UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

Before Administrative Judges:
Helen F. Hoyt, Chairperson
Gustave A. Linenberger, Jr.
Dr. Jerry Harbour

In the Matter of PUBLIC SERVICE COMPANY OF NEW HAMPSHIRE, ET AL. (Seabrook Station, Units 1 and 2)	Docket Nos. 50-443-444-OL (Off-site EP) September 14, 1987

TESTIMONY OF AVISHAI CEDER ON BEHALF OF THE ATTORNEY GENERAL FOR THE COMMONWEALTH OF MASSACHUSETTS ON SAPL 31 AND TOG III (EVACUATION ROADWAY CAPACITIES)

Department of the Attorney General
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One Ashburton Place
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I. IDENTIFICAION OF WITNESS

Q. Please identify yourself.

A. My name is Avishai Ceder. I am a Visiting Professor of Civil Engineering at Massachusetts Institute of Technology (M.I.T.) and principal-in-charge of traffic engineering and network optimization projects at M.I.T. Currently I am on an extended sabattical leave from Technion--Israel Institute of Technology.

Q. What is your educational background?

A. I received a Bachelor of Science in Industrial and Management Engineering from Technion--Israel Institute of Technology in 1971, a Master of Science from the University of

California at Berkeley in 1972, and a Ph.D from the University of California at Berkeley in 1975. Both my Masters and Ph.D theses are about traffic flow models and driver behavior. Since 1975 I have been teaching and working on research at Technion. During 1981 and 1982 and again during the past two years (1985-1987) I have been serving as a visiting professor at the Massachusetts Institute of Technology.

Q. What is your academic experience?

A. At the Technion I have taught graduate-and undergraduate-level courses in the areas of Transportation Systems Analysis (Introduction to Operations Research), Traffic Engineering, Quantitative Methods in Management and Engineering Systems, Public Transportation, and Urban and Interurban Transportation Services. At M.I.T., I have taught graduate-level courses in the areas of Traffic Engineering, Optimization Techniques, Public Transportation, Microcomputer Applications in Transportation and Transportation Systems Analysis. I have written three books entitled: Driver-Vehicle Modeling and Traffic Flow Characteristics, Network Theory and Selected Topics in Dynamic Programming, and Public Transportation. I have authored more than 40 papers in scientific journals, and as many as 30 research reports. I also have participated in more than 25 international conferences.

Q. What is your professional research experience?

A. Since 1975, in addition to my academic appointment, I have been a senior engineer at the Transportation Research

Institute and Road Safety Center at the Technion Research and Development Foundation Ltd. My research interests have focused on developing and applying methods in five major areas: (1) traffic engineering; (2) traffic safety; (3) traffic flow and human factors; (4) public transportation; and (5) transit scheduling. My contributions to the areas of transportation engineering and transportation science can be summarized in three main categories: (1) developing new traffic flow models which interpret the traffic flow phenomena through a human factors or driver's perspective and which were used for on-and-off line freeway control in Los Angeles; (2) developing a safety evaluation approach for road improvement projects which was implemented on a main frame computer in Israel and resulted in a reliable evaluation of before-and-after safety studies about road improvement projects; and (3) developing new theory and methods for transit scheduling which create automated transit time tables and vehicle and crew schedules and have been successfully incorporated into a software package currently implemented in four transit agencies worldwide. A more detailed statement of my professional qualifications is attached to this testimony (Attachment 1).

