THE VISUAL ENVIRONMENT: ITS EFFECTS ON TRAFFIC FLOW

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This study was directed toward exploring the relationship between urban arterial traffic flow and the arterials' visual surrounding. The hypothesis was that the visual environment in which an arterial resides provides an input into the operation of a vehicle, and because it provides an input into this operation it might logically contribute to the output of the operation. The concern in this study was directed toward defining how various visual inputs from an arterial street's visual environment related to the operational output of the driver-vehicle system. Specifically, the question to be answered was: Does poor visual environment for driving have a direct relationship to the breakdown in urban areterial flow? The visual input into the driver-vehicle system was defined by three generalized categories: (a) color contrasts of possible focal points, (b) dynamics of possible focal points, and (c) naturalness of focal areas. The effects that variance in these three categories of visual input had on the breakdown of the operational output of the driver-vehicle system was categorized by the number of accidents and the amount of interference to travel apparent along the study segments. The results of the study indicate that there does indeed exist a direct relationship between an arterial's visual environment and the ability of that arterial to handle traffic without a high number of accidents and/or a high rate of interference to traffic flow.

•ONE of the most complex and frustrating problems in the urban environment is the loss of mobility. It seems incongruous that in the space age intracity travel by automobile requires an inordinate use of time and can cause the destruction of property and, in some cases, even life.

The main source of mobility in the city is the combination of arterial streets and the private automobile. When this combination of facility and hardware breaks down, the transportation system of the city collapses.

The effects that a breakdown in the automobile-arterial street system has on the city are conclusive evidence, if any were needed, that the arterial street system is an integral part of the larger system in which it exists—the city.

A great amount of time, energy, and money has been spent on the evaluation of the effects that the arterial street system has on the areas it serves and on its city in general. In the jargon of systems engineering, the arterial street system is an open system; i.e., its functioning affects the functioning of the environment in which it operates. If, indeed, this is the evaluation premise being used, then it must also be accepted that the functioning of the environment affects the functioning of the arterial streets. Mutual interaction is the definition of an open system.

It is the purpose of this report to state the findings of a study designated to explore the relationship between the environment in which an arterial is confined and the functioning of that arterial. Specifically, we were concerned with the effects the visual display along an arterial had on the traffic flow characteristics and the accident history of

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that arterial. The question toward which this study was directed was: Does an unattractive visual environment stimulate traffic congestion and contribute to the causation of traffic accidents?

Kansas City, Missouri, is the hub of a growing metropolitan area of more than 1 million population. The importance of the arterial streets in this city may be greater than in others because of the city's early commitment to certain parkways that now serve as the main network facilitating traffic flow. A compounding factor has been the rather slow and ineffectual freeway development that has perpetuated the use of the parkways as the main traffic-carrying system.

Kansas City is an excellent example of a city dependent on arterials and the private automobile for mobility. Because of this dependence and because of pertinent studies (3) previously conducted there, Kansas City was selected as the study site.

STUDY APPROACH

This study was predicated on the premise that the basic element in a study of arterial vehicular flow is the driver-vehicle (D-V) system. The D-V system is a combination of man and machine that accomplishes, as an output of their interaction, movement or mobility.

Because the D-V system has the output of movement, interest concerning the input into this system and how this input is perceived must be expressed. Human beings manage the system, and their response to sensory stimuli when driving is most important. Therefore, we are concerned with inputs into the D-V unit that are stimuli to the human senses.

The most profoundly important of the driver's senses is of course the sense of sight. Thus, if the basic element of vehicular flow to be analyzed is the input-output system known as the driver-vehicle system, then the inputs into this system are elements serving as stimuli to the human senses (mainly the sense of sight) and the output of this system is movement:

We were concerned in this study with the failure of the output of the D-V unit and the visual input associated with this failure. In this regard, the breakdown in arterial flow was seen as a collective breakdown in the outputs of the large number of individual D-V units involved. This breakdown of arterial flow as seen by the individual driver took the form of (a) interference with his travel desires (such as congestion) and (b) inability of his vehicle to function (such as might occur as the result of being involved in an accident).

If interference and accidents represent the breakdown in the output of the D-V system, the question to be explored is: What are the inputs in the D-V system associated with this breakdown? More specifically, are there certain visual inputs emanating from the arterial street environment, from the signs, people, buildings, parked cars, color combinations, etc., that help cause this breakdown in output?

Study Methodology

There should be little question that any analysis of the effects of visual input on traffic flow is based on incomplete knowledge. We simply do not know all there is to know about the situation; therefore, the mathematics of this study was based on inductive reasoning. For this reason the standard correlation analysis technique was forsaken in favor of a simpler and, in the authors' opinion, more pertinent inductive type of analysis. In this type of analysis statements concerning the elements that one wants to relate are made, and these statements are in turn converted directly into the appropriate probability equation (1).

The following discussion is presented to aid in understanding this type of analysis.

A capital letter symbol is used to represent a statement. An example of this would be C = the capacity does not exceed 2,000 vph. A lower case letter is used to present the declaration of "untruth" or the denial of the capital letter symbol. This is exemplified by c = the capacity exceeds 2,000 vph.

The manner by which two or more statements are combined depends on the thought one desires to express. The conjunction form is taken to mean that the statements are all true. This conjunction combination can be seen in the following example:

Suppose

Statement D = the volume exceeds 2,000 vph

Now

CD = the capacity does not exceed 2,000 vph and the volume exceeds 2,000 vph

A second form (inclusive disjunction) makes use of a plus sign (+) to combine the statements and is taken to mean that one or the other or both the statements are true. For instance:

C + D = the capacity does not exceed 2,000 vph, or the volume exceeds 2,000 vph, or both the capacity does not exceed 2,000 vph and the volume exceeds 2,000 vph

"The equal sign does not mean that the statements mean the same thing. Rather if two statements are said to be equal we mean they have the same truth table. That is, if A = B we mean that whenever A is true, B is true and whenever A is false B is false. Also, whenever B is true, A is true and whenever B is false, A is false (1)".

"An important relationship is given by the pair of equations:

$$A = BC$$

$$a = b + c$$

"This is verified by the following truth table.

B	C	A = BC	a = b + c
T	T	T	F
T	F	F	T
F	F	F	T
F	T	F	T

"It is seen that the denial of (BC) is (b + c) as shown in the first column" (1). A more detailed description of this procedure is given by Tribus (1).

