VEHICLE DELAY AT 4-WAY STOP INTERSECTIONS

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CHAPTER I

INTRODUCTION

Urban street intersections determine the capacity of urban streets, due to the interruption in vehicle free flow. Hence, vehicle delay at intersections has been a major problem of highway departments and traffic engineers for years. As the frequency and severity of intersection conflicts and congestion increase, traffic regulation and control becomes more necessary. Many types of intersection control devices are employed to prevent or reduce accidents, and to increase intersection capacity. Even though these traffic control devices have been utilized for more than 50 years, there is still a need for evaluation and improvement in their efficiency.

Since the cost of fuel is increasing and the installation of traffic signals is becoming more expensive, traffic engineers are seeking for other effective traffic control methods for regulating and controlling traffic at intersections. Four-way stop control, one of the appropriate and efficient intersection controls, has been widely used since the 1920's. However, studies of this control method are limited. Previous studies were concerned with the time vehicles spent traversing the intersection, relative safety, and cost. A few comparative studies of traffic control devices were also performed in which most of the motorists favored the four-way stop control. However, a need was found for quantitative data to evaluate the effectiveness of the four-way stop control devices. Wholly empirical studies of traffic behavior have tended to be expensive, time consuming, and difficult to evaluate.

To date, with the rapid development of high speed computers, most of the problems associated with time analysis of traffic are solved by using a computer simulation program. Traffic simulation is becoming an important tool for traffic engineers and transportation planners for several reasons. It enables the study of a complex traffic problem in the laboratory rather than in the field. Traffic simulation experiments are comparatively economical and quick, and their results are valuable in making decisions.

The primary objective of this research is to develop a computer simulation program that will be utilized to evaluate the efficiency of the single intersection controlled by a four-way stop control device. The intersection in this study has a two-way four-lane street crossing a two-way two-lane street without separate turning lanes.

The first stage of this research concerns the development of the computer simulation program, written in the GPSS (General Purpose Simulation System) language and executed on the IBM 370/168 computer. The GPSS language is able to generate random vehicles throughout the intersection system, and is easy to understand because of its simple language. The outputs of the computer program consists of clock time, block, facility, and tabulated statistics. The frequency tables showing number of entries, mean values, standard deviation, and frequency classes indicate all required traffic statistics such as the queue length and vehicle travel time through the intersection system. Statistical output in graphical form can also be presented by this computer simulation program.

The second stage of this research consists of traffic field studies. Traffic data are observed and collected from a studied intersection by employing the time-lapse photography method. In those instances where greater accuracy is required than is possible with time-lapse photography, such as stop-waiting time and intersection travel time, stop watches and tape recorders are utilized. All traffic statistics are carefully observed and precisely analyzed for use as input information for the computer simulation program.

The third and final stage is the comparison between field observations and the computer simulation results. Extension of this research into additional areas is discussed and recommended.

CHAPTER II

REVIEW OF RELATED LITERATURE AND STUDIES

Studies of traffic delay at at-grade intersections have been carried out since the 1920's (1). However, a detailed study of traffic flow at four-way stop intersections has never been presented. The earliest intersection studies were conducted to compare traffic delay at stop controlled and signalized intersections (2, 6, 10). Many methods were utilized to observe traffic behavior and collect traffic data at intersections (2, 5, 10). Since World War II, the use of the computer to solve problems associated with vehicle movement has increased. Various computer languages, including GPSS language, have been used to construct models simulating traffic behavior.

The first part of this chapter will describe previous field studies and study methods related to at-grade intersections controlled by stop signs. The second part will be the development of computer simulation models to solve traffic problems occurring at at-grade intersections.

Previous Studies of Stop-Sign Controlled Intersections

In the 1930's, the first two papers describing the study of stop-sign controlled devices at urban intersections were presented. Morrison (1) observed traffic behavior at stop-sign controlled intersections and studied the degree of obedience to stop signs. He also studied accident experience at intersections at which signals were installed, replacing stop signs. Brown (2) used E. P. Goodrich's formula* for determining maximum theoretical capacity of a four-way stop intersection. He concluded that the delay or loss of time at four-way stop intersections was less than with signals.

There were also two papers on the study of four-way stop controlled intersections in the 1940's. Harrison (3) concluded that more than 90 percent of motorists favored four-way stop control to traffic signals. In the same year, McEachern (4) surveyed the use of four-way stop control in many cities. His investigations indicated that in some

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*E. P. Goodrich's formula is expressed as:

$$n = \frac{5280V}{c + b + 2L}$$

where

V = Average velocity of vehicles crossing the intersection;
c = Clearance allowance;
b = Width of traffic lane;
L = Vehicle length in feet;
n = Average number of vehicles per lane per hour.

instances four-way stops had been used to replace fixed-time signals.

By the 1950's, there had been an increase in the use of vehicle transportation on urban streets which accentuated the problem of traffic delay at intersections. Many delay studies were conducted in this decade, including Raff's study (5). He used the Esterline-Angus Graphic Time Recorder to collect traffic data at two-way stop-sign controlled intersections. This equipment was also used to record and compare traffic delay caused by different traffic control devices at an intersection in the urban area by Hall (7). At his studied intersection, a traffic signal was replaced by four-way stop signs. Hall showed that the average intersection delay with stop sign control was less than the average delay with signalization. Wilkie (8) presented a paper describing vehicle performance at the stop-line of stop-sign controlled intersections. Hanson (9) presented his paper on the advantages of four-way stop control devices. The warrants for four-way stop signs were presented in a paper written by Marks (10). Minimum and maximum volumes required at four-way stop intersections were given. Marks also described advantages and disadvantages of four-way stop control devices.

A paper describing capacities, and lag and gap acceptances at stop controlled intersections was presented by Hebert (11) in 1963. He determined the basic and practical capacities of four-way stop intersections under various geometric and traffic conditions. Three years later, Solberg and Oppenlander (12) studied lag and gap acceptance at intersections at which minor streets were controlled by stop-signs. Vodrazka et al. (13) studied traffic delay and warrants for intersection control devices in 1971. Vodrazka observed the total delay and traffic split at four-way stop intersections, and recommended volume warrants for this intersection control device.

Development of Computer Simulation Models for Traffic Studies

There has been an increasing use of computers to simulate traffic behavior since 1949 (14). However, no published paper discussing possible techniques has been presented, and no documented traffic simulation actually run on a computer until 1954 (15). Most of the studies were concerned with how to formulate traffic simulations. The first paper describing the utilization of modern high-speed automatic computers to simulate traffic flow was presented by Mathewson et al. (16) in 1954. Mathewson developed a computer model for simulation of traffic flow at a simple intersection by means of a general purpose discrete-variable computer. The first traffic simulation model run on a general purpose digital computer was presented by Goode et al. (18). This study was limited in scope to intersection problems in which all vehicles entered the intersection system within a single lane and at uniform speeds. In the same year, Gerlough (17) simulated freeway traffic by the general purpose digital computer. His paper described simulation of the movement of vehicles on highways where traffic moved in several parallel lanes and at widely varying speeds, Wong (19) also presented a computer model simulating traffic flow on a 12-lane boulevard by the digital computer.

Another Gerlough paper (20) describing traffic inputs for a simulation model was presented in 1959. He presented some methods for accomplishing the artificial generation of traffic. The statistical distributions used in his study were: Poisson, exponential, shifted exponential, and composite exponential. One year later, Perchonok (21) and Wohl (22) utilized the digital computer to study the problem of freeway on-ramp traffic operations. Glickstein et al. (23) also applied computer simulation techniques to on and off-ramp problems at interchanges.

In 1962, two traffic simulation models using digital computers were reported (24, 25). Kell (24) developed a simulation model, coded for an IBM 701 computer, for the intersection of two two-lane two-way streets, with the minor street being controlled by stop signs. One year later, he utilized his computer simulation model for determining traffic delay at an intersection under stop sign control and under fixed-time signal control (25). He found that the total intersection delay was increased by the installation of a traffic signal.

Lewis et al. (26) has presented a computer simulation model for an intersection of a four-lane two-way street and a two-lane two-way street, controlled by two-way stop-signs and by semi-traffic actuated signals. His simulation was based on a uniform headway distribution and similar deceleration for every entering vehicle; however, in a second paper (27) he proposed a modified binomial distribution employing two different levels of probability, for traffic simulation models. In the same year, 1963, Worrall (28) employed the Monte Carlo method to generate simulated traffic in his simulation model. Constantine (29) presented another traffic simulation model using negative exponential distribution to generate simulated traffic. Grecco and Sword (30) also modified Schuhl's headway distribution for a traffic simulation model.

In recent years, Lee (38) has developed the TEXAS model for intersection traffic. He presented a procedure for applying this computer simulation model in evaluating the capacity and level of service of single unsignalized intersections. Ferrara (39) has also presented two simulation models in FORTRAN language to analyze the delay to bicycles and vehicles at crossings and intersections controlled by two-way stop signs and signals.

Since development of the General Purpose Simulation System (GPSS) in 1961 (36), engineers and planners have developed computer simulation models written in GPSS language to solve problems in business, industrial, and complex projects (34, 35). The first traffic simulation model written in GPSS II and FAP language for the IBM 7090/94 systems was developed by Blum (31, 33). Recently in 1976 Jarernswan (37) has developed a computer simulation program, written in GPSS and run on the IBM 360/65 computer. He utilized his simulation model to evaluate the efficiency of a traffic signal control system at an intersection with a separate left-turn lane on each approach.

CHAPTER III

TRAFFIC PERFORMANCE AT FOUR-WAY STOP INTERSECTIONS

Traffic behavior at four-way stop-sign controlled intersections is different from that at signalized intersections. Almost all vehicles approaching a four-way stop controlled intersection will reduce their speeds when reaching the point where the stream of traffic is influenced by the stop-sign at the intersection. This point, usually several hundred feet from the intersection, is called the intersection system entrance, as shown in Figure 1. Outside the intersection system entrance, all vehicles are moving independently at their own speeds, modified only by the prevailing speed limit. Their characteristics are not yet affected by the intersection congestion. Their arrival times will generally be considered random, making the distribution of successive time space between vehicles (inter-arrival time) an exponential relationship (32).

When passing the intersection system entrance, the driver will begin to decelerate and observe the changing pattern of the preceeding vehicles. He will decelerate until joining the build-up of a queue of stopped vehicles or other decelerating vehicles. If there is no vehicle ahead,

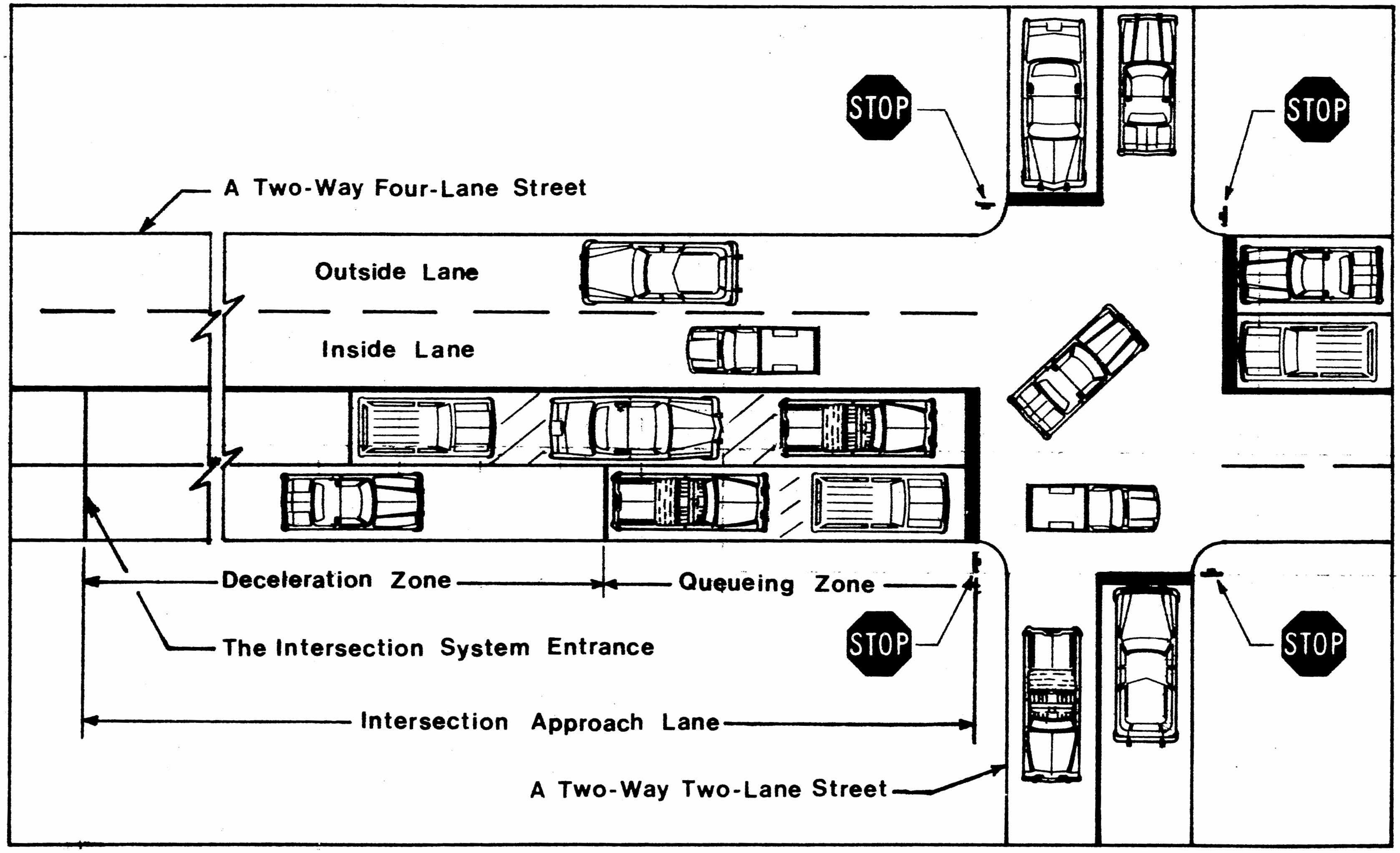

Figure 1. Illustration of Traffic Behavior at a Typical Four-Way Stop Controlled Intersection

the driver will decelerate until stopping at the stop-line. The driver will check if the intersection is available for his entrance. He will then start accelerating and enter the intersection, moving either straight ahead or performing a truning movement. At the intersection exit, drivers will increase speed as desired.

To develop the traffic simulation model, it is necessary to observe all of the movements, pauses and delays necessitated by the roadway, the four-way stop signs, and other vehicles.

Vehicle Arrivals at Intersection System Entrances

At any point where vehicles are moving without constraint, vehicle arrivals are random and continuous (24). Many mathematical distributions and methods of securing random numbers have been applied to describe the traffic flow at intersections. The first application of the Poisson distribution to traffic problems was discussed by Kinzer (40) in 1933. Greenshields et al. (41) showed that the vehicle distributions at intersections, with low to moderate flow and with a sufficient number of approach lanes, follow the Poisson distribution. Following Greenshields, Gerlough (43) has proposed the shifted negative exponential distribution in his study of traffic problems.

At the intersection system entrance, vehicles are starting to decelerate so that they cannot pass and some minimum non-zero headways between successive vehicles will occur. It is possible to apply the shifted negative exponential distribution to describe vehicle arrivals at four-way stop controlled intersections. This distribution can be derived from the Poisson distribution and the negative exponential distribution (41, 43). The Poisson distribution is generally expressed as:

$$P(x) = \frac{m^x e^{-m}}{x!} \qquad (3.1)$$

where

m = mean of observed values;

x = number of occurrences 0, 1, 2, ...n;

P(x) = the probability of exactly x occurrences.

If the mean number of arrivals in time t is replaced by qt, the form of distribution becomes:

$$P(x) = \frac{(qt)^x e^{-qt}}{x!} \qquad (3.2)$$

where

q = the mean flow rate in vehicles per unit time;

t = the time between vehicle arrivals.

The probability of no arrivals x = 0 in time t becomes:

$$P(o) = e^{-qt} \qquad (3.3)$$

But to have no arrivals in an interval t, there must be a headway or gap greater than or equal to t:

$$P(h \geq t) = e^{-qt} \qquad (3.4)$$

where

h = time headway or gap between two vehicles.

Correspondingly, the probability that the headway h is less than t is:

$$P(h<t) = 1 - e^{-qt} \tag{3.5}$$

Further, it will be observed that the mean flow rate q is equal to 1/T (the reciprocal of the mean headway).

Substituting $q = \frac{1}{T}$ into Eq. (3.5):

$$P(h<t) = 1 - e^{-\frac{t}{T}} \tag{3.6}$$

where

T = mean of vehicle headways.

Equation (3.6) represents the negative exponential distribution as shown in Figure 2, an appropriate model for headways in low, free-flowing traffic volumes.

The headways or vehicle arrivals predicted by the negative exponential distribution differ greatly from observations of high traffic volumes. Vehicles possess length and obviously cannot follow at an infinitesimal headway, as the distribution predicts. In order to achieve a more realistic modeling of high volume conditions, the shifted negative exponential distribution was developed (43).

In the shifted negative exponential distribution, a minimum observed headway, (τ), is specified. This has the effect of simply translating the negative exponential distribution to the right by an amount equal to the minimum observed headway τ (see Figure 3) such that:

$$P(h<t) = 1 - e^{-(t-\tau)/(T-\tau)} \tag{3.7}$$

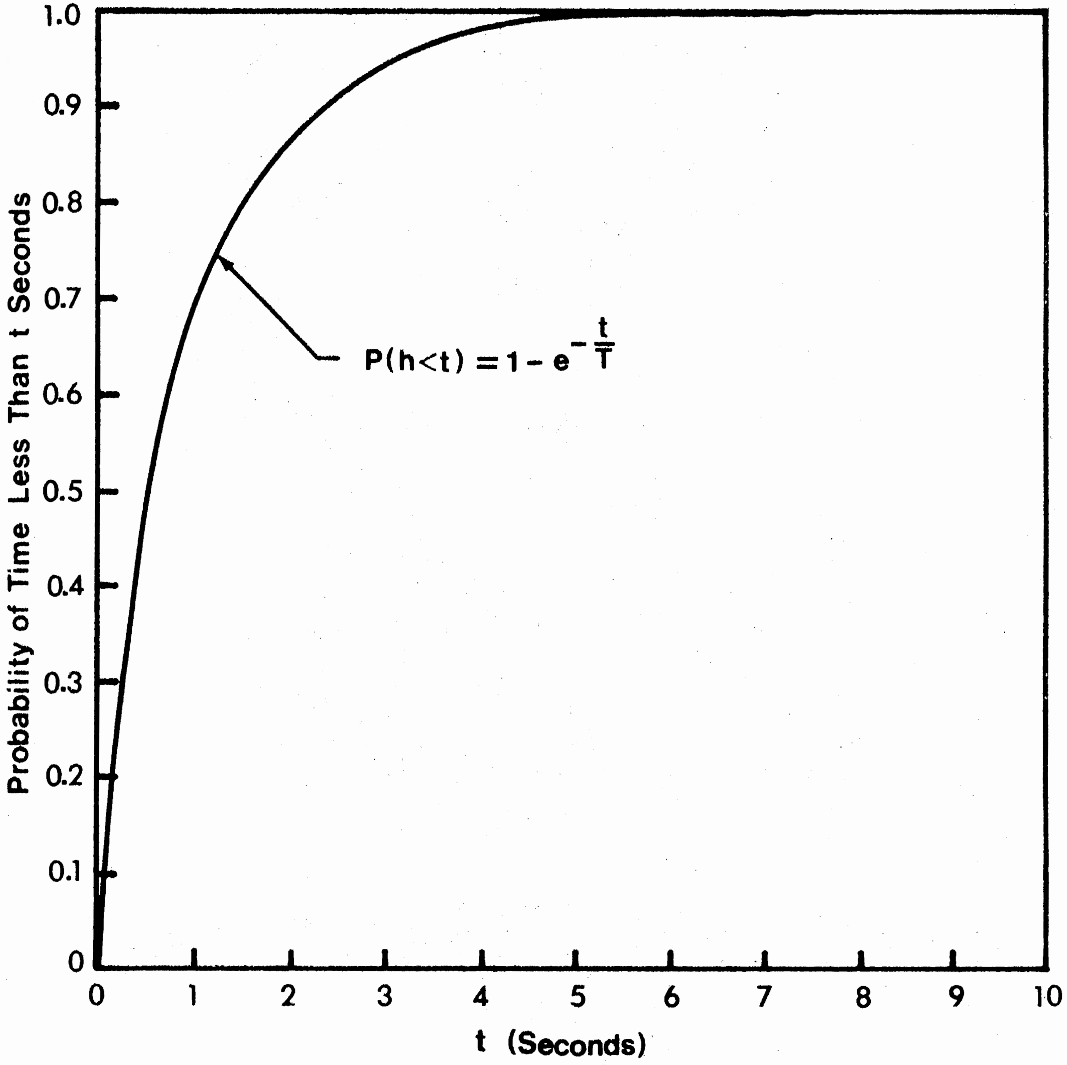

Figure 2. Probability of Gaps (Headways) Less Than t (41)

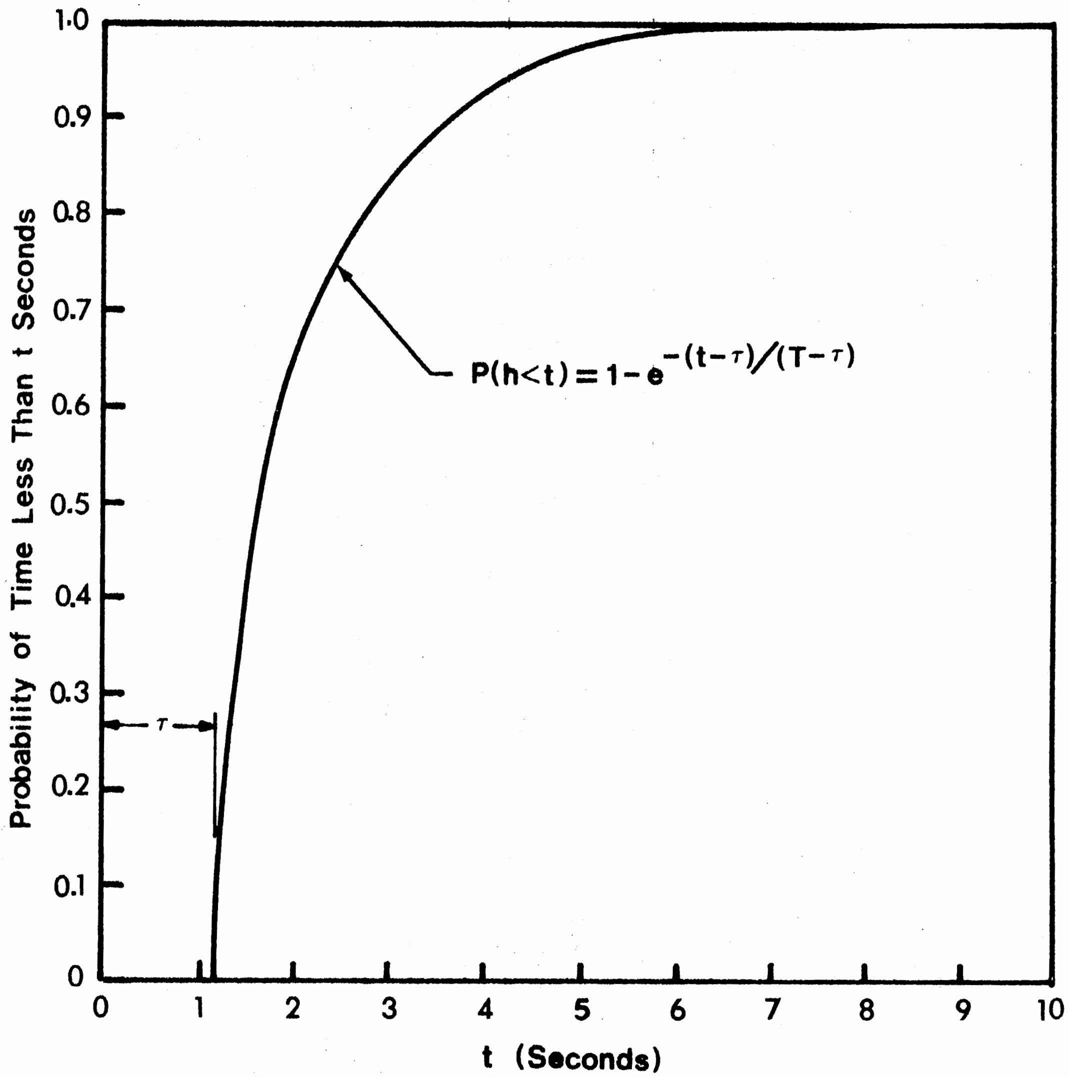

Figure 3. The Shifted Negative Exponential Distribution (43)

Other distributions applied to traffic problems are the Erlang distribution (42) and the composite negative exponential distribution (43).

Deceleration of Approach Vehicles

After entering the intersection system entrance, the driver will reduce his speed preparing to join a queue if the preceding vehicles are stopped or slowing to enter the intersection. When no preceding vehicle is waiting at the stop-line, the driver is able to decelerate to a stop at the stop-line. The deceleration zone of any approach lane is variable in length from the intersection system entrance to the queueing zone or to the stop-line (see Figure 1).

The deceleration rates of vehicles at four-way stop intersections can be evaluated from the laws of motion (46). For vehicles that move directly to stop-lines, the formula of straight line motion is applied:

For uniformly decelerated motion:

$$V = V_o - dt \qquad (3.8)$$

and

$$S = V_o t - \frac{1}{2} dt^2 \qquad (3.9)$$

and

$$V^2 = V_o^2 - 2dS \qquad (3.10)$$

where

V_o = initial velocity, ft/sec;

V = final velocity, ft/sec;

S = distance in feet;

t = time in seconds;

d = deceleration, ft/sec^2.

The deceleration rates of vehicles approaching four-way stop intersections are dependent on approach speeds and the distance from the intersection system entrance to queueing vehicles or to stop-lines. For vehicles decelerating to a stop, previously conducted tests have shown that the maximum deceleration rate of vehicles varies from 19 to 22 ft/sec^2 (44). The National Safety Council has adopted a deceleration rate of 17 ft/sec^2 as the maximum for comfort (45), but a better target deceleration is 8 ft/sec^2 (56).

Vehicle Queueing at Intersection Approaches

After entering the intersection system entrance and decelerating, the driver will join the line of queueing vehicles if the preceding vehicles are still in the queue waiting to enter the intersection. Then, the driver is a member of the queue. Queueing time for any vehicle is the length of time from the first stop behind previously queued vehicles to the last stop at the stop-line. The vehicle having zero queueing time is the one that decelerates and stops at the stop-line. In this case, the headway between the stopping vehicle and the preceding vehicle is great, since the preceding vehicle has already left the stop-line.

Queue length and queueing time of vehicles in each approach lane are associated with both arrival rate and departing rate (number of vehicles leaving the intersection system per unit of time). The behavior of queuing vehicles has been described by the application of queueing models (15, 46). In this study, the computer simulation model written in GPSS language will be utilized to describe the behavior of queueing vehicles at four-way stop controlled intersections.

Vehicle Stopping Performance

It is the intent of four-way stop control devices that every vehicle in each approach lane must stop completely at the stop-line and prepare to accelerate across the intersection. Waiting times of approach vehicles vary and depend directly on how busy the intersection is. The waiting vehicle will spend less time at the stop-line if the driver is able to enter the intersection immediately. The crossing vehicles moving in the intersection will extend waiting times of those vehicles waiting at stop-lines. Morrison (1) and Wilkie (8) concluded that there were four characteristic behaviors of vehicles at such intersections, including voluntary stops, involuntary, rolling, and no stops. Another type of stop occurring at the four-way stop controlled intersection is stopping behind another stopped vehicle in a queue at the intersection.

Vehicle Accelerating Across the Intersection

When the intersection is not busy (crossing vehicles are leaving the intersection), the driver of the first stop-waiting* vehicle starts accelerating across the intersection, either turning or traveling directly across. The opposite vehicle at stop-line is also able to enter the intersection simultaneously if they are not pursuing conflicting paths. The law of motion again can be applied to evaluate the relationship of vehicular operating characteristics including initial speed, speed at the system exit, travel distance, and acceleration (46).

For uniformly accelerated motion:

$$V = V_o + at \tag{3.11}$$

and

$$S = V_o t + \frac{1}{2}at^2 \tag{3.12}$$

$$V^2 = V_o^2 + 2aS \tag{3.13}$$

where

V_o = initial velocity, ft/sec;
V = final velocity, ft/sec;
S = travel distance in feet;
t = time in seconds;
a = acceleration, ft/sec^2.

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*The term "stop-waiting vehicle" is used to differentiate a vehicle waiting at the stop-line from one waiting in queue.

Although the actual rates of acceleration are not uniform, a previous study (25) has assumed a uniform rate of speed change as an adequate approximation to the real case, in the computer simulation model. The maximum acceleration obtained from previous studies was 14.67 ft/sec^2 (56), but the comfortable acceleration is believed to be about 10 ft/sec^2 (44). At four-way stop controlled intersections, the drivers are free to select a rate of acceleration to accelerate from stop-lines to the intersection exits or to the points that vehicles start moving at constant speed.

Vehicle Turning Performance

At four-way stop controlled intersections, all approach vehicles are required to stop at stop-lines before entering the intersection. Turning vehicles generally show their proposed turning directions by turn indicators. Maximum turning speed is related to turning radius and side friction (46). By equating the components of centrifugal force and centripetal force, we obtain the equation:

$$\frac{V^2}{gR} = f \qquad (3.14)$$

Solving for V:

$$V_{max} = \sqrt{fgR} \qquad (3.15)$$

where

V_{max} = maximum turning speed, in ft/sec;

f = coefficient of side friction;

g = acceleration of gravity, 32.2 ft/sec^2;

R = turning radius, in feet.

For a 90 degree turn, the minimum turning radius for passenger vehicles is 24 feet (47). In the case of left turn vehicles, the turning radius is always greater than the turning radius of right turn vehicles.

At a four-way stop intersection, a left-turning vehicle poised to enter the intersection has potential conflict only with a vehicle from the opposite direction traveling straight across the intersection. Unlike a free, or a signalized intersection, there is no need to wait for a succession of opposing vehicles. A right-turning vehicle driver is free to make his move as soon as a vehicle traveling from his left to his right has cleared the intersection.

Speeds of Vehicles Approaching the Intersection System

Speed is a primary factor in all modes of transportation, and it is a basic measure of traffic performance. In studying traffic delay, it is necessary to recognize that speeds of vehicles entering an intersection system are likewise the most important factor affecting vehicle delay at intersections.

All free flowing vehicles are moving at fairly constant speeds until they enter the intersection system entrances. At these entrances, vehicle speeds are considered in this study to be constant, under speed limits. There are no vehicles accelerating and overtaking the preceeding vehicle.

Data required for the speed study of vehicles approaching four-way stop controlled intersections can be collected at the system entrances. To study the speeds of vehicles entering the intersection system, many methods based on measurement of time and distance have been employed (47). The Stop Watch method and the Time-Lapse Photography method are the most commonly used. Both of these methods are employed in this investigation.

CHAPTER IV

FIELD OBSERVATIONS AND STUDIES

Traffic Data Collection

The objectives of the reported field studies were to observe traffic behavior and to collect traffic data at an at-grade intersection controlled by four-way stop signs. Before developing a traffic simulation model to evaluate the efficiency of four-way stop control devices, it is important to study and observe the real traffic behavior at the studied intersection. This empirical study, involving collection and analysis of field data, was conducted to provide an objective basis for the decision-making processes and the quantitative input traffic data for the traffic simulation model. There are many traffic variables associated with characteristics of vehicles, some with characteristics of the roadway, and others with characteristics of drivers. Nearly all of these variables are of a statistical nature.

In reported intersection delay studies in which a comparison was made between traffic simulation models and actual field observations (25, 26) satisfactory correlation was obtained at roughly one-half of the intersections. Recently Jarernswan (37) has shown that actual field data collected for input to the traffic simulation program, if available, is more authentic than the assumed values and leads to more realistic results. The simulation results in his study agree with the field observations.

To prepare traffic data for input to the computer simulation program, there is a need for observing and recording all variables associated with traffic flow at the selected four-way stop controlled intersection, including:

1. Location of the intersection system entrance at each approach.
2. Vehicle speeds before entering the intersection system.
3. Arrival times of vehicles at intersection system entrances.
4. Inter-arrival times of vehicles at intersection system entrances.
5. Arrival rates at intersection system entrances.
6. Deceleration times of vehicles after entering the intersection system.
7. Queueing times of vehicles in each approach lane.
8. Vehicle arrival times at stop-lines.
9. Vehicle stop-waiting times at stop-lines.
10. Time of vehicle entry into the intersection.
11. Intersection travel time for each vehicle.
12. Time of vehicle departure from the intersection.
13. Departure rates-of-speed at intersection system exits.

14. Maximum number of queueing vehicles in each approach lane.

15. Percent and direction of turning vehicles.

16. Total travel times of vehicles in the intersection system.

17. Number of vehicles entering the intersection system.

In addition to the traffic variables mentioned above, the geometry of the selected four-way stop controlled intersection, e.g., lane width and intersection length, also affects traffic delay and capacity of the intersection.

Methods for Intersection Field Studies

Increasing volumes of traffic in recent years have accentuated the problem of traffic delay at intersections. As a result, numerous methods for investigating delay have been proposed and applied (48, 49, 50, 51, 52, 53, 54, 55). Among these methods and techniques, the time-lapse photography method has become popular in studying traffic problems both at intersections and elsewhere. One early effort to quantify traffic behavior on the roadway was reported by Greenshields (48) in 1934. His employment of a 16-millimeter camera to capture vehicle flow for subsequent speed analysis in the laboratory made this early work particularly note worthy. Greenshields also used time-motion pictures in his study of traffic performance at urban intersections (41) in 1947. Dart (32) reported that the time-lapse

16-millimeter filming technique was found to be the most satisfactory and economical procedure for his intersection study. Diewald et al. (52) utilized a compact 35-millimeter camera with a 200-foot film magazine to collect field data for his intersection study. Jarernswan (37) also found that with the capability of the time lapse camera, precise and quantitative traffic data regarding volume, turning movements, vehicle arrival distributions, and other variables associated with signalized intersections could be recorded on film. He analyzed his time-lapse film and used collected data for input to his computer simulation model. Another paper describing time-lapse technique for measuring delay at intersections was presented by Reilly (55).

In this research, the time-lapse photography method was considered the most effective method to gather necessary data required for the study of four-way stop control at a selected intersection. For more precise and accurate results, stop watches were used to obtain these traffic data such as the exact time a vehicle passed the speed checking points, and intersection travel times. Tape recorders were also used to record observed times for checking vehicle speeds and intersection travel intervals.

Time-Lapse Equipment and Filming Procedure

In order to obtain field data by the time-lapse photography method, the time-lapse camera, Nizo S-80 Schneider Verigon, as shown in Figure 4, was employed. This camera

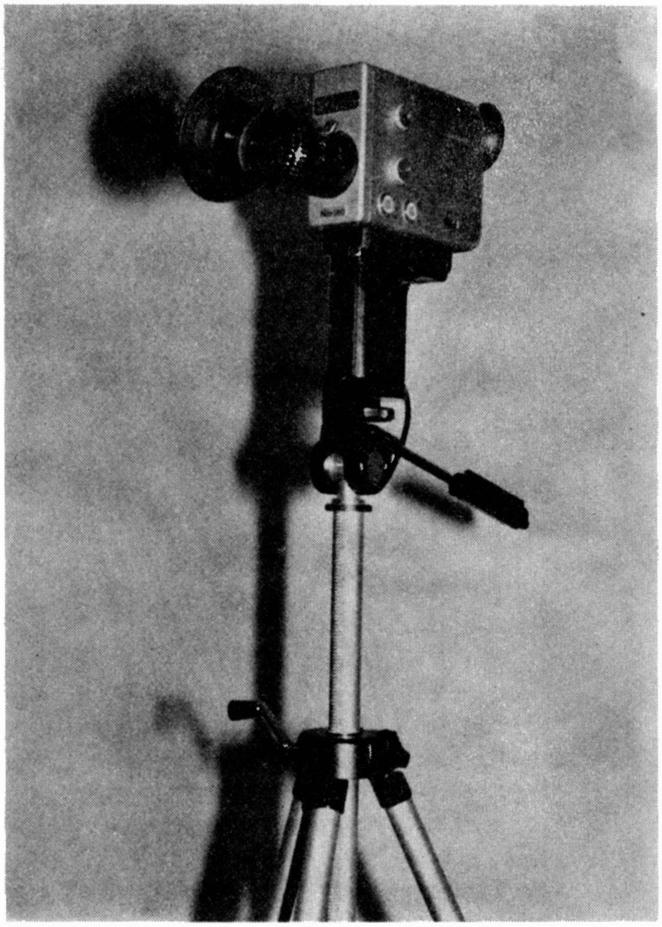


Figure 4. Time-Lapse Movie Camera

can take automatically exposed pictures at any required rate from one frame per minute to 54 frames per second. The filming process is operated by six 1.5 volt batteries (AA cells). Super-8 film cartridges, 50 feet in length, are required for this time-lapse camera. One advantage of this camera is its power zooming ability of from 10 to 80 millimeters. The camera can be mounted at a considerable distance from the intersection and still obtain close-up pictures.

To apply the time-lapse photography method for gathering field data, it is important to consider the placement of the time-lapse camera. Ideally the camera should be installed vertically above the selected intersection and at sufficient height to get a picture showing all four approaches back to the intersection system entrances. Due to lack of such an aerial platform, or even tall buildings or towers near the selected intersection, the time-lapse camera was mounted on an aerial bucket truck parked 500-600 feet away from the intersection. The position of the camera was about 40-50 feet above the ground level. Only a portion of the intersection was visible from one such position.

In order to get the desired speed of the filming process, the time-lapse controller dial, used for setting the single frame exposure, required calibration. To perform this calibration, the controller dial was set and checked with a stop watch prior to the field observation period. It was very difficult to set exactly the desired rate of filming time for each single frame. During the film analysis it was necessary, therefore, to carefully check the time intervals between frames. In this study, the single frame dial was set about 0.5 second intervals. The time for each filming period was also checked by stop watches to determine the actual time of the single frame.

The movie film employed in the field study was Kodak Ektachrome G160 in super-8 cartridges. This color film enables the analyst to observe and recognize vehicle movement conveniently and easily. The initial stops of vehicles and turning directions can also be observed from the color film. With the filming rate of 0.5 second per frame, one film cartridge is able to record field data for half an hour.

To analyze traffic data from developed films, both the Kodak and Ektagraphic MFS-8 projector and the Minette-Viewer Editor 55, as illustrated in Figure 5, were used. The advantage of this movie projector is its still mode for a single frame analysis. Like the Minette-Viewer Editor 55, it also can be operated at various speeds and reversed to check previous events in the movie films.

With the technique of time-lapse photography, all traffic data from the selected four-way stop controlled intersection were permanently recorded and were available for study in the laboratory at any time.

Measuring Time by Stop Watch Method

There is a need for measuring accurately the times of

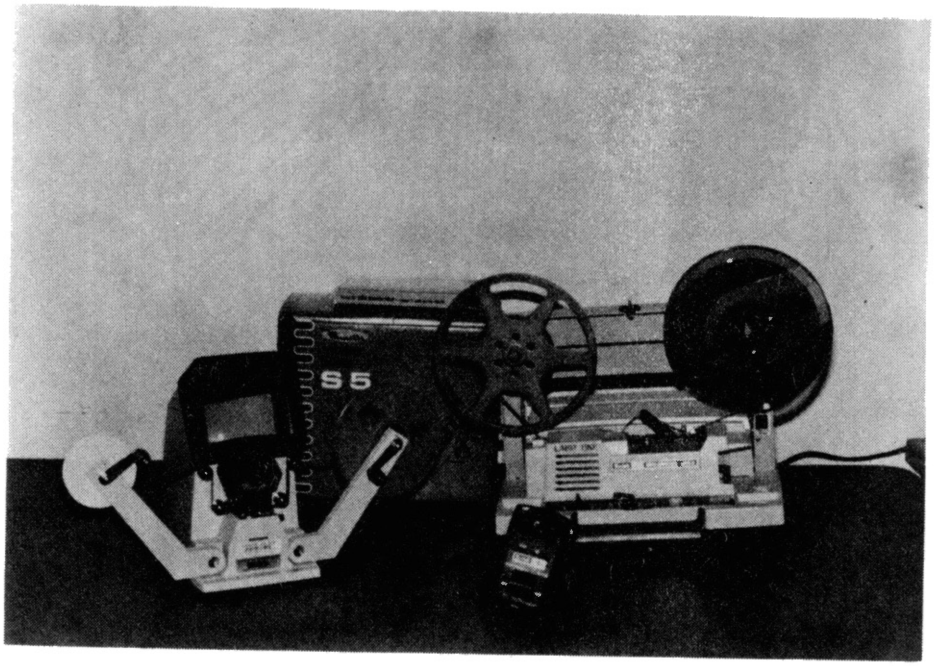


Figure 5. Stop-Action Movie Projector and Viewer

events occurring at the four-way stop intersection. These events include the time intervals of vehicles passing over a measured distance for speed study and time intervals required for crossing the intersection. The Heuer Microsplit LCD stop watch and Seiko Alarm-Chronograph used in this study are able to indicate the time precisely and accurately, reading to one-hundredth of a second with a six-digit readout. In addition, the Sony Micro Cassette-Corder M-102 was used for recording observed times. Use of this tape recorder makes it possible to later analyze traffic data from the studied intersection.

To record the time of each vehicle passing the measured distance in the observed lane and vehicle travel time crossing the intersection, three observers, with stop watches and tape recorders, located themselves near the studied sections and recorded times without interrupting traffic movement. Each observer studied a different vehicle. By this procedure, all statistics of vehicle speeds and intersection travel times during the studied period were recorded.

CHAPTER V

INTERSECTION FIELD STUDY

The selected site for this research was the intersection at North Washington Street and McElroy Street in Stillwater, Oklahoma. Washington Street is a two-way four-lane street running north and south and, McElroy Street is the two-way two-lane street with a down hill slope on the west approach.

Field observations were conducted during morning and evening peak hours in April, 1979. Peak hours at the selected intersection are 7:30 - 8:30 a.m. and 4:30 - 5:30 p.m. During the morning peak, the heaviest traffic flows are southbound on North Washington Street and westbound on McElroy Street. In the evening, heavy traffic exists from the directions opposite to those in the morning peak hours. Because of the difficulty in mounting the time-lapse camera directly above the studied intersection and at sufficient height to collect traffic data from all approaches, data were collected during the peak half hour for each approach twice on different days. The camera was mounted on a city-owned bucket truck parked about 500 - 600 feet away from the intersection and 40 - 50 feet above the ground surface.

Before collecting traffic data, the intersection entrance line for each approach was defined, based on observation of vehicle behavior. This is the point at which most vehicles start decelerating from their normal travel speed. Intersection approach lengths obtained from preliminary observation are listed in Table I.

Intersection Approach Speeds

The purpose of studying vehicle speeds uninhibited by the intersection control system was to compare them with the reduced speeds within the zone of influence of the intersection controls, and to utilize these speeds as input for the computer simulation model in determining delays at the studied intersection. Speeds of vehicles entering each intersection system entrance were analyzed by observing free flowing vehicles moving over a distance of 100 feet beyond the entrance. By the stop watch method, speeds of vehicles were determined by dividing the distance by the recorded times. From the time-lapse movie, vehicle speeds were also obtained by dividing the 100 foot distance by the total time determined from the number of frames needed for a vehicle to traverse the distance. Appendix A shows cumulative speed distribution of vehicles for each approach lane in feet per second.

Observed speeds of vehicles in each approach lane were approximately equal to the speed limits, except for the eastbound vehicles, for which the median speed was about 31.5 feet per second. The reason for the lower speed of

TABLE I

INTERSECTION APPROACH LENGTHS

Street	Direction of Traffic	Lane	Approach Length (feet)
McElroy St.	Eastbound	-	550
	Westbound	-	400
N. Washington St.	Northbound	outside	500
		inside	500
	Southbound	outside	400
		inside	400

these vehicles was the five percent down hill approach slope, requiring vehicles to use low speeds in order to stop in queue or at the stop-line. The median speeds of all vehicles entering the intersection system are shown in Table II.

Vehicle Arrival Times at Intersection System Entrances

Arrival times of vehicles in each approach lane at intersection system entrances were determined by analyzing the single frames of the recorded time-lapse movie. The time represented between single frames is 0.5 - 0.6 second. Arrival time of each vehicle was recorded when its front wheeels crossed the reference line. Inter-arrival time or headway between two successive vehicles was also determined from the time-lapse movie. The minimum headways of vehicles in each approach lane, shown in Table III, vary between 1.1 and 1.8 second. The headway distributions of vehicles agree with the shifted negative exponential distribution expressed in formula 3.7 (Chapter III). The mean and minimum headway for each approach lane obtained from Table III are used in this equation to evaluate the inter-arrival time distributions in this study. All results of headway distributions are presented in Appendix B.

Travel Time Across the Intersection

At a four-way stop intersection, the rate of acceleration of vehicles entering the intersection will affect the

TABLE II

MEDIAN SPEEDS OF OBSERVED VEHICLES

Direction of Traffic	Lane	Median Speed	
		Ft/sec	MPH
Eastbound	-	31.5	21.5
Westbound	-	41.5	28.3
Northbound	outside	41.7	28.4
	inside	42.3	28.8
Southbound	outside	42.5	29.0
	inside	45.2	30.8

TABLE III

MEAN AND MINIMUM VEHICLE HEADWAYS (SECONDS)

Direction of Traffic	Lane	Number of Observed Vehicles	Vehicle Headway	
			Mean	Minimum
Eastbound	-	201	8.95	1.40
Westbound	-	182	9.94	1.20
Northbound	outside	164	10.97	1.30
	inside	149	12.08	1.10
Southbound	outside	151	11.92	1.20
	inside	105	17.14	1.80

stop-waiting times of crossing vehicles at stop-lines. The longer the time used for a vehicle to travel through the intersection, the more delay the crossing vehicle has at the stop-line. From field observation of the intersection under study, average intersection travel times of westbound vehicles (including those turning left or right) are greater than the average intersection travel times for other approaches. The steep grade at the stop-line of the westbound approach causes vehicle delays in starting across the intersection. East and westbound vehicles also have a greater intersection travel length, since they must cross four lanes of traffic. Table IV shows the details of intersection travel times for vehicles from each approach. These observed intersection travel times were employed in the computer simulation model.

Turning Traffic

There were high percentages of left-turn vehicles in all intersection approaches. It was noticed that the numbers of right-turn vehicles were also high in the north and south approaches, but very low in the east and west approaches. The observations of turning traffic in each approach lane are summarized in Table V.

Vehicle Travel Time Through the Intersection System

At a four-way stop intersection, the travel time of each vehicle passing through the intersection system is

TABLE IV

AVERAGE INTERSECTION TRAVEL TIME OF VEHICLES IN EACH APPROACH (SECONDS)

Traffic Direction	Intersection Approach					
			Northbound		Southbound	
	Eastbound	Westbound	Outside Lane	Inside Lane	Outside Lane	Inside Lane
Right-turn	3.38	3.87	3.07	-	3.52	-
Through	4.58	4.93	3.97	3.98	3.79	4.16
Left-turn	4.56	5.04	-	4.60	-	5.00

TABLE V

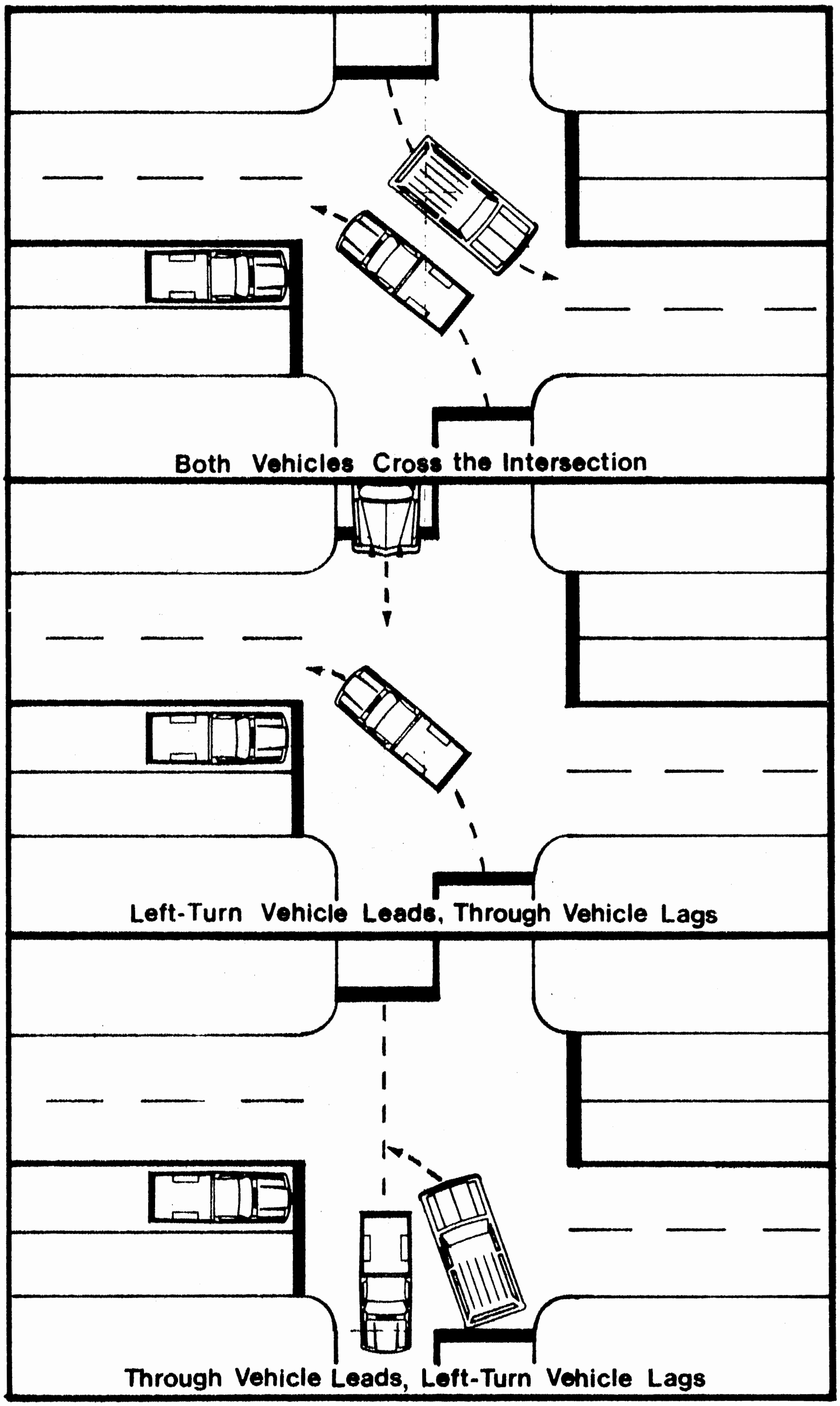
PERCENTAGE OF TURNING TRAFFIC

Traffic Direction	Lane	Approach Volume	Right-turn Vehicles		Left-turn Vehicles	
			Volume	Percentage	Volume	Percentage
Eastbound	-	191	12	6.3	62	31.9
Westbound	-	181	5	2.8	65	35.9
Northbound	outside	164	78	47.5	-	-
	inside	146	-	-	34	23.3
Southbound	outside	151	44	29.1	-	-
	inside	105	-	-	13	12.4

considered to be the time interval from when it enters the intersection system entrance until it exits the intersection. Travel times of vehicles are obtained by analyzing the time-lapse movies frame by frame. The vehicle travel time is also evaluated by summing the deceleration time, queueing time, and intersection travel time of each vehicle. Appendix C shows the vehicle travel times of through traffic, right-turn traffic, and left-turn traffic in each approach lane.

Vehicle Turning Characteristics

According to the basic rule of the four-way stop control device, the first vehicle and the opposing vehicle at stop-lines are able to enter the intersection simultaneously. If the first vehicle makes a left-turn, the opposing vehicle must wait until the first one crosses the intersection exit. If both vehicles are turning left, they are both able to enter the intersection and make the left turn at the same time. All left-turn characteristics of vehicles at the studied intersection are shown in Figure 6. It is obvious that at the four-way stop controlled intersection, the first vehicle has an opportunity to turn right quickly unless the crossing vehicle from the left side is still moving in the intersection.



Both Vehicles Cross the Intersection

Left-Turn Vehicle Leads, Through Vehicle Lags

Through Vehicle Leads, Left-Turn Vehicle Lags

Figure 6. Left Turning Vehicle Characteristics

CHAPTER VI

THE TRAFFIC SIMULATION MODEL

The simulation model for the delay study at a four-way stop controlled intersection was developed using the General Purpose Simulation System (GPSS). This traffic simulation was performed on the IBM 370, model 168 computer. The GPSS language was employed because it provides efficient random number generation techniques for running stochastic models on the computer. It was designed to be used by analysts who were not specialists in computer programming. The use of flowcharts to describe a system is well-known, hence GPSS was structured as a block-oriented language. Its powerful program statements can represent the entire behavior of the project or system from which it was developed. This language also provides simple procedures for the analyst to specify and gather data of specific importance to the current model. GPSS language, therefore, is particularly well suited to traffic problems, because it accepts random and queueing vehicles.

