A METHODOLOGY OF AGGREGATING DISCRETE MICROSCOPIC TRAFFIC DATA FOR MACROSCOPIC MODEL CALIBRATION AND NONEQUILIBRIUM VISUAL DETECTION PURPOSES/

A Thesis Presented to
The Faculty of the College of Engineering and Technology
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In Partial Fulfillment
of the Requirements for the Degree
Master of Industrial and Systems Engineering

by
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ACKNOWLEDGMENTS

This research document represents a combined effort between the Ohio University’s College of Engineering and Technology and the Federal Highway Administration (FHWA). It now becomes appropriate to recognize and thank those people who helped to make this research project possible.

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On a personal note, my lovely wife Virginia and mother Dolores deserve much reward for their cooperation, patience, and support while this thesis was being researched and written. Lastly, I would like to admit much gratitude to my deceased father Dennis B. Blythe, and deceased stepfather James R. McLain, for their memories are largely attributable towards the realization of this accomplishment.
SUMMARY

The research constituting this thesis originates from a Federal Highway Administration's Graduate Research Fellowship entitled "Calibration of RFLO Traffic Simulation Program." The RFLO Simulation Program provides a macroscopic description of vehicular traffic flow. The majority of the research was performed at the FHWA's Turner-Fairbank Highway Research Center (McLean, Va.) during the time from June 15 to September 15, 1989. The actual calibration procedure centered around RFLO's Relaxation Constant parameter, a partial differential equation - containing the parameter - representing the acceleration/deceleration of macroscopic traffic, and the microscopic traffic data sets that were available at the research facility.

Initially, the microscopic traffic data needed transformed into a macroscopic traffic description in order to facilitate a legitimate comparison to RFLO. While becoming acquainted with the data sets several types of errors and misconceptions were identified and subsequently streamlined from the recorded traffic descriptions. The transformation process would create quantities of Volume (Q), Density (k), and Speed (v) describing a facility's traffic behavior dependent upon a distance region (DX) and time interval (DT). In order to justify these averaging regions a DX-DT Aggregation Analysis resulted. This analysis used carefully selected DX-DT combinations and the Rational Subgruopping Concept (Montgomery, 1985) to arrive at the conclusion, for the Roscoe Boulevard data set, of using a DX of 200 feet and a DT equal to 3 seconds. By performing the transformation to this aggregation level an "optimal" overall macroscopic description of the Roscoe Boulevard's traffic behavior was attained.

The calibration of RFLO's Relaxation Constant was expected to provide additional agreement with Prigogine and Herman (1971) whom suggest that the (RFLO) "forcing function" is a disastrous simplification of the manner and ability for which macroscopic traffic reacts to changing conditions within the transportation medium. The calibration procedure isolated the "forcing function," from various constraints within the model, by selecting a traffic response that would most effectively represent a very quick and unconstrained acceleration to the free flow speed of the facility. After estimating the required variables necessary to RFLO, for facility definition, the calibration procedures were performed. These procedures used a wide range of Relaxation Constant values and a three-dimensional calibration methodology while attempting to minimize the difference between the actual behavior data and that produced by the RFLO model. The results of the calibration indicate that RFLO does react more efficiently (quickly), than the actual traffic behavior, to such an extent that the largest relaxation time could not retard this behavior.
The last examination of this thesis pertains to non-equilibrium behavior, an optimal aggregation level for macroscopic traffic representation, and a concept towards manipulating traffic data by means of a three-dimensional visual model. Previous research has produced two (Wagner & May, 1963) and three-dimensional (Makigami et al, 1985) visual traffic representations which have provided a better understanding of the actual behavior occurring. However, with the aforementioned "optimal" macroscopic aggregation level and several manipulative concepts it may be possible to enable nonequilibrium traffic phenomenon to be detected from visual models of various traffic behavior characteristics. The results of this examination provide several suggestions. However, the representations of vehicular speed standard deviations, fully composing each and every macroscopic speed, and a coefficient of variation model provide the best outcomes for the final investigation of this thesis. Although these visual models are suggested in the thesis the three-dimensional graphing capabilities, offered at the Turner-Fairbank Highway Research Center, limited the extent for proving their actual value.
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CHAPTER I

INTRODUCTION

A. Introductory Remarks

The reoccurrence of vehicular traffic congestion has become reality for nearly every urban area in the United States. According to the Federal Highway Administration (FHWA), 65% of the traffic associated with peak travel times on interstates in urban areas moves at an average speed of less than 35 mph, up from 54% in 1983 (Perry, 1989). There are many causes for this ever increasing problem. For example, the growing number of commuters traveling to and from work have contributed to longer periods of traffic demand near the available roadway capacity. This demand increase creates further damage when periodic emergency or preventive maintenance, to road surfaces and bridges, constrict the capacity of the previously congested roadways.

In several cities across the nation efficient transportation systems (infrastructure) are contributing towards the successful growth of the community. A recent survey ranked Atlanta, which boasts an impressive array of freeways, mass transit, and air transportation facilities, as the "best" location for a business. In contrast, the gridlocked City of Los Angeles plans to invest $200 million in an Automated Traffic Surveillance and Control Center to boost the efficiency of its freeway system (Perry, 1989). In a recent survey, chief executives of U.S. corporations tabbed the
quality of an area’s existing infrastructure (i.e. highways, airports, water supply, etc.) as one of the five critical requirements for relocating a business in a prospective area (Labich, 1989). Hence, frequently reoccurring vehicular traffic congestion is not only causing short-term inconveniences but the long-term economic erosion of unpreparing urban areas.

Many different models (theories) have been developed in hope of adequately representing the nonequilibrium phenomenon occurring within congested vehicular traffic. The nonequilibrium behavior is caused by the actions and chain-reactions of drivers traveling within a section of congested freeway. These events ultimately rob a freeway of its traffic throughput potential. A satisfactory model could be universally used to study urban freeway situations in hope of maximizing their throughput. Unfortunately, at the time of this research, no single model of vehicular traffic has the overwhelming acceptance of the transportation research community.

The uncertainty surrounding the adequate representation of vehicular traffic is causing lengthy delays and wasted tax dollars by implementing solutions that have been inadequately engineered. This situation is by no means a result of incompetence, rather it is an effect of the complexity of the system being modeled and the modeler’s subjective interpretation of it. These two factors could theoretically result in a near infinite number of different vehicular traffic models. Therefore, future success in effectively
dealing with vehicular traffic problems (nonequilibrium) will unquestionably rely on the amount of common ground shared throughout the transportation research community.

The complex system encompassing vehicular traffic activities is characterized by variables numbering in the hundreds or possibly thousands (Bekey, 1971). Further complicating the identification (modeling) process is the fact that the boundaries between the particular system being studied and other systems are not distinct. Success in modeling is not measured by creating a bigger and/or more sophisticated representation but that it adequately answers the original questions for which it was developed (Wilson, 1984). Hence, each vehicular traffic model that has been developed could be considered successful if it represents what the modeler had originally intended. This fact makes it very difficult to objectively compare performances between models for validation purposes.

The complexity of the system encompassing vehicular traffic and the procedures of model building have resulted in microscopic, queueing theory, and macroscopic theories of vehicular traffic representation. Although each level represents vehicular traffic, the difference in model resolution naturally provides a distinct area of problem solving that a higher or lower aggregate level model may not accommodate. Therefore, no single aggregation level is considered as being the best for all possible instances of vehicular traffic representation.

The microscopic representations of traffic are commonly
referred to as car following models. These formulations are concerned with the response of each individual vehicle. The macroscopic theories represent traffic as a response based on averages of flow rate (volume), density, and speed. These models are commonly used to represent freeway traffic due to their direct applicability to long distances and large quantities of vehicles (Gerlough, 1964). Finally, queueing theory representations bridge the gap between microscopic and macroscopic levels. Basically, queueing theory representations model vehicular traffic as platoons of vehicle queues. They are commonly used in ramp control and particularly in gap merging control applications. However, the queueing theory models have historically not incorporated the large distances associated with an urban area's freeway system (Payne, 1984). Therefore, a macroscopic model, that effectively predicts the responses of congested traffic, might be presumed to be the most useful in improving an urban area's vehicular freeway transportation system.

B. Macroscopic Traffic Representation

Generally, macroscopic representations of vehicular traffic can be considered analogous to a stream of water. However, at this aggregation level the reaction of a specific water molecule (vehicle) is not considered important. What is of major importance is for the stream bed (roadway) to efficiently contain and transport the dynamic activity currently demanded of it. The identification of macroscopic
vehicular traffic is completely defined by the following variables $Q$, $k$, and $v$ which represent quantities of volume (vehs/hr), density (vehs/mi), and speed (mi/hr). For a given traffic stream these quantities can be determined in a number of different ways (Edie, 1965). Nonetheless, most macroscopic theories generally agree on the mathematical relationship between these quantities: volume = density * speed (Ross, 1988).

Typically, a model’s level of complexity decreases as the aggregation level increases. Thus, a macroscopic model will generally be less complex and will therefore run much faster than a microscopic model. Also, a traffic response occurring in the real world can always be considered as being somewhat random. A macroscopic model generally incorporates the description of traffic as an average response. Thus enabling the model to calculate a single average response rather than successively determining a comprehensive sample of possible outcomes for the current traffic condition. However, one drawback of macroscopic traffic models is that they are generally less accurate than the more minute aggregate levels of traffic representation (Gerlough, 1964).

A macroscopic representation of vehicular traffic is an analytic model whose variables have a hypothesized relationship (deterministic) and are time-dependent (dynamic). These types of models commonly incorporate differential equations as their modeling language (Wilson, 1984). Since traffic models are time and space dependent, the macroscopic
theories typically use partial differential equations. Most macroscopic theories use a partial differential equation commonly known as the "continuity of vehicles." This equation, similar to the conservation of mass, states that vehicles are neither created or destroyed as they pass through a freeway section (Lighthill & Whitham, 1955).

A common discrepancy between the different macroscopic theories involves a partial differential equation described as the "forcing function." This equation controls the rate at which the traffic attempts to negotiate the circumstances occurring within the roadway. The "forcing function" is actually the aggregated mechanism that attempts to represent the dynamic response associated with the forced deceleration and/or anticipated acceleration of a group of drivers. As mentioned earlier, this area of traffic research is so complex that every variable associated with a real-world response could never be substantiated. Hence, this activity is often represented differently depending on the researcher's subjective interpretation.

Although there are many theories concerning vehicular traffic, the progression of the scientific method will continue to develop "new" theories. Recently, a macroscopic traffic model named RFLO has been developed. It has been praised as simulating congested traffic faster and more accurately than any previous macroscopic model. RFLO's representation is innovative for two reasons: 1) traffic flowing with a density equal to $k_{\text{jam}}$ is explicitly recognized as being incompressible, and 2) no speed-density
relationship is contained in or implied by the traffic formulation (Ross 1988). If the praises are justified, RFLO could potentially be the "best" traffic model for resolving freeway traffic congestion problems.

The research representing this study was funded under the FHWA Grants for Research Fellowships (GRF) Program and entitled "Calibration of RFLO Traffic Simulation Program." The investigation was performed at the Turner-Fairbank Highway Research Center (McLean, VA) from June 15 to September 15, 1989.

C. Statement of the Problem

Consider the calibration of a macroscopic vehicular traffic model (RFLO) that has been praised as being faster and more accurate, for representing congested traffic, than the best previous models. If true, this model could benefit many urban areas throughout the United States. The calibration process requires that RFLO's performance be compared to actual congested traffic behavior data. The most extensive traffic data available, at the Turner-Fairbank Highway Research Center, was in microscopic form resulting from aerial photograph study entitled "Freeway Data Collection for Studying Vehicle Interactions." In order to accomplish the comparison procedures the vast amount of microscopic data had to be aggregated (averaged) to a user justified macroscopic level. The objectives and scope of this thesis are described below.
1. **Objective A**

To qualitatively calibrate the Relaxation Constant contained within the RFLO Traffic Simulation Program. The Relaxation Constant, appearing within the "forcing function," is inversely proportional to the rate at which the macroscopic traffic responds to circumstances occurring within the roadway. However, RFLO’s forcing function completely omits the disturbances (inefficiencies) caused by driver interaction which do appear within congested traffic. Therefore, is it possible for RFLO’s congested traffic responses to be less severe than what actually occurs in the real world? Investigating this question might reveal a significant shortcoming of RFLO.

2. **Objective B**

To provide a qualitative analysis that results in a justifiable estimation of the "best" aggregation level (averaging region) for the macroscopic representation of congested vehicular traffic. The results of this objective will be used in the attempt to calibrate the Relaxation Constant (Objective A). In general, microscopic theories pertain to each individual vehicle while macroscopic theories define traffic as average values (density, speed, and volume) without any previously justifiable advice on sample size. Therefore, is it possible to justify an averaging region, that best represents macroscopic traffic, by mathematically examining the effect(s) of various grouping sizes?
3. **Objective C**

To investigate the possibility of determining nonequilibrium activity by suggesting various three-dimensional representations of macroscopic traffic behavior. With the successful completion of determining the "best" macroscopic aggregation level (Objective B), could it be possible for nonequilibrium responses to be visually identifiable through direct data manipulation strategies?

4. **Objective D**

To suggest improvements concerning the aerial photographic traffic data that was used throughout the entire study. The magnitude of cost and time expended on this extensive form of data collection requires that its final usefulness be maximized.

**D. Theoretical Framework of Study**

As previously mentioned, the current research effort originated from the study funded by the Federal Highway Administration (FHWA). The primary goal of the FHWA study was the calibration of the parameter contained within the RFLO Traffic Simulation Program. It was decided that this investigation would employ vehicular data sets originating from a FHWA funded study entitled "Freeway Data Collection for Studying Vehicle Interactions." However, since RFLO is a macroscopic based model and the available data sets constitute microscopic traffic, an analysis was needed to qualitatively justify the aggregation level of the data.

The method used to justify the microscopic to macro-
scopic transformation will be referred to as the DX-DT Aggregation Analysis. The analysis is based on the Rational Subgrouping Concept which is commonly used in quality control applications. The concept states that subgroups (or samples) should be selected so that the chance for differences between subgroups will be maximized, while the chance for differences within a subgroup will be minimized (Montgomery, 1985).

The aggregation investigation is concerned with the "optimal" dimensions of a traffic response averaging region defined by an arbitrary section of congested highway (ft) and an arbitrary time interval (sec). As individual vehicles enter the roadway facility they can collectively be described as a subgroup of the entire traffic stream. By continuously monitoring the variability among vehicle speeds, within and between all subgroups while successively repeating the process with different DX and DT values, a "best" aggregation level may result. By using this "best" aggregation level, to perform the microscopic to macroscopic data transformation, each average speed value corresponding to a subgroup of vehicles will be associated with minimal variability. Hence, the average will represent the best macroscopic traffic (speed) estimate of what actually occurred within that time and location.

Once the aggregation intervals (time & space) are properly defined the calibration of the RFLO Traffic Simulation Model proceeds. The methodology developed for the calibration process is primarily concerned with data that repre-
sents accelerating vehicular traffic. Specifically, traffic initially flowing at low speeds (15 mph) that rapidly increase and climax at a much higher speed (55 mph) is of primary interest. It is believed that this scenario will provide the greatest potential feedback associated with the sensitivity and "best" value(s) for the parameter concerned (Relaxation Constant).

RFLO's representation of traffic activity and the aggregated real-world data are compared by creating three-dimensional contour diagrams of speed versus time and facility location. The comparison will be performed by calculating the mean and standard deviation of error(s) (difference) between the actual and predicted responses. Therefore, by strategically altering the parameter's magnitude the "best" value(s) will correspond to the resulting minimal mean and standard deviation of error.

According to information provided to this researcher by Ross, an estimate for the relaxation of traffic flow was determined to be approximately 0.006 hours. This estimate was determined by investigating freeway traffic flow accelerating away from a full stop at a traffic signal. Since this estimate includes real-world driver interactions, RFLO's "best" parameter value(s), found during the calibration process, is expected to be significantly greater than the aforementioned estimate.

As mentioned earlier, macroscopic vehicular traffic is completely defined by averaging the volume, speed, and density of a traffic stream. Three-dimensional contour graphs
of these quantities have been previously used to aid in the understanding of macroscopic traffic. Although these visual aids provide a great deal of information, could it be possible that other representations may prove to be more powerful?

Nonequilibrium behavior is normally associated with a significant deviation from normal operating conditions. Hence, a contour graph of standard deviations, associated with average speeds of actual macroscopic traffic, may provide clues to the existence of nonequilibrium. Also, a contour graph of the coefficient of variation and other data manipulations may unveil information concerning this performance robbing activity. Although these visual models are by no means difficult to comprehend the hardware and software, available at the FHWA facility, did not include any output devices capable of three dimensional graphics. This concludes the sequence for the research activity constituting this thesis.
CHAPTER II

REVIEW OF LITERATURE

The investigations constituting this thesis include the following: an Aggregation Analysis to justify the macroscopic level of traffic data, the Calibration of a Traffic Simulation Program (RFLO) parameter, and the manipulation of several three-dimensional visual traffic characteristic models that may reveal the performance robbing phenomenon known as nonequilibrium. Initially, the investigations may not appear to be interrelated. However, their common denominator is to simply learn more about the activities occurring within congested (macroscopic) traffic. Hopefully, the results of this thesis will contribute towards a more efficient methodology for managing vehicular traffic congestion.

A. Discussion of Macroscopic Theories

As mentioned in Chapter 1, a representation of vehicular traffic flow can be defined by the variables Q, k, and v which represent quantities of volume (vehs/hr), density (vehs/mi), and speed (mi/hr). These quantities are related by the following equation: volume = density * speed. Macroscopic models describe traffic as a simultaneous movement of a vehicle stream (Treiterer & Taylor, 1966). However, assuming the vehicular activity to be homogeneous throughout a congested traffic stream is unreasonable. In order to model congested traffic Payne (1984) developed a macroscopic
representation that assumes homogeneous vehicular activity within a finite unit of freeway length (DX). The set of traffic representations sharing this common assumption are known as aggregate variable models.

1. Conceptual Differences - RFLO vs. FREFLO

FREFLO, the model developed by Payne, is the macroscopic freeway component of the TRAFLO Simulation code. The FREFLO theory provides a more realistic representation of congested traffic behavior, than previous models, by eliminating a common "lockup" problem (Ross, 1988). However, the occurrence of impossibly high densities is a known problem of the FREFLO theory (Rathi, Lieberman and Yedlin, 1987).

A recently developed aggregate variable (macroscopic) model, named RFLO, has recently been praised as the best available model for representing congested macroscopic traffic (Ross, 1988). For RFLO, the maximum achievable traffic density is limited by the value $k_{jam}$. According to a discussion this researcher had with Ross, the estimate of $k_{jam}$ (143 veh/lane-mi) is the result of an investigation concerning the vehicular density of a slow moving queue. This restriction eliminates the previously mentioned "lockup" problem, associated with FREFLO, which developed from unbelievably high densities. An objective (A) of this thesis is to calibrate the Relaxation Constant that is found within RFLO. The calibration procedures may yield information to help prove or refute RFLO as being a superior traffic modeling theory.

The two aforementioned theories are composed of similar
and contrasting assumptions. Both theories use partial
differential equations to represent their time dependency
and hypothesized relationships between the variables con-
cerned. One such partial differential equation, represented
identically by both, is commonly referred to as the "conti-
nuity of vehicles." This equation represents vehicles as
being neither created or destroyed as they pass along a
freeway section (Lighthill & Whitham, 1955). A second par-
tial differential equation, referred to as the "forcing
function," has conflicting representations within each
theory.

The "forcing function" is a hypothesized mechanism used
to represent an average driver's acceleration/deceleration
response depending upon some of the following factors: actu-
al average speed, equilibrium/desired speed, relaxation
time, local-density, and downstream density. Basically,
this function represents the "program" that the average
driver follows while encountering (un)congested related
activities within a traffic stream. Specifically, will the
average driver, who is encountering congested traffic, rig-
idly adhere to the program he/she would have followed if
driving under ideal conditions (i.e. low density) or will
he/she adapt rigidly to the new conditions? The differences
between the models' "forcing functions" are attributed to
how their creators hypothesize this response.
2. Mathematical Differences - RFLO vs. FREFLO

The "forcing function" for each of the aforementioned theories is shown below:

\[
\text{(FREFLO)} \quad \frac{\partial v}{\partial t} + v \frac{\partial v}{\partial x} = \frac{[F(k) - v]}{T} - \frac{(g/T) \partial k}{\partial x} \\
\text{(RFLO)} \quad \frac{\partial v}{\partial t} + v \frac{\partial v}{\partial x} = \frac{(F - v)}{T}, \; k < k_{jam};
\]

where: \( F \) = equilibrium/desired speed (mph), \( T \) = Relaxation Constant (hrs), \( g \) = anticipation constant (m^3ph), and \( k_{jam} \) = maximum achievable density (veh/mi).

For both equations, the terms left of the equal sign represent the acceleration of traffic as experienced in a frame of moving vehicles (Ross, 1988). The first term, right of the equal sign, arises from the actual traffic speed being unequal to its equilibrium or desired speed. Hence, causing the acceleration or deceleration of a magnitude directly proportional to the difference between the desired and actual speeds.

The first term, right of the equal sign, differs considerably between theories and/or "forcing functions." In RFLO, an assumption is made that the traffic's desired speed is independent of any density relationship. This is based on recent observations that congestion does not reduce the desired traffic speed of drivers. It may reduce the actual traffic speed but the drivers continue to desire to travel at the desired speed of the freeway (Ross, 1988). However, FREFLO speculates that the desired speed of a traffic stream is dependent upon its current density. FREFLO also assumes
that the actual traffic speed will always tend to return to the equilibrium speed-density curve. Therefore, in reality RFLO assumes a rigidly followed low-density response program while FREFLO assumes a more flexibly followed speed-density response program.

The FREFLO model incorporates a second term into its "forcing function." This term is used to help represent the inefficiency caused by driver interaction. This term equates the average concentration difference, between the current and next downstream section of freeway, to the driver's programed response. The magnitude and sign of this concentration difference will cause the drivers in the current section to alter their response programs. The RFLO model excludes any explicit representation of driver interaction. Hence, RFLO's "forcing function" refers to a freeway with dilute traffic (Prigogine and Herman, 1971). This fact could theoretically eliminate congested traffic activity from RFLO's modeling domain. Hence, RFLO's representation of congested traffic flow may be too simplistic as to what might actually occur in the real-world.

The objective concerning this investigation (A) is the Calibration of RFLO's Relaxation Constant. According to a discussion this researcher had with Ross, an estimate of this parameter was found to be 0.006 hours. This estimate was determined by examining the speeds of vehicles accelerating away from a freeway stop light. These responses contain real-world vehicle interactions such as "propagating starting waves." For this reason the calibrated value of
RFLO's Relaxation Constant is expected to be larger than the previous estimate due to the model's implicit assumption that congested traffic responds as quickly and efficiently as dilute traffic. The larger value will tend to retard the more efficient (predicted) response when being compared to the real data. The magnitude of this difference may further introduce skepticism into whether RFLO is genuinely applicable to congested vehicular traffic.

B. Discussion of DX-DT Aggregation Analysis

The theories pertaining to RFLO and FREFLO are built upon the aggregate variable model concept. This concept suggests that a continuous and nonhomogeneous stream of traffic can be quantitatively represented by segmenting it into homogeneous sections of finite length (Payne, 1984). However, neither Ross nor Payne have provided justifiable estimates concerning this quantity of length.

The variables that define macroscopic traffic are only meaningful as averages (Edie, 1965). The averaging equations, used to calculate these quantities, vary widely depending on the circumstance of data collection. Research performed by Edie (1965) provides general guidelines for determining the appropriate averaging equations. For each data collection situation discussed the size of the two-dimensional averaging region (time & space) was considered extremely important. So important, in fact, that the recommended averaging equations depended greatly upon the "short" and/or "long" quantities of length and time associated with
the averaging region. However, no quantifiable estimate of "short" or "long" was provided by Edie (1965).

Since macroscopic traffic is defined by quantities averaged in two-dimensional space, three-dimensional visual representations have previously occurred. These visual representations generally incorporate time and distance as their x and y-axes (averaging region) while the averaged quantity lies along the z-axis. The amount of information portrayed, by the visual model's contour, will depend upon the relative size of the averaging region and consequently the sample size. However, historically the justification of averaging regions have been based on the "good judgement" of a researcher’s visual perception rather than a formal computation (Makigami et al, 1971).

At this point it should be evident that the averaging region, associated with macroscopic traffic, has not previously been qualitatively investigated. In engineering "good judgment" is dependent upon mathematical calculations and a large safety factor. However, in developing a better understanding of traffic congestion (nonequilibrium) the need for a strong foundation is critical towards the effective progression of the scientific method. For instance, how can models be effectively theorized when the collected traffic responses being studied do not favorably represent the actual activity? Hence, the objective of this specific investigation (B) is to analyze the possibility of a "best" DX-DT aggregation interval by using a formal computation.
C. Discussion of Macroscopic 3-D Visual Models

The visual representation of macroscopic traffic is not a new discovery. In fact, a two-dimensional contour diagram representing vehicular densities was being used by the 1960's (Wagner & May, 1963). Many of the studies associated with visual models have used data resulting from aerial photography. This method of data collection can capture a tremendous amount of information with each frame of film and is very appealing for studying vehicular traffic activity.

A three-dimensional visual model was first proposed by Haynes while considering the relationship between volume, speed, and density. In this case, a visual model was constructed for each macroscopic traffic variable by using aerial photographs from a study of freeway surveillance control (Makigami et al, 1985). Although the size of the averaging region was never justified the visual models were determined to be very helpful.

The objective of this specific investigation (C) is to suggest potential (three-dimensional) visual models and their ability to provide information for suspecting nonequilibrium traffic behavior. The ability to visually detect nonequilibrium activity could be used to change the characteristics of a traffic stream before the potential for gridlock occurs. This tool would also be helpful to traffic researchers attempting to locate nonequilibrium activity within a large traffic database such as the one used throughout this thesis.

The results of the DX-DT Aggregation Analysis will
provide the best representation of vehicular speeds and possibly volume and density. This by itself should yield a more descriptive relationship between volume, speed, and density. However, the primary purpose of the investigation is to manipulate the macroscopic traffic data to provide a quick determination of the activity concerned.

Obviously, the possibility of nonequilibrium activity occurring within a large observed density deserves merit. However, could it be possible for a visually detectable signal of nonequilibrium to be associated with the variability of vehicle speeds (average)? Likewise, could the coefficient of variation, with respect to vehicle speeds, provide clues concerning the stability of the transportation medium? These, and other possibilities will be theorized in hope of discovering a visual model(s) that will provide valuable traffic information to future researchers.
CHAPTER III

SUMMARY OF TRAFFIC DATA USED DURING RESEARCH

The research activity constituting this thesis was conducted with traffic data previously collected from a study sponsored by the Federal Highway Administration (FHWA). The study, entitled "Freeway Data Collection for Studying Vehicle Interactions," was performed by JHK & Associates of Alexandria, VA. The objective of the data collection study was to develop a series of data sets representing microscopic vehicular traffic flow for selected types of freeway bottleneck sections. The methodology used in developing these data sets involved the digitizing of vehicle positions from time-lapse aerial photography. The purpose of this chapter is to provide an overview of the data's origination and format.

Although the data sets represent microscopic vehicular traffic flow, much of this thesis is based on a DX-DT Aggregation Analysis (Objective B). The Aggregation Analysis is concerned with justifying the "best" dimensions of an averaging region $A_n$, defined by arbitrary lengths of highway (ft) and time (sec), for calculating values of macroscopic speed as shown in Figure 1. This analysis would not be possible if this data had been originally collected to represent macroscopic vehicular traffic. The calibration of RFLO (Objective A), a macroscopic traffic flow model, will be
Fig. 1. Explanation of a Macroscopic Speed Being Calculated From an Area, $A_n$, of Arbitrary Size (DX, DT) in the Vehicle Trajectory Plane ($x$, $t$).
performed after aggregating the extensive microscopic data to a justifiable macroscopic level.

A. Data Collection Methodology

1. Aerial Photography

In order to investigate the flow of microscopic traffic, in freeway bottleneck sections, detailed vehicle trajectory data are required. Microscopic traffic data is the most difficult type to obtain since each vehicle’s position must be defined often, every 1 to 3 seconds, and throughout every freeway section (Smith, 1985).

The data collection methodologies using axle detectors and/or tape switches are impractical due to the number of detectors needed to effectively distinguish each vehicle’s trajectory from within the congested traffic. An alternative method is for vehicles to be tracked through a freeway section by recording their positions, at discrete points in time, through aerial photography. From two successive photographs a vehicle’s average speed can then be determined by the distance traveled during the time elapsed.

2. Equipment Used

The methodology used to collect the vast amount of vehicular data required numerous pieces of equipment. Pilot experiments were used to help ensure that the system of equipment chosen would produce the required results. A detailed description of the equipment configurations considered can be found in the final report by Smith (1985).
a. **Aircraft Used.** A Helio-Courier STOL (Short Take-Off and Landing) aircraft was selected for the data collection process. Some factors influencing this selection included the need for: a stable filming platform, a tight circling radius around the freeway site, and the ability to fly safely at speeds of 30 to 40 knots.

b. **Camera Used.** A Flight Research Model 207 camera was selected for the data collection process. The camera was equipped with an industrial grade Nikkor (35 mm) focal length lens and auto exposure control. The exposure attachment was necessary to minimize the disruption caused by the constantly changing angle between the camera lens and sun.

c. **Film Used.** A full-frame (35 mm) format was used in the photography process. A (35 mm) color negative film (Eastman 5247), with a 250 ASA rating, was selected. Color film was required to help identify the identical vehicles from frame to frame in the reduction process. Negative film was used for a greater range in exposure settings and since the per frame expenses were less than for color reversal film. To benefit the reduction process each frame number, associated with the data collection process, was superimposed on the film's image. Finally, a relatively fast film was required to allow for the use of a rapid shutter speed (1/500 sec) which minimized the blurring effects of both aircraft vibration and vehicular motion (Smith, 1985).

d. **Temporary Landmarks Used.** Prior to filming, a set of
targets, which would be visible in the film, were placed along the shoulders of the roadway. The relative position of these targets was established through a ground survey. The targets were made of a dayglow orange material, square in shape (3-4 ft), and affixed to the pavement through nylon mesh permanently attached along each landmark’s perimeter. The purpose of the targets was to establish a ground coordinate system, in the plane of the roadway, which could be used in the digitizing process to calibrate the scale and orientation of each photograph (Smith, 1985).

3. Site Selection Criteria

The site selection process used a set of criteria to measure the profitability of each site for future traffic research. The characteristics of both the site itself and the traffic conditions generally occurring within the site were considered throughout the selection process.

A potential site had to contain one or more of the following geometric configurations: ramp merge, weaving section, upgrade section, reduced width section, lane drop, and/or horizontal curve (Smith, 1985). These geometric features had to be fully, or partially, the cause of recurrent traffic congestion. Also, a potential site had to provide for the possibility of including the transition period between uncongested and congested flows for it to be considered. Finally, each site’s normal congestion could not be the effect of a condition occurring downstream.

The metropolitan areas of Washington, D.C. and Los Angeles, CA. were designated as areas for acceptable filming
sites. Initially, 54 sites were identified and later reduced to the 18 sites actually filmed. Of the 18 sites filmed, 14 are available as data sets with no further explanation, given by Smith (1985), to the discarded 4 data sets.

4. Filming Procedures

The data collection (filming) procedures occurred between May 25 and June 17, 1983. The filming was conducted primarily in the afternoon (p.m.) peak traffic periods due to photographic problems caused by low sun angles during the peak morning (a.m.) periods. With a one-hour filming duration, an effort was made at each site to start filming at a time having the most likelihood of capturing the transition from light to heavy traffic flow. Determining this time instant quickly became the most difficult decision concerning the scheduling process (Smith, 1985).

Prior to filming the set of aforementioned landmarks were set out and attached to the roadway surface. Each landmark pair were generally located across from one another. Typically, four landmark pairs were used on each section of roadway. For each filming period the camera was angled out the rear pilot-side door of the aircraft, while both the camera operator and pilot held the responsibility of keeping the freeway section continuously in view. Each site was filmed at approximately one frame per second, with the aircraft flying clockwise at a slow speed around each site at altitudes ranging between 2,500 and 4,500 feet.
B. Data Reduction Methodology

1. Digitizing System Equipment

The data reduction system, used in the aerial photograph study, consisted of the following equipment: a digitizing tablet and processor, a microcomputer and terminal, a voice synthesizer, and a 35 mm full-frame filmstrip projector. The equipment was used to effectively extract vehicle trajectories, associated with a roadway section, from the aerial photographs taken.

a. Microcomputer Used. A SAGE IV microcomputer was used in the data reduction system. This microcomputer had 512 kB of internal (working) memory and an 18 MB hard disk. It was operated under a multiuser configuration enabling two digitizing systems to be operated simultaneously which decreased the time necessary to extract the data from each film.

b. Computing Language Used. The programming language UCSD Pascal was used throughout the system.

c. Digitizer Used. A Calcomp Series 6000 rear projection digitizer was configured into the data reduction system. The digitizer consists of a digitizing tablet, processor, and cursor pad. Their combined function is to transmit the x and y coordinates, of any point projected on the tablet, to a computer when instructed by the operator via the cursor pad.

d. Projector Used. An Apollo Viewlex V-25 film projector was selected to be used. The projector used a 3 inch (76
mm) focal length lens and was located approximately 6 feet to the digitizing surface. The projector was positioned so that the line passing through the lens center was perpendicular to the surface of the digitizing tablet.

e. **Speech Synthesizer Used.** An Echo GP general purpose speech synthesizer, manufactured by Street Electronics Corporation, was used in the system. This device enabled the system operator to receive instructions from the computer without having to take his or her eyes off the digitizing tablet. This component helped to reduce the amount of operator fatigue accumulated during the data reduction process.