The logic statements were structured in accordance with this analysis technique and with the D-V input-output base used in this study. The structuring was done in two separate and distinct phases. The first phase analyzed was the output component. In this component, interest was directed toward the breakdown of the D-V unit, described previously as being accidents and interference, during a sample period approximating the peak hour.

Symbolically these statements were recorded as follows:

E = no accident involving D-V unit
F = no interference with D-V unit
G = no breakdown of D-V unit during peak-hour sample

Therefore, $EF = G$

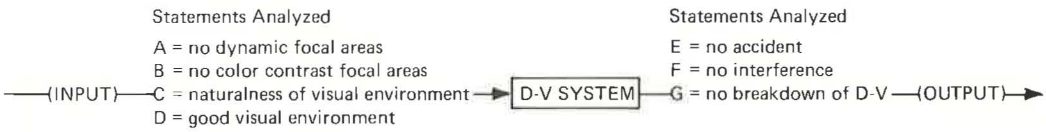
The second phase analyzed was the input component. In this phase we were concerned with describing "good visual environment for driving." Specifically, we wanted to test how dynamic areas of possible focus, focal areas of contrasting color, and naturalness of visual environment related to good visual environment for driving. The use of these three criteria will be discussed in more detail in a later section, but it should be pointed out now that it was felt that, as dynamic areas of possible focus (areas that either are moving or are capable of eminent movement) and focal areas of contrasting color increased in the visual environment along an arterial, and as the naturalness of the visual environment diminished, a resultant increase in D-V output breakdown would occur.

Symbolically these statements were recorded as follows:

A = no dynamic focal areas
B = no color contrast of focal areas
C = naturalness of focal areas
D = good visual environment for driving

Therefore, $ABC = D$

A summary of the modeling technique is provided in the following schematic diagram:



As is always the case in the use of input-output systems analysis, we were interested exclusively in the inputs and the resultant outputs and not in the process of assimilation that occurs in the system itself.

In order to quantify these symbolisms, four points had to be considered:

1. Designation of arterial streets to be studied, with the criterion for selection being that the streets be functionally the same but visually dissimilar;
2. Calibration of the accident history of the arterials to be studied in universal numerical terms, namely, probabilities;
3. Calibration of the interference on the arterials to be studied; and
4. Measurement of the three visual input categories from the environment in which the study arterials reside.

DETERMINATION OF POINTS OF CONSIDERATION

Designation of Study Arterials

The first step in the development of the study arterials was the functional classification of Kansas City's roadway network (Fig. 1).

The functional classification scheme (2) contained five categories: (a) principal, (b) primary, (c) secondary, (d) tertiary, and (e) local. In developing this functional classification, all existing and committed streets were studied. This study was directed toward defining, in a hierarchy, the functions performed by each street and highway. Function in this context refers simultaneously to the predominant characteristics of the facility such as traffic volumes, trip lengths, trip purpose, and adjacent traffic generators. Specifically, if a roadway "connected" several principal traffic generators, carried a great deal of traffic, and handled mostly through trips, it was said that the roadway was serving a principal function. If the roadway served primary traffic generators, a somewhat lower volume, and a lower percentage of through trips, it was said that the roadway was serving a primary function.

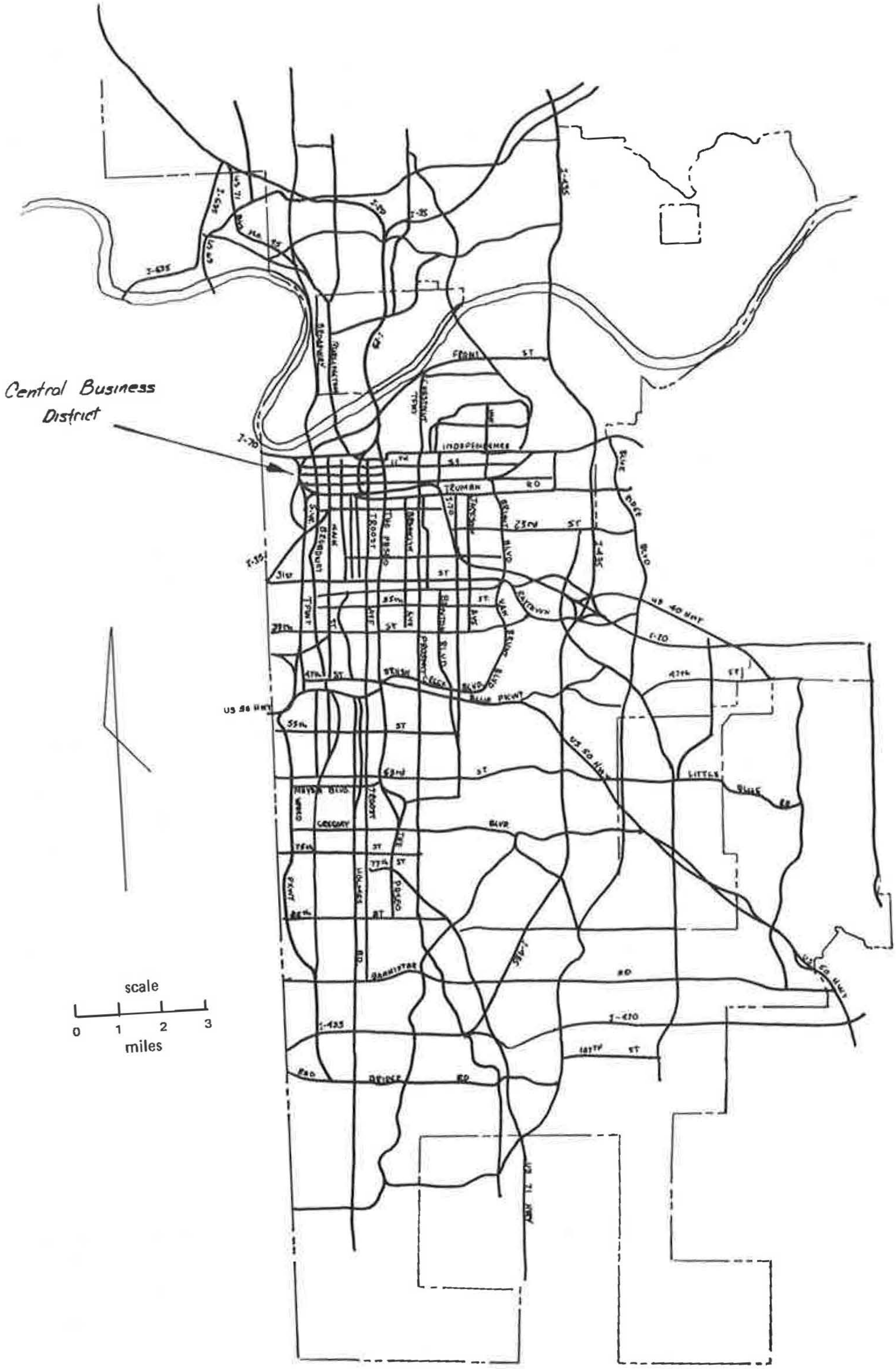


Figure 1. Kansas City's arterial network.