The General Purpose Simulation System Language

The General Purpose Simulation System (GPSS) was originally developed in conjunction with network analysis being performed by Geoffrey Gordon at the Bell Telephone Laboratories during the late 1950's (36). The original version was then further developed and generalized by Gordon, Barbieri, and Efron, and first made available in 1961. At that time, the language was titled GPS (General Purpose System Simulator). In 1963, a second version, GPSS II, was introduced as an extension and improvement of GPS. GPSS III was initiated in 1966 for use on the larger second-generation IBM computers. GPSS III is substantially different from GPSS II; it has more features, runs faster, and is easier to use. In 1967, the General Purpose Simulation System (GPSS/360) language was introduced and became available in 1968.

The GPSS design is based upon the premise that most systems can be adequately simulated through the use of only a few types of entities: dynamic entities (transactions), equipment entities (facilities and storages), statistical entities (queues and tables), and operational entities (blocks). The operational entities or blocks, like the blocks of a diagram, provide the logic of a system, instructing the transactions where to go and what to do next. These blocks, in conjunction with the other entities identified above, constitute the language of GPSS/360 used in this study.

Constructing a GPSS Model

In order to develop a traffic simulation program. it is necessary to translate the studied problem into a GPSS program. The four-way stop controlled intersection system must be defined and analyzed so that its elements and their interactions and functions are clearly understood. The acquisition of relevant empirical data and the preparation of the intersection system flow diagram are usually important parts of this translating process.

Intersection System Description

The simulation model used in this research represents the traffic operation at a four-way stop controlled intersection. The selected intersection has a two-way four-lane street intersecting a two-way two-lane street as shown in Figure 7. Approach vehicles are influenced by the intersection system when they enter the intersection system entrances, stop at stop-lines, and leave the intersection exits, the points at which all vehicles are able to regain their desired speeds. The intersection system consists of the following elements:

1. Lanes. All approach lanes are assigned different numbers and symbols as below:

L_1 or LANEB, denoting eastbound lane.

L_2 or LANWB, denoting westbound lane.

L_{31} or LANNO, denoting northbound outside lane.

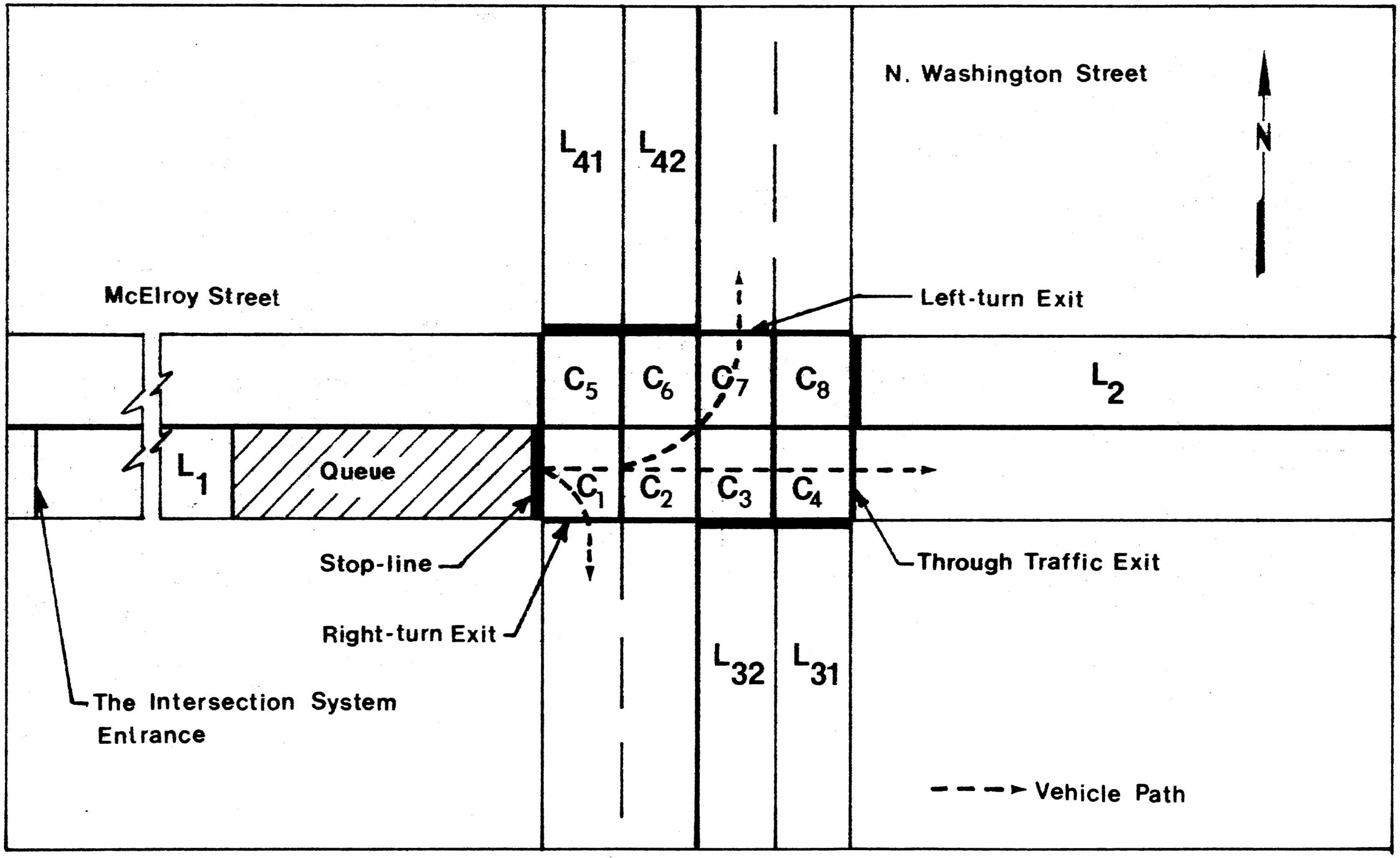


Figure 7. An Intersection Module and Traffic Paths

L_{32} or LANNI, denoting northbound inside lane.

L_{41} or LANSO, denoting southbound outside lane.

L_{42} or LANSI, denoting southbound inside lane.

2. Intersection cells. The intersection is divided into a "checkerboard" arrangement of cells of similar size. The boundaries of each cell are determined by the region formed by pairs of intersecting lanes in the intersection. The cell is the minimum area that may be occupied by any vehicle when attempting to cross the intersection. In Figure 7 each cell is numbered in a designated sequence, shown as C_1, C_2, C_3 and so on. Typical vehicle paths in the three directions are also shown.

Simulation of Vehicle Flow

At the selected intersections, there are three different vehicle flow types as shown in Figure 8 to Figure 10. The vehicle flow charts are constructed under real conditions and behavior of approach vehicles in each lane. Eastbound and westbound vehicles, on the two-way two-lane street, will move through the approach lane with no separate left-turn or right-turn lane. For northbound and southbound approaches, on the two-way four-lane street, turning vehicles can make right-turns from the outside lane, and make left-turns from the inside lane (Figure 1).

A vehicle enters the intersection system when it crosses the system entrance 400 - 550 feet away from the intersection. It will decelerate and join a vehicle queue if

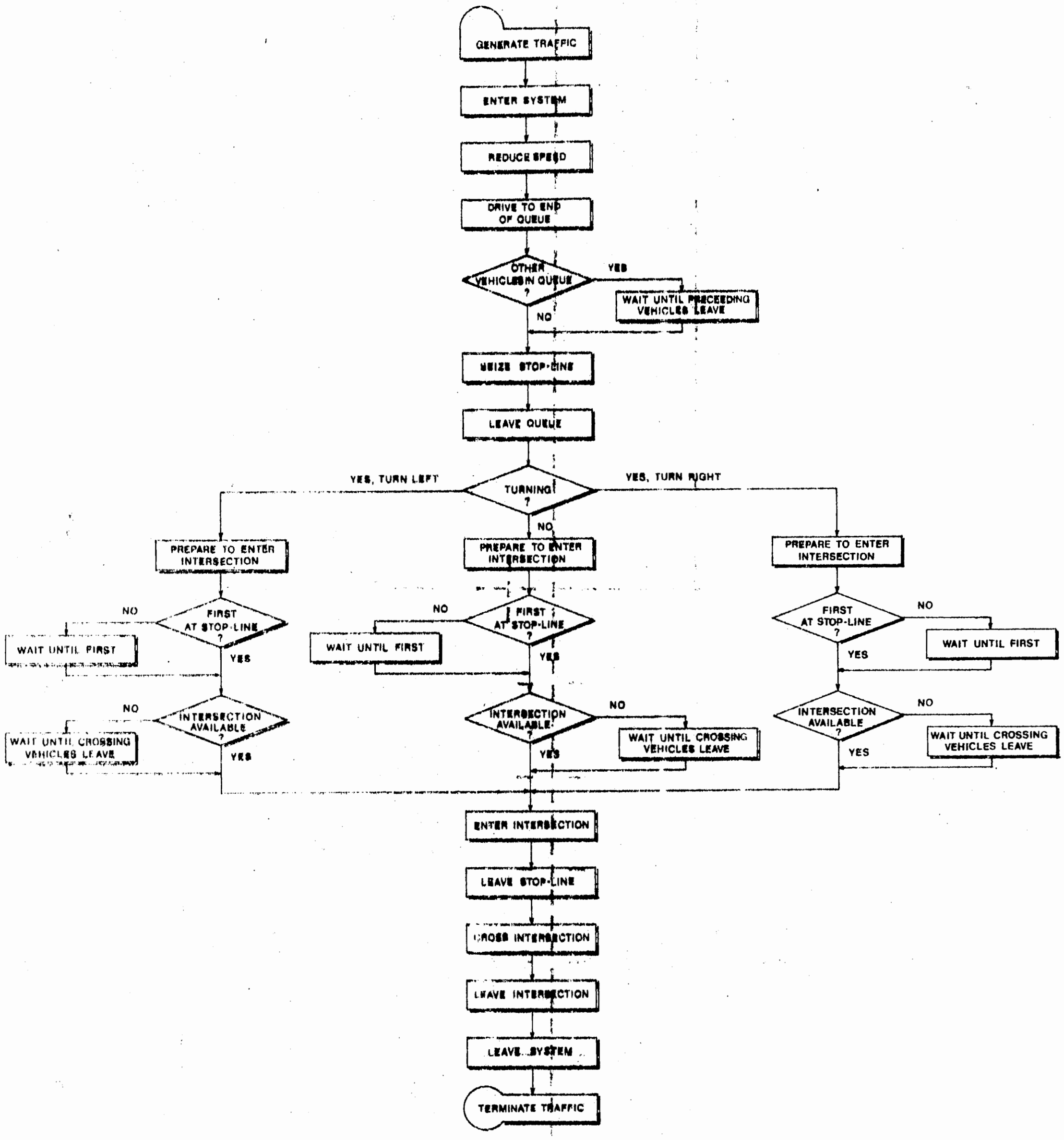


Figure 8. Lane Vehicle Flow (Two-Lane Roadway)

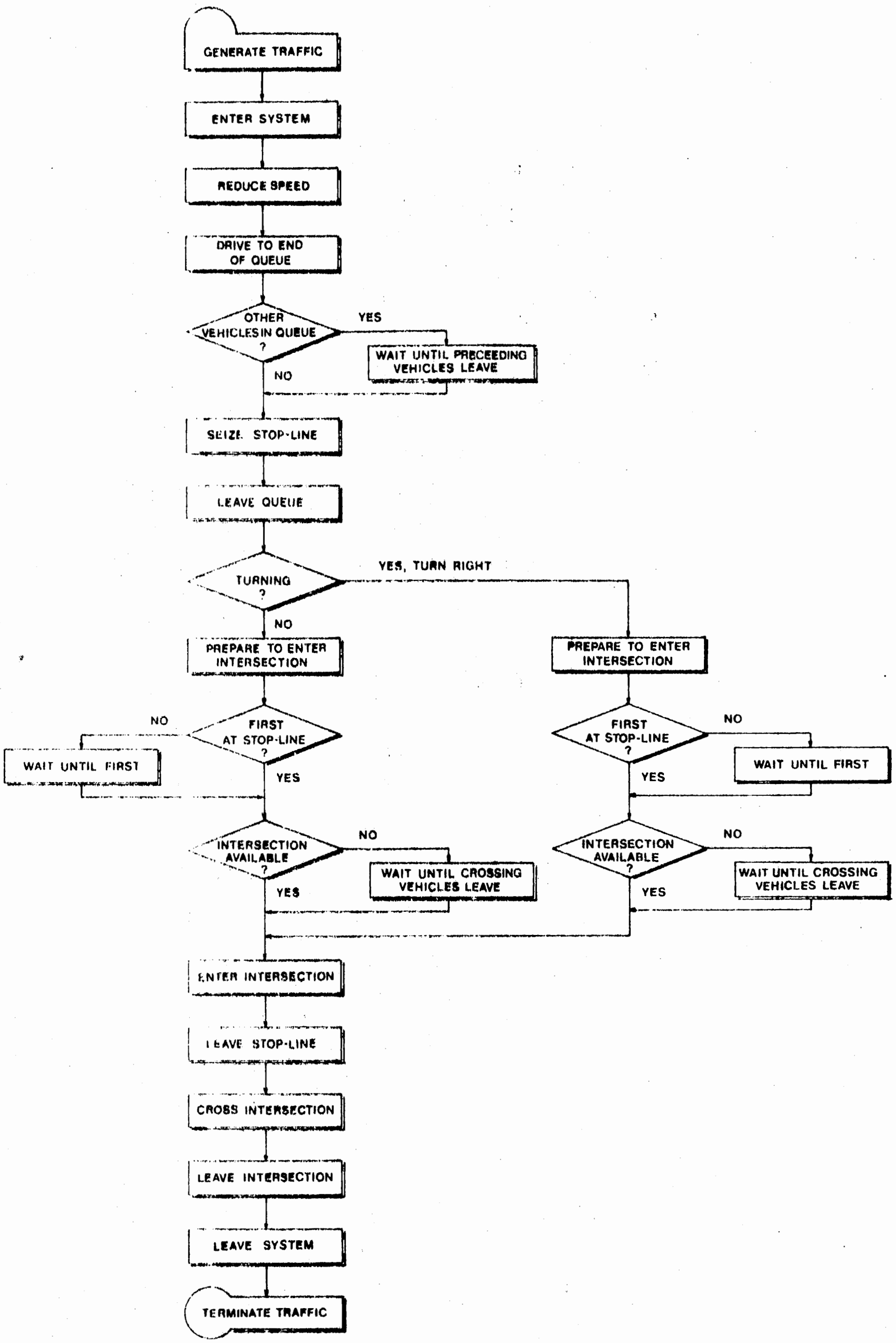


Figure 9. Outside Lane Vehicle Flow (Four-Lane Roadway)

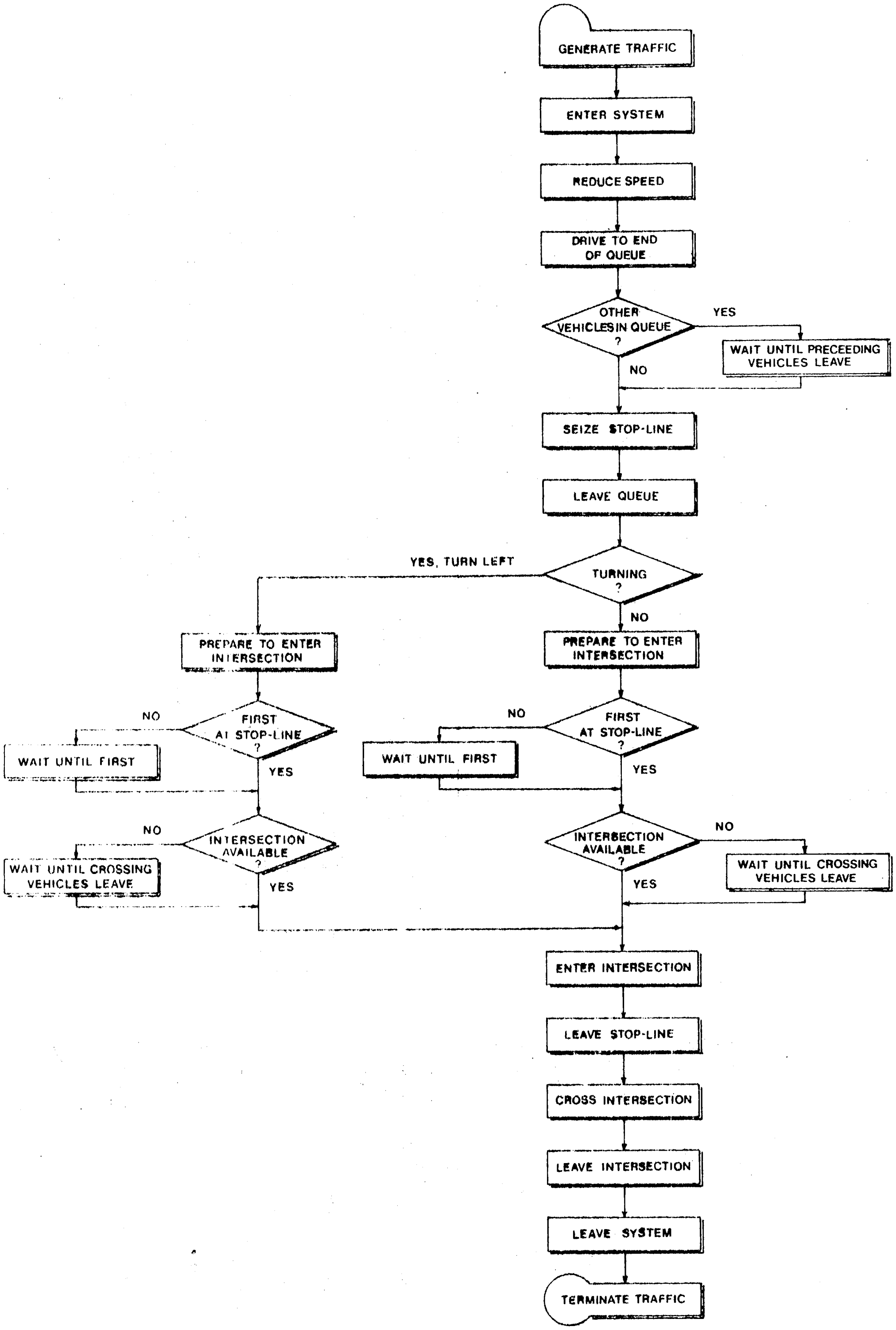


Figure 10. Inside Lane Vehicle Flow (Four-Lane Roadway)

preceding vehicles are waiting for intersection entrance. If there is no queue, the arriving vehicle will slow down until stopping at the stop-line. The vehicle driver will check his priority at the stop-line, and check if the intersection is available. The vehicle will then cross the intersection and leave the intersection system in the desired direction.

Operation of the Traffic Simulation Model

The GPSS computer model is constructed to follow the details of the vehicle flow charts. This computer language allows the analyst to submit a model to the computer in the form of a network of blocks, connected in the same order as a sequence of events. In this study, the computer model simulates vehicle movements from all approach lanes from the time they enter the intersection system entrances until they leave the system. Traffic in each lane is programmed independently for realistic simulation of the traffic stream. Vehicles in the system are represented by transactions moving through the block diagram under control of the blocks and are created and terminated as required.

Vehicles entering the intersection system are created by the GENERATE block, and sent into the system at random intervals as specified by the observed headway distribution of traffic in each approach lane. All observed traffic statistical distributions are listed in the FUNCTION entities and are selected randomly during the simulation run. Simulation begins by setting the simulated clock time within the program to zero. The simulated time unit in the model is equivalent to one-tenth of a second for each second of actual time. The first vehicle in each lane can be created at any time after simulation starts by the offset time specified by the GENERATE block.

The transaction or vehicle then joins its group in each lane by the JOIN block, and forms a queue by means of the QUEUE block. In the computer program, stop-lines and each intersection block (formed by intersecting lanes) are represented by facility entities, SEIZE and ENTER blocks. When the vehicle arrives at the stop-line, it is said to "seize" the stop-line facility. The vehicle direction through the intersection was assigned randomly by the TRANSFER block and the FUNCTION entity.

To simulate the real vehicle waiting to enter the intersection at each stop-line, a "user chain" is used to control any number of transactions and allow only the leading vehicle, linked to the chain, to "seize" the stop-line. The "user chain" is also employed to assign proper speeds to vehicles entering the speed checking points. At stop-lines, vehicle priority is checked, along with appropriate conditions to enter the intersection, by the use of TEST blocks and Boolean variables, BVARIABLE. If they meet all requirements, they are able to progress to the following blocks or the intersection in the real system.

It is noted that a transaction will move through the system in zero clock time until it encounters a block that blocks or delays it. The ADVANCE block is the only GPSS block that can delay a transaction for a specified period of time. In this traffic model, the ADVANCE blocks were used to specify deceleration, acceleration, queueing, and travel times of vehicles in the system.

All statistical information is accumulated automatically by the GPSS program whenever a transaction enters a TABULATE block with a TABLE card. At the end of the program, the transaction in each lane is eliminated from the system by the TERMINATE block.

CHAPTER VII

TRAFFIC SIMULATION RESULTS

One important reason the GPSS language was employed to develop the computer simulation model in this research stems from its power to accumulate results in the form of statistical distributions. It is possible not only to accumulate queue statistics, but also other statistics such as speed distributions and headway distributions and have them printed out in the form of frequency tables. It automatically provides a complete output of system statistics without the need for instructions pertaining to the accumulation or formating of these statistics. The normal standard output produced by the simulation model in this investigation consists of the following: clock times, block counts, facility statistics, storage statistics, queue statistics, and frequency tables. These statistics are collected and computed continuously as the run proceeds.

Standard Simulation Output

The simulation output obtained from this investigation as shown in Appendices D to O presents clock and block entities, vehicle queue statistics, and all traffic statistical frequency tables. The computer results include the distribution of headway, speed, queue length, travel time, arrival and departure rate, and delay of vehicles in each approach lane.

Appendix D shows block entities, including relative and absolute clock time, and a list of block counts. In this program, both relative and absolute elapsed clock time are 18,000 clock units (exactly one-half hour of simulation) corresponding to the periods of field observation. The current counts show a number of transactions at each block when the run ends, and the total counts reflect the number of transactions entering each block since the beginning of a run. These are useful for checking the movement and number of vehicles at any part of the intersection system.

The statistics for queueing vehicles in each approach lane are shown in Appendix E. In these queue statistics, maximum contents mean the maximum number of transactions in each queue at any time during the simulation run. Total entries show the number of transactions entering into each queue.

Appendices F through O contain the frequency table statistics of vehicle behavior from the moment of entering the intersection system entrance until leaving the system. These frequency tables show the total number of transactions, average elapsed time for various transactions, standard deviation, frequency classes, and cumulative percentage of total entries that fell into that frequency class or lower classes.

Generation of Random Variables

In this GPSS simulation model, transactions or vehicles are created at the GENERATE block and are input to the system at random intervals as specified by the FUNCTION cards. Vehicles entering the system in each approach lane are generated simultaneously by different sets of the observed headway distributions. Appendix B shows the comparison between observed headway distributions of vehicles at the intersection system entrances and computer random generated values. The computer results agree very well with the field observations and fit the shifted negative exponential distribution. The distributions of vehicle speeds at the intersection system entrances, observed from the studied site, also agree well with the simulation values (see Appendix A).

The sequential flow of transactions can be randomly altered by the use of TRANSFER statements. In this simulation model, turning vehicles were generated randomly by the TRANSFER blocks. For left-turning and right-turning vehicles from the same approach lane, the TRANSFER block was utilized to generate transactions as specified by the FUNCTION statements. The comparison of percentage of turning vehicles between the computer values and field observed values is shown in Table VI. The greatest difference is 4.09 percent for the westbound, left-turn traffic, while the smallest difference is 0.0 percent for the same approach, right-turn traffic. Overall the percentage of turning vehicles from computer results are very close to field values.

TABLE VI

COMPARISON OF PERCENTAGE OF TURNING VEHICLES

Traffic Direction	Type of Turn	Percent Turning Vehicles		
		Observed	Simulated	Differences
Eastbound	Right-turn	6.28	6.73	+0.45
	Left-turn	31.94	30.57	-1.37
Westbound	Right-turn	2.77	2.77	0.0
	Left-turn	35.91	40.00	+4.09
Northbound	Right-turn	24.92	24.67	-0.25
	Left-turn	10.86	14.67	+3.81
Southbound	Right-turn	17.25	18.25	+1.00
	Left-turn	5.10	5.55	+0.45

Simulation Statistical Outputs

All of the traffic statistical frequency tables obtained from the computer output are shown in Appendices D to O. These frequency tables are concerned with the arrival times, deceleration times, stop-waiting times, and acceleration times of vehicles in each approach lane. The frequency table consists of number of entries during a run, the mean value, standard deviation, frequency intervals, observed frequency, and cumulative percentage. The important traffic statistics shown in these frequency tables are the vehicle travel time and vehicle queueing statistics.

The vehicle travel time of straight through, right-turn and left-turn vehicles passing through the intersection system are shown in Appendices I through K. The computer results show the maximum travel times are associated with eastbound traffic. The average travel times of the eastbound straight through, right-turn, left-turn traffic are 85.48, 92.23, and 95.17 seconds respectively. The southbound traffic spent the least travel time through the intersection; 24.35, 19.87, 23.32, and 20.07 seconds for outside lane-through traffic, inside lane-through traffic, right-turn traffic, and left-turn traffic respectively.

Appendix H includes the queue length distribution of vehicles in each approach lane. Eastbound traffic has the highest average queue length at the intersection, 8.482. The lowest average value is 0.241 vehicles (southbound inside lane traffic).

The delay of vehicles at the studied intersection is presented in Appendices L through O. Delay times are computed by subtracting from system vehicle travel times the amount of travel time that would be required for an undelayed vehicle. From this investigation, the eastbound traffic has the maximum average delay times; 66.67, 74.92, and 76.79 seconds for through, right-turn and left-turn traffic respectively.

The comparison of vehicle travel times in each lane between field observed values and the computer values is shown in Appendix C. The results from computer outputs agree well with field observed values but the computer travel times are slightly less than the actual values. It obviously shows that the computer assumes perfect drivers for the simulation model. The drivers in the real system usually spend more time at stop-lines than the drivers in the computer simulation model. The average stop-waiting times obtained from the computer results are included in Appendix E.

From the computer outputs, the number of arriving and departing vehicles can be summarized and compared with the field observed values. Table VII shows good agreement, in comparing the number of turning vehicles, between the computer results and the field observed values.

TABLE VII

COMPARISON OF THE NUMBER OF ARRIVAL AND DEPARTURE VEHICLES

Vehicle Direction	Lane	Arrival Vehicles		Departure Vehicles					
				Total		Right-turn Vehicles		Left-turn Vehicles	
		Observed	Simulated	Observed	Simulated	Observed	Simulated	Observed	Simulated
Eastbound	-	201	199	191	193	12	13	61	59
Westbound	-	182	182	181	180	5	5	65	72
Northbound	outside	164	159	164	153	78	74	-	-
	inside	149	152	146	147	-	-	34	44
Southbound	outside	151	157	151	154	44	46	-	-
	inside	105	100	104	98	-	-	13	14

CHAPTER VIII

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

This research has been concerned with the development of a traffic simulation model to evaluate the efficiency of four-way stop controlled intersections. The computer language utilized in this investigation is GPSS (General Purpose Simulation System) language.

The traffic simulation model gives the traffic engineer an effective tool by which he can make quantitative decisions toward the improvement of the capacity of similar intersections. Employing the GPSS computer language and the capabilities of a large capacity computer system, it is possible to simulate the random traffic movement at a complex four-way stop controlled intersection system. It is also a useful alternative to empirical studies which tend to be costly and time consuming. A realistic simulation model can be constructed which incorporates the actual traffic behavior and variables observed from a studied intersection.

Based upon the results of this traffic simulation, the following conclusions may be drawn:

1. To obtain field data for input of the computer

simulation model, a time-lapse photography method with a one-half second exposure interval, as applied in this investigation, appears to be an economical method for collecting traffic data such as headways, travel times, queueing times, turning percentages, and the number of vehicles entering and and leaving the intersection system. For more precise data, when required, an accurate stop watch may be employed to study vehicle speeds, stop-waiting times, and intersection travel times. All traffic data collected, both by the time-lapse and stop watch techniques were used as input to the computer simulation model.

2. The GPSS computer simulation model developed in this research is found to be a powerful tool for analysis of the four-way stop controlled intersection. The simulation results agree well with the field observations except for a slight difference in percent of turning vehicles entering the intersection. This difference is caused by decimal truncation in the computer, and by the small number of vehicles left within the system at termination.

3. It is obvious that the actual traffic headway distributions agree well with the shifted negative exponential distribution. Therefore, in a traffic simulation model the shifted negative exponential distribution can be recommended for random traffic generation to obtain a realistic simulation model.

4. It appears that the combination of lane widths, the number of lanes, vehicle speeds, and approach gradient

produced a relative constant intersection system entrance distance. Vehicle approach speed appears to reduce directly proportional to the increase in approach gradient. Increased number of lanes increases the vehicle approach speed. Additional research should be conducted to more accurately define the relationship of the intersection system entrance distance, vehicle speed, the number of lanes, lane width and terrain.

5. The results of field observations and the simulation model indicate that the four-way stop sign control is an appropriate control device for the studied intersection. The total observed approach volume for the peak half hour was 937 vehicles, while the computed value was 925 vehicles.

The GPSS computer simulation program developed for this research is a useful program which can be extended to other intersection operations such as intersections controlled by two-way stop signs, and uncontrolled intersections.

Recommendations

An interesting extension of the subject study of delay at four-way stop intersections would be to simulate an intersection similar to that studied except that it has separate left-turn lanes for the minor (two-lane) roadway. The simulation model developed in this research could be applied directly to this situation.

Future studies are needed to evaluate the efficiency of other types of four-way stop controlled intersections than the four-lane major street crossing the two-lane minor street as selected for this research. The following are some of the intersection types for investigation in order to extend the scope of the application of this GPSS computer simulation model:

1. A four-way stop controlled intersection of a two-lane street crossing a two-lane street.

2. A four-way stop controlled intersection of a four-lane street crossing a four-lane street without separate turning lanes.

3. A four-way stop controlled intersection of a four-lane street crossing a four-lane street with separate left-turn lanes.

It is also recommended that a study be made on the quantity of fuel consumption while vehicles are delayed at four-way stop intersections.

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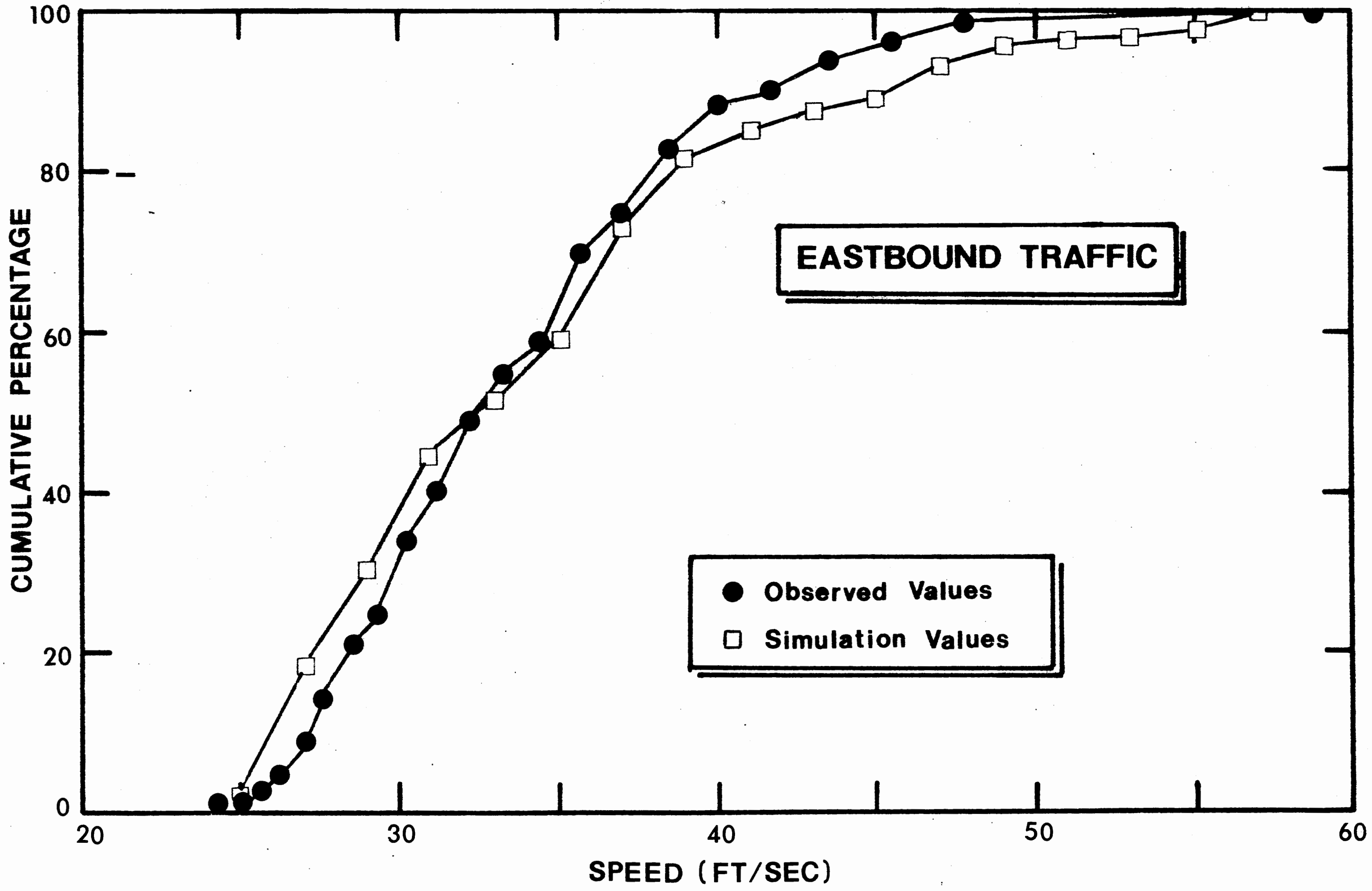
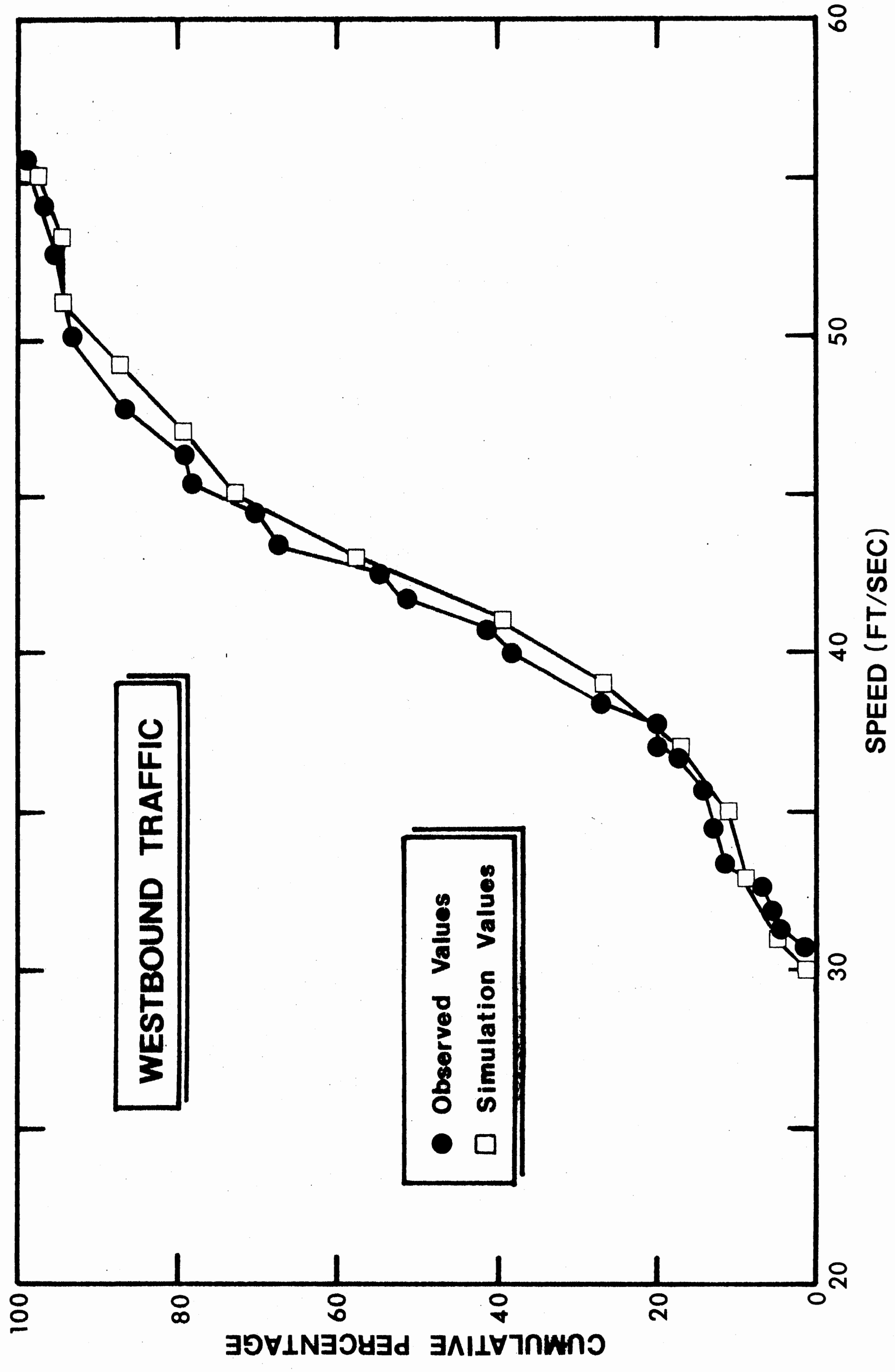
APPENDICES

APPENDIX A

COMPARISON OF SPEED DISTRIBUTIONS


EASTBOUND TRAFFIC
● Observed Values
□ Simulation Values
CUMULATIVE PERCENTAGE
100
80
60
40
20
0
20
30
40
50
60
SPEED (FT/SEC)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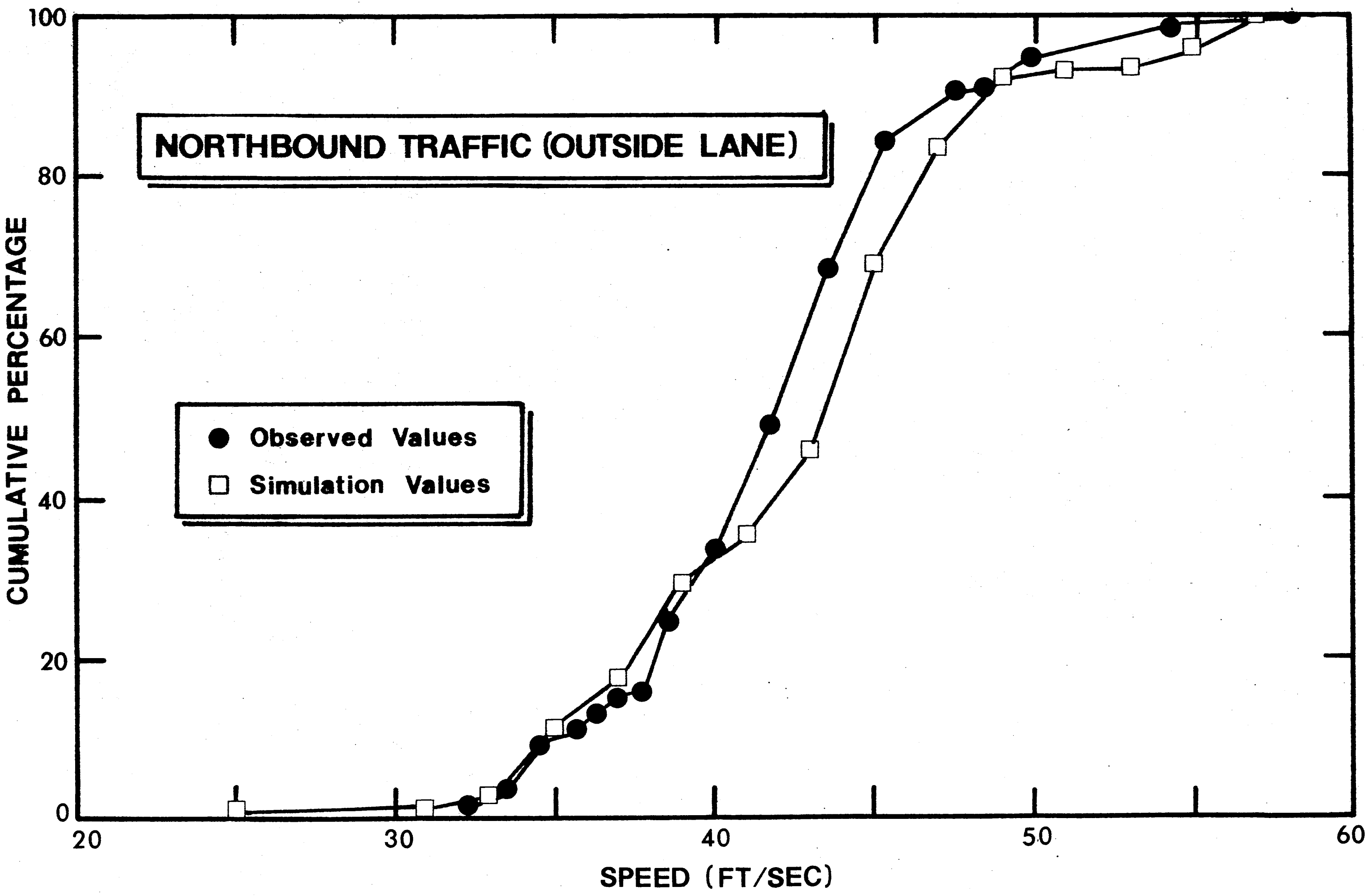
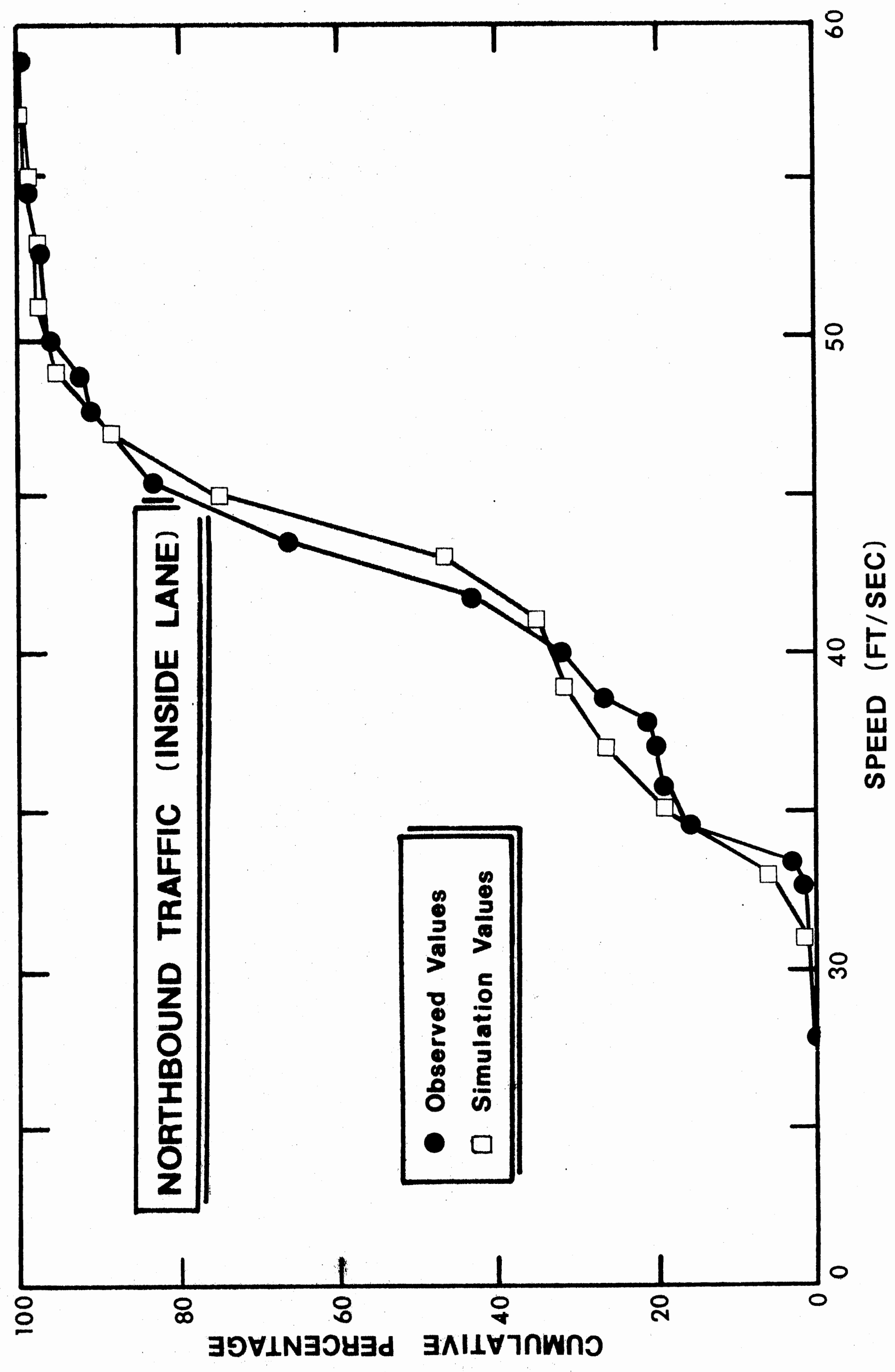
● Observed Values
□ Simulation Values
SPEED (FT/SEC)
20
30
40
50
60
CUMULATIVE PERCENTAGE
0
20
40
60
80
100


NORTHBOUND TRAFFIC (OUTSIDE LANE)
● Observed Values
□ Simulation Values
CUMULATIVE PERCENTAGE
0
20
40
60
80
100
SPEED (FT/SEC)
20
30
40
50
60


NORTHBOUND TRAFFIC (INSIDE LANE)
● Observed Values
□ Simulation Values
CUMULATIVE PERCENTAGE
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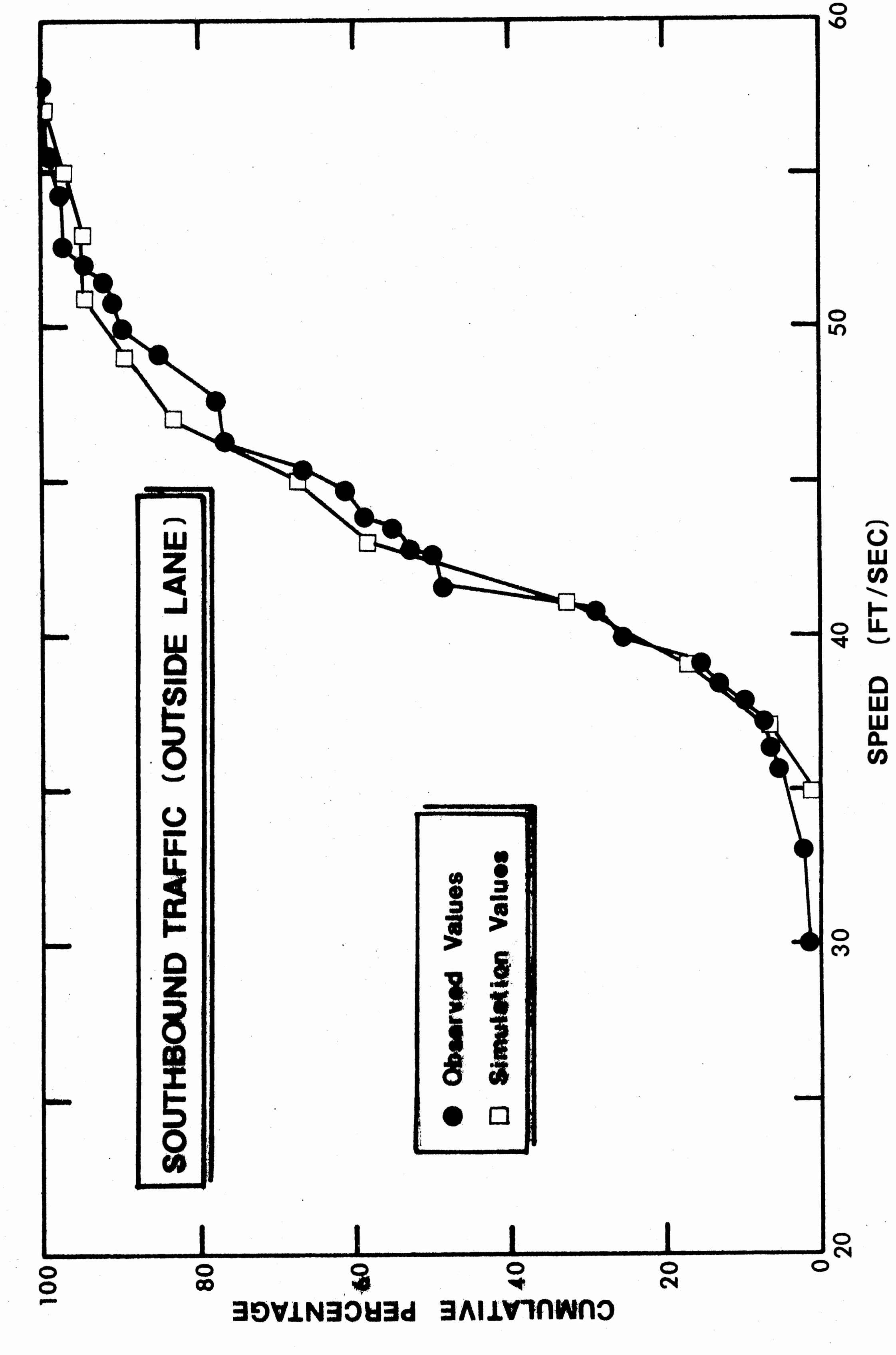
20
40
60
80
100
SPEED (FT/SEC)
0
30
40
50
60