2. **Digitizing Procedures**

The procedures enabling an operator to effectively reduce a site's aerial photographs, into quantifiable vehicle trajectories, can be separated into the following three activities: 1) activities occurring at the beginning of each film, 2) activities occurring during the initial frame of the film, and 3) activities occurring at each subsequent frame of the current film. A summary of the activities occurring in each of these reduction periods is provided below.

a. **Initial Frame Preparation.** At the start of a site's film, the ground coordinates of the control points are entered into the computer program. These coordinates were previously identified through a survey performed on the plane (ground) that contained the targets. After compila-
tion, the program is executed and the aforementioned four pair of control points are digitized using the initial frame of the aerial photographs. This procedure was needed to calibrate the coefficients of various equations required in the film-to-ground and ground-to-highway coordinate transformations. Following the calibration, a fifth point whose ground coordinates are known is digitized. The fifth point is used as an error checking device to ensure the calibration yields a satisfactory minimal error else the operator reperforms the calibration process.

After a successful calibration, the geometry of the freeway section is digitized. This procedure entails the identification and isolation of homogeneous geometric subsections of the facility (freeway). Upon the identification of a straight subsection the operator defines its length by digitizing the endpoints at the right edge of the pavement. A curved subsection is defined by digitizing endpoints along the pavement’s outside edge with a single point representing an origin of the curve’s radius.

At this time the preliminaries are over concerning the beginning of the film. Therefore, if the center of a vehicle’s front bumper is digitized the ground-to-highway coordinate transformation process can determine its current longitudinal and latitudinal location within the roadway section for that time instant (frame).

b. Activity During Initial Frame. After the previous procedures are completed, the operator’s attention then focuses on the vehicles contained within the first frame of film.
Initially, the operator must define all the vehicles appearing in this first frame. This is accomplished by digitizing the front and back of each vehicle appearing within the roadway section. Each vehicle’s color, type, and lane are entered, proceeding from vehicle to vehicle, in an upstream direction. Any errors that were detected by the system (or operator) are corrected and the operator ends the digitizing of the initial frame by entering an exit code. After exiting, the microcomputer sorts the data records by longitudinal position and stores them to a file on the hard disk.

c. Activity During Each Subsequent Frame. The digitizing of each subsequent frame of film begins with the operator entering (via the keyboard) the next frame number to be digitized. The aforementioned four pair of control points are then digitized, and following a computer calibration that determines the scale and orientation of the frame, a fifth point with known ground coordinates is used to check the calibration.

Following a successful calibration the computer recalls the most downstream vehicle, digitized in the previous frame, and through the voice synthesizer prompts the operator with the following items of information: 1) the color of the vehicle, 2) the vehicle type, and 3) the lane which the vehicle is traveling in. Based on this information, the operator would locate the vehicle by initializing his/her search at the downstream end of the freeway section.

After locating the vehicle, the operator records its
position by pressing a key while the digitizing pad's cross-
hair is over the center of the front bumper. The computer
then performs the film-to-ground and ground-to-highway
coordinate transformations and performs a series of checks
to screen out any possible errors made by the operator.
Provided the computer finds no errors, a new record is
created and written to a file contained in the computer's
working memory. The new record includes the frame number,
the unique ID for that specific vehicle, the vehicle's
lateral and longitudinal position, and other data such as
the vehicle's color, type, and length. If a vehicle has
passed through the defined freeway section, when requested
by the voice synthesizer, the operator informs the computer
of this by pressing a button on the cursor pad.

The computer then prompts the operator with the next
upstream vehicle which the operator then attempts to locate
in the current frame as was done for the first vehicle. The
digitizing proceeds in the upstream direction until all the
vehicles which appeared in the previous frame are digitized
in the current frame or otherwise accounted for. The
vehicles that have entered the section since the previous
frame are then digitized in an upstream direction.

Each new vehicle's color, type, and lane number are
entered by using the digitizer's cursor pad. The vehicle's
length is obtained at this point by digitizing the center of
the front and rear bumpers. When all the new vehicles have
been digitized the computer checks for any errors. The
operator subsequently ends the digitizing of that frame by
entering an exit code after which the vehicles are sorted by unique identification and longitudinal position and appended to the file on the hard disk.

At this point the digitizing process can continue by selecting the next frame or the process can be ended and the data file closed. If the operator continues the process, the "each subsequent frame" activities would then be repeated until the digitizing process was complete or until the operator decided to halt the process.

3. Digitizing Personnel

The employees involved in the data reduction process were primarily temporary personnel since most were students at local colleges and universities within the Virginia area.

a. Training Involved. Each operator was given a training session of approximately four hours. The session included the explanation of the procedures that each operator was expected to perform. Following the training session, each operator was carefully observed during the initial stages of the operations to ensure that the quality of their work had reached the expected standards.

b. Operator Fatigue. Originally there was great concern that the tedious aspects of the digitizing process would quickly create operator fatigue. If this were to occur it would ultimately constrain the digitizing process to short sessions before a break was necessary. However, the digitizing was found to be considerably less tiresome than expected and many of the operators could work a full 8-hour
day while taking only "normal" breaks. This unanticipated reduction in fatigue could be partially attributable to the voice synthesizer although the manner in which the fatigue was measured is not mentioned in the report.

c. Digitizing Rate. The digitizing process was a tedious operation and worsened as the quality of the film decreased. As mentioned earlier the use of the multiuser configuration enabled the data reduction process to progress at twice the rate then would have been otherwise possible. The use of earphones allowed each operator to hear his/her synthesized messages without disturbing one another. Each digitizing tablet was used approximately 60 hours per week to further accelerate the data reduction process. However, even at this rate the digitizing of 14 films required 18 months. Assuming minimal need for error corrections the time to digitize one frame of film, according to Smith (1985), would ordinarily take between 4 and 12 minutes depending upon such factors as section length, number of cars, and overall film quality.

4. Problems Encountered

The majority of problems encountered in the data reduction methodology were discovered and eliminated in a pilot study which preceded the data set development. However, several problems were unavoidable and had to be tolerated by the operators. For example, sections of asphalt pavement tended to be more difficult to digitize because of the greater difficulty in seeing dark-colored vehicles on the
dark pavement. Hence, better contrast was achieved on concrete sections of roadway.

Another problem arose from the circular flight path of the aircraft. As the aircraft circled the roadway a large vehicle positioned in the near lane, with respect to the aircraft, would visually block any of the vehicles traveling alongside it. This required the data reduction operator to estimate the hidden vehicles' locations which ultimately contributed to the amount of noise (error) included in the data set (Smith, 1985).

5. Digitizing Accuracy

The accuracy of each vehicle's longitudinal and lateral positions are dependent upon a multitude of factors. For instance, as the points being digitized become farther from the nearest control point pair the higher the error is likely to be. Points digitized close to a control point pair will be subject primarily to operator errors in placing the cursor's cross-hair over the true position of the vehicle.

With the above mentioned errors in mind, the overall positional error for a vehicle was estimated to be 5 feet in the longitudinal direction and 3 feet in the lateral direction (Smith, 1985). If the errors are assumed to follow a normal distribution, the aforementioned estimates of deviation imply a mean positional error of approximately 15 feet in the longitudinal direction and 9 feet in the lateral direction. These estimates are made by presuming that
99.73% of the normally distributed values fall within the six-sigma limits defined by Montgomery (1985).

C. Description of Data Sets

1. Format of Data Sets

The data sets, created as a result of the digitizing process, represent microscopic vehicular traffic flow within freeway bottleneck sections. The format of these data sets can be seen in Figure 2. The data in this figure represent the traffic flow on Roscoe Boulevard (Van Nuys, CA.) during a portion of the filming period. A sketch representing Roscoe Boulevard’s geometric features can be viewed in Figure A-1. This freeway section has 1,788 feet of four-lane mainline as well as an acceleration lane available for merging traffic.

The format of the data sets resemble a two-dimensional array. Each row (record) of the array represents a single vehicle while each of the nine columns (fields) represent characteristics pertaining to that vehicle. The first field specifies the film’s frame number in which the current vehicle has been recorded. The second field specifies the current vehicle’s identification (ID) number. This identification number is unique to that specific vehicle and is the only number that is used to identify it. The third field represents the vehicle’s type (i.e. sedan, truck, etc.). The fourth field specifies the length of the vehicle (ft), while the fifth field defines the vehicle’s speed (mph).

The quantity of speed, contained within the fifth
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<th>Distance From Start Of Section To Front Bumper Of Vehicle</th>
<th>Distance From Right Edgeline To Middle Of Vehicle's Front Bumper</th>
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### Key To Fields

- b - Blank Field (space)
- 1 - Frame Number
- 2 - Vehicle ID
- 3 - Vehicle Type Code
- 4 - Vehicle Length (ft)
- 5 - Vehicle Speed (mph)
- 6 - Distance From Start Of Section To Front Bumper Of Vehicle.
- 7 - Distance From Right Edgeline To Middle Of Vehicle's Front Bumper.
- 8 - Vehicle Color Code
- 9 - Lane Number (Right Lane= Lane 1).

Fig. 2. Sample of the Formatting Used to Retain the Microscopic Traffic Information for Each Data Set (Roscoe Blvd).
field, is determined by locating the specific vehicle within two successive photographs. The average speed is specified by the distance the vehicle has traveled between the current and previously recorded instant of time (1 sec). Hence, the speed associated with the vehicle, when frame 149 was recorded, is actually the average speed of the vehicle during the time (frame) interval: $148 \leq t \leq 149$.

The sixth field specifies the longitudinal location of the vehicle (ft) measured from the beginning of the freeway section to the middle of the vehicle’s front bumper. The seventh field specifies the latitudinal location of the vehicle (ft) as measured from the right edgeline of the roadway to the middle of the vehicle’s front bumper. The eighth field specifies a numeric code that pertains to the color of the vehicle while the ninth field and final field specifies the lane number that the vehicle was traveling in when the photograph was taken.

2. Precautions for Data Analyses

Due to the vast amount of data recorded, virtually any measure of traffic performance can be derived from the data sets including measures such as: lane change frequencies, lane change gap acceptance, and car-following characteristics (Smith, 1985). Obviously these data sets can potentially provide a tremendous amount of information to the traffic research community. However, there are some important precautions to keep in mind when analyzing any of these data sets.

First, conclusions based on the analysis of one site
are not necessarily valid for other sites of the same type. The reasoning behind this is that there are many factors that can effect traffic flow that these data sets do not quantify. Secondly, Smith (1985) suggests using a smoothing algorithm to minimize the noise (error) that is included with the true signal.

Third, in some cases, vehicle positions were estimated because of shadows and/or obstructions (other vehicles). If these estimates proved to be incorrect the vehicle would be accelerated or decelerated, within the limits of normal vehicle operation, until the digitized vehicle’s approximated position converged upon the actual vehicle’s location. Obviously, these particular estimates contributed to the amount of noise included in the collected data.

Fourth, as mentioned earlier, the ID numbers were assigned to vehicles in a sequential order. However, due to a shadow or spot, appearing on the film, the operator often assumed a vehicle when one did not actually exist. Therefore, some ID numbers may not appear within the data set due to their subsequent removal provided the operator or computer identified the mistake.

Fifth and finally, for the sites having on/off-ramps, ramp vehicles were added or deleted from the roadway section at the point where the ramp actually merged or diverged to/from the mainline (Smith, 1985). Therefore, although a ramp may appear in a figure, representing the geometric characteristics of a facility, no vehicular traffic behavior is included in the data set for that portion of roadway.
3. Requesting a Data Set

Each data set, resulting from the previously mentioned photographic collection study, is available on 9-track magnetic tape from the: FHWA Office of Research, HSR-10, Turner-Fairbank Highway Research Center, 6300 Georgetown Pike, McLean, Virginia 22101. Persons interested in obtaining copies of one or more data sets should write to the FHWA at this location.
The research activity representing this thesis was conducted with traffic data previously collected during a study funded by the Federal Highway Administration. The purpose of this chapter is to document the errors found in the data and suggest refinements which would further enhance its usefulness.

The data study resulted in fourteen individual representations of microscopic vehicular traffic flow for various types of freeway bottleneck sections. The research comprising this thesis is based on three of these data sets. The decision of which data sets to use was based on the following three factors: 1) the geometric configuration of the site, 2) documentation (final report) concerning any incidents occurring during the filming period, and 3) a time constraint limiting the number of data sets that could be effectively used.

The following three data sets were selected to be used in the research effort: Roscoe Boulevard, Backlick Road, and Mulholland Drive. The geometric configurations of these data sets can be seen in Figures A-1, A-2, and A-3. The following documentation of errors and refinements are explicitly associated with these three data sets. However, these observations can objectively construe the probable
improvements needed for each of the fourteen data sets.

A. Errors in Data Sets

1. Inconceivable Speeds

Each data set (file) has a defined length equal to the number of records (rows) contained within it. Every record has a length of 9 fields, one of which pertains to the speed (mph) of a specific vehicle. Each vehicle’s speed is determined by the longitudinal distance it travels between two successive photographs which are separated in time by one second.

The concept of inconceivable speeds is based on the presumption that a single vehicle is unlikely to be traveling, in dense traffic, at a speed near the magnitude of one-hundred miles per hour. Furthermore, a vehicle traveling at this high speed, for a short period of time (1-3 sec), signifies a peculiar event when the resultant acceleration and/or deceleration is considered. Hence, these occurrences resulted in the examination of vehicle trajectories to ensure the large speeds were not in error. The vehicle speeds that were proven to be correct (feasible) are not to be considered inconceivable. Only a high speed, occurring within a vehicle trajectory, that obviously originated by error is to be considered as being inconceivable. For example, a vehicle accelerating from 63 to 90 mph in one second is obviously in error.

The inconceivable speeds associated with each original data set can be seen in Table 1. Each of the inconceivable
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Table 1. Inconceivable Speeds Found Within the Original Roscoe Boulevard, Backlick Road, and Mulholland Drive Data Sets.
speeds were corrected before the research effort advanced in any detail. However, an original copy of one of the fourteen data sets, obtained from the Federal Highway Administration, will contain these errors.

2. Vanishing Vehicles

Each data set contains trajectories, sampled at one second intervals, for all vehicles entering the freeway section during the one hour filming period. As mentioned in the digitizing procedures (Chap. III) problems arose from operators mistakenly digitizing a shadow or spot as a vehicle. This mistake may have gone unnoticed for that specific frame. However, as the traffic flow progressed downstream, during successive frames, it should become evident to the operator or computer that a vehicle had been defined incorrectly. If the mistaken vehicle is not completely erased from the data file, the result will be the vehicle's abrupt disappearance somewhere within the freeway section boundaries.

The occurrence of this error has been discovered in each of the data sets used. These errors were discovered while examining a vehicle trajectory for inconceivable speeds. An obvious result of this error will be the overestimation of traffic volume (vehs/hr) in the effected upstream portion of the freeway. An error checking algorithm could have easily identified these vehicles during the digitizing procedures and/or before the completion of each data set. In either case, by simply cross-referencing
vehicle identities, speeds, and longitudinal locations, between digitized frames, an error would be detected when a vehicle unexpectedly disappeared from the freeway section’s boundaries.

The vanishing vehicles discovered in each original data set can be seen in Table 2. These vehicles were erased from existence, throughout the associated data set, before the research constituting this thesis progressed. However, it should be mentioned that each data set was not examined specifically for vanishing vehicles. In each case the examined area was believed to be the location of an inconceivable speed. Therefore, there is reason to believe that more vanishing vehicles exist, in the three data sets, even after the streamlining procedures. Also, the aforementioned tables reveal, upon careful observation, that there is a tendency for these two errors to occur together or even one error being the cause of the other.

3. Inconsistent Formatting

The digitizing procedures consist of three primary activities: 1) activities occurring at the beginning of each film, 2) activities occurring at the first frame of the film, and 3) activities occurring at each subsequent frame. A detailed description of the digitizing procedures is provided in the previous chapter (III). The second activity includes the digitizing of each vehicle appearing in the first frame of the film. Upon completion of the second activity each vehicle’s identification number, type, length, position, and color are explicitly defined. However, each
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Table 2. Vanishing Vehicles Identified Within the Original Roscoe Boulevard, Backlick Road, and Mulholland Drive Data Sets.
vehicle’s speed is undefined because only the current positions are known. Therefore, all records associated with the first frame of a data set should have speeds equal to zero (undefined). This however, is not the case with the Mulholland Drive data set as can be seen in Figure 3.

The inconsistent format that is used for the Mulholland Drive data set only effects the records associated with the first frame of film. However, this discrepancy between data set formating could easily lead to erroneous results and/or the frustrating setback of a researcher. For this reason it is hoped that future data sets being developed attempt to eliminate inconsistent formatings in order to maximize the usefulness and versatility of the traffic data.

B. Other Refinements Needed

1. Speed Assignment Bias

The data collection procedures (filming) capture each vehicle, sampled at one second intervals, as it travels through the freeway section. The filming lasted approximately one hour in duration for each data set. The Roscoe Boulevard data set, developed by digitizing approximately 3,600 separate frames of film, consists of nearly 180,000 records. Each of these records include a definition of a specific vehicle’s location and speed at a point in time.

A histogram for the vehicle speeds occurring within the Roscoe Boulevard, Backlick Road, and Mulholland Drive data sets are shown in Figures A-4, A-5, and A-6. The data portrayed in these figures have had the aforementioned
Fig. 3. Inconsistent Formating Between the Mulholland Drive's Vehicle Speed Field (#5) and the Remaining Data Sets.
errors removed. When creating a histogram, it is not recommended to group a vast amount of data into narrow cells (Montgomery, 1985). However, in this case the objective is to show the speed data in detail to demonstrate a tendency that needs to be refined. With respect to the vehicle speed data, the distributions are roughly symmetric and bell-shaped. However, a very interesting phenomenon can be seen from each of these histograms. It appears that there was a tendency for vehicle speeds to be calculated (rounded) as even quantities near the central region of each distribution and as odd quantities near each distributions' tails. The severity of this problem is most likely minimal. However, this simple refinement may increase the user's confidence in the vast amount of data.

2. Vehicle Speed-Position Misconception

Determining a vehicle's speed, through aerial photography, requires two successive recordings of known vehicle positions and the time elapsed between recordings. For example, if a vehicle's longitudinal location is known at both time $T$ and at time $T+S$, a measure of speed can easily be determined. In the current data study, this speed quantity is associated with the vehicle's longitudinal location at time $T+S$. This implied association is theoretically incorrect because the speed quantity determined is actually the average speed of the vehicle during the time interval $T < t \leq T+S$, not at the instant of time $T+S$.

This misrepresentation would surely cause larger
problems if \( S \) were to represent a value greater than one second. For this reason, it is hoped that any future aerial photographic traffic data collection procedures will, at the very least, explicitly describe the aforementioned relationships to help ensure that the user understands the origination and qualitative consequences of the speed term being used.

The research activity representing this thesis resolved the speed definition discrepancy. By displacing each vehicle from its recorded longitudinal position to a longitudinal midpoint, which exactly corresponds to the theoretical location of the vehicle's average speed, a more accurate trajectory is believed to have been developed. A more detailed description of this procedure is given in the following chapter (V).

3. Inadequate Uncongested Flow

A primary objective of the data collection study was to capture the transition from noncongested to congested traffic flow (Smith, 1985). The methodology used to attain this goal was based on the surveillance of each selected freeway section. The inspection process was judged complete when a satisfactory estimate of the starting time had been determined.

After examining the three data sets used in this research activity, the aforementioned objective was obviously unsuccessful. Typically, one-sixteenth of each data set represented noncongested free-flowing traffic. This minimal amount of free-flow data is an extremely disappointing and
is an inadequate result of the data collection study.

Traffic is an extremely complicated process during periods of congested flow. Hence, a typical research effort will begin by examining a stable transportation medium for a specified facility. However, this is not a possibility while using these specific data sets. An obvious solution to this problem would have been to film the freeway section for a longer period of time. Ironically, just prior to filming it was decided to photograph two separate freeway sections with a single (1000 ft) film magazine. This decision was made to reduce the short term costs associated with the data collection procedures (Smith, 1985). However, the long term costs of this decision may far outweigh any savings that may have occurred.

4. Insufficient Site Information

Each freeway section was selected by using a set of criteria to measure its potential profitability for future traffic research. Each site was then examined to identify a time period that would enable the uncongested and congested flows to be captured within the limited one-hour time span. Hence, a significant amount of time had been spent studying each possible site.

In actuality, the data collected during the filming process only represents a small sample of each site’s traffic characteristics. The data sets would provide much more information if an attempt had been made to explain each site’s significant characteristics in more detail. For
example, even though each site was considered as being a bottleneck no quantitative estimate of site capacity was provided. Likewise, an estimate of the average vehicle speed distribution, associated with low traffic flows, would have been extremely helpful. Although a realistic microscopic traffic representation was the primary goal, the extra amount of time and money needed to determine this information would enable a traffic researcher to develop a more qualitative assumption of the traffic behavior in each freeway section.

5. **Warnings of Estimates**

During the digitizing process the operator occasionally estimated the actual location of a vehicle. This became necessary due to the visual obstructions appearing in the film’s image. In some cases a considerable amount of error is assumed to be included in these estimates. For research purposes, where quality traffic data is essential, the opportunity to eliminate estimates would enable greater utilization of the traffic data. This improvement could easily be realized by marking an estimated value in an explicit manner. Hopefully, this and all other aforementioned enhancements described will be used in future traffic data collection schemes.
CHAPTER V

DATA SET STREAMLINING

METHODOLOGY

The research activity constituting this thesis involves the use of four traffic data sets developed from time-lapse aerial photography. Each data set captures one hour of microscopic vehicular traffic activity occurring along a specifically chosen freeway section. The purpose of this chapter is to describe the methodology used in streamlining these data sets from the errors and misrepresentations they originally contained.

A. Minimizing Size of Data Sets

Each data set was originally contained on a 9-track magnetic tape. A Sun workstation, equipped with a tape drive, was used to copy each data set from the 9-track tape to the workstation’s hard-disk. Typically, a single data set (ex. Roscoe Boulevard), originally in ASCII format, required 6.3 megabytes of computer memory. An external data file of this size could easily cause storage and/or processing problems. For this reason, each data set was reformatted as a binary-sequential data file to maximize the available computer memory and minimize the total processing time associated with the required multiple I/O procedures.

The reformating procedure entailed the creation and execution of the HexBin.For computer program (Fig. B-1).
Initially, the HexBin.For program extracts a record from the original ASCII formatted external data file (Roscoe.Dat). Secondly, the nine fields, which collectively form the record, are disaggregated and each is defined as a one or two byte integer. Finally, the nine integers are written to a new data file (Rosco1B.Dat) in a more compact binary-sequential format. The reformated Roscoe Boulevard data file required 2.4 megabytes of external memory. Hence, the reformating procedure resulted in a 61.9% reduction in the original memory requirements. The reformating procedures for the remaining two data sets obtained similar results.

B. Discovering and Correcting Errors

With each data set’s storage requirements reduced to a more reasonable size the streamlining procedures would continue upon a discovery while attempting to develop a vehicle speed histogram. The histograms were being developed to more clearly understand the traffic activities recorded. The development of each vehicle speed histogram is based on two procedures: 1) determining the maximum and minimum speeds occurring in each data set, and 2) creating a frequency distribution of all vehicle speeds, recorded in the filming process, that fall within the above mentioned limits. These procedures were completed for each data set by creating and executing the MaxMin.For (Fig. B-2) and Freq.For (Fig. B-3) computer programs.
1. Discovering Inconceivable Speeds

Obvious errors, concerning maximum vehicle speeds, were discovered in each data set upon the completion of the MaxMin.For computer program. The maximum speed found within each of the Roscoe Boulevard, Backlick Road, and Mulholland Drive data sets were 153, 554, and 196 mph. Although a vehicle speed of 153 miles per hour is possible the probability of it occurring given a congested freeway section obviously under surveillance might be speculated as zero. The frequency distributions for all vehicle speeds were then created by executing the Freq.For computer program. The results of this program reinforced the earlier concerns by providing a handful of large speeds thought to be inconceivable for each of the three data sets.

In order to objectively claim a vehicle’s speed to be inconceivable it became necessary to investigate the data set region where each unlikely speed occurred. The computer program Looker.For (Fig. B-4) was created and used to extract information concerning frame and vehicle identification numbers for each data sets’ questionable vehicle speeds. This information was then inputed into the DRegion.For (Fig. B-5) computer program which retrieved the appropriate data set region in which the questionable speed(s) appeared. Provided with the conspicuous data set region, a manual search was then performed to locate and extract the trajectory of the vehicle(s) involved. Through the investigation of these vehicle trajectories another type of error was discovered.
2. Discovering Vanishing Vehicles

The information concerning successive occurring positions and speeds, for a peculiar vehicle, led to the discovery of vehicles vanishing from the data set where no physical exits existed. These particular instances were a total surprise. Obviously, a vehicle's disappearance from a data set should be associated with it traversing the defined boundaries of the freeway section (ex. downstream end, off-ramp). However, this was not the case since no exits were anywhere near the vanishing vehicles' previous locations. Obviously vanishing vehicles would provide intriguing possibilities but their existence in a traffic data set has little value.

3. Correcting the Errors

Obviously, any significant errors that were discovered needed to be corrected before any effective research could proceed. The correcting process, following the examination of the data set regions, was performed by a computer program carrying out one of the following actions in the systematic order provided: 1) eliminate all records associated with the vehicle because it did not actually exist (ex. vanishing vehicle), 2) recalculate the "correct" speed of the vehicle by examining the distance traveled between successive recordings and insert it into the data set, or 3) do nothing, the vehicle speed thought to be inconceivable is actually correct.

After completing the individual investigation of each
speculated data region, the hypothesized errors could finally be justifiably proven to exist. The errors which actually existed in each original data set are: 1) Inconceivable Speeds (Table 1), and 2) Vanishing Vehicles (Table 2). Each data set’s corrective action was performed by the Correct.For (Fig. B-6) computer program. Basically, this computer program examined, possibly edited, and finally rewrote each original record to a new data file (Rosco2B.Dat). Upon the identification of a previously noted record, proven to contain an error, the computer program would correct it and either rewrite it to the new data file or delete it from existence. Thus, a data file streamlined from all the discovered Inconceivable Speeds and Vanishing Vehicles resulted. Although these errors had been corrected, further streamlining would continue by eliminating a misconception concerning the vehicle speed-position association made throughout each data set.

C. Minimizing Vehicle Speed-Position Misconception

The aerial photography technique of traffic data collection requires two successive recordings, of known vehicle positions and the time elapsed, to determine a speed value associated with the vehicle. For example, if a vehicle’s longitudinal location is known at both time T and T+Δ, a speed value can be determined. For the current data sets being used, this speed value is implied to occur at the vehicle’s longitudinal location at time T+Δ. However, this is theoretically incorrect because the speed quantity deter-
mined is the average speed of the vehicle during the time interval $T < t \leq T + \delta$, not at the instant of time $T + \delta$.

An objective (A) of this thesis is concerned with the calibration of RFLO's Relaxation Constant. This term is inversely proportional to the rate at which traffic attempts to reach the desired (free-flow) speed of the facility. The calibration will be attempted by comparing (3-D regression) space mean-speeds of real-world data with that of the RFLO representation. Since the process will be based on vehicle speeds, a weak representation of the speeds concerning in the real-world traffic activity could result in a poor Relaxation Constant estimate. Therefore, the following procedure is an attempt to improve the speed-position relationship in order to provide a more accurate replica of traffic patterns occurring during the data collection procedures.

The aerial photography technique provides vehicle position information, along a freeway section, recorded at discrete points in time. The average speed value determined from this information should be associated with the center (midpoint) of the freeway region in which it occurred. Currently, it is associated with the region's latter endpoint. The improvement was realized by displacing the vehicle's longitudinal location backwards to the position which theoretically agreed with the average speed location. This procedure was performed for each data set by the creation and execution of the Change.For (Fig. B-7) computer program. After executing this computer program a revised data file existed (Rosco1Q.Dat).
This particular refinement has two minor drawbacks that should be mentioned. First, when the vehicle's longitudinal location is displaced backwards the time at which its position actually occurred is now associated with a smaller longitudinal distance. Hence, the refinement is actually setting the "new" data sets' vehicle trajectories back in time by approximately one-half second without actually changing the time (frame) at which it occurred. Secondly, a vehicle was originally ignored if it was located outside a freeway section's defined region. Hence, after this correction the last portion of each freeway section will not contain any traffic activity because the actual vehicles that were recorded in the area have been displaced backwards. This, in effect, will reduce the longitudinal length of each section filmed.

D. Final Data Distributions Used

The vehicle speed-position refinements completed the streamlining procedures for each of the three data sets. The aforementioned MaxMin.For and Freq.For computer programs were then reexecuted to capture the information necessary for creating vehicle speed histograms for each of the following data sets: Roscoe Boulevard (Fig. A-4), Backlick Road (Fig. A-5), and Mulholland Drive (Fig. A-6). The traffic data in these distributions (Rosco1Q.Dat) represent the final streamlined microscopic data originally used for the research activity represented in this thesis.
The goal of this chapter is to investigate the possibility of there being an "optimal" DX-DT aggregation interval for transforming discretely sampled microscopic traffic behavior into an aggregate-variable (macroscopic) representation. Historically, formal computations have never successfully united the traffic research community into a generally accepted definition of macroscopic aggregation. Currently, macroscopic aggregation intervals are being justified upon the visual examination of a few possibilities (Makigami et al, 1971).

An aggregation investigation appears within this thesis for primarily two reasons. First, the calibration of the RFLO Simulation Program (Objective A) requires comparisons between modeled representations and the actual traffic behavior (microscopic) recorded in the respective data set. For this to be accomplished the recorded traffic data must be transformed, from the original microscopic context, into the macroscopic representation in which RFLO is based. Second, the data sets employed throughout this thesis suggest the use of a smoothing algorithm to minimize the error (noise) introduced into the data collection procedures through mechanical vibrations and human positional deviations. Therefore, if the DX-DT Aggregation Analysis is
successful it will provide valuable information for the traffic research community as well as for any other research conducted with this specific data.

A. Data Used in Analysis

The research effort representing this thesis was conducted at the Turner-Fairbank Highway Research Center in McLean, VA. The most extensive and accurate traffic data available at the research facility originated from a study by Smith (1985) entitled "Freeway Data Collection for Studying Vehicle Interactions." This study resulted in a collection of microscopic traffic behavior for fourteen different freeway regions located throughout the Washington, D.C. and Los Angeles, California areas. The traffic data was collected through aerial photography and reduced to individual vehicle trajectories through a tedious digitizing process. Each designated freeway region was photographed at successive one-second intervals for an approximate duration of one-hour.

The DX-DT Aggregation Analysis was conducted on each of the three following data sets: Roscoe Boulevard, Backlick Road and Mulholland Drive. These data sets were selected to be used throughout this thesis primarily due to documented references indicating incidents and/or traffic jams occurring during the filming process. Errors concerning Vanishing Vehicles and Infeasible Speeds were found within each of these original data sets. However, these errors were removed during the streamlining operations preceding this
B. Development of Aggregation Scheme

The objective supporting this analysis deals with the capability to more effectively distinguish varying forms of vehicular traffic behavior. If an "optimal" macroscopic aggregation level does transpire the traffic research community could use it to develop more realistic models of vehicular traffic. This contribution would surely lead to a more qualitative understanding of the vehicular traffic congestion problem.

1. Identifying the Aggregation Rationale

In order to accomplish the Aggregation Analysis a principle was adopted so that an optimizing function could ultimately be developed. The principle exclusively used in this analysis is the Rational Subgrouping Concept. This concept is commonly used in the field of Statistical Quality Control. It states that subgroups or samples should be selected from a population so that the chance for differences between subgroups will be maximized while the chance for differences within subgroups are minimized (Montgomery, 1985). Before the Rational Subgrouping Concept can completely govern the Aggregation Analysis several particulars received attention.

a. Grouped Traffic Characteristic. In order to use the optimizing principle a characteristic of vehicular traffic must be specified as being subject to the Aggregation
Rationale. The primary goal of this thesis (Objective A) pertains to the calibration of a parameter contained within the RFLO Traffic Simulation Program. This parameter, known as the Relaxation Constant, is inversely proportional to the rate at which a traffic stream approaches the desired speed of a roadway facility. The equation containing this parameter incorporates the actual and desired speeds as variables. The calibration effort will compare RFLO's vehicular speed responses, for varying parameter values, with the actually recorded real world response. Therefore, by optimally grouping the microscopic traffic speeds, as to the results of the Aggregation Analysis, the direct beneficiary will be the calibration procedure.

b. Grouping Reference Frame. The Rational Subgrouping Concept is concerned with extracting samples from a particular population of events and comparing them to samples of a different size and/or orientation. Before the DX-DT Aggregation Analysis can incorporate this optimizing concept the reference frame associated with the subgroups must be defined. For this, two reference frame possibilities are identified: 1) create subgroups by referencing vehicles, that are close in physical arrangement with one another, as they pass along a roadway section DX during time DT or 2) create vehicle subgroups by directly referencing the individual roadway sections of length DX for a time length DT. Obviously, either grouping technique could be used. However, the respective data sets being used represent traffic flowing on three and/or four freeway lanes. Obviously,
the complications of tracking an ever changing group of vehicles would surely prove to be somewhat inaccurate. Therefore, the aggregation procedures and the resulting macroscopic data file will represent the latter of the two reference frame possibilities.

2. Limiting Range of DX-DT Combinations

The idea of analyzing different DX-DT combinations requires that a feasible range of possible values be specified. This range is determined by identifying upper and lower limits, of possible DX and DT quantities, associated with each data set. These limits are actually determined by examining the physical constraints corresponding to the manner, amount, and freeway regions in which each data set was collected.

The maximum and minimum DX and DT limits, for each of the three data sets used, can be seen in Table 3. The minimum DX interval, for each data set, is constrained by the average error contained within a vehicle's longitudinal position. This error is approximated as being 15 feet from the information specified in the study's final report (Smith, 1985). However, the maximum DX value, for each individual data set, corresponds to the length of the defined roadway section being filmed.

The minimum value of DT, for each data set, is approximately one-second. This is the minimal time aggregate since all of the data was originally collected at successive one-second intervals. Finally, the maximum DT value corresponds
Table 3. The Maximum and Minimum Limits of Feasible DX and DT Values For The Aggregation Analysis.
to the total length of time that each individual data set was actually filmed.

3. Selected DX-DT Aggregation Combinations

After declaring the maximum and minimum DX-DT limits the remaining aggregate values can easily be defined. These values are determined by considering, for a given data set, the implications of any datum being included in one DX-DT combination and excluded in any other. If this were to occur it would certainly damage the qualitative nature of the analysis. Therefore, this analysis is designed so as to eliminate this possibility through the use of geometric multiples as discussed below.