Following these criteria, generators of each category were located and roadways serving these generators were designated. It was frequently found that, because of the limited capacity on many of the principal streets, two streets in a corridor were serving a principal function. When this situation occurred, both streets were classified as principal arterials.

The arterial streets in Kansas City that were classified as principal arterials were selected as the arterials for study. The functional classification used to designate these arterials was important in that it helped ensure that the comparison of study arterials would not be warped by differences in characteristics such as trip length.

To reduce this rather formidable system into a more manageable network and to obtain an array of visual environments, the following arterial segments were selected for detailed study (Fig. 2):

1. Ward Parkway, 52nd to 75th Streets;
2. Broadway Avenue, 29th to 47th Streets;
3. Main Street, 29th to 47th Streets;
4. Troost Street, 29th to 47th Streets;
5. The Paseo, 29th to 47th Streets;
6. 31st Street, Southwest Trafficway to Woodland Avenue;
7. Linwood Boulevard, Southwest Trafficway to Woodland Avenue; and
8. 47th Street and Brush Creek Boulevard, Southwest Trafficway to Woodland Avenue.

It should be noted that these segments represent arterials with quite similar functional characteristics but different visual characteristics. (It should be further noted that the functional similarity includes the number of major streets with which the segments intersect.)

System Breakdown Caused by Accidents on Arterial System

A vehicular accident is the first indication that the D-V system has failed. In order to relate this type of D-V output, it was assumed that an accident is an occurrence during a trip to which a probability can be assigned (3).

A systematic analysis of accident rates was conducted. The first step in this analysis was the totaling of the mid-block accidents for each of the mid-block segments on the study arterials. The second step was the determination of the volume of each of these locations. From these data, the probability of the occurrence of a mid-block accident on each of the arterial segments was developed.

The quantitative statement of a mid-block accident probability was determined by dividing the number of accidents occurring in a mid-block during an average accident day by the number of vehicles through that location in a day (average daily traffic).

The result of this analysis was the probability of a mid-block accident per D-V unit trip through the study segment. The results are given in Table 1.

System Breakdown Caused by Interference on Arterial System

To relate travel interference quantitatively to the D-V unit breakdown phenomenon it was necessary to simultaneously relate desire for travel with the study segments' ability to meet this desire.

A common means of obtaining such data is by the standard speed and delay studies. However, speed and delay data are related to so many other phenomena that their legitimacy as a determination of arterial functionality is in some doubt. Other studies, less used, offer informational output that is much more pertinent than are speed and delay studies.

An automobile trip can be idealized as an isolated driver-vehicle unit negotiating conflicts derived from various forms of extraneous interference. Extraneous interference in this context may be thought of as any stimuli input into the driver-vehicle system that causes an overt reaction perceivable as a change in velocity. An extraneous interference may be any of the following: (a) other vehicles, (b) pedestrians, (c) geometric configuration, (d) traffic control equipment, and (e) other visual input from environment.