SOUTHBOUND TRAFFIC (OUTSIDE LANE)
● Observed Values
□ Simulation Values
CUMULATIVE PERCENTAGE
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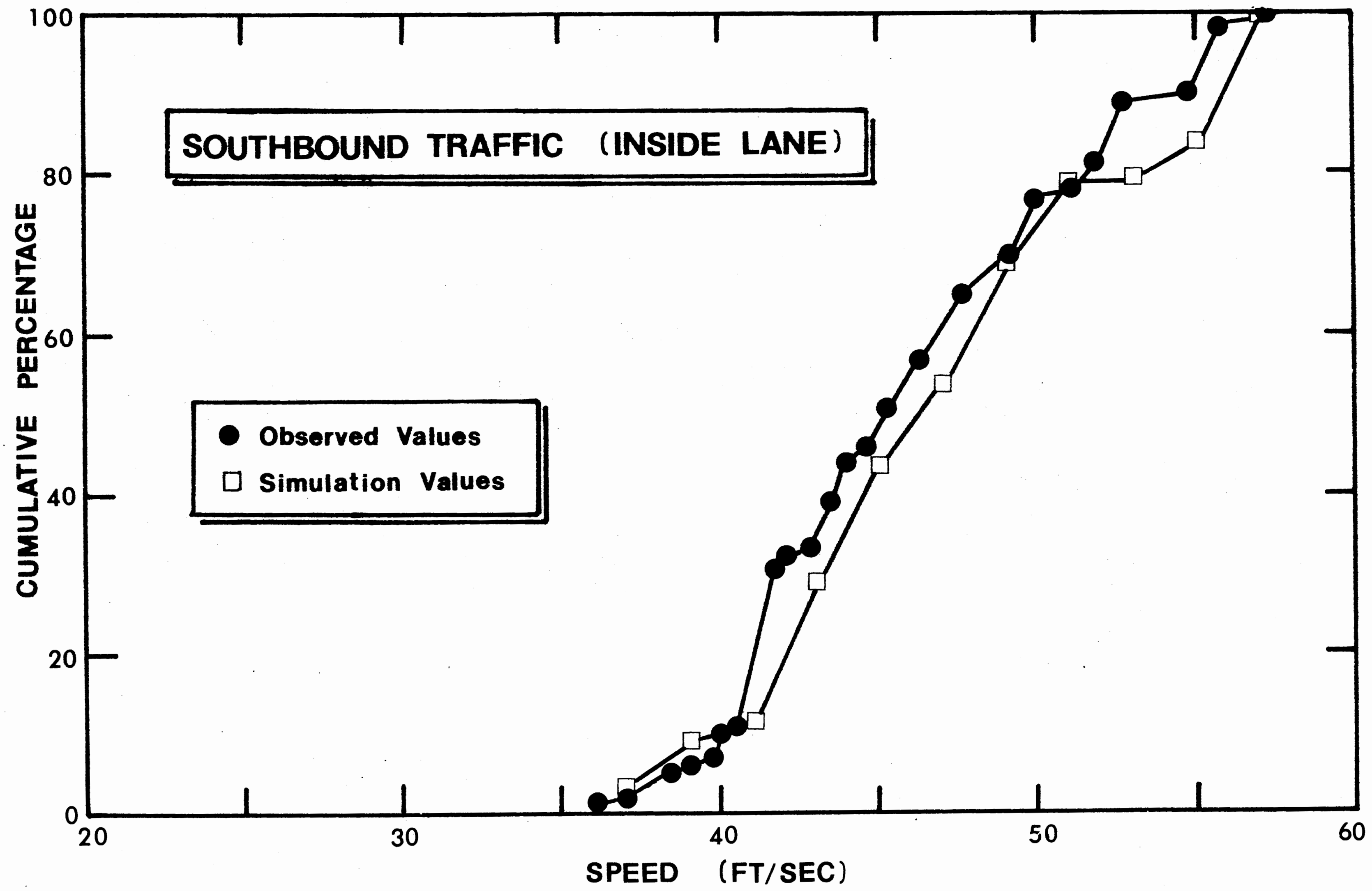
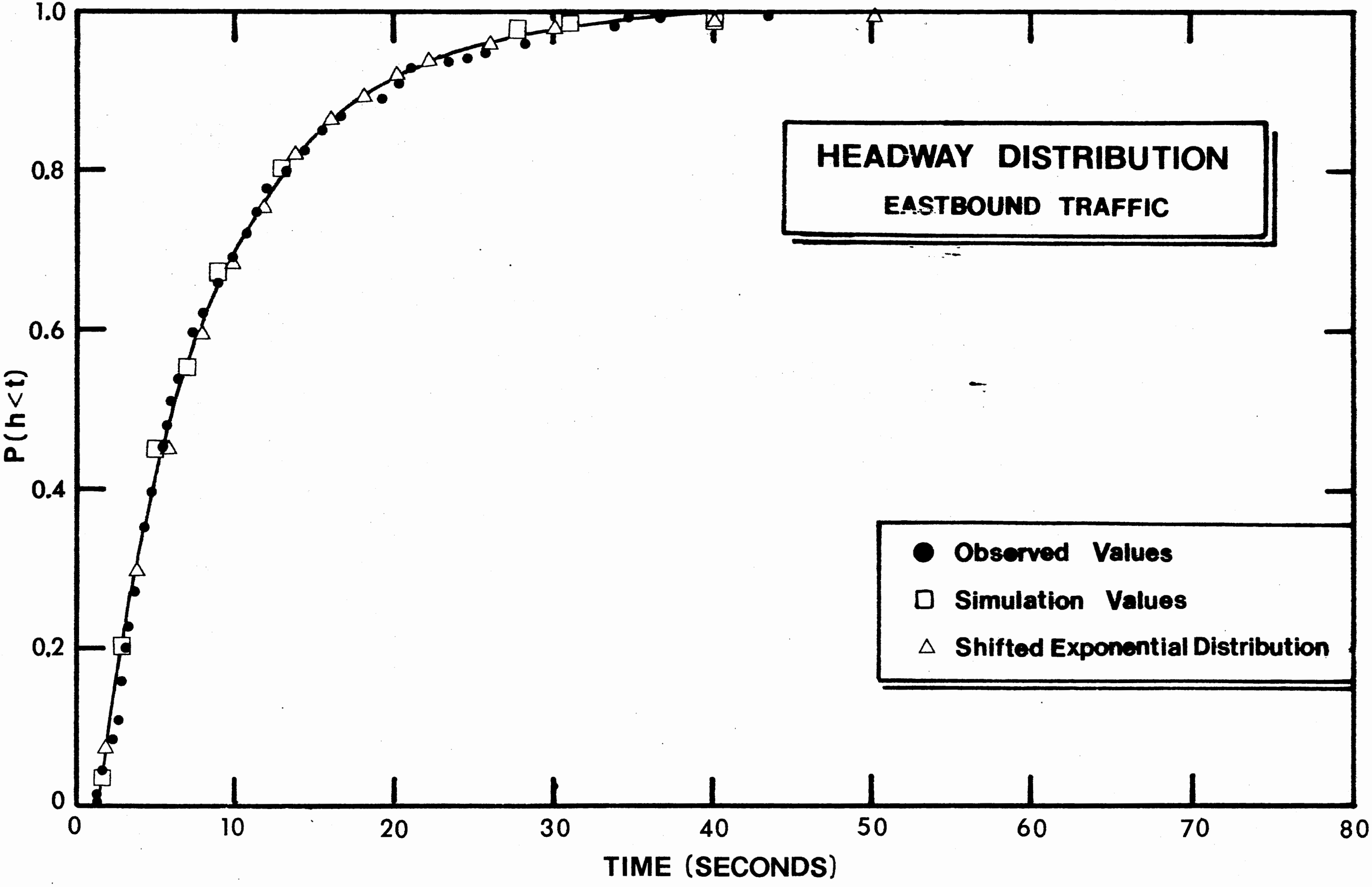
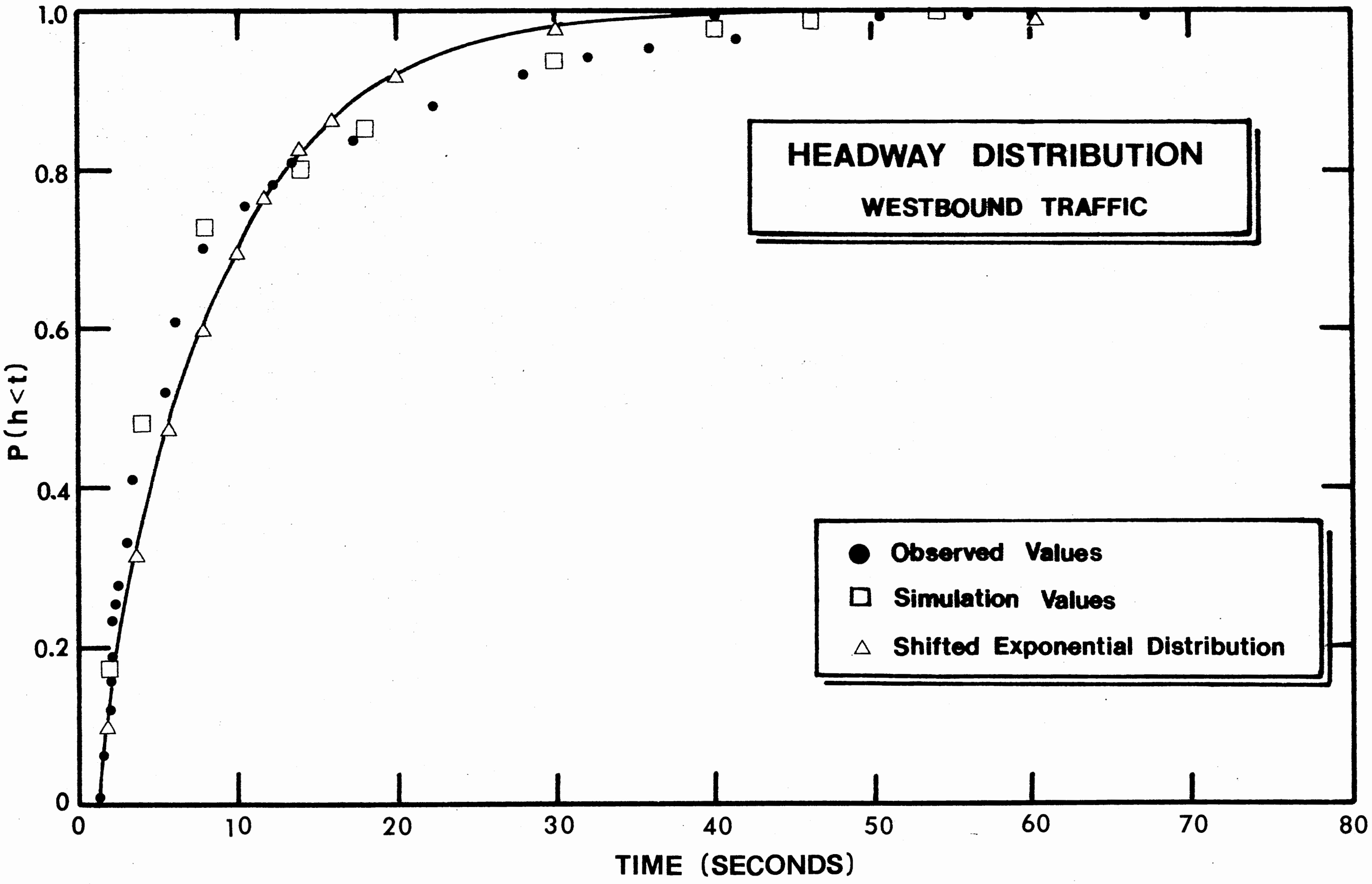
20
40
60
80
100
SPEED (FT/SEC)
20
30
40
50
60

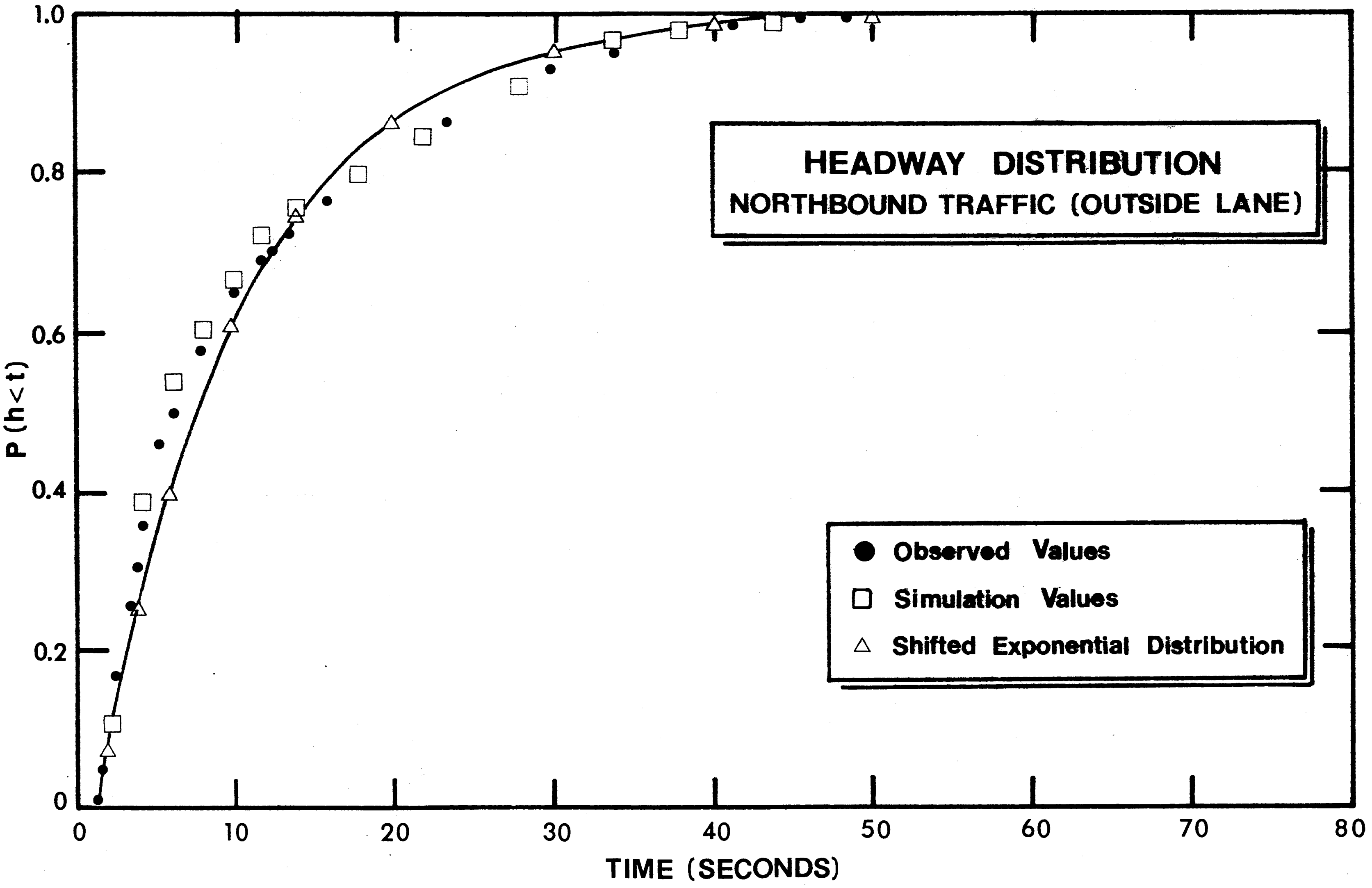

SOUTHBOUND TRAFFIC (INSIDE LANE)
● Observed Values
☐ Simulation Values
CUMULATIVE PERCENTAGE
0
20
40
60
80
100
SPEED (FT/SEC)
20
30
40
50
60

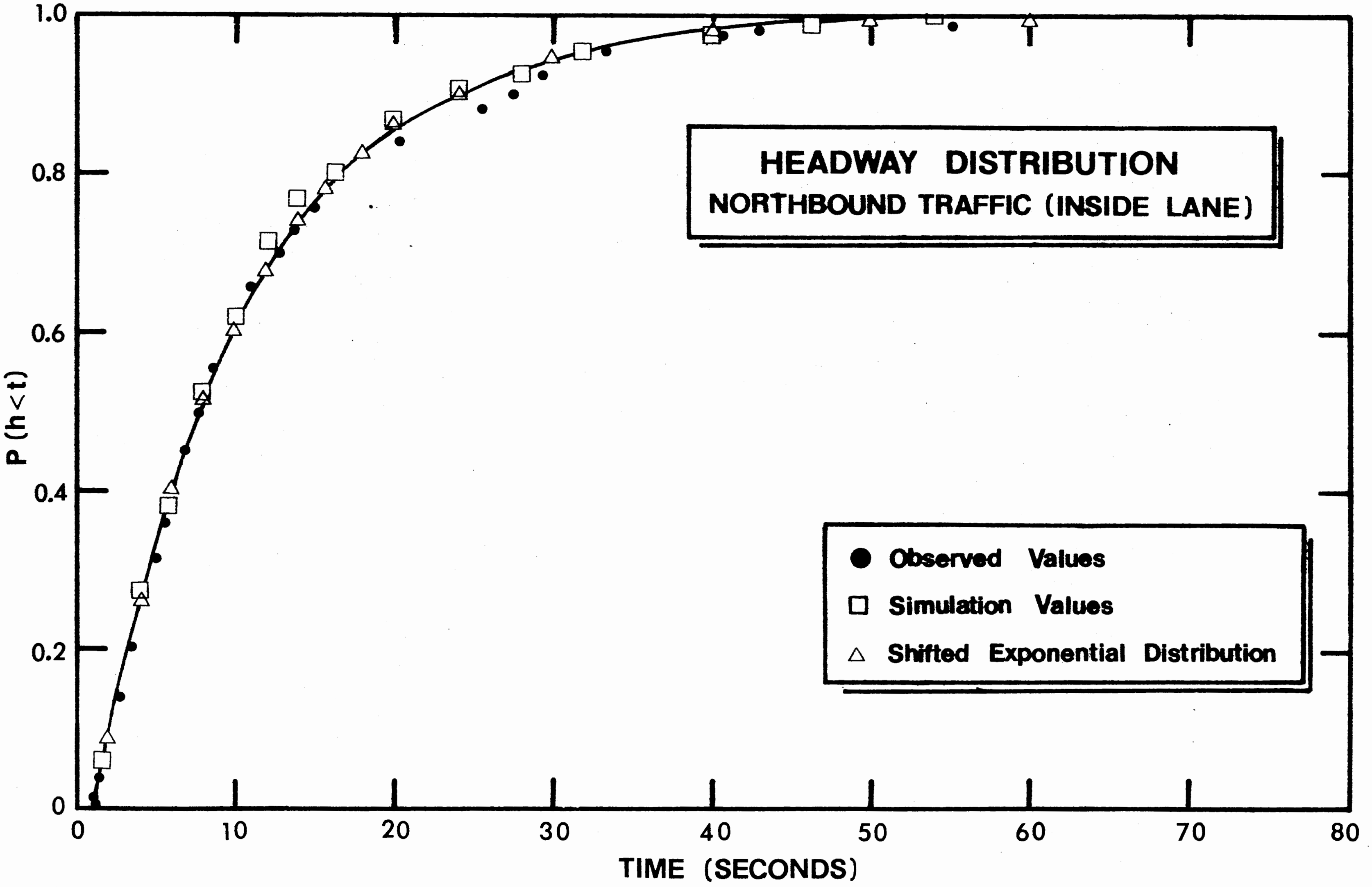
APPENDIX B

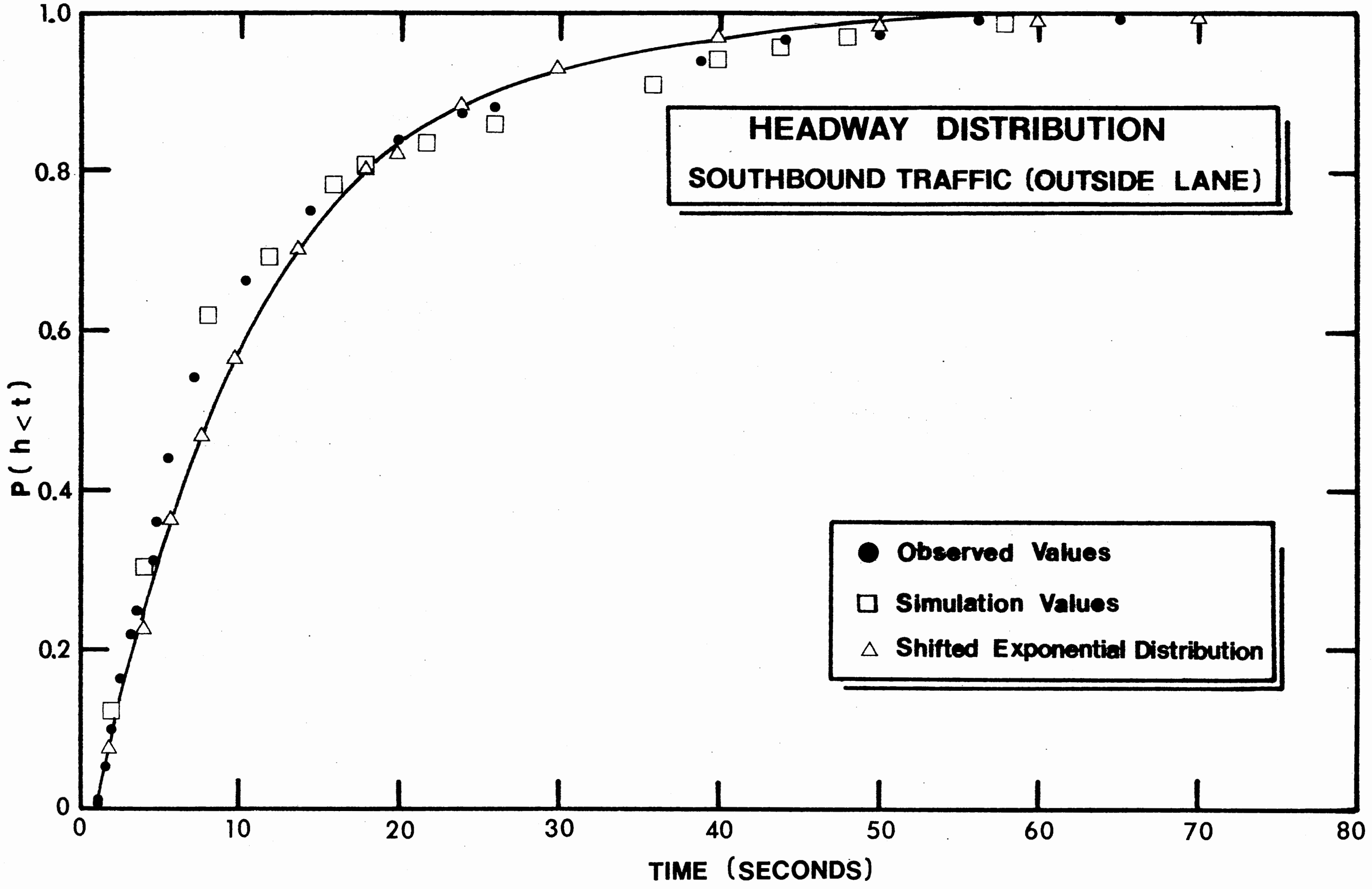
COMPARISON OF HEADWAY DISTRIBUTIONS

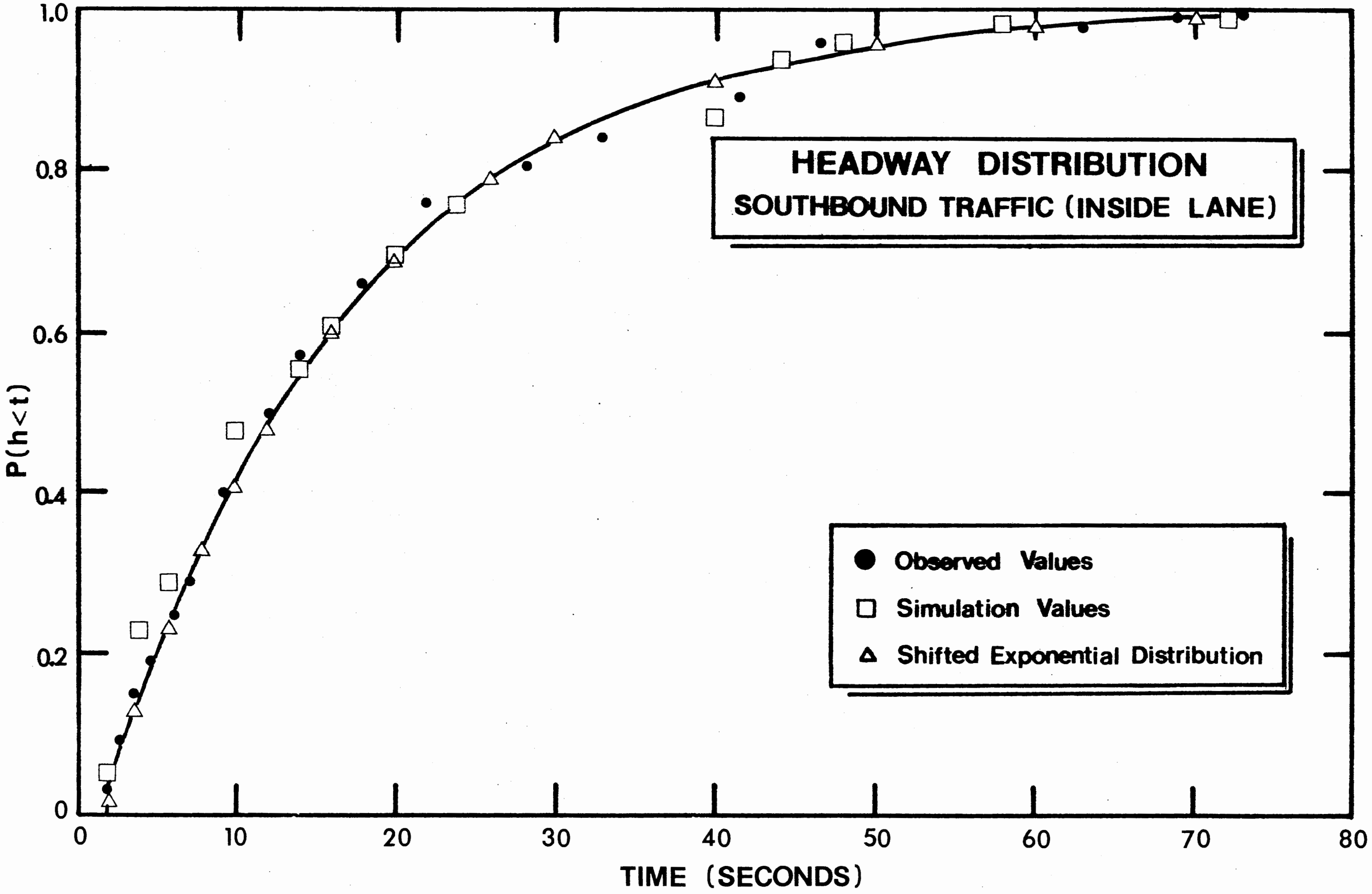

HEADWAY DISTRIBUTION
EASTBOUND TRAFFIC
● Observed Values
□ Simulation Values
△ Shifted Exponential Distribution
P(h<t)
1.0
0.8
0.6
0.4
0.2
0
0
10
20
30
40
50
60
70
80
TIME (SECONDS)


HEADWAY DISTRIBUTION
WESTBOUND TRAFFIC
● Observed Values
☐ Simulation Values
△ Shifted Exponential Distribution
P(h<t)
1.0
0.8
0.6
0.4
0.2
0
0
10
20
30
40
50
60
70
80
TIME (SECONDS)


HEADWAY DISTRIBUTION
NORTHBOUND TRAFFIC (OUTSIDE LANE)
● Observed Values
□ Simulation Values
△ Shifted Exponential Distribution
P (h<t)
1.0
0.8
0.6
0.4
0.2
0
0
10
20
30
40
50
60
70
80
TIME (SECONDS)

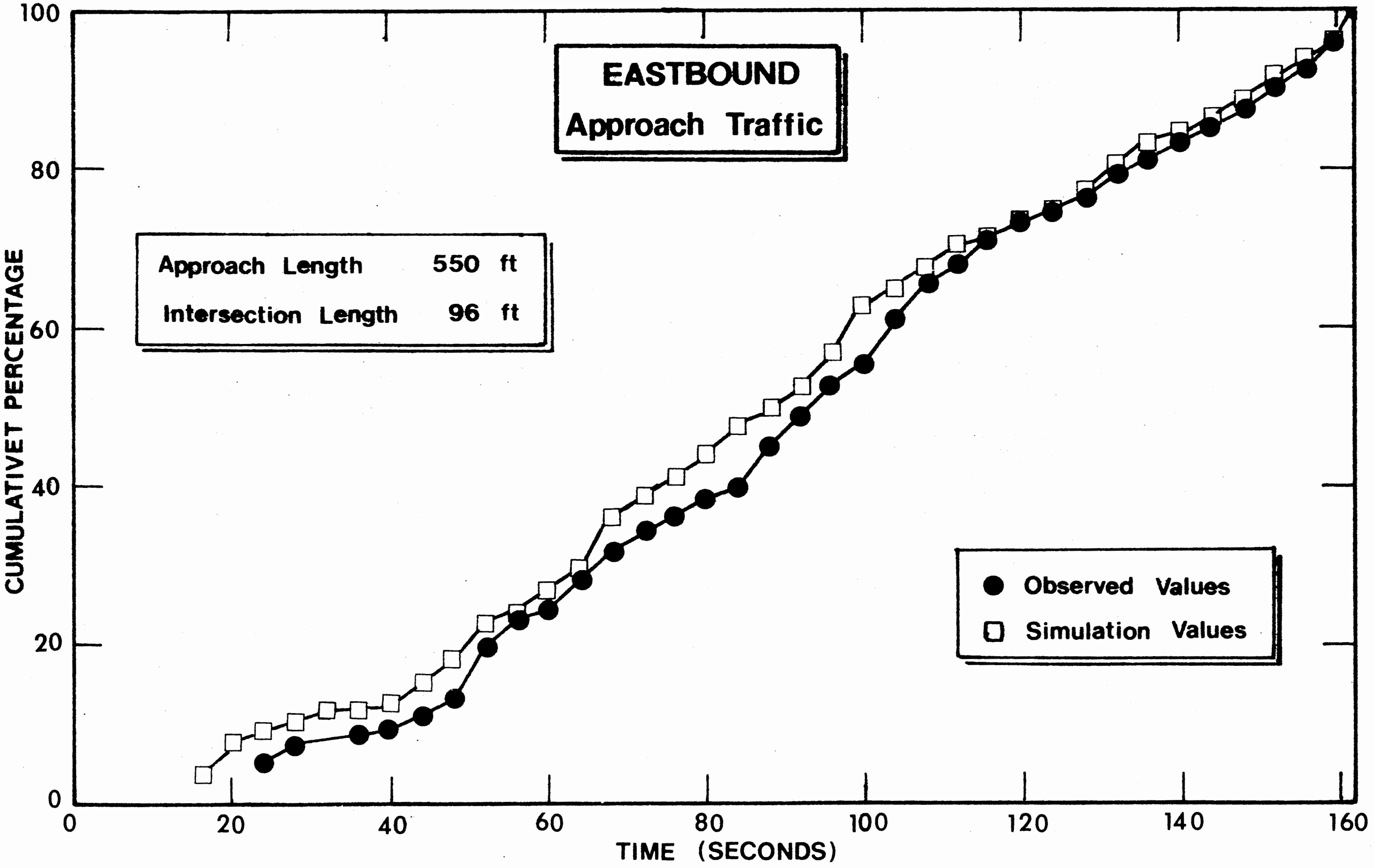

HEADWAY DISTRIBUTION
NORTHBOUND TRAFFIC (INSIDE LANE)
● Observed Values
☐ Simulation Values
△ Shifted Exponential Distribution
P (h<t)
1.0
0.8
0.6
0.4
0.2
0
0
10
20
30
40
50
60
70
80
TIME (SECONDS)

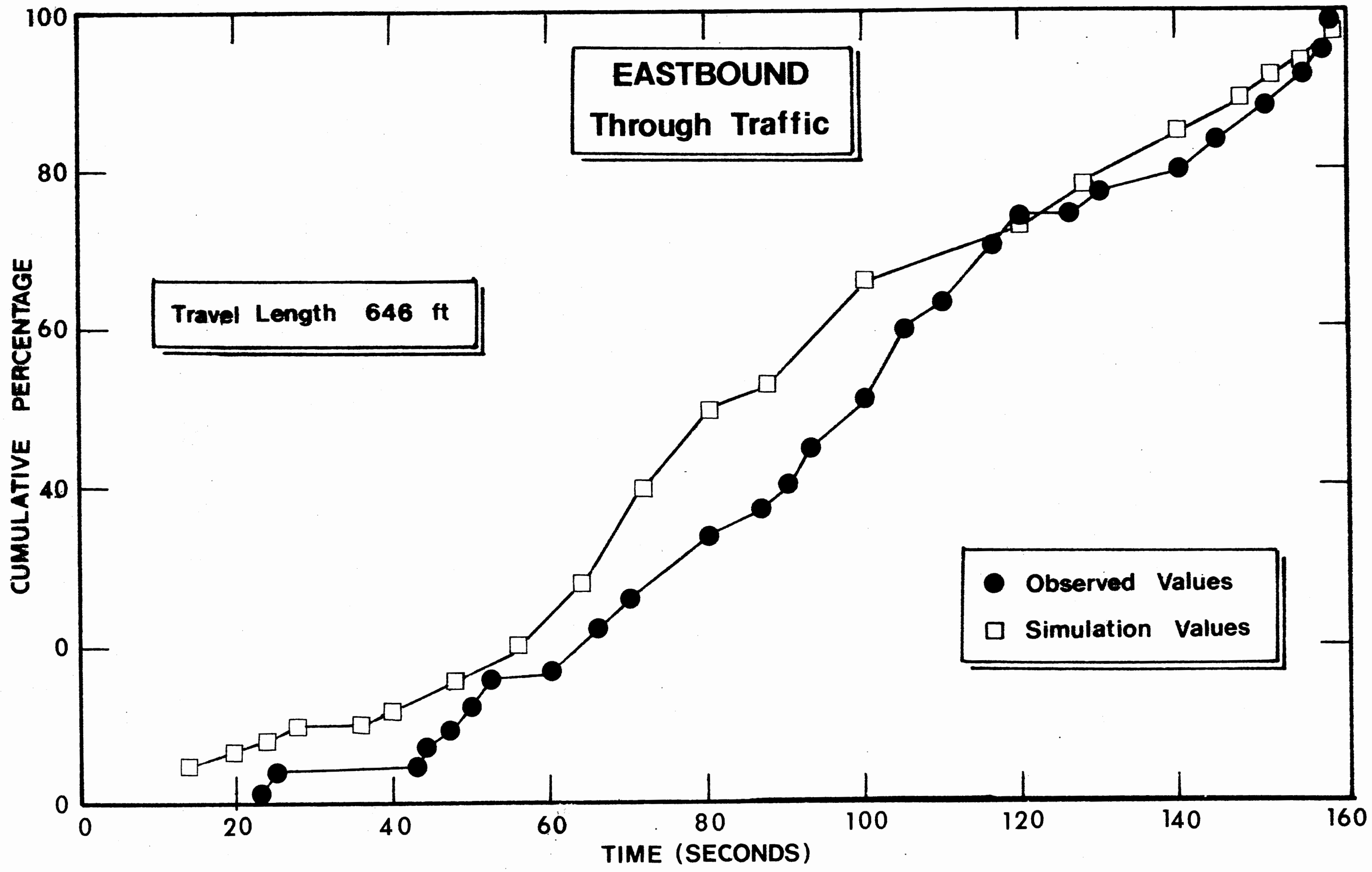

HEADWAY DISTRIBUTION
SOUTHBOUND TRAFFIC (OUTSIDE LANE)
● Observed Values
□ Simulation Values
△ Shifted Exponential Distribution
P (h < t)
1.0
0.8
0.6
0.4
0.2
0
0
10
20
30
40
50
60
70
80
TIME (SECONDS)


HEADWAY DISTRIBUTION
SOUTHBOUND TRAFFIC (INSIDE LANE)
● Observed Values
☐ Simulation Values
△ Shifted Exponential Distribution
P(h<t)
1.0
0.8
0.6
0.4
0.2
0
0
10
20
30
40
50
60
70
80
TIME (SECONDS)

APPENDIX C

COMPARISON OF VEHICLE TRAVEL TIME DISTRIBUTIONS


EASTBOUND
Approach Traffic
Approach Length 550 ft
Intersection Length 96 ft
● Observed Values
☐ Simulation Values
CUMULATIVET PERCENTAGE
0
20
40
60
80
100
TIME (SECONDS)
0
20
40
60
80
100
120
140
160


EASTBOUND
Through Traffic
Travel Length 646 ft
● Observed Values
□ Simulation Values
CUMULATIVE PERCENTAGE
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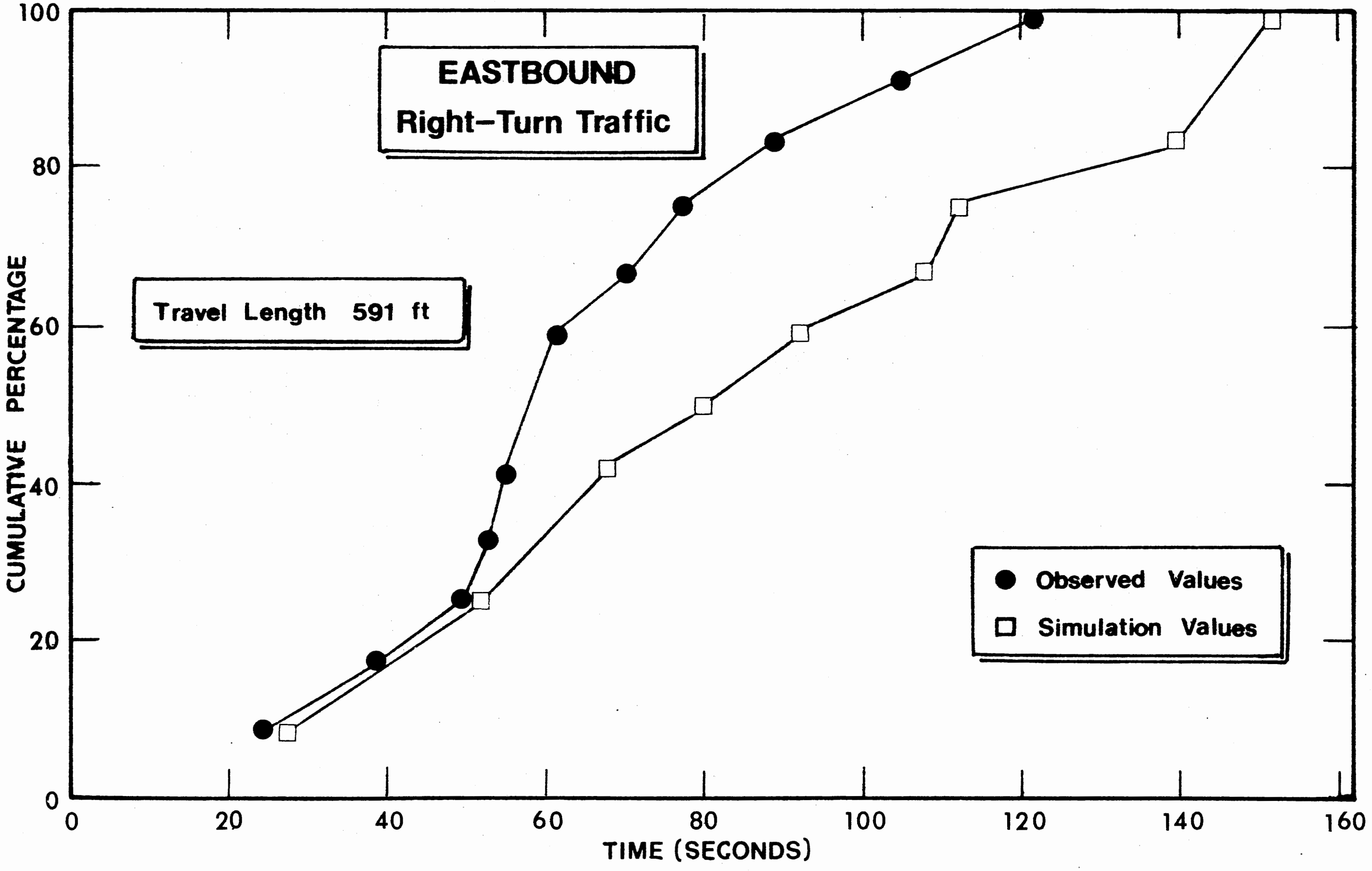
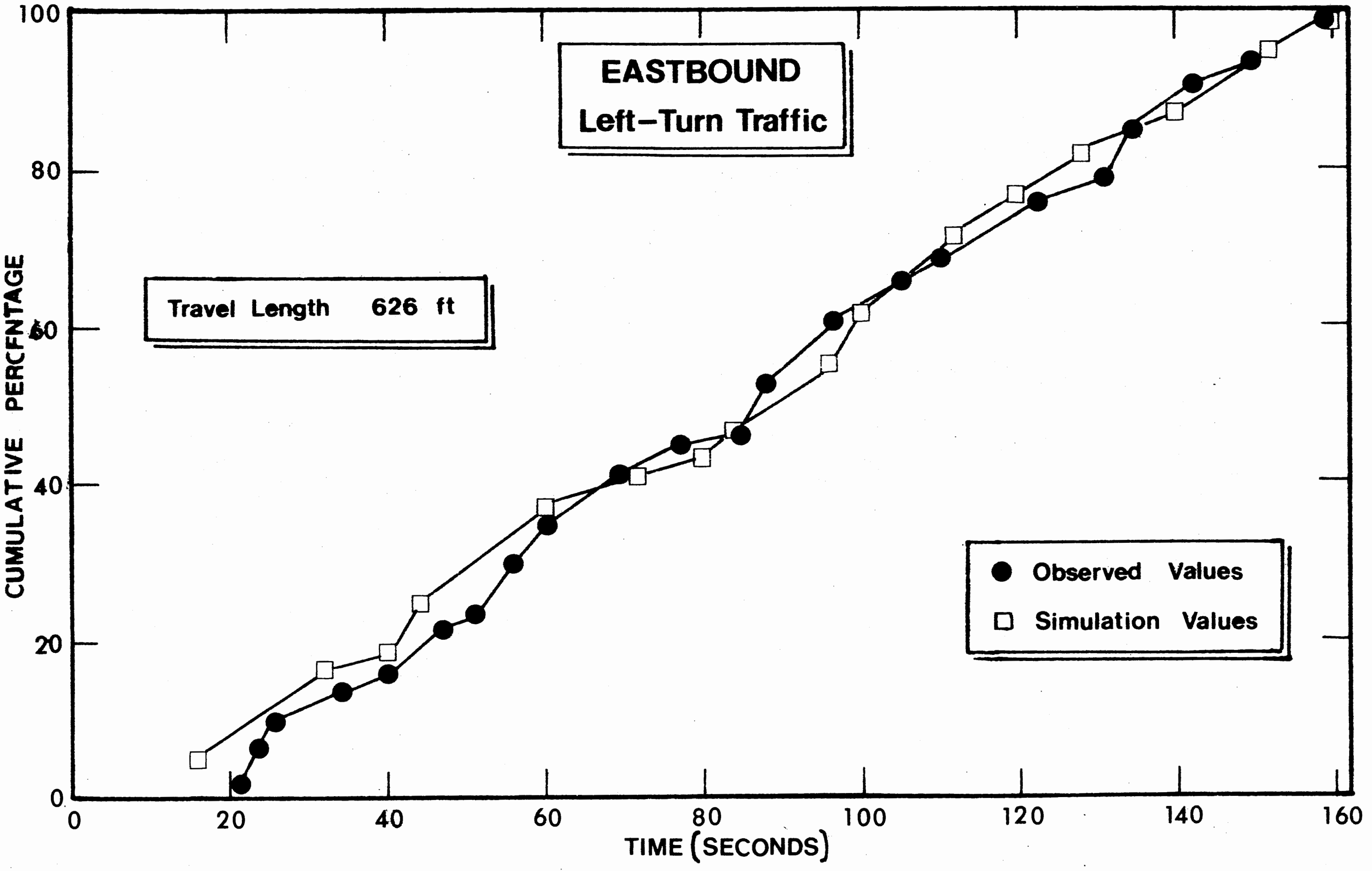
80
60
40
0
0
0
20
40
60
80
100
120
140
160
TIME (SECONDS)


EASTBOUND
Right-Turn Traffic
Travel Length 591 ft
● Observed Values
□ Simulation Values
CUMULATIVE PERCENTAGE
100
80
60
40
20
0
0
20
40
60
80
100
120
140
160
TIME (SECONDS)


EASTBOUND
Left–Turn Traffic
Travel Length 626 ft
● Observed Values
□ Simulation Values
CUMULATIVE PERCENTAGE
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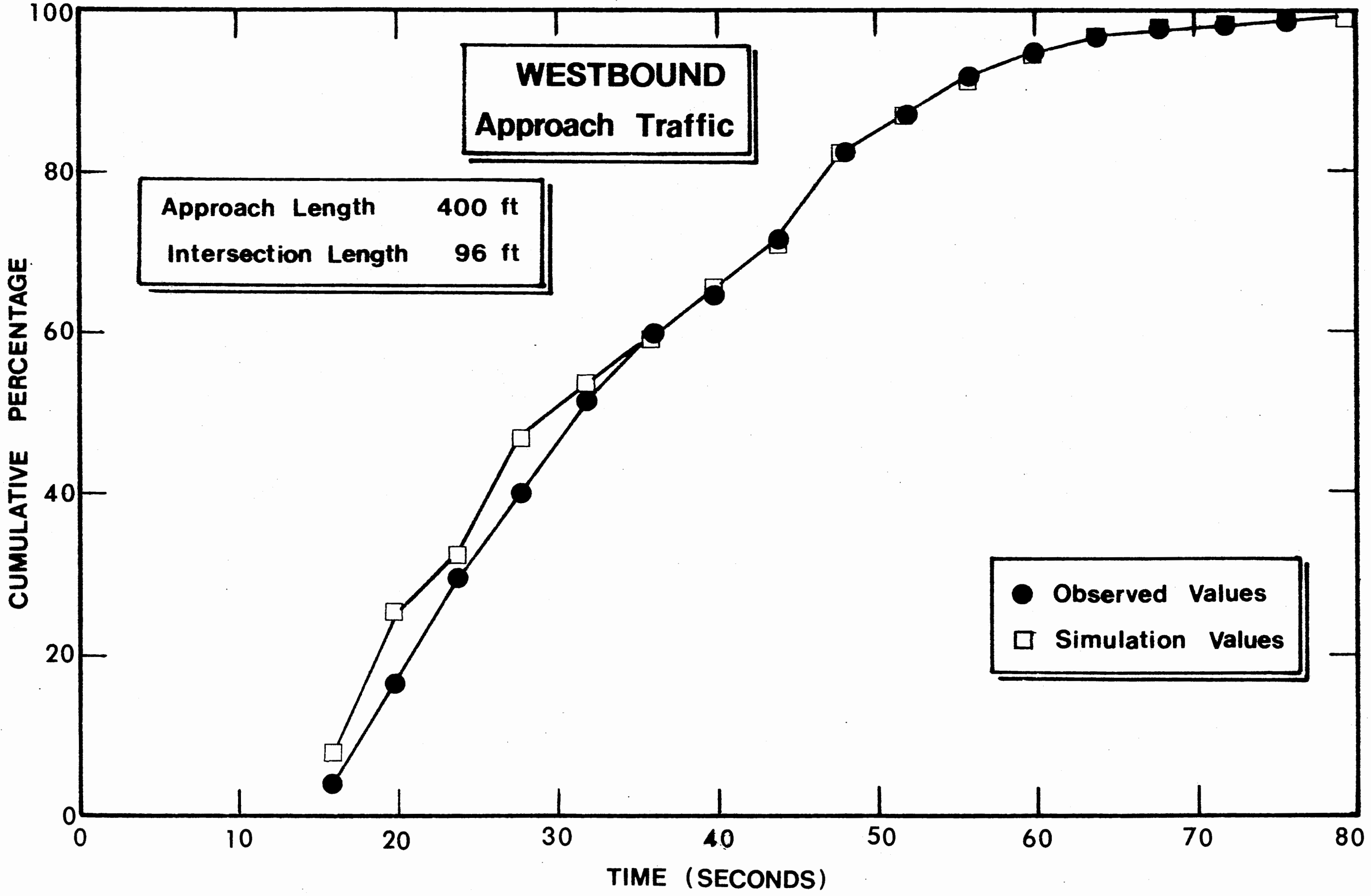
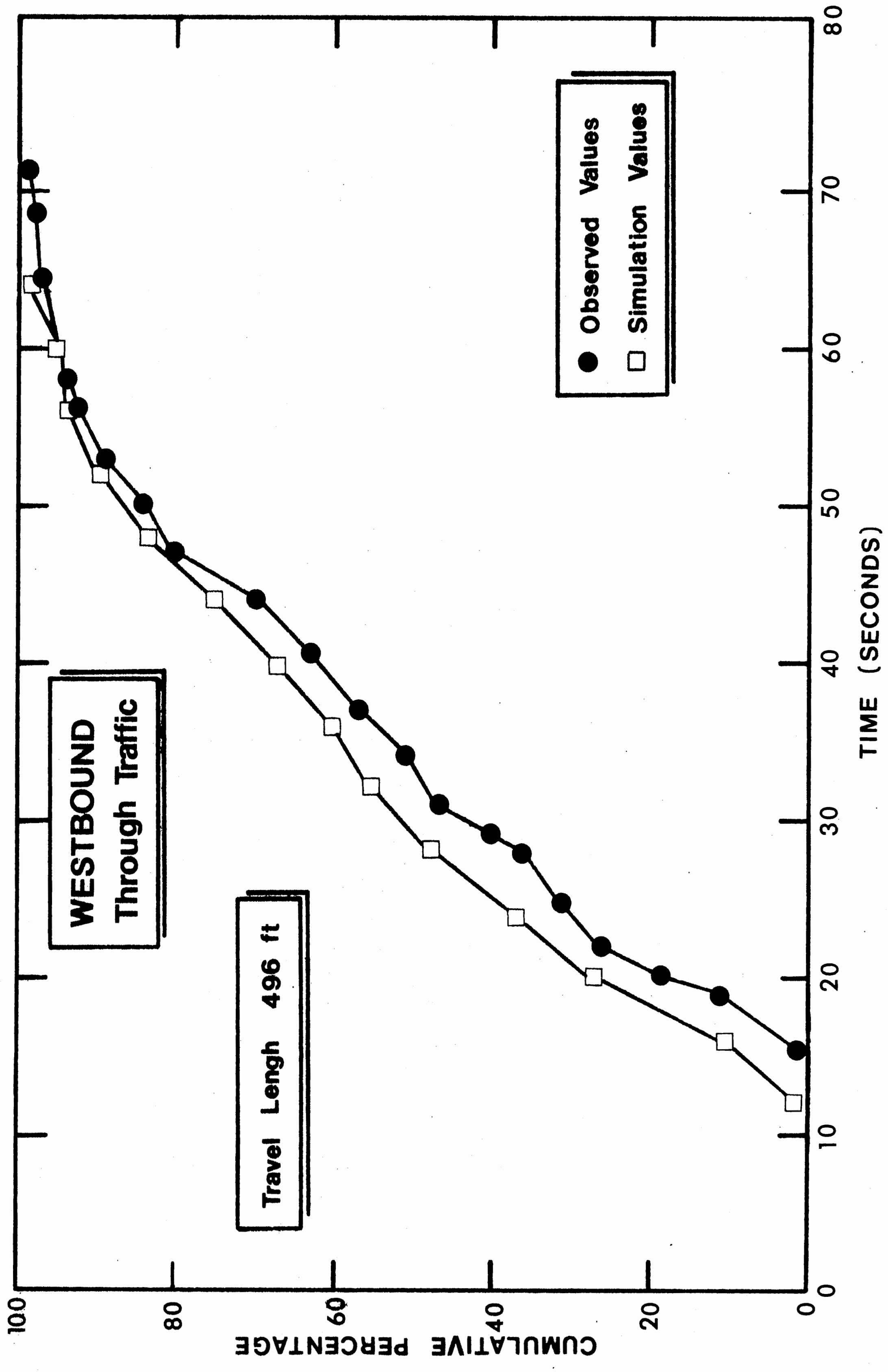
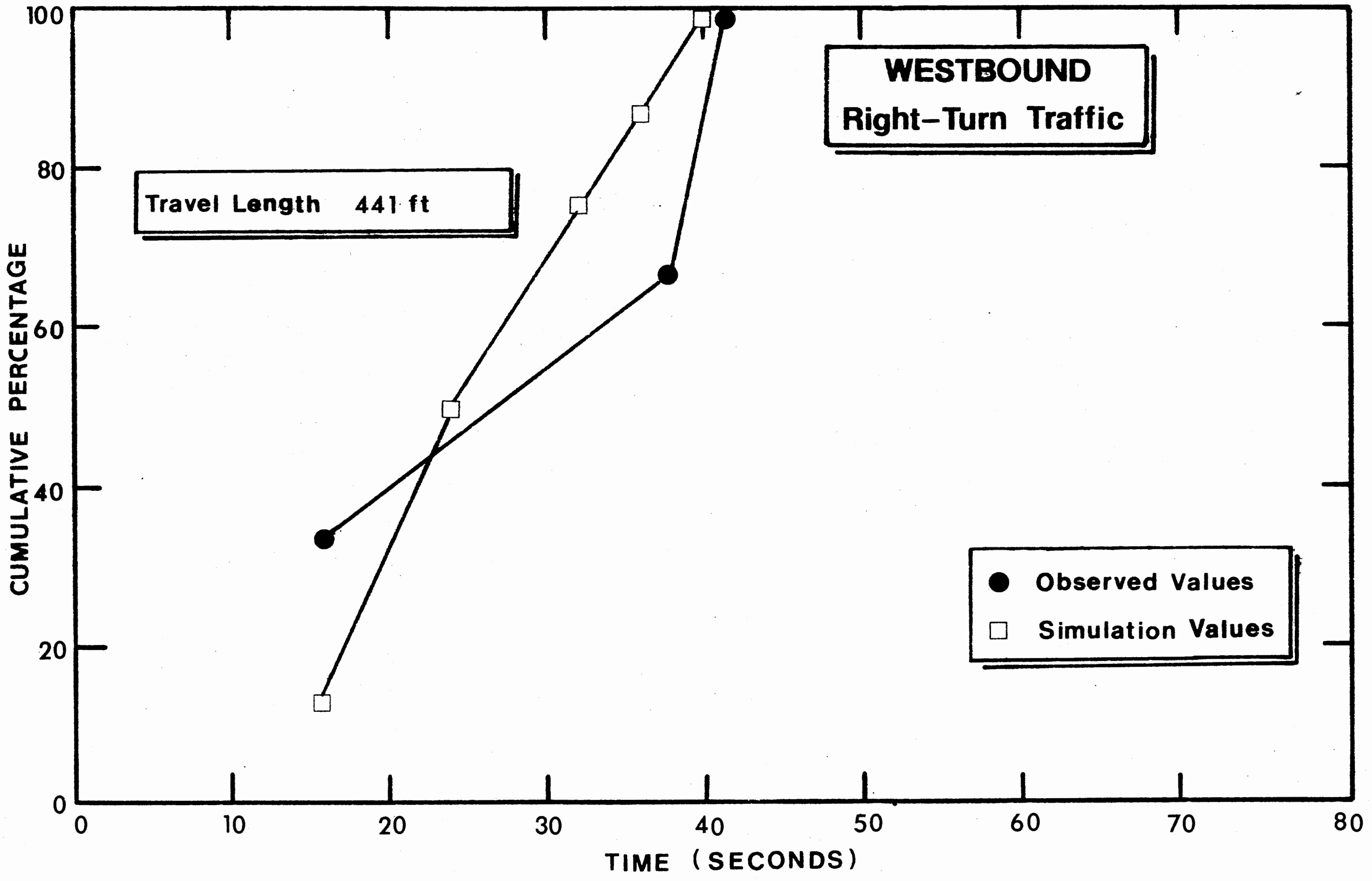
20
40
60
80
100
TIME (SECONDS)
0
20
40
60
80
100
120
140
160