For a given data set, each individual set of DX-DT Combinations are selected so that every DX or every DT value are successive multiples of one another. As the different combinations are performed, each will use the same datum, only their respective subgroups will change. Thus, all the DX and DT values can be declared, for a given data set, by equating a series of numbers constrained by the lower and upper limits defined above and that they are geometric multiples of one another. The DX-DT aggregation combinations can be seen in Table 4.

A particular objective followed during this procedure was to maximize the amount of possible datum used in each of the provided data sets. In order to comply with this objective it became necessary to use a DX value slightly less than the aforementioned minimum value. It is believed that this decision will have little effect on the results of
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<td>DT (sec) 1 2, 4, 8, 16, 32, 64, 128, 256, 512, 1024</td>
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Table 4. The DX and DT Values Selected To Be Used In The Aggregation Analysis.
this analysis.

4. Implementing the Aggregation Rationale

At this point the manner and size (orientation) of the grouping process has been discussed. The aggregation rationale suggests that differences between subgroups be maximized while differences within subgroups are minimized. However, in order to finally implement the Rational Subgrouping Concept into the analysis a definition concerning the meaning of "difference" must be conceived.

The Aggregation Analysis, for a single DX-DT combination, will produce an exact number of subgroups each quantifying the transportation medium speed along a roadway section of specific length (ft) and time (sec). In general, a sample of data is only as informative and valuable as the amount of variability it contains. Therefore, in order to qualitatively compare one DX-DT combination with another the sample deviation of vehicle speeds, within and between subgroups, is used.

In order to equate the Rational Subgrouping Concept into the DX-DT Aggregation Analysis an optimizing function is developed. The optimization concept supporting the DX-DT Aggregation Analysis is as follows:

1) Minimize ($S_w$) the average sample standard deviation of speeds within each subgroup and
2) Maximize ($S_B$) the sample standard deviation of averaged speed quantities between all subgroups for the aforementioned different DX-DT aggregation levels.
The specific formulated equations, used to carry out this analysis, can be viewed in Figure C-1.

The optimization concept, described above, may seem odd with respect to average standard deviations and standard deviations of average speeds. However, it quickly became necessary to simplify the comparison procedure due to the huge magnitude of subgroups, their varying number of DX-DT combinations, and the unenviable task of comparing sampled data (subgroups) that are not independent of one another.

C. Anticipated Result Argument

By theorizing the aforementioned comparison procedures, probable results of this analysis can be hypothesized. Obviously, manipulating quantities of distance and time will increase and/or decrease the number of vehicles (sample size) contained within each subgroup. When determining a measure of variability, the size of the respective sample is important to the convergence and/or divergence of the sampled variability to that of the entire populations.

By considering the sample standard deviation as a function of sampling size the probable effect follows from the concepts represented in Figure 4. The two relationships depicted suggest the following: 1) the sample standard deviation of vehicle speeds within subgroups will increase with the increasing sample size and 2) the standard deviation of vehicle speed averages between subgroups will decrease with an increasing sample size. Although no specifics are known concerning the values between the estimated
Figure 4. The possible Effects of Sample Size on the Sample Standard Deviation, Within and Between Subgroups, for the DX-DT Aggregation Analysis.
endpoints a somewhat linear relationship might be assumed. Through this a presumption can be made that the smallest possible sample size will result in the best estimates of the actual macroscopic behavior (speed) occurring within a traffic stream. However, this result would be disappointing due to: 1) it being microscopic in nature, and 2) the excessive amount of data and computing time needed to represent a typical traffic response pattern in such detail. Therefore, as depicted in the figure, it is hoped (hypothesized) that a "break" in the above assumed tendency will be revealed so as to justify a qualitatively developed aggregation level for macroscopic traffic. If this "break" were to occur at the same DX-DT combination, for each of the three data sets analyzed, it might be difficult to be disregarded by the traffic research community.

D. Anticipated Problems with Chosen DX-DT Values

The combination between particular DX-DT combinations and the comparison procedures is expected to provide obscure results in some instances throughout the Aggregation Analysis. These results develop due to Fortran's (ver. 5.0) maximum allotted memory being of only 4-bytes for any given variable. The erroneous results will appear when the square of summed vehicle speed datum, contained within a single subgroup, surpasses the largest positive number capable of being contained in 4-bytes of computer memory (2.15 * 10^{10^9}). This calculation is performed while attempting to determine the sample standard deviation of vehicle speeds,
within subgroups, as defined in the optimization function.

Predicting the effected DX-DT combinations is accomplished by estimating the average number of datum contained within a subgroup and the average value per datum (mph) for each of the three data sets used. Obviously this prediction process is based on a simplifying assumption that traffic volume remains constant throughout the one-hour data collection period. The mathematical representation used for predicting occurrences of erroneous results are available in Figure C-2. The effected DX-DT combinations, expected to provide erroneous results, are those whose subgroup region size (DX*DT) exceeds: 36,765 ft*sec for Roscoe Boulevard, 47,073 ft*sec for Backlick Road, and 41,084 ft*sec for Mulholland Drive. DX-DT matrices revealing effected and uneffected combinations, for each data set, are provided in Figures C-3, C-4, and C-5.

Although the occurrence of erroneous results have been specified it would be helpful to estimate the magnitude of a standard deviation that has been effected by the 4-byte memory limitations. By knowing the magnitude of an erroneous result it will become easier to recognize its occurrence. The equations associated with this estimate are provided in Figure C-6. Through this reasoning it is anticipated that the approximate magnitude of erroneous standard deviations, associated with the DX-DT Aggregation Analysis, will approach 53.3 mph.
E. Executing the Aggregation Scheme

The numerical calculations and the tremendous I/O procedures, associated with the DX-DT Aggregation Analysis, were conducted by executing two individual computer programs. These computer programs, named StdDevW.For and StdDevB.For, can be seen in Figures C-7 and C-8. For a given data set, these programs calculate either the sample standard deviation within or between subgroups for all the DX-DT combinations associated with a specific data set. The input data (files) used in the aforementioned computer programs are provided in Figures C-9, C-10, and C-11.

The programs were executed on a SUN Workstation due to the large amount of I/O processing power needed for this particular application. Even with this considerable amount of computing power each program needed approximately 14-hours (average) to process (batch) the DX-DT combinations for a given data set. This magnitude of time was needed due to the following: 1) each respective data file was externally located to the working memory, 2) the data files averaged 180,000 records in length, and 3) all 96 DX-DT combinations (8 x 12) were processed, for each data set, in a iterative batch sequence. The data resulting from the DX-DT Aggregation Analysis can be seen in Figures C-12, C-13, C-14, C-15, C-16, and C-17.
CHAPTER VII

SUMMARY OF THE RFLO TRAFFIC SIMULATION PROGRAM

The purpose of this chapter is to provide the reader with an introduction to the RFLO Traffic Simulation Program. A more detailed description of the program can be found in the RFLO User's Manual (Ross, 1989). The RFLO Macroscopic Traffic Simulation Program describes traffic as a simultaneous movement of a vehicular stream. The macroscopic traffic model uses the quantities density, speed, and volume to define the transportation medium. RFLO's traffic flow is considered analogous to a fluid that is incompressible beyond a maximum vehicular density (kjam).

RFLO's formulation assumes traffic to be continuously trying to "relax" to the free-flow speed of the facility. The Relaxation Constant is inversely proportional to the rate at which the traffic flow reaches this equilibrium speed. The qualitative calibration of the Relaxation Constant, as found in the RFLO model, is a primary objective (A) of this thesis. In addition, the RFLO formulation does not contain or imply a speed-density relationship. Although traffic responses are to some extent random RFLO contains no stochastic elements. RFLO's representation of a single traffic incident should be considered as the average response of same incident repeated many times (Ross, 1989).

The RFLO Traffic Simulation Program resulted from the
approval (Oct. 23, 1987) of the Federal Highway Administration (FHWA) Staff Research Study entitled "Improved Simulation of Freeway Networks" (Ross, 1989). The study's objective was a freeway network simulation program (RFLO), for IBM personal computers, based on a theory previously developed by Ross (1988). The initial versions of RFLO (i.e. 0.70, 0.81) were distributed to field testers in March of 1988 and in February of 1989. Experience with these versions indicate that RFLO is considerably faster than any other simulation program and suggest that its reproductions of congested traffic are superior (Ross, 1988). The latest version (0.90) had been intended to improve the theoretical representation of RFLO's vehicular traffic flow. However, this goal was not entirely achieved by Ross due to the time needed to create and test the refined formulations (Ross, 1989). RFLO's version 0.81 was used exclusively in the research pertaining to this thesis.

A. The RFLO Theory

The theory incorporated into RFLO is based on an aggregate variable model. These models use volume, density, and speed \((Q, k, \text{ and } v)\) to define macroscopic traffic flow within a finite unit of length. Therefore, for any roadway the three quantities above are dependent on a location \((x)\) and time \((t)\) as follows:

Let \( Q = Q(x,t) = \text{traffic volume (veh/hr)}, \)
\( k = k(x,t) = \text{traffic density (veh/mi)}, \)
\( v = v(x,t) = \text{traffic speed (mi/hr)}, \)
where
\[ x = \text{a position along the roadway (mi), and} \]
\[ t = \text{time in hours}. \]

The theory constituting RFLO is composed of six equations. The first equation simply provides a relation between the definitions of volume, density, and speed:

\[ Q = k \times v \quad \text{(1)} \]

This equation is generally accepted throughout the traffic research community as a valid relationship concerning the activities of macroscopic traffic.

The second equation, commonly known as the "continuity of vehicles," was pointed out by Lighthill & Whitham (1955):

\[ \frac{\partial k}{\partial t} + \frac{\partial Q}{\partial x} = S(x, t), \quad \text{(2)} \]

where
\[ \frac{\partial k}{\partial t} \text{ is the average change in density during an interval of time } t, \]
\[ \frac{\partial Q}{\partial x} \text{ is the average change in volume within an interval of distance } x, \text{ and} \]
\[ S(x, t) \text{ represents the mean inflow (+) or outflow (-) rate (veh/mi-hr) from any minor roads intersecting the mainline.} \]

This equation governs the fact that there is no creation or destruction of vehicles as they pass through the freeway section. It can easily be compared to a conservation of mass governing equation.
Since there are three unknowns (Q, k, and v) within RFLO’s representation of traffic three equations between them are required. The final required equation originates from RFLO’s assumption that there is an equilibrium speed to which the actual speed "relaxes" for a specific roadway. This hypothesis is expressed as the "forcing function" within RFLO:

\[ \frac{\partial v}{\partial t} + v \frac{\partial v}{\partial x} = \frac{(F - v)}{T}, \quad k < k_{jam} \tag{3} \]

where

\[ F = \text{free flow speed(s) for the facility}, \]
\[ T = \text{relaxation constant (hr)}, \]
\[ k_{jam} = \text{maximum density (jam) for traffic (veh/mi)}. \]

The partial differentiation that appears to the left of the equality is the acceleration of traffic as experienced by the vehicles moving within that particular reference frame (Ross, 1988). This equation (3) is of primary interest for this thesis because it is the only place where the Relaxation Constant appears within the RFLO Traffic Simulation Program.

The fourth equation provides a means for the actual traffic speed to depart from its equilibrium speed. If the predicted volume through a section of roadway would exceed the section’s capacity RFLO assumes that the traffic will reduce its speed. This is easily expressed as a restriction on the (average) speed of a traffic section:

\[ v \leq \text{Capacity}/k. \tag{4} \]
According to Ross (1988), observations have confirmed that this is at least qualitatively what happens during bottleneck behavior.

According to Ross (1988), the four equations that have been mentioned provide a representation of traffic flow at low densities. However, so far there is nothing to prevent the density \( k \) from becoming too large. Hence, the following restriction is applied to prevent the density values from becoming unreasonably high:

\[
    k \leq \text{Jam Density.} \tag{5}
\]

In RFLO, \( k_{\text{jam}} \) is considered constant dependent only upon the number of lanes and uniquely independent of traffic speed. The generally accepted density value of 143 veh/lane-mi is suggested to be used within the RFLO Traffic Simulation Program (Ross, 1989).

According to Ross (1988), the above mentioned description of traffic still contains one serious fault. This problem arises from accelerating traffic flow entering an area of vehicular congestion (queue). With the current formulation, larger traffic volumes would occur at the rear of the queue instead of at the front (Ross, 1988). This compounded activity would finally cause the simulation program to "lock-up" due to the upstream volume building in excess of the downstream capacity. To eliminate this potential problem Ross (1988) has theorized that traffic flow is incompressible beyond a maximum density value of \( k_{\text{jam}} \). This addition eliminates the potential "lock-up" problem that has
victimized earlier traffic models (FREFLO). In mathematical terms this concept can be expressed in the following manner:

\[
\frac{\partial Q}{\partial x} = 0, \text{ when } k = k_{\text{jam}}. \tag{6}
\]

The RFLO Traffic Simulation Program is simply a numerical integration of equations 1 through 3, subject to the restrictions contained in equations 4, 5, and 6. The algorithms used to accomplish this process can be found in RFLO's source listing which is available in the final report by Ross (1989).

B. RFLO's Input

1. Preparing Input File

In order to use the Macroscopic Traffic Simulation Program an input file must be created by the user. A text editor that can create simple ASCII text files must be used. This is required to ensure that the files do not have embedded commands for margins, underlines, and other textual formatting necessities.

The contents of the input file are arranged in eight 10-column fields. An actual input file can be viewed in Figure 5. The eight fields are specified by the following names: 1) TIME, 2) LINK ID, 3) COMMAND, 4) PARAM1, 5) PARAM2, 6) PARAM3, 7) PARAM4, and 8) PARAM5. These fields are used to specify a command to the RFLO simulation program although no single command uses all eight fields. Commands are specified within RFLO by placing a blank or numeric character in the first field of the input file. All
<table>
<thead>
<tr>
<th>TIME</th>
<th>LINK ID</th>
<th>COMMAND</th>
<th>PARAM1</th>
<th>PARAM2</th>
<th>PARAM3</th>
<th>PARAM4</th>
<th>PARAM5</th>
</tr>
</thead>
</table>

**DEFINE FIRST LINK TO BE "ROSCOE BD."** IT IS 0.30296 MI (1600 FT) LONG.
0  
ROSCOE BD LINK  0.30296

**CAPACITY ON ROSCOE BD. IS 9000 VEH/HR FROM 0.12500 TO 0.21970 MI.**
CAPACITY  9000  0.12500  0.21970

**FREE-SPEED ON ROSCOE BD. IS 61.5 MPH FROM 0.12500 TO 0.21970 MI.**
FREE-SPEED  61.5  0.12500  0.21970

**JAM DENSITY ON ROSCOE BD. IS 715 VEH/MI FROM 0.12500 TO 0.21970 MI.**
JAM  715  0.12500  0.21970

**INITIAL SPEEDS FOR THE FOLLOWING RANGES OF DISTANCE ALONG ROSCOE BD.**
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<td>***</td>
<td>***</td>
<td>***</td>
</tr>
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**INITIAL DENSITIES FOR THE FOLLOWING RANGES OF DISTANCE ALONG ROSCOE BD.**
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<td>***</td>
<td>***</td>
<td>***</td>
</tr>
<tr>
<td>DENSITY</td>
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</tr>
</tbody>
</table>

**VOLUME COMING OFF RAMP AT LOCATION 0.12500 MI AT TIME ZERO**
ONOFF  0.12500  422.4

**SPEEDS, VOLUMES, AND DENSITIES ENTERING THE ROADWAY DURING THE SIMULATION PERIOD.**
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</tr>
<tr>
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<td>0.12500</td>
<td>792.0</td>
<td></td>
</tr>
</tbody>
</table>

**SIMULATION ENDS AT 0.064218 HR.**
0.064218  QUIT

---

Fig. 5. Abridged RFLO Input File Emphasizing a Link Definition, Throughout Time and Space, as a Function of Traffic Volume, Density, and Speed.
other lines of code, including blank lines, are considered to be comments and are ignored by RFLO.

2. Links in RFLO

A roadway existing in the real-world is modeled by RFLO as a link. A link contains traffic traveling in only one direction and can be of any length. Different parts of the link may require various capacities, free speeds, and jam densities to fully represent the real-world site. Likewise, for a single link there may be many sources (on-ramps) and/or sinks (off-ramps). Therefore, practically any roadway can be represented in RFLO by a single link.

RFLO simulates traffic by integrating the two aforementioned partial differential equations (2 and 3) subject to the remaining relationship and constraints. To accomplish the integration the traffic density, speed, and volume must be defined over the entire link at the start of the simulation. These values must also be defined at the upstream end of the link (milepost zero) throughout the entire simulation period. These upstream inputs are specified by the user and are not changed by RFLO. However, RFLO does change the quantities at non-zero mileposts throughout the simulation period. Within RFLO, a link is analogous to a flag waving in the wind. The zero end or pole is fixed while the free end is able to respond to the constantly changing conditions (Ross, 1989).

3. Sequence of RFLO Commands

RFLO reads and completely executes each command before
reading the next command. Execution of a command is delayed until the simulated time reaches the activation time located within the command's first field. Therefore, RFLO's commands must be in the correct time sequence or they will not be activated at the correct simulation time. RFLO can execute any command at any time. When several commands have the same activation time, each is processed and executed completely at the concerned instant of time before examining the command that follows. The Figure D-1 provides a simplified summary of the commands used in RFLO.

4. The Parameter File

RFLO contains a parameter file for all quantities that are likely to remain the same throughout several simulations. For example, the units of length and time, associated with a simulation, are declared within the parameter file. This file is already created leaving only blanks to be filled with the specifics required. For instance, the integration step sizes of length and time must be smaller than the phenomenon the user is trying to simulate. Hence, these values need to be occasionally changed and are therefore located within the parameter file. Other values declared within the parameter file are: frequency of output, relaxation constant, default capacity, default jam density, adjustments for different printers, and an array of output file configurations including the luxury of three-dimensional graphics files for density, speed, and volume.
C. RFLO’s Output

Most of RFLO’s output goes directly to the printer. Copies of the input commands are printed as they are read and any error messages are printed immediately following the command that caused the problem. Other printed output is collected in temporary files on disk and dumped to the printer after the simulation is complete.

1. Screen Display

RFLO creates a density graphic display on the CRT screen as the simulation progresses, an example is provided in Figure 6. The format of the display is represented as columns and rows. Each of the columns, across the page, represent a single simulation station (milepost) located a distance DX apart. The first column to the left is not an actual simulated station. Rather, it is the user defined input flowing into the modeled link. Each of the rows represent instances occurring successively every elapsed unit of time DT. Hence, the character in each column and row represents the traffic density at the corresponding station and time. A "0" means that the density was 0.0-9.9% of the value corresponding to 75% of the jam density (107 veh/lane-mi). A "6" means that the density was 60.0-69.9% of the aforementioned density value. A "*" means the density was greater than 75% of the reference jam density value. According to Ross (1989), for all practical purposes a "*" represents a slow moving queue of vehicular traffic.
Fig. 6. Example of RFLO’s "Density Graphic Display" that Appears on VDT as Simulation Progresses
(From Ross, 1989).
2. "Picture" Output

The next item associated with RFLO's printed output is a "picture" of the entire network before the first simulation pass. A sample of the "picture" output can be seen in Figure 7. This "picture" indicates that link five is named "I-495." The traffic volume flowing into the upstream end of the link consists of 22% of the vehicles leaving "I-66," 41% of the vehicles leaving "Feeder Ramp," plus an additional volume of 2400 veh/hr.

At the first milepost on link I-495 (i.e. 6.10 mi), the traffic variables are: density = 38.1 veh/mi (total including all lanes); average speed = 63.0 mi/hr; and capacity = 3600 veh/hr. In this example a ramp is located at a milepost defined at 6.20 of link five. A net total of +168 veh/hr enter the roadway and 0% of the vehicles on the roadway exit via this ramp. Hence, from the "picture" output, a very thorough understanding of the current traffic conditions can be formulated.

3. "MOE" Output

At the end of the simulation, and at any time upon demand, RFLO prints a summary of the network performance occurring since the last measure of effectiveness request. The algorithms used to compute the average speed and delay are (Ross, 1989):

\[
\text{Average Speed} = \frac{\sum(\text{Volume})}{\sum(\text{Density})}
\]

\[
\text{Average Delay} = \text{Elapsed Time} * \left[1 - \frac{\sum(\text{Volume}/\text{Free speed})}{\sum(\text{Density})}\right]
\]
Fig. 7. Example of RFLO's "Picture Output" for Entire Link System Before First Simulation Pass
(From Ross, 1989).
Note that the average delay can be negative if the actual speed is greater than the free speed. This often occurs when a high free speed section of roadway flows into a low free speed section.

4. "Report" Output

RFLO can also provide a detailed history of traffic at a user requested time and place. This output is generated by the REPORT command. For this output device three columns are given for each milepost location: Density (veh/mi), Speed (mi/hr) and Volume (veh/hr).

5. "Graphic" Output

Finally, RFLO prints simplified graphic displays of the network's traffic density, speed, and volume as functions of time and location. The density display is very similar to the console display that appears during the execution of RFLO. Similar pages are printed for the average traffic speed and total volume. The reference values, above which "*" is printed, are shown at the top of each page.

6. "3-D" Output

The opportunity for creating three-dimensional wire-frame drawings is provided by the RFLO Traffic Simulation Program. On request, RFLO will create specially formatted graphics files which can then be read by the computer program AcroSpin. At the end of the simulation, it is possible to view three-dimensional drawings of density, speed, and/or volume. The presentation of this information, in a compact visual model, benefits the RFLO program greatly although
automatic axes preparation is not provided. However, in order to use this option the user must own a copy of the AcroSpin program. Details surrounding the purchase of this program can be found in the final report by Ross (1989).
The purpose of this chapter is to describe the methodology used to calibrate a parameter within the RFLO Traffic Simulation Program. This parameter, known as the Relaxation Constant, is inversely proportional to the rate at which traffic flow attempts to "relax" (converge) to the free-flow speed of the roadway. It has been claimed that RFLO's reproductions of light to moderate flows are equal to the best previous traffic formulation (FREFLO) and its representations of congested and bottleneck flow are superior (Ross, 1988). However, at the time of this claim no detailed study of RFLO had yet been done.

The calibration of RFLO succeeds the DX-DT Aggregation Analysis so that the averaging region, associated with the microscopic to macroscopic data transformation, could be qualitatively justified. Therefore, unless specified otherwise, any reference to the actual macroscopic flow of traffic should be considered as average values of density, volume, and speed aggregated to the following intervals of space and time: DX= 200 ft and DT= 3 sec. The actual data transformation (aggregation) process was accomplished by creating and executing the Rect.For computer program which can be seen in Figure D-2. The resulting data file (R200_3.REC), depicted in Figure D-4, is recognized as being
accurate through the creation and execution of the RectBin. For computer program (Fig. D-3).

A. Desired Traffic Behavior

The calibration process will be accomplished by successively comparing RFLO's reproductions of a traffic flow situation against an actual real world recorded response. The calibration process is specifically concerned with the "forcing function," described earlier in Chapter 7, for it is the only place where the Relaxation Constant appears within RFLO. The "forcing function" attempts to macroscopically model the manner in which the average driver responds to changing conditions within the flow of traffic. Hence, the calibration procedures will investigate the "best" estimate of this parameter by focusing on the speeds associated with vehicular traffic flow.

In order to qualitatively estimate the Relaxation Constant the recorded traffic flow activity must isolate RFLO's "forcing function" from constraints impeding the model's responsiveness. This isolation will enable RFLO's behavior to be more solely representative of the "forcing function" and thus the parameter concerned. A situation such as a bottleneck or incident, where vehicles accelerate away from slow moving congestion, should isolate this function.

According to RFLO, the vehicles' acceleration should continue to exist, if unimpeded, until the traffic stream has reached a speed near the equilibrium speed of the roadway. This is the traffic behavior that is desired in order
to effectively calibrate the RFLO Traffic Simulation Program’s Relaxation Constant. It should be mentioned that RFLO’s "forcing function" can also drive traffic speeds downward. This can occur when fast moving vehicles enter a section of roadway that has a free-flow speed lower than the traffic’s current velocity. Using real world data that follows this scenario, for the purpose of calibrating the Relaxation Constant, would be extremely difficult since the actual cause of the recorded response would be nearly impossible to identify. Therefore, this possibility (deceleration) was not considered any further for the calibration procedures.

B. Data Used in Calibration

The desired traffic behavior, mentioned above, was the only criterion used in selecting a data region to simulate. The final report of the aerial photograph study provides a sketch and documentation for each available data set. These sketches provide specific information concerning possible bottlenecks caused by the geometric configuration of the roadways while the documentation actually indicates any incidents that occurred during the filming period. From this knowledge, three data sets were selected in hope of finding the desired traffic behavior. The selected data sets are Roscoe Boulevard, Backlick Road, and Mulholland Drive while each roadway’s geometric characteristics are depicted in Figures A-1, A-2, and A-3.

A time constraint, associated with the study length (3
months) at the Federal Highway Administration (FHWA) facility, demanded that only one data region be used for the calibration procedures. The constraint became bothersome due to the large amount of time needed to extract the necessary information for RFLO and the time required to engineer the DX-DT Aggregation Analysis. The Roscoe Boulevard data set was selected due to its geometric configuration, occurrence of incidents, and due to it being the most familiar of the three data sets to the researcher. Although the calibration will use three dimensions the FHWA facility lacked this plotting capability. Therefore, in order to identify an appropriate traffic response, for simulation purposes, it became necessary to reaggregate the respective data to accommodate two-dimensional graphing techniques. This was accomplished, for the Roscoe Boulevard data set, by using an aggregation interval of DT= 3 seconds and DX= 1788 feet, which exactly coincides with the roadway section’s defined length, and the ParEst.For computer program (Fig. D-11).

Next, a spreadsheet (Lotus 1-2-3) program was used to create a two-dimensional graph (Fig. D-12) representing the traffic medium behavior with respect to speeds. From this a visual stimuli the Desired Traffic Behavior responses were identified for the Roscoe Boulevard data set. The regions of the graph containing the desired traffic (speed) behavior are identified as: 520≤XT≤590, 664≤XT≤740, and 1080≤XT≤1115.

The traffic response that was randomly chosen to be simulated occurs within the data set at the following aggregated time interval: 664≤XT≤740 (Simulation A), where each
increment of XT corresponds to a three-second period previously justified by the DX-DT Aggregation Analysis. This response occurs within the original microscopic data set at the time interval: 2141 FRAME 2369, where FRAME corresponds to the freeway section photographs taken at successive one-second intervals. It should be noted that the different time frames are related by the following relationship:
FRAME = 3*XT + IFRAME, where IFRAME = 149 for the Roscoe Boulevard data set.

The selected traffic response includes a region in which vehicle speeds momentarily decrease sharply at time XT = 700 (Fig. D-12) while the corresponding traffic density increases significantly within this time period (Fig. D-13). Obviously, hypothesized (inverse) relationships of speed and density have previously existed. However, RFLO's formulation does not contain or imply this assumption. Hence, it could be very interesting to see if RFLO actually represents the traffic flow deceleration behavior although the actual real world cause of the recorded behavior can never be identified.

Obviously, traffic responses are somewhat random so expecting RFLO to respond similarly to a single sample of a real world traffic occurrence would be ridiculous. Therefore, to help insure against the possibility of RFLO not reproducing the traffic deceleration, the real world response occurring before this unanticipated activity will also be simulated. This response will be specified as Simulation B and occurs within the data set at the following
aggregated time interval: 664 ≤ XT ≤ 693 (2141 ≤ FRAME ≤ 2228).

C. Information Needed by RFLO

The RFLO Traffic Simulation Program models macroscopic traffic occurring on a defined link. The program requires the user to provide enough information to fully describe the transportation facility concerned and its anticipated saturation levels. This information is extracted from the Roscoe Boulevard macroscopic (R200_3.REC) and microscopic (Rosco2B.Dat, Rosco1Q.Dat) data sets representing various qualitative levels of traffic flow occurring on the Roscoe Boulevard freeway section.

The RFLO program requires that the traffic density, speed, and volume be defined as initial conditions along the link (roadway) while the upstream source (milepost 0) be defined throughout the simulation. The SimPrep.For computer program (Fig. D-5) was created to extract this information from the aggregated Roscoe Boulevard data set (R200_3.REC). The data resulting from this computer program can be seen in Figure D-6.

The D2Den.For computer program (Fig. D-7) was created to extract the upstream vehicle densities from the microscopic data set representing Roscoe Boulevard (Rosco2B.Dat). The output from this program can be seen in Figure D-8. An unaggregated (microscopic) data set is needed in this case since each vehicle's initial identification, which is associated with an undefined speed, was previously removed in the preceding Speed-Position Misconception Streamlining.
Procedure.

Obviously, each vehicle's initial identification is critical towards correctly estimating the density associated with the initial upstream portion of the roadway (link). Hence, if the original data are not used, the resulting values of traffic density will be underestimated. This would essentially lead RFLO to believe that the density and/or volume, entering the link, are small as opposed to the levels that had actually occurred. It should be mentioned that neither the original or macroscopic data sets contained identifiable speeds for these newly arriving vehicles. Therefore, by using the aggregated data set the velocity of the upstream flow was estimated as best as possible.

To effectively model the macroscopic traffic that occurred on Roscoe Boulevard, the traffic volume entering the roadway via the on-ramp must also be defined throughout the simulation period. As previously mentioned in Chapter 7, RFLO's "continuity of vehicles" equation requires only the volume to be known for traffic entering and/or exiting the mainline. The Ramp.For computer program (Fig. D-9) was created to extract this information from the Rosco1Q.Dat (microscopic) data set. This procedure was accomplished by monitoring the 200 foot ramp section, longitudinally located from the 800 to the 1000 foot milepost, intersecting the mainline. The Rosco1Q.Dat microscopic data set is needed due to the merging lane traffic being aggregated (included) with that of the mainline at the corresponding intersection point. The data resulting from the Ramp.For computer
The RFLO computer program characterizes each link by the following three geometric parameters: 1) its CAPACITY(s) for carrying traffic, 2) FREE-SPEED(s) and 3) the "JAM" DENSITY(s) of the roadway facility concerned. Estimates of these quantities typically result from the generally accepted constants found within a Highway Capacity Manual. However, in hope of qualitatively calibrating RFLO, the traffic data specifically representing the facility was used to improve the usual estimation process.

The ParEst.For computer program (Fig. D-11) was developed to acquire information concerning the estimates of the three aforementioned geometric parameters. This information was acquired by aggregating (Rect.For) the microscopic traffic data to the aforementioned following aggregation level: DX= 1788 ft and DT= 3 sec. As mentioned earlier, this aggregation level was used in order to reduce the visual model from three to two dimensions. The elimination of a dimension is possible through defining the aggregation distance (DX) to that of Roscoe Boulevard’s actual length (1788 ft). The reduction of a single dimension makes it much easier to accomplish the estimation process while three-dimensional graphing capabilities offered at the Turner-Fairbank Highway Research Center were nonexistent.

The ParEst.For program uses an aggregated traffic data file (R1788_3. REC) to determine the (averaged) quantities of speed, volume, and density for the three data sets. These files are then used to create two-dimensional graphs of
speed, volume, and density (vs. time) by importing them into a spread-sheet program. Obviously, only the Roscoe Boulevard data set graphs were used during the parameter estimation procedures. However, the three aforementioned graphs, for each data set, can be viewed in Figures D-12, D-13, D-14, D-15, D-16, D-17, D-18, D-19, and D-20.

By viewing the speed and density graphs an estimated value of $k_{jam}$ cannot justifiably be made since the traffic speed and associated density never correspond to a slow moving queue (5 mph) of vehicles. Therefore, $k_{jam}$ is estimated by the following relationship which was previously developed in a traffic study described by Ross (1989):

$$k_{jam} = \frac{N}{143} \text{veh/lane-mi;}$$

where $N$ corresponds to the number of lanes contained within the roadway section.

The FreeSpeed and Capacity quantities are estimated by using the information gathered from the Roscoe Boulevard roadway section. Although the density of the roadway section never approaches zero, RFLO's default freespeed of 63 mph seems to correspond nicely with the graph's maximum macroscopic speeds. However, in order to effectively estimate Roscoe Boulevard's Freespeed at the merging traffic area a weighted average was used to relate the freespeeds of the mainline and merging area with their corresponding volumes.

The TotVol.For computer program (Fig. D-21) was developed to find the following quantities for the aforementioned estimate: 1) ramp volumes and 2) mainline volumes occurring upstream of the merging area. The data resulting from the
TotVol.For computer program can be viewed in Figure D-22. These results were used to estimate the FreeSpeed of the Merging Area (FSMA) from the weighted average shown below:

\[ \text{FSMA} = \left( \frac{(\text{mainline vol})(\text{mainline freespeed}) + (\text{ramp vol})(\text{ramp freespeed})}{\text{total volume}} \right), \]

\[ 61.5 \text{ mph} = \left( \frac{(7060 \text{ veh/hr})(63.0 \text{ mph}) + (905 \text{ veh/hr})(50.0 \text{ mph})}{7965 \text{ veh/hr}} \right), \]

where: ramp freespeed is estimated at 50 mph by Ross, and total volume is the sum of ramp and mainline volumes.

The information provided by TotVol.For also helped to estimate the capacity of the Roscoe Boulevard roadway section. The areas upstream and downstream of the merging section were estimated to have a capacity of 7600 veh/hr which is consistent with the information provided to this researcher by Ross of capacity being approximately 1900 vehicles per hour per lane. However, the merging area associated with Roscoe Boulevard contains five-lanes of highway. Therefore, the capacity estimate for this area was determined by considering the acceleration lane as having 75% of a typical highway lane's capacity. Hence, the capacity of the merging area was estimated as being 9000 veh/hr. At this point, all the necessary information has been collected for RFLO.

**D. Creating the Input File**

Since the required inputed information has been col-
lected it must now be transformed into a format in which RFLO can interpret and subsequently model. The actual traffic data that will be used to compare RFLO's representations has already been aggregated to a user defined macroscopic level of DT= 3 seconds and DX= 200 feet (R200_3.REC). Therefore, any phenomenon occurring at a more microscopic level will be indistinguishable within the aggregated traffic data.