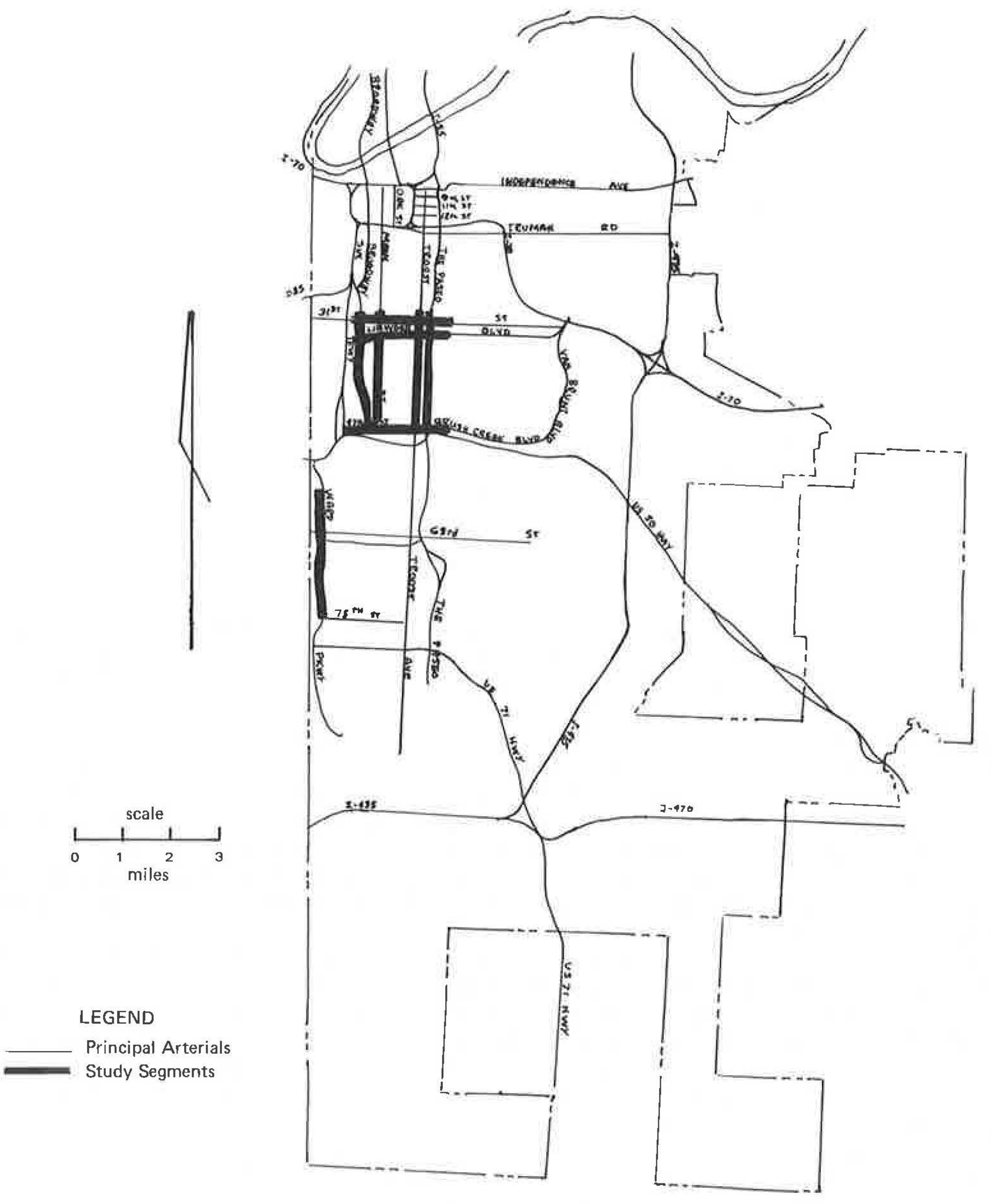


Figure 2. Principal arterial streets and study segments.

If this idealization can be accepted, the problem of rating the functionality of an arterial becomes the problem of determining the interference along the arterial. One technique giving good results in rating interference is termed acceleration noise (4). Acceleration noise refers to the acceleration pattern established by an individual's inability to maintain a uniform velocity due to extraneous stimuli. Acceleration noise is the result of extraneous stimuli and is therefore an indication of the interference that a driver encounters along the trip. The analysis of acceleration noise in the manner often used on freeways as a measure of flow interference does not work satisfactorily on arterial streets because of the programmed stops occurring at signalized intersections.

TABLE 1

RESULTS OF ANALYSIS OF BREAKDOWN OF D-V FLOW BY ACCIDENT CAUSATION

Location	ADT	Average Number of Accidents per Day	Probability of Accidents per Trip
Ward Parkway, 52nd to 75th Streets	32,000	0.27	0.0000085
47th Street and Brush Creek Boulevard, S.W. Trafficway to Woodland Avenue	15,000	0.21	0.000014
Linwood Boulevard, S.W. Trafficway to Woodland Avenue	20,000	0.44	0.000022
The Paseo, 29th to 47th Streets	20,000	0.52	0.000026
31st Street, S.W. Trafficway to Woodland Avenue	12,500	0.31	0.000026
Broadway Avenue, 29th to 47th Streets	22,000	0.62	0.000028
Main Street, 29th to 47th Streets	25,000	1.17	0.000047
Troost Street, 29th to 47th Streets	15,000	1.10	0.000074

If we idealize the measurable effects of acceleration noise, we can say that when a driver starts a trip on an open road he desires to accelerate to a certain speed and maintain that speed rather uniformly the length of his trip. Interference with the driver will cause him to change speed; that is, it will make him accelerate. This acceleration, or change in speed, has two components: (a) acceleration in response to interference and (b) acceleration back to desired speed.

An idealized trip on an urban arterial takes a form similar to that found on the open road except that the interference is more frequent and disruptive. A driver initiating a trip on an urban arterial desires to accelerate to a certain speed, assumed to be the legal speed limit, and to maintain that speed for the length of his trip. The main characteristic that arterials and open roadways do not share is that a vehicle on an arterial is periodically required to make a complete stop.

In this study, the interference a driver negotiates was assumed to be related to the speed he desired to maintain and was measured by a technique similar to acceleration noise. Whereas acceleration noise deals with the rate of change in speed as a measure of interference, this study used incremental change in speed as a measure of interference.

Specifically, this study used the approach that interference along an arterial is related to incremental changes in speed and to average speed. Incremental changes in speed were seen as a good measure of the type of interference causing "stop and go" flow. Average speed was seen as a good measure of the type of interference manifest in slow-moving, bumper-to-bumper, congested traffic flow.

To state this relation mathematically, it can be said that good arterial functionality, or little arterial interference, is related directly to average speed and inversely to the absolute value of incremental change in speed. Stated in equation form this relationship becomes

$$\mathrm{F.C.} = \frac{V_{avg}}{|\Delta V|}$$

where

F. C. = functionality coefficient,
V_{avg} = average speed, and
$|\Delta V|$ = total absolute value of incremental changes in speed.

The functionality coefficient is a dimensionless number less than 1. The lower the value of this coefficient is, the more intense is the interference, the lower is the level of service being provided, and hence the lower is the desire for this type of travel. The higher the value of the functionality coefficient, the less intense is the interference, the higher is the level of service provided, and the higher is the desire for this type of travel.

Information needed in this analysis consisted of speed changes and stopped time. Both of these were tied to a time check at key intersections. This information was gathered quite easily by a driver using the average vehicle method (7) equipped with a stopwatch and tape recorder.

The driver was instructed to record the following information during runs on each of the study segments:

1. Time stopped at signals,
2. Time at control intersections, and
3. Speed at each 5-mph change on the speedometer.

After this information was gathered it was plotted on a speed versus time graph for convenience in data reduction (Fig. 3). The results of the data reduction are given in Table 2.

Because the theoretical basis of the calculation of interference was driver desire, it was felt that the functionality coefficient was a statement of probability of the driver desiring the type of interference represented by the coefficient. This being the case, the probability of people viewing a given flow condition as representing a breakdown of the D-V unit was taken from the class mark at intervals of 0.08 as determined by the functionality coefficient.

Measure of Visual Input

In order to analyze the visual input from the environment, colored slides were taken at various points on each of the arterials. The slides were made during normal travel periods. Positioning of the camera was such that the slides represented the driver's view of the visual environment.

Four slides were made on each arterial, two at the ends of the study segments looking toward the section to be analyzed and two at the approximate center of the segment, one facing each direction.