WESTBOUND
Approach Traffic
Approach Length 400 ft
Intersection Length 96 ft
● Observed Values
□ Simulation Values
CUMULATIVE PERCENTAGE
TIME (SECONDS)
0
20
40
60
80
100
0
10
20
30
40
50
60
70
80


WESTBOUND
Through Traffic
Travel Lengh 496 ft
● Observed Values
□ Simulation Values
TIME (SECONDS)
0
10
20
30
40
50
60
70
80
CUMULATIVE PERCENTAGE
0
20
40
60
80
100


WESTBOUND
Right-Turn Traffic
Travel Length 441 ft
Observed Values
Simulation Values
CUMULATIVE PERCENTAGE
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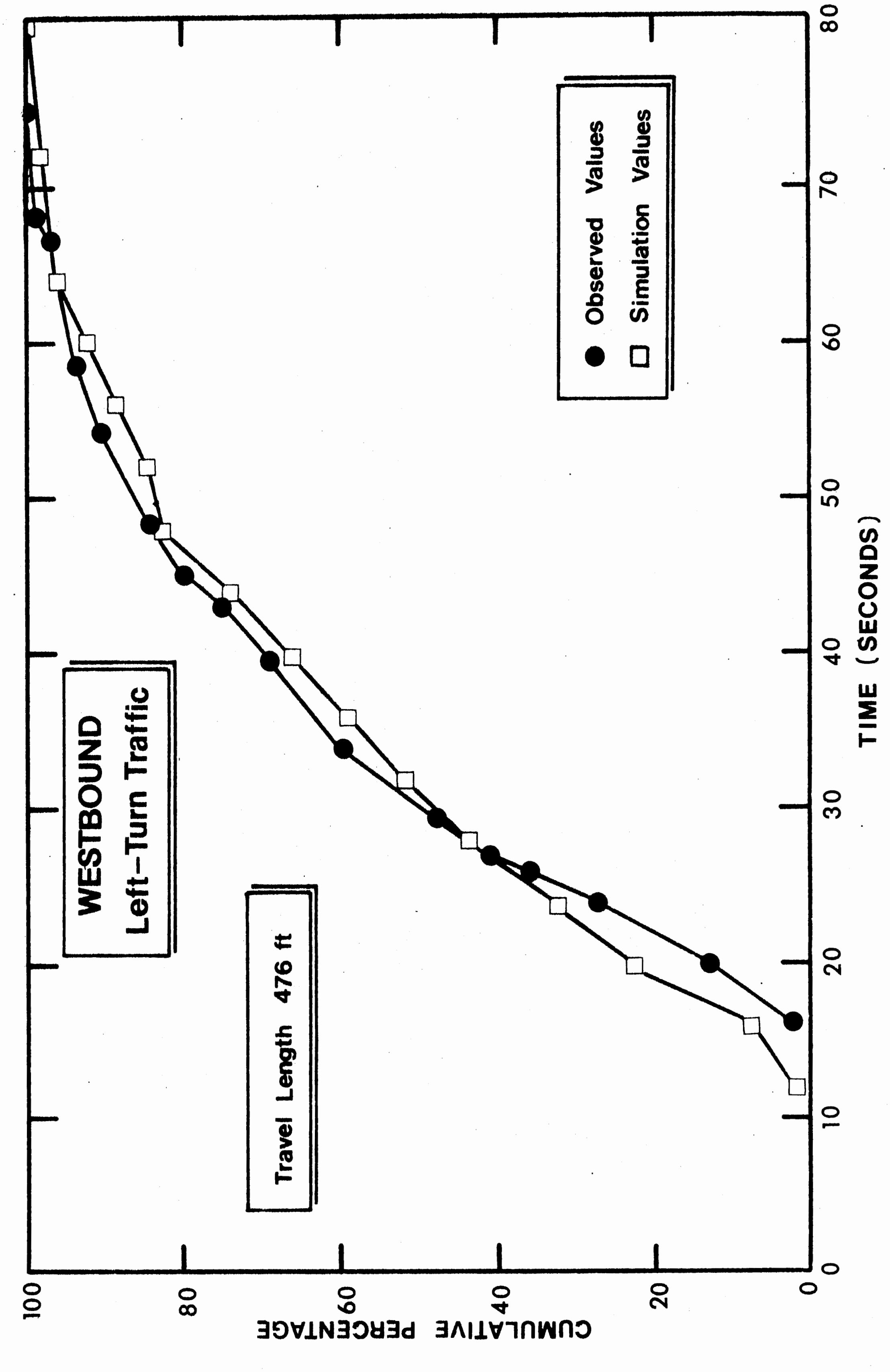
40
60
80
100
0
10
20
30
40
50
60
70
80
TIME (SECONDS)


WESTBOUND
Left-Turn Traffic
Travel Length 476 ft
● Observed Values
□ Simulation Values
CUMULATIVE PERCENTAGE
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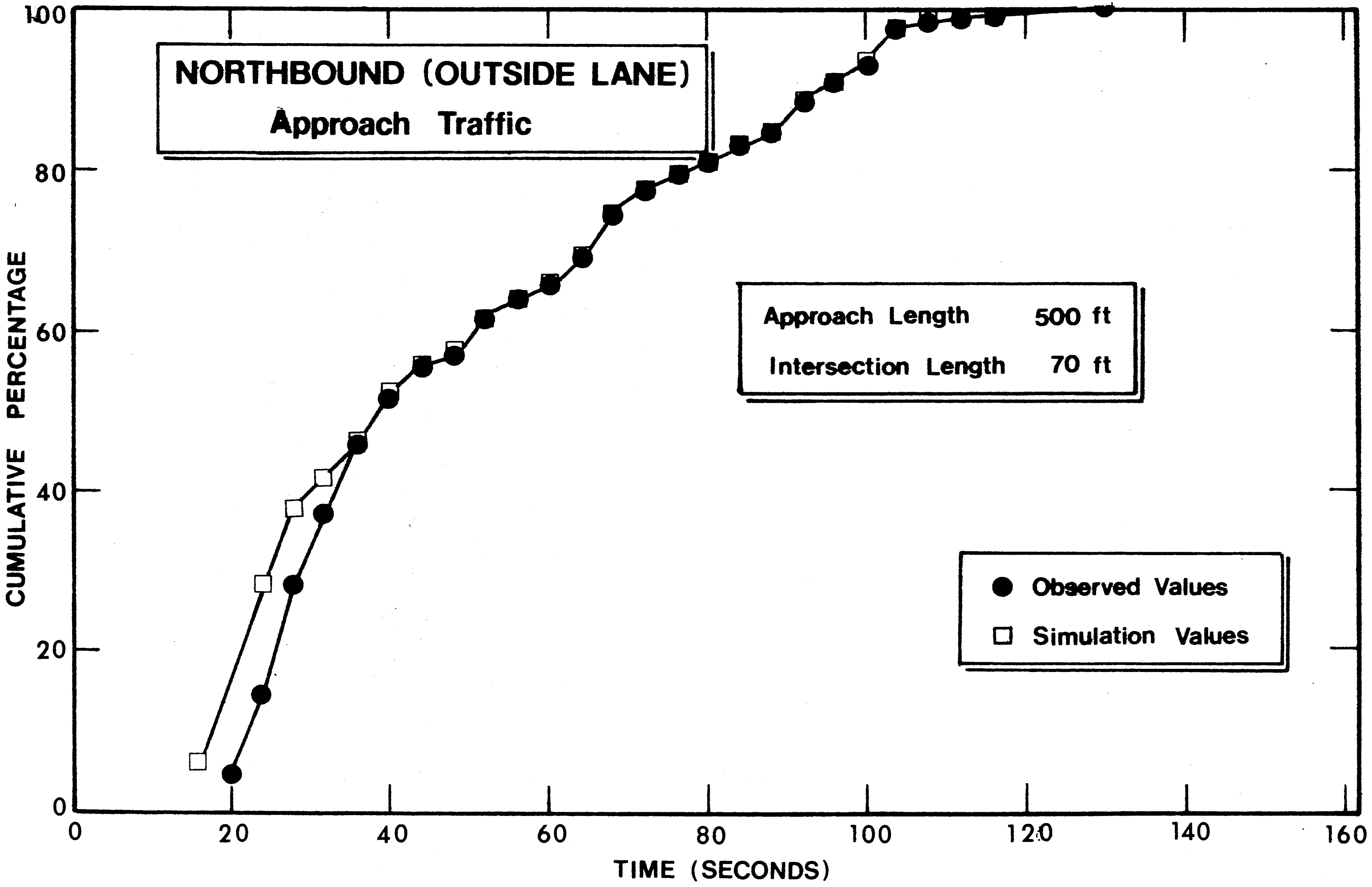
40
60
80
100
TIME (SECONDS)
0
10
20
30
40
50
60
70
80


NORTHBOUND (OUTSIDE LANE)
Approach Traffic
Approach Length 500 ft
Intersection Length 70 ft
● Observed Values
☐ Simulation Values
CUMULATIVE PERCENTAGE
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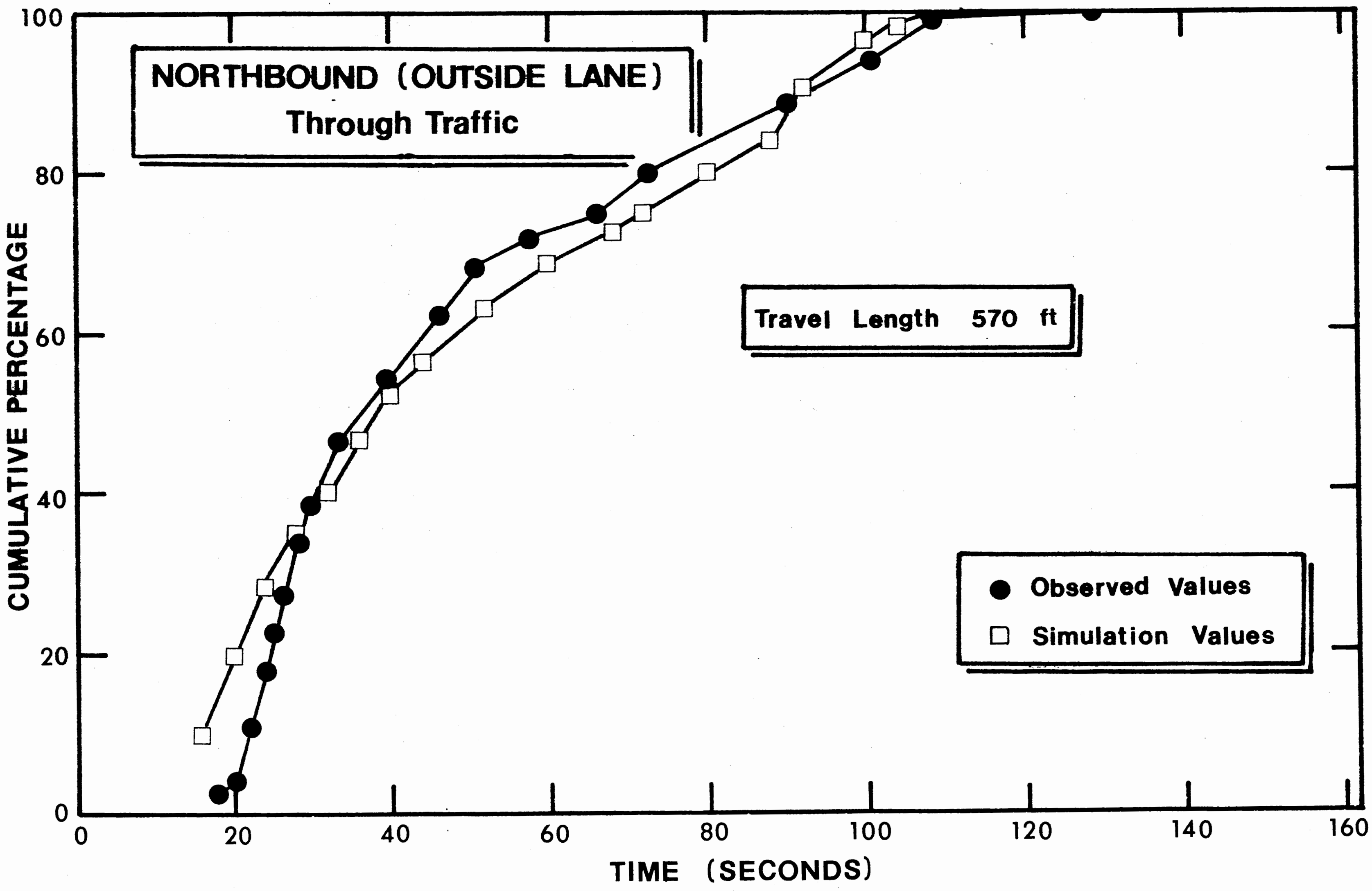
20
40
60
80
100
TIME (SECONDS)
0
20
40
60
80
100
120
140
160


NORTHBOUND (OUTSIDE LANE)
Through Traffic
Travel Length 570 ft
● Observed Values
☐ Simulation Values
CUMULATIVE PERCENTAGE
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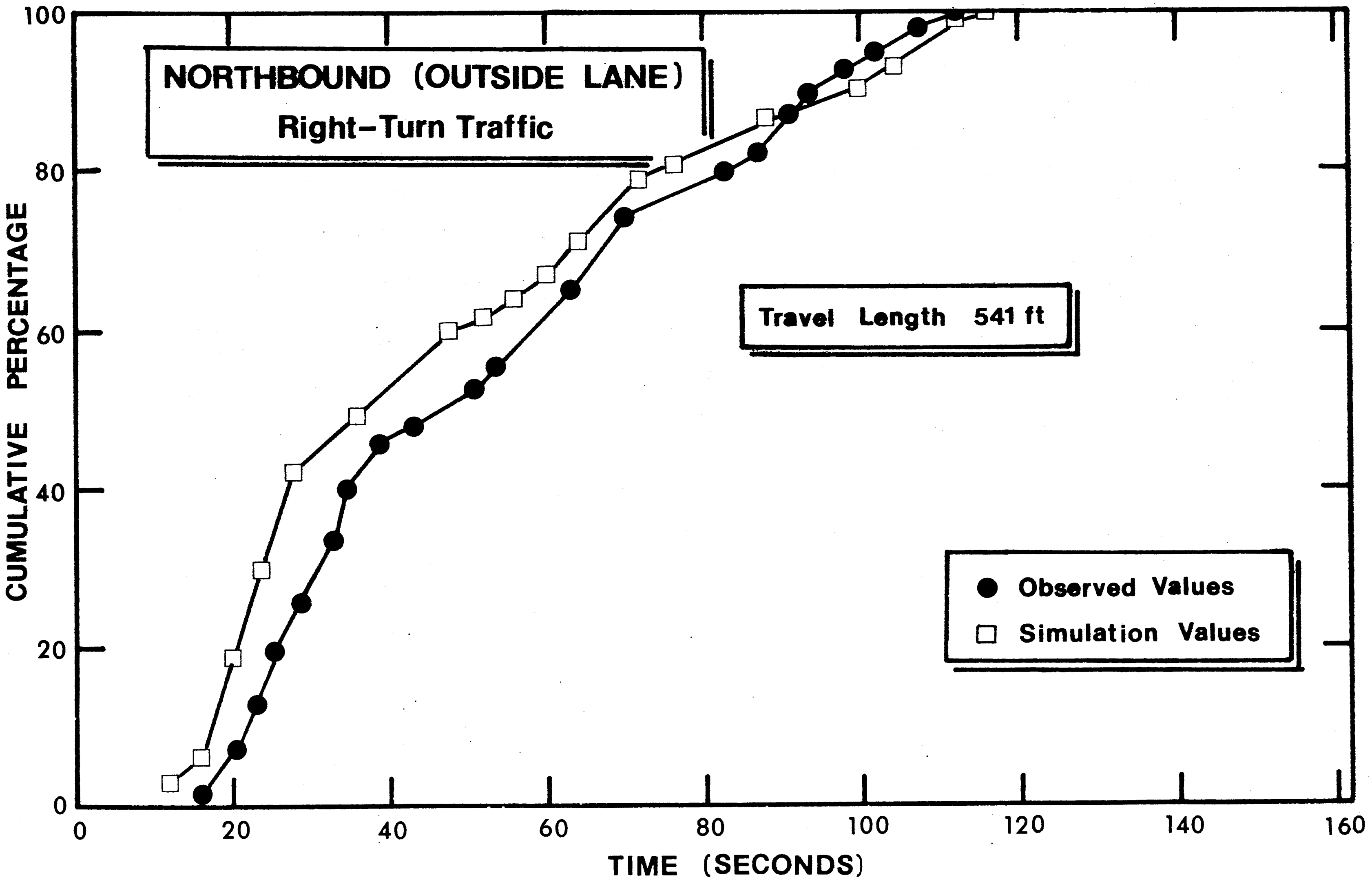
20
40
60
80
100
TIME (SECONDS)
0
20
40
60
80
100
120
140
160


NORTHBOUND (OUTSIDE LANE)
Right-Turn Traffic
Travel Length 541 ft
● Observed Values
□ Simulation Values
CUMULATIVE PERCENTAGE
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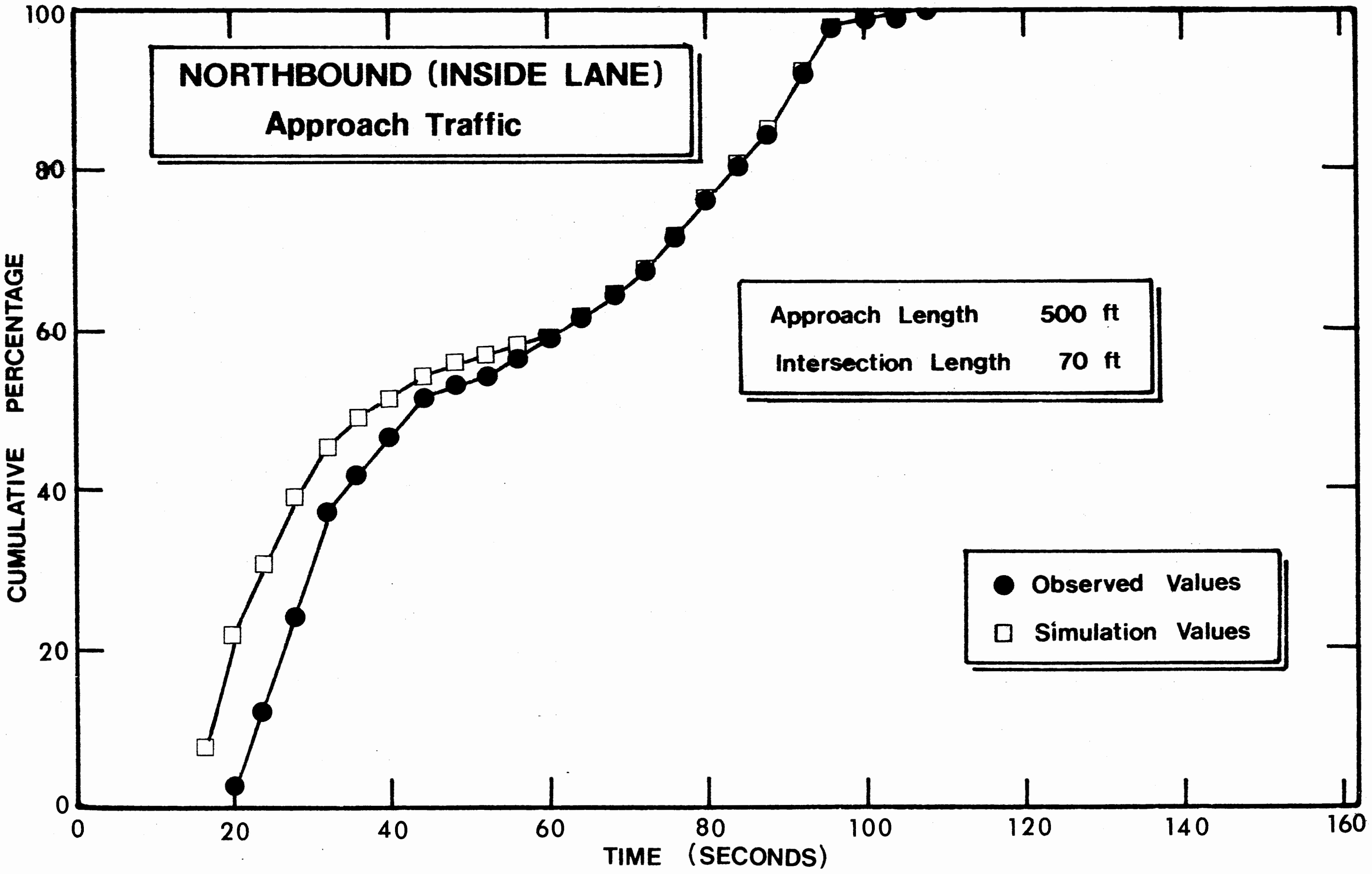
20
40
60
80
100
TIME (SECONDS)
0
20
40
60
80
100
120
140
160


NORTHBOUND (INSIDE LANE)
Approach Traffic
Approach Length 500 ft
Intersection Length 70 ft
● Observed Values
□ Simulation Values
CUMULATIVE PERCENTAGE
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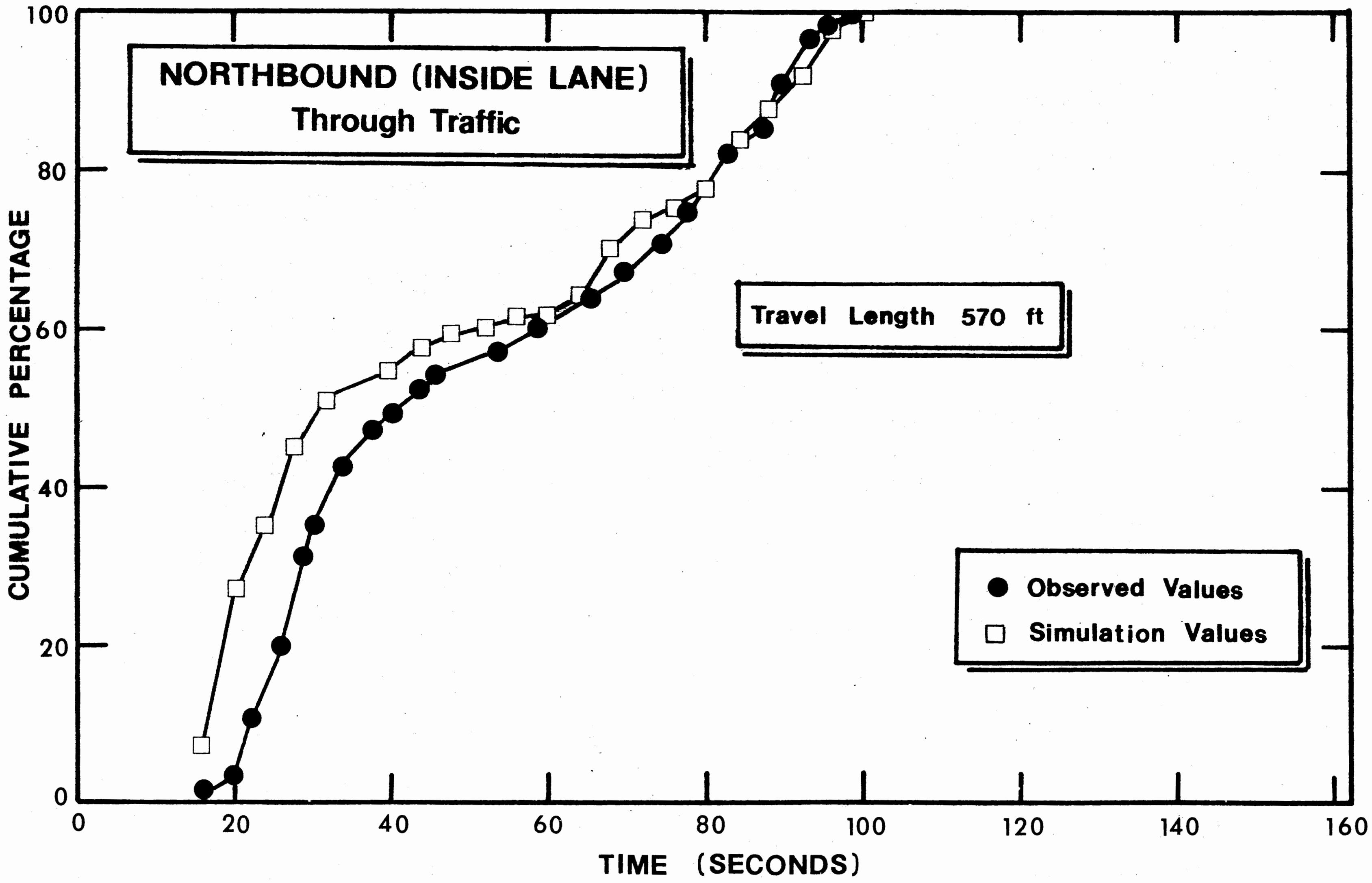
20
40
60
80
100
TIME (SECONDS)
0
20
40
60
80
100
120
140
160


NORTHBOUND (INSIDE LANE)
Through Traffic
Travel Length 570 ft
● Observed Values
□ Simulation Values
CUMULATIVE PERCENTAGE
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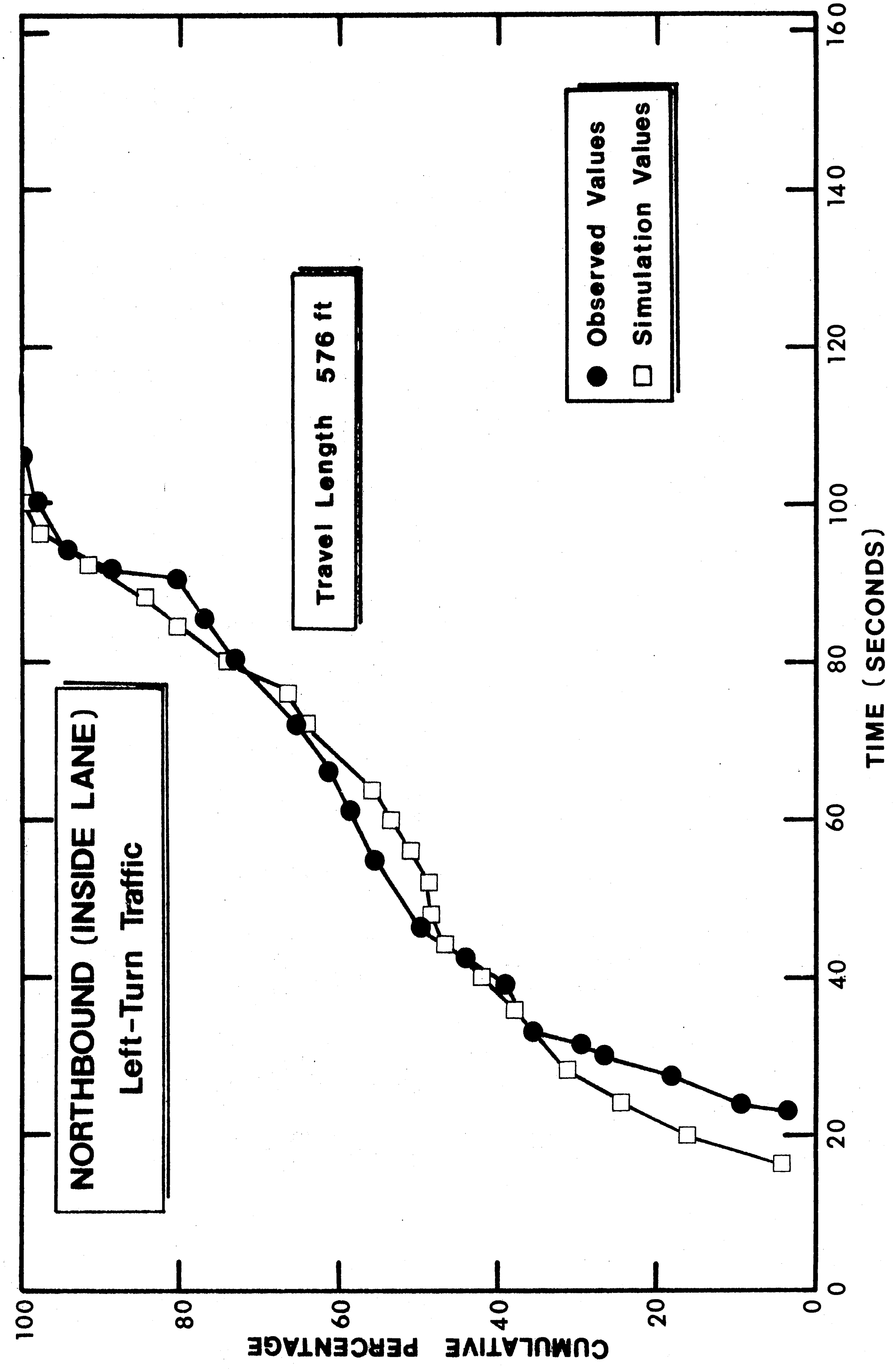
80
60
40
20
0
0
20
40
60
80
100
120
140
160
TIME (SECONDS)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Left-Turn Traffic
Travel Length 576 ft
● Observed Values
□ Simulation Values
CUMULATIVE PERCENTAGE
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60
80
100
TIME (SECONDS)
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20
40
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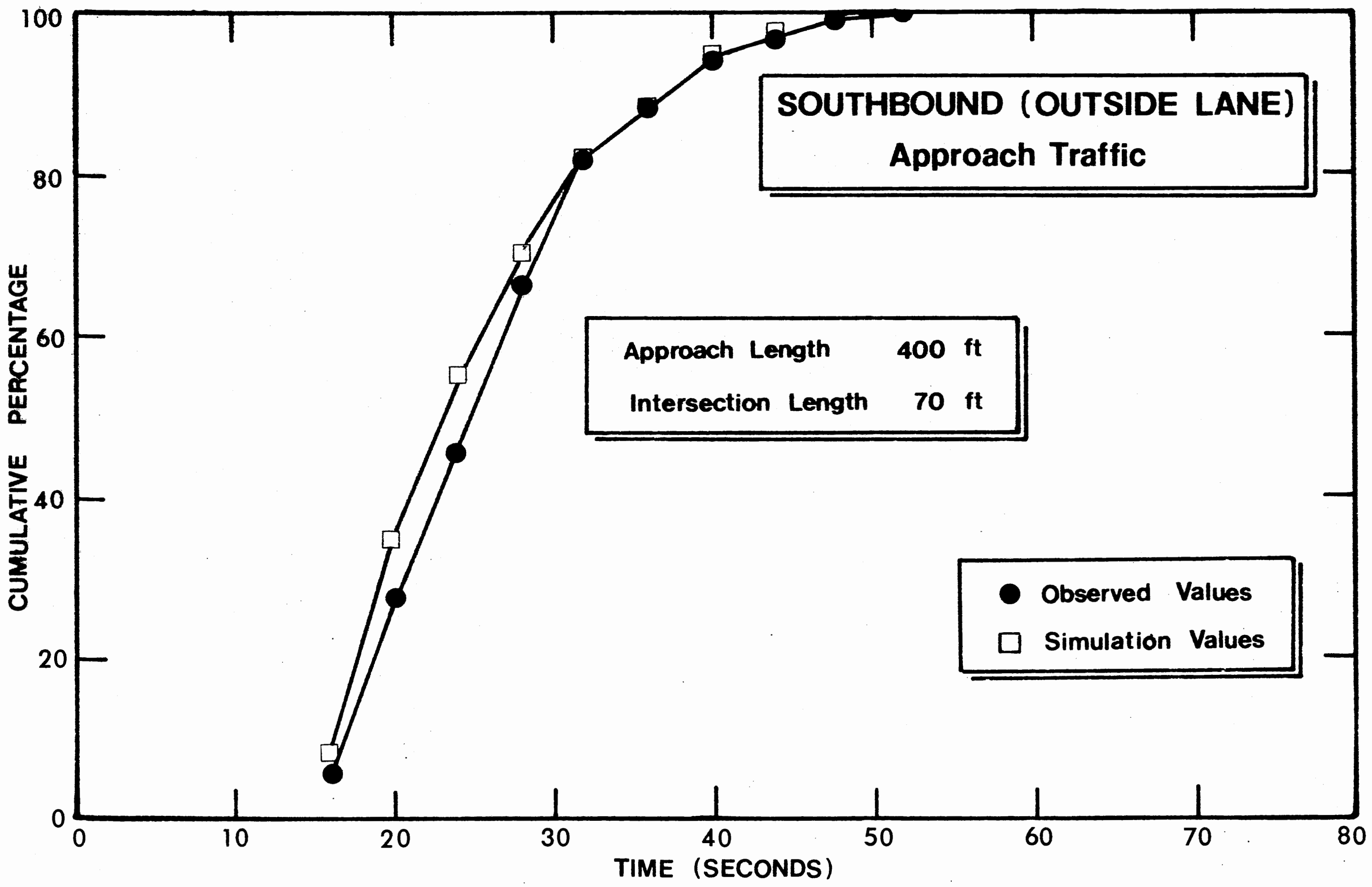
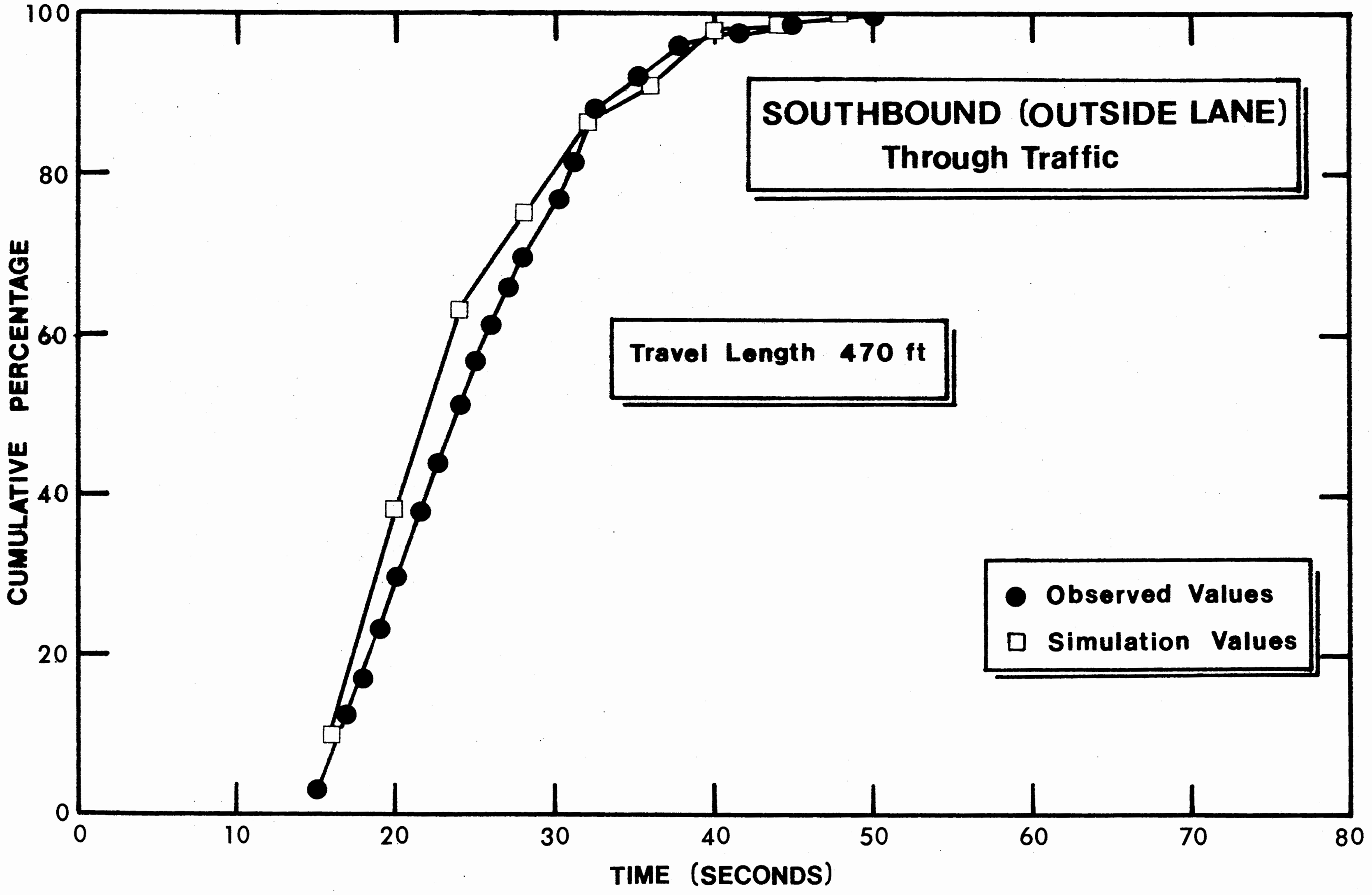
80
100
120
140
160


SOUTHBOUND (OUTSIDE LANE)
Approach Traffic
Approach Length 400 ft
Intersection Length 70 ft
● Observed Values
☐ Simulation Values
CUMULATIVE PERCENTAGE
0
20
40
60
80
100
0
10
20
30
40
50
60
70
80
TIME (SECONDS)


SOUTHBOUND (OUTSIDE LANE)
Through Traffic
Travel Length 470 ft
● Observed Values
□ Simulation Values
CUMULATIVE PERCENTAGE
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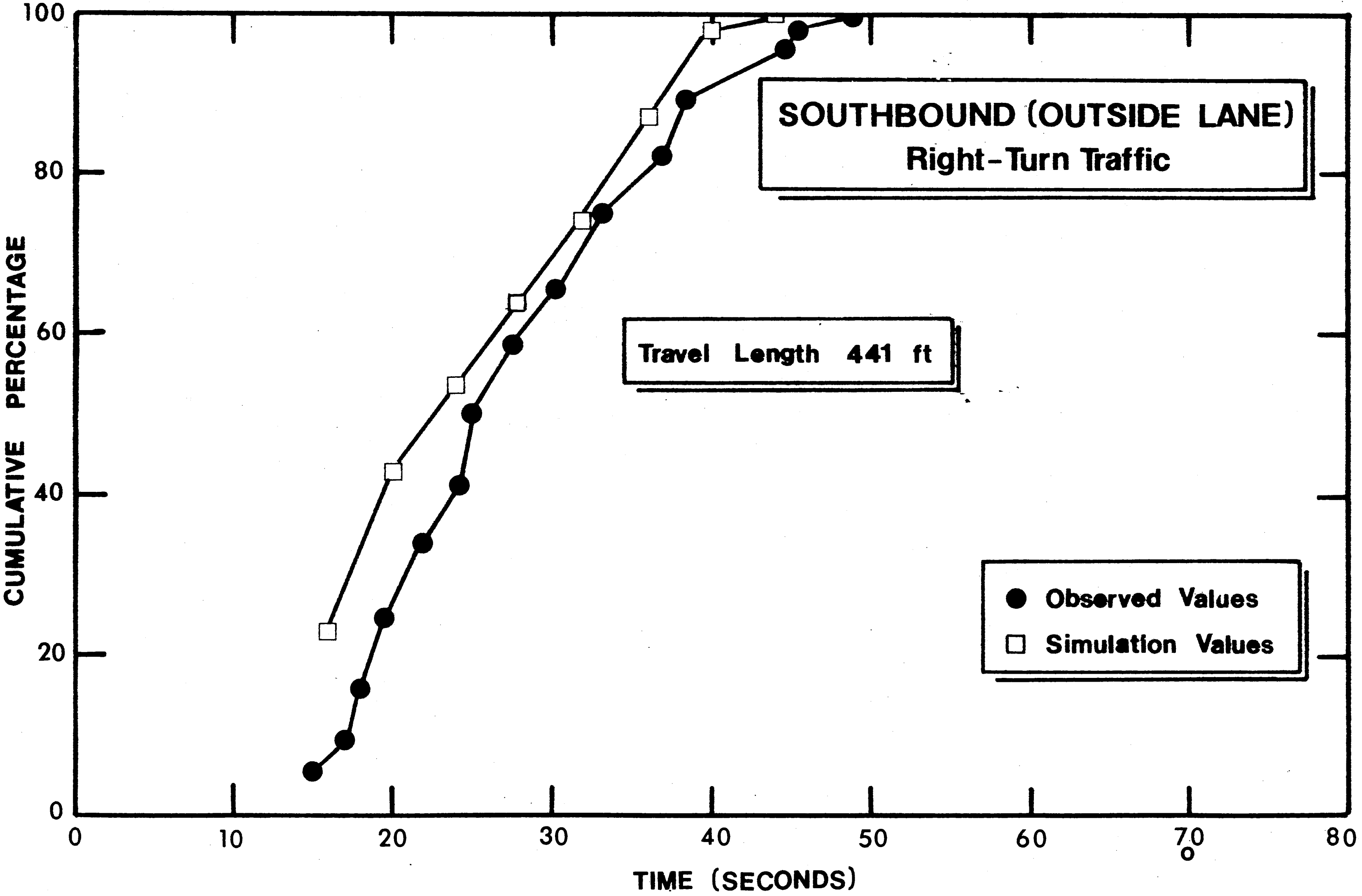
60
80
100
0
10
20
30
40
50
60
70
80
TIME (SECONDS)


SOUTHBOUND (OUTSIDE LANE)
Right-Turn Traffic
Travel Length 441 ft
● Observed Values
□ Simulation Values
CUMULATIVE PERCENTAGE
TIME (SECONDS)
0
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40
60
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10
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50
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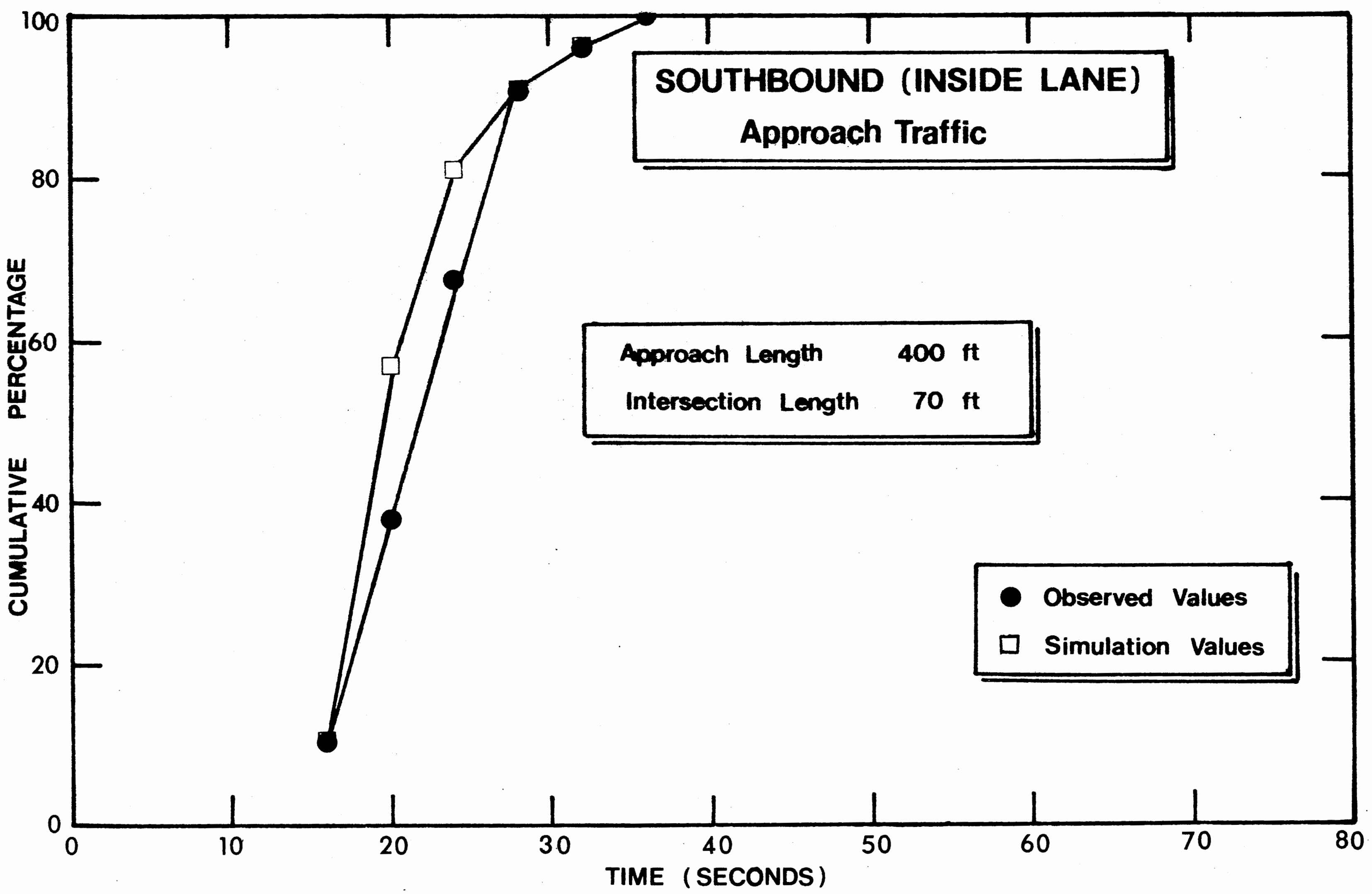
70
80


SOUTHBOUND (INSIDE LANE)
Approach Traffic
Approach Length 400 ft
Intersection Length 70 ft
● Observed Values
☐ Simulation Values
CUMULATIVE PERCENTAGE
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40
60
80
100
TIME (SECONDS)
0
10
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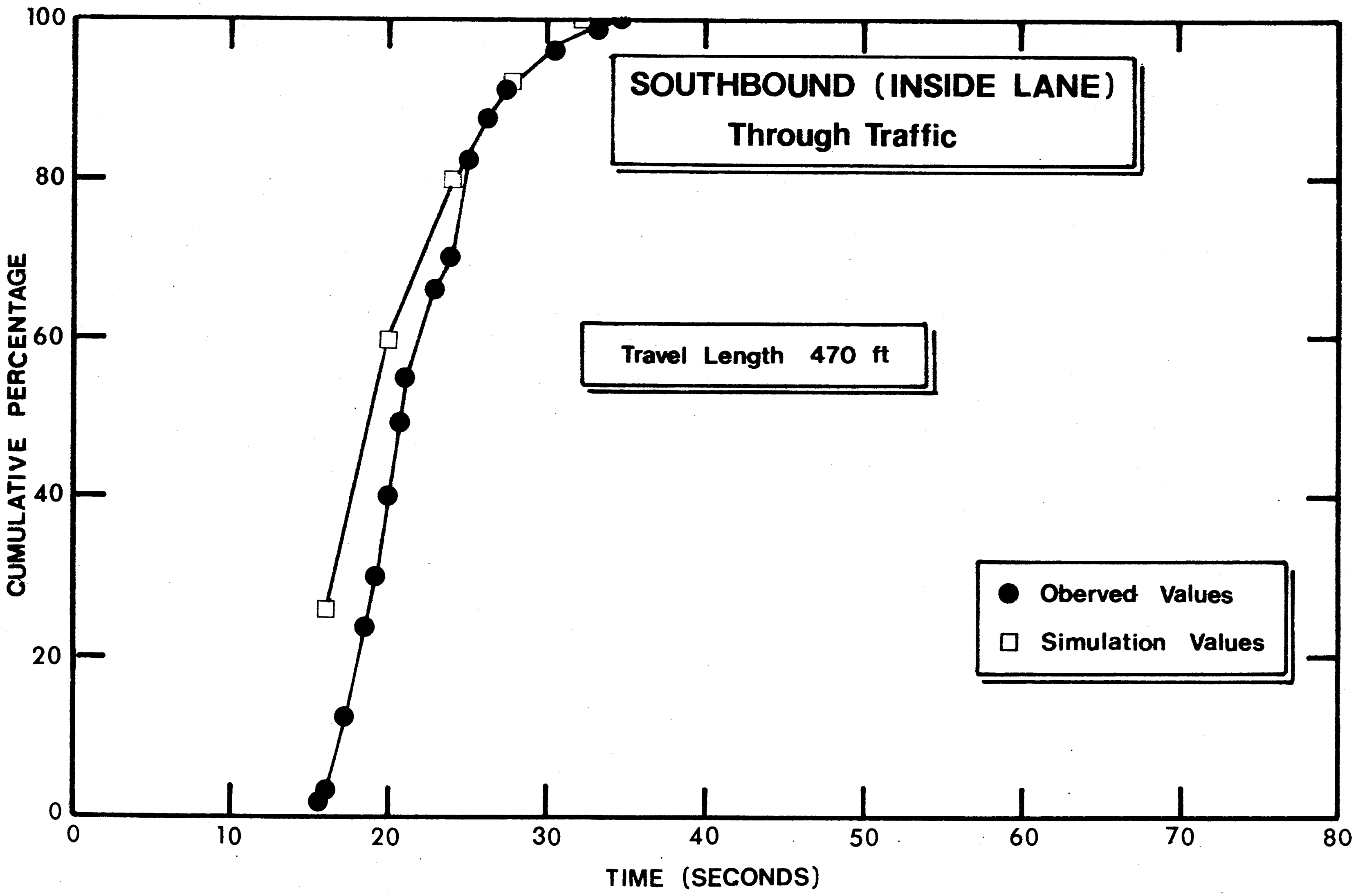
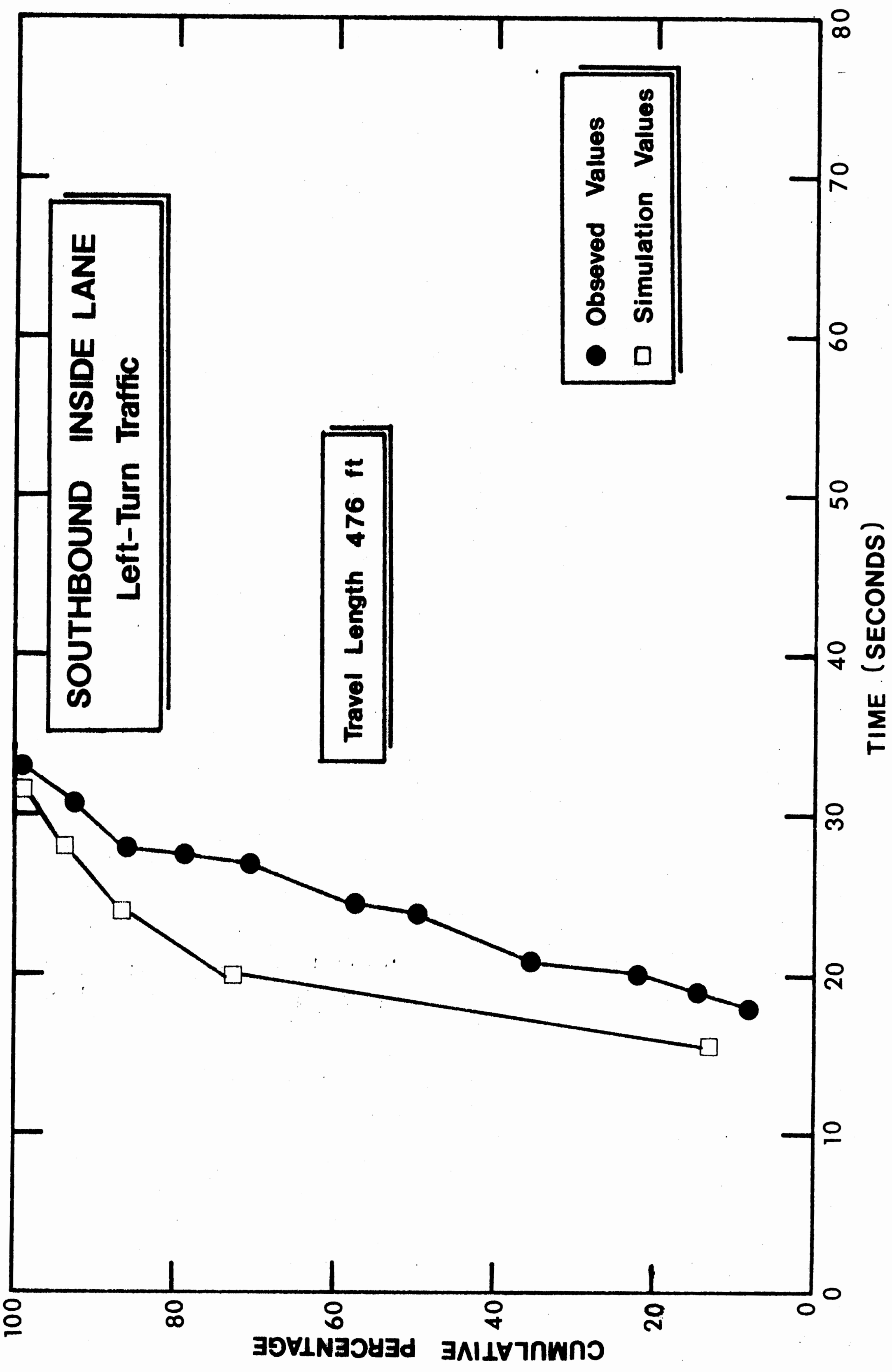
50
60
70
80