It makes good sense for RFLO to represent traffic at an aggregation (macroscopic) level comparable to that of the recorded data. Unfortunately, integration step-sizes of DT= 1.5 sec and DX= 200 ft were forced to be used for RFLO due to a "flag" inherent within the simulation program. This "flag" produced a warning message whenever the user defined DX, DT, and Freespeed values were deemed incompatible for RFLO's purposes (Ross, 1989). Thus, the difference in DT values will cause the RFLO model to update its representation twice as often as the aggregated data set.

The Roscoe Boulevard roadway section, which must be defined as a link in RFLO's world, is 1788 feet in length. As mentioned earlier, this link must have a user defined upstream source of traffic flow to provide continuous input into the model. However, the photographic data study only included vehicles appearing within the defined roadway section. Therefore, in order to provide RFLO with a known upstream source (i.e. density, volume, and speed) the initial 200 foot section of Roscoe Boulevard's mainline must be sacrificed. Thus, the "sacrificed" traffic flow correspond-
ing to the initial section of Roscoe Boulevard will enter RFLO's link at milepost zero. The remaining length of Roscoe Boulevard (1588 ft) will be simulated by RFLO.

The second 200 foot section of Roscoe Boulevard is defined by the distance interval: 200 ft < x ≤ 400 ft. The traffic occurring on this section will be compared to the model's representation (link) at milepost 0.03787 (200 ft). Ideally, this section of Roscoe Boulevard would be compared with the midpoint (100 ft) of RFLO's response. However, specifics pertaining to RFLO would not allow this to occur. Subsequently, each following 200 foot section of Roscoe Boulevard will be compared to the link's mileposts in the exact same manner. The last 200 foot section (188 ft) of Roscoe Boulevard will be compared with the link at milepost 0.3029 (1600 ft).

The comparison between the actual and modeled traffic occurring along the roadway will be accomplished every three seconds. However, as mentioned earlier, the traffic being modeled by RFLO will be updated every 1.5 seconds. This offset is made possible by informing RFLO that the number of time steps (DT) between print-outs is equal to two. This communication link is provided from within RFLO's parameter file which can be seen in Figure D-25.

The input files that are used to simulate the Roscoe Boulevard roadway section can be viewed in Figures D-23 and D-24. It may be helpful to review the RFLO commands, shown in Figure D-1, before examining the actual input files. Unfortunately, the time and distance units demanded by RFLO
are in hours and miles. Although RFLO can accommodate time in seconds, it is unable to represent distances in feet. Hence, a rather laborious conversion process is necessary to compare the Roscoe Boulevard roadway, originally defined in fact, with the link defined in the input file. It is hoped that this inconvenience will be eliminated in any future versions of RFLO.

E. Strategy for Calibration

As mentioned previously, the calibration procedures will be based on the comparison between two segments of an actual traffic response and RFLO’s representations of them. The traffic behavior, randomly selected from several adequate responses, is contained within the Roscoe Boulevard data set during the following interval of time: 664 XT 740. The second traffic response to be modeled is contained within the initial half of the above mentioned data region (664 ≤ XT ≤ 693). The second simulation is needed to help ensure that the momentary deceleration, occurring in the middle of the initial traffic activity, will not completely disrupt the calibration effort.

The calibration will be accomplished by comparing the macroscopic traffic speeds of the recorded and simulated responses. The RFLO program will be successively executed, with increasing values of the Relaxation Constant, for each of the two recorded responses selected. After RFLO has been successively executed, for all the parameter values selected, the best parameter value should be associated with the
response yielding the least average difference (error) between the actual and predicted traffic behaviors.

The quantifiable difference between responses will be determined by subtracting the actual recorded speed from the speed simulated by RFLO for each of the averaging regions $A_n$ which are contained within the time-space plane. The order of the difference calculation is based on the hypothesis that RFLO will respond (accelerate) faster and more efficiently than the behavior that had actually occurred during the data collection period. Thus, when all speed differences are considered, for a given parameter value, a positive mean error (difference) is anticipated. However, a "large" value of the Relaxation Constant, with respect to the previous estimate of 0.006 hours, is expected to slow RFLO's response enough so as to minimize this mean difference. The magnitude of this "large" value may help to reveal how well RFLO is suited to model congested vehicular traffic flow.

The Me.For (Fig. D-26) computer program was created to accomplish the accumulation of mean speed differences between the recorded traffic behavior and each simulated response. The computer program also calculates the standard deviation of speed differences for each parameter value. Since the streamlined Roscoe Boulevard data set has been aggregated and separately retained to a user defined macroscopic level, each speed is easily distinguishable within the time-space plane. However, in order to capture RFLO's macroscopic speed values a three-dimensional plotting option
was selected. This option creates a data file that is formatted for the AcroSpin plotting program as can be seen in Figure D-27. These two, previously generated, external data files are then searched until the many associated average speeds are found, interpreted, and their differences accumulated.

Before examining the Relaxation Constant's effect on an RFLO simulation a justifiable range of parameter values was determined. Although the current estimate of 0.006 hours is suggested by Ross (1988), a wide range of feasible values need to be qualitatively spanned. Obviously, one value within the Relaxation Constant's range should correspond to the previous estimate of 0.006 hours. It follows that some parameter values should be considerably smaller and larger than the previous estimate so that the feasible range of values are covered. It was decided that the lower limit, of Relaxation Constants' values, should not differ by more than 100% of the previous estimate. This decision was primarily based on the limited range of values between 0.006 hours and the infeasible value of zero. It was decided that the upper limit should be large enough so as to surely impede RFLO's traffic flow velocity below that of the actual recorded response.

It was decided that 12 parameter values could surely exhaust the aforementioned feasible range. The initial 8 values, going from small to large, differ from one another by 50% while the remaining 3 values are sufficiently large so as to surely compensate for RFLO's expected hasty accel-
eration. The actual parameter values chosen and the data representing the calibration results can be seen in Figures D-28 and D-29. A detailed discussion concerning the calibration results appears in the final chapter (10) of this thesis.
CHAPTER IX

METHODOLOGY TOWARDS DETERMINING
NONEQUILIBRIUM FROM VISUAL MODELS

The goal of this chapter is to create a working hypothesis towards several visual models (3-D) that may provide valuable information towards indicating nonequilibrium behavior or conditions within the flow of macroscopic traffic. A thorough investigation into the actual performance of these models is not possible due to the insufficient resources concerning three-dimensional output (plotting) devices. The objective does not include a strict definition of nonequilibrium traffic flow behavior. Rather, it provides a tool(s) for researchers to quickly locate probable nonequilibrium activity from within a vast amount of data such as that used throughout this thesis. Several of the visual models developed within this chapter could possibly lend usefulness to traffic control strategists such as those attacking congestion in the downtown Los Angeles area (Perry, 1989).

Historically in traffic research, two-dimensional visual models have been used for representing vehicular densities (Wagner and May, 1963) while a three-dimensional visual model was first introduced by Haynes for representing the macroscopic relationship between volume, speed, and density (Makigami et al, 1985). Although the aforementioned macroscopic research proceeds this particular investigation these
visual models did not qualitatively justify the DX-DT Aggregation Intervals used to depict the transportation information. Thus, it is hoped that the current investigation will be used as a catalyst to create more effective visual representations and definitions of the throughput robbing phenomenon known as (vehicular) nonequilibrium.

The concept of nonequilibrium, for this investigation, will be based on certain macroscopic traffic behavior(s) deviating significantly from their normal operating conditions. Thus, each proposed model would be visually scanned and any particular event(s), associated with a less efficient transportation medium, could be presumed to belong to that of a nonequilibrium traffic activity. It should also be noted that an objective of this investigation is to retain the information of identifiable time and distance locations for all models so as to ensure the ability to trace any visual stimulus back to the original data set.

A. Improved Macroscopic Visual Model

The original three-dimensional visual models, constructed by Haynes, were used to represent the macroscopic traffic variables volume, speed, and density (Makigami et al, 1985). These models assumed a DX-DT Aggregation Interval without qualitatively justifying it. Therefore, the traffic behavior displayed may have not been optimally represented which would reduce the effectiveness and reliability of the model. By using the DX-DT Aggregation Analysis to provide justification for the macroscopic averaging interval


(A_n) an improved representation of the original model will be achieved. Although the new model is an improvement a quantifiable difference cannot be substantiated. However, in qualitative terms the traffic research community may now have a procedure that will enable all traffic research projects to share similar "optimal" representations of macroscopic vehicular behavior. As described in Chapter 6, the DX-DT Aggregation Analysis is based solely on optimally grouping vehicles with respect to their speeds. Thus, it does not account necessarily for the grouping of volumes and densities. Although accounting for all three macroscopic variables would obviously be best it would be very difficult and might be more complex than useful. However, of the three macroscopic variables, the speed (mph) quantity provides possibly the most useful initial information because the effectiveness of the transportation medium can be more easily assumed. Each of the volume and density variables do not relate any information about possible driver frustration from slow moving vehicular queues.

B. Visual Models For Quantity of Vehicles

Within Averaging Region (A_n)

The notion of associating the number of vehicles contained within a given aggregation region (A_n) with the possibility of nonequilibrium traffic behavior deserves merit. Obviously, nonequilibrium, or a significant deviation from normal operating conditions, does have a tendency to occur or be caused from a transportation facility (region) being
congested with vehicles. In either case this model suggests that the occurrence or possibility of the inefficient transportation monster can be monitored by concentrating on the number of vehicles appearing in each macroscopic region \((A_n)\) and the difference among these regions throughout the facility over a period of time. Note that the monitoring of \(N\) is synonymous with that of measuring macroscopic vehicular density.

It should also be mentioned that the definition of \(N\) is the total number of vehicles found within the \(x^{th}\) and \(t^{th}\) region \((A_n)\) of the proposed DX-DT combination. A more detailed definition of these and other variables can be found in Figure C-1 which defines the optimizing function used in the DX-DT Aggregation Analysis. From the aforementioned definition, the value \(k\) appearing within Figure C-1 will equal the \(N\) in this investigation except that \(k\) represents the number of speeds and \(N\) represents the number of vehicles. Note that for this thesis it would be possible for a single vehicle to contribute a quantity of 3 to a single \(N\) value associated with an averaging region \(A_n\).

1. Actual \(N\) For Each Aggregating Region

Typically, when the concept of monitoring sample size \((N)\) is suggested the initial application would be to compare each space and time averaging region \((A_n)\) with every other applicable region for a given facility. This visual model configuration will allow the analyst to view the actual values of \(N\) which can be compared through space and time to reveal drastic changes that might accompany or be a result
of nonequilibrium. The hypothesis that the probability of (for) nonequilibrium activity increases with an increasing \( N \) value forms the basis for this configuration.

A typical traffic researcher, studying nonequilibrium, could easily produce such a visual model and apply it by viewing the entire data set while concentrating on the local and absolute \( N \) value maxima. This procedure could save a considerable amount of the time previously required to locate possible deviating behavior scenarios.

The shortcomings of this tool are somewhat numerous when the possibility of it being used in a "real-time" monitoring/controlling situation is considered. First, vigilance might result from viewing a rapid and continuously changing representation, of this visual model, if no positive (nonequilibrium) signals were relayed back to the observer (Wickens, 1984). This would obviously decrease the usefulness of this information. In addition, this visual representation provides the majority of its information, for a given datum point (region), after a considerable period of time has elapsed so as to make comparisons with \( N \) values appearing later in time. This would surely decrease the time available to detect and begin making recommendations for eliminating or minimizing the nonequilibrium activity. A schematic example of this visual model configuration is presented in Figure 8.

2. **Cumulative \( N \) For Each Aggregated Time Interval**

The concept of cumulating \( N \) values, from upstream to
Fig. 8. 3-D Visual Model Representing the Quantity of Vehicles (N) for the Identification of Probable Nonequilibrium Behavior.
downstream facility regions \((x = 1 \text{ to } M)\), for each aggregated time interval \((t)\) may provide a better overall representation of traffic behavior than the previous method. By viewing this model configuration the participant should digest any trends of \(N\) by orienting the figure's axes such that the time horizon is situated in the front, from left (origin) to right, while the distance axis is directed back in the common z-axis location. This model still provides for individual comparisons for like facility locations although each data point now represents a cumulative \(N\) equal to current and all upstream regions.

The quick trend determination would become most evident when comparing the most downstream region \((M)\) through time. The configuration could also be used in detecting bottlenecking situations from a relatively stable level of cumulative \(N\) values appearing downstream of the site experiencing the capacity constraint. Also of possible importance is that the downstream region \(M\), having the maximum cumulative \(N\) value, is associated with the time in which the greatest number of vehicles were within the facility. These aforementioned characteristics of the visual model could provide valuable information for both the traffic researcher and "real-time" strategist. A schematic example of this visual model configuration is presented in Figure 9.
Fig. 9. 3-D Visual Model Representing the Cumulative Quantity of Vehicles, Through Time $t$, for the Identification of Probable Nonequilibrium Behavior.
C. Visual Models For Standard Deviations Of Speeds Within Averaging Region ($A_n$)

The idea for determining macroscopic traffic nonequilibrium behavior is built on the premise that it will be constituted by any significant deviation from normal operating conditions. For this particular type of visual model configuration nonequilibrium vehicular traffic conditions are expected as the standard deviation of vehicle speeds, appearing within an averaging region ($A_n$), increases beyond their normal operating characteristics. Thus, the greater the deviation among closely oriented vehicle speeds, the greater the probability of nonequilibrium. It should be noted that this is based on the concept that the more interference between closely related vehicles the more likely the result of a sizeable loss in overall effectiveness.

Throughout the majority of this thesis macroscopic speeds have been used to quantify traffic activities. The use of traffic speeds to monitor this nonequilibrium behavior is possible since this quantifiable variable represents the effect, or summation, of many factors acting upon vehicles within the traffic stream. Thus this single variable provides a tremendous amount of information on what is being experienced within the facility.

1. Standard Deviation of Speeds Within Averaging Regions

From the discussion above, vehicular speeds will obviously play an important role in almost any definition of nonequilibrium. When the vehicle speeds (microscopic)
decrease, during congested traffic, it can be assumed to be a result of each involved vehicle's immediate headway gap being reduced to below the least acceptable (safe) distance as predefined by the specific driver(s). However, with respect to macroscopic traffic each of these viewable deviating speeds are composed of a set of microscopic speeds which have been averaged to provide the resultant speed. Therefore, equilibrium may in fact be a function of how different the speeds of close traveling vehicles are from one another. This could actually provide an estimate of homogeneity for the traffic speed activity composing a macroscopic vehicle speed. It should also be kept in mind that as vehicle speeds deviate more, from one another, the traffic stream density is being lessened which will ultimately rob the facility of its throughout (volume) potential. It should be obvious that this particular visual model configuration provides a great deal of possible applications to the nonequilibrium problem.

This visual model configuration could be used by the researcher or traffic engineer alongside the Macroscopic (average) Speed Model, which was discussed in the Improved Macroscopic Visual Model section, to help identify nonequilibrium traffic activity. The Standard Deviation model would be visually examined for large values of the deviation quantity which would be presumed to be associated with nonequilibrium activity. If these large standard deviation values appear in the same (approximate) time and space region(s) as suddenly decreased speed quantities then an
even greater possibility of nonequilibrium can be ventured. Also of possible help would be to include the Volume Visual Model which might help to indicate the magnitude of the nonequilibrium behavior if substantial losses in volume are recognized.

Obviously these large standard deviation values would be associated with quickly changing speeds that did not seem to be universally common among the vehicles within each subgroup. A large deviation value might be caused by a single lane being extremely congested and slow while neighboring lanes are operating much more normally (steadily). This activity could surely be presumed to be deviating from the normal circumstance and at least providing the potential for nonequilibrium behavior. This model will also enable the researcher to see how the standard deviations of the individual speed distributions vary from one another. In any case the benefit will be the ability to associate large standard deviations with the likelihood of non-equilibrium. A schematic example of this visual model configuration is presented in Figure 10.

2. Coefficient Of Variation for Speeds Within Averaging Regions.

The preceding visual model representing standard deviations of vehicle speeds contains one minor flaw. Suppose that there is a tendency for the variability among vehicle speeds (microscopic), for a given aggregation region $A_n$, to lessen as the average speed of that vehicular group goes to zero (0 mph). This may occur when the vehicular deceler-
Fig. 10. 3-D Visual Model Representing the Standard Deviation of Vehicle Speeds for the Identification of Probable Nonequilibrium Behavior.
ation is anticipated and unavoidable to the participating drivers. The end result of this assumption is that the researcher will interpret equilibrium behavior, with respect to standard deviations, when the actual traffic flow is converging to a complete halt. Although no single macroscopic vehicular nonequilibrium definition is followed religiously throughout the traffic research community it should be safe to assume that a total stoppage of flow (speed= 0) on a highway facility would never be associated with a state of equilibrium. Obviously, this condition must be eliminated if nonequilibrium conditions are to be found reliably.

By creating a visual model depicting the Coefficient Of Variation, with respect to vehicle speeds, a representation is formed that accounts for the standard deviation of microscopic speeds and the subsequent magnitude of the average speed value involved. This should therefore eliminate the aforementioned misrepresentation of equilibrium behavior by associating the COV's larger quantities with that of the inefficient nonequilibrium monster. This model could potentially yield a wealth of quality information for the future traffic researcher and/or strategist. A schematic example of the COV visual model configuration is presented in Figure 11. This concludes the nonequilibrium visual model methodology that constitutes a portion of this thesis.
COV – Coefficient Of Variance For Vehicle Speeds Appearing Within Each Averaging Interval $A_n$

Fig. 11. 3-D Visual Model Representing the Coefficient Of Variance, of Vehicle Speeds, for the Identification of Probable Nonequilibrium Behavior.
The results pertaining to this thesis can be most easily explained through the careful examination of the four objectives declared in Chapter 1. Although this thesis is rather large it should not be forgotten that the original requirement was to complete the Federal Highway Administration's Graduate Research Fellowship concerning the RFLO Traffic Simulation Program. The majority of this thesis is work that was necessary to accomplish the RFLO research in a qualitative manner. The traffic data used throughout this thesis resulted from a study by Smith (1985) entitled "Freeway Data Collection for Studying Vehicle Interactions." The data sets selected for use, from the above study, are Roscoe Boulevard (Fig. A-1), Backlick Road (Fig. A-2), and Mulholland Drive (Fig. A-3).

A. Results of Objective A

The goal to qualitatively calibrate the Relaxation Constant, which appears within the RFLO Traffic Simulation Program, was successful. As hypothesized, RFLO responded much more efficiently (quickly) than the two recorded macroscopic responses. RFLO's quick response behavior continued even while using ridiculously large values (0.1667 hr.) of the Relaxation Constant. Note that these large values were used only to help ensure that the mean error speed, as defined by
the difference of actual from simulated, would approach or attain a negative value.

The significance of this result is that the RFLO macroscopic model should not be used to simulate real-world congested traffic behavior. The degree to which RFLO responds more efficiently is somewhat clouded by the fact that the comparison of each pair of macroscopic speeds, during the calibration procedures, did not exactly coincide with one another in the longitudinal or x direction of the facility's length. For example, an aggregated (recorded) speed datum, corresponding to the midpoint of a 200 foot distance interval (DX), was compared to a simulated speed datum that was unfortunately located at the aggregated interval's upper edge or at a distance of 100 feet. Although the simulated datum value was located at the upper edge of the 200 foot aggregated interval region the situation was far from being an optimal comparison technique.

The result of this mismatch would obviously add to the resultant quickened response although the magnitude is unclear. The problem was caused by the fact that RFLO would not allow a 100 foot DX integration value which could then be manipulated to exactly coincide with the midpoints of each 200 foot freeway region as defined by the aggregated data. Unfortunately RFLO incorporates a somewhat conservative minimal DX*DT integration constraint. However, this was not considered by Ross or this student before or during the aggregation procedures.

Another major obstacle that was underestimated was the
difficulty in reasonably estimating the remaining variables required by RFLO, for modeling a facility and its traffic behavior, and their possible effect on the model’s performance. For example, RFLO requires estimates for the following: Free Flow Speed(s), \( k_{\text{jam}} \), and Capacity(s) within the facility, as well as the Relaxation Constant. At the very minimum four variables would need to be approximated while for this application obviously one of these was estimated quite extensively. If any one of the remaining three variables were quantified inappropriately the RFLO model’s performance would suffer. However, the amount of time required to vary each of these variables, through a feasible range of values, while attempting to minimize the difference between the actual and simulated responses is surely infeasible. Therefore, the calibration procedure included a considerable number of estimates that may or may not provide an optimal RFLO performance.

In retrospect, the performance of RFLO in this particular thesis certainly damages the documented expectations (Ross, 1988) that considered it as being the best macroscopic model for simulating congested traffic behavior. However, this would certainly not surprise Prigogine and Herman (1971) whom documented the exact "forcing function," used by RFLO, as being one that could only represent dilute macroscopic traffic. Although RFLO may be inappropriate for simulating the world’s current traffic congestion it may be quite valuable for approximating the increased throughput potential of an IVHS system if it were to be installed on
any current urban facility. This direct applicability is due to the omission, in RFLO's "forcing function," of a quantifiable variable representing the interaction between drivers. Because of this a vehicular queue in RFLO will accelerate together with no deviation. The concept of minimizing vehicular speed deviations is a major objective of an IVHS system. These systems are being considered as possible solutions to the many insufficient facility capacity problems currently being faced throughout the United States and the World.

B. Results of Objective B

The goal to qualitatively determine an macroscopic aggregation level for the microscopically collected traffic data was successful. The results of the DX-DT Aggregation Analysis were used to justify an aggregation interval for the eventual transformation of the original microscopic traffic data. Although neither of the three data sets incorporate the exact same (set) DX-DT combination a statistic concerning the average number of vehicles, within each subgroup, was retained from the analysis so as to enable a relatively simple comparison of the best aggregation interval(s) for each of the three data sets investigated.

The objective to minimize the (average) standard deviation of speeds, within subgroups, brought convincingly good results to each of the data sets. The global minimum standard deviation of 5.28 mph resulted, for Roscoe Boulevard, from the DX-DT combination of 208 feet and 2 seconds. Simi-
lar global minimum standard deviation values of 4.46 and 5.50 mph resulted, for Backlick Road and Mulholland Drive, from the DX-DT combinations of 192 feet and 1 second and 160 feet and 2 seconds. These global minimum standard deviation values resulted as hoped (Fig. 4) since there was a tendency for the standard deviation values to grow in a linear fashion with the increasing sample sizes.

The objective of maximizing the standard deviation between (average) vehicle speeds resulted to be less conclusive and indicated that there was little change in the hypothesized linear relationship (Fig. 4). Hence, a maximum standard deviation value is still intended but the 8.15 mph associated with a DX-DT combination of 13 feet and 1 second, with an average (rounded) sample size of zero, is far from a feasible result with respect to the computer processing and memory requirements.

The DX-DT Aggregation combination used for this thesis to aggregate the microscopic Roscoe Boulevard data set is equal to 200 feet and 3 seconds. This combination was used since the DX row of 208 feet contained several minimum standard deviation values while the DT value of 3 seconds was associated with the midpoint separating DT’s of 2 and 4 seconds whose standard deviation values differed by only 1/100th of a mph. The approximate number of vehicles contained in this averaging area \(A_n\), for the Roscoe Boulevard data set, is found to be 17 through interpolation. Although the remaining two data set’s aggregation results were not used any further in this thesis they seemed to indicate a
DX = 96 or 192 feet and DT = 2 or 4 seconds for the Backlick Road data set, while a DX = 160 feet and a DT = 2 or 4 seconds appeared best for the Mulholland Drive data set. Through interpolation the number of vehicles contained within these averaging areas appears to be approximately 14 for Backlick Road and 17 for the Mulholland Drive data set. These results indicate that a good macroscopic aggregation level can be obtained by grouping close traveling vehicles, appearing in congested traffic, in groups of a size equal to 14 to 17 vehicles.

Although these results are somewhat surprising they could also be used in the IVHS traffic systems that were mentioned earlier in this chapter. These results may provide groundwork for indicating the platoon size of vehicles that are to be controlled by this automated guidance system. If congested vehicles travel most effectively in this relative group size then it might be possible that this finding be used to add to the IVHS effectiveness.

It should also be mentioned that this particular investigation omitted any reference to the number of lanes available in the transportation facility. Thus what DX-DT Aggregation intervals work nicely on a congested 4 lane freeway may not be effective for a 2, 3, or 5 lane facility. A research project that accounts for these lanes and/or a grouping mechanism independent of lane quantity could result in a tremendous finding for the traffic research community.
C. Results of Objective C

The goal of progressing the possible determination of nonequilibrium macroscopic traffic behavior from conceptualizing various three-dimensional visual models was very successful. Although several visual models were discussed it is believed that the standard deviation of microscopic vehicle speeds, appearing within the averaging area $A_n$, and the related Coefficient of Variance visual model could potentially provide a great deal of information for identifying nonequilibrium activity in a quick and accurate manner. These models are conceived on a macroscopic concept that the greater the speed deviation among close traveling vehicles the greater the probability for the existence of nonequilibrium activity.

Visual Models (3-D) could provide huge amounts of information for identifying conditions and/or behaviors from any macroscopic vehicular transportation medium. However, asking a human to focus on this potential information would take considerable training as well as the eventual problem of visual and mental fatigue among the observers. Therefore, this scenario might provide a successful environment for the application of the Neural Network form of Artificial Intelligence (AI). This tool could be integrated into a monitoring and/or surveillance system and subsequently be trained to digest the pertinent information being displayed and produce decisions that could be exceptionally accurate. Research in this area could provide handsome rewards for the traffic research community.
D. Results of Objective D

During the initial activities at the Turner-Fairbank Highway Research Center it became quite obvious that many improvements could be made to the data sets that would be used throughout this thesis. These suggestions are made to provide any future data collection projects with various ideas to more effectively capture, retain, and provide for the ease of extraction for the intended users of the results. Chapter IV provides a detailed description of each detected problem so they need just to be referenced below.

The enhancements can be divided into the following two separate entities: obvious errors needing correction, and refinements that would be beneficial to virtually any traffic researcher. The obvious errors discovered included Inconceivable Speeds, Vanishing Vehicles, and to a lesser extent Inconsistent Formatting. Other refinements that would greatly benefit any future data set design include eliminating the Speed Assignment Bias and Vehicle Speed-Position Misconception. While still others include providing more Uncongested traffic Flow and Site Information providing explicit Warnings of any Estimates used while quantifying the characteristics of any traffic activity. These improvement suggestions conclude the results discussion of this thesis.
REFERENCES


REFERENCES (cont.)


APPENDIX A

Geometric Configuration and Histogram of Microscopic Vehicular Speeds For Each Respective Data Set.
Fig. A-1. Geometric Configuration of the Roscoe Boulevard Freeway Section Used in Study (From Smith, 1985).
Fig. A-2. Geometric Configuration of the Backlick Road Freeway Section Used in Study (From Smith, 1985).
Site Type: Upgrade
Section length = 1341'
Tangent
Lane Width = 11'
Grade = +3.0%
Cross-slope = .02
Shoulders = 10' Right
4' Left

Note: Section is near top of an approximate 2.5 mile grade

Fig. A-3. Geometric Configuration of the Mulholland Drive Freeway Section Used in Study (From Smith, 1985).
Fig. A-4. Histogram of Individual Vehicle Speeds Occurring Within the Streamlined Roscoe Boulevard Microscopic Data Set.
Fig. A.5. Histogram of Individual Vehicle Speeds Occurring Within the Streamlined Backlick Road Microscopic Data Set.

- Mean: $\mu = 34.01$ mph
- Standard Deviation: $\sigma = 9.31$ mph
- Minimum: $min = 1$ mph
- Maximum: $max = 80$ mph
Fig. A-6. Histogram of Individual Vehicle Speeds Occurring Within the Streamlined Mulholland Drive Microscopic Data Set.
APPENDIX B

Computer Programs Used While Streamlining Data Sets.
Program Name: HexBin.For written in MS FORTRAN (Vers. 5.0)

Purpose: To minimize the size of the data set files in order to maximize the available memory. This program will read a record from the original ASCII formatted data file and rewrite each record in a more compact binary-sequential format.

Date: June 22, 1989

Defining of Variables

```
INTEGER FRAME, VID, VTYPE, VLENGTH, VSPEED, LONGLD, LATD
INTEGER VCOLOR, LANENUM
INTEGER*1 VTYPE, VLENGTH, VSPEED, VCOLOR, LLANENUM
INTEGER*2 FFRAME, VID, LLONGD, LLATD
```

Meaning of Variables

** FRAME : A number corresponding to the value of the frame category for a given record from the current data set.
** VID : The number given to a vehicle as it enters the "roadway" section (Vehicle Identification).
** VTYPE : The TYPE of Vehicle associated with VID (car, truck, etc.).
** VLENGTH : The LENGTH of the Vehicle associated with VID.
** VSPEED : The SPEED of the Vehicle associated with VID.
** LONGLD : The LONGitudinal Distance between the front bumper (center) of the vehicle and the beginning of the "roadway" section.
** LATD : The LATitudinal Distance between the center of the front bumper and the roadway edgeline.
** VCOLOR : The COLOR of the Vehicle associated with VID.
** LANENUM : The LANE NUMBER which the vehicle is traveling in.

Let's open these external files!

```
OPEN (11, FILE = 'C:\KEVIN\ROSCOE.DAT', BLOCKSIZE = 6400)
OPEN (12, FILE = 'C:\KEVIN\ROSCOIB.DAT', BLOCKSIZE = 6400, + FORM = 'BINARY', ACCESS = 'SEQUENTIAL')
```

Let's read a record from the current data set!

```
100 READ (11, 200, END = 400) FRAME, VID, VTYPE, VLENGTH, VSPEED, + LONGLD, LATD, VCOLOR, LANENUM
200 FORMAT ( I4, 1X, I4, 1X, I1, 1X, I2, 1X, I3, 1X, I4, I3, 1X, I1, 1X, I1 )
```

Let's reduce the defaulted 4 byte values to one or two bytes each!

```
FFRAME = FRAME
VVID = VID
VVTYPE = VTYPE
VVLENGTH = VLENGTH
VVSPED = VSPEED
LLONGD = LONGLD
LLATD = LATD
VCOLOR = VCOLOR
LLANENUM = LANENUM
```

Fig. B.1. HexBin.For Computer Program Used In The Data Set Streamlining Procedures.
Let's right the values to a new file in a more compact form!

    WRITE (12) FFRAME, VVID, VVTYPE, VVLENGTH, VSPEED, LLONGD, 
    + LLATD, VVCOLOR, LLANENUM

* Let's go get another record!

    GOTO 100

* Let's get outta here!

400 STOP
END

---

Fig. B-1 (cont). HexBin. For Computer Program Used In The Data Set Streamlining Procedures.
**** Program Name : MaxMin.For written in MS FORTRAN (Vers. 5.0) ****
**** Purpose : To determine the maximum and minimum values of speed that are contained within the current data set. The max and min values will be used as endpoints on the histogram that will be created with the information gained in Freq.For. ****

Date : July 31, 1989 ****

Defining of Variables

** INTEGER*1 VTYPE, VLENGTH, VSPEED, VCOLOR, LANENUM
** INTEGER*2 FRAME, VID, MNGD, LATD
** INTEGER MAX, MIN

Meaning of Variables

** FRAME : A number corresponding to the value of the frame category for a given record from the current data set.
** VID : The number given to a vehicle as it enters the "roadway" section (Vehicle Identification).
** VTYPE : The TYPE of Vehicle associated with VID (car, truck, etc.).
** VLENGTH : The LENGTH of the Vehicle associated with VID.
** VSPEED : The SPEED of the Vehicle associated with VID.
** LONGD : The LONgitudinal Distance between front bumper (center) of the vehicle and the beginning of the "roadway" section.
** LATD : The LATitudinal Distance between the center of the front bumper and the roadway edgeline.
** VCOLOR : The COLOR of the Vehicle associated with VID.
** LANENUM : The LANE NUMBER which the vehicle is traveling in.
** MAX : The maximum value of speed that occurs within the data set.
** MIN : The minimum value of speed that occurs within the data set.

* Let's initialize these variables accordingly!
  MAX = 0
  MIN = 100

* Let's open these external data files!
  OPEN ( 12, FILE = 'C:\KEVIN\ROSC01B.DAT', BLOCKSIZE = 6400,
  + FORM = 'BINARY', ACCESS = 'SEQUENTIAL')
  OPEN ( 17, FILE = 'LPT1')

* Let's read a record from the current data set!
  100 READ (12, END = 200) FRAME, VID, VTYPE, VLENGTH, VSPEED,
  + LONGD, LATD, VCOLOR, LANENUM

* If the speed of the current vehicle is greater than the previous maximum, then the current speed is the maximum speed!
  IF ( VSPEED .GT. MAX ) THEN
    MAX = VSPEED
  ENDIF

Fig. B-2. MaxMin.For Computer Program Used In The Data Set Streamlining Procedures.
*-----------------------------------------------------------------------*
If the speed of the current vehicle is less than the previous
* minimum, then the current speed is the minimum speed !

    IF ( VSPEED .LT. MIN ) THEN
        MIN = VSPEED
    ENDIF
*-----------------------------------------------------------------------*

* Let's go get another record !
GOTO 100

*-----------------------------------------------------------------------*
* Let's make a header for the output and print out the maximum and
* minimum speed for the current data set !

200   WRITE (17,*) ' FOR ROSCO1B.DAT : '
     WRITE (17,*) '
     WRITE (17,300) MIN, MAX
300   FORMAT (1X, 'The minimum speed is ',I3,2X, 'The maximum speed
          + is', I3)
*-----------------------------------------------------------------------*

* Let's get outta here !
STOP
END

*-----------------------------------------------------------------------*

Fig. B-2 (cont). MaxMin.For Computer Program Used In
The Data Set Streamlining Procedures.
Program Name: Freq.For written in MS FORTRAN (Vers. 5.0)

Purpose: To determine the frequency of speeds from the data set. The maximum and minimum speeds have already been determined from the program "MaxMin.For". These two values are needed to dimension the frequency array "count." For example, the min and max values for Rosco1B.Dat data file are 1 and 87. The result of this program will enable the user to create a histogram to help in determining the population's distribution of vehicle speeds.