In analyzing these slides, general categories of possible focal area types were constructed. In addition to these categories, tabulations were made of areas having adjacent contrasting colors. By totaling the possible focal area types along the individual study segments and by applying the fact that some focal areas tend to "override" other areas, a quantitative statement of the existence of the focal "override" areas could be made. It was anticipated, for instance, that, as the percentage of focal areas of dynamic character increased and as the percentage of focal areas of contrasting color increased, the chance of traffic flow breakdown would also increase.

The basis for development of these categories and the theoretical validation for the use of focal area categories was taken from the laws of perceptual groups. These laws originate from the fact that (5) "A set of elements tends to become organized in perception. The elements tend not to be seen as isolated but to be grouped. Wertheimer (English translation, 1958) has presented principles termed the laws of grouping. They include the following:"

1. "Proximity—Elements which are in the proximity of other elements or which are near each other tend to be seen as belonging to each other" (5). One tends to see the following 2's as four sets of three 2's rather than twelve 2's:

222 222 222 222

2. "Similarity—When other factors are equal, elements similar to each other are grouped together to the exclusion of dissimilar elements. The x's and o's... tend to form columns rather than rows" (5):

o x o x o x
o x o x o x
o x o x o x
o x o x o x
o x o x o x

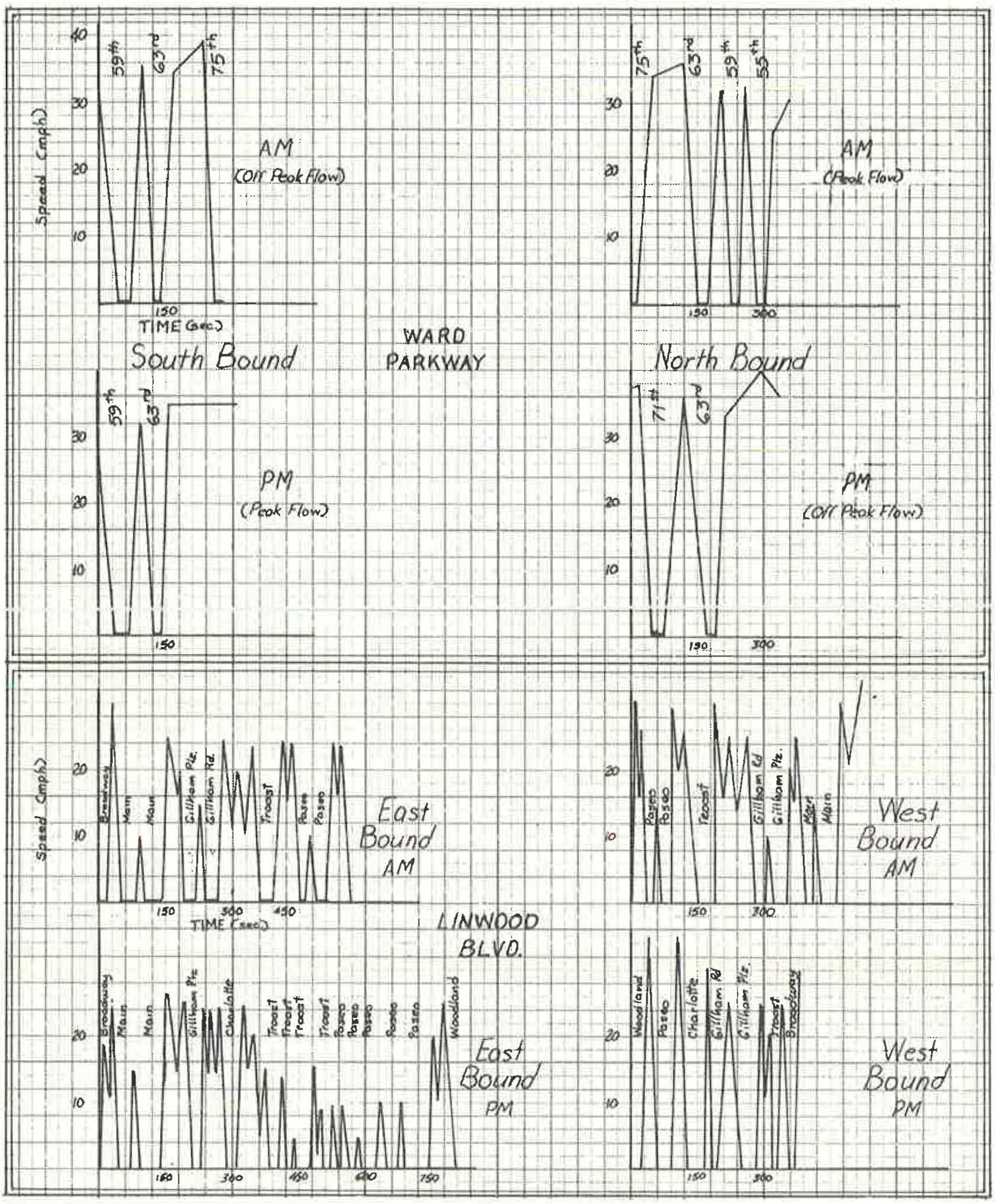


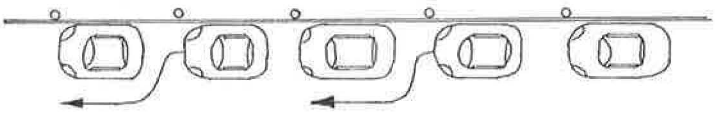
Figure 3. Example plot of speed versus time for analysis of interference coefficient.

3. "Common Fate—Elements moving in a common direction relative to other elements tend to be grouped together. Suppose that alternate x's. . . were moving downward together at the same rate" (5):

x x x x x x x x x x

As stated previously three elements were tested as to how they related to "good visual environment for driving": (a) no dynamic areas of possible focus, (b) no focal areas of contrasting color, and (c) naturalness of visual environment.

The first of these three elements, dynamic areas of possible focus, is related to the common fate law of grouping. For instance, if one perceives a line of parked cars, two of which are pulling out of their parking spaces, one would tend to see them as a group:



Another example of the same principal would be the tendency in the perception of dynamic neon signs. In this situation, one tends to catalog the dynamic symbols that compose the neon sign in a distinct group separate from painted signs.