SOUTHBOUND (INSIDE LANE)
Through Traffic
Travel Length 470 ft
● Oberved Values
□ Simulation Values
CUMULATIVE PERCENTAGE
0
20
40
60
80
100
TIME (SECONDS)
0
10
20
30
40
50
60
70
80


SOUTHBOUND INSIDE LANE
Left-Turn Traffic
Travel Length 476 ft
● Obseved Values
□ Simulation Values
CUMULATIVE PERCENTAGE
0
20
40
60
80
100
TIME (SECONDS)
0
10
20
30
40
50
60
70
80

APPENDIX D

OUTPUT OF CLOCK AND BLOCK ENTITIES

```
CLOCK TIME AT THE END OF SIMULATION RUN

 RELATIVE CLOCK         18000  ABSOLUTE CLOCK         18000

TRAFFIC FLOWS AT FOUR-WAY STOP INTERSECTION
 BLOCK COUNTS
 BLOCK CURRENT      TOTAL    BLOCK CURRENT      TOTAL    BLOCK CURRENT      TOTAL    BLOCK CURRENT      TOTAL    BLOCK CURRENT      TOTAL
     1       0        199       11       0        100       21       5        198       31       0          5       41       0         13
     2       0        199       12       0        100       22       0        193       32       0          5       42       0         13
     3       0        192       13       0        199       23       0        193       33       0          1       43       0         13
     4       0        192       14       0        199       24       0         13       34       0          1       44       0         13
     5       0        159       15       0        199       25       0         13       35       0          8       45       0         13
     6       0        159       16       0        199       26       0         13       36       0         13       46       0         13
     7       0        152       17       0        199       27       0         13       37       0         13       47       0         13
     8       0        152       18       0        199       28       0         13       38       0         13       48       0        121
     9       0        157       19       1        199       29       0         13       39       0         13       49       0        121
    10       0        157       20       0        198       30       0         12       40       0         13       50       0        121

 BLOCK CURRENT      TOTAL    BLOCK CURRENT      TOTAL    BLOCK CURRENT      TOTAL    BLOCK CURRENT      TOTAL    BLOCK CURRENT      TOTAL
    51       0        121       61       0          1       71       0        121       81       0         59       91       0         14
    52       0        121       62       0         41       72       0        121       82       0         59       92       0         14
    53       0        121       63       0        121       73       0        121       83       0         59       93       0         12
    54       0        121       64       0        121       74       0        121       84       0         59       94       0         12
    55       0         80       65       0        121       75       1        121       85       0         59       95       0         16
    56       0         79       66       0        121       76       0        120       86       0         59       96       0         59
    57       0         79       67       0        121       77       0        120       87       0         59       97       0         59
    58       0         18       68       0        121       78       0        120       88       0         43       98       0         59
    59       0         18       69       0        121       79       0        120       89       0         31       99       0         59
    60       0          1       70       0        121       80       0        120       90       0         31      100       0         59

 BLOCK CURRENT      TOTAL    BLOCK CURRENT      TOTAL    BLOCK CURRENT      TOTAL    BLOCK CURRENT      TOTAL    BLOCK CURRENT      TOTAL
   101       0         59      111       0        192      121       0        182      131       0          5      141       0          1
   102       0         59      112       0        192      122       0        182      132       0          5      142       0          4
   103       0         59      113       0        192      123       0        182      133       0          5      143       0          5
   104       0         59      114       0        192      124       0        182      134       0          5      144       0          5
   105       0         59      115       0        192      125       0        182      135       0          5      145       0          5
   106       0         59      116       0        192      126       0        182      136       0          5      146       0          5
   107       0         59      117       0        192      127       0        182      137       0          4      147       0          5
   108       0         59      118       0        192      128       2        182      138       0          1      148       0          5
   109       0         59      119       0        192      129       0        180      139       0          1      149       0          5
   110       0        192      120       0        192      130       0        180      140       0          1      150       0          5

 BLOCK CURRENT      TOTAL    BLOCK CURRENT      TOTAL    BLOCK CURRENT      TOTAL    BLOCK CURRENT      TOTAL    BLOCK CURRENT      TOTAL
   151       0          5      161       0        103      171       0        103      181       0        103      191       0         72
   152       0          5      162       0         69      172       0        103      182       0        103      192       0         72
   153       0          5      163       0         65      173       0        103      183       0        103      193       0         72
   154       0          5      164       0         65      174       0        103      184       0        103      194       0         72
   155       0        103      165       0         11      175       0        103      185       0        103      195       0         59
   156       0        103      166       0         11      176       0        103      186       0        103      196       0         44
   157       0        103      167       0          4      177       0        103      187       0        103      197       0         44
   158       0        103      168       0          4      178       0        103      188       0         72      198       0          6
   159       0        103      169       0         34      179       0        103      189       0         72      199       0          6
   160       0        103      170       0        103      180       0        103      190       0         72      200       0         15

 BLOCK CURRENT      TOTAL    BLOCK CURRENT      TOTAL    BLOCK CURRENT      TOTAL    BLOCK CURRENT      TOTAL    BLOCK CURRENT      TOTAL
   201       0         15      211       0         72      221       1        180      231       0        159      241       0         74
   202       0         13      212       0         72      222       0        179      232       0        159      242       0         74
   203       0         72      213       0         72      223       0        179      233       2        159      243       0         74
   204       0         72      214       0         72      224       0        179      234       0        157      244       0         63
   205       0         72      215       0         72      225       0        179      235       4        157      245       1         27
   206       0         72      216       0         72      226       0        179      236       0        153      246       0         26
   207       0         72      217       0        180      227       0        159      237       0        153      247       0         11
   208       0         72      218       0        180      228       0        159      238       0         74      248       0         11
   209       0         72      219       0        180      229       0        159      239       0         74      249       0         47
   210       0         72      220       0        180      230       0        159      240       0         74      250       0         73
```

```
BLOCK CURRENT     TOTAL   BLOCK CURRENT     TOTAL   BLOCK CURRENT     TOTAL   BLOCK CURRENT     TOTAL   BLOCK CURRENT     TOTAL
 251        0        73    261        0        72    271        0        52    281        0        79    291        0       151
 252        0        73    262        0        79    272        0        11    282        0        79    292        0       151
 253        0        73    263        0        79    273        0        11    283        0        79    293        0       151
 254        1        73    264        0        79    274        0         0    284        0        79    294        0       151
 255        0        72    265        0        79    275        0         0    285        0        79    295        0       151
 256        6        72    266        0        79    276        0        27    286        0        79    296        0       151
 257        0        72    267        0        79    277        0        79    287        0        79    297        0       151
 258        0        72    268        0        79    278        0        79    288        0       151    298        0       152
 259        0        72    269        0        52    279        0        79    289        0       151    299        0       152
 260        0        72    270        0        52    280        0        79    290        0       151    300        0       152

BLOCK CURRENT     TOTAL   BLOCK CURRENT     TOTAL   BLOCK CURRENT     TOTAL   BLOCK CURRENT     TOTAL   BLOCK CURRENT     TOTAL
 301        0       152    311        0       103    321        0         1    331        0       103    341        0        44
 302        0       152    312        0       103    322        0         7    332        0       103    342        0        44
 303        2       152    313        0       103    323        0       103    333        0       103    343        0        37
 304        0       150    314        0       103    324        0       103    334        0       103    344        0        37
 305        3       150    315        0        96    325        0       103    335        0        44    345        0         0
 306        0       147    316        0        95    326        0       103    336        0        44    346        0         0
 307        0       147    317        0        95    327        0       103    337        0        44    347        0         7
 308        0       103    318        0         0    328        0       103    338        0        44    348        0         7
 309        0       103    319        0         0    329        0       103    339        0        44    349        0         0
 310        0       103    320        0         1    330        0       103    340        0        44    350        0        44

BLOCK CURRENT     TOTAL   BLOCK CURRENT     TOTAL   BLOCK CURRENT     TOTAL   BLOCK CURRENT     TOTAL   BLOCK CURRENT     TOTAL
 351        0        44    361        0        44    371        0       147    381        0       156    391        0        40
 352        0        44    362        0        44    372        0       147    382        1       156    392        0        16
 353        0        44    363        0        44    373        0       147    383        0       155    393        0        16
 354        0        44    364        0       147    374        0       157    384        0       155    394        0         6
 355        0        44    365        0       147    375        0       157    385        0        46    395        0         6
 356        0        44    366        0       147    376        0       157    386        0        46    396        0        30
 357        0        44    367        0       147    377        0       157    387        0        46    397        0        46
 358        0        44    368        0       147    378        0       157    388        0        46    398        0        46
 359        0        44    369        0       147    379        0       157    389        0        46    399        0        46
 360        0        44    370        0       147    380        1       157    390        0        46    400        0        46

BLOCK CURRENT     TOTAL   BLOCK CURRENT     TOTAL   BLOCK CURRENT     TOTAL   BLOCK CURRENT     TOTAL   BLOCK CURRENT     TOTAL
 401        0        46    411        0       108    421        0         0    431        0       106    441        0       151
 402        0        46    412        0       108    422        0         0    432        0       106    442        0       151
 403        0        46    413        0       108    423        0        36    433        0       106    443        0       151
 404        0        46    414        0       108    424        0       107    434        0       106    444        0       151
 405        0        46    415        0       106    425        0       107    435        0       152    445        0       108
 406        1        46    416        0        72    426        0       107    436        0       152    446        0       108
 407        0        46    417        1        72    427        1       107    437        0       152    447        0       160
 408        0        46    418        0        71    428        0       106    438        0       152    448        0       108
 409        0       109    419        0        15    429        0       108    439        1       152    449        0       108
 410        0       109    420        0        15    430        0       106    440        0       151    450        2       108

BLOCK CURRENT     TOTAL   BLOCK CURRENT     TOTAL   BLOCK CURRENT     TOTAL   BLOCK CURRENT     TOTAL   BLOCK CURRENT     TOTAL
 451        0        98    461        0        84    471        0        84    481        0        84    491        0        18
 452        0        98    462        0        77    472        0        84    482        0        14    492        0         0
 453        0        98    463        0        77    473        0        84    483        0        14    493        0         0
 454        0        98    464        0        77    474        0        84    484        0        14    494        0         3
 455        0        84    465        0         0    475        0        84    485        0        14    495        0         2
 456        0        84    466        0         0    476        0        84    486        0        14    496        0         1
 457        0        84    467        0         0    477        0        84    487        0        14    497        0        14
 458        0        84    468        0         0    478        0        84    488        0        14    498        0        14
 459        0        84    469        0         7    479        0        84    489        0        13    499        0        14
 460        0        84    470        0        84    480        0        84    490        0        10    500        0        14

BLOCK CURRENT     TOTAL   BLOCK CURRENT     TOTAL   BLOCK CURRENT     TOTAL   BLOCK CURRENT     TOTAL   BLOCK CURRENT     TOTAL
 501        0        14    511        0        98    521        0        29
 502        0        14    512        0        98    522        0        29
 503        0        14    513        0        98    523        0        29
 504        0        14    514        0        98    524        0        29
 505        0        14    515        0        98    525        0        29
 506        0        14    516        0        98    526        0        29
 507        0        14    517        0        98    527        0        29
 508        0        14    518        0        98    528        0        29
 509        0        14    519        0        98    529        0         1
 510        0        14    520        0        98    530        0         1
```

APPENDIX E

OUTPUT OF QUEUE AND FACILITY STATISTICS

```
STATISTICS OF VEHICLES IN QUEUES

 QUEUE      MAXIMUM    AVERAGE     TOTAL      ZERO    PERCENT     AVERAGE     $AVERAGE     TABLE    CURRENT
           CONTENTS   CONTENTS   ENTRIES   ENTRIES     ZEROS   TIME/TRANS   TIME/TRANS    NUMBER   CONTENTS
 SYSEE          16      9.763       199                   .0     883.170      883.170        65          7
 QUEEE          14      7.949       198         5        2.5     722.656      741.378        19          5
 SYSWW           9      3.435       182                   .0     339.769      339.769        66          2
 QUEWW           7      1.700       182        31       17.0     168.214      202.748        20          2
 SYSNO           8      3.950       159                   .0     447.282      447.282        67          8
 QUENO           6      2.393       157        33       21.0     274.413      347.443        21          4
 SYSNI           9      4.210       152                   .0     498.644      498.644        68          5
 QUENI           7      2.680       150        24       15.9     321.693      382.968        22          3
 SYSSO           7      2.108       157                   .0     241.726      241.726        69          5
 QUESO           5       .667       156        40       25.6      77.070      103.646        23          2
 SYSSI           4      1.109       100                   .0     199.769      199.769        70          2
 QUESI           2       .174        98        41       41.8      32.091       55.175        24
  $AVERAGE TIME/TRANS = AVERAGE TIME/TRANS EXCLUDING ZERO ENTRIES
```

```
AVERAGE STCP-WAITING TIME AND INTERSECTION TRAVEL TIME OF VEHICLES IN EACH LANE (SECOND)

                                               -AVERAGE  UTILIZATION  DURING-
FACILITY       NUMBER          AVERAGE          TOTAL     AVAIL.    UNAVAIL.      CURRENT          PERCENT          TRANSACTION NUMBER
               ENTRIES         TIME/TRAN        TIME      TIME       TIME         STATUS        AVAILABILITY        SEIZING  PREEMPTING
    STP01         13            22.692          .016                                                100.0
    STP02        121            25.884          .174                                                100.0
    STP03         59            27.458          .090                                                100.0
    STP04          5            19.800          .005                                                100.0
    STP05        103            26.039          .149                                                100.0
    STP06         72            23.583          .094                                                100.0
    STP07         74            26.595          .109                                                100.0            61
    STP08         79            25.557          .112                                                100.0
    STP09        103            19.893          .113                                                100.0
    STP10         44            19.182          .046                                                100.0
    STP11         46            23.391          .059                                                100.0
    STP12        108            24.648          .147                                                100.0            53
    STP13         84            21.738          .101                                                100.0
    STP14         14            24.429          .019                                                100.0
    INET1        121            27.162          .182                                                100.0
    INET2        121             4.124          .027                                                100.0
    INET3        121             4.000          .026                                                100.0
    INET4        121             8.868          .059                                                100.0            34
    INWT1        103            28.883          .165                                                100.0
    INWT2        103             4.184          .023                                                100.0
    INWT3        103             4.010          .022                                                100.0
    INWT4        103             9.942          .056                                                100.0
    INOT1         79            25.785          .113                                                100.0
    INOT2         79            10.671          .046                                                100.0
    INIT1        103            26.320          .150                                                100.0
    INIT2        103            11.000          .062                                                100.0
    ISOT1        107            24.869          .147                                                100.0             3
    ISOT2        106            10.236          .060                                                100.0
    ISIT1         84            28.131          .131                                                100.0
    ISIT2         84            11.357          .053                                                100.0
    INEL1         59            30.254          .099                                                100.0
    INEL2         59             3.000          .009                                                100.0
    INEL3         59             9.763          .032                                                100.0
    INWL1         72            35.292          .141                                                100.0
    INWL2         72             3.028          .012                                                100.0
    INWL3         72            10.903          .043                                                100.0
    INIL1         44            28.366          .069                                                100.0
    INIL2         44             3.045          .007                                                100.0
    INIL3         44            12.159          .029                                                100.0
    ISIL1         14            30.429          .023                                                100.0
    ISIL2         14            33.214          .025                                                100.0
    ISIL3         14            14.071          .010                                                100.0
```

```
                                        ***************************************
                                        *                                     *
                                        *              STORAGES               *
                                        *                                     *
                                        ***************************************

                                                                   -AVERAGE  UTILIZATION  DURING-
 STORAGE     CAPACITY      AVERAGE       ENTRIES      AVERAGE       TOTAL     AVAIL.    UNAVAIL.   CURRENT        PERCENT        CURRENT      MAXIMUM
                           CONTENTS                  TIME/UNIT      TIME      TIME       TIME      STATUS     AVAILABILITY     CONTENTS     CONTENTS
  INER1          2           .024           13        33.339        .012                                          100.0                          1
  INWR1          2           .010            5        36.600        .005                                          100.0                          1
  INOR1          2           .122           73        29.566        .060                                          100.0             1            2
  ISOR1          2           .083           46        34.587        .044                                          100.0                          2
  SPDNO         10           .194          151        23.126        .019                                          100.0                          2
  SPDNI         10           .192          147        23.537        .019                                          100.0                          3
  SPDSO         10           .188          152        22.322        .018                                          100.0             1            2
  SPDSI         10           .113           98        20.755        .011                                          100.0                          2
  SPDEO         10           .306          192        28.672        .030                                          100.0                          2
  SPDWO         10           .235          180        23.478        .023                                          100.0             1            2
```

```
USER CHAIN STATISTICS

 USER CHAIN          TOTAL         AVERAGE        CURRENT       AVERAGE       MAXIMUM
                    ENTRIES      TIME/TRANS      CONTENTS      CONTENTS      CONTENTS
    ETH11               22         12.954                          .015             2
    ELT11                7         50.285                          .019             2
    SPDEE                7          4.571                          .001             1
    WTH31               15         20.666                          .017             1
    WLT31                4         16.500                          .003             1
    SPDWW                6          7.666                          .002             1
    NRT21               11         15.818                          .009             2
    INT07                7         13.000                          .005             1
    NTH21               12         15.416                          .010             2
    SPDNO                5          6.199                          .001             1
    NTH22               12         17.833                          .011             2
    SPDNI                7          4.428                          .001             1
    SRT41                2          3.500                          .000             1
    INT11                1         10.000                          .000             1
    STH41               24         24.000            1             .031             2
    SPDSO                2          3.000                          .000             1
    STH42               10         18.199                          .010             2
    SLT42                1          8.000                          .000             1
    SPDSI                2          7.000                          .000             1
```

APPENDIX F

OUTPUT OF HEADWAY DISTRIBUTIONS

```
EASTBOUND TRAFFIC HEADWAY DISTRIBUTION -- LANE L1  (TENTH OF SECOND)

 TABLE    1
 ENTRIES IN TABLE        MEAN ARGUMENT          STANDARD DEVIATION         SUM OF ARGUMENTS
             198                90.474                       75.250              17914.000        NON-WEIGHTED

           UPPER       OBSERVED       PER CENT      CUMULATIVE     CUMULATIVE      MULTIPLE       DEVIATION
           LIMIT      FREQUENCY       OF TOTAL      PERCENTAGE      REMAINDER       OF MEAN       FROM MEAN
               0              0            .00              .0          100.0         -.000          -1.202
              20             12           6.06             6.0           93.9          .221           -.936
              40             45          22.72            28.7           71.2          .442           -.670
              60             36          18.18            46.9           53.0          .663           -.404
              80             23          11.61            58.5           41.4          .884           -.139
             100             24          12.12            70.7           29.2         1.105            .126
             120             15           7.57            78.2           21.7         1.326            .392
             140              6           3.03            81.3           18.6         1.547            .658
             160              9           4.54            85.8           14.1         1.768            .923
             180              1            .50            86.3           13.6         1.989           1.189
             200              7           3.53            89.8           10.1         2.210           1.455
             220              7           3.53            93.4            6.5         2.431           1.721
             240              1            .50            93.9            6.0         2.652           1.987
             260              3           1.51            95.4            4.5         2.873           2.252
             280              1            .50            95.9            4.0         3.094           2.518
             300              2           1.01            96.9            3.0         3.315           2.784
             320              1            .50            97.4            2.5         3.536           3.050
             340              2           1.01            98.4            1.5         3.757           3.315
             360              2           1.01            99.4             .5         3.979           3.581
             380              0            .00            99.4             .5         4.200           3.847
             400              0            .00            99.4             .5         4.421           4.113
             420              1            .50           100.0             .0         4.642           4.379
 REMAINING FREQUENCIES ARE ALL ZERO
```

```
WESTBOUND TRAFFIC HEADWAY DISTRIBUTION -- LANE L2  (TENTH OF SECOND)

 TABLE    2
 ENTRIES IN TABLE        MEAN ARGUMENT          STANDARD DEVIATION         SUM OF ARGUMENTS
              181              98.049                      129.562                17747.000        NON-WEIGHTED

             UPPER       OBSERVED        PER CENT       CUMULATIVE        CUMULATIVE        MULTIPLE        DEVIATION
             LIMIT      FREQUENCY        OF TOTAL       PERCENTAGE         REMAINDER         OF MEAN        FROM MEAN
                 0              0             .00               .0             100.0           -.000            -.756
                20             29           16.02             16.0              83.9            .203            -.602
                40             63           34.80             50.8              49.1            .407            -.448
                60             30           16.57             67.4              32.5            .611            -.293
                80              5            2.76             70.1              29.8            .815            -.139
               100             10            5.52             75.6              24.3           1.019             .015
               120              3            1.65             77.3              22.6           1.223             .169
               140              4            2.20             79.5              20.4           1.427             .323
               160              4            2.20             81.7              18.2           1.631             .478
               180              2            1.10             82.8              17.1           1.835             .632
               200              2            1.10             83.9              16.0           2.039             .786
               220              1             .55             84.5              15.4           2.243             .941
               240              3            1.65             86.1              13.8           2.447            1.095
               260              1             .55             86.7              13.2           2.651            1.249
               280              4            2.20             88.9              11.0           2.855            1.404
               300              0             .00             88.9              11.0           3.059            1.558
               320              3            1.65             90.6               9.3           3.263            1.713
               340              3            1.65             92.2               7.7           3.467            1.867
               360              2            1.10             93.3               6.6           3.671            2.021
               380              1             .55             93.9               6.0           3.875            2.176
               400              2            1.10             95.0               4.9           4.079            2.330
               420              0             .00             95.0               4.9           4.283            2.484
               440              1             .55             95.5               4.4           4.487            2.639
               460              1             .55             96.1               3.8           4.691            2.793
               480              1             .55             96.6               3.3           4.895            2.947
               500              2            1.10             97.7               2.2           5.099            3.102
               520              2            1.10             98.8               1.1           5.303            3.256
               540              0             .00             98.8               1.1           5.507            3.411
               560              1             .55             99.4                .5           5.711            3.565
               580              0             .00             99.4                .5           5.915            3.719
               600              0             .00             99.4                .5           6.119            3.874
               620              1             .55            100.0                .0           6.323            4.028
 REMAINING FREQUENCIES ARE ALL ZERO
```

```
NORTHBOUND OUTSIDE LANE TRAFFIC HEADWAY DISTRIBUTION -- LANE L31 (TENTH OF SECOND)

 TABLE   3
 ENTRIES IN TABLE       MEAN ARGUMENT        STANDARD DEVIATION       SUM OF ARGUMENTS
            158              113.689                  103.562              17963.000        NON-WEIGHTED

         UPPER      OBSERVED    PER CENT     CUMULATIVE    CUMULATIVE     MULTIPLE    DEVIATION
         LIMIT     FREQUENCY    OF TOTAL     PERCENTAGE     REMAINDER      OF MEAN    FROM MEAN
             0             0         .00             .0         100.0        -.000       -1.097
            20            15        9.49            9.4          90.5         .175        -.904
            40            38       24.05           33.5          66.4         .351        -.711
            60            15        9.49           43.0          56.9         .527        -.518
            80            21       13.29           56.3          43.6         .703        -.325
           100             7        4.43           60.7          39.2         .879        -.132
           120             7        4.43           65.1          34.8        1.055         .060
           140             6        3.79           68.9          31.0        1.231         .254
           160             7        4.43           73.4          26.5        1.407         .447
           180             4        2.53           75.9          24.0        1.583         .640
           200             4        2.53           78.4          21.5        1.759         .833
           220             6        3.79           82.2          17.7        1.935        1.026
           240             6        3.79           86.0          13.9        2.111        1.219
           260             2        1.26           87.3          12.6        2.286        1.412
           280             4        2.53           89.8          10.1        2.462        1.605
           300             4        2.53           92.4           7.5        2.638        1.799
           320             2        1.26           93.6           6.3        2.814        1.992
           340             5        3.16           96.8           3.1        2.990        2.185
           360             1         .63           97.4           2.5        3.166        2.378
           380             0         .00           97.4           2.5        3.342        2.571
           400             1         .63           98.1           1.8        3.518        2.764
           420             2        1.26           99.3            .6        3.694        2.957
           440             0         .00           99.3            .6        3.870        3.150
           460             1         .63          100.0            .0        4.046        3.343
 REMAINING FREQUENCIES ARE ALL ZERO
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NORTHBOUND INSIDE LANE TRAFFIC HEADWAY DISTRIBUTION  --LANE L32 (TENTH OF SECOND)

 TABLE    4
 ENTRIES IN TABLE          MEAN ARGUMENT          STANDARD DEVIATION          SUM OF ARGUMENTS
              151                118.258                      97.687                 17857.000          NON-WEIGHTED

            UPPER       OBSERVED        PER CENT       CUMULATIVE       CUMULATIVE       MULTIPLE       DEVIATION
            LIMIT      FREQUENCY        OF TOTAL       PERCENTAGE        REMAINDER        OF MEAN       FROM MEAN
                0              0             .00               .0            100.0          -.000          -1.210
               20              6            3.97              3.9             96.0           .169          -1.005
               40             25           16.55             20.5             79.4           .338           -.801
               60             23           15.23             35.7             64.2           .507           -.596
               80             18           11.92             47.6             52.3           .676           -.391
              100             18           11.92             59.6             40.3           .845           -.186
              120             10            6.62             66.2             33.7          1.014            .017
              140              4            2.64             68.8             31.1          1.183            .222
              160              9            5.96             74.8             25.1          1.352            .427
              180              4            2.64             77.4             22.5          1.522            .632
              200              6            3.97             81.4             18.5          1.691            .836
              220              4            2.64             84.1             15.8          1.860           1.041
              240              3            1.98             86.0             13.9          2.029           1.246
              260              7            4.63             90.7              9.2          2.198           1.450
              280              0             .00             90.7              9.2          2.367           1.655
              300              3            1.98             92.7              7.2          2.536           1.860
              320              1             .66             93.3              6.6          2.705           2.065
              340              6            3.97             97.3              2.6          2.875           2.269
              360              1             .66             98.0              1.9          3.044           2.474
              380              1             .66             98.6              1.3          3.213           2.679
              400              0             .00             98.6              1.3          3.382           2.884
              420              0             .00             98.6              1.3          3.551           3.088
              440              0             .00             98.6              1.3          3.720           3.293
              460              0             .00             98.6              1.3          3.889           3.498
              480              1             .66             99.3               .6          4.058           3.703
              500              0             .00             99.3               .6          4.228           3.907
              520              1             .66            100.0               .0          4.397           4.112
 REMAINING FREQUENCIES ARE ALL ZERO
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SOUTHBOUND OUTSIDE LANE TRAFFIC HEADWAY DISTRIBUTION -- LANE L41 (TENTH OF SECOND)

 TABLE    5
 ENTRIES IN TABLE          MEAN ARGUMENT           STANDARD DEVIATION          SUM OF ARGUMENTS
              156                114.948                       130.000                17932.000           NON-WEIGHTED

           UPPER         OBSERVED          PER CENT        CUMULATIVE        CUMULATIVE      MULTIPLE         DEVIATION
           LIMIT        FREQUENCY          OF TOTAL        PERCENTAGE         REMAINDER       OF MEAN         FROM MEAN
               0                0               .00                .0             100.0         -.000             -.884
              20               17             10.89              10.8              89.1          .173             -.730
              40               30             19.23              30.1              69.8          .347             -.576
              60               38             24.35              54.4              45.5          .521             -.422
              60               10              6.41              60.8              39.1          .695             -.268
             100               11              7.05              67.9              32.0          .869             -.114
             120                2              1.28              69.2              30.7         1.043              .038
             140                5              3.20              72.4              27.5         1.217              .192
             160                3              1.92              74.3              25.6         1.391              .346
             180                4              2.56              76.9              23.0         1.565              .500
             200                8              5.12              82.0              17.9         1.739              .654
             220                1               .64              82.6              17.3         1.913              .808
             240                9              5.76              88.4              11.5         2.087              .961
             260                1               .64              89.1              10.8         2.261             1.115
             280                0               .00              89.1              10.8         2.435             1.269
             300                0               .00              89.1              10.8         2.609             1.423
             320                1               .64              89.7              10.2         2.783             1.577
             340                1               .64              90.3               9.6         2.957             1.731
             360                3              1.92              92.3               7.6         3.131             1.885
             380                2              1.28              93.5               6.4         3.305             2.038
             400                5              3.20              96.7               3.2         3.479             2.192
             420                0               .00              96.7               3.2         3.653             2.346
             440                0               .00              96.7               3.2         3.827             2.500
             460                0               .00              96.7               3.2         4.001             2.654
             480                1               .64              97.4               2.5         4.175             2.808
             500                0               .00              97.4               2.5         4.349             2.961
             520                1               .64              98.0               1.9         4.523             3.115
             540                0               .00              98.0               1.9         4.697             3.269
             560                0               .00              98.0               1.9         4.871             3.423
             580                1               .64              98.7               1.2         5.045             3.577
             600                0               .00              98.7               1.2         5.219             3.731
             620                0               .00              98.7               1.2         5.393             3.885
             640                1               .64              99.3                .6         5.567             4.038
             660                1               .64             100.0                .0         5.741             4.192
 REMAINING FREQUENCIES ARE ALL ZERO
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SOUTHBOUND INSIDE LANE TRAFFIC HEADWAY DISTRIBUTION  --LANE L42 (TENTH OF SECOND)

 TABLE   6
 ENTRIES IN TABLE          MEAN ARGUMENT          STANDARD DEVIATION          SUM OF ARGUMENTS
        99                    181.292                     166.250                17948.000         NON-WEIGHTED

        UPPER        OBSERVED        PER CENT      CUMULATIVE      CUMULATIVE      MULTIPLE       DEVIATION
        LIMIT       FREQUENCY        OF TOTAL      PERCENTAGE      REMAINDER        OF MEAN       FROM MEAN
            0               0             .00              .0           100.0          -.000          -1.090
           20               4            4.04             4.0            95.9           .110           -.970
           40              12           12.12            16.1            83.8           .220           -.849
           60              10           10.10            26.2            73.7           .330           -.729
           80               7            7.07            33.3            66.6           .441           -.609
          100               8            8.08            41.4            58.5           .551           -.488
          120               8            8.08            49.4            50.5           .661           -.368
          140               8            8.08            57.5            42.4           .772           -.248
          160               5            5.05            62.6            37.3           .882           -.128
          180               3            3.03            65.6            34.3           .992           -.007
          200               3            3.03            68.6            31.3          1.103            .112
          220               4            4.04            72.7            27.2          1.213            .232
          240               2            2.02            74.7            25.2          1.323            .353
          260               0             .00            74.7            25.2          1.434            .473
          280               3            3.03            77.7            22.2          1.544            .593
          300               0             .00            77.7            22.2          1.654            .714
          320               3            3.03            80.8            19.1          1.765            .834
          340               1            1.01            81.8            18.1          1.875            .954
          360               1            1.01            82.8            17.1          1.985           1.074
          380               1            1.01            83.8            16.1          2.096           1.195
          400               1            1.01            84.8            15.1          2.206           1.315
          420               3            3.03            87.8            12.1          2.316           1.435
          440               3            3.03            90.9             9.0          2.427           1.556
          460               3            3.03            93.9             6.0          2.537           1.676
          480               1            1.01            94.9             5.0          2.647           1.796
          500               0             .00            94.9             5.0          2.757           1.917
          520               0             .00            94.9             5.0          2.868           2.037
          540               1            1.01            95.9             4.0          2.978           2.157
          560               0             .00            95.9             4.0          3.088           2.277
          580               0             .00            95.9             4.0          3.199           2.398
          600               0             .00            95.9             4.0          3.309           2.518
          620               0             .00            95.9             4.0          3.419           2.638
          640               1            1.01            96.9             3.0          3.530           2.759
          660               1            1.01            97.9             2.0          3.640           2.879
          680               0             .00            97.9             2.0          3.750           2.999
          700               1            1.01            98.9             1.0          3.861           3.120
          720               1            1.01           100.0              .0          3.971           3.240
 REMAINING FREQUENCIES ARE ALL ZERO
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APPENDIX G

OUTPUT OF SPEED DISTRIBUTIONS

EASTBOUND TRAFFIC SPEED DISTRIBUTION-- LANE L1 (FT/SEC)

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TABLE  13
ENTRIES IN TABLE          MEAN ARGUMENT          STANDARD DEVIATION          SUM OF ARGUMENTS
             192                 36.041                          7.695                6920.000        NON-WEIGHTED

          UPPER         OBSERVED          PER CENT        CUMULATIVE        CUMULATIVE          MULTIPLE           DEVIATION
          LIMIT        FREQUENCY          OF TOTAL        PERCENTAGE         REMAINDER           OF MEAN           FROM MEAN
              0                0               .00                .0             100.0             -.000              -4.683
              2                0               .00                .0             100.0              .055              -4.423
              4                0               .00                .0             100.0              .110              -4.163
              6                0               .00                .0             100.0              .166              -3.903
              8                0               .00                .0             100.0              .221              -3.643
             10                0               .00                .0             100.0              .277              -3.384
             12                0               .00                .0             100.0              .332              -3.124
             14                0               .00                .0             100.0              .388              -2.864
             16                0               .00                .0             100.0              .443              -2.604
             18                0               .00                .0             100.0              .499              -2.344
             20                0               .00                .0             100.0              .554              -2.084
             22                0               .00                .0             100.0              .610              -1.824
             24                1               .52                .5              99.4              .665              -1.564
             26                5              2.60               3.1              96.8              .721              -1.304
             28               23             11.97              15.1              84.8              .776              -1.045
             30               18              9.37              24.4              75.5              .832               -.785
             32               21             10.93              35.4              64.5              .887               -.525
             34               25             13.02              48.4              51.5              .943               -.265
             36               19              9.89              58.3              41.6              .998               -.005
             38               31             16.14              74.4              25.5             1.054                .254
             40               10              5.20              79.6              20.3             1.109                .514
             42                7              3.64              83.3              16.6             1.165                .774
             44                8              4.16              87.4              12.5             1.220               1.034
             46                1               .52              88.0              11.9             1.276               1.294
             48                8              4.16              92.1               7.8             1.331               1.553
             50                3              1.56              93.7               6.2             1.387               1.813
             52                2              1.04              94.7               5.2             1.442               2.073
             54                0               .00              94.7               5.2             1.498               2.333
             56                2              1.04              95.8               4.1             1.553               2.593
             58                8              4.16             100.0                .0             1.609               2.853
REMAINING FREQUENCIES ARE ALL ZERO
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WESTBOUND TRAFFIC SPEED DISTRIBUTION-- LANE L2 (FT/SEC)

 TABLE  14
 ENTRIES IN TABLE        MEAN ARGUMENT          STANDARD DEVIATION         SUM OF ARGUMENTS
          179                 43.418                          6.589                7772.000        NON-WEIGHTED

           UPPER        OBSERVED       PER CENT       CUMULATIVE       CUMULATIVE       MULTIPLE       DEVIATION
           LIMIT       FREQUENCY       OF TOTAL       PERCENTAGE        REMAINDER        OF MEAN       FROM MEAN
               0               0            .00               .0            100.0          -.000          -6.588
               2               0            .00               .0            100.0           .046          -6.285
               4               0            .00               .0            100.0           .092          -5.981
               6               0            .00               .0            100.0           .138          -5.678
               8               0            .00               .0            100.0           .184          -5.374
              10               0            .00               .0            100.0           .230          -5.071
              12               0            .00               .0            100.0           .276          -4.767
              14               0            .00               .0            100.0           .322          -4.464
              16               0            .00               .0            100.0           .368          -4.160
              18               0            .00               .0            100.0           .414          -3.857
              20               0            .00               .0            100.0           .460          -3.553
              22               0            .00               .0            100.0           .506          -3.250
              24               0            .00               .0            100.0           .552          -2.946
              26               0            .00               .0            100.0           .598          -2.643
              28               0            .00               .0            100.0           .644          -2.339
              30               0            .00               .0            100.0           .690          -2.036
              32               9           5.02              5.0             94.9           .737          -1.732
              34              13           7.26             12.2             87.7           .783          -1.429
              36               3           1.67             13.9             86.0           .829          -1.125
              38              18          10.05             24.0             75.9           .875           -.822
              40               9           5.02             29.0             70.9           .921           -.518
              42              28          15.64             44.6             55.3           .967           -.215
              44              20          11.17             55.8             44.1          1.013            .088
              46              25          13.96             69.8             30.1          1.059            .391
              48              16           8.93             78.7             21.2          1.105            .695
              50               9           5.02             83.7             16.2          1.151            .998
              52              16           8.93             92.7              7.2          1.197           1.302
              54               0            .00             92.7              7.2          1.243           1.605
              56               5           2.79             95.5              4.4          1.289           1.909
              58               8           4.46            100.0               .0          1.335           2.212
 REMAINING FREQUENCIES ARE ALL ZERO
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NORTHBOUND OUTSIDE LANE TRAFFIC SPEED DISTRIBUTION LANE L31 (FT/SEC)

 TABLE  15
 ENTRIES IN TABLE          MEAN ARGUMENT           STANDARD DEVIATION          SUM OF ARGUMENTS
            151                   43.695                         4.839                   6598.000          NON-WEIGHTED

           UPPER        OBSERVED       PER CENT        CUMULATIVE       CUMULATIVE        MULTIPLE         DEVIATION
           LIMIT        FREQUENCY      OF TOTAL        PERCENTAGE        REMAINDER         OF MEAN         FROM MEAN
               0                0           .00                .0            100.0           -.000            -9.028
               2                0           .00                .0            100.0            .045            -8.615
               4                0           .00                .0            100.0            .091            -8.201
               6                0           .00                .0            100.0            .137            -7.788
               8                0           .00                .0            100.0            .183            -7.375
              10                0           .00                .0            100.0            .228            -6.962
              12                0           .00                .0            100.0            .274            -6.548
              14                0           .00                .0            100.0            .320            -6.135
              16                0           .00                .0            100.0            .366            -5.722
              18                0           .00                .0            100.0            .411            -5.309
              20                0           .00                .0            100.0            .457            -4.895
              22                0           .00                .0            100.0            .503            -4.482
              24                0           .00                .0            100.0            .549            -4.069
              26                0           .00                .0            100.0            .595            -3.656
              28                0           .00                .0            100.0            .640            -3.242
              30                0           .00                .0            100.0            .686            -2.829
              32                0           .00                .0            100.0            .732            -2.416
              34                3          1.98               1.9             98.0            .778            -2.003
              36                5          3.31               5.2             94.7            .823            -1.590
              38               11          7.28              12.5             87.4            .869            -1.176
              40               18         11.92              24.5             75.4            .915             -.763
              42               22         14.56              39.0             60.9            .961             -.350
              44               20         13.24              52.3             47.6           1.006              .062
              46               32         21.19              73.5             26.4           1.052              .476
              48               23         15.23              88.7             11.2           1.098              .889
              50                6          3.97              92.7              7.2           1.144             1.302
              52                4          2.64              95.3              4.6           1.190             1.715
              54                0           .00              95.3              4.6           1.235             2.129
              56                3          1.98              97.3              2.6           1.281             2.542
              58                4          2.64             100.0               .0           1.327             2.955
 REMAINING FREQUENCIES ARE ALL ZERO
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NORTHBOUND INSIDE LANE TRAFFIC SPEED DISTRIBUTION LANE L32 (FT/SEC)

 TABLE  16
 ENTRIES IN TABLE        MEAN ARGUMENT          STANDARD DEVIATION        SUM OF ARGUMENTS
              147               43.102                        5.710                6336.000        NON-WEIGHTED

          UPPER        OBSERVED       PER CENT      CUMULATIVE      CUMULATIVE      MULTIPLE      DEVIATION
          LIMIT       FREQUENCY       OF TOTAL      PERCENTAGE       REMAINDER       OF MEAN      FROM MEAN
              0               0            .00              .0           100.0         -.000         -7.547
              2               0            .00              .0           100.0          .046         -7.197
              4               0            .00              .0           100.0          .092         -6.846
              6               0            .00              .0           100.0          .139         -6.496
              8               0            .00              .0           100.0          .185         -6.146
             10               0            .00              .0           100.0          .232         -5.796
             12               0            .00              .0           100.0          .278         -5.446
             14               0            .00              .0           100.0          .324         -5.095
             16               0            .00              .0           100.0          .371         -4.745
             18               0            .00              .0           100.0          .417         -4.395
             20               0            .00              .0           100.0          .464         -4.045
             22               0            .00              .0           100.0          .510         -3.695
             24               0            .00              .0           100.0          .556         -3.344
             26               0            .00              .0           100.0          .603         -2.994
             28               0            .00              .0           100.0          .649         -2.644
             30               0            .00              .0           100.0          .696         -2.294
             32               0            .00              .0           100.0          .742         -1.943
             34               5           3.40             3.4            96.5          .788         -1.593
             36              21          14.28            17.6            82.3          .835         -1.243
             38              10           6.80            24.4            75.5          .881          -.893
             40               9           6.12            30.6            69.3          .928          -.543
             42              10           6.80            37.4            62.5          .974          -.192
             44              19          12.92            50.3            49.6         1.020           .157
             46              37          25.17            75.5            24.4         1.067           .507
             48              20          13.60            89.1            10.8         1.113           .857
             50               5           3.40            92.5             7.4         1.160          1.207
             52               2           1.36            93.8             6.1         1.206          1.558
             54               0            .00            93.8             6.1         1.252          1.908
             56               4           2.72            96.5             3.4         1.299          2.258
             58               5           3.40           100.0              .0         1.345          2.608
 REMAINING FREQUENCIES ARE ALL ZERO
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SOUTHBOUND OUTSIDE LANE TRAFFIC SPEED DISTRIBUTION LANE L41 (FT/SEC)

 TABLE  17
 ENTRIES IN TABLE         MEAN ARGUMENT          STANDARD DEVIATION         SUM OF ARGUMENTS
      151                     44.761                        4.890                 6759.000        NON-WEIGHTED

         UPPER        OBSERVED        PER CENT       CUMULATIVE      CUMULATIVE       MULTIPLE        DEVIATION
         LIMIT       FREQUENCY        OF TOTAL       PERCENTAGE       REMAINDER        OF MEAN        FROM MEAN
             0               0             .00               .0           100.0          -.000           -9.152
             2               0             .00               .0           100.0           .044           -8.743
             4               0             .00               .0           100.0           .089           -8.334
             6               0             .00               .0           100.0           .134           -7.925
             8               0             .00               .0           100.0           .178           -7.516
            10               0             .00               .0           100.0           .223           -7.107
            12               0             .00               .0           100.0           .268           -6.698
            14               0             .00               .0           100.0           .312           -6.289
            16               0             .00               .0           100.0           .357           -5.880
            18               0             .00               .0           100.0           .402           -5.472
            20               0             .00               .0           100.0           .446           -5.063
            22               0             .00               .0           100.0           .491           -4.654
            24               0             .00               .0           100.0           .536           -4.245
            26               0             .00               .0           100.0           .580           -3.836
            28               0             .00               .0           100.0           .625           -3.427
            30               0             .00               .0           100.0           .670           -3.018
            32               0             .00               .0           100.0           .714           -2.609
            34               1             .66               .6            99.3           .759           -2.200
            36               0             .00               .6            99.3           .804           -1.791
            38              10            6.62              7.2            92.7           .848           -1.382
            40              10            6.62             13.9            86.0           .893            -.973
            42              30           19.86             33.7            66.2           .938            -.564
            44              29           19.20             52.9            47.0           .982            -.155
            46              20           13.24             66.2            33.7          1.027             .253
            48              19           12.58             78.8            21.1          1.072             .662
            50              10            6.62             85.4            14.5          1.117            1.071
            52              13            8.60             94.0             5.9          1.161            1.480
            54               0             .00             94.0             5.9          1.206            1.889
            56               6            3.97             98.0             1.9          1.251            2.297
            58               3            1.98            100.0              .0          1.295            2.706
 REMAINING FREQUENCIES ARE ALL ZERO
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```
SOUTHBOUND INSIDE LANE TRAFFIC SPEED DISTRIBUTION LANE L42 (FT/SEC)

 TABLE  18
 ENTRIES IN TABLE          MEAN ARGUMENT            STANDARD DEVIATION           SUM OF ARGUMENTS
               98                 48.571                         5.527                   4760.000          NON-WEIGHTED

           UPPER        OBSERVED        PER CENT       CUMULATIVE       CUMULATIVE       MULTIPLE         DEVIATION
           LIMIT       FREQUENCY        OF TOTAL       PERCENTAGE        REMAINDER        OF MEAN         FROM MEAN
               0               0             .00               .0            100.0          -.000            -8.787
               2               0             .00               .0            100.0           .041            -8.425
               4               0             .00               .0            100.0           .082            -8.063
               6               0             .00               .0            100.0           .123            -7.701
               8               0             .00               .0            100.0           .164            -7.340
              10               0             .00               .0            100.0           .205            -6.978
              12               0             .00               .0            100.0           .247            -6.616
              14               0             .00               .0            100.0           .288            -6.254
              16               0             .00               .0            100.0           .329            -5.892
              18               0             .00               .0            100.0           .370            -5.530
              20               0             .00               .0            100.0           .411            -5.169
              22               0             .00               .0            100.0           .452            -4.807
              24               0             .00               .0            100.0           .494            -4.445
              26               0             .00               .0            100.0           .535            -4.083
              28               0             .00               .0            100.0           .576            -3.721
              30               0             .00               .0            100.0           .617            -3.359
              32               0             .00               .0            100.0           .658            -2.998
              34               0             .00               .0            100.0           .699            -2.636
              36               0             .00               .0            100.0           .741            -2.274
              38               1            1.02              1.0             98.9           .782            -1.912
              40               5            5.10              6.1             93.8           .823            -1.550
              42               2            2.04              8.1             91.8           .864            -1.188
              44              18           18.36             26.5             73.4           .905             -.827
              46              12           12.24             38.7             61.2           .947             -.465
              48              13           13.26             52.0             47.9           .988             -.103
              50              14           14.28             66.3             33.6          1.029              .258
              52              13           13.26             79.5             20.4          1.070              .620
              54               0             .00             79.5             20.4          1.111              .982
              56               7            7.14             86.7             13.2          1.152             1.343
              58              13           13.26            100.0               .0          1.194             1.705
 REMAINING FREQUENCIES ARE ALL ZERO
```

APPENDIX H

OUTPUT OF TRAFFIC QUEUE DISTRIBUTIONS

```
EASTBOUND TRAFFIC QUEUE LENGTH -- LANE L1

 TABLE  25
 ENTRIES IN TABLE          MEAN ARGUMENT            STANDARD DEVIATION          SUM OF ARGUMENTS
              29                   8.482                          2.320                   246.000        NON-WEIGHTED

          UPPER         OBSERVED        PER CENT        CUMULATIVE       CUMULATIVE       MULTIPLE        DEVIATION
          LIMIT        FREQUENCY        OF TOTAL        PERCENTAGE        REMAINDER        OF MEAN        FROM MEAN
              0                0             .00                .0            100.0          -.000           -3.655
              1                0             .00                .0            100.0           .117           -3.224
              2                0             .00                .0            100.0           .235           -2.793
              3                0             .00                .0            100.0           .353           -2.362
              4                0             .00                .0            100.0           .471           -1.931
              5                3           10.34              10.3             89.6           .589           -1.500
              6                3           10.34              20.6             79.3           .707           -1.070
              7                6           20.68              41.3             58.6           .825            -.639
              8                3           10.34              51.7             48.2           .943            -.208
              9                4           13.79              65.5             34.4          1.060             .222
             10                4           13.79              79.3             20.6          1.178             .653
             11                3           10.34              89.6             10.3          1.296            1.084
             12                1            3.44              93.1              6.8          1.414            1.515
             13                2            6.89             100.0               .0          1.532            1.946
 REMAINING FREQUENCIES ARE ALL ZERO


WESTBOUND TRAFFIC QUEUE LENGTH -- LANE L2

 TABLE  26
 ENTRIES IN TABLE          MEAN ARGUMENT            STANDARD DEVIATION          SUM OF ARGUMENTS
              29                   1.931                          1.644                    56.000        NON-WEIGHTED

          UPPER         OBSERVED        PER CENT        CUMULATIVE       CUMULATIVE       MULTIPLE        DEVIATION
          LIMIT        FREQUENCY        OF TOTAL        PERCENTAGE        REMAINDER        OF MEAN        FROM MEAN
              0                7           24.13              24.1             75.8          -.000           -1.174
              1                6           20.68              44.8             55.1           .517            -.566
              2                6           20.68              65.5             34.4          1.035             .041
              3                5           17.24              82.7             17.2          1.553             .650
              4                3           10.34              93.1              6.8          2.071            1.258
              5                1            3.44              96.5              3.4          2.589            1.866
              6                1            3.44             100.0               .0          3.107            2.474
 REMAINING FREQUENCIES ARE ALL ZERO
```

```
NORTHBOUND OUTSIDE LANE TRAFFIC QUEUE LENGTH -- LANE L31

 TABLE  27
 ENTRIES IN TABLE          MEAN ARGUMENT          STANDARD DEVIATION          SUM OF ARGUMENTS
           29                      2.482                        1.296                   72.000        NON-WEIGHTED

           UPPER        OBSERVED         PER CENT       CUMULATIVE      CUMULATIVE        MULTIPLE        DEVIATION
           LIMIT       FREQUENCY         OF TOTAL       PERCENTAGE       REMAINDER         OF MEAN        FROM MEAN
               0               1             3.44              3.4            96.5           -.000           -1.914
               1               6            20.68             24.1            75.8            .402           -1.143
               2               9            31.03             55.1            44.8            .805            -.372
               3               6            20.68             75.8            24.1           1.208             .398
               4               5            17.24             93.1             6.8           1.611            1.169
               5               2             6.89            100.0              .0           2.013            1.941
 REMAINING FREQUENCIES ARE ALL ZERO




NORTHBOUND INSIDE LANE TRAFFIC QUEUE LENGTH -- LANE L32

 TABLE  28
 ENTRIES IN TABLE          MEAN ARGUMENT          STANDARD DEVIATION          SUM OF ARGUMENTS
           29                      3.000                        1.460                   87.000        NON-WEIGHTED

           UPPER        OBSERVED         PER CENT       CUMULATIVE      CUMULATIVE        MULTIPLE        DEVIATION
           LIMIT       FREQUENCY         OF TOTAL       PERCENTAGE       REMAINDER         OF MEAN        FROM MEAN
               0               1             3.44              3.4            96.5           -.000           -2.053
               1               4            13.79             17.2            82.7            .333           -1.368
               2               6            20.68             37.9            62.0            .666            -.684
               3               6            20.68             58.6            41.3           1.000            -.000
               4               8            27.58             86.2            13.7           1.333             .684
               5               3            10.34             96.5             3.4           1.666            1.368
               6               1             3.44            100.0              .0           2.000            2.053
 REMAINING FREQUENCIES ARE ALL ZERO
```

```
SOUTHBOUND OUTSIDE LANE TRAFFIC QUEUE LENGTH -- LANE L41

 TABLE  29
 ENTRIES IN TABLE          MEAN ARGUMENT          STANDARD DEVIATION          SUM OF ARGUMENTS
         29                      .655                          .768                   19.000        NON-WEIGHTED

            UPPER        OBSERVED        PER CENT       CUMULATIVE       CUMULATIVE        MULTIPLE         DEVIATION
            LIMIT        FREQUENCY       OF TOTAL       PERCENTAGE        REMAINDER         OF MEAN         FROM MEAN
                0               14          48.27             48.2             51.7           -.000              -.852
                1               12          41.37             89.6             10.3           1.526               .448
                2                2           6.89             96.5              3.4           3.052              1.749
                3                1           3.44            100.0               .0           4.578              3.049
 REMAINING FREQUENCIES ARE ALL ZERO
```

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SOUTHBOUND INSIDE LANE TRAFFIC QUEUE LENGTH -- LANE L42

 TABLE  30
 ENTRIES IN TABLE          MEAN ARGUMENT          STANDARD DEVIATION          SUM OF ARGUMENTS
         29                      .241                          .435                    7.000        NON-WEIGHTED