Date: July 31, 1989

Defining of Variables

INTEGER*1 VTYPE, VLENGTH, VSPEED, VCOLOR, LANENUM
INTEGER*2 FRAME, VID, LONGD, LATD
INTEGER COUNT, K, L
DIMENSION COUNT (1, 87)

Meaning of Variables

FRAME: A number corresponding to the value of the frame category for a given record from the current data set.
VID: The number given to a vehicle as it enters the "roadway" section (Vehicle Identification).
VTYPE: The TYPE of Vehicle associated with VID (car, truck, etc.).
VLENGTH: The LENGTH of the Vehicle associated with VID.
VSPEED: The SPEED of the Vehicle associated with VID.
LONGD: The LONGitudinal Distance between front bumper (center) of the vehicle and the beginning of the "roadway" section.
LATD: The LATitudinal Distance between the center of the front bumper and the roadway edgeline.
VCOLOR: The COLOR of the Vehicle associated with VID.
LANENUM: The LANE NUMBER which the vehicle is traveling in.
COUNT: This is used as a bucket to accumulate the number of occurrences for each speed within the data set.
K: This is used as a counting variable to iterate through the "Count" array.
L: This is used as a counting variable to iterate through the "Count" array.

Let's initialize each element, of the array count, to zero!

DO 100, K = 1, 87
   COUNT (K) = 0
100 CONTINUE

Let's open these external data files!

OPEN (12, FILE = 'C:\KEVIN\ROSC01B.DAT', BLOCKSIZE = 6400, + FORM = 'BINARY', ACCESS = 'SEQUENTIAL')
OPEN (17, FILE = 'LPT1')

Fig. B-3. Freq.For Computer Program Used In The Data Set Streamlining Procedures.
* Let's read a record from the current data set!

200 READ (12, END = 300) FRAME, VID, VTYPE, VLENGTH, VSPEED
   + LONGD, LATD, VCOLOR, LANENUM

* Let's increase the frequency of the current vehicle speed by one!

   COUNT(VSPEED) = COUNT(VSPEED) + 1

* Let's go get another record!

   GOTO 200

* Let's write the final frequency distribution of vehicle speeds for
* the current data file!

300 DO 700, L = 1, 87
   WRITE (17,*)
   WRITE (17,400) L, COUNT(L)
   400 FORMAT (1X, 'The frequency of speed ',I3,1X,' is ',1X,I6)

700 CONTINUE

* Let's get outta here!

   STOP
   END

*-----------------------------------------------------------------------

Fig. B-3 (cont). Freq. For Computer Program Used In The Data Set Streamlining Procedures.
*** Program Name: Looker.For written in MS FORTRAN (Vers. 5.0) ***

Purpose: To extract information concerning frame numbers and vehicle identifications for speeds hypothesized as being inconceivable. This program is executed for each of the three data sets. The information gained from this program will be used to extract data set regions in order to examine them for inconceivable speeds.

Date: August 7, 1989

Defining of Variables

INTEGER*1 VTYPE, VLENGTH, VSPEED, VCOLOR, LANENUM
INTEGER*2 FRAME, VID, LONGD, LATD

Meaning of Variables

** FRAME: A number corresponding to the value of the frame category for a given record from the current data set.
** VID: The number given to a vehicle as it enters the "roadway" section (Vehicle IDentification).
** VTYPE: The TYPE of Vehicle associated with VID (car, truck, etc.).
** VLENGTH: The LENGTH of the Vehicle associated with VID.
** VSPEED: The SPEED of the Vehicle associated with VID.
** LONGD: The LONGitudinal Distance between front bumper (center) of the vehicle and the beginning of the "roadway" section.
** LATD: The LATitudinal Distance between the center of the front bumper and the roadway edgeline.
** VCOLOR: The COLOR of the Vehicle associated with VID.
** LANENUM: The LANE NUMBER which the vehicle is traveling in.

Let's open these external data files!

```
OPEN (12, FILE = 'C:\KEVIN\ROSCO1B.DAT', BLOCKSIZE = 6400,
+ FORM = 'BINARY', ACCESS = 'SEQUENTIAL')
```

```
OPEN (17, FILE = 'LPT1')
```

Let's read a record from the data set!

```
100 READ (12, END = 300) FRAME, VID, VTYPE, VLENGTH, VSPEED,
+ LONGD, LATD, VCOLOR, LANENUM
```

Let's search for speeds ranging from 70 mph to the maximum speed for the current data set found in MaxMin.For!

```
IF (( VSPEED .GE. 70 ) .AND. ( VSPEED .LE. 153 )) THEN
```

Let's write the pertinent information for the record containing a possible inconceivable speed!

```
WRITE (17,200) FRAME, VID, VSPEED, LATD, LANENUM, LONGD
```

```
200 FORMAT (1X, 'For Frame = ',I7, ' VID = ',I6, ' VSPEED = ',
+ I3,2X,' LATD = ',I4,2X,' LANENUM = ',I3,1X,' LONGD = ',I5)
```

**Fig. B-4. Looker.For Computer Program Used In The Data Set Streamlining Procedures.**
WRITE (17,*) ' 
ENDIF
*-----------------------------------------------------------------------*
Let's go get another record!
GOTO 100
*-----------------------------------------------------------------------*
Let's get outta here!
300 STOP
END

Fig. B-4 (cont). Looker. For Computer Program Used In The Data Set Streamlining Procedures.
**** Program Name : DRegion.For written in MS FORTRAN (Vers. 5.0) ****

Purpose : To retrieve the regions of the data sets in which
the hypothesized inconceivable speeds appear.
These regions are needed to objectively prove a
speed's inconceivability. The length of the
interval region, surrounding the inconceivable
speed, is left up to the user. However, there is
no advantage in printing frames that will surely
not contain the concerned vehicle.

Date : August 10, 1989

Defining of Variables

INTEGER*1 VTYPE, VLENGTH, VSPEED, VCOLOR, LANENUM
INTEGER*2 FRAME, VID, LONGD, LATD
INTEGER STARTF, ENDF

Meaning of Variables

FRAME : A number corresponding to the value of the frame category
for a given record from the current data set.
VID : The number given to a vehicle as it enters the "roadway"
section (Vehicle Identification).
VTYPE : The TYPE of Vehicle associated with VID (car, truck, etc.).
VLENGTH : The LENGTH of the Vehicle associated with VID.
VSPEED : The SPEED of the Vehicle associated with VID.
LONGD : The LONGitudinal Distance between front bumper (center) of
the vehicle and the beginning of the "roadway" section.
LATD : The LATitudinal Distance between the center of the front
bumper and the roadway edgeline.
VCOLOR : The COLOR of the Vehicle associated with VID.
LANENUM : The LANE NUMBER which the vehicle is traveling in.
STARTF : The first frame number associated with the specified
data set region.
ENDF : The last frame number associated with the specified data
set region.

Let's open these external data files !

OPEN (12, FILE = 'C:\KEVIN\ROSCO1B.DAT', BLOCKSIZE = 6400,
+ FORM = 'BINARY', ACCESS = 'SEQUENTIAL')

OPEN (17, FILE = 'LPT1')

Enter the frame number associated with the beginning of the region !

WRITE (*, '(A,\r') ' What is the starting frame (STARTF) ? ----> ' READ (*,*) STARTF
WRITE (*,*) ' 
WRITE (*,*) ' 
WRITE (*,*) ' The value of STARTF is ', STARTF
WRITE (*,001)
001 FORMAT (35(' ', 65X))

Fig. B-5. DRegion. For Computer Program Used In The Data
Set Streamlining Procedures.
Enter the frame number associated with the ending of the region:

```
WRITE (*,'(A,\')' ' What is the ending frame (ENDF) ? ---->

READ (*,*) ENDF
WRITE (*,*')
WRITE (*,*')
WRITE (*,*') ' The value of ENDF is ', ENDF
WRITE (*,001)
001 FORMAT (35(' ', 65X))
```

Let's read a record from the current data set!

```
100 READ (12, END = 300) FRAME, VID, VTYPE, VLENGTH, VSPEED, LONGD,
+ LATD, VCOLOR, LANENUM
```

If the current frame number is not in the above specified region, then we don't want it!

```
IF ( FRAME .LT. STARTF ) THEN
  GOTO 100
ENDIF

IF ( FRAME .GT. ENDF ) THEN
  GOTO 300
ENDIF
```

The current frame number is within the specified region!

```
WRITE (17, 200) FRAME, VID, VTYPE, VLENGTH, VSPEED, LONGD,
+ LATD, VCOLOR, LANENUM
200 FORMAT (3X,I4,4X,I4,1X,I1,1X,I2,3X,I2,2X,I4,3X,I3,2X,I1,3X,I1)
```

Let's go get another record!
```
GOTO 100
```

Let's get outta here!
```
300 STOP
END
```

---

Fig. B-5 (cont). DRegion. For Computer Program Used In The Data Set Streamlining Procedures.
Program Name: CorrectFor written in MS FORTRAN (Vers. 5.0)

Purpose: To correct the vanishing vehicle and inconceivable speed errors for each data set. The program searches the current data set for records associated with the above mentioned errors. When the error is found it is corrected by performing one of two procedures: 1) erase vehicle from existence because it is a vanishing vehicle, or 2) replace the inconceivable speed with a corrected value.

Date: August 7, 1989

Defining of Variables

```
INTEGER*1 VTYPE, VLENGTH, VSPEED, VCOLOR, LANENUM
INTEGER*2 FRAME, VID, LONGD, LATD
```

Meaning of Variables

** FRAME : A number corresponding to the value of the frame category for a given record from the current data set.
** VID : The number given to a vehicle as it enters the "roadway" section (Vehicle Identification).
** VTYPE : The TYPE of Vehicle associated with VID (car, truck, etc.).
** VLENGTH : The LENGTH of the Vehicle associated with VID.
** VSPEED : The SPEED of the Vehicle associated with VID.
** LONGD : The LONGitudinal Distance between front bumper (center) of the vehicle and the beginning of the "roadway" section.
** LATD : The LATitudinal Distance between the center of the front bumper and the roadway edgeline.
** VCOLOR : The COLOR of the Vehicle associated with VID.
** LANENUM : The LANE NUMBER which the vehicle is traveling in.

Let's open these external data files!

```
OPEN (12, FILE = 'C:\KEVIN\ROSC01B.DAT', BLOCKSIZE = 6400, FORM = 'BINARY', ACCESS = 'SEQUENTIAL')
OPEN (13, FILE = 'C:\KEVIN\ROSC02B.DAT', BLOCKSIZE = 6400, FORM = 'BINARY', ACCESS = 'SEQUENTIAL')
```

Let's read a record from the current data set!

```
100 READ (12, END = 200) FRAME, VID, VTYPE, VLENGTH, VSPEED, + LONGD, LATD, VCOLOR, LANENUM
```

If the current record is identified by one of the following "IF" statements, then alter it's contents in the described manner:

```
IF ( VID .EQ. 6163 ) THEN
    GOTO 100
ENDIF

IF (( FRAME .EQ. 2474 ) .AND. ( VID .EQ. 5399 )) THEN
    VSPEED = 60
ENDIF

IF ( VID .EQ. 8474 ) THEN
    GOTO 100
ENDIF
```

Fig. B-6. CorrectFor Computer Program Used In The Data Set Streamlining Procedures.
Let's write the corrected record, if at all, to the new streamlined data file:

```fortran
WRITE (13) FRAME, VID, VTYPE, VLENGTH, VSPEED, LONGD, + LATD, VCOLOR, LANNUM
```

Let's go get another record!

```fortran
GOTO 100
```

Let's get outta here!

```fortran
200 STOP
END
```

---

Fig. B-6 (cont). Correct. For Computer Program Used In The Data Set Streamlining Procedures.
Program Name: Change.For written in MS FORTRAN (Vers. 5.0)

Purpose: To convert the longitudinal distance quantities in the data set from the current values to the qualitatively correct midpoint values associated with the current frame number and the previous frame number. The speed that is associated with a record is actually the average speed over the distance that the vehicle has traveled in the past second. However, that speed is currently associated with the position of the vehicle when the frame was recorded.

Date: July 28, 1989

Defining of Variables

** INTEGER*1 VTYPE, VLENGTH, VSPEED, VCOLOR, LANENUM
** INTEGER*2 FRAME, VID, LONGD, LATD, INTERD
** INTEGER CHECK (9000), OLDLD (9000)

Meaning of Variables

** FRAME: A number corresponding to the value of the frame category for a given record from the current data set.
** VID: The number given to a vehicle as it enters the "roadway" section (Vehicle IDentification).
** VTYPE: The TYPE of Vehicle associated with VID (car, truck, etc.).
** VLENGTH: The LENGTH of the Vehicle associated with VID.
** VSPEED: The SPEED of the Vehicle associated with VID.
** LONGD: The LONGitudinal Distance between front bumper (center) of the vehicle and the beginning of the "roadway" section.
** LATD: The LATitudinal Distance between the center of the front bumper and the roadway edgeline.
** VCOLOR: The COLOR of the Vehicle associated with VID.
** LANENUM: The LANE NUMBER which the vehicle is traveling in.
** INTERD: The interpolated longitudinal location of the vehicle between two successive recordings.
** CHECK: Is an array that is used to monitor the arrival of vehicles into the study. The first occurrence of a given vehicle will coincide with an undefined speed (VSPEED = 0).
** OLDLD: The last, originally recorded, longitudinal location of the vehicle identified by VID.

* Let's initialize this variable to zero:

  INTERD = 0

Let's open these external data files:

  OPEN (11, FILE = 'C:\KEVIN\ROSC01Q.DAT', BLOCKSIZE = 6400, + FORM = 'BINARY', ACCESS = 'SEQUENTIAL')
  OPEN (12, FILE = 'C:\KEVIN\ROSC02B.DAT', BLOCKSIZE = 6400, + FORM = 'BINARY', ACCESS = 'SEQUENTIAL')

Let's read a record from the current data set:

100 READ (12, END = 200) FRAME, VID, VTYPE, VLENGTH, VSPEED, + LONGD, LATD, VCOLOR, LANENUM

Fig. B-7. Change.For Computer Program Used In The Data Set Streamlining Procedures.
The current vehicle must have had a defined speed earlier to be included in the interpolation process!

IF ( CHECK (VID) .EQ. 1 ) THEN
  INTERD = ( FLOAT ( OLDDL(VID) + LONGD ) / 2.0 ) + 0.5
  OLDDL (VID) = LONGD

* Let's write the record to the new streamlined data file!
  WRITE (11) FRAME, VID, VTYPE, VLENGTH, VSPEED, INTERD,
  + LATD, VCOLOR, LANENUM

* Let's go get another record!
  GOTO 100

* If not, then we should still do the above operations if the current vehicle has a defined speed:
ELSE
  IF ( VSPEED .NE. 0 ) THEN
    CHECK (VID) = 1
    INTERD = ( FLOAT ( OLDDL(VID) + LONGD ) / 2.0 ) + 0.5
    OLDDL (VID) = LONGD
    WRITE (11) FRAME, VID, VTYPE, VLENGTH, VSPEED, INTERD,
    + LATD, VCOLOR, LANENUM
    GOTO 100

* If the current vehicle does not have a defined speed then we should save it's current position for next time!
ELSE
  OLDDL (VID) = LONGD
  GOTO 100
ENDIF
ENDIF

* Let's get outta here!
200 STOP
END

Fig. B-7 (cont). Change. For Computer Program Used In The Data Set Streamlining Procedures.
APPENDIX C

Methodology, Computer Programs, and Data
Representing the DX-DT Aggregation Analysis.
1) Minimize 
\[ S_W = \frac{\sum_{t=1}^{N} \sum_{x=1}^{M} S(x,t)}{M \times N} \]

2) Maximize \( S_B \)

where:

\[ S(x,t) = \sqrt{\frac{\sum_{i=1}^{k} (V(x,t,i)) - ((\sum_{i=1}^{k} V(x,t,i))^2 / k)}{k-1}} \]

\[ S_B = \sqrt{\frac{\sum_{t=1}^{N} \sum_{x=1}^{M} (\overline{V}(x,t))^2 - ((\sum_{t=1}^{N} \sum_{x=1}^{M} \overline{V}(x,t))^2 / M \times N)}{M \times N - 1}} \]

\[ \overline{V}(x,t) = \frac{\sum_{i=1}^{k} V(x,t,i)}{k} \]

**Fig. C-1. Definition Of Optimizing Function Used To Accomplish The DX-DT Aggregation Analysis.**
$S_{(x,t)}$ : sample standard deviation, of vehicle speeds, associated with a single averaging region for specified DX-DT combination.

$S_B$ : sample standard deviation, of average vehicle speeds, between subgroups for current DX-DT combination.

$D_{X_{\text{max}}}$ : largest quantity of distance (DX), to be used as an averaging interval, that provides an ample number of lesser values each being a multiple of it.

$D_{T_{\text{max}}}$ : largest quantity of time (DT), to be used as an averaging interval, that provides an ample number of lesser values each being a multiple of it.

$V_{(x,t,i)}$ : an actual vehicle speed found within the $x^{\text{th}}$ and $t^{\text{th}}$ region of the current DX-DT combination for a specific data set.

$k$ : the total number of vehicle speeds found within the $x^{\text{th}}$ and $t^{\text{th}}$ region of the current DX-DT combination for a specific data set.

---

**Fig. C-1 (cont). Definition Of Optimizing Function Used To Accomplish The DX-DT Aggregation Analysis.**
To accomplish the DX-DT aggregation analysis.

\[ \alpha \] average standard deviation of vehicle speeds within all subgroups for current DX-DT combination.

\[ N = DT_{max}/DT \]

\( N \)

counted with the current DX-DT combination

\[ M = DX_{max}/DX \]

\( M \)

set, associated with the current DX-DT combination

\[ M \]

number of distance intervals (length= DX), for a given data set

\[ N \]

number of time intervals (length= DT), for a given data set

Fig. C-1 (cont). Definition of Optimizing Function Used

Subgroups for current DX-DT combination.

\[ M \]

number of distance intervals (length= DX), for a given data set
1) \( N_r = \) total number of vehicle speeds used in Aggregation Analysis for specified data set?

**EXAMPLE:** Roscoe Blvd.

\[
N_r = \frac{N_{\text{MAX}}}{(D_{\text{ABS-MAX}} \times D_{\text{TABS-MAX}})} \times (D_{\text{MAX}} \times D_{\text{TMAX}})
\]

\[
N_r = \frac{200,000 \text{ records}}{(1788 \text{ ft} \times 3632 \text{ sec})} \times (1664 \text{ ft} \times 3072 \text{ sec}) = 157,431 \text{ records}
\]

Where:

- \( N_{\text{MAX}} \): total number of vehicle speeds contained within the current data set.
- \( D_{\text{ABS-MAX}} \): absolute maximum averaging distance possible for current data set (roadway length).
- \( D_{\text{TABS-MAX}} \): absolute maximum averaging time length possible for current data set (filming period length).
- \( D_{\text{MAX}} \): maximum averaging distance used in DX-DT Aggregation Analysis for current data set.
- \( D_{\text{TMAX}} \): maximum averaging time length used in DX-DT Aggregation Analysis for current data set.

Likewise:

- Backlick Rd.: \( N_r = 136,600 \) records
- Mulholland Dr.: \( N_r = 113,969 \) records

**Fig. C-2.** Estimation Procedures Used To Predict DX-DT Combinations Returning Erroneous Standard Deviation Results From Aggregation Analysis.
2) \( \bar{v} \) = average vehicle speed for specified data set?

**EXAMPLE:** Roscoe Blvd.

\[ \bar{v} = 45.51 \text{ mph (fig.A-4)} \]

**Likewise:** Backlick Rd.: \( \bar{v} = 34.01 \text{ mph (fig.A-5)} \)
Mulholland Dr.: \( \bar{v} = 39.92 \text{ mph (fig.A-6)} \)

3) \( C_N \) = largest positive unsigned 4-byte numeral (critical number)?

\[ C_N = 7F \text{FF} \text{FF} \text{FF}_{16} = 2.148 \times 10^9 \]

**NOTE:** any larger 4-byte number has a set sign-bit which corresponds to a negative quantity.

4) \( M \times N \) = number of vehicle speed subgroups, per DX-DT Combination, that will not cause erroneous results?

**EXAMPLE:** Roscoe Blvd.

\[ M \times N = \frac{\sqrt{C_N}}{\bar{v} \times N_r} \quad M \times N = \frac{\sqrt{2.148 \times 10^9 \text{ mph}^2}}{45.51 \text{ mph} \times 141,597 \text{ records}} = 139.04 \]

**Likewise:** Backlick Rd.: \( M \times N = 100.24 \)
Mulholland Dr.: \( M \times N = 95.71 \)

---

**Fig. C-2 (cont).** Estimation Procedures Used To Predict DX-DT Combinations Returning Erroneous Standard Deviation Results From Aggregation Analysis.
5) the DX-DT Combinations, predicted to be effected by the erroneous results, should follow this relationship:

**EXAMPLE:** Roscoe Blvd.

\[
\frac{D_{\text{MAX}} \times D_{\text{T MAX}}}{D_{\text{X}} \times D_{\text{T}}} > M \times N
\]

\[
\frac{1664 \text{ ft} \times 3072 \text{ sec}}{D_{\text{X}} \times D_{\text{T}}} > 139.04 \text{ vehicle speed subgroups}
\]

\[
\therefore D_{\text{X}} \times D_{\text{T}} > 36,765 \text{ ft} \cdot \text{sec}
\]

**Likewise:** Becklick Rd.: \( D_{\text{X}} \times D_{\text{T}} > 47,073 \text{ ft} \cdot \text{sec} \)

Mulholland Dr.: \( D_{\text{X}} \times D_{\text{T}} > 41,084 \text{ ft} \cdot \text{sec} \)

---

**Fig. C-2 (cont).** Estimation Procedures Used To Predict DX-DT Combinations Returning Erroneous Standard Deviation Results From Aggregation Analysis.
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**Legend:**

✓ signifies that $DX \times DT \leq 36,765$ ft·sec

✗ signifies that $DX \times DT > 36,765$ ft·sec

---

Fig. C-3. The DX-DT Combinations Predicted To Provide Erroneous Results For The Roscoe Boulevard Data Set.
Legend:

✓ signifies that $DX \times DT \leq 47,073$ ft⋅sec

✗ signifies that $DX \times DT > 47,073$ ft⋅sec

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Fig. C-4. The DX-DT Combinations Predicted To Provide Erroneous Results For The Backlick Road Data Set.
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**Legend:**  
✓ signifies that $DX \times DT \leq 41,084$ ft·sec  
× signifies that $DX \times DT > 41,084$ ft·sec  

**Fig. C-5.** The DX-DT Combinations Predicted To Provide Erroneous Results For The Mulholland Drive Data Set.
1) $k =$ estimated number of vehicle speeds per subgroup?

   Example: Roscoe Blvd.

   $$k = \frac{N_r}{\frac{D_{\text{MAX}} \times D_{\text{MAX}}}{D_{\text{X}} \times D_{\text{T12}}}}$$

   $$k = 157,431 \text{ vehicle speeds} / \frac{1664 \text{ ft} \times 3072 \text{ sec}}{39,936 \text{ ft} \times \text{sec}} \approx 1,230 \text{ vehicle speeds/subgroup}$$

   where: $D_{X} \times D_{T12}$ corresponds to Roscoe Blvd's DX-DT Combination equal to $D_{X} = 13 \text{ ft}$ and $D_{T} = 1664 \text{ sec}$.

2) $s =$ sample standard deviation of vehicle speeds within a specific subgroup?

   $$s = \sqrt{\frac{\sum_{i=1}^{k} \nabla^2 - (\sum_{i=1}^{k} \nabla)^2 / k}{k-1}}$$

   where: $\bar{\nabla}$ is the average vehicle speed occurring within the Roscoe Blvd data set (= 45.51 mph).

Fig. C-6. Estimation Procedures Used To Predict Standard Deviation Magnitude For DX-DT Combinations Returning Erroneous Results.
2b) \[ \sum_{i=1}^{k} \bar{y}^2 \approx (k \cdot \bar{y})^2 = 3,133,458,115_{10} > 2,147,483,647_{10} \]

- \( 2,147,483,648_{10} \) \( \left(\begin{array}{c} 00000000000000000000000000000002 \end{array}\right) \)

computer interprets (positive) number as being negative.

\[ \therefore \left( \sum_{i=1}^{k} \bar{y} \right)^2 = -2,147,483,647_{10} + (3,133,458,115_{10} - 2,147,483,647_{10}) \]
\[ \approx -1,161,509,181_{10} \]

\[ \therefore s = \sqrt{\frac{(45.51)^2(1230)}{1229} - \frac{(-1,161,509,181 / 1230)}} = 53.3 \text{ mph} \]

Fig. C-6 (cont). Estimation Procedures Used To Predict Standard Deviation Magnitude For DX-DT Combinations Returning Erroneous Results.
Program Name: StdDevW.For written in MS FORTRAN (Vers. 5.0)

Purpose: To measure the effect of different DX-DT combinations, for traffic flow aggregation, on the variability within the sample cell distributions.

The goal of this will be to find a DX-DT combination that will minimize the variability within each cell.

The program requires a data file from the aerial photograph study. Also required is an external data file stddevw_cti containing: the initial frame of the data file (IFrame), the portion of the roadway distance that we are interested in (TLDIST), the portion of the data file with respect to time that we are interested in (TLTIME), and the last frame number that we want to observe (LFRAME). Also required is the external data files dx.ctl and dt.ctl containing the values corresponding to averaging intervals of distance and time that the program will iterate through to achieve the different DX-DT combinations. The results of the program will be written to the screen as well as to an external file named stddevw.out.

The program was executed on a SUN Workstation and required, on average, 13 hours for each of the three data sets used in the DX-DT Aggregation Analysis.

Date: July 9, 1989

Defining of Variables

```
INTEGER*1 VTYPE, VLENGTH, VSPEED, VCOLOR, LANENUM
INTEGER*2 VID, LONGD, LATD, FRAME
INTEGER IFRAME, MFRAME, LFRAME, DT, DX, XT, AVEN
INTEGER D1, D2, NN, TLDIST, TLTIME, N2 (130,3100)
INTEGER CHECK (9000), SUMMXXI (130), NN (130), SUM2XI (130)
REAL AVE, VAR, SD, AVESPD (130,3100), SUMAVE
REAL VAR2 (130,3100), SUMVAR
```

Meaning of Variables

```
* DT : The amount of time (sec.) that will be used as the constant averaging interval length to iterate from IFRAME to TLTIME.
* DX : The distance (feet) that will be used as the constant averaging interval length to iterate from the beginning of the "roadway" system (0 feet) to TLDIST.
* FRAME : A number corresponding to the value of the frame field for a given record associated with the current data set.
* VID : The number given to a vehicle as it enters the "roadway" system (Vehicle Identification).
* VTYPE : The TYPE of Vehicle associated with VID (car, truck, etc.).
* VLENGTH : The LENGTH of the Vehicle associated with VID.
* VSPEED : The SPEED of the Vehicle associated with VID.
* LONGD : The LONGitudinal Distance between the vehicle's front bumper (center) and the beginning of the "roadway" system.
* LATD : The LATitudinal Distance between the vehicle's front bumper (center) and the roadway's edgeline (rh-side).
* VCOLOR : The COLOR of the Vehicle associated with VID.
* LANENUM : The LANE number which the vehicle is traveling in (right most lane= 1, next lane to left=2, etc. while any accel/decel lane= 8).
* IFRAME : The FRAME number of the Initial record in the current data set.
* MFRAME : The FRAME number that corresponds to the last frame of the current averaging interval of time length DT.
```

Fig. C-7. The StdDevW.For Computer Program (Subroutines) Used In The DX-DT Aggregation Analysis.
** LFRAME : The Last FRAME number in current data set that we are interested in for the DX-DT Analysis.
** TTIME : The Total elapsed TIME (sec.) of vehicular traffic being considered from the current "roadway" system (data set) for the DX-DT Analysis.
** TLDIST : The Total Longitudinal DISTance currently being considered with the current "roadway" system (data set) for the DX-DT Analysis.
** XT : A dummy variable that is used to keep count of the # of different time intervals for the current DT and TTIME values (ex. XT = 1, 2, 3, ...M; where M = an integer equal to TTIME /DT).
** D1 : A dummy variable used to accumulate the summation of the averaging distance interval for the given DX (ex. for DX= 200 ft, D1= 200, 400, 600, etc.)
** D2 : A dummy variable used to convert D1 into values ranging from 1, 2, 3, ...M; where M = D1/DX.
** CHECK : Is an array that is used to monitor the vehicles before they are used in the study. The first occurrence of a given vehicle will coincide with an undefined speed (VSPEED = 0). This is a side-effect of the data reduction process and needs to be excluded from the analysis.
** AVESPD : Is a 2-D array that will store an average speed for each two-dimensional cell of area DX-DT.
** N2 : A two-dimensional array that is used to store the # of speeds used while determining the AVESPD value above.
** VAR2 : A two-dimensional array containing the variance of vehicle speeds occurring within DX-DT area associated with AVESPD and N2 above.
** SUMMXI: A one-dimensional array that is used to accumulate a vehicle speeds which will be ultimately used in calculating AVESPD and VAR2 above.
** SUM2XI: Is used to accumulate the square of each average speed which will ultimately be used in calculating VAR2 above.
** N : A one-dimensional array that is used to count the number of vehicles occurring within roadway section "D2" during current time section.
** SUMAVE : Is used to accumulate all the average speeds that are greater than zero.
** SUMVAR : Is used to accumulate all the variances that are greater than zero.
** NN : Used to count the number of cells containing a non-zero average speed (AVESPD (D2,T2)).
** AVEN : The average number of vehicles contained within a cell for the current DX-DT combination.
** AVE : The grand average speed associated with a DX-DT combination calculated from the accumulation of each cell’s average speed.
** VAR : The average variability associated with the speeds occurring within each cell for a DX-DT combination.
** SD : The average standard deviation associated with the speeds occurring within each cell for a DX-DT combination.

******************************************************************************

** Let's open these external files !

OPEN (12, FILE = 'ROSCOIQ.DAT', FORM = 'BINARY', + ACCESS = 'SEQUENTIAL')
OPEN (5, FILE = 'stddevw.ctl')
OPEN (7, FILE = 'dx.ctl', ACCESS = 'SEQUENTIAL')
OPEN (8, FILE = 'dt.ctl', ACCESS = 'SEQUENTIAL')
OPEN (17, FILE = 'stddevw.out')

******************************************************************************

Fig. C-7 (cont). The StdDevW. For Computer Program (Subroutines) Used In The DX-DT Aggregation Analysis.
* Let's read all the records in the 'stddevw.ctl' control file!

    READ (5,*) IFRAME
    READ (5,*) TLDIST
    READ (5,*) TLTIME
    READ (5,*) LFRAME

* Let's prepare a heading for the output file 'stddevw.out'!

    WRITE (17,*)
    WRITE (17,*)' This is the stddevw.out file for Roscoe Blvd.'
    WRITE (17,*)
    WRITE (17,*)'-----------------------------------------------'

* Let's initialize these variables to zero!

    XT = 0
    SUMVAR = 0.0
    SUMAVE = 0.0

    DO 040, D1 = DX, TLDIST, DX
        D2 = D1/DX
        SUMXI (D2) = 0
        SUM2XI (D2) = 0
        N (D2) = 0
    040 CONTINUE

* Let's read the value of DX from 'dx.ctl'!

    050 READ (7,*) DX

* Let's see if we have read through the entire list of DX values!

    IF ( DX .EQ. 9999 ) THEN
        GOTO 600
    ENDIF

* Let's read the value of DT from 'dt.ctl'!

    075 READ (8,*) DT

* Let's see if we have read through the entire list of DT values!

    IF ( DT .EQ. 9999 ) THEN
        GOTO 500
    ENDIF

* What frame # corresponds to the last frame of current time interval?

    MFRAME = IFRAME + DT - 1

Fig. C-7 (cont). The StdDevW. For Computer Program (Subroutines) Used In The DX-DT Aggregation Analysis.
Let's read a record from the current data set!

```
100 READ (12, END = 400) FRAME, VID, VTYPE, VLENGTH, VSPEED, LONGD, + LATD, VCOLOR, LANENUM
```

* If current frame # belongs in next time interval then current time
  * interval is finished and operations must be done to determine the
  * variability of speeds for current time interval along with the
  * preparation (clean-up) for the next time interval!

```
IF ( FRAME .GT. MFRAME ) THEN

  XT = XT + 1
  CALL CELL-AVEVAR-W ( DX, N, SUMMXI, AVESPD, XT, TLDIST, N2, + VAR2, SUM2XI )

  MFRAME = MFRAME + DT

  DO 200, D1 = DX, TLDIST, DX
    D2 = D1 / DX
    SUMMXI (D2) = 0
    SUM2XI (D2) = 0
    N (D2) = 0
  200 CONTINUE

ENDIF
```

* Let's check if current frame number is further than we want to look!

```
IF ( FRAME .GT. LFRAME ) THEN
  GOTO 400
ENDIF
```

* The current record must have a defined speed for it to be included in
  * the analysis (side effect of original data reduction operation)!

```
IF ( CHECK (VID) .EQ. 1 ) THEN
  CALL SPEED-BUCKET-W ( DX, LONGD, SUMMXI, VSPEED, N, TLDIST, + SUM2XI )
ELSE
  IF ( VSPEED .NE. 0 ) THEN
    CHECK (VID) = 1
    CALL SPEED-BUCKET-W ( DX, LONGD, SUMMXI, VSPEED, N, + TLDIST, SUM2XI )
  ENDIF
ENDIF
```

* Let's go get another record!

```
GOTO 100
```

---

**Fig. C-7 (cont).** The StdDevW. For Computer Program (Subroutines) Used In The DX-DT Aggregation Analysis.
Fig. C-7 (cont). The StdDevW. For Computer Program (Subroutines) Used In The DX-DT Aggregation Analysis.
Subroutine Name: CELL-AVEVAR-W

Purpose: A subroutine to calculate the average speed and variance of speeds for vehicles on the roadway during the current section of time.