The second input element, possible focal areas of contrasting color, is related to the similarity law of grouping. If colors were to replace the x's and o's in the example, this relationship would be as follows:

RED	BLUE	RED	BLUE
RED	BLUE	RED	BLUE
RED	BLUE	RED	BLUE
RED	BLUE	RED	BLUE

Using possible areas of contrasting color, we coded the tendency to group by color into our analysis. Specifically, it is known that some grouping tendencies are stronger than others. For instance, if the foregoing example of similarity were changed to rows of red and pink, there would still be a tendency to group into alternating rows; however, the tendency would not be as great as before. This assumption can be tested by constructing alternating rows of blue, pink, and red. In this case the tendency would be to group the blue and the shades of red with a secondary tendency to group all three colors separately.

The third element to be tested, no naturalness of visual environment, refers to the fact that perception tends toward a state of equilibrium. In the study area this perceptual equilibrium is still largely one provided by nature; i.e., the groupings that collectively represent the pastoral scene are better related to than are the groupings that comprise a totally man-made scene such as, say, Time Square. Further information on sensory organization is given by Kohler (6).

This element represents the coding into the analysis of the desire to perceive a

TABLE 2

RESULTS OF ANALYSIS OF BREAKDOWN OF D-V FLOW BY INTERFERENCE CAUSATION

Location	Interference Coefficient	
	Average	Range
Ward Parkway, 52nd to 75th Streets	0.68	1.00 - 0.10
47th Street and Brush Creek, S.W. Trafficway to Woodland Avenue	0.28	0.40 - 0.14
Troost Street, 29th to 47th Streets	0.15	0.35 - 0.10
Main Street, 29th to 47th Streets	0.12	0.14 - 0.11
The Paseo, 29th to 47th Streets	0.10	0.18 - 0.05
Linwood Boulevard, S.W. Trafficway to Woodland Avenue	0.09	0.13 - 0.06
31st Street, S.W. Trafficway to Woodland Avenue	0.09	0.11 - 0.09
Broadway Avenue, 29th to 47th Streets	0.09	0.20 - 0.10

TABLE 3

RESULTS OF ANALYSIS OF VISUAL INPUT

Location	Cars		Buildings		Light Poles		Traffic Signs		Trees	
	No.	Prob.	No.	Prob.	No.	Prob.	No.	Prob.	No.	Prob.
Ward Parkway	22	0.10	25	0.12	13	0.06	21	0.10	105	0.49
47th Street and Brush Creek Boulevard	34	0.11	17	0.06	42	0.14	51	0.17	94	0.32
Linwood Boulevard	43	0.15	32	0.11	45	0.16	45	0.16	52	0.18
The Paseo	46	0.17	36	0.13	26	0.09	29	0.11	49	0.18
31st Street	69	0.22	36	0.11	34	0.10	45	0.14	37	0.12
Broadway Avenue	59	0.21	33	0.12	27	0.10	45	0.16	26	0.09
Main Street	81	0.21	36	0.10	48	0.13	50	0.13	20	0.05
Troost Street	88	0.23	42	0.10	68	0.17	45	0.11	17	0.04

Location	Commercial Signs		Other		Color Contrast		Dynamic Areas		Naturalness
	No.	Prob.	No.	Prob.	No.	Prob.	No.	Prob.	Prob.
Ward Parkway	–	–	30	0.14	22	0.10	24	0.11	0.49
47th Street and Brush Creek Boulevard	–	–	60	0.20	36	0.12	44	0.15	0.32
Linwood Boulevard	32	0.11	41	0.14	45	0.16	65	0.22	0.18
The Paseo	26	0.10	62	0.23	53	0.19	61	0.22	0.18
31st Street	46	0.17	42	0.13	53	0.19	80	0.25	0.12
Broadway Avenue	50	0.18	35	0.13	50	0.18	84	0.26	0.09
Main Street	83	0.22	58	0.15	67	0.18	100	0.27	0.05
Troost Street	81	0.20	44	0.11	74	0.19	109	0.28	0.04

relationship among all groups in the visual environment. As the number of focal groups increases, it becomes more difficult to relate them and, hence, to reach a state of perceptual equilibrium. As stated previously, it was assumed in this study that the natural setting is the type of visual environment most likely to create spontaneously a state of perceptual equilibrium. It was further assumed that the degree to which the visual environment of the arterials provided this "natural setting" is directly related to the ability of the arterial to handle traffic flow without breaking down.

The compilation and associated probabilities from this analysis are given in Table 3. It should be noted that every effort was made to make the slides representative of the type of visual environment existing in the study segments.

ANALYSIS

The purpose of this study was to test the hypothesis that "good visual environment for driving" is an input into the D-V system that results in an output of "no breakdown of the D-V unit."

The mathematical analysis was conducted by applying the symbolic statements in the manner previously described. The analysis of the Ward Parkway segment serves as an example of all of the calculations (Figs. 4 through 7):

Input Statements

A_1 = no dynamic focal areas
B_1 = no color contrasts of focal areas
C_1 = naturalness of focal areas
D_1 = good visual environment for driving

$$A_1B_1C_1 = D_1$$

$$P(A_1B_1C_1|D_1) = P(A_1|D_1)\,P(B_1|D_1)\,P(C_1|D_1)$$

Figure 4. Northward view on Ward Parkway at 75th Street.

Figure 5. Southward view on Ward Parkway at 52nd Street.

Referring to Table 3,

$$P(A_1|D_1) = (1 - 0.11) = 0.89$$
$$P(B_1|D_1) = (1 - 0.10) = 0.90$$
$$P(C_1|D_1) = 0.49$$

$$P(A_1B_1C_1|D_1) = 0.89 \times 0.90 \times 0.49 = 0.392$$

Output Statements

E_1 = no accidents involving D-V units
F_1 = no interference with D-V units
G_1 = no breakdown of D-V units

$$E_1F_1 = G_1$$

$$P(E_1F_1|G_1) = P(E_1|G_1)\,P(F_1|G_1)$$

Figure 6. Northward view on Ward Parkway at Meyer Boulevard.

Figure 7. Southward view on Ward Parkway at Meyer Boulevard.