            UPPER        OBSERVED        PER CENT       CUMULATIVE       CUMULATIVE        MULTIPLE         DEVIATION
            LIMIT        FREQUENCY       OF TOTAL       PERCENTAGE        REMAINDER         OF MEAN         FROM MEAN
                0               22          75.86             75.8             24.1           -.000              -.554
                1                7          24.13            100.0               .0           4.142              1.742
 REMAINING FREQUENCIES ARE ALL ZERO
```

APPENDIX I

OUTPUT OF THROUGH TRAFFIC TRAVEL TIME

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EASTBOUND THROUGH TRAFFIC TRAVEL TIME (SECOND)

 TABLE  31
 ENTRIES IN TABLE        MEAN ARGUMENT          STANDARD DEVIATION          SUM OF ARGUMENTS
            120                 85.483                      39.562              10258.000         NON-WEIGHTED

                UPPER      OBSERVED       PER CENT     CUMULATIVE     CUMULATIVE     MULTIPLE      DEVIATION
                LIMIT     FREQUENCY       OF TOTAL     PERCENTAGE      REMAINDER      OF MEAN      FROM MEAN
                    0             0            .00             .0          100.0        -.000         -2.160
                    4             0            .00             .0          100.0         .046         -2.059
                    8             0            .00             .0          100.0         .093         -1.958
                   12             0            .00             .0          100.0         .140         -1.857
                   16             4           3.33            3.3           96.6         .187         -1.756
                   20             3           2.49            5.8           94.1         .233         -1.655
                   24             2           1.66            7.4           92.5         .280         -1.554
                   28             0            .00            7.4           92.5         .327         -1.452
                   32             3           2.49            9.9           90.0         .374         -1.351
                   36             2           1.66           11.6           88.3         .421         -1.250
                   40             3           2.49           14.1           85.8         .467         -1.149
                   44             2           1.66           15.8           84.1         .514         -1.048
                   48             5           4.16           19.9           80.0         .561          -.947
                   52             4           3.33           23.3           76.6         .608          -.846
                   56             5           4.16           27.4           72.5         .655          -.745
                   60             4           3.33           30.8           69.1         .701          -.644
                   64             5           4.16           34.9           65.0         .748          -.543
                   68             2           1.66           36.6           63.3         .795          -.441
                   72             4           3.33           39.9           60.0         .842          -.340
                   76             2           1.66           41.6           58.3         .889          -.239
                   80             2           1.66           43.3           56.6         .935          -.138
                   84             6           4.99           48.3           51.6         .982          -.037
                   88             4           3.33           51.6           48.3        1.029           .063
                   92             6           4.99           56.6           43.3        1.076           .164
                   96             5           4.16           60.8           39.1        1.123           .265
                  100             3           2.49           63.3           36.6        1.169           .366
                  104             7           5.83           69.1           30.8        1.216           .468
                  108             3           2.49           71.6           28.3        1.263           .569
                  112             6           4.99           76.6           23.3        1.310           .670
                  116             3           2.49           79.1           20.8        1.356           .771
                  120             2           1.66           80.8           19.1        1.403           .872
                  124             1            .83           81.6           18.3        1.450           .973
                  128             2           1.66           83.3           16.6        1.497          1.074
                  132             2           1.66           84.9           15.0        1.544          1.175
                  136             1            .83           85.8           14.1        1.590          1.276
                  140             2           1.66           87.4           12.5        1.637          1.377
                  144             3           2.49           89.9           10.0        1.684          1.479
                  148             3           2.49           92.4            7.5        1.731          1.580
                  152             1            .83           93.3            6.6        1.778          1.681
                  156             2           1.66           94.9            5.0        1.824          1.782
                  160             4           3.33           98.3            1.6        1.871          1.883
                  164             2           1.66          100.0             .0        1.918          1.984
 REMAINING FREQUENCIES ARE ALL ZERO
```

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WESTBOUND THROUGH TRAFFIC TRAVEL TIME (SECOND)

 TABLE  32
 ENTRIES IN TABLE         MEAN ARGUMENT          STANDARD DEVIATION          SUM OF ARGUMENTS
              103                34.291                      16.937                  3532.000         NON-WEIGHTED

           UPPER       OBSERVED       PER CENT       CUMULATIVE      CUMULATIVE      MULTIPLE        DEVIATION
           LIMIT      FREQUENCY       OF TOTAL       PERCENTAGE       REMAINDER       OF MEAN        FROM MEAN
               0              0            .00               .0           100.0         -.000           -2.024
               4              0            .00               .0           100.0          .116           -1.788
               8              0            .00               .0           100.0          .233           -1.552
              12              0            .00               .0           100.0          .349           -1.316
              16             10           9.70              9.7            90.2          .466           -1.079
              20             19          18.44             28.1            71.8          .583            -.843
              24              9           8.73             36.8            63.1          .699            -.607
              28             12          11.65             48.5            51.4          .816            -.371
              32              8           7.76             56.3            43.6          .933            -.135
              36              4           3.88             60.1            39.8         1.049             .100
              40              5           4.85             65.0            34.9         1.166             .337
              44              7           6.79             71.8            28.1         1.283             .573
              48              8           7.76             79.6            20.3         1.399             .809
              52              5           4.85             84.4            15.5         1.516            1.045
              56              4           3.88             88.3            11.6         1.633            1.281
              60              3           2.91             91.2             8.7         1.749            1.517
              64              3           2.91             94.1             5.8         1.866            1.754
              68              2           1.94             96.1             3.8         1.983            1.990
              72              0            .00             96.1             3.8         2.099            2.226
              76              1            .97             97.0             2.9         2.216            2.462
              80              2           1.94             99.0              .9         2.332            2.698
              84              1            .97            100.0              .0         2.449            2.934
 REMAINING FREQUENCIES ARE ALL ZERO
```

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NORTHBOUND OUTSIDE LANE THROUGH TRAFFIC TRAVEL TIME (SECOND)

 TABLE  33
 ENTRIES IN TABLE          MEAN ARGUMENT            STANDARD DEVIATION           SUM OF ARGUMENTS
               79                 44.341                          28.437                  3503.000       NON-WEIGHTED

             UPPER        OBSERVED        PER CENT       CUMULATIVE      CUMULATIVE       MULTIPLE        DEVIATION
             LIMIT       FREQUENCY        OF TOTAL       PERCENTAGE       REMAINDER        OF MEAN        FROM MEAN
                 0               0             .00               .0           100.0          -.000           -1.559
                 4               0             .00               .0           100.0           .090           -1.418
                 8               0             .00               .0           100.0           .180           -1.277
                12               1            1.26              1.2            98.7           .270           -1.137
                16               4            5.06              6.3            93.6           .360            -.996
                20              15           18.98             25.3            74.6           .451            -.855
                24               9           11.39             36.7            63.2           .541            -.715
                28               8           10.12             46.8            53.1           .631            -.574
                32               2            2.53             49.3            50.6           .721            -.433
                36               4            5.06             54.4            45.5           .811            -.293
                40               1            1.26             55.6            44.3           .902            -.152
                44               3            3.79             59.4            40.5           .992            -.012
                48               3            3.79             63.2            36.7          1.082             .128
                52               4            5.06             68.3            31.6          1.172             .269
                56               0             .00             68.3            31.6          1.262             .409
                60               1            1.26             69.6            30.3          1.353             .550
                64               2            2.53             72.1            27.8          1.443             .691
                68               4            5.06             77.2            22.7          1.533             .831
                72               3            3.79             81.0            18.9          1.623             .972
                76               0             .00             81.0            18.9          1.713            1.113
                80               2            2.53             83.5            16.4          1.804            1.253
                84               1            1.26             84.8            15.1          1.894            1.394
                88               2            2.53             87.3            12.6          1.984            1.535
                92               5            6.32             93.6             6.3          2.074            1.675
                96               0             .00             93.6             6.3          2.165            1.816
               100               2            2.53             96.2             3.7          2.255            1.957
               104               0             .00             96.2             3.7          2.345            2.097
               108               2            2.53             98.7             1.2          2.435            2.238
               112               0             .00             98.7             1.2          2.525            2.379
               116               1            1.26            100.0              .0          2.616            2.519
 REMAINING FREQUENCIES ARE ALL ZERO
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NORTHBOUND INSIDE LANE THROUGH TRAFFIC TRAVEL TIME (SECOND)

 TABLE  34
 ENTRIES IN TABLE          MEAN ARGUMENT          STANDARD DEVIATION          SUM OF ARGUMENTS
        103                      47.563                       26.562                 4899.000         NON-WEIGHTED

           UPPER        OBSERVED        PER CENT      CUMULATIVE      CUMULATIVE       MULTIPLE        DEVIATION
           LIMIT       FREQUENCY        OF TOTAL      PERCENTAGE       REMAINDER        OF MEAN        FROM MEAN
               0               0             .00              .0           100.0          -.000           -1.790
               4               0             .00              .0           100.0           .084           -1.640
               8               0             .00              .0           100.0           .168           -1.489
              12               0             .00              .0           100.0           .252           -1.338
              16               3            2.91             2.9            97.0           .336           -1.188
              20              16           15.53            18.4            81.5           .420           -1.037
              24              14           13.59            32.0            67.9           .504            -.887
              28               7            6.79            38.8            61.1           .588            -.736
              32               5            4.85            43.6            56.3           .672            -.585
              36               4            3.88            47.5            52.4           .756            -.435
              40               3            2.91            50.4            49.5           .840            -.284
              44               3            2.91            53.3            46.6           .925            -.134
              48               2            1.94            55.3            44.6          1.009             .016
              52               2            1.94            57.2            42.7          1.093             .167
              56               2            1.94            59.2            40.7          1.177             .317
              60               3            2.91            62.1            37.8          1.261             .468
              64               5            4.85            66.9            33.0          1.345             .618
              68               6            5.82            72.8            27.1          1.429             .769
              72               5            4.85            77.6            22.3          1.513             .919
              76               3            2.91            80.5            19.4          1.597            1.070
              80               4            3.88            84.4            15.5          1.681            1.221
              84               4            3.88            88.3            11.6          1.766            1.371
              88               3            2.91            91.2             8.7          1.850            1.522
              92               3            2.91            94.1             5.8          1.934            1.672
              96               3            2.91            97.0             2.9          2.018            1.823
             100               3            2.91           100.0              .0          2.102            1.974
 REMAINING FREQUENCIES ARE ALL ZERO
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SOUTHBOUND OUTSIDE LANE THROUGH TRAFFIC TRAVEL TIME (SECOND)

 TABLE  35
 ENTRIES IN TABLE         MEAN ARGUMENT          STANDARD DEVIATION         SUM OF ARGUMENTS
             106                24.349                       8.226                 2581.000          NON-WEIGHTED

            UPPER       OBSERVED        PER CENT       CUMULATIVE       CUMULATIVE       MULTIPLE       DEVIATION
            LIMIT      FREQUENCY        OF TOTAL       PERCENTAGE        REMAINDER        OF MEAN       FROM MEAN
                0              0             .00               .0            100.0          -.000          -2.959
                4              0             .00               .0            100.0           .164          -2.473
                8              0             .00               .0            100.0           .328          -1.987
               12              0             .00               .0            100.0           .492          -1.501
               16             16           15.09             15.0             84.9           .657          -1.014
               20             26           24.52             39.6             60.3           .821           -.528
               24             20           18.86             58.4             41.5           .985           -.042
               28             18           16.98             75.4             24.5          1.149            .443
               32             11           10.37             85.8             14.1          1.314            .930
               36              6            5.66             91.5              8.4          1.478           1.416
               40              2            1.88             93.3              6.6          1.642           1.902
               44              5            4.71             98.1              1.8          1.807           2.388
               48              1             .94             99.0               .9          1.971           2.874
               52              0             .00             99.0               .9          2.135           3.361
               56              1             .94            100.0               .0          2.299           3.847
 REMAINING FREGUENCIES ARE ALL ZERO
```

```
SOUTHBOUND INSIDE LANE THROUGH TRAFFIC TRAVEL TIME (SECOND)

 TABLE  36
 ENTRIES IN TABLE         MEAN ARGUMENT           STANDARD DEVIATION          SUM OF ARGUMENTS
               84                19.869                        3.898                  1669.000        NON-WEIGHTED

           UPPER        OBSERVED        PER CENT        CUMULATIVE        CUMULATIVE        MULTIPLE        DEVIATION
           LIMIT       FREQUENCY        OF TOTAL        PERCENTAGE         REMAINDER         OF MEAN        FROM MEAN
               0               0             .00                .0             100.0          -.000           -5.096
               4               0             .00                .0             100.0           .201           -4.070
               8               0             .00                .0             100.0           .402           -3.044
              12               0             .00                .0             100.0           .603           -2.018
              16              19           22.61              22.6              77.3           .805            -.992
              20              32           38.09              60.7              39.2          1.006             .033
              24              23           27.38              88.0              11.9          1.207            1.059
              28               8            9.52              97.6               2.3          1.409            2.085
              32               1            1.19              98.8               1.1          1.610            3.111
              36               1            1.19             100.0                .0          1.811            4.137
 REMAINING FREQUENCIES ARE ALL ZERO
```

APPENDIX J

OUTPUT OF RIGHT-TURN TRAFFIC TRAVEL TIME

```
EASTBOUND RIGHT-TURN TRAFFIC TRAVEL TIME (SECOND)

 TABLE  37
 ENTRIES IN TABLE         MEAN ARGUMENT          STANDARD DEVIATION         SUM OF ARGUMENTS
             13                 92.230                      37.750                 1199.000        NON-WEIGHTED

          UPPER        OBSERVED        PER CENT      CUMULATIVE      CUMULATIVE       MULTIPLE       DEVIATION
          LIMIT       FREQUENCY        OF TOTAL      PERCENTAGE       REMAINDER        OF MEAN       FROM MEAN
              0               0             .00              .0           100.0          -.000          -2.443
              4               0             .00              .0           100.0           .043          -2.337
              8               0             .00              .0           100.0           .086          -2.231
             12               0             .00              .0           100.0           .130          -2.125
             16               0             .00              .0           100.0           .173          -2.019
             20               1            7.69             7.6            92.3           .216          -1.913
             24               0             .00             7.6            92.3           .260          -1.807
             28               0             .00             7.6            92.3           .303          -1.701
             32               0             .00             7.6            92.3           .346          -1.595
             36               0             .00             7.6            92.3           .390          -1.489
             40               0             .00             7.6            92.3           .433          -1.383
             44               1            7.69            15.3            84.6           .477          -1.277
             48               0             .00            15.3            84.6           .520          -1.171
             52               0             .00            15.3            84.6           .563          -1.065
             56               0             .00            15.3            84.6           .607           -.959
             60               0             .00            15.3            84.6           .650           -.853
             64               0             .00            15.3            84.6           .693           -.747
             68               1            7.69            23.0            76.9           .737           -.641
             72               0             .00            23.0            76.9           .780           -.535
             76               1            7.69            30.7            69.2           .824           -.429
             80               0             .00            30.7            69.2           .867           -.323
             84               1            7.69            38.4            61.5           .910           -.218
             88               0             .00            38.4            61.5           .954           -.112
             92               2           15.38            53.8            46.1           .997           -.006
             96               0             .00            53.8            46.1          1.040            .099
            100               0             .00            53.8            46.1          1.084            .205
            104               1            7.69            61.5            38.4          1.127            .311
            108               1            7.69            69.2            30.7          1.170            .417
            112               0             .00            69.2            30.7          1.214            .523
            116               0             .00            69.2            30.7          1.257            .629
            120               0             .00            69.2            30.7          1.301            .735
            124               2           15.38            84.6            15.3          1.344            .841
            128               1            7.69            92.3             7.6          1.387            .947
            132               0             .00            92.3             7.6          1.431           1.053
            136               0             .00            92.3             7.6          1.474           1.159
            140               0             .00            92.3             7.6          1.517           1.265
            144               0             .00            92.3             7.6          1.561           1.371
            148               0             .00            92.3             7.6          1.604           1.477
            152               0             .00            92.3             7.6          1.648           1.583
            156               0             .00            92.3             7.6          1.691           1.689
            160               1            7.69           100.0              .0          1.734           1.795
 REMAINING FREQUENCIES ARE ALL ZERO
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WESTBOUND RIGHT-TURN TRAFFIC TRAVEL TIME (SECOND)

 TABLE  38
 ENTRIES IN TABLE          MEAN ARGUMENT          STANDARD DEVIATION          SUM OF ARGUMENTS
                5                 25.199                       9.390                   126.000         NON-WEIGHTED

            UPPER        OBSERVED        PER CENT       CUMULATIVE       CUMULATIVE        MULTIPLE        DEVIATION
            LIMIT       FREQUENCY        OF TOTAL       PERCENTAGE        REMAINDER         OF MEAN        FROM MEAN
                0               0             .00               .0            100.0           -.000           -2.683
                4               0             .00               .0            100.0            .158           -2.257
                8               0             .00               .0            100.0            .317           -1.831
               12               0             .00               .0            100.0            .476           -1.405
               16               1           19.99             19.9             80.0            .634            -.979
               20               0             .00             19.9             80.0            .793            -.553
               24               2           39.99             59.9             40.0            .952            -.127
               28               0             .00             59.9             40.0           1.111             .298
               32               1           19.99             79.9             20.0           1.269             .724
               36               0             .00             79.9             20.0           1.428            1.150
               40               1           19.99            100.0               .0           1.587            1.576
 REMAINING FREQUENCIES ARE ALL ZERO
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NORTHBOUND RIGHT-TURN TRAFFIC TRAVEL TIME (SECOND)

 TABLE  39
 ENTRIES IN TABLE          MEAN ARGUMENT          STANDARD DEVIATION          SUM OF ARGUMENTS
               72                45.777                       30.562                  3296.000         NON-WEIGHTED

           UPPER         OBSERVED        PER CENT       CUMULATIVE      CUMULATIVE       MULTIPLE       DEVIATION
           LIMIT        FREQUENCY        OF TOTAL       PERCENTAGE       REMAINDER        OF MEAN       FROM MEAN
               0                0             .00               .0           100.0          -.000          -1.497
               4                0             .00               .0           100.0           .087          -1.366
               8                0             .00               .0           100.0           .174          -1.236
              12                0             .00               .0           100.0           .262          -1.105
              16                9           12.50             12.5            87.5           .349           -.974
              20                8           11.11             23.6            76.3           .436           -.843
              24                7            9.72             33.3            66.6           .524           -.712
              28                8           11.11             44.4            55.5           .611           -.581
              32                5            6.94             51.3            48.6           .699           -.450
              36                2            2.77             54.1            45.8           .786           -.319
              40                3            4.16             58.3            41.6           .873           -.189
              44                3            4.16             62.4            37.5           .961           -.058
              48                3            4.16             66.6            33.3          1.048            .072
              52                0             .00             66.6            33.3          1.135            .203
              56                0             .00             66.6            33.3          1.223            .334
              60                0             .00             66.6            33.3          1.310            .465
              64                3            4.16             70.8            29.1          1.398            .596
              68                3            4.16             74.9            25.0          1.485            .727
              72                3            4.16             79.1            20.8          1.572            .857
              76                2            2.77             81.9            18.0          1.660            .988
              80                0             .00             81.9            18.0          1.747           1.119
              84                0             .00             81.9            18.0          1.834           1.250
              88                1            1.38             83.3            16.6          1.922           1.381
              92                1            1.38             84.7            15.2          2.009           1.512
              96                2            2.77             87.4            12.5          2.097           1.643
             100                4            5.55             93.0             6.9          2.184           1.774
             104                3            4.16             97.2             2.7          2.271           1.905
             108                1            1.38             98.6             1.3          2.359           2.035
             112                1            1.38            100.0              .0          2.446           2.166
 REMAINING FREQUENCIES ARE ALL ZERO
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SOUTHBOUND RIGHT-TURN TRAFFIC TRAVEL TIME (SECOND)

 TABLE  40
 ENTRIES IN TABLE         MEAN ARGUMENT          STANDARD DEVIATION         SUM OF ARGUMENTS
               46                23.326                       8.316                 1073.000        NON-WEIGHTED

           UPPER      OBSERVED      PER CENT      CUMULATIVE     CUMULATIVE      MULTIPLE      DEVIATION
           LIMIT     FREQUENCY      OF TOTAL      PERCENTAGE      REMAINDER       OF MEAN      FROM MEAN
               0             0           .00              .0          100.0         -.000         -2.804
               4             0           .00              .0          100.0          .171         -2.323
               8             0           .00              .0          100.0          .342         -1.842
              12             0           .00              .0          100.0          .514         -1.361
              16            13         28.26            28.2           71.7          .685          -.880
              20             8         17.39            45.6           54.3          .857          -.399
              24             6         13.04            58.6           41.3         1.028           .081
              28             8         17.39            76.0           23.9         1.200           .562
              32             3          6.52            82.6           17.3         1.371          1.042
              36             3          6.52            89.1           10.8         1.543          1.523
              40             4          8.69            97.8            2.1         1.714          2.004
              44             1          2.17           100.0             .0         1.886          2.485
 REMAINING FREQUENCIES ARE ALL ZERO
```

APPENDIX K

OUTPUT OF LEFT-TURN TRAFFIC TRAVEL TIME

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EASTBOUND LEFT-TURN TRAFFIC TRAVEL TIME (SECOND)

 TABLE  41
 ENTRIES IN TABLE          MEAN ARGUMENT          STANDARD DEVIATION         SUM OF ARGUMENTS
               59                 95.169                      40.000                 5615.000        NON-WEIGHTED

             UPPER        OBSERVED       PER CENT     CUMULATIVE     CUMULATIVE      MULTIPLE     DEVIATION
             LIMIT       FREQUENCY       OF TOTAL     PERCENTAGE      REMAINDER       OF MEAN     FROM MEAN
                 0               0            .00             .0          100.0         -.000        -2.379
                 4               0            .00             .0          100.0          .042        -2.279
                 8               0            .00             .0          100.0          .084        -2.179
                12               0            .00             .0          100.0          .126        -2.079
                16               1           1.69            1.6           98.3          .168        -1.979
                20               0            .00            1.6           98.3          .210        -1.879
                24               0            .00            1.6           98.3          .252        -1.779
                28               0            .00            1.6           98.3          .294        -1.679
                32               0            .00            1.6           98.3          .336        -1.579
                36               0            .00            1.6           98.3          .378        -1.479
                40               2           3.38            5.0           94.9          .420        -1.379
                44               1           1.69            6.7           93.2          .462        -1.279
                48               1           1.69            8.4           91.5          .504        -1.179
                52               5           8.47           16.9           83.0          .546        -1.079
                56               2           3.38           20.3           79.6          .588         -.979
                60               2           3.38           23.7           76.2          .630         -.879
                64               5           8.47           32.2           67.7          .672         -.779
                68               1           1.69           33.8           66.1          .714         -.679
                72               2           3.38           37.2           62.7          .756         -.579
                76               2           3.38           40.6           59.3          .798         -.479
                80               0            .00           40.6           59.3          .840         -.379
                84               2           3.38           44.0           55.9          .882         -.279
                88               3           5.08           49.1           50.8          .924         -.179
                92               1           1.69           50.8           49.1          .966         -.079
                96               2           3.38           54.2           45.7         1.008          .020
               100               3           5.08           59.3           40.6         1.050          .120
               104               1           1.69           61.0           38.9         1.092          .220
               108               2           3.38           64.4           35.5         1.134          .320
               112               1           1.69           66.1           33.8         1.176          .420
               116               2           3.38           69.4           30.5         1.218          .520
               120               0            .00           69.4           30.5         1.260          .620
               124               3           5.08           74.5           25.4         1.302          .720
               128               0            .00           74.5           25.4         1.344          .820
               132               0            .00           74.5           25.4         1.386          .920
               136               0            .00           74.5           25.4         1.429         1.020
               140               5           8.47           83.0           16.9         1.471         1.120
               144               2           3.38           86.4           13.5         1.513         1.220
               148               1           1.69           88.1           11.8         1.555         1.320
               152               1           1.69           89.8           10.1         1.597         1.420
               156               2           3.38           93.2            6.7         1.639         1.520
               160               1           1.69           94.9            5.0         1.681         1.620
               164               2           3.38           98.3            1.6         1.723         1.720
               168               0            .00           98.3            1.6         1.765         1.820
               172               0            .00           98.3            1.6         1.807         1.920
               176               0            .00           98.3            1.6         1.849         2.020
               180               1           1.69          100.0             .0         1.891         2.120
 REMAINING FREQUENCIES ARE ALL ZERO
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WESTBOUND LEFT-TURN TRAFFIC TRAVEL TIME (SECOND)

 TABLE  42
 ENTRIES IN TABLE          MEAN ARGUMENT            STANDARD DEVIATION         SUM OF ARGUMENTS
               72                 33.333                        16.750                 2400.000        NON-WEIGHTED

          UPPER        OBSERVED         PER CENT        CUMULATIVE       CUMULATIVE        MULTIPLE        DEVIATION
          LIMIT       FREQUENCY         OF TOTAL        PERCENTAGE        REMAINDER         OF MEAN        FROM MEAN
              0               0              .00                .0            100.0           -.000           -1.990
              4               0              .00                .0            100.0            .120           -1.751
              8               0              .00                .0            100.0            .240           -1.512
             12               2             2.77               2.7             97.2            .360           -1.273
             16               4             5.55               8.3             91.6            .480           -1.034
             20              12            16.66              24.9             75.0            .600            -.796
             24              12            16.66              41.6             58.3            .720            -.557
             28               9            12.50              54.1             45.8            .840            -.318
             32               6             8.33              62.4             37.5            .960            -.079
             36               0              .00              62.4             37.5           1.079             .159
             40               4             5.55              68.0             31.9           1.199             .398
             44               5             6.94              74.9             25.0           1.319             .636
             48               2             2.77              77.7             22.2           1.439             .875
             52               7             9.72              87.4             12.5           1.559            1.114
             56               3             4.16              91.6              8.3           1.679            1.353
             60               1             1.38              93.0              6.9           1.800            1.592
             64               0              .00              93.0              6.9           1.920            1.830
             68               1             1.38              94.4              5.5           2.039            2.069
             72               0              .00              94.4              5.5           2.159            2.308
             76               2             2.77              97.2              2.7           2.279            2.547
             80               2             2.77             100.0               .0           2.399            2.786
 REMAINING FREQUENCIES ARE ALL ZERO
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NORTHBOUND LEFT-TURN TRAFFIC TRAVEL TIME (SECOND)

 TABLE  43
 ENTRIES IN TABLE          MEAN ARGUMENT          STANDARD DEVIATION          SUM OF ARGUMENTS
               44                 56.022                      30.125                  2465.000         NON-WEIGHTED

           UPPER       OBSERVED       PER CENT      CUMULATIVE      CUMULATIVE      MULTIPLE       DEVIATION
           LIMIT      FREQUENCY       OF TOTAL      PERCENTAGE       REMAINDER       OF MEAN       FROM MEAN
               0              0            .00              .0           100.0         -.000          -1.859
               4              0            .00              .0           100.0          .071          -1.726
               8              0            .00              .0           100.0          .142          -1.594
              12              0            .00              .0           100.0          .214          -1.461
              16              1           2.27             2.2            97.7          .285          -1.328
              20              6          13.63            15.9            84.0          .356          -1.195
              24              2           4.54            20.4            79.5          .428          -1.062
              28              5          11.36            31.8            68.1          .499           -.930
              32              2           4.54            36.3            63.6          .571           -.797
              36              2           4.54            40.9            59.0          .642           -.664
              40              0            .00            40.9            59.0          .713           -.531
              44              3           6.81            47.7            52.2          .785           -.399
              48              1           2.27            49.9            50.0          .856           -.266
              52              0            .00            49.9            50.0          .928           -.133
              56              0            .00            49.9            50.0          .999           -.000
              60              0            .00            49.9            50.0         1.070            .132
              64              0            .00            49.9            50.0         1.142            .264
              68              2           4.54            54.5            45.4         1.213            .397
              72              2           4.54            59.0            40.9         1.285            .530
              76              1           2.27            61.3            38.6         1.356            .663
              80              2           4.54            65.9            34.0         1.427            .795
              84              2           4.54            70.4            29.5         1.499            .928
              88              5          11.36            81.8            18.1         1.570           1.061
              92              3           6.81            88.6            11.3         1.642           1.194
              96              4           9.09            97.7             2.2         1.713           1.327
             100              1           2.27           100.0              .0         1.784           1.459
 REMAINING FREQUENCIES ARE ALL ZERO
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SOUTHBOUND LEFT-TURN TRAFFIC TRAVEL TIME (SECOND)

 TABLE  44
 ENTRIES IN TABLE        MEAN ARGUMENT          STANDARD DEVIATION          SUM OF ARGUMENTS
               14               20.071                       3.769                   281.000         NON-WEIGHTED

            UPPER      OBSERVED       PER CENT      CUMULATIVE      CUMULATIVE      MULTIPLE       DEVIATION
            LIMIT     FREQUENCY       OF TOTAL      PERCENTAGE       REMAINDER       OF MEAN       FROM MEAN
                0             0            .00              .0           100.0         -.000          -5.324
                4             0            .00              .0           100.0          .199          -4.263
                8             0            .00              .0           100.0          .398          -3.202
               12             0            .00              .0           100.0          .597          -2.141
               16             2          14.28            14.2            85.7          .797          -1.080
               20             7          50.00            64.2            35.7          .996           -.018
               24             3          21.42            85.7            14.2         1.195           1.042
               28             2          14.28           100.0              .0         1.395           2.103
 REMAINING FREQUENCIES ARE ALL ZERO
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APPENDIX L

OUTPUT OF EASTBOUND TRAFFIC DELAY

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EASTBOUND THROUGH TRAFFIC DELAY (SECOND)

 TABLE   51
 ENTRIES IN TABLE          MEAN ARGUMENT            STANDARD DEVIATION          SUM OF ARGUMENTS
              120                 66.666                        39.562                  8000.000            NON-WEIGHTED

            UPPER         OBSERVED         PER CENT        CUMULATIVE       CUMULATIVE        MULTIPLE         DEVIATION
            LIMIT        FREQUENCY         OF TOTAL        PERCENTAGE        REMAINDER         OF MEAN         FROM MEAN
                0                6             4.99               4.9             95.0           -.000            -1.685
                4                2             1.66               6.6             93.3            .060            -1.583
                8                2             1.66               8.3             91.6            .120            -1.482
               12                1              .83               9.1             90.8            .180            -1.381
               16                3             2.49              11.6             88.3            .240            -1.280
               20                0              .00              11.6             88.3            .300            -1.179
               24                5             4.16              15.8             84.1            .360            -1.078
               28                5             4.16              19.9             80.0            .420             -.977
               32                2             1.66              21.6             78.3            .480             -.876
               36                7             5.83              27.4             72.5            .540             -.775
               40                3             2.49              29.9             70.0            .600             -.674
               44                2             1.66              31.6             68.3            .660             -.572
               48                3             2.49              34.1             65.8            .720             -.471
               52                4             3.33              37.4             62.5            .780             -.370
               56                4             3.33              40.8             59.1            .840             -.269
               60                4             3.33              44.1             55.8            .900             -.168
               64                3             2.49              46.6             53.3            .960             -.067
               68                5             4.16              50.8             49.1           1.019              .033
               72                6             4.99              55.8             44.1           1.079              .134
               76                4             3.33              59.1             40.8           1.139              .235
               80                5             4.16              63.3             36.6           1.199              .337
               84                3             2.49              65.8             34.1           1.259              .438
               88                7             5.83              71.6             28.3           1.319              .539
               92                1              .83              72.4             27.5           1.380              .640
               96                9             7.49              79.9             20.0           1.439              .741
              100                1              .83              80.8             19.1           1.500              .842
              104                2             1.66              82.4             17.5           1.559              .943
              108                1              .83              83.3             16.6           1.619             1.044
              112                1              .83              84.1             15.8           1.679             1.145
              116                2             1.66              85.8             14.1           1.739             1.246
              120                2             1.66              87.4             12.5           1.800             1.348
              124                2             1.66              89.1             10.8           1.859             1.449
              128                2             1.66              90.8              9.1           1.920             1.550
              132                1              .83              91.6              8.3           1.979             1.651
              136                5             4.16              95.8              4.1           2.039             1.752
              140                1              .83              96.6              3.3           2.099             1.853
              144                4             3.33             100.0               .0           2.159             1.954
 REMAINING FREQUENCIES ARE ALL ZERO
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EASTBOUND RIGHT-TURN TRAFFIC DELAY (SECOND)

TABLE  57
ENTRIES IN TABLE         MEAN ARGUMENT          STANDARD DEVIATION          SUM OF ARGUMENTS
             13                 74.923                      38.125                  974.000         NON-WEIGHTED

       UPPER        OBSERVED       PER CENT       CUMULATIVE      CUMULATIVE       MULTIPLE        DEVIATION
       LIMIT       FREQUENCY       OF TOTAL       PERCENTAGE       REMAINDER        OF MEAN        FROM MEAN
           0               0           .00               .0           100.0          -.000           -1.965
           4               1          7.69              7.6            92.3           .053           -1.860
           8               0           .00              7.6            92.3           .106           -1.755
          12               0           .00              7.6            92.3           .160           -1.650
          16               0           .00              7.6            92.3           .213           -1.545
          20               0           .00              7.6            92.3           .266           -1.440
          24               1          7.69             15.3            84.6           .320           -1.335
          28               0           .00             15.3            84.6           .373           -1.230
          32               0           .00             15.3            84.6           .427           -1.125
          36               0           .00             15.3            84.6           .480           -1.020
          40               0           .00             15.3            84.6           .533            -.916
          44               1          7.69             23.0            76.9           .587            -.811
          48               0           .00             23.0            76.9           .640            -.706
          52               0           .00             23.0            76.9           .694            -.601
          56               1          7.69             30.7            69.2           .747            -.496
          60               0           .00             30.7            69.2           .800            -.391
          64               0           .00             30.7            69.2           .854            -.286
          68               1          7.69             38.4            61.5           .907            -.181
          72               1          7.69             46.1            53.8           .960            -.076
          76               1          7.69             53.8            46.1          1.014             .028
          80               0           .00             53.8            46.1          1.067             .133
          84               0           .00             53.8            46.1          1.121             .238
          88               1          7.69             61.5            38.4          1.174             .343
          92               1          7.69             69.2            30.7          1.227             .447
          96               0           .00             69.2            30.7          1.281             .552
         100               0           .00             69.2            30.7          1.334             .657
         104               2         15.38             84.6            15.3          1.388             .762
         108               0           .00             84.6            15.3          1.441             .867
         112               0           .00             84.6            15.3          1.494             .972
         116               1          7.69             92.3             7.6          1.548            1.077
         120               0           .00             92.3             7.6          1.601            1.182
         124               0           .00             92.3             7.6          1.655            1.287
         128               0           .00             92.3             7.6          1.708            1.392
         132               0           .00             92.3             7.6          1.761            1.497
         136               0           .00             92.3             7.6          1.815            1.602
         140               1          7.69            100.0              .0          1.868            1.706
REMAINING FREQUENCIES ARE ALL ZERO
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EASTBOUND LEFT-TURN TRAFFIC DELAY (SECOND)

 TABLE  61
 ENTRIES IN TABLE         MEAN ARGUMENT          STANDARD DEVIATION         SUM OF ARGUMENTS
                59               76.796                       39.625                 4531.000         NON-WEIGHTED

          UPPER       OBSERVED       PER CENT      CUMULATIVE     CUMULATIVE     MULTIPLE      DEVIATION
          LIMIT      FREQUENCY       OF TOTAL      PERCENTAGE      REMAINDER      OF MEAN      FROM MEAN
              0              1           1.69             1.6           98.3        -.000         -1.938
              4              0            .00             1.6           98.3         .052         -1.837
              8              0            .00             1.6           98.3         .104         -1.736
             12              0            .00             1.6           98.3         .156         -1.635
             16              0            .00             1.6           98.3         .208         -1.534
             20              1           1.69             3.3           96.6         .260         -1.433
             24              1           1.69             5.0           94.9         .312         -1.332
             28              0            .00             5.0           94.9         .364         -1.231
             32              3           5.08            10.1           89.8         .416         -1.130
             36              3           5.08            15.2           84.7         .468         -1.029
             40              5           8.47            23.7           76.2         .520          -.928
             44              2           3.38            27.1           72.8         .572          -.827
             48              3           5.08            32.2           67.7         .625          -.726
             52              1           1.69            33.8           66.1         .677          -.625
             56              2           3.38            37.2           62.7         .729          -.524
             60              0            .00            37.2           62.7         .781          -.423
             64              2           3.38            40.6           59.3         .833          -.322
             68              4           6.77            47.4           52.5         .885          -.221
             72              2           3.38            50.8           49.1         .937          -.121
             76              2           3.38            54.2           45.7         .989          -.020
             80              2           3.38            57.6           42.3        1.041           .080
             84              3           5.08            62.7           37.2        1.093           .181
             88              0            .00            62.7           37.2        1.145           .282
             92              2           3.38            66.1           33.8        1.197           .383
             96              1           1.69            67.7           32.2        1.250           .484
            100              2           3.38            71.1           28.8        1.302           .585
            104              2           3.38            74.5           25.4        1.354           .686
            108              0            .00            74.5           25.4        1.406           .787
            112              0            .00            74.5           25.4        1.458           .888
            116              0            .00            74.5           25.4        1.510           .989
            120              3           5.08            79.6           20.3        1.562          1.090
            124              2           3.38            83.0           16.9        1.614          1.191
            128              4           6.77            89.8           10.1        1.666          1.292
            132              0            .00            89.8           10.1        1.718          1.393
            136              1           1.69            91.5            8.4        1.770          1.494
            140              2           3.38            94.9            5.0        1.822          1.595
            144              0            .00            94.9            5.0        1.875          1.695
            148              1           1.69            96.6            3.3        1.927          1.796
            152              1           1.69            98.3            1.6        1.979          1.897
            156              0            .00            98.3            1.6        2.031          1.998
            160              1           1.69           100.0             .0        2.083          2.099
 REMAINING FREQUENCIES ARE ALL ZERO
```

APPENDIX M

OUTPUT OF WESTBOUND TRAFFIC DELAY

```
WESTBOUND THROUGH TRAFFIC DELAY (SECOND)

 TABLE  52
 ENTRIES IN TABLE        MEAN ARGUMENT         STANDARD DEVIATION         SUM OF ARGUMENTS
        103                   22.485                      17.312               2316.000        NON-WEIGHTED

        UPPER        OBSERVED       PER CENT       CUMULATIVE      CUMULATIVE       MULTIPLE       DEVIATION
        LIMIT       FREQUENCY       OF TOTAL       PERCENTAGE       REMAINDER        OF MEAN       FROM MEAN
            0               1            .97               .9            99.0          -.000          -1.298
            4              10           9.70             10.6            89.3           .177          -1.067
            8              15          14.56             25.2            74.7           .355           -.836
           12              12          11.65             36.8            63.1           .533           -.605
           16              12          11.65             48.5            51.4           .711           -.374
           20              10           9.70             58.2            41.7           .889           -.143
           24               2           1.94             60.1            39.8          1.067            .087
           28               4           3.88             64.0            35.9          1.245            .318
           32               8           7.76             71.8            28.1          1.423            .549
           36               7           6.79             78.6            21.3          1.601            .780
           40               5           4.85             83.4            16.5          1.778           1.011
           44               5           4.85             88.3            11.6          1.956           1.242
           48               0            .00             88.3            11.6          2.134           1.473
           52               6           5.82             94.1             5.8          2.312           1.704
           56               2           1.94             96.1             3.8          2.490           1.935
           60               0            .00             96.1             3.8          2.668           2.166
           64               1            .97             97.0             2.9          2.846           2.397
           68               2           1.94             99.0              .9          3.024           2.628
           72               1            .97            100.0              .0          3.202           2.860
 REMAINING FREQUENCIES ARE ALL ZERO
```

```
WESTBOUND RIGHT-TURN TRAFFIC DELAY (SECOND)

 TABLE  58
 ENTRIES IN TABLE          MEAN ARGUMENT          STANDARD DEVIATION          SUM OF ARGUMENTS
                5                 14.399                        8.441                    72.000       NON-WEIGHTED

            UPPER        OBSERVED        PER CENT      CUMULATIVE      CUMULATIVE        MULTIPLE        DEVIATION
            LIMIT       FREQUENCY        OF TOTAL      PERCENTAGE       REMAINDER         OF MEAN        FROM MEAN
                0               0             .00              .0           100.0           -.000           -1.705
                4               1           19.99            19.9            80.0            .277           -1.232
                8               0             .00            19.9            80.0            .555            -.758
               12               1           19.99            39.9            60.0            .833            -.284
               16               1           19.99            59.9            40.0           1.111             .189
               20               1           19.99            79.9            20.0           1.388             .663
               24               0             .00            79.9            20.0           1.666            1.137
               28               1           19.99           100.0              .0           1.944            1.611
 REMAINING FREQUENCIES ARE ALL ZERO
```

```
WESTBOUND LEFT-TURN TRAFFIC DELAY (SECOND)

 TABLE   62
 ENTRIES IN TABLE          MEAN ARGUMENT            STANDARD DEVIATION          SUM OF ARGUMENTS
               72                 21.638                         17.000               1558.000          NON-WEIGHTED

           UPPER        OBSERVED        PER CENT        CUMULATIVE        CUMULATIVE         MULTIPLE         DEVIATION
           LIMIT       FREQUENCY        OF TOTAL        PERCENTAGE         REMAINDER          OF MEAN         FROM MEAN
               0               0             .00                .0             100.0            -.000            -1.272
               4               7            9.72               9.7              90.2             .184            -1.037
               8              10           13.88              23.6              76.3             .369             -.802
              12              11           15.27              38.8              61.1             .554             -.566
              16              12           16.66              55.5              44.4             .739             -.331
              20               5            6.94              62.4              37.5             .924             -.096
              24               0             .00              62.4              37.5            1.109              .138
              28               3            4.16              66.6              33.3            1.293              .374
              32               5            6.94              73.6              26.3            1.478              .609
              36               3            4.16              77.7              22.2            1.663              .844
              40               7            9.72              87.4              12.5            1.848             1.080
              44               3            4.16              91.6               8.3            2.033             1.315
              48               1            1.38              93.0               6.9            2.218             1.550
              52               0             .00              93.0               6.9            2.403             1.785
              56               1            1.38              94.4               5.5            2.587             2.021
              60               1            1.38              95.8               4.1            2.772             2.256
              64               1            1.38              97.2               2.7            2.957             2.491
              68               0             .00              97.2               2.7            3.142             2.727
              72               2            2.77             100.0                .0            3.327             2.962
 REMAINING FREQUENCIES ARE ALL ZERO
```

APPENDIX N

OUTPUT OF NORTHBOUND TRAFFIC DELAY

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NORTHBOUND OUTSIDE LANE THROUGH TRAFFIC DELAY (SECOND)

 TABLE  53
 ENTRIES IN TABLE          MEAN ARGUMENT           STANDARD DEVIATION          SUM OF ARGUMENTS
        79                      30.898                        28.375                   2441.000        NON-WEIGHTED

           UPPER        OBSERVED        PER CENT       CUMULATIVE      CUMULATIVE       MULTIPLE        DEVIATION
           LIMIT       FREQUENCY        OF TOTAL       PERCENTAGE       REMAINDER        OF MEAN        FROM MEAN
               0               1            1.26              1.2            98.7          -.000           -1.088
               4               9           11.39             12.6            87.3           .129            -.947
               8              15           18.98             31.6            68.3           .258            -.807
              12               6            7.59             39.2            60.7           .388            -.666
              16               8           10.12             49.3            50.6           .517            -.525
              20               1            1.26             50.6            49.3           .647            -.384
              24               3            3.79             54.4            45.5           .776            -.243
              28               1            1.26             55.6            44.3           .906            -.102
              32               4            5.06             60.7            39.2          1.035             .038
              36               4            5.06             65.8            34.1          1.165             .179
              40               2            2.53             68.3            31.6          1.294             .320
              44               1            1.26             69.6            30.3          1.424             .461
              48               2            2.53             72.1            27.8          1.553             .602
              52               0             .00             72.1            27.8          1.682             .743
              56               4            5.06             77.2            22.7          1.812             .884
              60               3            3.79             81.0            18.9          1.941            1.025
              64               2            2.53             83.5            16.4          2.071            1.166
              68               1            1.26             84.8            15.1          2.200            1.307
              72               1            1.26             86.0            13.9          2.330            1.448
              76               5            6.32             92.4             7.5          2.459            1.589
              80               1            1.26             93.6             6.3          2.589            1.730
              84               2            2.53             96.2             3.7          2.718            1.871
              88               0             .00             96.2             3.7          2.848            2.012
              92               1            1.26             97.4             2.5          2.977            2.153
              96               1            1.26             98.7             1.2          3.106            2.294
             100               0             .00             98.7             1.2          3.236            2.435
             104               1            1.26            100.0              .0          3.365            2.576
 REMAINING FREQUENCIES ARE ALL ZERO
```

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NORTHBOUND INSIDE LANE THROUGH TRAFFIC DELAY (SECOND)

 TABLE  54
 ENTRIES IN TABLE          MEAN ARGUMENT          STANDARD DEVIATION          SUM OF ARGUMENTS
          103                   33.805                      26.687                  3482.000         NON-WEIGHTED

            UPPER        OBSERVED        PER CENT       CUMULATIVE       CUMULATIVE         MULTIPLE        DEVIATION
            LIMIT       FREQUENCY        OF TOTAL       PERCENTAGE        REMAINDER          OF MEAN        FROM MEAN
                0               3            2.91              2.9             97.0            -.000           -1.266
                4               6            5.82              8.7             91.2             .118           -1.116
                8              15           14.56             23.3             76.6             .236            -.966
               12              12           11.65             34.9             65.0             .354            -.817
               16               6            5.82             40.7             59.2             .473            -.667
               20               4            3.88             44.6             55.3             .591            -.517
               24               4            3.88             48.5             51.4             .709            -.367
               28               3            2.91             51.4             48.5             .828            -.217
               32               3            2.91             54.3             45.6             .946            -.067
               36               2            1.94             56.3             43.6            1.064             .082
               40               2            1.94             58.2             41.7            1.183             .232
               44               3            2.91             61.1             38.8            1.301             .381
               48               4            3.88             65.0             34.9            1.419             .531
               52               4            3.88             68.9             31.0            1.538             .681
               56               5            4.85             73.7             26.2            1.656             .831
               60               6            5.82             79.6             20.3            1.774             .981
               64               4            3.88             83.4             16.5            1.893            1.131
               68               2            1.94             85.4             14.5            2.011            1.281
               72               5            4.85             90.2              9.7            2.129            1.431
               76               3            2.91             93.2              6.7            2.248            1.581
               80               2            1.94             95.1              4.8            2.366            1.730
               84               4            3.88             99.0               .9            2.484            1.880
               88               1             .97            100.0               .0            2.603            2.030
 REMAINING FREQUENCIES ARE ALL ZERO
```

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NORTHBOUND RIGHT-TURN TRAFFIC DELAY (SECOND)

 TABLE  59
 ENTRIES IN TABLE         MEAN ARGUMENT          STANDARD DEVIATION          SUM OF ARGUMENTS
           72                 32.986                         30.625                2375.000          NON-WEIGHTED

          UPPER        OBSERVED         PER CENT        CUMULATIVE       CUMULATIVE        MULTIPLE         DEVIATION
          LIMIT       FREQUENCY         OF TOTAL        PERCENTAGE        REMAINDER         OF MEAN         FROM MEAN
              0               2             2.77               2.7             97.2           -.000            -1.077
              4               6             8.33              11.1             88.8            .121             -.946
              8               8            11.11              22.2             77.7            .242             -.815
             12              11            15.27              37.4             62.5            .363             -.685
             16               5             6.94              44.4             55.5            .485             -.554
             20               5             6.94              51.3             48.6            .606             -.424
             24               3             4.16              55.5             44.4            .727             -.293
             28               4             5.55              61.1             38.8            .848             -.162
             32               1             1.38              62.4             37.5            .970             -.032
             36               3             4.16              66.6             33.3           1.091              .098
             40               0              .00              66.6             33.3           1.212              .229
             44               0              .00              66.6             33.3           1.333              .359
             48               0              .00              66.6             33.3           1.455              .490
             52               4             5.55              72.2             27.7           1.576              .620
             56               2             2.77              74.9             25.0           1.697              .751
             60               3             4.16              79.1             20.8           1.818              .882
             64               1             1.38              80.5             19.4           1.940             1.012
             68               1             1.38              81.9             18.0           2.061             1.143
             72               0              .00              81.9             18.0           2.182             1.273
             76               1             1.38              83.3             16.6           2.303             1.404
             80               2             2.77              86.1             13.8           2.425             1.535
             84               2             2.77              88.8             11.1           2.546             1.665
             88               2             2.77              91.6              8.3           2.667             1.796
             92               3             4.16              95.8              4.1           2.789             1.926
             96               3             4.16             100.0               .0           2.910             2.057
 REMAINING FREQUENCIES ARE ALL ZERO
```

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NORTHBOUND LEFT-TURN TRAFFIC DELAY (SECOND)

 TABLE  63
 ENTRIES IN TABLE        MEAN ARGUMENT          STANDARD DEVIATION          SUM OF ARGUMENTS
              44                42.204                      30.000                  1857.000          NON-WEIGHTED

           UPPER        OBSERVED       PER CENT      CUMULATIVE      CUMULATIVE      MULTIPLE       DEVIATION
           LIMIT       FREQUENCY       OF TOTAL      PERCENTAGE       REMAINDER       OF MEAN       FROM MEAN
               0               1           2.27             2.2            97.7         -.000          -1.406
               4               2           4.54             6.8            93.1          .094          -1.273
               8               4           9.09            15.9            84.0          .189          -1.140
              12               5          11.36            27.2            72.7          .284          -1.006
              16               4           9.09            36.3            63.6          .379           -.873
              20               1           2.27            38.6            61.3          .473           -.740
              24               1           2.27            40.9            59.0          .568           -.606
              28               0            .00            40.9            59.0          .663           -.473
              32               3           6.81            47.7            52.2          .758           -.340
              36               1           2.27            49.9            50.0          .852           -.206
              40               0            .00            49.9            50.0          .947           -.073
              44               0            .00            49.9            50.0         1.042            .059
              48               0            .00            49.9            50.0         1.137            .193
              52               0            .00            49.9            50.0         1.232            .326
              56               2           4.54            54.5            45.4         1.326            .459
              60               3           6.81            61.3            38.6         1.421            .593
              64               1           2.27            63.6            36.3         1.516            .726
              68               1           2.27            65.9            34.0         1.611            .859
              72               5          11.36            77.2            22.7         1.705            .993
              76               4           9.09            86.3            13.6         1.800           1.126
              80               3           6.81            93.1             6.8         1.895           1.259
              84               3           6.81           100.0              .0         1.990           1.393
 REMAINING FREQUENCIES ARE ALL ZERO
```

APPENDIX O

OUTPUT OF SOUTHBOUND TRAFFIC DELAY

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SOUTHBOUND OUTSIDE LANE THROUGH TRAFFIC DELAY (SECOND)

 TABLE  55
 ENTRIES IN TABLE          MEAN ARGUMENT          STANDARD DEVIATION          SUM OF ARGUMENTS
         106                    13.518                         8.304                1433.000        NON-WEIGHTED

          UPPER      OBSERVED      PER CENT      CUMULATIVE      CUMULATIVE      MULTIPLE      DEVIATION
          LIMIT      FREQUENCY     OF TOTAL      PERCENTAGE      REMAINDER        OF MEAN      FROM MEAN
              0              0          .00              .0          100.0          -.000         -1.627
              4             11        10.37            10.3           89.6           .295         -1.146
              8             22        20.75            31.1           68.8           .591          -.664
             12             23        21.69            52.8           47.1           .887          -.182
             16             17        16.03            68.8           31.1          1.183           .298
             20             13        12.26            81.1           18.8          1.479           .780
             24              8         7.54            88.6           11.3          1.775          1.262
             28              5         4.71            93.3            6.6          2.071          1.743
             32              3         2.83            96.2            3.7          2.367          2.225
             36              2         1.88            98.1            1.8          2.662          2.707
             40              1          .94            99.0             .9          2.958          3.188
             44              1          .94           100.0             .0          3.254          3.670
 REMAINING FREQUENCIES ARE ALL ZERO



SOUTHBOUND INSIDE LANE THROUGH TRAFFIC DELAY (SECOND)

 TABLE  56
 ENTRIES IN TABLE          MEAN ARGUMENT          STANDARD DEVIATION          SUM OF ARGUMENTS
          84                     9.821                         3.941                 825.000        NON-WEIGHTED

          UPPER      OBSERVED      PER CENT      CUMULATIVE      CUMULATIVE      MULTIPLE      DEVIATION
          LIMIT      FREQUENCY     OF TOTAL      PERCENTAGE      REMAINDER        OF MEAN      FROM MEAN
              0              0          .00              .0          100.0          -.000         -2.491
              4              4         4.76             4.7           95.2           .407         -1.476
              8             32        38.09            42.8           57.1           .814          -.462
             12             25        29.76            72.6           27.3          1.221           .552
             16             20        23.80            96.4            3.5          1.629          1.567
             20              2         2.38            98.8            1.1          2.036          2.582
             24              1         1.19           100.0             .0          2.443          3.597
 REMAINING FREQUENCIES ARE ALL ZERO
```