SUBROUTINE CELL-AVEVAR-W (DX, N, SUMMXI, AVESPD, XT, TLDIST, N2 + VAR2, SUM2XI)

Defining of Variables

INTEGER D1, D2, TLDIST, DX, XT, N (130), SUMMXI (130)
INTEGER N2 (130,3100), SUM2XI (130)
REAL AVESPD (130,3100), VAR2 (130,3100)

* Let's iterate through the sections of roadway for current DX!
DO 100, D1 = DX, TLDIST, DX
    D2 = D1 / DX

* Let's calculate the average speed and the variance of speeds for each section of roadway for the current section of time:
    IF (( N (D2) .EQ. 0 ) .OR. ( SUMMXI (D2) .EQ. 0 )) THEN
        AVESPD (D2,XT) = 0.0
        N2 (D2,XT) = N (D2)
        VAR2 (D2,XT) = 0.0
    ELSE
        AVESPD (D2,XT) = FLOAT (SUMMXI (D2)) / FLOAT (N (D2))
        VAR2 (D2,XT) = (FLOAT (SUM2XI (D2)) - (FLOAT (SUMMXI (D2)**2) / FLOAT (N (D2)))) / FLOAT (N (D2) - 1)
        N2 (D2,XT) = N (D2)
    ENDIF

* Let's go look at the next section of roadway!
100 CONTINUE

* Let's get outta here!
RETURN
END

Fig. C-7 (cont). The StdDevW.For Computer Program (Subroutines) Used In The DX-DT Aggregation Analysis.
Subroutine Name: SPEED-BUCKET-W

Purpose: The purpose of this program is to accumulate the actual speed of every vehicle as it passes through the sections of roadway for the current section of time (XT). The accumulation process includes the necessary procedures to enable the later calculation of the variance in CELL-AVEVAR-W.

SUBROUTINE SPEED-BUCKET-W (DX, LONGD, SUMMXI, VSPEED, N, TLDIST, SUMZXI)

** Defining of Variables **

INTEGER*1 VSPEED
INTEGER*2 LONGD
INTEGER D1, D2, ALARM, TLDIST, DX, N (130), SUMMXI (130), SUMZXI (130)

* Let's initialize alarm to zero!

ALARM = 0

* Let's iterate through the sections of roadway for current DX!

DO 100, D1 = DX, TLDIST, DX
   D2 = D1 / DX

* Let's check if current speed has been added to a section of roadway!

IF ( ALARM .EQ. 1 ) THEN
   GOTO 200
ENDIF

* Let's check if car's location falls within current roadway section,
* so we can accumulate the necessary information to later calculate the mean and variance, or let's make sure we keep looking for the correct roadway section!

IF ( LONGD .LE. D1 ) THEN
   SUMMXI (D2) = SUMMXI (D2) + VSPEED
   SUMZXI (D2) = SUMZXI (D2) + VSPEED ** 2
   N (D2) = N (D2) + 1
   ALARM = 1
ELSE
   ALARM = 0
ENDIF

* Let's go look at the next section of roadway!

100 CONTINUE

* Let's get outta here!

200 RETURN

END

---

Fig. C-7 (cont). The StdDevW.For Computer Program (Subroutines) Used In The DX-DT Aggregation Analysis.
Subroutine Name: GRAND-AVESD-W

Purpose: The purpose of this subroutine is to accumulate the averages and variances that were calculated earlier (CELL-AVEVAR-W). This process will enable the grand average speed and the average variance within each of the cells for a given DX-DT combination to be calculated.

SUBROUTINE GRAND-AVESD-W (DX, DT, AVESPD, SUMAVE, NN, AVE, N2, AVEN, VAR, SD, TLDIST, TLTIME, VAR2, SUMVAR)

*** Defining of Variables ****************************************************

INTEGER D1, D2, T1, T2, SUMN, Z, DX, DT, NN, TLDIST, TLTIME
INTEGER N2 (130,3100), AVEN
REAL AVESPD (130,3100), SUMAVE, VAR2 (130,3100)
REAL AVE, VAR, SD, SUMVAR, NVAR

* Let's initialize these to zero!

NN = 0
NVAR = 0
SUMN = 0
Z = 0
SUMAVE = 0
SUMVAR = 0

* Let's iterate through the sections of roadway for current DX!

DO 100, D1 = DX, TLDIST, DX
   D2 = D1 / DX

* Let's iterate through the sections of time for current DT!

DO 200, T1 = DT, TLTIME, DT
   T2 = T1 / DT

* Let's do the necessary accumulations to later determine the average number of vehicles per cell!

   SUMN = SUMN + N2 (D2,T2)
   Z = Z + 1

* Let's do the necessary accumulations to later determine the grand average speed and average variability of speeds within all cells!

   IF ( AVESPD (D2, T2) .NE. 0 ) THEN
      SUMAVE = SUMAVE + AVESPD (D2,T2)
      SUMVAR = SUMVAR + VAR2 (D2,T2)
      NN = NN + 1
   ENDIF

Fig. C-7 (cont). The StdDevW. For Computer Program (Subroutines) Used In The DX-DT Aggregation Analysis.
* Let's go get another section of time for current value of DT!
200 CONTINUE

* Let's go get another section of roadway for current value of DX!
100 CONTINUE

* Let's calculate the average # of vehicles per cell, the grand average
* speed per cell, and the average variability of speeds within all
* cells for the current DX-DT combination!
  AVEN = ( FLOAT(SUMN) / FLOAT(Z) ) + 0.5
  AVE  = FLOAT(SUMAVE) / FLOAT(NN)
  VAR  = SUMVAR / NN

* Let's calculate the average standard deviation of speeds within all
* cells for the current DX-DT combination!
  IF ( VAR .EQ. 0 ) THEN
    SD = 0
  ELSE
    SD = SQRT(VAR)
  ENDIF

* Let's get outta here!
RETURN
END

Fig. C-7 (cont). The StdDevW. For Computer Program (Subroutines) Used In The DX-DT Aggregation Analysis.
Subroutine Name: FRNSTUF-W

Purpose: The purpose of this subroutine is to write the grand average speed, the average standard deviation, and the average number of vehicles contained within all cells for the current DX-DT combination to the screen and to the external file stddevw.out.

SUBROUTINE FRNSTUF-W (DX, DT, AVE, SD, AVEN)

INTEGER DX, DT, AVEN
REAL AVE, SD

WRITE (17, 100) DX, DT
100 FORMAT (1X, 'For DX = ', I4, '(feet), and DT = ', I4, '(sec)')
WRITE (*, 105) DX, DT
105 FORMAT (1X, 'For DX = ', I4, '(feet), and DT = ', I4, '(sec)')

WRITE (17, *) '
WRITE (17, *) '
WRITE (*,*) '
WRITE (*,*) '

WRITE (17, 200) AVE, SD
200 FORMAT (1X, 'Ave = ', F7.4, 4X, 'SD = ', F7.4)
WRITE (*, 205) AVE, SD
205 FORMAT (1X, 'Ave = ', F7.4, 4X, 'SD = ', F7.4)

WRITE (17, 300) AVEN
300 FORMAT (1X, 'Aven = ', I7)
WRITE (*, 305) AVEN
305 FORMAT (1X, 'Aven = ', I7)

WRITE (17,*) '
WRITE (17,*) '
WRITE (17,*) '---------------------------------------------------'
WRITE (*,*) '
WRITE (*,*) '
WRITE (*,*) '---------------------------------------------------'

* Let's get outta here!
RETURN
END

Fig. C-7 (cont). The StdDevW.For Computer Program (Subroutines) Used In The DX-DT Aggregation Analysis.
**Subroutine Name**: ZZERO-W

**Purpose**: The purpose of this subroutine is to "zero" all the relevant variables to enable the batch processing to calculate the correct values.

```plaintext
SUBROUTINE ZZERO-W ( DX, TLDIST, XT, AVESPD, SUMMXI, N, MFRAME, 
                      SUMAVE, NN, AVE, VAR, SD, CHECK, N2, SUM2XI, VAR2, SUMVAR 
                      AVEN )

*** Defining of Variables ****************************

INTEGER DX, TLDIST, XT, D2, MFRAME, NN, SUMXI(130), AVEN
INTEGER CHECK(9000), VID, D1, N(130), SUMMMXI(130)
REAL AVESPD(130,3100), SUMAVE, VAR2(130,3100), SUMVAR
REAL AVE, VAR, SD

* Let's iterate through the sections of roadway for current DX !
DO 100, D1 = DX, TLDIST, DX
   D2 = D1 / DX

* Let's iterate through the sections of time regardless of current DT !
DO 200, XT = 1, 3100, 1

* Let's make sure that the average and variability of speeds are all set to zero !
   AVESPD(D2,XT) = 0
   N2(D2,XT) = 0
   VAR2(D2,XT) = 0

* Let's go get another section of time regardless of current DT !
200 CONTINUE

* Let's make sure these accumulators are set to zero !
   SUMMXI(D2) = 0
   N(D2) = 0
   SUM2XI(D2) = 0

* Let's go get another section of roadway for current value of DX !
100 CONTINUE

* Let's make sure that these variables (accumulators) are set to zero !
   MFRAME = 0
   XT = 0
   SUMAVE = 0
   NN = 0
```

Fig. C-7 (cont). The StdDevW. For Computer Program (Subroutines) Used In The DX-DT Aggregation Analysis.
AVE = 0
VAR = 0
SD = 0
SUMVAR = 0
AVEN = 0
SUMN = 0
Z = 0

*-----------------------------------------------------------------------
* Let's iterate through Vehicle ID's and erase memory of occurrences:
DO 300, VID = 1, 9000, 1
    CHECK (VID) = 0
100  CONTINUE
*-----------------------------------------------------------------------
* Let's get outta here!
    RETURN
END

*-----------------------------------------------------------------------

Fig. C-7 (cont). The StdDevW. For Computer Program (Subroutines) Used In The DX-DT Aggregation Analysis.
Program Name: StdDevB.Form written in MS FORTRAN (Vers. 5.0)

Purpose: To measure the effect of different DX-DT combinations, for traffic flow aggregation, on the variability between the sample cell distributions. The goal of this will be to find a DX-DT combination that will maximize the variability between each cell. The program requires a data file from the aerial photograph study. Also required is an external data file stddevw.ctl containing: the initial frame of the data file (IFRAME), the portion of the roadway distance that we are interested in (TLDIST), the portion of the data file with respect to time that we are interested in (TLTIME), and the last frame number that we want to observe (DFRAME). Also required is the external data files dx.ctl and dt.ctl containing the values corresponding to averaging intervals of distance and time that the program will iterate through to achieve the different DX-DT combinations. The results of the program will be written to the screen as well as to an external file named stddev.out. This program was executed on a SUN Workstation and required, on average, 13 hours for each of the three data sets used in the DX-DT Aggregation Analysis.

Date: July 11, 1989

Defining of Variables

```
INTEGER*1 VTYPE, VLENGTH, VSPEED, VCOLOR, LANENUM
INTEGER*2 VID, LONGD, LATD, FRAME
INTEGER IFRAME, MFRAME, LFRAME, DT, DX, XT, D1, D2, NN
INTEGER TLDIST, TLTIME, CHECK (9000), SUMXI (130), N (130)
REAL AVE, VAR, SD, AVESPD (130,3100), SUMXI, SUM2XI
```

Meaning of Variables

** DT : The amount of time (sec.) that will be used as the constant averaging interval length from IFRAME to TLTIME.**
** DX : The distance (feet) that will be used as the constant averaging interval length to iterate from the beginning of the "roadway" system (0 feet) to TLDIST.**
** FRAME : A number corresponding to the value of the frame field for a given record associated with the current data set.**
** VID : The number given to a vehicle as it enters the "roadway" system (Vehicle Identification).**
** VTYPE : The TYPE of Vehicle associated with VID (car, truck, etc.).**
** VLENGTH : The LENGTH of the Vehicle associated with VID.**
** VSPEED : The SPEED of the Vehicle associated with VID.**
** LONGD : The LONGitudinal Distance between the vehicle's front bumper (center) and the beginning of the "roadway" system.**
** LATD : The LATitudinal Distance between the vehicle's front bumper and the roadway's edgeline (right side).**
** VCOLOR : The COLOR of the Vehicle associated with VID.**
** LANENUM : The LANE NUMBER which the vehicle is traveling in (right most lane= 1, nearest lane to left= 2, etc., while any accel/decel lane= 8.**
** IFRAME : The FRAME number of the Initial record in the current data set.**
** MFRAME : The FRAME number that corresponds to the last frame of the current averaging interval of time length DT.**
** LFRAME : The Last FRAME number in current data set that we are interested in for the DX-DT Analysis.**

Fig. C-8. The StdDevB.Form for Computer Program (Subroutines) Used In The DX-DT Aggregation Analysis.
** TLTIME : The Total elapsed TIME (sec.) of vehicular traffic flow
** being considered from the current "roadway" system (data
** set) for the DX-DT Analysis.
** TLDIST : The Total Longitudinal DISTance currently being considered
** with the current "roadway" system (data set) for the DX-DT
** Analysis.
** XT : A dummy variable that is used to keep count of the # of
** different time intervals for the current DT and TLTIME
** values (ex. XT= 1, 2, 3,...M; where M= an integer equal to
** (TLTIME /DT).
** D1 : A dummy variable used to accumulate the summation of the
** averaging distance interval for the given DX (Ex. for DX=
** 200 ft., D1= 200, 400, 600, etc.).
** D2 : A dummy variable used to convert D1 into values ranging
** from 1, 2, 3,... M; where M= D1/DX.
** CHECK : Is an array that is used to monitor the vehicles they are
** used in the study. The first occurrence of a given vehicle
** will coincide with an undefined speed (VSPEED= 0). This is
** a side-effect of the data reduction process and needs to be
** excluded from our analysis.
** AVESPD : Is a 2-D array that will store an average speed for each
** two-dimensional cell of area DX-DT.
** N : A one-dimensional array that is used to store the # of speeds
** (vehicles) used while determining the AVESPD value above.
** SUMMXI: A one-dimensional array that is used to accumulate
** vehicle speeds which will be ultimately used in calculating
** the AVESPD value above.
** NN : Used to count the number of non-zero AVESPD values which will
** ultimately be used in calculating VAR below.
** SUMXI: Is used to accumulate the average vehicle speeds which will
** ultimately be used in calculating VAR below.
** SUM2XI: Is used to accumulate the square of each average speed
** which will ultimately be used in calculating VAR below.
** AVE : The grand average speed, associated with a DX-DT combination,
** calculated from the accumulation (SUMXI) of each cell's
** average speed.
** VAR : The variability between the non-zero average speeds from the
** cells for the DX-DT combination.
** SD : The standard deviation between the non-zero average speeds
** from the cells for the DX-DT combination.

Let's open these external files:

OPEN (12, FILE = 'ROSC01Q.DAT', FORM = 'BINARY',
+ ACCESS = 'SEQUENTIAL')
OPEN (5, FILE = 'stddevb.ctl')
OPEN (7, FILE = 'dx.ctl', ACCESS = 'SEQUENTIAL')
OPEN (8, FILE = 'dt.ctl', ACCESS = 'SEQUENTIAL')
OPEN (17, FILE = 'stddevb.out')

Let's read all the records in the 'stddevb.ctl' control file:

READ (5,*), IFRAME
READ (5,*), TLDIST
READ (5,*), TLTIME
READ (5,*), LFRAME

Fig. C-8 (cont). The StdDevB. For Computer Program
(Subroutines) Used In The DX-DT Aggregation Analysis.
* Let's prepare a heading for the output file 'stddevb.out'!

WRITE (17,*) '      ' 
WRITE (17,*) ' This is the stddevb.out file for Roscoe Blvd.'
WRITE (17,*) '      ' 
WRITE (17,*) '-----------------------------------------------'
WRITE (17,*) '      ' 

* Let's initialize these variables to zero:

XT = 0
SUMXI = 0
SUM2XI = 0
NN = 0

DO 040, D1 = DX, TLDIST, DX
  D2 = D1/DX
  SUM2XI (D2) = 0
  N (D2) = 0
040 CONTINUE

* Let's read the value of DX from 'dx.ctl'!

050 READ (7,*) DX

* Let's see if we have read through the entire list of DX values!

IF ( DX .EQ. 9999 ) THEN
  GOTO 600
ENDIF

* Let's read the value of DT from 'dt.ctl'!

075 READ (8,*) DT

* Let's see if we have read through the entire list of DT values!

IF ( DT .EQ. 9999 ) THEN
  GOTO 500
ENDIF

* What frame # corresponds to the last frame of current time interval?

MFRAME = IFRAME + DT - 1

* Let's read a record from the current data set!

100 READ (12, END = 400) FRAME, VID, VTYPE, VLENGTH, VSPEED, LONGD, 
    LATD, VCOLOR, LANENUM

Fig. C-8 (cont). The StdDevB. For Computer Program 
(Subroutines) Used In The DX-DT Aggregation Analysis.
* If current frame number is further than we want to look !
  IF ( FRAME .GT. LFRAME ) THEN
    GOTO 400
  ENDIF
*
* Let's go get another record !
  GOTO 100
*
* We are finished reading records for current DX-DT combination !
  CALL GRAND-AVESD-B ( DX, DT, AVESPD, SUMXI, NN, SUM2XI, AVE, VAR, SD, TLDIST, TLTIME )
  CALL PRNSTUFF-B ( DX, DT, AVE, SD )
  CALL ZZERO-B ( DX, TLDIST, XT, AVESPD, SUMXI, N, MFRAME, SUMXI, NN, SUM2XI, AVE, VAR, SD, CHECK )

Fig. C-8 (cont). The StdDevB.For Computer Program (Subroutines) Used In The DX-DT Aggregation Analysis.
* Let's rewind the current data set to its first record!
  
  REWIND (12)

* Let's go get the next DT value that we are going to use!
  
  GOTO 075

* Let's rewind the external file 'dt.ctl' to its first record!
  
  500  REWIND (8)

* Let's go get the next DX value that we are going to use!
  
  GOTO 050

* Let's get outta here!
  
  600  STOP

END

Fig. C-8 (cont). The StdDevB. For Computer Program (Subroutines) Used In The DX-DT Aggregation Analysis.
Subroutine Name: CELL-AVE-B

Purpose: A subroutine to calculate the average speed for vehicles on the roadway during the current section.

SUBROUTINE CELL-AVE-B (DX, N, SUMMXI, AVESPD, XT, TLDIST)

Defining of Variables:

INTEGER D1, D2, TLDIST, DX, XT, N (130), SUMMXI (130)
REAL AVESPD (130,3100)

* Let's iterate through the sections of roadway for current DX!

DO 100, D = DX, TLDIST, DX
  D2 = D1 / DX

* Let's calculate the average speed for each section of roadway for the current section of time!

  IF ((N (D2) .EQ. 0) .OR. (SUMMXI (D2) .EQ. 0)) THEN
  AVESPD (D2, XT) = 0
  ELSE
  AVESPD (D2, XT) = FLOAT(SUMMXI (D2)) / FLOAT(N (D2))
  ENDIF

* Let's go look at the next section of roadway!

100 CONTINUE

* Let's get outta here!

RETURN
END

Fig. C-8 (cont). The StdDevB.For Computer Program (Subroutines) Used In The DX-DT Aggregation Analysis.
Subroutine Name: SPEED-BUCKET-B

Purpose: The purpose of this program is to accumulate the actual speed of every vehicle as it passes through the sections of roadway for the current section of time (XT). The accumulation process includes the necessary procedures to enable the later calculation of the average in AVERX.

Subroutine SPEED-BUCKET-B (DX, LONGD, SUMMXI, VSPEED, N, TLDIST)

Defining of Variables

INTEGER*1 VSPEED
INTEGER*2 LONGD
INTEGER D1, D2, ALARM, TLDIST, DX, N (130), SUMMXI (130)

* Let's initialize alarm to zero!

ALARM = 0

* Let's iterate through the sections of roadway for current DX!

DO 100, D1 = DX, TLDIST, DX
   D2 = D1 / DX

* Let's check if current speed has been added to a section of roadway!

IF ( ALARM .EQ. 1 ) THEN
   GOTO 200
ENDIF

* Let's check if car's location falls within current roadway section so we can do the necessary procedures to calculate the mean later, or we should be sure to keep looking for the correct freeway region!

IF ( LONGD .LE. D1 ) THEN
   SUMMXI (D2) = SUMMXI (D2) + VSPEED
   N (D2) = N (D2) + 1
   ALARM = 1
ELSE
   ALARM = 0
ENDIF

* Let's go look at the next section of roadway!

100 CONTINUE

* Let's get outta here!

200 RETURN

END

Fig. C-8 (cont). The StdDevB.For Computer Program (Subroutines) Used In The DX-DT Aggregation Analysis.
**Subroutine Name**: GRAND-AVESD-B

**Purpose**: The purpose of this subroutine is to accumulate the averages that were calculated earlier (AVERX). This process will enable the grand average speed and the variance between average speeds for a given DX-DT combination to be calculated.

SUBROUTINE GRAND-AVESD-B (DX, DT, AVESPD, SUMXI, NN, SUM2XI, AVE, VAR, SD, TLDIST, TLTIME)

***Defining of Variables***

INTEGER D1, D2, T1, T2, DX, DT, NN, TLDIST, TLTIME
REAL AVESPD (130,1100), SUMXI, SUM2XI, AVE, VAR, SD

* Let's initialize NN to zero!
  
  NN = 0

* Let's iterate through the sections of roadway for current DX!

DO 100, D1 = DX, TLDIST, DX
  D2 = D1 / DX

* Let's iterate through the sections of time for current DT!

DO 200, T1 = DT, TLTIME, DT
  T2 = T1 / DT

* Let's do the necessary accumulations to later determine the grand average and the variability among individual cell averages!

IF (AVESPD (D2, T2) .NE. 0) THEN
  SUMXI = SUMXI + AVESPD (D2,T2)
  SUM2XI = SUM2XI + (AVESPD (D2,T2) ) ** 2
  NN = NN + 1
ENDIF

* Let's go get another section of time for current value of DT!

200 CONTINUE

* Let's go get another section of roadway for current value of DX!

100 CONTINUE

---

*Fig. C-8 (cont). The StdDevB.For Computer Program (Subroutines) Used In The DX-DT Aggregation Analysis.*
Let's calculate the grand average speed for all time and distance sections!

```
IF ( NN .EQ. 0 ) THEN
    AVE = 0
ELSE
    AVE = SUMXI / FLOAT (NN)
ENDIF
```

Let's calculate the variability among individual cell averages!

```
IF ( NN .LE. 1 ) THEN
    VAR = 0
ELSE
    VAR = (SUM2XI - (((SUMXI)**2) / FLOAT (NN))) / (FLOAT (NN-1))
ENDIF
```

Let's calculate standard deviation from the variance above!

```
IF ( VAR .EQ. 0 ) THEN
    SD = 0
ELSE
    SD = SQRT (VAR)
ENDIF
```

Let's get outta here!

```
RETURN
END
```

Fig. C-8 (cont). The StdDevB.For Computer Program (Subroutines) Used In The DX-DT Aggregation Analysis.
**Subroutine Name:** PRNSTUF-B

*** Purpose: *** The purpose of this subroutine is to write the grand average speed and the standard deviation between individual cell averages to the screen and to the external file stddevb.out.

**SUBROUTINE PRNSTUF-B (DX, DT, AVE, SD)**

**Defining of Variables**

```
INTEGER DX, DT
REAL AVE, SD
```

```
WRITE (17, 100) DX, DT
100 FORMAT (1X, 'For DX = ', I4, '(feet), and DT = ', I4, '(sec)')
WRITE (*, 105) DX, DT
105 FORMAT (1X, 'For DX = ', I4, '(feet), and DT = ', I4, '(sec)')
WRITE (17, *) '
WRITE (17, *) '
WRITE (*,*) '
WRITE (*,*) '
WRITE (17, 200) AVE, SD
200 FORMAT (1X, 'Ave = ', F7.4, 4X, 'SD = ', F7.4)
WRITE (*, 205) AVE, SD
205 FORMAT (1X, 'Ave = ', F7.4, 4X, 'SD = ', F7.4)
WRITE (17,*) '
WRITE (17,*) '---------------------------------------------------'
WRITE (*,*) '
WRITE (*,*) '---------------------------------------------------'
WRITE (17, *) 'Let's get outta here!
RETURN
END
```

*Fig. C-8 (cont). The StdDevB. For Computer Program (Subroutines) Used In The DX-DT Aggregation Analysis.*
**** Subroutine Name: ZZERO-B

Purpose: The purpose of this subroutine is to "zero" all the relevant variables to enable the batch processing to calculate the correct values.

SUBROUTINE ZZERO-B (DX, TLDIST, XT, AVESPD, SUMMXI, N, MFRAME, ...

Defining of Variables

INTEGER DX, TLDIST, XT, D2, MFRAME, NN
INTEGER CHECK (9000), VID, D1, N (130), SUMMXI (130)
REAL AVESPD (130,3100), SUMXI, SUM2XI, AVE, VAR, SD, CHECK

Let's iterate through the sections of roadway for current DX!
DO 100, D1 = DX, TLDIST, DX
   D2 = D1 / DX

Let's iterate through the sections of time and make sure that the average speeds are all set to zero!
DO 200, XT = 1, 3100, 1
   AVESPD (D2,XT) = 0
200 CONTINUE

Let's make sure these accumulators are set to zero!
SUMXI (D2) = 0
N (D2) = 0

Let's go get another section of roadway for current value of DX!
100 CONTINUE

Let's make sure that these variables (accumulators) are set to zero!
MFRAME = 0
XT = 0
SUMXI = 0
NN = 0
SUM2XI = 0
AVE = 0
VAR = 0
SD = 0

Let's iterate through Vehicle ID's and erase memory of occurrences!
DO 300, VID = 1, 9000, 1
   CHECK (VID) = 0
300 CONTINUE

Let's get outta here!
RETURN
END

Fig. C-8 (cont). The StdDevB For Computer Program (Subroutines) Used In The DX-DT Aggregation Analysis.
Legend: Shaded Area (□□□□) Represents the Raw Data Used as Input Files.

Fig. C-9. The stddevw.ctl and stddevb.ctl Data Files Used Within the StdDevW.For and StdDevB.For Computer Programs. (Note both control files are identical for same data set.)
### Fig. C-10. The dx.ctl Data Files Used Within the StdDevW.For and StdDevB.For Computer Programs. (Note that both computer programs use same dx.ctl file for each data set.)

<table>
<thead>
<tr>
<th>Roscoe Boulevard</th>
<th>Backlick Road</th>
<th>Mulholland Drive</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td>12</td>
<td>10</td>
</tr>
<tr>
<td>26</td>
<td>24</td>
<td>20</td>
</tr>
<tr>
<td>52</td>
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Legend: Shaded Area (□) Represents the Raw Data Used as Input Files.
For: Roscoe Boulevard,
Backlick Road, and
Mulholland Drive Data Sets.

Legend: Shaded Area ( ) Represents the
Raw Data Used as Input Files.

Fig. C-11. The dt.ctl Data File Used Within the StdDevW.For
and StdDevB.For Computer Programs. (Note that both
computer programs use same dt.ctl file for all data sets.)
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Fig. C-12. Output From StdDevW.For (Out) Concerning Standard Deviations Within Cells (top) and the Average Number of Vehicle Speeds Per Cell (bottom) for the Roscoe Boulevard Data Set.
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**Fig. C-13.** Output From StdDevB. For (Out) Concerning Standard Deviations, of Average Speeds, Between Cells for the Roscoe Boulevard Data Set.
Fig. C-14. Output From StdDevW.For (Out) Concerning Standard Deviations Within Cells (top) and the Average Number of Vehicle Speeds Per Cell (bottom) for the Backlick Road Data Set.
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**Fig. C-15.** Output From StdDevB.For (Out) Concerning Standard Deviations, of Average Speeds, Between Cells for the Backlick Road Data Set.
Fig. C-16. Output From StdDevW.For (Out) Concerning Standard Deviations Within Cells (top) and the Average Number of Vehicle Speeds Per Cell (bottom) for the Mulholland Drive Data Set.
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Fig. C-17. Output From StdDevB.For (Out) Concerning Standard Deviations, of Average Speeds, Between Cells for the Mulholland Drive Data Set.
APPENDIX  D

Computer Programs and Data Representing the Calibration of RFLO's Relaxation Constant.
<table>
<thead>
<tr>
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</table>

**LINK COMMAND**

The **LINK** command defines new links.

**Field 4:** LENGTH (Columns 31-40)  
The length of the new link in miles (or whatever unit of length is specified in the parameter file).

**Field 5:** TO LNK (Columns 41-50)  
If all the vehicles leaving this link leave the network, this, and all subsequent fields are blank. If, however, some (or all) of the vehicles go to another link, this field contains the name of the receiving link.

**Field 6:** % (Columns 51-60)  
The percent of the volume that goes to the link named in field 5.

**Field 7:** TO LNK (Columns 61-70)  
The name of any other link that receives traffic from this link. Blank if these vehicles exit the system.

**Field 8:** % (Columns 71-80)  
The percent of the volume that goes to the link named in field 7.

---

Fig. D-1. Summary of the RFLO Commands Commonly Used in a Simulation Instance (From Ross, 1989).
ONOFF COMMAND

The ONOFF command instructs RFLO to create traffic sources and sinks (on-and off-ramps). ONOFF has the most complex command syntax in RFLO.

Field 4: LOCAT (Columns 31-40) The milepost location of the ramp.

Field 5: ABS (Columns 41-50) The "absolute" on-flow (veh/hr) on this ramp. "200" here would mean that 200 veh/hr enter the roadway via a ramp at this location. "-200" would mean that 200 veh/hr LEAVE the road (regardless of how many vehicles are actually on the road).

Field 6: % (Columns 51-60) The "relative" off-flow (veh/hr) on this ramp. "12" here means that 12% of the flow on the mainline exits here. ("-12" would mean that a volume equal to 12% of the mainline flow ENTERS the road via this ramp. Entering volumes are rarely specified as fractions of the volume already on the roadway.)

Field 7: LINK (Columns 61-70) If, in addition to the above absolute on-ramp flow and relative off-ramp flow, there are also vehicles using this ramp that came from an off-ramp somewhere else in the network, give the name of the link which has that off-ramp here.

Field 8: LOCAT (Columns 71-A0) Milepost of matching ramp on the link named in field 7. The vehicles flowing off the mainline via the ramp described in fields 7 and 8 are added to the vehicles flowing onto the mainline via the ramp described in fields 2 and 4.

Fig. D-1 (cont). Summary of the RFLO Commands Commonly Used in a Simulation Instance (From Ross, 1989).
CAPACITY COMMAND
FREESPEED COMMAND
JAM COMMAND

Each location on a link is characterized by three geometric parameters: its capacity to carry traffic, the free speed of the traffic, and the "jam" density of vehicles. The CAPACITY, FREESPEED, and JAM commands set (or change) these parameters. The syntax of all three commands is the same:

Field 4: VALUE (Columns 31-40)
The numerical value of capacity, free speed, or jam density to be assigned. When a link is created, all locations are assigned default values for CAPACITY, FREESPEED, and JAM according to the defaults set in the parameter file. (RFLO.PAM and QUICK.PAM are initially supplied with values appropriate for two-lane freeways:
- CAPACITY 3600 veh/hr
- FREESPEED 63 mi/hr
- JAM 286 veh/mi.
No CAPACITY, FREESPEED, or JAM instruction is needed if these defaults are acceptable.)

Field 5: START (Columns 41-50)
The value in field 4 applies over a section of roadway within this link. The section starts at the milepost specified in field 5 and runs to the "End" given in field 6. Start and End are given in miles (or whatever units are specified in the parameter file).

Field 6: END (Columns 51-60)
End of the section which starts at "Start."

Field 7: Not used. (Columns 61-70)
Field 8: Not used. (Columns 71-80)

MOE COMMAND

As with PICTURE, the only parameter associated with the MOE command is the activation time in field 1.

At the time specified, the link and network measures of effectiveness are printed out. The MOEs printed are average speed and average delay per vehicle since the last call to MOE.

MOEs are printed at the end of the simulation automatically.

Fig. D-1 (cont). Summary of the RFLO Commands Commonly Used in a Simulation Instance (From Ross, 1989).
Each point on a link is characterized by three traffic variables: the density of vehicles (veh/ml), the average speed of the traffic (mi/hr), and the volume (veh/hr). The DENSITY, SPEED, and VOLUME commands set specific values for these variables. These commands are normally used to provide initial values of density, speed, and volume along the link and the permanent upstream inputs to the link (i.e., the density, speed, and volume at 0.00 mi). The density, speed, and volume along the link are recalculated by RFLO, but the 0.00 mi milepost values are fixed—not considered to be part of the link. New DENSITY, SPEED, and VOLUME commands are required during the simulation in order to change the 0.00 mi values. DENSITY, SPEED, and VOLUME commands can also set arbitrary densities, speeds and volumes along the link during the execution of the simulation. The syntax of all three commands is:

**Field 4:** VALUE

(Columns 31-40) The numerical value of density, speed, or volume to be assigned. (When a link is created, all locations are assigned default densities, speeds, and volumes according to the following scheme: If two of the three variables, DENSITY, SPEED, VOLUME are given by the user, the third is deduced from Volume = Speed * Density.

If only one variable is given by the user, the remaining two variables are assigned consistent with

Volume = Speed * Density.

the local capacity, and equilibrium speed.

If no variable is specified by the user, the volume is half the capacity and the speed is the equilibrium speed.)

**Field 5:** START

(Columns 41-50) The value in field 4 applies over a section of roadway within this link. The section starts at the milepost specified in field 5 and runs to the "End" given in field 6. Start and End are given in miles.

**Field 6:** END

(Columns 51-60) End of the section which starts at "Start."

**Field 7:** Not used.

(Columns 61-70)

**Field 8:** Not used.

(Columns 71-80)
REPORT COMMAND

REPORT instructs RFLO to print a detailed history of the density, speed, and volume, at a specified milepost. The exact traffic density, speed, and volume are printed at regular intervals specified in the parameter file.

RFLO will not try to print more columns of detailed output than will fit on the printer. For example, only three sets of detailed output will fit on a 80-column page; if five report mileposts have been specified, the first two will be omitted. (The number of printer columns available is NCOLS set in the parameter file. RFLO.PAM and QUICK.PAM are supplied with NCOLS = 80.)

Except for the restriction due to number of printer columns, any number of reporting locations may be specified. Up to five may be put in a single command if they are on the same link.

