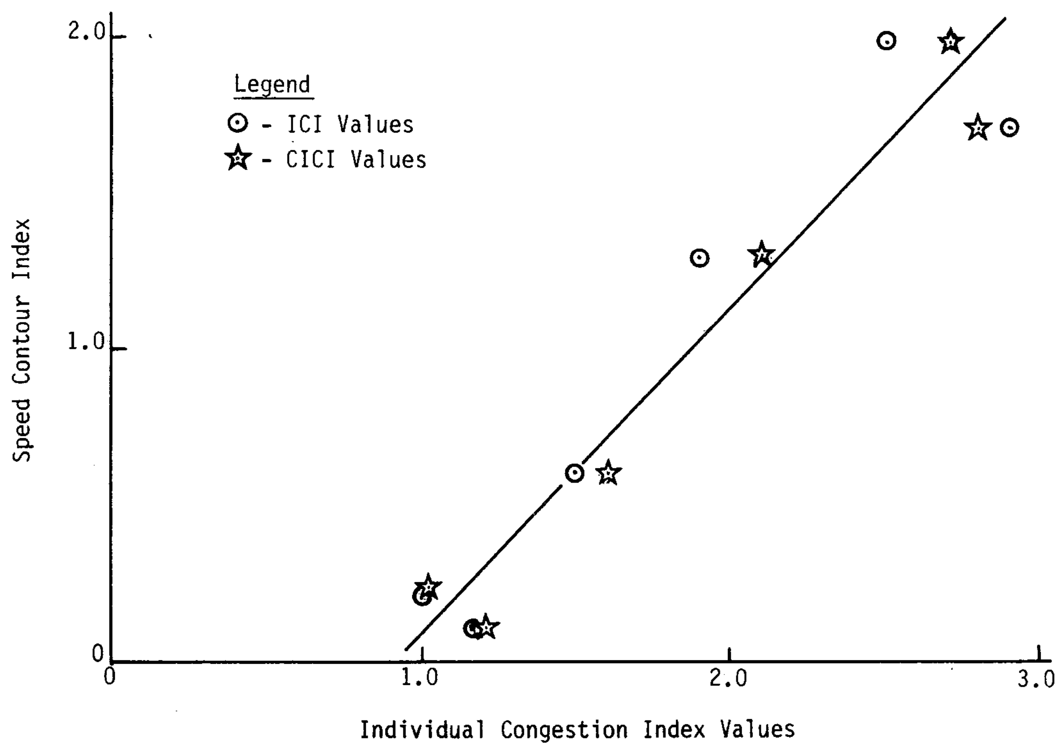

Figure 4: Check of Validity of Candidate Indices - Individual's Perspective

A reasonably good correlation between the candidate indices and the data based on Speed Contour Maps is depicted by Figure 4. The CICI values agree slightly better than the ICI values; however, both indices appear to provide a reasonably good measure of congestion.

Societal Congestion Index[5]

The two elements of congestion that were identified from society's perspective are:

1. Total costs to society (delay, pollution, fuel wasted, etc.), and
2. Rate of increase in congestion.

The importance of the first element is obvious. The second element is included as an indication of the level of public concern about a congestion problem. It seems that the general public becomes far more concerned if congestion is increasing at a perceptible rate. In other words, the level of public concern seems to be more closely related to the rate of increase in congestion than to the actual severity of the congestion problem.

Even though the rate of increase in congestion is a key element in how society views the congestion problem, it does not seem to be an appropriate measure to be included in a congestion index. Rather, it seems more appropriate to use the rate of increase as a separate consideration in addition to the congestion index. For example, a freeway with a moderately severe congestion index and a rapid growth rate might be considered equally in need of urgent corrective measures as a freeway that has a critical congestion index but is exhibiting little traffic growth.

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[5] Refer to footnotes 1 and 2, page iv.

Of course, congestion itself can be a limiting factor in the rate of increase in traffic on a specific freeway. However, one surprising observation about the growth rates presented in Table 6 is that traffic volumes are continuing to increase rapidly on several freeways that were severely congested in 1972. Specific examples of this are North Central (US 75) in Dallas and Southwest (US 59) in Houston. Generally, the growth rates noted tend to reflect the rate of development along certain corridors within each city.

It is interesting to note that El Paso freeways exhibit the highest average increase in traffic at 37%, while Houston edges out Dallas for second highest at 25% compared to 22%. If these high growth rates continue, severe congestion will soon develop on freeways that are not presently encountering major problems. As noted previously, however, growth rates seem more appropriately a separate factor to consider rather than a component of a congestion index.