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SOUTHBOUND RIGHT-TURN TRAFFIC DELAY (SECOND)

 TABLE  60
 ENTRIES IN TABLE         MEAN ARGUMENT          STANDARD DEVIATION          SUM OF ARGUMENTS
               46                12.826                       8.609                   590.000           NON-WEIGHTED

            UPPER      OBSERVED        PER CENT        CUMULATIVE      CUMULATIVE       MULTIPLE        DEVIATION
            LIMIT     FREQUENCY        OF TOTAL        PERCENTAGE       REMAINDER        OF MEAN        FROM MEAN
                0             0             .00                .0           100.0          -.000           -1.489
                4             9           19.56              19.5            80.4           .311           -1.025
                8            11           23.91              43.4            56.5           .623            -.560
               12             5           10.86              54.3            45.6           .935            -.095
               16             7           15.21              69.5            30.4          1.247             .368
               20             6           13.04              82.6            17.3          1.559             .833
               24             1            2.17              84.7            15.2          1.871            1.297
               28             3            6.52              91.3             8.6          2.183            1.762
               32             3            6.52              97.8             2.1          2.494            2.227
               36             1            2.17             100.0              .0          2.806            2.691
 REMAINING FREQUENCIES ARE ALL ZERO
```

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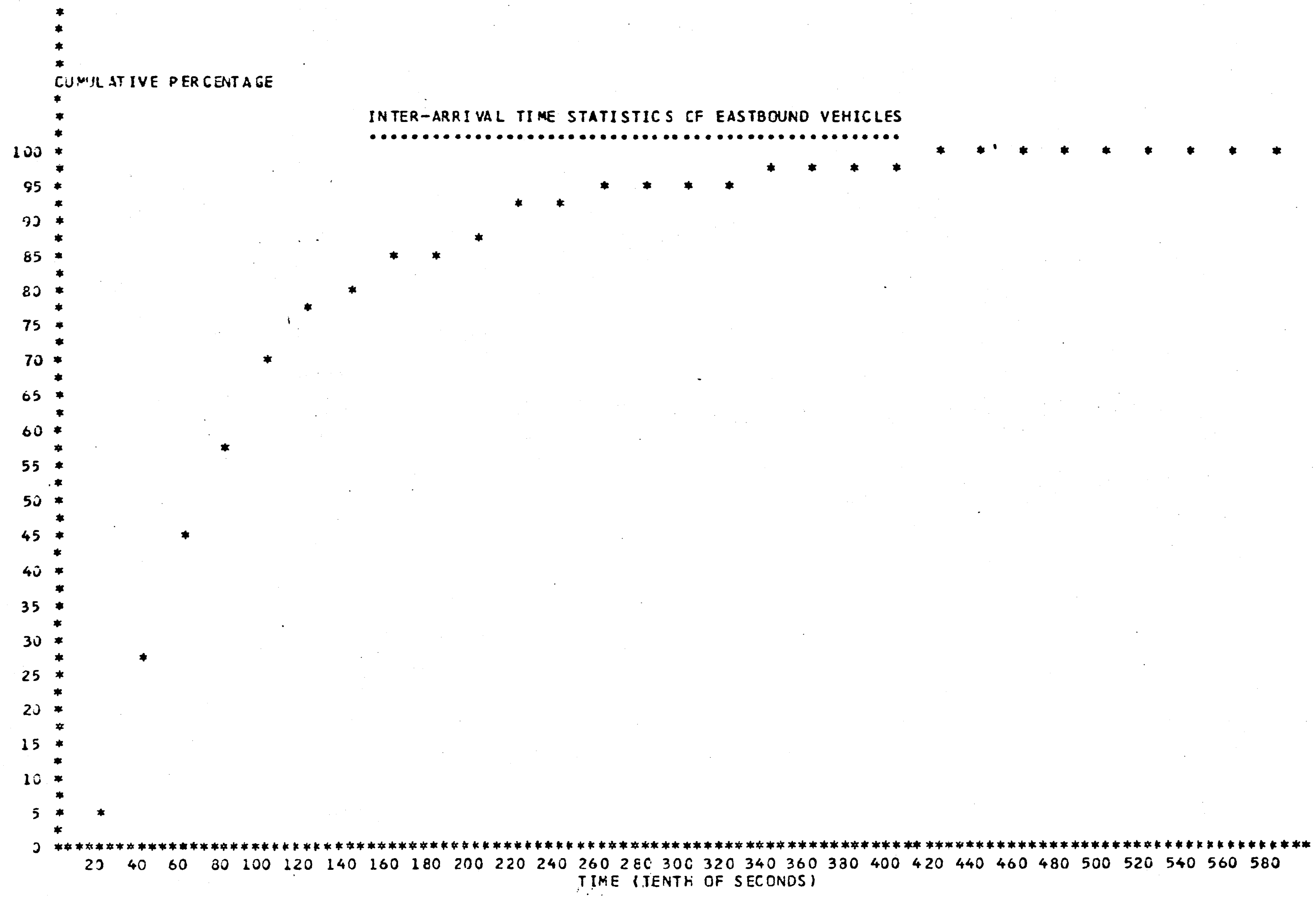
SOUTHBOUND LEFT-TURN TRAFFIC DELAY (SECOND)

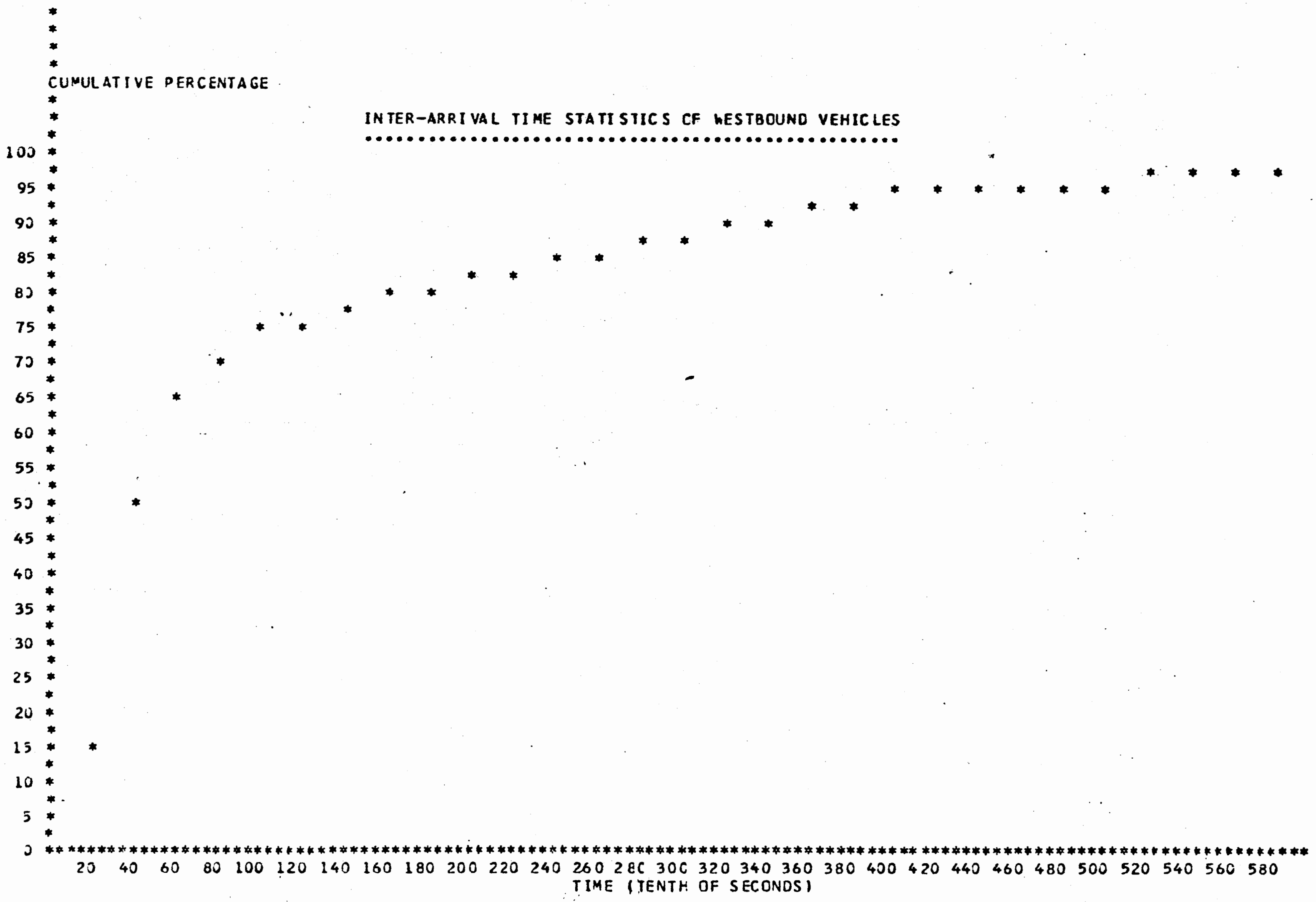
 TABLE  64
 ENTRIES IN TABLE         MEAN ARGUMENT          STANDARD DEVIATION          SUM OF ARGUMENTS
               14                 9.928                       3.687                   139.000           NON-WEIGHTED

            UPPER      OBSERVED        PER CENT        CUMULATIVE      CUMULATIVE       MULTIPLE        DEVIATION
            LIMIT     FREQUENCY        OF TOTAL        PERCENTAGE       REMAINDER        OF MEAN        FROM MEAN
                0             0             .00                .0           100.0          -.000           -2.692
                4             0             .00                .0           100.0           .402           -1.607
                8             7           50.00              50.0            50.0           .805            -.523
               12             5           35.71              85.7            14.2          1.208             .561
               16             0             .00              85.7            14.2          1.611            1.646
               20             2           14.28             100.0              .0          2.014            2.731
 REMAINING FREQUENCIES ARE ALL ZERO
```

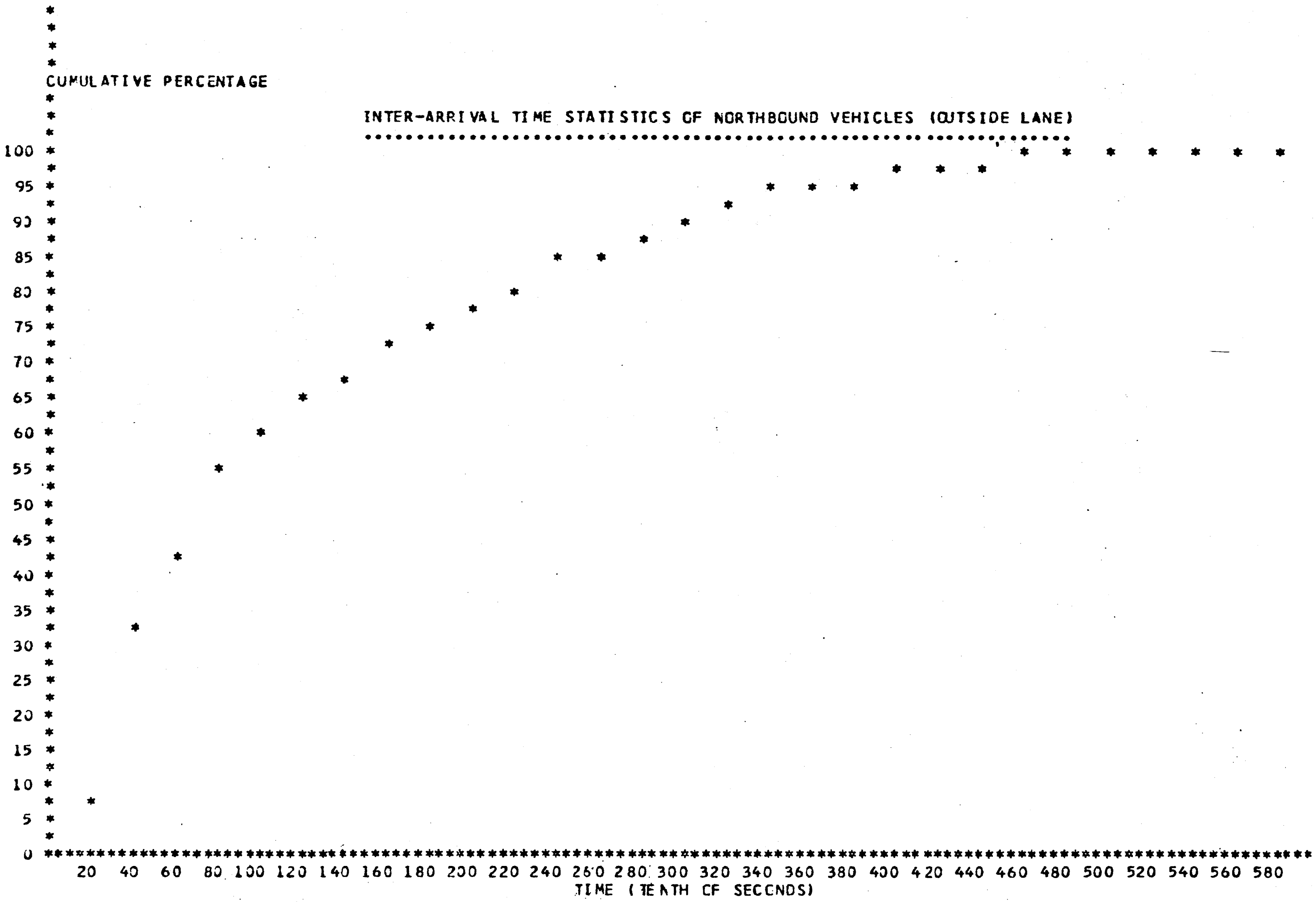
APPENDIX P

OUTPUT OF GRAPHICAL STATISTICS

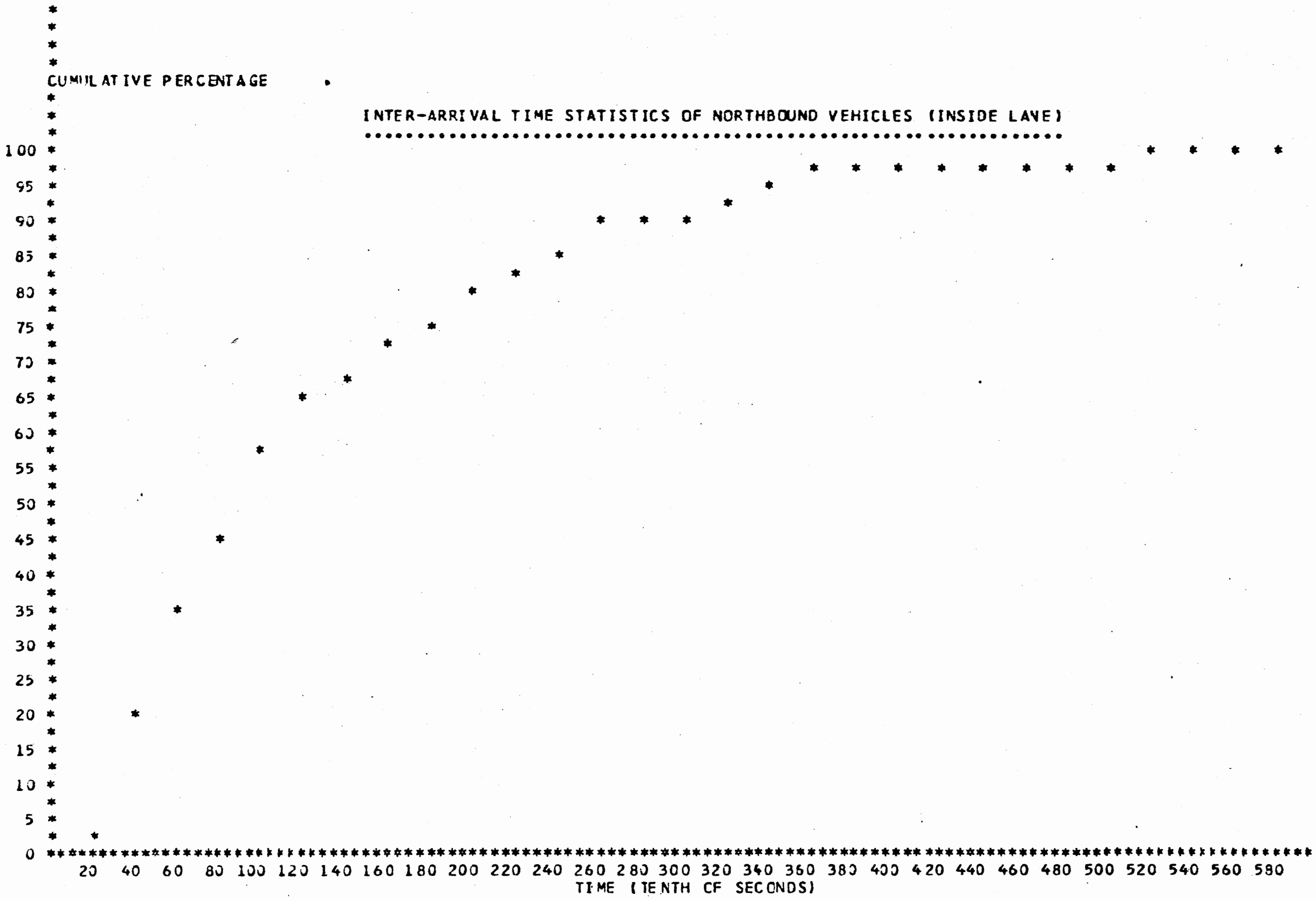

CUMULATIVE PERCENTAGE
INTER-ARRIVAL TIME STATISTICS OF EASTBOUND VEHICLES
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360 380 400 420 440 460 480 500 520 540 560 580
TIME (TENTH OF SECONDS)



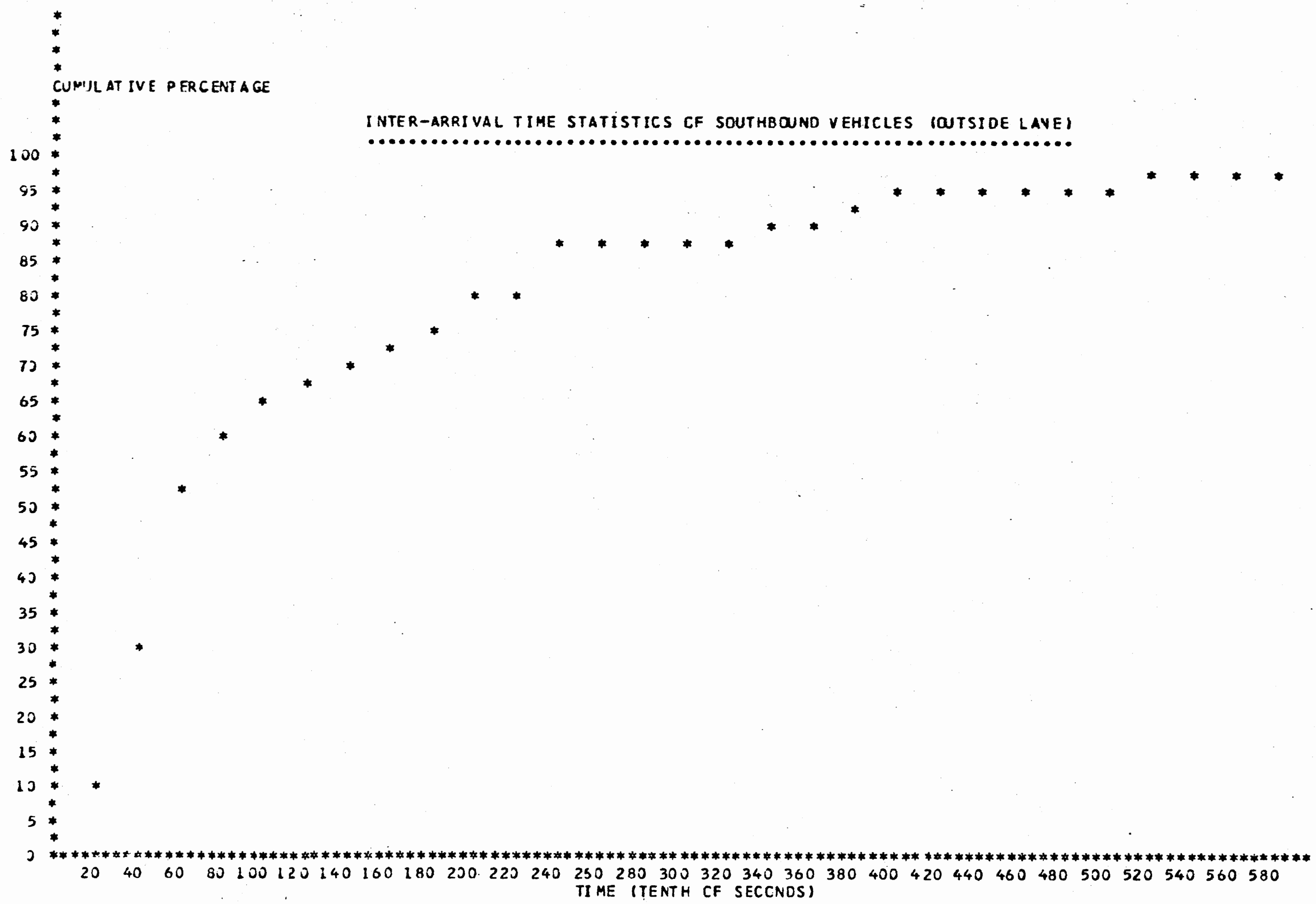
INTER-ARRIVAL TIME STATISTICS OF WESTBOUND VEHICLES



INTER-ARRIVAL TIME STATISTICS OF NORTHBOUND VEHICLES (OUTSIDE LANE)



INTER-ARRIVAL TIME STATISTICS OF NORTHBOUND VEHICLES (INSIDE LANE)


CUMULATIVE PERCENTAGE
INTER-ARRIVAL TIME STATISTICS OF SOUTHBOUND VEHICLES (OUTSIDE LANE)
100
95
90
85
80
75
70
65
60
55
50
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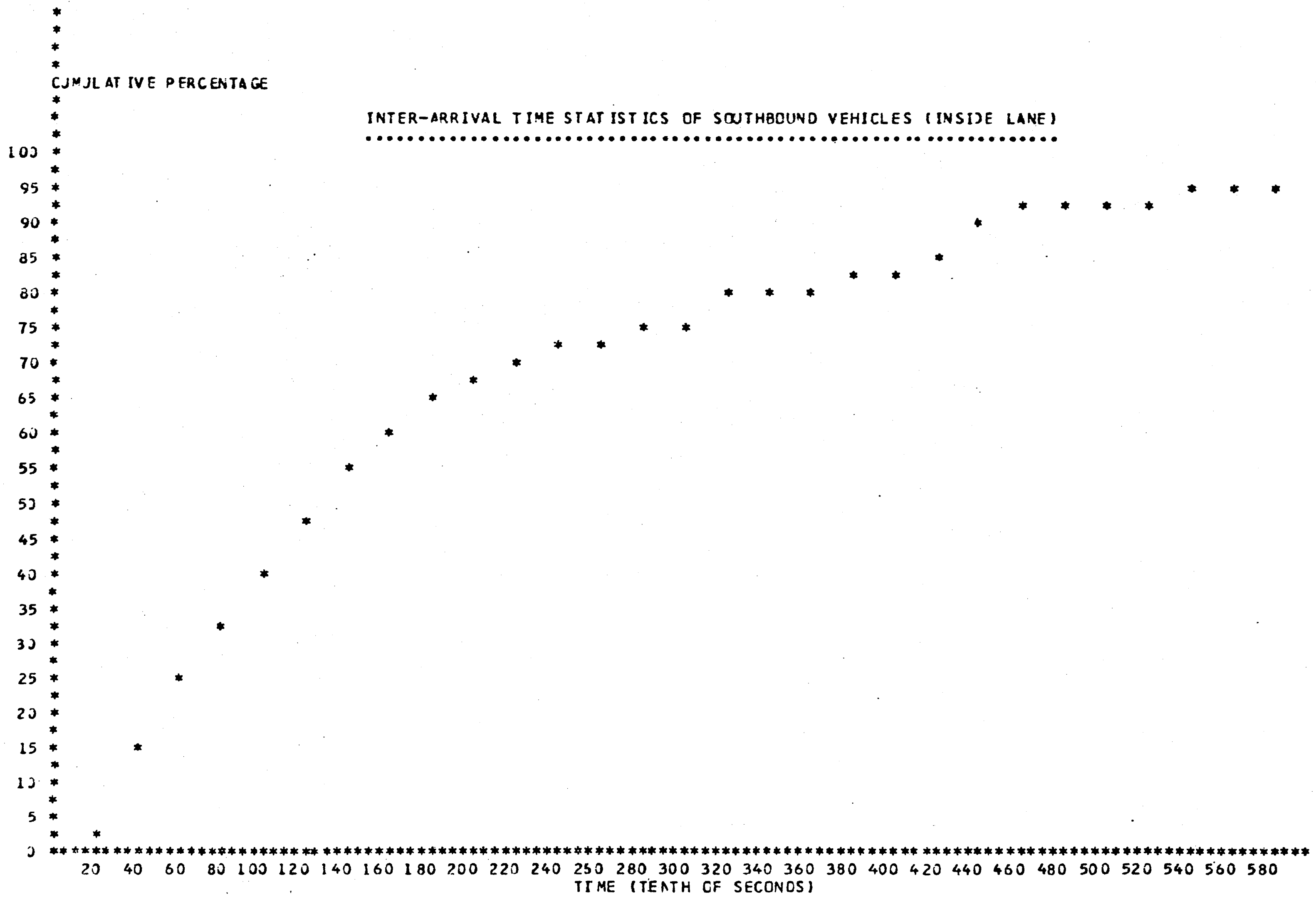
TIME (TENTH OF SECONDS)


CUMULATIVE PERCENTAGE
INTER-ARRIVAL TIME STATISTICS OF SOUTHBOUND VEHICLES (INSIDE LANE)
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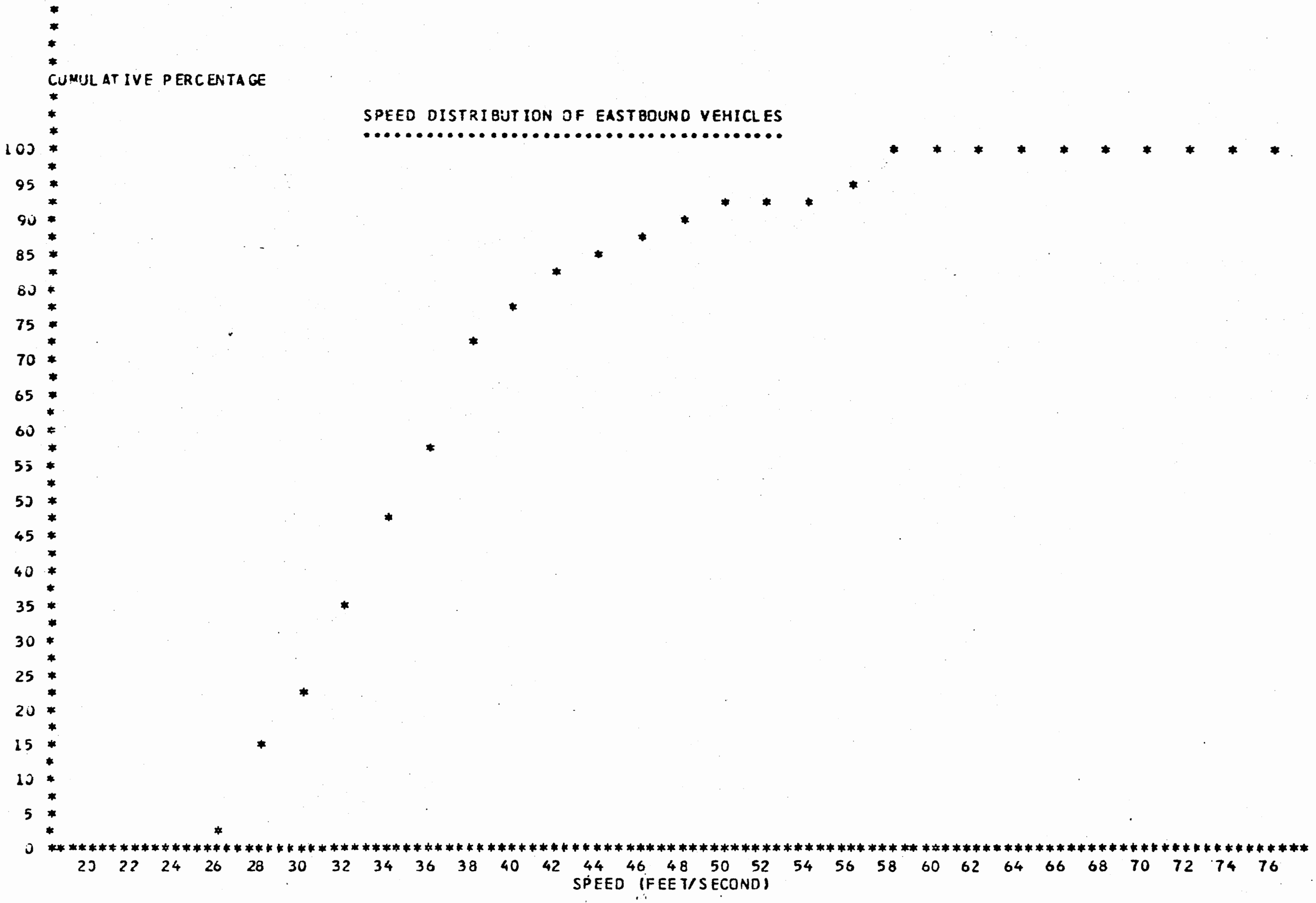
TIME (TENTH OF SECONDS)


CUMULATIVE PERCENTAGE
SPEED DISTRIBUTION OF EASTBOUND VEHICLES
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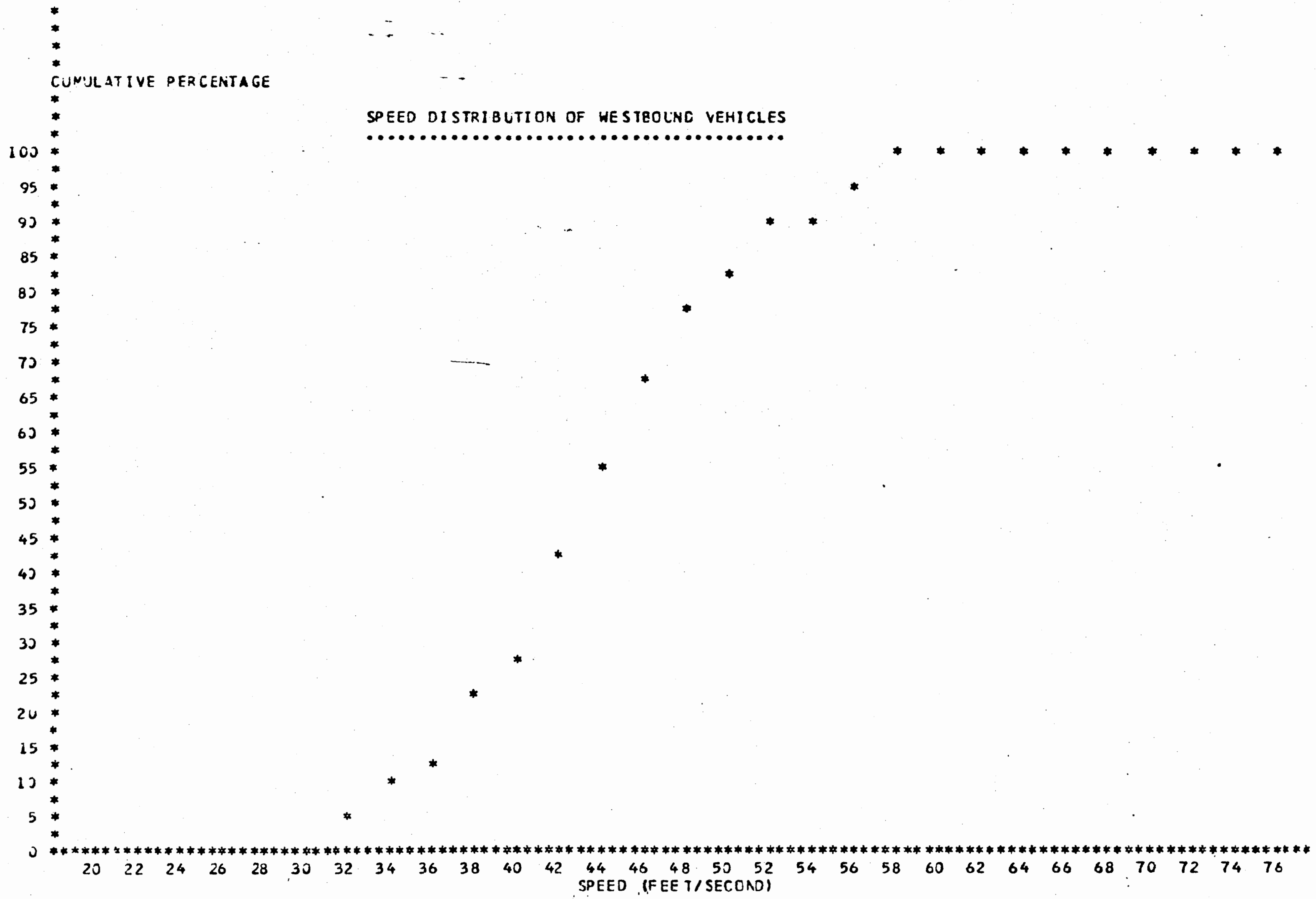
76
SPEED (FEET/SECOND)


CUMULATIVE PERCENTAGE
SPEED DISTRIBUTION OF WESTBOUND VEHICLES
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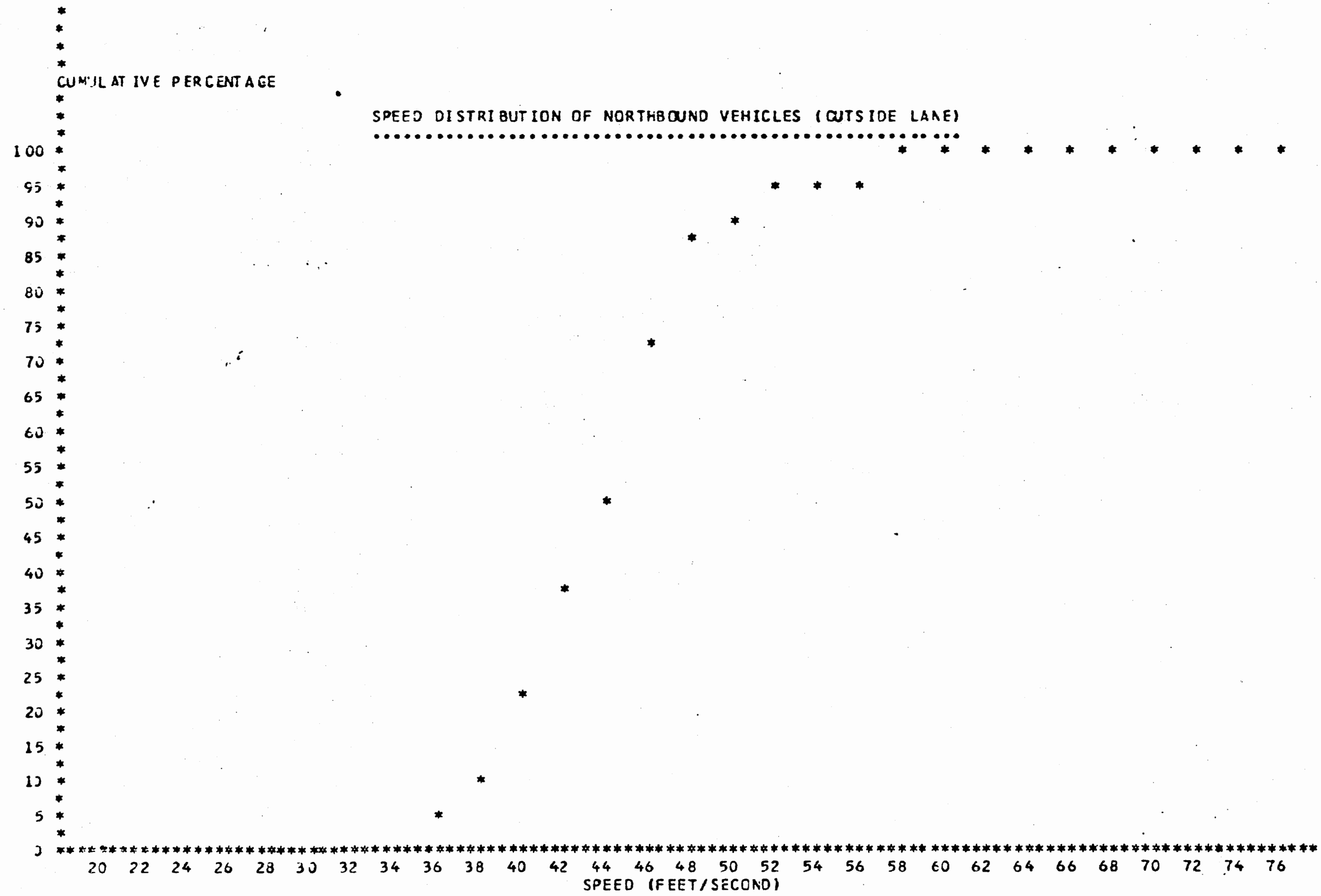
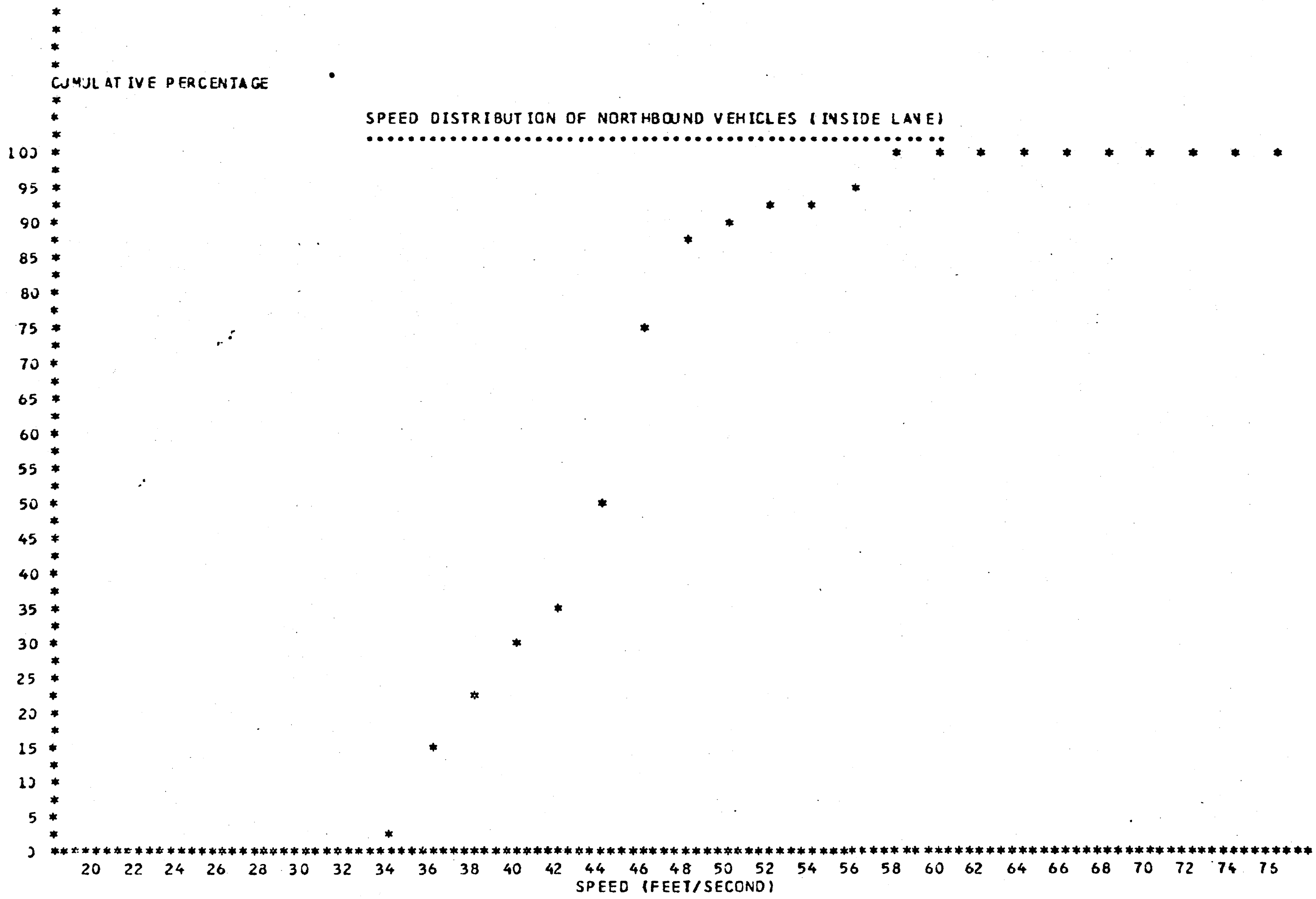
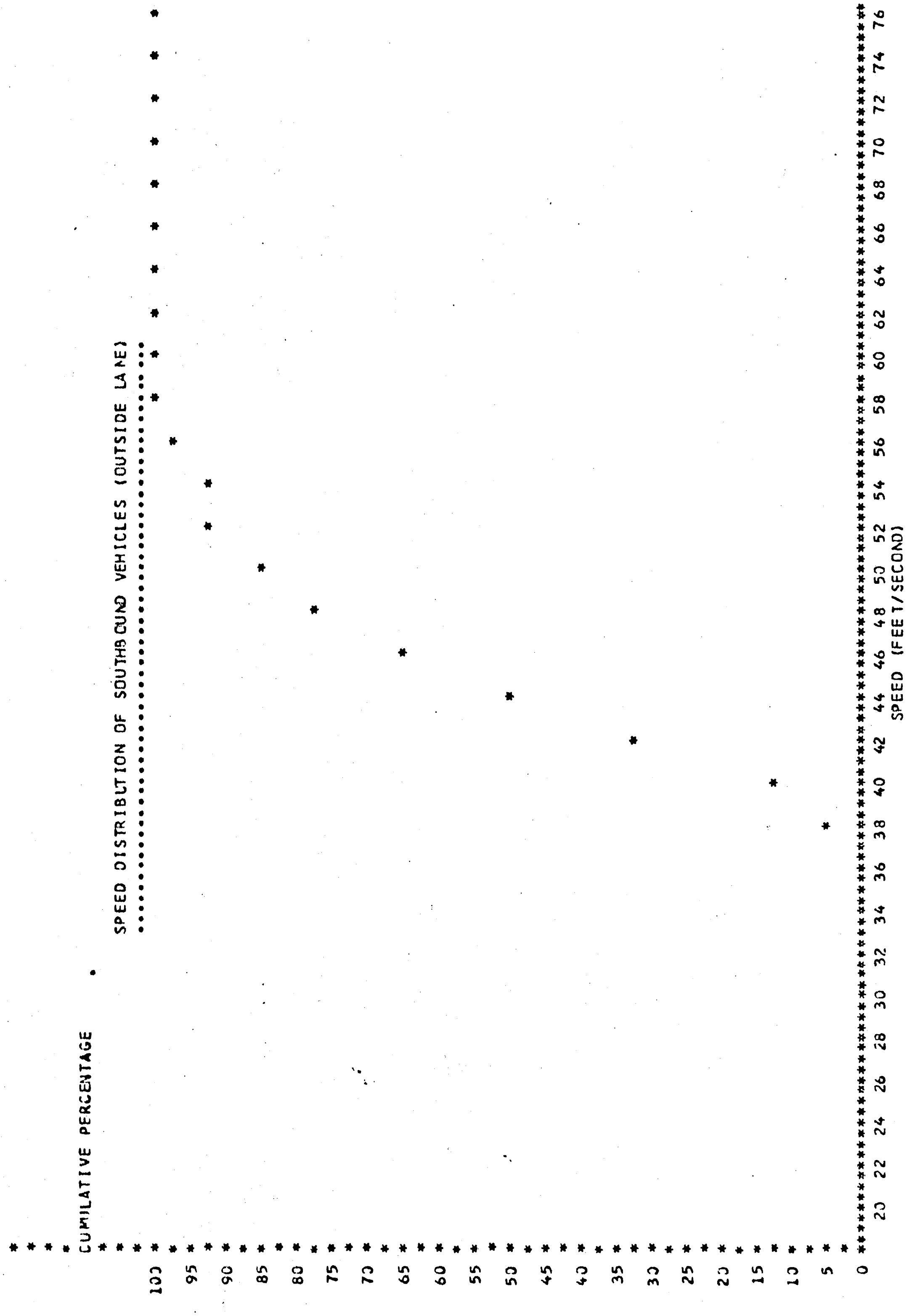
SPEED (FEET/SECOND)



SPEED DISTRIBUTION OF NORTHBOUND VEHICLES (OUTSIDE LANE)



SPEED DISTRIBUTION OF NORTHBOUND VEHICLES (INSIDE LANE)


SPEED DISTRIBUTION OF SOUTHBOUND VEHICLES (OUTSIDE LANE)
CUMULATIVE PERCENTAGE
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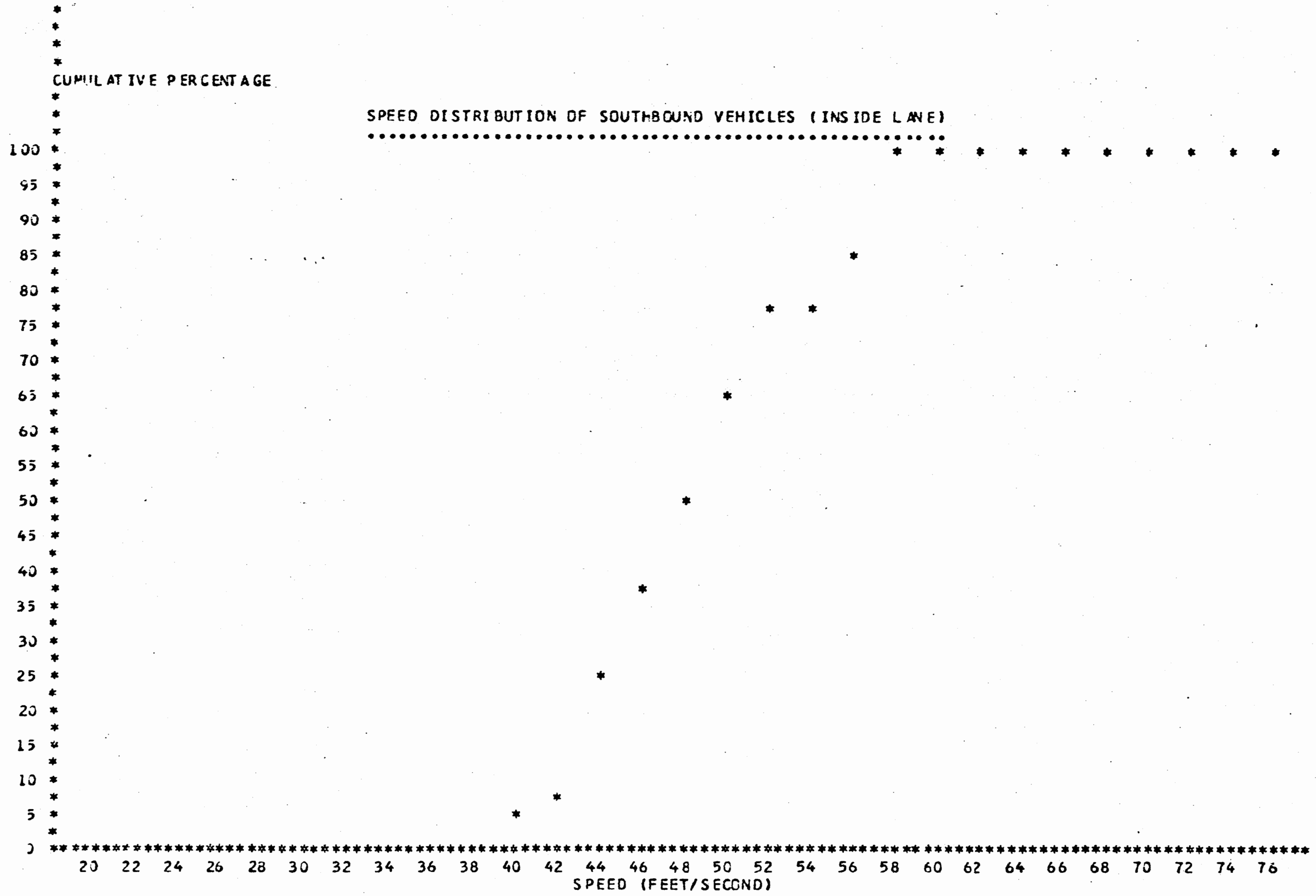
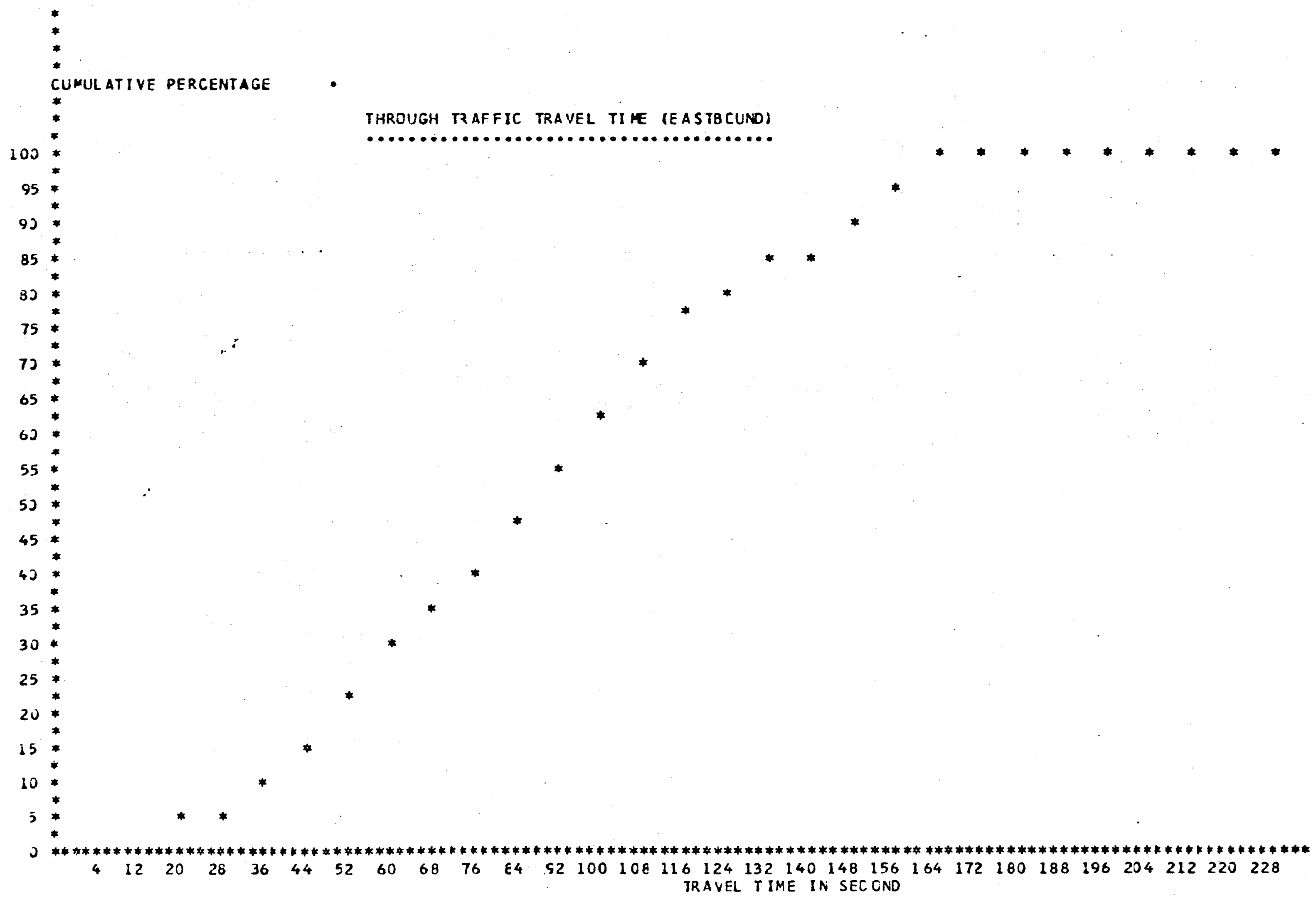
SPEED (FEET/SECOND)



SPEED DISTRIBUTION OF SOUTHBOUND VEHICLES (INSIDE LANE)