Although it is customary to specify reporting stations at the beginning of the simulation, they may be added at any time.

Field 4: LOCAT A milepost on this link that (Columns 31-40) is to be reported in detail.
Field 5: LOCAT Another milepost on this link that (Columns 41-50) is to be reported in detail.
Field 6: LOCAT Another milepost on this link that (Columns 51-60) is to be reported in detail.
Field 7: LOCAT Another milepost on this link that (Columns 61-70) is to be reported in detail.
Field 8: LOCAT Another milepost on this link that (Columns 71-80) is to be reported in detail.

Fig. D-1 (cont). Summary of the RFLO Commands Commonly Used in a Simulation Instance (From Ross, 1989).
PICTURE COMMAND

PICTURE is one of the simplest RFLO commands. The only parameter is the activation time (field 1). No link name is necessary.

At the time specified in the PICTURE command, RFLO prints a "picture" of the network. That is, RFLO prints out the current values for the variables (density, speed, volume), parameters (jam density, free speed, capacity), and ramp data. This information is printed for every simulation station in the network. A picture is principally a trouble-shooting aid to show exactly what is going on at a particular time. A picture is printed automatically before the first simulation pass; thereafter, pictures are printed only on request.

QUIT COMMAND

QUIT has only one parameter, the activation time in field 1. RFLO quits simulating at this time. The maximum time for QUIT is 32000 * DT = 16 hrs.

---

Fig. D-1 (cont). Summary of the RFLO Commands Commonly Used in a Simulation Instance (From Ross, 1989).
**** Program Name : Rect.For written in MS FORTRAN (Vers. 5.0) ****

**** Purpose : To aggregate the microscopic traffic data to a macroscopic level. Traffic, at this level, is described by volume, speed, and density. Two, of the three quantities, must be known. This program determines the speed (average) and density of vehicles appearing within a cell of dimensions DX and DT. The program also collects information to enable a user to later determine the variability of the speeds occurring within a cell. The user must specify what values of DX and DT to use. The benefit of this program is that it reduces the amount of time that is gained by not doing the aggregation procedures each time the information is needed. ****

**** Defining of Variables ****************************************************

INTEGER*1 VTYPE, VLENGTH, VSPEED, VCOLOR, LANENUM, D2, N (10)
INTEGER*2 FRAME, VID, LONGD, LATD, XT
INTEGER D1, NN, TLDIST, TTIME, COUNT, CHECK (9000), DT, DX
INTEGER SUMMXI (10), SUM2XI (10), SUMXI2 (10), IFRAME, MFRAME
REAL AVESPD (10), DENSITY (10)

**** Meaning of Variables ****************************************-------------

** ** FRAME : A number corresponding to the value of the frame category for a given record from the current data set.
** ** VID : The identifier given to a vehicle as it enters the "roadway" section (Vehicle Identification).
** ** VTYPE : The TYPE of Vehicle associated with VID (car, truck, etc.).
** ** VLENGTH : The LENGTH of the Vehicle associated with VID.
** ** VSPEED : The SPEED of the Vehicle associated with VID.
** ** LONGD : The LONGitudinal Distance between the center of the roadway and bumper (center) of the vehicle and the beginning of the "roadway" section.
** ** LATD : The LATitudinal Distance between the center of the front bumper and the roadway edgeline.
** ** VCOLOR : The COLOR of the Vehicle associated with VID.
** ** LANENUM : The LANE NUMBER which the vehicle is traveling in.
** ** CHECK : Is an array that is used to monitor the arrival of vehicles into the study. The first occurrence of a given vehicle will coincide with an undefined speed (VSPEED = 0).
** ** DT : The unit of time (sec.) that determines the specific intervals for averaging across the entire duration of the study.
** ** DX : The unit of distance (feet) that determines the specific intervals for averaging along the entire length of the study.
** ** IFRAME : The frame number of the initial record of the data set.
** ** MFRAME : The frame number that corresponds to the upper-edge of an interval of time that is a factor of DT.
** ** XT : A dummy variable that is used to specify an interval of time of length equal to DT.
** ** D1 : A dummy variable used to cycle through the intervals of distance, along the current roadway, of length equal to DX.
** ** D2 : A dummy variable used to convert D1 into values ranging from 1, 2, 3,..., to approximately TLDIST/DX. These values are used to specify elements of an array.
** ** SUMMXI : Is an array that is used to accumulate the values of speed for each cell, of size DT x DX, during the current interval of time.
** ** N : Is an array that is used to accumulate the number of speeds that have been placed into an element of SUMMXI.

Fig. D-2. The Rect.For Computer Program (Subroutines) Used In Calibrating The Relaxation Constant.
** AVESPD : Is a 1-D array that will store the average speeds, during ** the current interval of time, for each interval of ** distance along the current roadway. ** TLDIST : Is the total longitudinal distance associated with the ** current "roadway" section. The user should increment the ** actual TLDIST value, to make it a factor of DX, if maxi- ** mizing the use of the available data is important. For ** example, since Roscoe Blvd is 1788 ft long and DX=200 ** feet, the best value for TLDIST would be 1800 so the last ** 188 feet of roadway data is not wasted. ** TLTIME : Is the total time (sec.) that is associated with the data ** from the current "roadway" section. ** SUM2XI : A variable that accumulates the square of each average ** speed, during the current time interval, for each ** interval of distance along the current roadway. ** SUMXI2 : A variable that is the result of the square of SUMMXI. It ** could be used to calculate the variance of speeds within ** a specific cell of size DT x DX. ** DENSITY : Is the number of vehicles per mile for a given cell of ** size DT x DX. ** COUNT : A variable that controls the spacing of the "endpoint" and ** "line from" commands associated with Acrospin. ** NN : A variable that counts the number of accumulation occurrences ** associated with SUMMXI. **

***********************************************************************
* Let's clear the screen from all previous output !

001  FORMAT (35(' ', 65X))

***********************************************************************
* User enters the number associated with the initial frame of current *
* data set !

002  FORMAT (35(' ', 65X))

***********************************************************************
* User enters the number associated with the length of the roadway in *
* the current data set. Note, please see definition of this first !

003  FORMAT (35(' ', 65X))

Fig. D-2 (cont). The Rect. For Computer Program (Subroutines) Used In Calibrating The Relaxation Constant.
User inputs the number corresponding to the time duration of the "current" data set!

```
WRITE (*, '(A,\:') ' What is the total length (sec) of the current + data set with respect to time (TLTIME) ? ----> '
READ (*,*) TLTIME
WRITE (*,*)
WRITE (*,*)
WRITE (*,*) ! The length (sec) of the current data set is ', TLTIME
WRITE (*,*)
WRITE (*,004)
004 FORMAT (35(' ',65X))
```

User inputs the value of DX that he/she wants to use!

```
WRITE (*, '(A,\:') ' What is the value of DX (feet) ? ----> '
READ (*,*) DX
WRITE (*,*)
WRITE (*,*)
WRITE (*,*) ! The value of DX is ', DX, ' feet.'
WRITE (*,*)
WRITE (*,005)
005 FORMAT (35(' ',65X))
```

User inputs the value of DT that he/she wants to use!

```
WRITE (*, '(A,\:') ' What is the value of DT (sec) ? ----> '
READ (*,*) DT
WRITE (*,*)
WRITE (*,*)
WRITE (*,*) ! The value of DT is ', DT, ' seconds.'
WRITE (*,*)
WRITE (*,006)
006 FORMAT (35(' ',65X))
```

Let's initialize these variables to zero!

```
COUNT = 0
XT = 0
```

Let's open these external data files!

```
OPEN (12, FILE = 'C:\KEVIN\ROSCO1Q.DAT', BLOCKSIZE = 6400, + FORM = 'BINARY', ACCESS = 'SEQUENTIAL')
OPEN (11, FILE = 'C:\KEVIN\R200_3.REC', BLOCKSIZE = 6400, + FORM = 'BINARY', ACCESS = 'SEQUENTIAL')
```

What frame # corresponds to the last frame of current time interval?

```
MFRAME = IFRAME + DT - 1
```

Let's read a record from the current data set:

```
100 READ (12, END = 400) FRAME, VID, VTYPE, VLENGTH, VSPEED, LONGD, + LATD, VCOLOR, LANENUM
```

---

Fig. D-2 (cont). The Rect. For Computer Program (Subroutines) Used In Calibrating The Relaxation Constant.
If current frame # belongs in next time interval then current time interval is finished. Operations must be done to determine the average speeds, density, and speed variability information associated with each longitudinal distance interval of length DX. Also, cleaning operations must be done to prepare for next time interval.

    IF ( FRAME .GT. MFRAME ) THEN
        XT = XT + 1
        CALL AVERX (DX,N,SUMMXI,AVESPD,XT,TLDIST,SUM2XI,SUMXI2,DT)
        MFRAME = MFRAME + DT
        DO 200, D1 = DX, TLDIST, DX
            D2 = D1 / DX
            SUMMXI (D2) = 0
            AVESPD (D2) = 0
            SUMXI2 (D2) = 0
            SUM2XI (D2) = 0
            DENSITY (D2) = 0
            N (D2) = 0
        CONTINUE
    ENDIF

The current record must have a defined speed for it to be included in the analysis (side effect of original data reduction operation).

    IF ( CHECK (VID) .EQ. 1 ) THEN
        CALL BUCKET (DX,LONGD,SUMMXI,VSPEED,N,TLDIST,SUM2XI)
    ELSE
        IF ( VSPEED .NE. 0 ) THEN
            CHECK (VID) = 1
            CALL BUCKET (DX,LONGD,SUMMXI,VSPEED,N,TLDIST,SUM2XI)
        ENDIF
    ENDIF

Let's go read another record from the current data set!

GOTO 100

The "end-of-file" record has been read, so we must remember to send the information collected from BUCKET to the subroutine AVERX if the last frame read corresponds to the end of the DT interval of time.

    IF ( FRAME .EQ. MFRAME ) THEN
        CALL AVERX (DX,N,SUMMXI,AVESPD,XT,TLDIST,SUM2XI,SUMXI2,DT)
    ENDIF

Let's get outta here!

STOP

END
SUBROUTINE AVERX (DX,N,SUMMXI,AVESPD,XT,TLDIST,SUM2XI,SUMXI2,DT)

*** Defining of Variables ****************************

INTEGER*1 D2, N (10)
INTEGER*2 XT
INTEGER D1, TLDIST, DX, DT, SUMMXI(10), SUM2XI(10), SUMXI2(10)
REAL AVESPD (10), DENSITY (10)

* Let's iterate through the sections of roadway for current DX!

DO 100, D1 = DX, TLDIST, DX
    D2 = D1 / DX

* Let's calculate the values of average speed, density, and variance!

    IF ((( N(D2) .EQ. 0 ) .OR. ( SUMMXI(D2) .EQ. 0 )) THEN
        AVESPD (D2) = 0.0
        DENSITY (D2) = 0.0
        SUMXI (D2) = 0
        SUMXI2 (D2) = 0
    ELSE
        AVESPD(D2) = (FLOAT (SUMMXI(D2)))/(FLOAT (N(D2))) + 0.05
        DENSITY (D2) = (((FLOAT (N(D2)) / FLOAT (DT)) / FLOAT (DX)) * 5280 ) + 0.05
        SUMXI2 (D2) = ( SUMMXI (D2)) ** 2
        SUM2XI (D2) = SUMXI (D2)
    ENDIF

* Let's write a record to the new aggregated data file!

    WRITE (11) XT, D2, AVESPD (D2), DENSITY (D2), N (D2),
    + SUM2XI (D2), SUMXI2 (D2)

* Let's get a new section of roadway!

100 CONTINUE

* Let's get outta here!

RETURN
END

Fig. D-2 (cont). The Rect. For Computer Program (Subroutines) Used in Calibrating The Relaxation Constant.
************ Subroutine Name : BUCKET ************

******** Purpose : The purpose of this subroutine is to accumulate the actual speed of every vehicle as it passes through the intervals of the longitudinal distance that is specified by DX. The accumulation process, for a specified interval along the longitudinal distance has a duration of DT. Information concerning the density and variability of speeds is also collected here. ********

SUBROUTINE BUCKET (DX, LONGD, SUMMXI, VSPEED, N, TLDIST, SUM2XI)

Defining of Variables

INTEGER*1 VSPEED, D2, N (10)
INTEGER*2 LONGD
INTEGER D1, ALARM, TLDIST, DX, SUMMXI (10), SUM2XI (10)

* Let's initialize this variable to zero!
ALARM = 0

* Let's iterate through the sections of roadway for current DX!
DO 100, D1 = DX, TLDIST, DX
   D2 = D1 / DX

* If ALARM = 1, then current record's VSPEED has already been placed in accumulator (SUMMXI) for a given interval of distance. The job is done, go back to main program!
IF ( ALARM .EQ. 1 ) THEN
   GOTO 200
ENDIF

* If LONG is less than or equal to the upper-end of the current distance interval, then it falls within that interval. If not then let's initialize ALARM to make certain that we keep looking!
IF ( LONGD .LE. D1 ) THEN
   SUMMXI (D2) = SUMMXI (D2) + VSPEED
   SUM2XI (D2) = SUM2XI (D2) + VSPEED ** 2
   N (D2) = N (D2) + 1
   ALARM = 1
ELSE
   ALARM = 0
ENDIF

* Let's go look at the next section of roadway!
100 CONTINUE

* Let's get outta here!
200 RETURN
END

Fig. D-2 (cont). The Rect. For Computer Program (Subroutines) Used In Calibrating The Relaxation Constant.
Program Name: RectBin.For

Purpose: To extract a portion of an aggregated data file to ensure that the aggregation process did indeed do what it was intended to do. Remember, the current data file is in a binary format.

Date: July 23, 1989

Defining Variables

INTEGER D2, N
INTEGER XT
INTEGER SUM2XI, SUMX2I
REAL AVESPD, DENSITY

Meaning of Variables

D2: Is used to specify the jth section, of length DX (200 ft), with regards to the current roadway. Hence, if the value of D2 is "N", then the Nth interval of distance DX, of the current roadway is specified.

N: Variable used to identify the number of vehicles contained in the area (rectangle) of time (DT) and distance (DX).

XT: Is used to specify the ith interval of time that is contained within the entire data set duration. Hence, if the value of XT is "M", then the Mth interval of time DT, of the current data set, is specified.

SUM2XI: Is the value resulting from the square of the accumulation of vehicle speeds occurring within the rectangle of size DT x DX specified by XT and D2.

SUMX2I: Is the value resulting from the accumulation of the square of each vehicle speed occurring within the rectangle of size DT x DX specified by XT and D2.

AVESPD: Is the average speed of all vehicles that occurred within the rectangle of size DT x DX specified by XT and D2.

DENSITY: Is the # of vehicles/mile associated with a specific rectangle. It was calculated by dividing the value "N" by the value of DT and DX and then converting the result from feet to miles.

Let's open these external devices!

OPEN (11, FILE = 'C:\KEVIN\R200_3.REC', BLOCKSIZE = 6400, + FORM = 'BINARY', ACCESS = 'SEQUENTIAL')

OPEN (17, FILE = 'C:\KEVIN\RECTBIN.OUT', BLOCKSIZE = 6400, + FORM = 'FORMATTED', ACCESS = 'SEQUENTIAL')

Let's make a "header" for the output!

WRITE (17,050)

050 FORMAT (4X,'XT',3X,'D2',4X, 'AVESPD',2X,'DENSITY',4X,'N',2X, + 'SUM2XI',2X,'SUMXI2')

WRITE (17,*) ' ' ' ' '

Fig. D-3. The RectBin.For Computer Program Used in Calibrating The Relaxation Constant.
* Let's read a record from the current data file!

100 READ (11) XT, D2, AVESPD, DENSITY, N, SUM2XI, SUMX2

* We are only concerned with the records up to, and including, XT= 30!
  IF ( XT .GT. 30 ) THEN
    GOTO 400
  ENDIF

* Let's print this record to disk file!

200 FORMAT (1X,115,1X,14,1X,F8.1,1X,F8.1,1X,15,1X,17,1X,17)

* Let's go get another record!

GOTO 100

* Let's get outta here!

400 STOP
END

Fig. D-3 (cont). The RectBin.For Computer Program Used In Calibrating The Relaxation Constant.
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![](Image)

Fig. D-4. The Aggregated Data (RectBin.Out) Resulting From The RectBin.For Computer Program.
Program Name: SimPrep.For written in MS FORTRAN (Vers. 5.0)

Purpose: To retrieve the information needed to prepare RFLO to simulate the current traffic response. This information is the Average Speed and Density for each distance interval at the beginning of the period to be simulated. Also, the Average Speed and Density of the upstream source must be known for all time intervals spanning the period to be simulated. However, the Density values, for the upstream source, must be determined from the D2Den.For computer program due to side-effects of the original data collection procedures. This program needs the "exact" starting and stopping intervals as input.

Date: July 28, 1989

Defining of Variables

INTEGER*1 D2, N
INTEGER*2 XT
INTEGER STARTT, ENDD, SUM2XI, SUMXI2
REAL AVESPD, DENSITY

Meaning of Variables

D2: Is used to specify the jth section, of length DX (200 ft), with regards to the current roadway. Hence, if the value of D2 is "N", then the Nth interval of distance DX, of the current roadway is specified.

N: Variable used to identify the number of vehicles contained in the area (rectangle) of time (DT) and distance (DX).

XT: Is used to specify the ith interval of time that is contained within the entire data set duration. Hence, if the value of XT is "M", then the Mth interval of time DT, of the current data set, is specified.

STARTT: Is used to specify the initial time interval that will be outputted to the external device (printer).

ENDD: Is used to specify the last time interval that will be outputted to the external device (printer).

SUM2XI: Is the value resulting from the square of the accumulation of vehicle speeds occurring within the rectangle of size DT x DX specified by XT and D2.

SUMXI2: Is the value resulting from the accumulation of the square of each vehicle speed occurring within the rectangle of size DT x DX specified by XT and D2.

AVESPD: Is the average speed of all vehicles that occurred within the rectangle of size DT x DX specified by XT and D2.

DENSITY: Is the # of vehicles/mile associated with a specific rectangle. It was calculated by dividing the value "N" by the value of DT and DX and then converting the result from feet to miles.

Let's open these external data files:

OPEN (11, FILE = 'C:/KEVIN/RZOO-3.REC', BLOCKSIZE = 6400,
+ FORM = 'BINARY', ACCESS = 'SEQUENTIAL')

OPEN (17, FILE = 'C:/KEVIN/SIMPREP.OUT', BLOCKSIZE = 6400,
+ FORM = 'FORMATTED', ACCESS = 'SEQUENTIAL')

Fig. D-5. The SimPrep.For Computer Program Used In Calibrating The Relaxation Constant.
* Let's create a "header" to help identify the output.

```
WRITE (17,*) 'Roscoe Blvd. Data Set Information needed by RFLO '
WRITE (17,*) 'NOTE* N/A MEANS THAT DENSITY VALUE SHOULD BE
WRITE (17,*) 'FOUND THROUGH THE D2DEN.FOR PROGRAM !'
```

* User inputs the interval number associated with the starting time
* of the simulation.

```
WRITE (*,*) 'What is the starting time interval (STARTT) ?'
READ (*,*) STARTT
WRITE (*,*) 'Output will start with time interval ',STARTT
WRITE (17,*)
```

* User inputs the interval number associated with the ending time
* of the simulation.

```
WRITE (*,*) 'What is the ending time interval (ENDD) ?'
READ (*,*) ENDD
WRITE (*,*) 'Output will end with time interval ',ENDD
WRITE (17,*)
```

* Let's put labels on the columns that will result from the output!

```
WRITE (17,050)
050 FORMAT (6X,'XT',3X,'D2',3X,'AVESPD',3X,'DENSITY',2X,''/,3X,'N/A1,2X,'
```

* Let's read a record from the aggregated data file!

```
100 READ (11, END = 600) XT, D2, AVESPD, DENSITY, N, SUM2XI, SUMXI2
```

* If current record is associated with the beginning of the output
* that was requested, then output the following!

```
IF ( XT .EQ. STARTT ) THEN
WRITE (17,150)
FORMAT (11X,'|',8X,'|',10X,'|',12X,'|')
```

```
IF ( D2 .EQ. 1 ) THEN
WRITE (17,175) XT, D2, AVESPD
```

```
175 FORMAT (3X,I5,2X,|',2X,I2,2X,'|',1X,F5.1,2X, +
        '|',2X,'N/A1,2X,'|')
```

Fig. D-5 (cont). The SimPrep. For Computer Program
Used In Calibrating The Relaxation Constant.
ELSE

WRITE (17,200) XT, D2, AVESPD, DENSITY
200 FORMAT (3X,I5,2X,' | ',2X,I2,2X,' | ',1X,F5.1,2X,  
     ' | ',2X,F6.1,2X,' | ')

ENDIF

WRITE (17,205) 
205 FORMAT (11X,'I',8X,'|',10X,'|',12X,'|')

WRITE (17,210) 
210 FORMAT (' ',44(' - '))

ENDIF

*-----------------------------------------------------------------------
* If current record follows "STARTT", while remaining within the 
* requested interval of output, then do the following!

IF ((( XT .GT. STARTT ) .AND. ( XT .LE. ENDD ) .AND. 
   + ( D2 .EQ. 1 ))) THEN

WRITE (17,*)' '

WRITE (17,220) 
220 FORMAT (' ',44(' - '))

WRITE (17,225) 
225 FORMAT (11X,'|',8X,'|',10X,'|',12X,'|')

WRITE (17,300) XT, D2, AVESPD 
300 FORMAT (3X,I5,2X,' | ',2X,I2,2X,' | ',1X,F5.1,2X,  
     ' | ',2X,F6.1,2X,' | ')

WRITE (17,305) 
305 FORMAT (11X,'|',8X,'|',10X,'|',12X,'|')

WRITE (17,310) 
310 FORMAT (' ',44(' - '))

ENDIF

*-----------------------------------------------------------------------
* If we have already read through the region of data that we are 
* interested in, then why continue?

IF ( XT .GT. ENDD ) THEN

GOTO 600

ENDIF

*-----------------------------------------------------------------------
* Let's go read another record!

GOTO 100

*-----------------------------------------------------------------------
* It's all downhill from here!

600 STOP

END
Roscoe Blvd. Data Set Information needed by RFLO

*NOTE* N/A MEANS THAT DENSITY VALUE SHOULD BE FOUND THROUGH THE D2DEN.FOR PROGRAM!

Output will start with time interval (XT =) 664
Output will end with time interval (XT =) 740

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Fig. D-6. The Output (SimPrep.Out) Resulting From The SimPrep.For Computer Program.
Fig. D-6 (cont). The Output (SimPrep.Out) Resulting From The SimPrep. For Computer Program.

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Fig. D-6 (cont). The Output (SimPrep.Out) Resulting From The SimPrep.For Computer Program.
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**Fig. D-6 (cont).** The Output (SimPrep.Out) Resulting From The SimPrep.For Computer Program.
**Program Name :** D2DEN.FOR written in MS FORTRAN (Vers. 5.0)

**Purpose :** To extract the actual density, of the vehicular traffic flow, occurring at the upstream end of the roadway section at time intervals of $DT = 3$ secs.

This information can only be accurately obtained from the initial data set, provided by the aerial photograph study, before the positions of the vehicles are interpolated. This is due to the loss of the information pertaining to the initial identification of every vehicle as it begins to pass through the roadway section. The speed pertaining to the upstream source is unaffected by this problem and will be provided by the "SimPrep.FOR" computer program. Thus, this program must find the vehicles associated with the first 200 ft (DX) section of the current roadway. The "association" includes a vehicle's interpolated location as well as it's initial entrance onto the roadway section.

**Meaning of Variables**

**FRAME** : A number corresponding to the value of the frame category for a given record from the current data set.

**VID** : The number given to a vehicle as it enters the "roadway" section (Vehicle Identification).

**VTYPE** : The TYPE of Vehicle associated with VID (car, truck, etc.).

**VLENGTH** : The LENGTH of the Vehicle associated with VID.

**VSPEED** : The SPEED of the Vehicle associated with VID.

**LONGD** : The LONgitudinal Distance between front bumper (center) of the vehicle and the beginning of the "roadway" section.

**LATD** : The LATitudinal Distance between the center of the front bumper and the roadway edgeline.

**VCOLOR** : The COLOR of the Vehicle associated with VID.

**LANENUM** : The LANE NUMBER which the vehicle is traveling in.

**CHECK** : Is an array that is used to monitor the arrival of vehicles into the study. The first occurrence of a given vehicle will coincide with an undefined speed (VSPEED = 0).

**MFRAME** : The frame number that corresponds to the upper-edge of an interval of time that is a factor of $DT$.

**XT** : A dummy variable that is used to specify an interval of length equal to $DT$.

**D2** : A dummy variable used to convert D1 into values ranging from 1, 2, 3, ... to approximately TLDIST/DX. These values are used to specify elements of an array.

**DENSITY** : Is the number of vehicles per mile for a given cell of size $DT \times DX$.

**K** : Is used as a dummy variable to iterate through the "CHECK" and the "OLDLD" arrays.

**INTERD** : Is the "Interpolated" distance associated with the vehicle's average speed and the instantaneous location.

**OLDLD** : Is an array that is used to retain the last instantaneous position of the concerned vehicle.
** N : Is the number of vehicles that fall within the first 200 ft section of roadway during the current 3 sec interval of time.

* Let's open these external data files!

```
OPEN (11, FILE = 'C:\KEVIN\ROSC02B.DAT', BLOCKSIZE = 6400,
+ FORM = 'BINARY', ACCESS = 'SEQUENTIAL')
```

* Let's create a header for the output!

```
WRITE (17,*) 'I',
WRITE (17,025) 025 FORMAT (4X,'XT',6X,'D2',7X,'N',6X,'DENSITY (VEH/MI)')
WRITE (17,030) 030 FORMAT (' ',45('-I'))
WRITE (17,*) 'I'
```

* Let's initialize the following variables in this manner!

```
MFRAME = 150
XT = 1
D2 = 1
N = 0
DO 050, K = 1, 9000
   CHECK (K) = 0
   OLDLD (K) = 0
050 CONTINUE
```

* Let's read a record from the current data set!

```
100 READ (11, END = 999) FRAME, VID, VTYPE, VLENGTH, VSPEED, LONGD,
+ LATD, VCOLOR, LANENUM
```

* If current frame # belongs in next time interval then the current
* time interval is finished. Operations must be done to determine the
* DENSITY associated with the current time interval and first 200 ft
* section of current roadway. Clean-up and iterative procedures must
* follow!

```
IF ( FRAME .GT. MFRAME ) THEN
   DENSITY = (FLOAT (N) / 600.0) * 5280
   IF ( ( XT .GE. 664 ) .AND. ( XT .LE. 740 ) ) THEN
      WRITE (17,200) XT, D2, N, DENSITY
      FORMAT (1X,I6,4X,I2,4X,I6,4X,F6.1)
   ENDIF
```

Fig. D-7 (cont). The D2Den. For Computer Program Used In Calibrating The Relaxation Constant.
N = 0
XT = XT + 1
MFRAME = MFRAME + 3
ENDIF

*-----------------------------------------------------------------------
* The current record has to be identified as occurring along the
* roadway section at a specific position!
* IF ( VSPEED .NE. 0 ) THEN
    CHECK (VID) = 1
    INTERD = (FLOAT ( OLDDL(VID) + LONGD ) / 2.0 ) + 0.5
    OLDDL (VID) = LONGD
ELSE
    OLDDL (VID) = LONGD
ENDIF

*-----------------------------------------------------------------------
* If the current record is associated with a vehicle occurring within
* the first 200 feet of roadway then it should be included in our
* density calculation!
* IF ( ( LONGD .LE. 200 ) .OR. ( INTERD .LE. 200 ) ) THEN
    N = N + 1
ENDIF

*-----------------------------------------------------------------------
* Let's go get another record!
GOTO 100

*-----------------------------------------------------------------------
* Let's get outta here!
999 STOP
END

Fig. D-7 (cont). The D2Den.For Computer Program Used In Calibrating The Relaxation Constant.
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Fig. D-8. The Output (D2Den.Out) Resulting From The D2Den.For Computer Program.
Fig. D-8 (cont). The Output (D2Den.Out) Resulting From The D2Den.For Computer Program.

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<td>15</td>
<td>132.0</td>
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<td>13</td>
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<td></td>
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<tr>
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<td></td>
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<tr>
<td>738</td>
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<td>79.2</td>
<td></td>
</tr>
<tr>
<td>739</td>
<td>1</td>
<td>13</td>
<td>114.4</td>
<td></td>
</tr>
<tr>
<td>740</td>
<td>1</td>
<td>11</td>
<td>96.8</td>
<td></td>
</tr>
</tbody>
</table>
Program Name: Ramp.For written in MS FORTRAN (Vers. 5.0)

Purpose:
To acquire information concerning the volume of vehicular traffic flow on a ramp during the selected simulation period. RFLO only requires the volume to be known due to the use of the "continuity of vehicles" equation used in the theory. This program provides RFLO with the volume at intervals of $DT = 3$ seconds. The output of this program will consist of a "hard-copy" of the volumes needed as well as a Symphony importable file that will enable the user to view the changes in volume, over time, which will aid in determining the value or values of volume over the simulation period.

Date: August 8, 1989

Defining of Variables

**FRAME**: A number corresponding to the value of the frame category for a given record from the current data set.
**VID**: The number given to a vehicle as it enters the "roadway" section (Vehicle Identification).
**VTYPE**: The TYPE of Vehicle associated with VID (car, truck, etc.).
**VLENGTH**: The LENGTH of the Vehicle associated with VID.
**VSPEED**: The SPEED of the Vehicle associated with VID.
**LONGD**: The LONGitudinal Distance between front bumper (center) of the vehicle and the beginning of the "roadway" section.
**LATD**: The LATitudinal Distance between the center of the front bumper and the roadway edgeline.
**VCOLOR**: The COLOR of the Vehicle associated with VID.
**LANENUM**: The LANE NUMBER which the vehicle is traveling in.
**DT**: The unit of time (sec.) that determines the specific intervals for averaging across the entire duration of the study.
**DX**: The unit of distance (feet) that determines the specific intervals for averaging along the entire length of the study.
**IFRAME**: The frame number of the initial record of the data set.
**MFRA ME**: The frame number that corresponds to the upper-edge of an interval of time that is a factor of $DT$.
**XT**: A dummy variable that is used to specify an interval of time of length equal to $DT$.
**TLDIST**: Is the total longitudinal distance (ft) associated with the current "roadway" section.
**TLTIME**: Is the total time (sec.) that is associated with the data from the current "roadway" section.
**DXINT**: Is the distance interval (size = $DX$) that we are interested in (i.e. ramp-mainline intersection).
**STARTT**: Is the interval number (w/ respect to time) which identifies the starting place of the simulation.
**ENDD**: Is the interval number (w/ respect to time) which identifies the ending place of the simulation.
**N**: Is a variable that is used to accumulate the number of speeds that have been placed into the variable SUMSPD.
**SUMSPD**: Is a variable that is used to accumulate the vehicle speeds (VSPEED's) that are important to us.

Fig. D-9. The Ramp.For Computer Program Used In Calibrating The Relaxation Constant.
** ALARM : Is a toggle that identifies whether the current time interval is one that we are actually interested in.
** LOWD : Is the value of distance (ft) that corresponds to the lower "edge" of the distance interval (size = DX) that we are interested in.
** HIGHD : Is the value of distance (ft) that corresponds to the upper "edge" of the distance interval (size = DX) that we are interested in.
** VOLUME : Is the value corresponding to the "volume" (veh/hr) of vehicles that have passed through the ramp section for a corresponding cell size DX x DT.