A rather simple approach to quantifying the total costs of congestion to society would be to take the congestion indices developed from an individual's perspective and multiply them by a measure for the total number of individuals involved. Hence, two candidate formulas for the Societal Congestion Index are as follows:

$$SCI = ICI \times \frac{AADT}{100{,}000}, \text{ and}$$

$$CSCI = CICI \times \frac{\text{200th Hourly Volume} \times \text{P.M. Directional Split}}{6000}$$

Resulting indices for the 19 selected freeways are compared in Table 7, page 22.

Table 6: Growth Rates in Traffic Volumes on Selected Freeways in Texas

FREEWAY	% INCREASE IN AADT* (1972-1977)	RANK
HOUSTON		
Southwest (US 59 South)	40	3
Katy (I-10 West)	25	8
North (I-45 North)	23	9
Eastex (US 59 North)	15	12
East (I-10 East)	37	5
Gulf (I-45 South)	20	10
West Loop (I-610)	13	14
DALLAS		
Stemmons (I-35E North)	8	16
N. Central (US 75 North)	33	6
Thornton East (I-30 East)	7	17
Thornton South (I-35E South)	18	11
LBJ North (I-635)	43	1
SAN ANTONIO		
S. PanAm (I-35 South)	-4	19
I-10 West	10	15
N. PanAm (I-35 North)	40	3
FORT WORTH		
West (I-20 West)	14	13
South (I-35 South)	7	17
EL PASO		
I-10 East	43	1
I-10 West	31	7

*From Traffic Volume Maps, State of Texas.

Table 7: Comparison of Candidate Indices for Freeway Congestion as Viewed by Society

Freeway	SCI		CSCI	
	Index Value	Rank	Index Value	Rank
HOUSTON				
Southwest (US 59 South)	4.4	3	3.0	1
Katy (I-10 West)	4.4	2	2.7	4
North (I-45 North)	3.8	4	2.6	5
Eastex (I-59 North)	2.5	7	1.8	8
East (I-10 East)	1.9	10	1.4	10
Gulf (I-45 South)	5.0	1	2.8	2
West Loop (I-610)	3.8	4	2.5	6
DALLAS				
Stemmons (I-35E North)	1.7	11	1.2	12
N. Central (US 75 North)	3.5	6	1.9	7
Thornton East (I-30 East)	2.2	8	2.8	2
Thornton South (I-35E South)	0.7	18	1.1	13
LBJ North (I-635)	1.5	12	1.1	13
SAN ANTONIO				
S. PanAM (I-35 South)	1.1	14	0.8	15
I-10 West	2.1	9	1.3	11
N. PanAm (I-35 North)	0.8	16	0.6	17
FORT WORTH				
West (I-30 West)	1.3	13	1.7	9
South (I-35W South)	0.8	16	0.8	15
EL PASO				
I-10 East	1.1	14	0.6	17
I-10 West	0.2	19	0	19

$$\text{Societal Congestion Index (SCI)} = \left[\frac{\text{Delay Time}}{10} + \frac{\text{AADT/Lane}}{20{,}000}\right] \times \frac{\text{AADT}}{100{,}000}$$

Commuter-Oriented Societal Congestion Index

$$\text{(CSCI)} = \left[\frac{\text{Delay Time}}{10} + \frac{\text{AWT/Lane x P.M. Dir. Split}}{10{,}000}\right] \times \frac{\text{200th hr. Vol. x P.M. Dir. Split}}{6{,}000}$$

Although the magnitude of the values shown for these two indices are different (SCI ranges from 0.2 to 5.0, while CSCI ranges from 0 to 3.0), the resulting rankings are not drastically different. The most significant difference is that R. L. Thornton (I-30) in Dallas is ranked 8th by the SCI and 2nd by the CSCI. This difference in rankings highlights the greater emphasis that the Commuter-Oriented Societal Congestion Index (CSCI) places on freeways that have severe congestion only during peak commuter traffic.

OBSERVATIONS AND RECOMMENDATIONS

The findings of this effort to quantify freeway congestion are not absolute and conclusive by any means and need to be viewed, primarily due to data deficiencies, as preliminary. However, several observations and recommendations can be made on the basis of this study.

Recommended Indices

Four candidate indices have been identified that appear to be suitable for use in quantifying freeway congestion. The potential uses for a congestion index that were identified in the Introduction are sufficiently different in nature that it seems appropriate to use two different indices--an Individual Congestion Index for correlating accident data or for predicting park-and-ride patronage, etc., and a Societal Congestion Index for evaluating the urgency for corrective action and allocating scarce funds. It should be noted that the indices are not directly comparable in that AADT traffic counts and the ATR traffic data used to develop the indices are not from the same location on the freeway.

The primary question that remains concerning appropriate indices is whether the commuter-oriented set of indices is more appropriate than the set that gives higher values for freeways with heavy midday use. Here again, the two sets of indices seem to be tailored to different uses. The commuter-oriented set appears better for evaluating the potential for mass transportation along a corridor, while the other set seems a better assessment of society's concerns.