CUMULATIVE PERCENTAGE
THROUGH TRAFFIC TRAVEL TIME (EASTBOUND)
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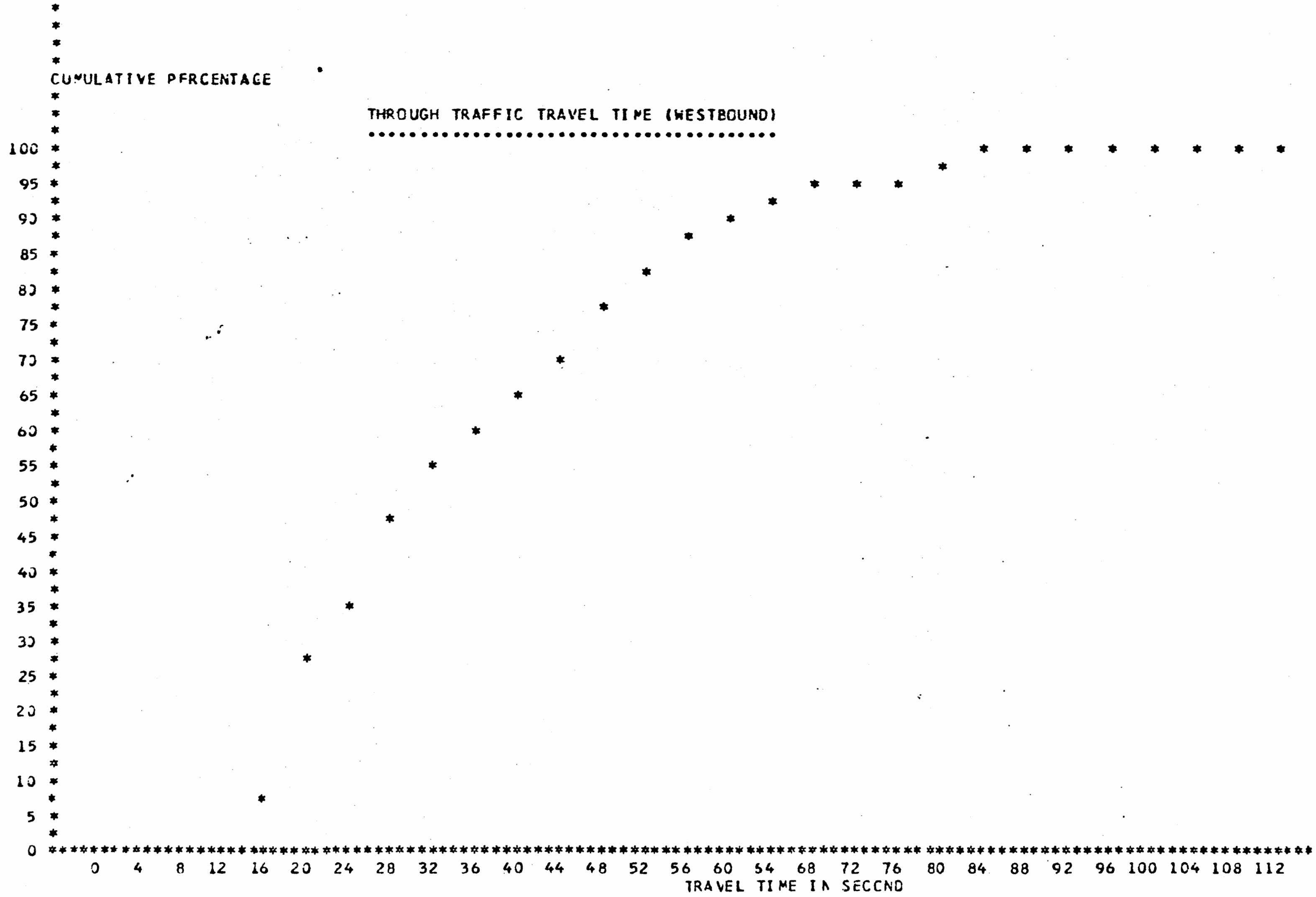
TRAVEL TIME IN SECOND


CUMULATIVE PERCENTAGE
THROUGH TRAFFIC TRAVEL TIME (WESTBOUND)
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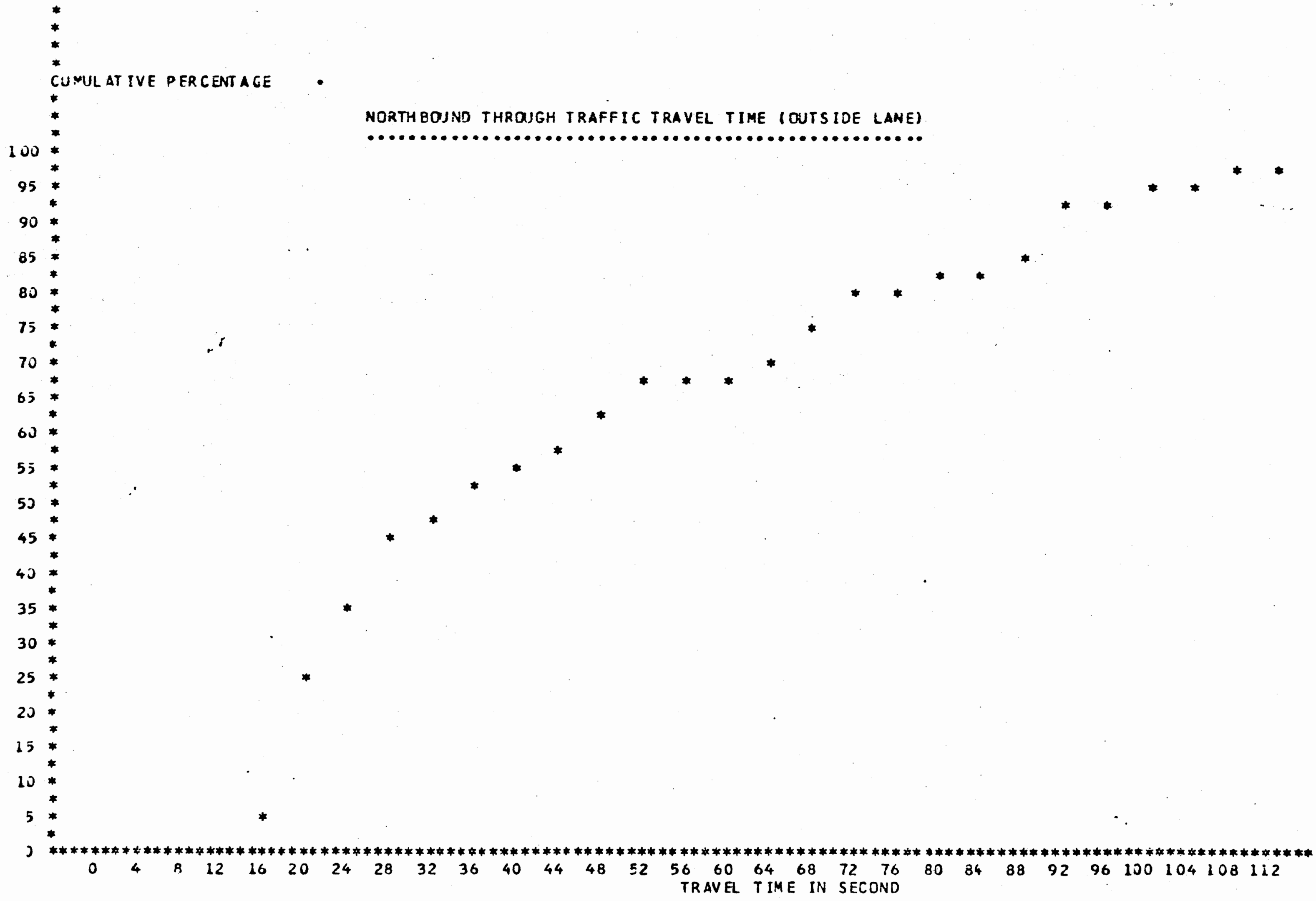
TRAVEL TIME IN SECOND


CUMULATIVE PERCENTAGE
NORTHBOUND THROUGH TRAFFIC TRAVEL TIME (OUTSIDE LANE)
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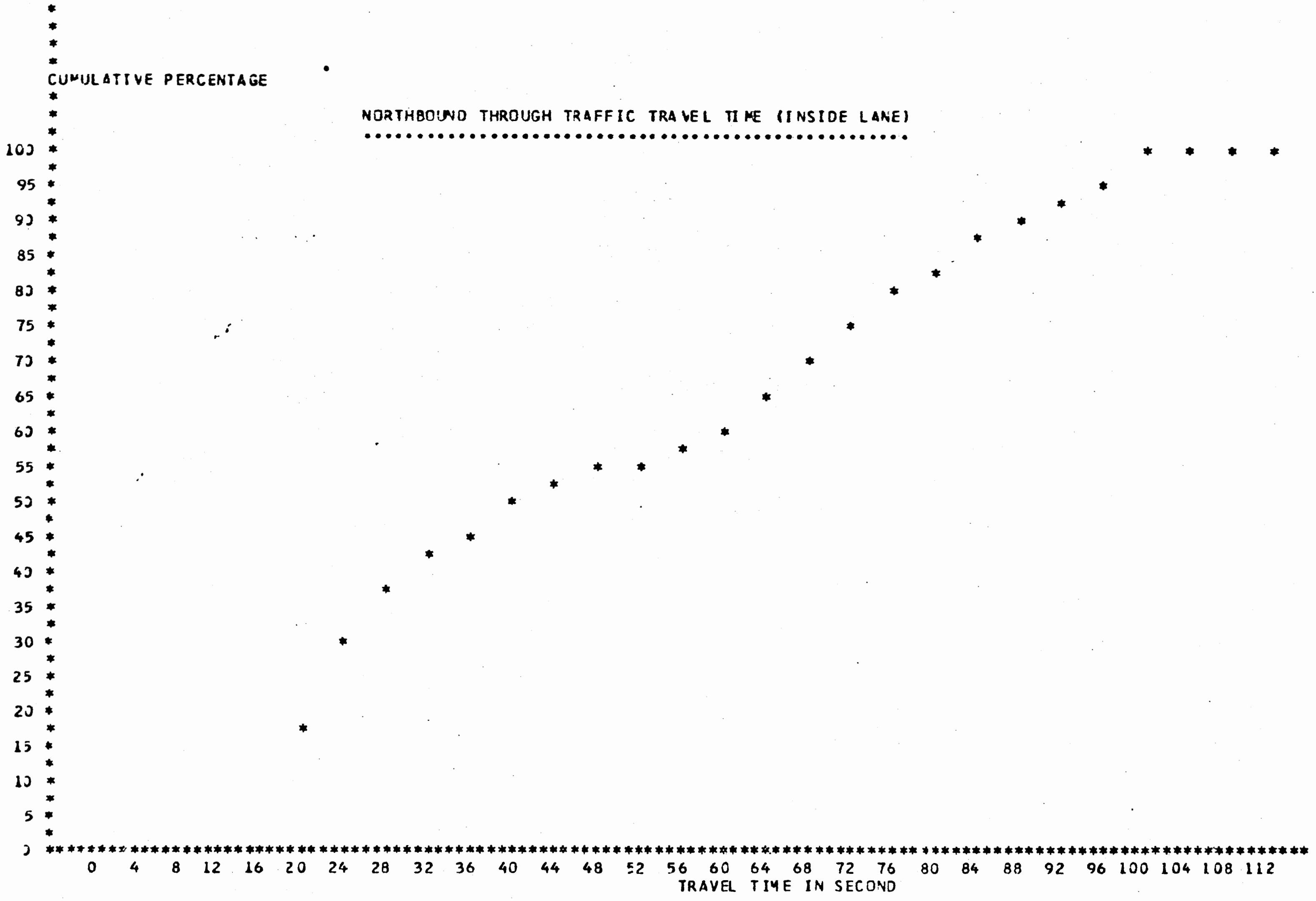
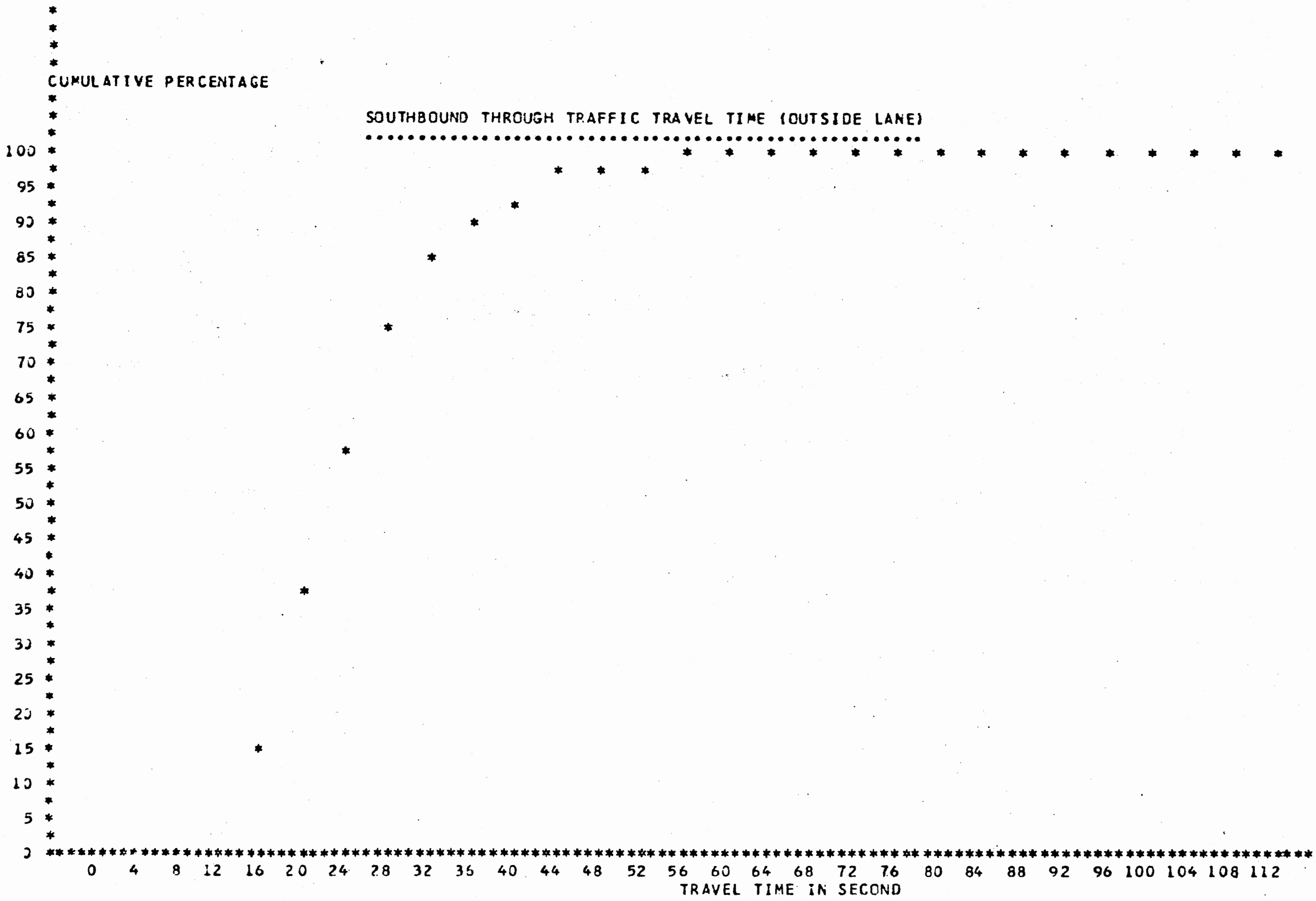
TRAVEL TIME IN SECOND


NORTHBOUND THROUGH TRAFFIC TRAVEL TIME (INSIDE LANE)


CUMULATIVE PERCENTAGE
SOUTHBOUND THROUGH TRAFFIC TRAVEL TIME (OUTSIDE LANE)
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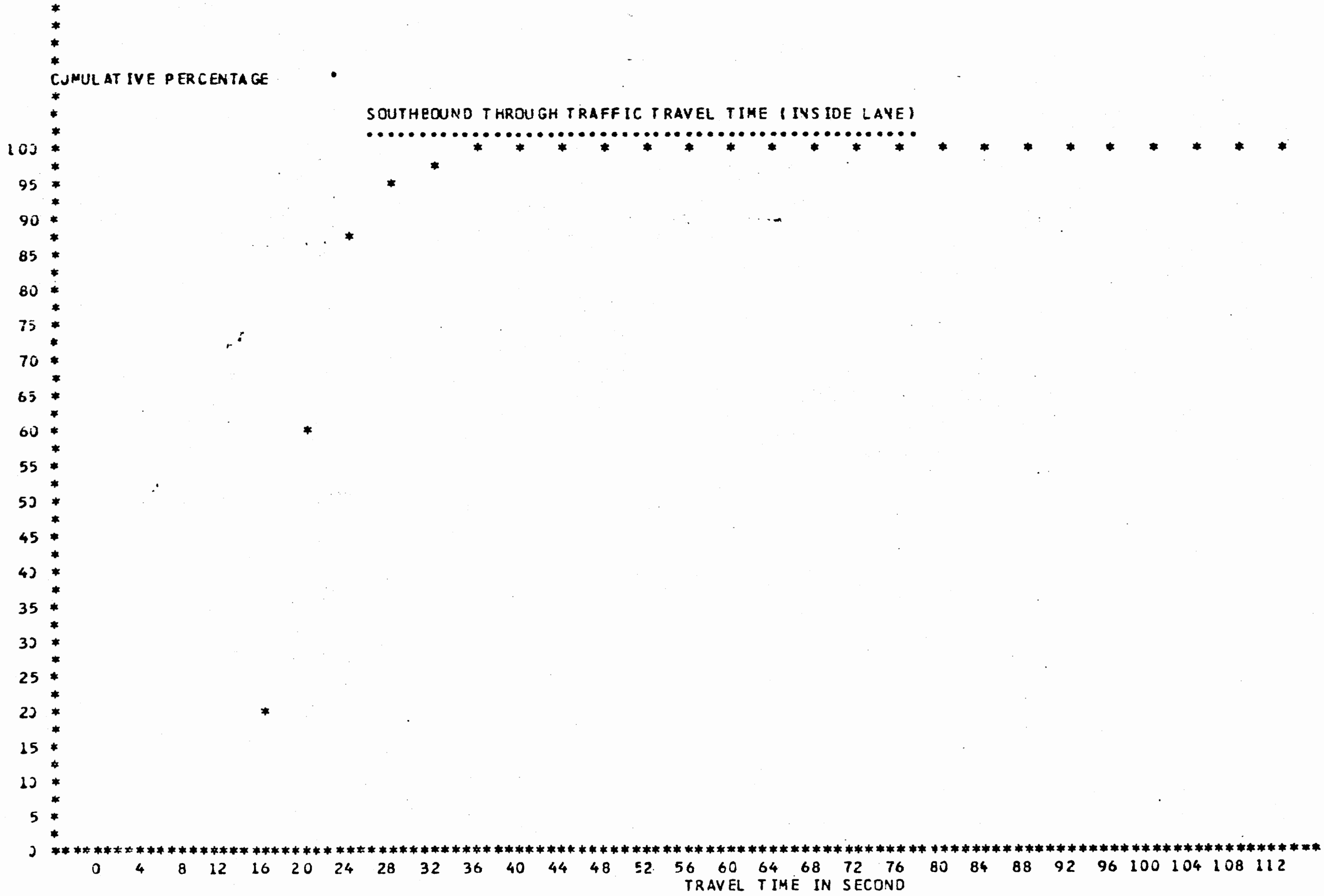
TRAVEL TIME IN SECOND


CUMULATIVE PERCENTAGE
SOUTHBOUND THROUGH TRAFFIC TRAVEL TIME (INSIDE LANE)
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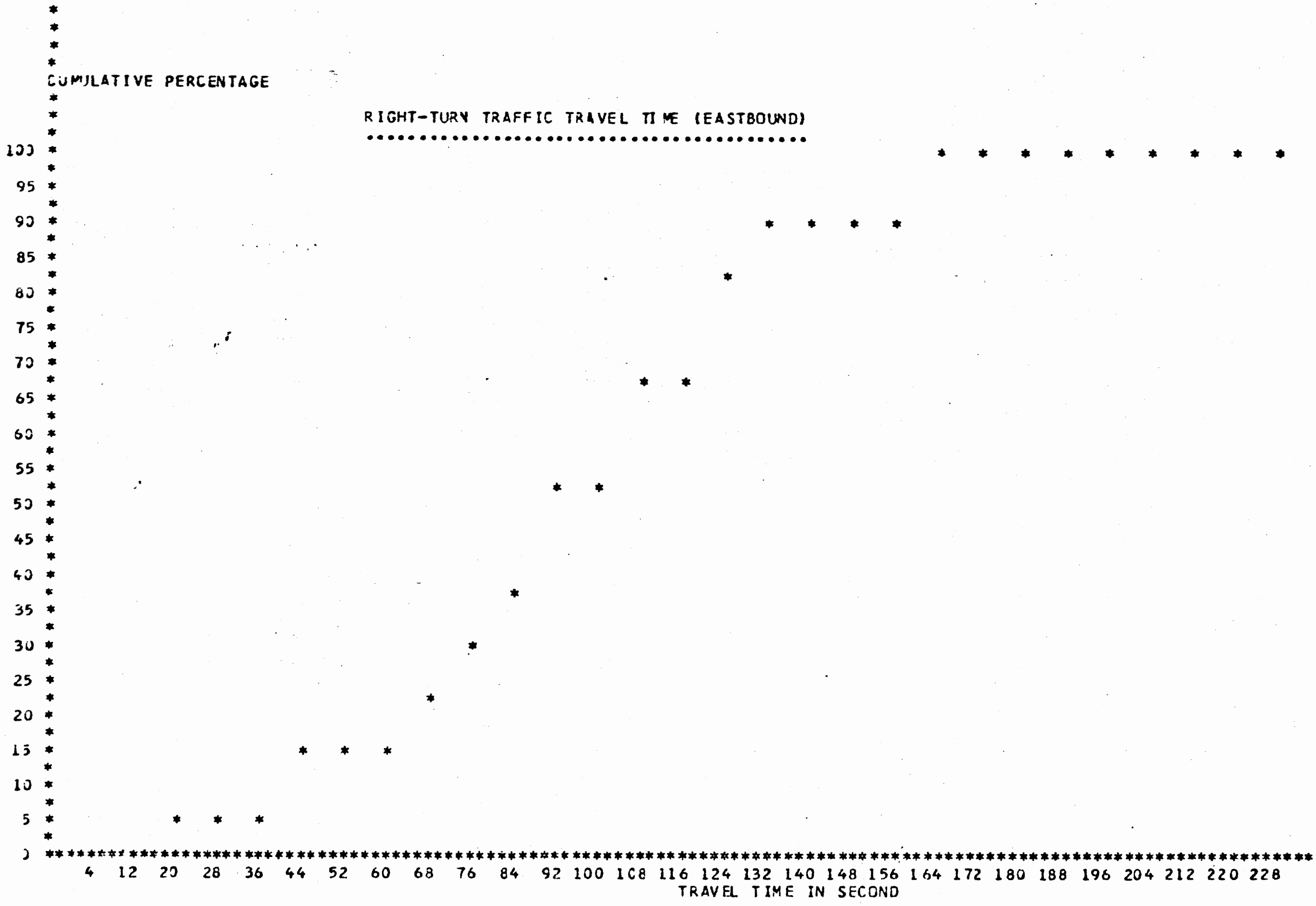
TRAVEL TIME IN SECOND


CUMULATIVE PERCENTAGE
RIGHT-TURN TRAFFIC TRAVEL TIME (EASTBOUND)
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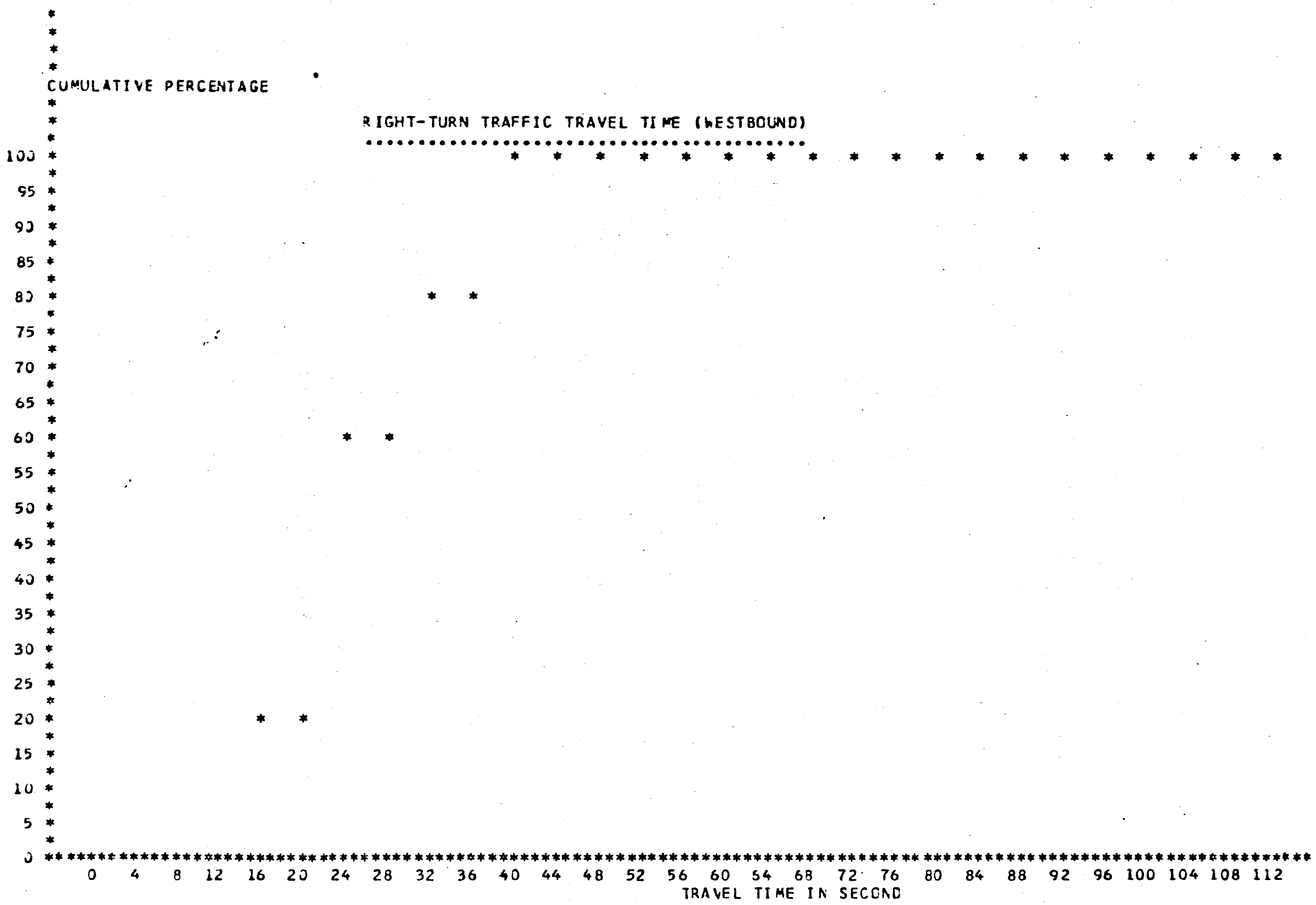
220
228
TRAVEL TIME IN SECOND


CUMULATIVE PERCENTAGE
RIGHT-TURN TRAFFIC TRAVEL TIME (WESTBOUND)
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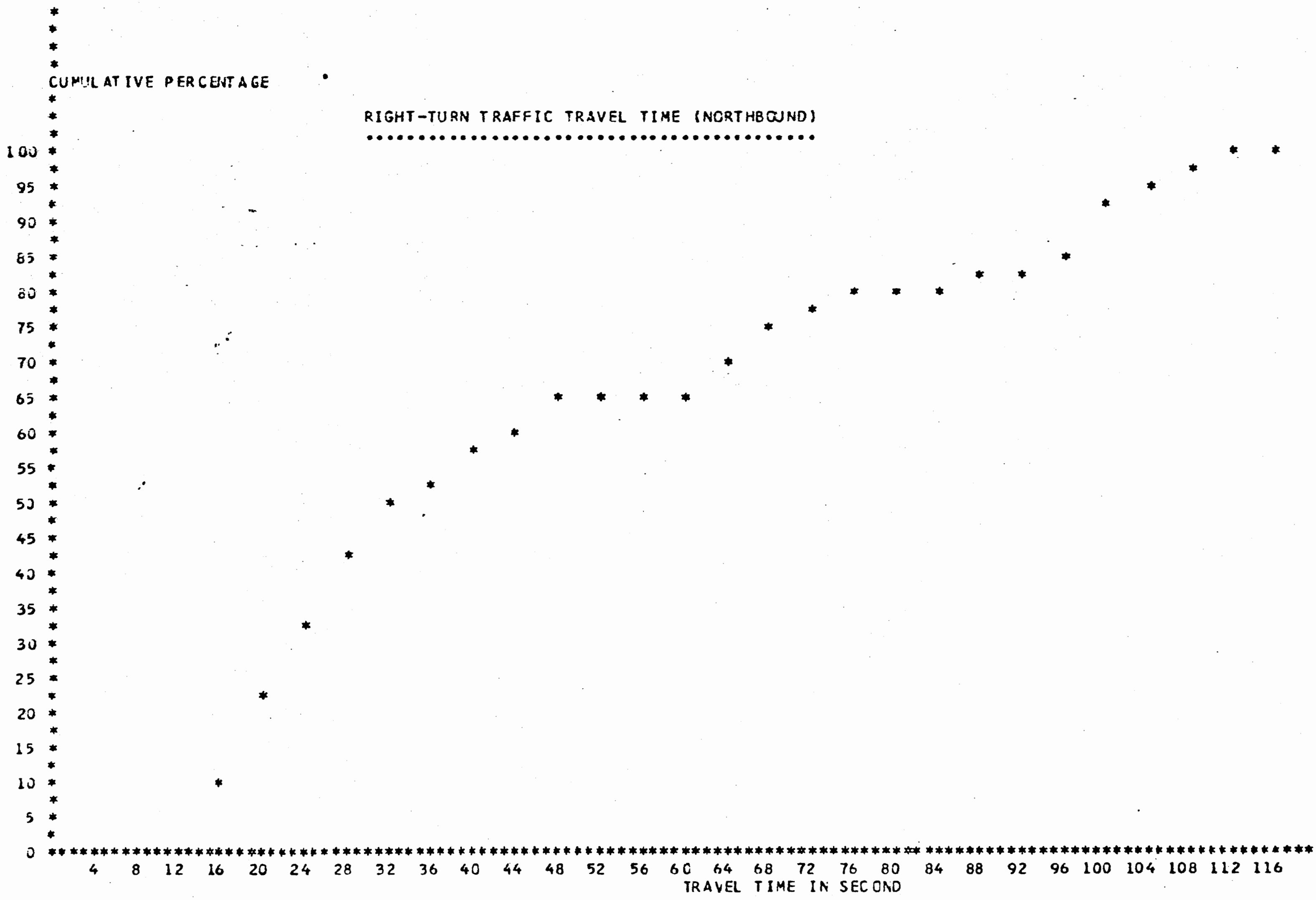
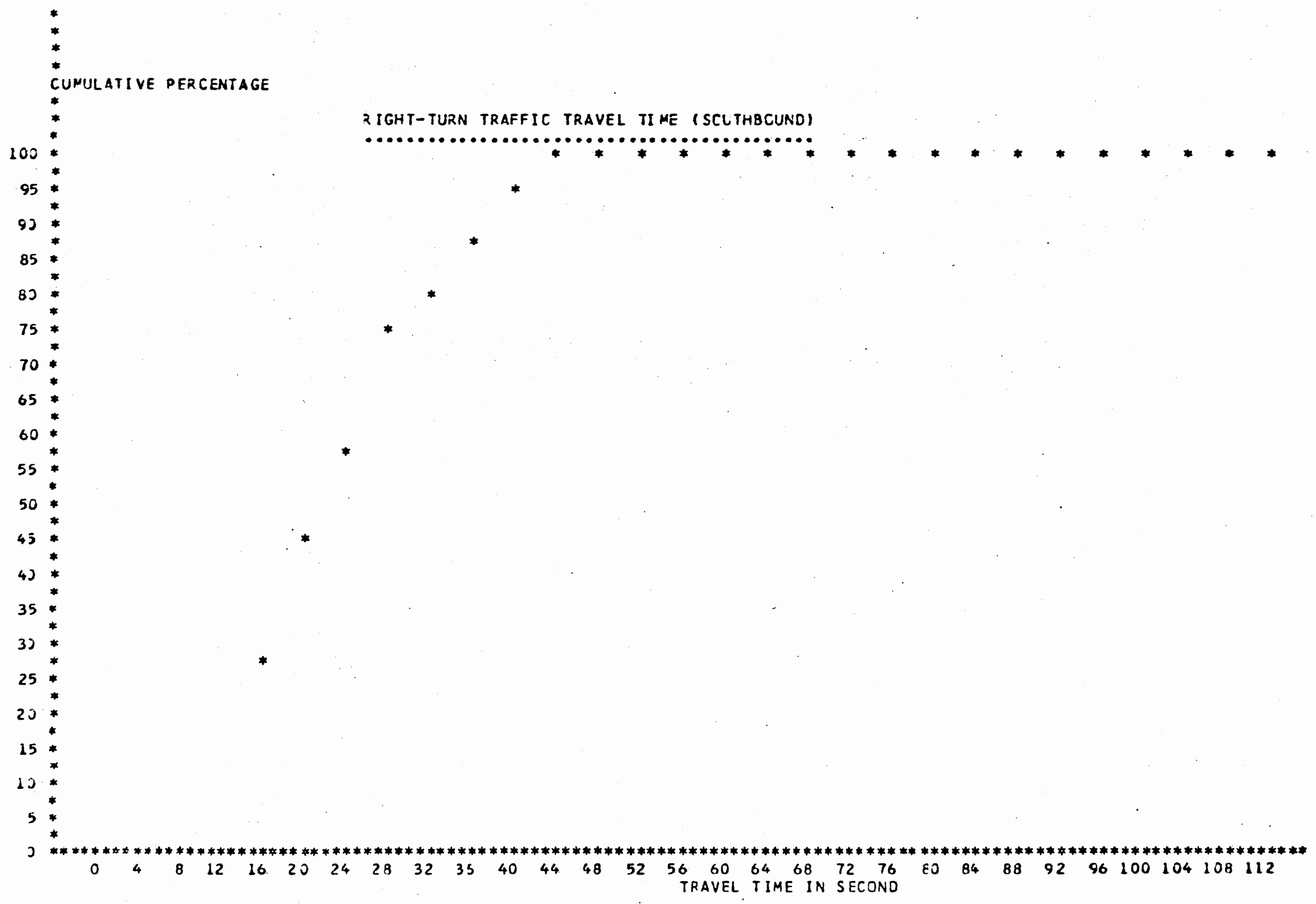
0 4 8 12 16 20 24 28 32 36 40 44 48 52 56 60 64 68 72 76 80 84 88 92 96 100 104 108 112
TRAVEL TIME IN SECOND



RIGHT-TURN TRAFFIC TRAVEL TIME (NORTHBOUND)


CUMULATIVE PERCENTAGE
RIGHT-TURN TRAFFIC TRAVEL TIME (SOUTHBOUND)
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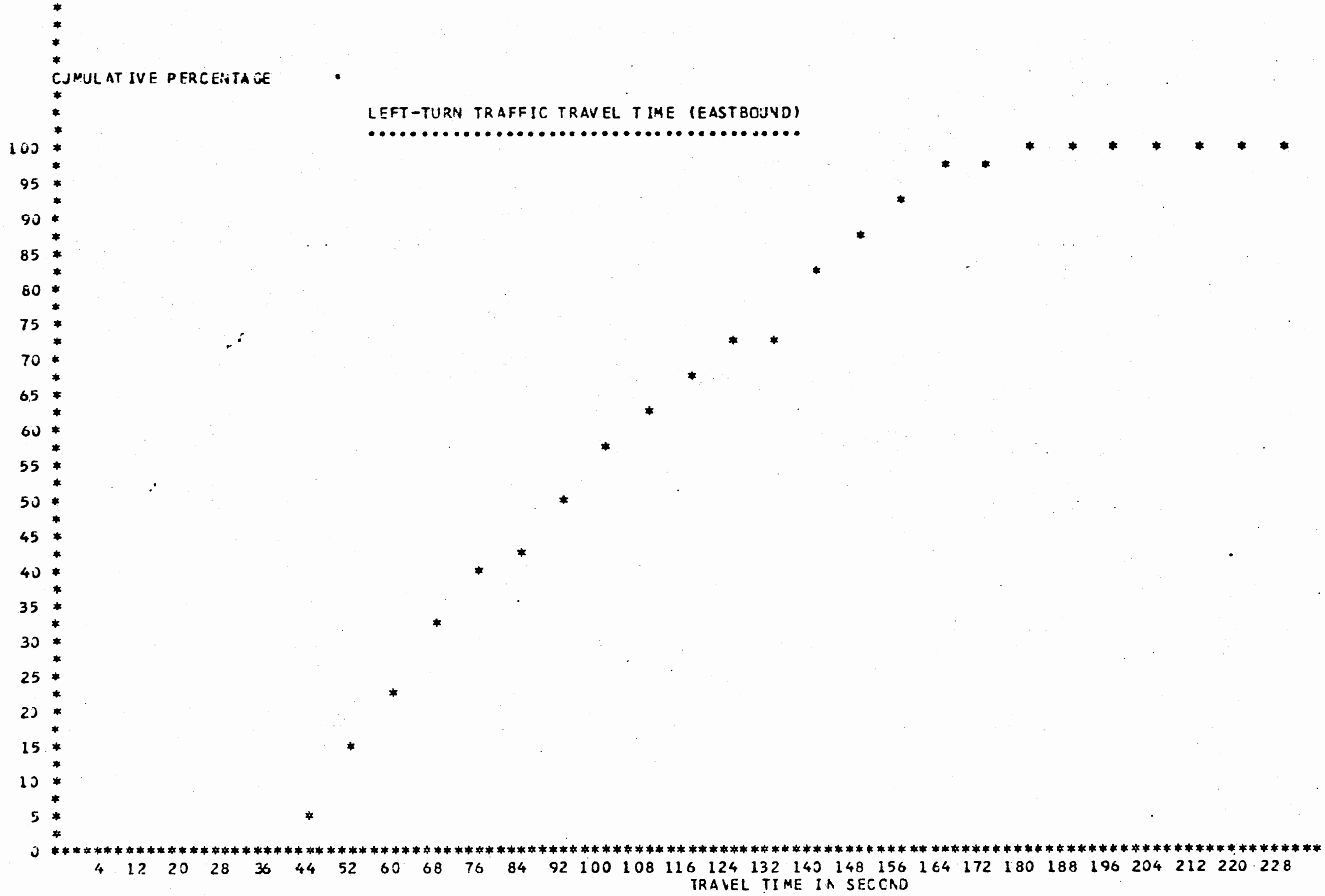
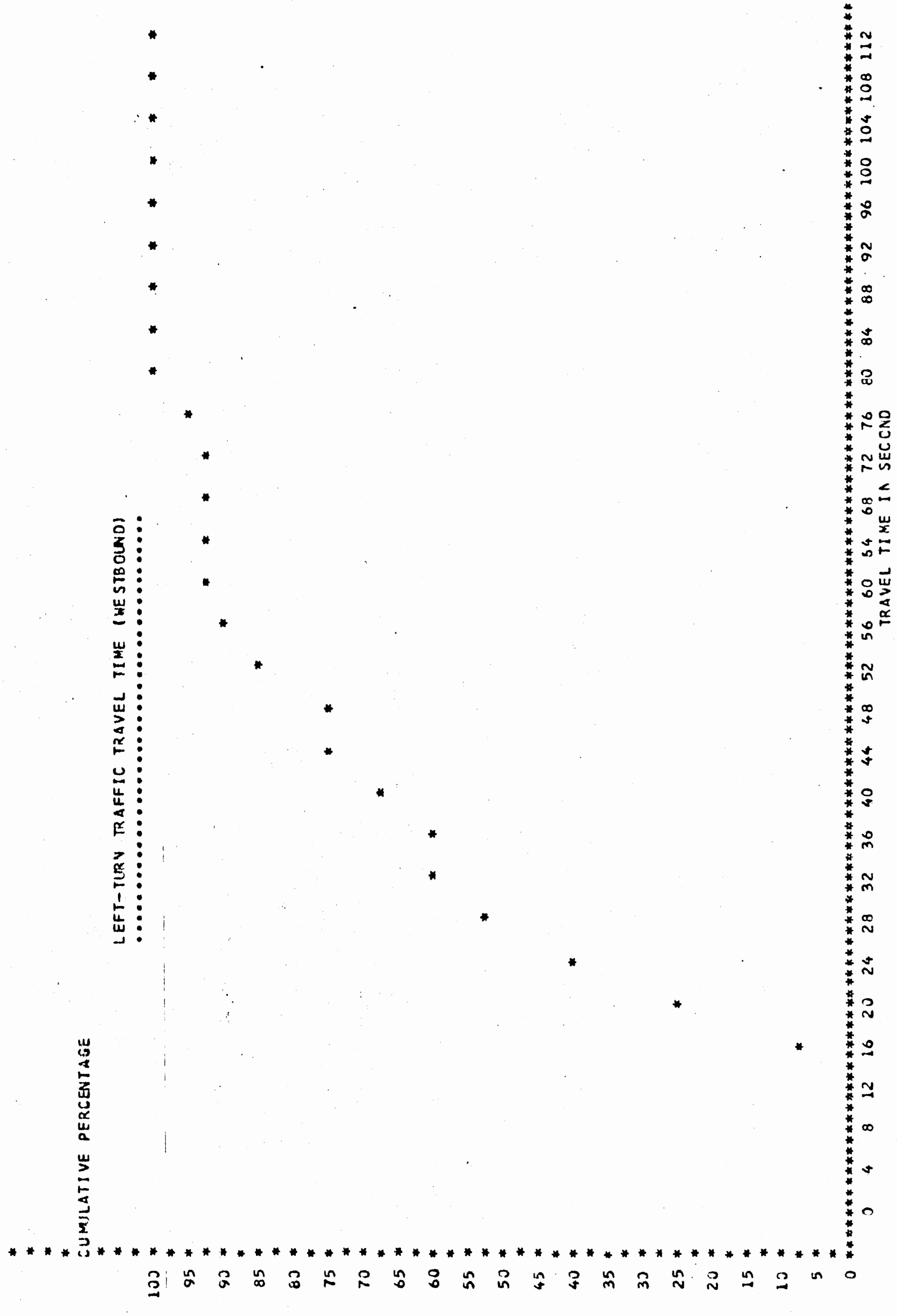
TRAVEL TIME IN SECOND



LEFT-TURN TRAFFIC TRAVEL TIME (EASTBOUND)


LEFT-TURN TRAFFIC TRAVEL TIME (WESTBOUND)
CUMULATIVE PERCENTAGE
100
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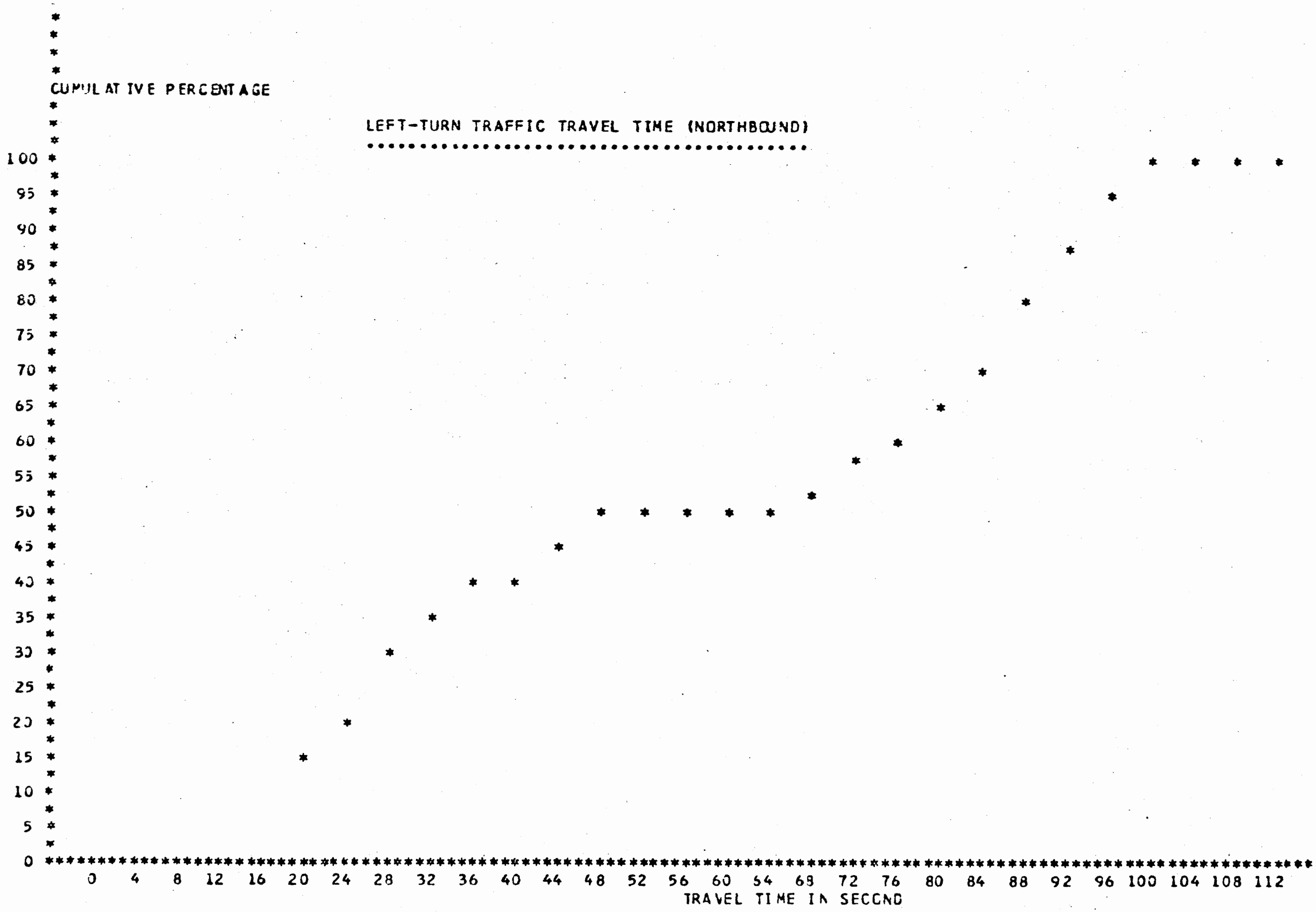
TRAVEL TIME IN SECCND


CUMULATIVE PERCENTAGE
LEFT-TURN TRAFFIC TRAVEL TIME (NORTHBOUND)
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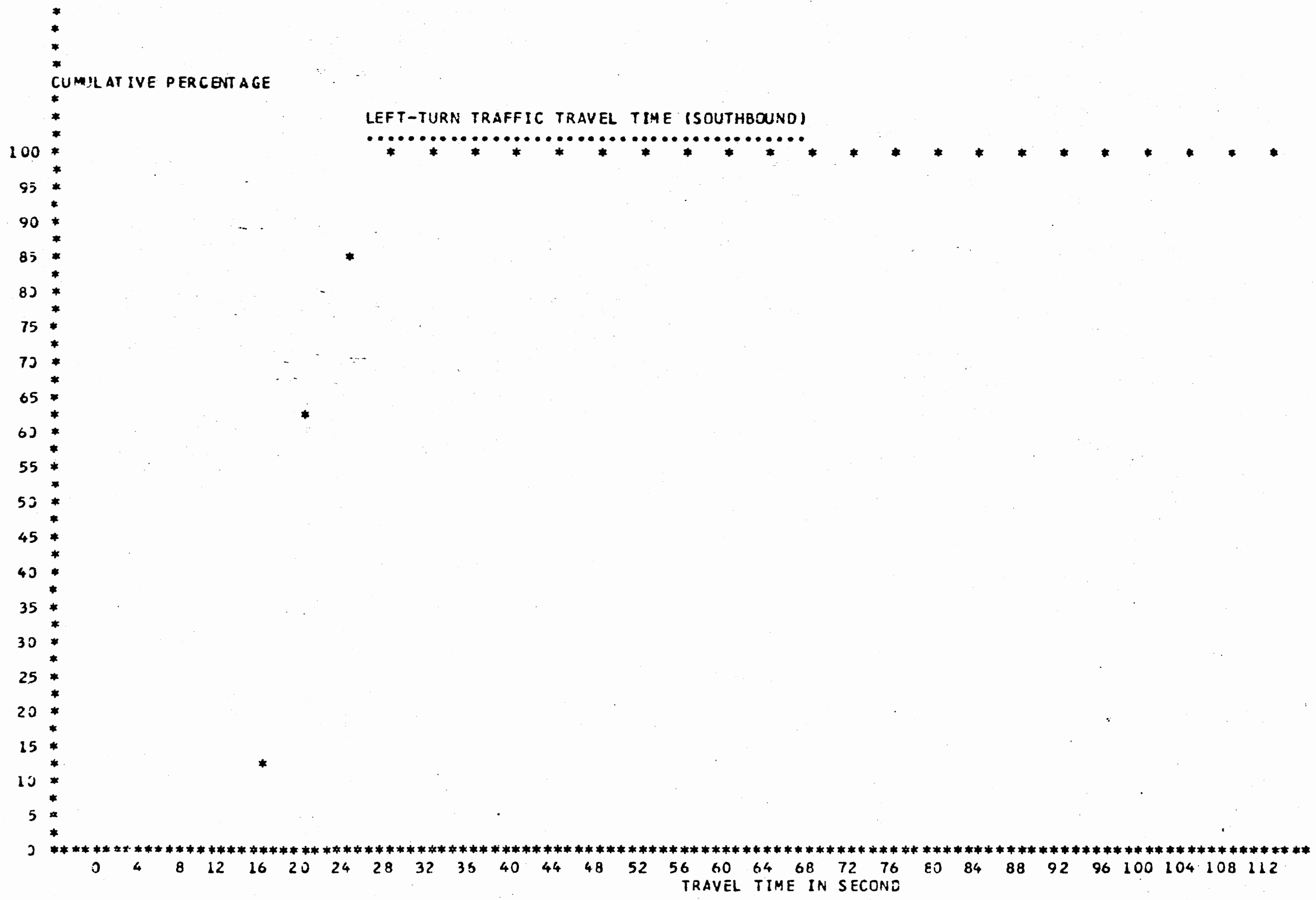
TRAVEL TIME IN SECOND


CUMULATIVE PERCENTAGE
LEFT-TURN TRAFFIC TRAVEL TIME (SOUTHBOUND)
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0 4 8 12 16 20 24 28 32 36 40 44 48 52 56 60 64 68 72 76 80 84 88 92 96 100 104 108 112
TRAVEL TIME IN SECOND

APPENDIX Q

SUMMARY OF SIMULATION OUTPUTS

TABLE VIII

MEANS OF APPROACH SPEEDS AND HEADWAYS

Direction of Traffic	Approach Lanes	Approach Speeds (feet/second)	Headways (Seconds)
Eastbound	-	36.04	9.04
Westbound	-	43.42	9.80
Northbound	Outside	43.69	11.37
	Inside	43.10	11.82
Southbound	Outside	44.76	11.50
	Inside	48.57	18.13

TABLE IX

AVERAGE TOTAL TRAVEL TIMES (SECONDS)

Traffic Direction	Approach Lanes	Through Vehicles	Right-turn Vehicles	Left-turn Vehicles
Eastbound	-	85.48	92.23	95.17
Westbound	-	34.29	25.20	33.33
Northbound	Outside	44.34	45.77	-
	Inside	47.56	-	56.02
Southbound	Outside	24.35	23.32	-
	Inside	19.87	-	20.07

TABLE X

AVERAGE DELAY OF VEHICLES IN EACH LANE (SECONDS)

Traffic Direction	Approach Lanes	Through Vehicles	Right-turn Vehicles	Left-turn Vehicles
Eastbound	-	66.66	74.92	76.97
Westbound	-	22.48	14.40	21.64
Northbound	Outside	30.90	32.98	-
	Inside	33.80	-	42.20
Southbound	Outside	13.52	12.82	-
	Inside	9.82	-	9.93

VITA 2

Prapansak Buranaprapa

Candidate for the Degree of

Doctor of Philosophy

Thesis: VEHICLE DELAY AT 4-WAY STOP INTERSECTIONS

Major Field: Civil Engineering

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Professional Experience: Assistant Project Engineer, Construction Division, Department of Highways (Thailand), 1967; Project Engineer, Construction Division, Department of Highways (Thailand), 1967-1972; Area Engineer, Feeder Road Construction Division, Department of Highways (Thailand), 1972-1975; Senior Design Engineer, Location and Design Division, Department of Highways (Thailand), 1975-1976; graduate teaching assistant, School of Civil Engineering, Oklahoma State University, 1978-1980.

Professional Organizations: Member of the Engineering Institute of Thailand, member of the Better Road Association of Thailand, member of Chi Epsilon.