* Let's clear the screen from all previous output!

```
WRITE (*,001)
001 FORMAT (35(' ',65X))
```

* User enters the number associated with the initial frame of current data set!

```
WRITE (*,'(A,\') ' What is the initial frame number in current + data set (IFRAME) ? ----> '
READ (*,* ) IFRAME
WRITE (*,* ) ' The initial frame number is ', IFRAME
WRITE (*,* ) IFRAME
WRITE (*,002)
002 FORMAT (35(' ',65X))
```

* User enters the number associated with the length of the roadway in the current data set. Note, please see definition of this first!

```
WRITE (*,'(A,\') ' What is the value of TLDIST for current data set ? ----> '
READ (*,* ) TLDIST
WRITE (*,* ) ' The value of TLDIST is ', TLDIST
WRITE (*,* ) TLDIST
WRITE (*,* ) TLDIST
WRITE (*,003)
003 FORMAT (35(' ',65X))
```

* User inputs the number corresponding to the time duration of the "current" data set!

```
WRITE (*,'(A,\') ' What is the total length (sec) of the current + data set with respect to time (TLTIME) ? ----> '
READ (*,* ) TLTIME
WRITE (*,* ) ' The length (sec) of the current data set is ', TLTIME
WRITE (*,* ) TLTIME
WRITE (*,004)
004 FORMAT (35(' ',65X))
```

** Fig. D-9 (cont). The Ramp For Computer Program Used In Calibrating The Relaxation Constant.**
* User inputs the value of DX that he/she wants to use!

```fortran
WRITE (*,'(A,/)') 'What is the value of DX (feet) ? ----> ' READ (*,*) DX
WRITE (*,*) ' The value of DX is ', DX, ' feet.'
WRITE (*,005) FORMAT (15(' ',65X))
```

* User inputs the value of DT that he/she wants to use!

```fortran
WRITE (*,'(A,/)') 'What is the value of DT (sec) ? ----> ' READ (*,*) DT
WRITE (*,*) ' The value of DT is ', DT, ' seconds.'
WRITE (*,006) FORMAT (15(' ',65X))
```

* User inputs the value corresponding to the DX interval that will be used to calculate the vehicular volumes of the ramp!

```fortran
WRITE (*,'(A,/)') 'What DX interval is associated with the ramp volumes ? ----> ' READ (*,*) DXINT
WRITE (*,*) ' The value of DXINT is ', DXINT
WRITE (*,007) FORMAT (15(' ',65X))
```

* User inputs the value corresponding to the starting time of the simulation in terms of intervals (i.e. XT)!

```fortran
WRITE (*,*) ' What is the starting time interval (STARTT) ? ' READ (*,*) STARTT
WRITE (*,*) ' The value of STARTT is ', STARTT
WRITE (*,008) FORMAT (15(' ',65X))
```

* User inputs the interval number associated with the ending time of the simulation.

```fortran
WRITE (*,*) ' What is the starting time interval (STARTT) ? ' READ (*,*) ENDD
WRITE (*,*) ' The value of ENDD is ', ENDD
WRITE (*,009) FORMAT (15(' ',65X))
```

**Fig. D-9 (cont). The Ramp. For Computer Program Used In Calibrating The Relaxation Constant.**
* Let's open the following external devices:

```plaintext
OPEN (12, FILE = 'C:\KEVIN\ROSCO1Q.DAT', BLOCKSIZE = 6400,
+ FORM = 'BINARY', ACCESS = 'SEQUENTIAL')
OPEN (11, FILE = 'C:\KEVIN\RMPVOL.DAT', BLOCKSIZE = 6400,
+ FORM = 'FORMATTED', ACCESS = 'SEQUENTIAL')
OPEN (17, FILE = 'LPT1')
```

* Let's initialize these variables:

```plaintext
XT = 1
SUMSPD = 0
N = 0
ALARM = 0
```

* Let's determine our "target" range of distance (ft):

```plaintext
LOWD = DX * (DXINT - 1)
HIGHD = DX * (DXINT)
```

* Let's determine the initial upper-limit of the current time interval:

```plaintext
MFRAME = IFRAME + DT - 1
```

* Let's create a header for the hardcopy:

```plaintext
WRITE (17,*), 'RAMP VOLUMES FOR SELECTED PORTION OF ROSCOE BLVD'
WRITE (17,*), 'DATA SET'
WRITE (17,*), 'DT INTERVAL OF ',STARTT,' THROUGH ',ENDD,'
+ ( i.e. XT = ).'
WRITE (17,*), 'DISTANCE INTERVAL OF ',LOWD,' THROUGH ',HIGHD,'
+ FEET.'
WRITE (17,*),
WRITE (17,*),
WRITE (17,*),
WRITE (17,*),
WRITE (17,050)
```

```plaintext
050 FORMAT (3X,'XT',7X,'VOLUME (VEH/HR)')
```

* Let's read a record:

```plaintext
100 READ (12, END = 999) FRAME, VID, VTYPE, VLENGTH, VSPEED, LONGD,
+ LATD, VCOLOR, LANENUM
```

* If all the vehicle occurrences have been taken care of for the
  * current time interval and distance interval then calculate the
  * volume, print the results, and prepare accumulators for next time
  *
```plaintext
IF (( FRAME .GT. MFRAME ) .AND. ( ALARM .EQ. 1 )) THEN
  IF ( N .NE. 0 ) THEN
```

---

Fig. D-9 (cont). The Ramp For Computer Program Used In Calibrating The Relaxation Constant.
VOLUME = ( FLOAT(SUMSPD) / FLOAT(N) ) * 
( ( FLOAT(N) / ( FLOAT(DX) * FLOAT(DT) ) ) ) * 5280 

ELSE 

VOLUME = 0.0 

ENDIF 

WRITE (11,200) XT, VOLUME 
FORMAT (1X,I6,'6X,F11.1) 

WRITE (17,300) XT, VOLUME 
FORMAT (1X,I6,3X,'I',3X,F11.1) 

WRITE (17,*) 
SUMSPD = 0 
N = 0 
ALARM = 0 

ENDIF 

*----------------------------------------------------------------------- 
* Is the current time interval over? 
* 
IF ( FRAME .GT. MFRAME ) THEN 

XT = XT + 1 
MFRAME = MFRAME + DT 

ENDIF 

*----------------------------------------------------------------------- 
* Let's check to see if the current record falls into our region of interest! 
* 
IF (( XT .GE. STARTT ) .AND. ( XT .LE. ENDD )) THEN 

ALARM = 1 

IF ( (LANENUM .EQ. 8) ) THEN 

IF ( (LONGD .GT. LOWD) .AND. (LONGD .LE. HIGHD) ) THEN 

N = N + 1 
SUMSPD = SUMSPD + VSPEED 

ENDIF 

ENDIF 

ENDIF 

*----------------------------------------------------------------------- 
* Let's go get another record! 

GOTO 100 

*----------------------------------------------------------------------- 
* Let's get outta here! 

999 STOP 

END 

*----------------------------------------------------------------------- 

Fig. D-9 (cont). The Ramp. For Computer Program Used In Calibrating The Relaxation Constant.
RAMP VOLUMES FOR SELECTED PORTION OF ROSCOE BLVD DATA SET

DT INTERVAL OF 664 THROUGH 740 (i.e. XT=).
DISTANCE INTERVAL OF 800 THROUGH 1000 FEET.

<table>
<thead>
<tr>
<th>XT</th>
<th>VOLUME (VEH/HR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>664</td>
<td>422.4</td>
</tr>
<tr>
<td>665</td>
<td>422.4</td>
</tr>
<tr>
<td>666</td>
<td>0.0</td>
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<tr>
<td>667</td>
<td>237.6</td>
</tr>
<tr>
<td>668</td>
<td>0.0</td>
</tr>
<tr>
<td>669</td>
<td>202.4</td>
</tr>
<tr>
<td>670</td>
<td>1064.8</td>
</tr>
<tr>
<td>671</td>
<td>457.6</td>
</tr>
<tr>
<td>672</td>
<td>1117.6</td>
</tr>
<tr>
<td>673</td>
<td>220.0</td>
</tr>
<tr>
<td>674</td>
<td>264.0</td>
</tr>
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<td>675</td>
<td>0.0</td>
</tr>
<tr>
<td>676</td>
<td>510.4</td>
</tr>
<tr>
<td>677</td>
<td>572.0</td>
</tr>
<tr>
<td>678</td>
<td>880.0</td>
</tr>
<tr>
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<tr>
<td>681</td>
<td>633.6</td>
</tr>
<tr>
<td>682</td>
<td>906.4</td>
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<tr>
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</tr>
<tr>
<td>689</td>
<td>492.8</td>
</tr>
<tr>
<td>690</td>
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</tr>
<tr>
<td>691</td>
<td>1196.8</td>
</tr>
</tbody>
</table>

Fig. D-10. The Output (RmpVol.Dat) Resulting From The Ramp. For Computer Program.
<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>692</td>
<td>668.8</td>
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<tr>
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<td>1029.6</td>
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<td>694</td>
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</tr>
<tr>
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<td>739.2</td>
</tr>
<tr>
<td>724</td>
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</tr>
</tbody>
</table>

Fig. D-10 (cont). The Output (RmpVol.Dat) Resulting From The Ramp For Computer Program.
Fig. D-10 (cont). The Output (RmpVol.Dat) Resulting From The Ramp, For Computer Program.
Program Name: ParEst.For written in MS FORTRAN (Vers. 5.0)

Purpose: To gain insight towards the estimation of the RFLO parameters "Capacity", "Free-Speed", and "Kjam."

Estimates of these parameters are needed because they are used by RFLO to help simulate the real-world dynamics of the traffic phenomenon. It is assumed that a file has been created that contains the Roscoe Blvd data aggregated to a level of DT = 3 sec and DX = 1788 ft. These values simplify the 3-D traffic to 2-dimensions.

Date: August 13, 1989

Defining of Variables

INTEGER*1 D2, N
INTEGER*2 XT
INTEGER SUM2XI, SUMXI2
REAL AVESPD, DENSITY, VOLUME

Meaning of Variables

** XT: A dummy variable that is used to specify an interval of time of length equal to DT.
** D2: A dummy variable used to convert D1 into values ranging from 1, 2, 3,..., to approximately TLDIST/DX. These values are used to specify elements of an array.
** N: Is a variable that contains the number of vehicles associated with a cell specified by time interval XT and distance interval D2.
** AVESPD: Is a 1-D array that will store the average speeds, during the current interval of time, for each interval of distance along the current roadway.
** SUM2XI: A variable that accumulates the square of each average speed, during the current time interval, for each interval of distance along the current roadway.
** SUMXI2: A variable that is the result of the square of SUMMXI. It could be used to calculate the variance of speeds within a specific cell of size DT x DX.
** DENSITY: Is the number of vehicles per mile for a given cell of size DT x DX.
** VOLUME: Is the number of vehicles per hour passing through the section of ramp during time interval of length DT.

Let’s open the external devices:

```fortran
OPEN (12, FILE = 'C:\KEVIN\R1788-3.REC', BLOCKSIZE = 6400,
+ FORM = 'BINARY', ACCESS = 'SEQUENTIAL')

OPEN (13, FILE = 'C:\KEVIN\RPARAV.DAT', BLOCKSIZE = 6400,
+ FORM = 'FORMATTED', ACCESS = 'SEQUENTIAL')

OPEN (14, FILE = 'C:\KEVIN\RPARD.DAT', BLOCKSIZE = 6400,
+ FORM = 'FORMATTED', ACCESS = 'SEQUENTIAL')

OPEN (15, FILE = 'C:\KEVIN\RPARV.DAT', BLOCKSIZE = 6400,
+ FORM = 'FORMATTED', ACCESS = 'SEQUENTIAL')
```

Fig. D-11. The ParEst.For Computer Program Used In Calibrating The Relaxation Constant.
* Let's read a record!

```fortran
100 READ (12,END=500) XT, D2, AVESPD, DENSITY, N, SUM2XI, SUMXI2
```

* Let's calculate the average volume associated with the cell:

```
VOLUME = ( DENSITY * AVESPD ) + 0.5
```

* Let's write the data to the external output devices!

```fortran
200 WRITE (13,200) XT, AVESPD
300 WRITE (14,300) XT, DENSITY
400 WRITE (15,400) XT, VOLUME
```

* Let's go get another record!

```
GOTO 100
```

* Let's get outta here!

```fortran
500 STOP
END
```

---

Fig. D-11 (cont). The ParEst. For Computer Program Used In Calibrating The Relaxation Constant.
Fig. D-12. The Vehicular Speeds Occurring On Roscoe Boulevard Aggregated At DX = 1788 ft and DT = 3 sec (RPARAV.DAT).
Fig. D-13. The Vehicular Density Occurring On Roscoe Boulevard Aggregated At DX = 1788 ft and DT = 3 sec (RPARD.DAT).
Fig. D-14. The Vehicular Volume Occurring On Roscoe Boulevard Aggregated At DX = 1788 ft and DT = 3 sec (RPARV.DAT).
Fig. D-15. The Vehicular Speeds Occurring On Backlick Road Aggregated At DX = 1641 ft and DT = 3 sec (BPARAV.DAT).
Fig. D-16. The Vehicular Density Occurring On Backlick Road Aggregated At $DX = 1641$ ft and $DT = 3$ sec (BPARD.DAT).
Fig. D-17. The Vehicular Volume Occurring On Backlick Road Aggregated At DX = 1641 ft and DT = 3 sec (BPARV.DAT).
Fig. D-18. The Vehicular Speeds Occurring On Mulholland Drive Aggregated At DX = 1341 ft and DT = 3 sec (MPARAV.DAT).
Fig. D-19. The Vehicular Density Occurring On Mulholland Drive Aggregated At DX = 1341 ft and DT = 3 sec (MPARD.DAT).
Fig. D-20. The Vehicular Volume Occurring On Mulholland Drive Aggregated At DX = 1341 ft and DT = 3 sec (MPARV.DAT).
**Program Name**: TotVol.For  **Written in MS FORTRAN (Vers. 5.0)**

**Purpose**: The purpose of this program is to determine the total mainline volume and total ramp volume for the current data set. This information is needed in order to calculate the "Free-speed" of the traffic flow in the region where the ramp merges into the mainline. This value is needed by RFLO to attempt to model the traffic behavior on the Roscoe Blvd roadway section.

**Date**: August 16, 1989

**Defining of Variables**

- INTEGER*1 VTYPE, VLENGTH, VSPEED, VCOLOR, LANENUM
- INTEGER*2 VID, LONGD, LATD, FRAME
- INTEGER MLINE (9000), RAMP (9000), K, MNUM, RNUM
- REAL MVOL, RVOL

**Meaning of Variables**

- **FRAME**: A number corresponding to the value of the frame category for a given record from the current data set.
- **VID**: The number given to a vehicle as it enters the "roadway" section (Vehicle Identification).
- **VTYPE**: The TYPE of Vehicle associated with VID (car, truck, etc.).
- **VLENGTH**: The LENGTH of the Vehicle associated with VID.
- **VSPEED**: The SPEED of the Vehicle associated with VID.
- **LONGD**: The Longitudinal Distance between front bumper (center) of the vehicle and the beginning of the "roadway" section.
- **LATD**: The Latitudinal Distance between the center of the front bumper and the roadway edgeline.
- **VCOLOR**: The COLOR of the Vehicle associated with VID.
- **LANENUM**: The LANE NUMBER which the vehicle is traveling in.
- **MLINE**: Is a 1-D array that is used to distinguish the initial arrival of a specific vehicle into the concerned section of mainline.
- **RAMP**: Is a 1-D array that is used to distinguish the initial arrival of a specific vehicle into the concerned section of the acceleration (ramp) section.
- **K**: A dummy variable used to iterate through all the elements of both MLINE and RAMP arrays.
- **MNUM**: A variable that accumulates the number of different vehicles passing through the concerned mainline section.
- **RNUM**: A variable that accumulates the number of different vehicles passing through the concerned acceleration (ramp) section.
- **MVOL**: A variable identifying the volume of traffic at the concerned mainline section.
- **RVOL**: A variable identifying the volume of traffic at the concerned acceleration (ramp) section.

Let's open all of the external devices!

OPEN (12, FILE = 'C:\KEVIN\ROSCOIQ.DAT'), BLOCKSIZE = 6400, + FORM = 'BINARY', ACCESS = 'SEQUENTIAL')

OPEN (17, FILE = 'LPT1')

---

Fig. D-21. The TotVol.For Computer Program Used In Calibrating The Relaxation Constant.
* Let's initialize the following variables to zero!

```
DO 100, K = 1, 9000
   MLINE (K) = 0
   RAMP (K) = 0
100  CONTINUE
   MNUN = 0
   RNUM = 0
```

* Let's read a record:

```
200  READ (12, END = 999) FRAME, VID, VTYPE, VLENGTH, VSPEED, LONGD, +   LATD, VCOLOR, LANENUM
```

* Let's determine if the current record belongs to the "set" of records that we are interested in:

```
   IF ( ( LONGD .GE. 400 ) .AND. ( LONGD .LE. 600 ) .AND. +   ( LANENUM .NE. 8 )) THEN
      IF ( MLINE (VID) .EQ. C ) THEN
         MNUN = MNUN + 1
         MLINE (VID) = 1
      ENDIF
   ENDIF
```

* Let's determine if the current record belongs to the "set" of records that we are interested in:

```
   IF ( ( LONGD .GE. 800 ) .AND. ( LONGD .LE. 1000 ) .AND. +   ( LANENUM .EQ. 8 )) THEN
      IF ( RAMP (VID) .EQ. 0 ) THEN
         RNUM = RNUM + 1
         RAMP (VID) = 1
      ENDIF
   ENDIF
```

* Let's go get another record!

```
   GOTO 200
```

* Let's calculate the volume that has occurred:

```
999  RVOL = ( FLOAT (RNUM) / 3632.0 ) * 3600
      MVOL = ( FLOAT (MNUN) / 3632.0 ) * 3600
```

Fig. D-21 (cont). The TotVol. For Computer Program Used In Calibrating The Relaxation Constant.
* Let's make a "header" for the output that will follow!

```fortran
WRITE (17,*) ' ='  
WRITE (17,*) ' TOTAL MAINLINE AND RAMP VOLUMES FOR THE ROSCOE BLV 
+D. DATA SET 
WRITE (17,*) ' 
WRITE (17,*) 
```

* Let's write the volume values to the printer for future reference!

```fortran
WRITE (17,*) 'The total ramp volume = ', RVOL, ' (veh/hr).'
WRITE (17,*) 'The total mainline volume = ', MVOL, ' (veh/hr).'
```

* Let's get outta here!

```fortran
STOP
END
```
THE MAINLINE AND RAMP VOLUMES FOR THE ROSCOE BLVD. DATA SET

The total ramp volume = 904.955900 (veh/hr).
The total mainline volume = 7060.242000 (veh/hr).

Fig. D-22. The Output (TotVol.Out) Resulting From The TotVol.For Computer Program.
DEFINE FIRST LINK TO BE "ROSCOE BD." IT IS 0.30296 MI (1600 FT) LONG.

CAPACITY ON ROSCOE BD. IS 9000 VEH/HR FROM 0.12500 TO 0.21970 MI.
CAPACITY 9000 0.12500 0.21970

FREE-SPEED ON ROSCOE BD. IS 61.5 MPH FROM 0.12500 TO 0.21970 MI.
FREESPEED 61.5 0.12500 0.21970

JAM DENSITY ON ROSCOE BD. IS 715 VEH/MI FROM 0.12500 TO 0.21970 MI.
JAM 715 0.12500 0.21970

INITIAL SPEEDS FOR THE FOLLOWING RANGES OF DISTANCE ALONG ROSCOE BD.

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VOLUME COMING OFF RAMP AT LOCATION 0.12500 MI AT TIME ZERO

ONOFF 0.12500 422.4

SPEEDS, VOLUMES, AND DENSITIES ASSOCIATED WITH THE ROADWAY DURING THE SIMULATION PERIOD.

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Fig. D-23 (cont). The Roscoe1.Sim RFLO Input File Used In Calibrating The Relaxation Constant.
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Fig. D-23. The Roscoe1.Sim RFLO Input File Used In Calibrating The Relaxation Constant.
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Fig. D-23 (cont). The Roscoe1.Sim RFLO Input File Used In Calibrating The Relaxation Constant.
Fig. D-23 (cont). The Roscoe1.Sim RFLO Input File Used In Calibrating The Relaxation Constant.
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SIMULATION ENDS AT 0.064218 HR.
QUIT

Fig. D-23 (cont). The Roscoe1.Sim RFLO Input File Used In Calibrating The Relaxation Constant.
DEFINE FIRST LINK TO BE "ROSCOE BD." IT IS 0.30296 MI (1600 FT) LONG.

0  ROSCOE BD LINK  0.30296

CAPACITY ON ROSCOE BD. IS 9000 VEH/HR FROM 0.12500 TO 0.21970 MI.
CAPACITY  9000  0.12500  0.21970

FREE-SPEED ON ROSCOE BD. IS 61.5 MPH FROM 0.12500 TO 0.21970 MI.
FREESPEED  61.5  0.12500  0.21970

JAM DENSITY ON ROSCOE BD. IS 715 VEH/MI FROM 0.12500 TO 0.21970 MI.
JAM  715  0.12500  0.21970

INITIAL SPEEDS FOR THE FOLLOWING RANGES OF DISTANCE ALONG ROSCOE BD.

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VOLUME COMING OFF RAMP AT LOCATION 0.12500 MI AT TIME ZERO

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SPEEDS, VOLUMES, AND DENSITIES ASSOCIATED WITH THE ROADWAY DURING THE SIMULATION PERIOD.

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Fig. D-24. The Roscoe2.Sim RFLO Input File Used In Calibrating The Relaxation Constant.
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Fig. D-24 (cont). The Roscoe2.Sim RFLO Input File Used In Calibrating The Relaxation Constant.
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<th>Density</th>
<th>On/Off</th>
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SIMULATION ENDS AT 0.025020 HR.
0.025020 QUIT

Fig. D-24 (cont). The Roscoe2.Sim RFLO Input File Used In Calibrating The Relaxation Constant.
LPT1 Name of unit of length (for use in printed output)
.03787 Space step length, DX
.000417 Time step length, DT, in hours
.000834 Time (hours) between printouts. Best if exact multiple of DT
.1667 Relaxation time, TAU, in hours
7600 Default capacity (veh/hr)
572 Default jam density (veh/unit length)
63 Default desired speed (unit length/hr)
80 Number of printer columns available, NCOLS
LPT1 Printer set-up string (try ' ' for compressed type)
RFLOTMP. #08 Temporary file for message output (1-63 characters)
RFLOTMP. #09 Temporary file for 'detailed' output
RFLOTMP. #10 Temporary file for density graphic output
RFLOTMP. #11 Temporary file for speed graphic output
RFLOTMP. #12 Temporary file for volume graphic output
LPT1 Final file for message output
LPT1 Final file for 'picture' and MOE output
NUL Final file for 'detailed' output
NUL Final file for density graphic output
NUL Final file for speed graphic output
NUL Final file for volume graphic output
500 Maximum size of "Acrospin" files (in kilobytes)
NUL File for "Acrospin" 3-D density graphic
RISPD.A File for "Acrospin" 3-D speed graphic
NUL File for "Acrospin" 3-D volume graphic

Fig. D-25. The RFLO Parameter File (RFLO.Pam) Used In Calibrating The Relaxation Constant.
Program Name: ME.For written in MS FORTRAN (Vers. 5.0)

Purpose: This program will calculate the Mean and Standard Deviation of Errors for speeds associated with the "real-world" data and the "simulated" data. The program will determine the estimates of error by reading each of the two external data files and comparing them for the corresponding TIME and DISTANCE intervals of each. The goal is to determine the value of the Relaxation Constant that minimizes RFLO's SD of Error, about the mean with respect to the real data. This program assumes that the current data set is represented by the data file produced by the program "Rect." For" and the simulated data is written in "Acro-spin" format by RFLO. This program will also create a file of RFLO's actual speeds as a function of XT and D2.

Date: September 1, 1989

Declaring of Variables

INTEGER*1 D2, N
INTEGER*2 XT
INTEGER SUM2XI, SUMX12, STN, TIME, SPD1, ISP1, STARTT
INTEGER ENDD, LSTINT, Z2, TOTNUM, ALARM, BUZZER
REAL AVESFD, DENSITY, SPDSTR, ACTSPD, SUM2E, SUME, ME
REAL VARE, SDE, T
CHARACTER POINT, CHECK, STUFF*9, Z*7
CHARACTER*80 STRING

Meaning of Variables

** D2 : Is used to specify the jth section, of length DX (200 ft), with regards to the current roadway. Hence, if the value of D2 is "INvt, then the Nth interval of distance DX, of the current roadway is specified.
** N : Variable used to identify the number of vehicles contained in the area (rectangle) of time (DT) and distance (DX).
** XT : Is used to specify the ith interval of time that is contained within the entire data set duration. Hence, if the value of XT is "M", then the Mth interval of time DT, of the current data set, is specified.
** SUM2XI: Is the value resulting from the square of the accumulation of vehicle speeds occurring within the rectangle of size DT x DX specified by X2 and D2.
** SUMX12: Is the value resulting from the accumulation of the square of each vehicle speed occurring within the rectangle of size DT x DX specified by XT and D2.
** AVESPD: Is the average speed of all vehicles that occurred within the rectangle of size DT x DX specified by XT and D2.
** DENSITY: Is the # of vehicles/mile associated with a specific rectangle. It was calculated by dividing the value "N" by the value of DT and DX and then converting the result from feet to miles.
** STN : Is the value corresponding to RFLO's station numbers. In RFLO, the station numbers range from station 0 through station N-1.
** TIME : Is the value corresponding to RFLO's time. In RFLO, the time begins at time 0 through the duration of the simulation by a predetermined constant value.
** SPD1 : Is the value of the maximum free-speed that was used in the RFLO simulation program. This information is needed to convert Acrospin's "Z" (speed) value to the uncoded actual speed.

Fig. D-26. The Me.For Computer Program Used In Calibrating The Relaxation Constant.
**ISPDl**: Is the value resulting from an equation concerning "SPDl". This is used in converting Acrospin's "Z" (speed) value to the uncoded true speed.

**STARTT**: Is used to store the starting interval of the "actual" speed data that was created by the program "Rect.For".

**ENDD**: Is used to store the ending interval of the "actual" speed data that was created by program "Rect.For".

**LSTINT**: Is used to store the value of the Nth (last) distance interval of equal length DX.

**Z**: Is the "coded" value representing the speed for an "endpoint" record of Acrospin's Simulated data file.

**TOTNUM**: Is the total number of "square" differences that have been accumulated in the "SUMSQg" bucket.

**SPDSTR**: Is the value resulting from an equation concerning "ISPDlV". This is used in converting Acrospin's "Z" (speed) value to the uncoded true speed.

**ACTSPD**: Is the value representing the actual speed (MPH) that resulted from the RFM Simulation of the real world data.

**SUM2E**: Is the accumulator of the squared speed differences of the "real" data and the "simulated" data.

**SUME**: Is the accumulator of the speed differences of the "real" data and the "simulated" data.

**ME**: Is the Mean Speed Error resulting from the "real" data and the "simulated" RFM data.

**POINT**: Is a character variable that is used to discover whether an "L" or an "E" appears as the first letter in the current record of the RFM (Acrospin) data.

**CHECK**: Is a character variable that is used to discover whether an "X" or a "blank" is located at column 43 in current record of the RFM (Acrospin) data.

**STUFF**: Is a character variable of length 9 that is used to store a region of the current record (RFM) in order to examine the "POINT" and "CHECK" variables to see if the record is an "endpoint" record.

**STRING**: Is a character variable, of length 80, that is used to read in a record of the external RFM (Acrospin) file all at once. Once located internally, the "STRING" will be dissected to gain information from it's contents.

**Z2**: Converts the number contained in Z from a string character to an integer value.

**VARE**: Is the sample variance of speed errors.

**SDE**: Is the sample standard deviation of speed errors.

**ALARM**: Is used to distinguish the initial blank line in the Acrospin formatted file from an "end-of-file" mark.

**T**: Is the value of the relaxation constant that was used in developing the current Acrospin formatted file.

**BUZZER**: Is used to signal that all of the user requested data has been read.

*-----------------------------------------------------------------------
* Let's open all the external devices!

```
OPEN (12, FILE = 'C:\KEVIN\RFM\R200.JREC', BLOCKSIZE = 6400,
+ FORM = 'BINARY', ACCESS = 'SEQUENTIAL')

OPEN (13, FILE = 'C:\KEVIN\RFM\RISPD.A', BLOCKSIZE = 6400,
+ FORM = 'FORMATTED', ACCESS = 'SEQUENTIAL')

OPEN (14, FILE = 'C:\KEVIN\R1PLOT.A', BLOCKSIZE = 6400,
+ FORM = 'BINARY', ACCESS = 'SEQUENTIAL')

OPEN (17, FILE = 'C:\KEVIN\MSOUT1.A', BLOCKSIZE = 6400,
+ FORM = 'FORMATTED', ACCESS = 'SEQUENTIAL')
```

-----------------------------------------------------------------------

Fig. D-26 (cont). The Me.For Computer Program Used In Calibrating The Relaxation Constant.
Let's clear the screen from all previous output!

WRITE (*,001)
001 FORMAT (35('I, 65X))

* User enters the number corresponding to the interval which is the
* start of the simulation!

WRITE (**)' 
WRITE ('(*)',' What is the starting interval (STARTT) ? ' 
READ (**) STARTT 
WRITE (**)' 
WRITE ('(*)',' The starting interval is ',STARTT 
WRITE (17,**)' 
WRITE (17,002) STARTT

002 FORMAT (1X, 'The starting interval is ',I5)

* User enters the number corresponding to the interval which is the
* end of the simulation!

WRITE (**)' 
WRITE ('(*)',' What is the ending interval (ENDD) ? ' 
READ (**) ENDD 
WRITE (**)' 
WRITE ('(*)',' The ending interval is ',ENDD 
WRITE (17,**)' 
WRITE (17,003) ENDD

003 FORMAT (1X, 'The ending interval is ',I5)

* User enters the number associated with the last distance interval!

WRITE (**)' 
WRITE ('(*)',' What is the last distance interval (LSTINT) ?' 
READ (**) LSTINT 
WRITE (**)' 
WRITE ('(*)',' The last distance interval is ',LSTINT 
WRITE (17,**)' 
WRITE (17,004) LSTINT

004 FORMAT (1X, 'The last distance interval is ',I5)

* User enters the maximum free-speed (mph) that was specified in the
* RFL0 input file!

WRITE (**)' 
WRITE ('(*)',' What is the maximum free-speed used (SPD1) ? ' 
READ (**) SPD1 
WRITE (**)' 
WRITE ('(*)',' The maximum free-speed is ',SPD1 
WRITE (17,**)' 
WRITE (17,005) SPD1

005 FORMAT (1X, 'The maximum free-speed is ',I5)

* User enters the value of the Relaxation Constant (hr) that is associ- 
* ated with the current Acrospin formatted file being used!

WRITE (**)' 
WRITE ('(*)',' What Relaxation Constant (T) is this (hrs) ? ' 
READ (**) T 
WRITE (**)' 
WRITE ('(*)',' The Relaxation Constant is ',T,' hrs.' 
WRITE (17,**)' 
WRITE (17,006) T

006 FORMAT (1X, 'The Relaxation Constant is ',F7.5,'hrs. ')

-----------------------------------------------------------------------

Fig. D-26 (cont). The Me. For Computer Program Used In Calibrating The Relaxation Constant.
Let's perform the arithmetic needed to convert RFLO's Acrospin speed files to the actual uncoded speeds!

\[ ISPD1 = \text{FLOAT}(SPD1) / 10.0 \]

\[ SPDSTR = 1.0 / \text{FLOAT}(ISPD1) \]

Let's initialize these variables to zero:

\[ ALARM = 0 \]
\[ BUZZER = 0 \]
\[ SUM2E = 0 \]
\[ SUME = 0 \]
\[ TOTNUM = 0 \]

Let's search the "real" data file until we get to the last record of the starting interval of time. The starting interval, remember, is not changed by RFLO!

```
100 READ (12, END = 999) XT, D2, AVESPD, DENSITY, N, SUM2XI, SUMXI2
    IF ((XT .EQ. STARTT) .AND. (C2 .EQ. LSTINT)) THEN
        GOTO 200
    ELSE
        GOTO 100
    ENDIF
```

Let's find the first speed from the Acrospin formatted file!

```
200 READ (13,300,END = 350) STRING
300 FORMAT (A80)
```

If we read the "end-of-file" mark of current Acrospin file then let's go to the end of this program. Alarm is used because the first line of the Acrospin formatted file is blank!

```
350 IF (STRING .EQ. '') THEN
    IF (ALARM .EQ. 1) THEN
        GOTO 999
    ELSE
        ALARM = 1
        GOTO 200
    ENDIF
ENDIF
```

---

Fig. D-26 (cont). The Me.For Computer Program Used In Calibrating The Relaxation Constant.
* Let's dissect the record to see if it is not an "endpoint" record,
* else it is an "endpoint" record!

READ (STRING, 400) POINT, Z, CHECK, STUFF

400 FORMAT (1X, A1, 27X, A7, 6X, A1, A9, 28X)

IF ((( POINT .EQ. 'L' ) .OR. ( CHECK .EQ. '' ))) THEN
  GOTO 200
ELSE
  READ (Z, 450) ZZ

450 FORMAT (17)
ENDIF

* Now that we know that the current record (RFLO) is an "endpoint"
* record, let's read the location and time and see if this is where we
* want to start comparing values. RFLO uses the starting data in the
* Acrospin plot, but we don't want it for this!

READ (STUFF, 500) STN, TIME

500 FORMAT (I4, 1X, I4)

IF ((( TIME .EQ. 0 ) .OR. ( STN .EQ. 0 ))) THEN
  GOTO 200
ENDIF

* Let's read the first record in our area!

600 READ (12, END = 999) XT, D2, AVESPD, DENSITY, N, SUM2XI, SUMXI2

IF ( ( D2 .EQ. 1 ) ) THEN
  GOTO 600
ENDIF

IF ((( XT .EQ. ENDD ) .AND. ( D2 .EQ. LSTINT ) ) THEN
  BUZZER = 1
ENDIF

* Let's calculate the difference between these two records!

ACTSPD = ( FLOAT (ZZ) / ( 20.0 * SPDSTR ) )
SUME = SUME + ( ACTSPD - AVESPD )
SUM2E = SUM2E + ( ACTSPD - AVESPD)**2
TOTNUM = TOTNUM + 1

* Let's save the actual speed, for current XT and D2, so we can create a
* plot of RFLO's response to current Relaxation Constant!

WRITE (14) XT, D2, ACTSPD

Fig. D-26 (cont). The Me.For Computer Program Used In Calibrating The Relaxation Constant.
Let's go get another pair of records!

IF ( BUZZER .NE. 1 ) THEN
  GOTO 200
ELSE
  GOTO 999
ENDIF

Let's make the final calculations and write it to a disk file!

ME = SUME / FLOAT (TOTNUM)
VARE = ( SUM2E - (((SUME)**2) / FLOAT(TOTNUM))) / FLOAT(TOTNUM-1)
SDE = SQRT (VARE)
WRITE (17,*) ' The Mean Speed Error (ME) = ', ME
WRITE (17,*) ' The Sample Standard Deviation of Speed Errors',
WRITE (17,1) ' (SDE) = ', SDE

It's all downhill from here!

STOP
END

Fig. D-26 (cont). The Me.For Computer Program Used In Calibrating The Relaxation Constant.
Fig. D-27. Example Of The Acrospin Formatted Data File (R1SPD.A) Used To Capture RFLO Vehicle Speeds During Relaxation Constant Calibration.
Fig. D-27 (cont). Example Of The Acrospin Formatted Data File (R1SPD.A) Used To Capture RFLO Vehicle Speeds During Relaxation Constant Calibration.
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Fig. D-27 (cont). Example Of The Acrospin Formatted Data File (R1SPD.A) Used To Capture RFLO Vehicle Speeds During Relaxation Constant Calibration.
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<tr>
<th>Attempt</th>
<th>Relaxation Constant (hrs)</th>
<th>Mean Error (mph)</th>
<th>Standard Deviation Of Errors (mph)</th>
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<tbody>
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<td>A</td>
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<td>7.029</td>
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Note: Each Attempt Consists Of N Individual Comparisons, Where N= 76 * 8 = 608.

Fig. D-28. The Selected Relaxation Constant Values And Calibration Results For Simulation A.
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<th>Mean Error (mph)</th>
<th>Standard Deviation Of Errors (mph)</th>
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Note: Each Attempt Consists Of N Individual Comparisons, Where N = 29 * 8 = 232.

**Fig. D-29.** The Selected Relaxation Constant Values And Calibration Results For Simulation B.