The question of which set of indices is better probably can never be answered to the satisfaction of everyone. More data collection and analysis would be needed to develop better indices. The relative availability of data for use in the two sets of indices is, however, a major consideration in selecting one for use. The commuter-oriented indices require data that are only collected at permanent Automatic Traffic Recorder stations. Currently, only 19 of a total of 30 freeways in the five largest cities in Texas have ATR stations on them--and some of those 19 are in a poor location for the purposes of a congestion index. Hence, it is recommended that the following formulas be used as freeway congestion indices:

$$\text{Individual Congestion Index (ICI)} = \frac{\text{Delay Time in min.}}{10''} + \frac{\text{AADT/Lane}}{20{,}000}$$

and

$$\text{Societal Congestion Index (SCI)} = \text{ICI} \times \frac{\text{AADT}}{10{,}000}.$$

Again, these indices are based on counts at one location on the freeway, and the resulting value is assumed to be representative of the freeway as a whole.

Interpretation of SCI Values

Although the index values cited in this report are carried to two significant figures, it should be recognized that the range of accuracy of the values is rather large. In other words, there may not be any real difference between the actual congestion on freeways that have index values of 3.5 and 3.8, respectively. As a minimum, these index values should be interpreted as having an error range of ±10 percent. Considerations such as frontage road volumes and inaccuracies in measuring delay could easily give an error range of ±25 percent. Major decisions concerning improvements needed should not be based on differences of less than this range.

Indeed, the recommended interpretation of index values is as follows:

SCI Value	Interpretation of Congestion Problems
>3	Critical
∿1.5 to 3	Severe
∿0.5 to ∿1.5	Bad
<0.5	Acceptable

According to this interpretation, at least six urban freeways in Texas have critical congestion problems (Table 8), and at least seven more have severe problems. Comparing the congestion index values of these Texas freeways to some rather well-known freeways elsewhere in the nation helps to support the "critical" label (Table 8).

Urgency for Action

Not only has the congestion problem already reached the critical state on several freeways in Texas, if recent trends continue, many more freeways will become critically congested before remedial measures can be implemented. This trend has been most dramatically evident in Houston in recent years. SCI values were calculated for Houston freeways for 1969 and 1973 as well as 1977. The resulting index values are presented in Table 9. In only eight years, the average SCI value for freeways in Houston jumped from 1.2 to 3.6--i.e., from merely "Bad" to "Critical."

Certainly, the need for remedial action is urgent. The comparison of freeway congestion on the San Bernardino Freeway presented in Figure 3 (page 8) demonstrates the potential that mass transportation offers at least in some instances in coping with the congestion problem in some metropolitan areas. It appears that a true need for mass transportation has developed in Texas.

Table 8: A Comparison of Congestion on Freeways in Texas and Other Locations

Freeway/City	SCI Value
Gulf-Houston (I-45S)	5.0
Katy-Houston (I-10W)	4.4
Southwest-Houston (US 59)	4.0
North-Houston (I-45N)	3.8
W. Loop-Houston (I-610)	3.8
N. Central-Dallas (US 75)	3.5
Eastex-Houston (US 59)	2.5
Thornton East-Dallas (I30E)	2.2
Northwest-San Antonio (I-10)	2.1
Carpenter-Dallas (SH 183)	2.0
East-Houston (I-10E)	1.9
Stemmons-Dallas (I-35)	1.7
LBJ North-Dallas (I-635)	1.5
Santa Monica-Los Angeles	4.7
San Bernardino-Los Angeles	3.3
Southeast-Boston	2.2
Banfield-Portland	1.8

$$SCI = \left[\frac{\text{Delay Time}}{10} + \frac{\text{AADT/Lane}}{20{,}000}\right] \times \frac{\text{AADT}}{100{,}000}$$

Table 9: Trends in Congestion on

Houston Freeways

Freeway	Societal Congestion Index*		
	1969	1973	1977
Southwest (US 59)	1.3	2.5	4.0
Katy (I-10W)	1.3	2.7	4.4
North (I-45N)	1.0	2.1	3.8
Eastex (US 59)	0.6	0.4	2.5
East (I-10E)	0.3	0.7	1.9
Gulf (I-45S)	3.1	3.2	5.0
W. Loop (I-610)	1.0	2.2	3.8
Average for All Freeways	1.2	2.0	3.6

$$\text{*SCI} = \left[\frac{\text{Delay Time}}{10} + \frac{\text{ADT/Lane}}{20{,}000}\right] \times \frac{\text{ADT}}{100{,}000}$$

Note: The delay times used in calculating the 1977 SCI were actually measured in 1976; thus, the actual congestion indices for 1977 are probably higher than shown.