TABLE 4

CORRELATION OF INPUT PROBABILITY AND OUTPUT PROBABILITY

Location	Probabilities			
	No Accidents in Peak Period	No Interference	Output	Input
Ward Parkway	0.983	0.68	0.668	0.392
47th Street and Brush Creek Boulevard	0.972	0.28	0.272	0.239
Linwood Boulevard	0.956	0.12	0.115	0.118
The Paseo	0.948	0.12	0.114	0.114
31st Street	0.948	0.12	0.114	0.073
Broadway Avenue	0.944	0.12	0.113	0.055
Main Street	0.906	0.12	0.109	0.030
Troost Street	0.852	0.12	0.102	0.023

Referring to Tables 1 and 2,

$$P = (E_1|G_1) = 0.983$$
$$P = (F_1|G_1) = 0.68$$

$$P(E_1F_1|G_1) = 0.668$$

In schematic form this example analysis is represented as follows:

—(INPUT)—0.392 → [D-V SYSTEM] —0.668—(OUTPUT)→

For the hypothesis of the study to be proved by the use of this technique, the output probability should go up as the input probability goes up. Table 4 and Figure 8 show the results of the analysis of all eight segments. As indicated in Table 4, the input probabilities do in fact continually increase with an increase in the output probability.

Figures 9 through 16 show the visual environment existing on the study segments; they have been placed in the order resulting from the analysis as given in Table 4.

RESULTS

This study resulted in the conclusion that there exists a very definite relationship between the visual field or visual environment in which an arterial is confined and the manner in which that arterial can be expected to function.

One cannot expect to overwhelm the sensory input mechanism of the D-V unit and expect the unit to continue to function properly. Stated much more simply, the masses of traffic signs, commercial signs, contrasting colors, and other visual displays found on many arterial streets have the pronounced effect of increasing the magnitude of congestion and the number of accidents.

Our ability to predict the number of vehicles to be carried on an arterial has been dependent chiefly on the set of deterministic factors found in the Highway Capacity Manual (8). These factors include such items as location in the city (CBD, fringe area, etc.), size of the city, and the peak hour factor. The approach offered by the Capacity Manual is one of input-output. It is, however, based on a roadway system, not a driver-vehicle system. That is, the system analyzed in the Manual is a piece of concrete or asphalt, the input to which is a set of physical criteria and the output from which is a capacity of traffic:

—(INPUT)—Physical Data→ [ROADWAY] —Vehicle No.—(OUTPUT)→

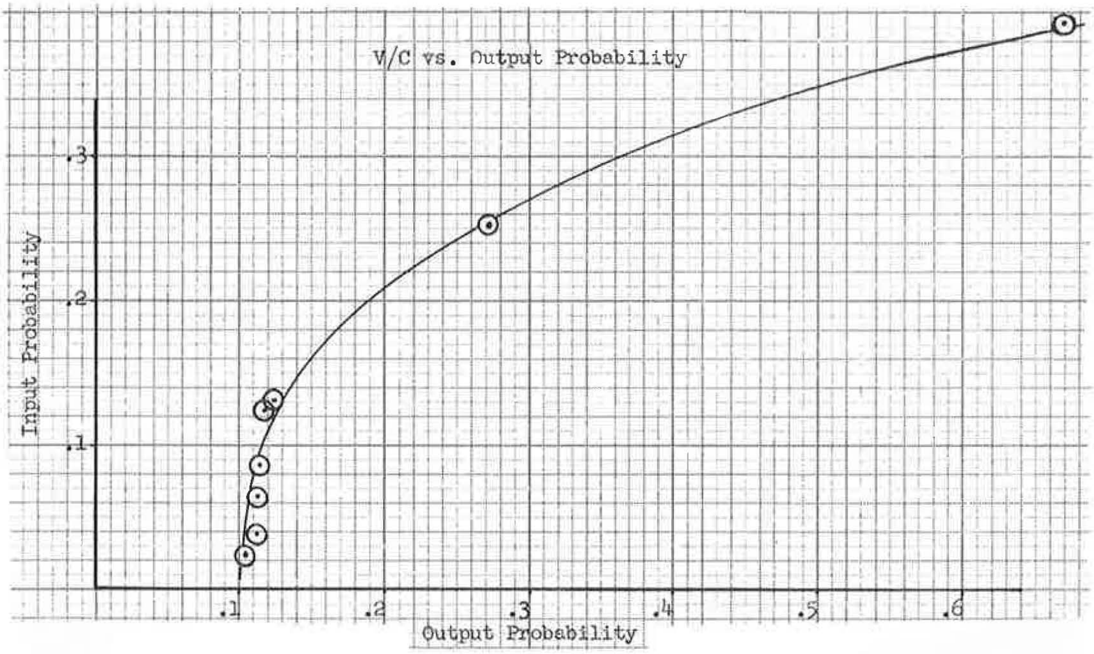


Figure 8. Input probability versus output probability.

The functionality of an arterial and the degree to which this arterial will break down is given through the capacity approach by means of the volume-to-capacity ratio. To determine the apparent relevancy of the volume-to-capacity (V/C) ratio to predict whether arterial flow will break down, the ratio of V/C ratio of the segments in question to the output probabilities developed in this study are plotted.

The V/C ratios, as given in Table 5, do not have a strong relationship with the D-V output probabilities. The V/C ratios were calculated at controlling locations. Figures 8 and 17 show graphical representations.

This exercise was not meant to criticize the value of capacity analysis. Quite the contrary, it was designed to show that the developers of capacity analysis did not consider it a law; they consider it a technique to establish a feeling for, not a precise statement of, the ability of a roadway to carry traffic.

Figure 9. Typical view on Ward Parkway.

Figure 10. Typical view on 47th Street.

Figure 11. Typical view on Linwood Boulevard.

Figure 12. Typical view on The Paseo.

Figure 13. Typical view on 31st Street.

Figure 14. Typical view on Broadway Avenue.

Figure 15. Typical view on Main Street.

Figure 16. Typical view on Troost Avenue.

TABLE 5

VOLUME-TO-CAPACITY RATIO OF STUDY SEGMENTS

Location	Volume (Peak Hour)	Capacity	V/C	Output Probability
Ward Parkway	2,160	2,240	0.96	0.668
47th Street	1,140	1,250	0.91	0.272
Linwood Boulevard	1,067	1,200	0.89	0.115
The Paseo	1,500	1,440	1.04	0.114
31st Street	1,015	980	1.04	0.114
Broadway Avenue	1,595	1,600	1.00	0.113
Main Street	1,710	1,500	1.14	0.109
Troost Street	1,105	1,050	1.06	0.102

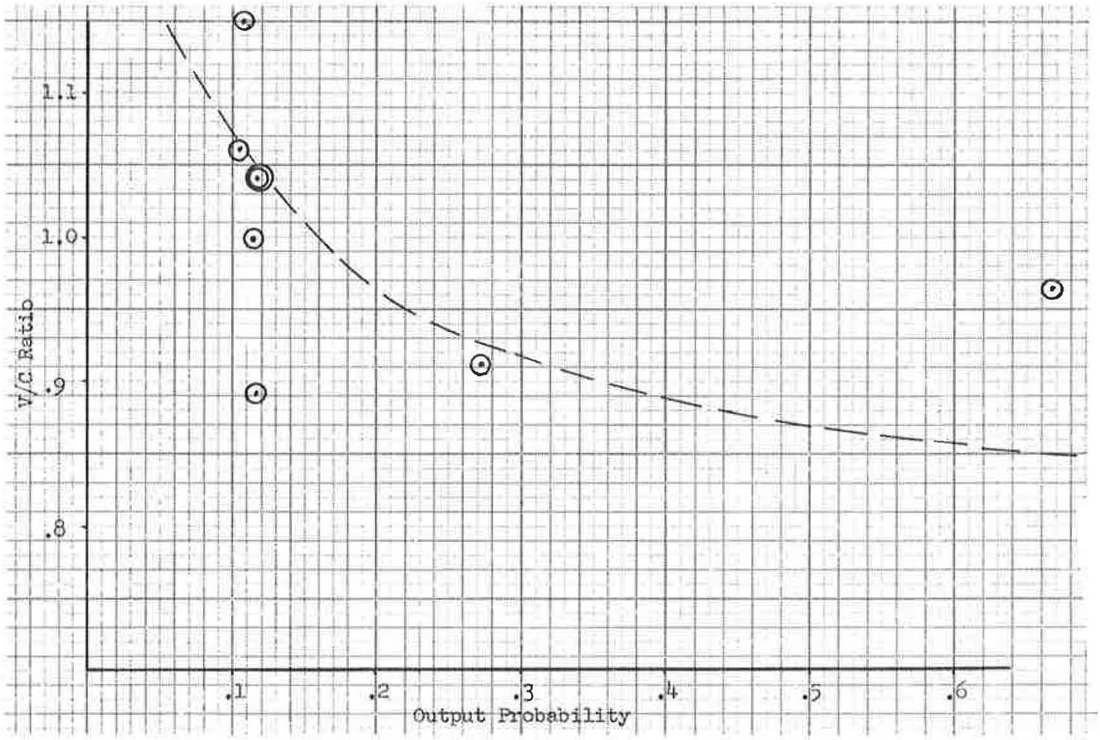


Figure 17. Volume-to-capacity ratio versus output probability.

CONCLUSION

To truly predict the ability of an arterial to handle traffic, one must realize that an arterial street must be considered as an open system. It must be considered as something more than a piece of pavement of certain dimensions. Likewise, the vehicles that travel the arterial must be considered as something other than a collection of left turns or right turns.

The Highway Capacity Manual says that increasing the roadway even 1 foot will increase capacity. This use of the word capacity is taken immediately to mean that congestion will be decreased (in order for this to occur it is mandatory to assume that volume will remain the same or decrease). The Manual also says that removal of parking will also increase capacity—decrease congestion. However, is it possible that congestion can be decreased by simply improving the visual environment? Can removal of commercial signs, organization of traffic signs, and other related steps have the same effects as physically altering the street?

The results of this study seem to indicate that the answer to these questions is yes. We must quickly state, however, that the eradication of a poor visual environment will not have the same effect on travel as the replacement of an arterial with a freeway. It is felt, however, that, where areas exist that cannot be significantly widened so that additional capacity can be gained, it is possible to gain some increased mobility and safety by improving or causing the improvement of the areas' visual environment.

To support our conclusion, it is pointed out that a concerted national effort is under way to incorporate international road signs into the present inventory of standard traffic signs. This is being done to convey a more recognizable, more easily interpreted, message to the passing motorist.

Within Kansas City a sizable effort is under way to inventory present traffic signs. This inventory is defining areas where the traffic signing conveys duplicating or conflicting information. Because of this inventory several areas have already been evaluated and rehabilitated. In the near future, it is expected that the entire central business district and other selected areas will receive similar treatment.

It should be noted as a final point that, in this era of concern for the environment, the authors feel that man's concern about environmental pollutants should not be limited to just physical pollutants. Water and air are only part of man's total environment, and we would be remiss if we did not conclude that certain "mental" pollutants are also detrimental to the total well-being of man. Some concern is now being registered about the "third pollutant"—noise. Noise seldom kills and only occasionally maims, but it is a quite frequent source of mental anguish and discomfort.

This study dealt with what the authors feel is the "fourth pollutant"—the pollution of the visual environment. Visual pollution, like noise pollution, is a pollutant of the human senses. The difference between the two is, of course, that excessive noise can maim, whereas visual chaos cannot. However, it was the authors' concern in initiating this study that visual pollution is a subversive causative factor in automobile accidents that do cause physical damage. It was also the authors' feeling that the visual pollution of the environment is a direct contributor to a quite common source of mental auguish in the urban areas, traffic congestion. It is felt that this study has served the purpose of suggesting that a relationship does indeed exist between visual input to the driver, the character of traffic flow, and the frequency of accidents. It is hoped that it will spur interest and additional, more detailed, studies into the true character of this relationship and into the true character of the fourth pollutant.

REFERENCES

1. Tribus, M. Rational Descriptions Decisions and Designs. Pergamon Press, 1969.
2. Functional Highway Classification in Urban Areas. Automotive Safety Foundation, 1967.
3. Smith, W. L. Probability Study of High Accident Locations in Kansas City, Missouri. Traffic Engineering Magazine, April 1970.
4. An Introduction to Traffic Flow Theory. HRB Spec. Rept. 79, 1964.
5. Weintraub, D. J., and Walker, E. L. Perception. Brooks/Cole Publishing Co., 1966.
6. Kohler, W. Gestalt Psychology. New American Library, 1947.
7. Cleveland, D. E. Manual of Traffic Engineering Studies. Institute of Traffic Engineers, 1964.
8. Highway Capacity Manual—1965. HRB Spec. Rept. 87, 1965.