II. BACKGROUND FOR TESTIMONY

Q. Would you describe for us in laymans terms the work that is presented in Volume 6 of the NHRERP.

A. Yes, certainly. Volume 6 of the New Hampshire Radiological Emergency Response Plum ("NHRERP") is a report describing (1) the Seabrook Station evacuation time estimate ("ETE") study and (2) the traffic management plan for evacuation of the 10 mile emergency planning zone ("EPZ") around the Seabrook nuclear plant. That ETE study was conducted for inclusion in the NHRERP by KLD Associates. In conducting this ETE study, KLD employed a computer modeling system, commonly called "I-DYNEV," to simulate evacuations of parts or all of the Seabrook EPZ under different evacuation scenarios. These simulated evacuations are all vehicular evacuations, i.e., what is simulated is the traffic flow as it would likely occur on the key evacuation routes in the EPZ. Stated simply, I-DYNEV is a computer model into which is put instructions describing each key link of roadway network and each key intersection to be used in the evacuation. The model is then given inputs for the number of vehicles entering the simulated roadway network at various "entry nodes," i.e., points at which vehicular evacuation trips originate. Next, the I-DYNEV model assigns the input vehicles to certain links (based on some behavioral assumptions) and simulates their movement across the network (based on some assumptions about speed, delay and congestion level). Following this simulation, the model calculates how long it would take to have all the vehicles travel to points 2 miles, 5 miles, and 10 miles from Seabrook Station (or to the EPZ boundary, which in some points is almost 14 miles from the nuclear plant). These time calculations are called evacuation time estimates or "ETEs." As is described in Volume 6, KLD Associates used the I-DYNEV model to produce Seabrook's evacuation time estimates for ten (10) different scenarios, depending on the season/day/time/weather combinations (e.g., Scenario 1 is for an evacuation occurring on a summer weekend at mid-day with good weather). ETEs for these scenarios are produced for the "entire" EPZ and for various sub-parts of the EPZ, called "Regions."

Q. Does use of a traffic simulation model such as I-DYNEV guarantee that an accurate set of ETEs will be produced?

A. No, not necessarily. As with any traffic simulation model, several fundamental concerns exist. First, is the model itself conceptually sound for accomplishing its intended purpose? All traffic simulation models are based on certain assumptions which may or may not be valid. In addition there are specific traffic behaviors that are difficult to quantify and, therefore, are left out, producing a poor real-life description. Second, are the inputs which describe each of the roadway network links and intersections accurate? For example, if a link's "capacity" to handle vehicles (expressed in vehicles/hour) is not stated accurately, then the simulation will not be an accurate one. Finally, are the other inputs accurate? For example, if the number of vehicles being loaded on the model at the various entry points are not correct, ETEs will not be accurately estimated. In sum, there are many potential sources of significant error that need to be examined in any traffic model before one can have any reasonable degree of assurance that it produces reliable results.

Q. Have you conducted an assessment of the I-DYNEV model and its use by KLD in generating the ETEs for Seabrook Station?

A. Yes, I have at the request of the Massachusetts Attorney General's office.

Q. What were you asked to do?

A. Generally, I was asked to examine the model conceptually, to see if it was sound with respect to the critical assumptions it makes about the conditions that are likely to exist during a real evacuation necessitated by a radiological accident, or potential accident, at Seabrook Station.

III. CONTENTIONS ADDRESSED

Q. What contentions does your work relate to?

A. TOH III(C) addresses a number of issues under the generic heading of "road capacities." This is appropriate in light of the structure of I-DYNEV because it adjusts link "capacities" to address a host of assumptions and variables involving roadway conditions and driver behavior. The mathematical quantity labelled "capacity" in the model is the surrogate for a wide range of factors that cause traffic delays in the real world. Basis (C)(4) specifically challenges KLD's estimates of "capacity" in I-DYNEV as being overstated, thereby presenting the issue of any variable or assumption that causes delay that I-DYNEV addresses by its "capacity" values. Basis (C)(6) asserts that I-DYNEV failed to account adequately for the impact of disabled vehicles on ETEs. Basis (C)(1) challenges KLD's I-DYNEV assumption that all roads will remain passable during the various evacuation scenarios. Basis (B) challenges the reduction factors KLD applied to I-DYNEV's capacities to reduce evacuation travel speeds on account of weather conditions. SAPL Contention 31 asserts that KLD "in some instances overestimates roadway capacity" and thereby "underestimates the amount of time it would take to evacuate the EPZ and its subparts." Basis 9 challenges KLD's assumption that all roads will remain passable during an evacuation. Basis 18 asserts that the I-DYNEV model appears to have some serious defects. A copy of these contentions and bases is attached to this testimony (Attachment 2).

IV. METHOD OF REVIEW OF I-DYNEV

Q. What specific approach did the Attorney General's office ask you to take in conducting your assessment?

A. I did not do a full-scale model audit and review. To do this I would have needed the source code, and I understand that KLD refused to provide this to the Attorney General's consultants. So I turned to the next best sources of information I had about I-DYNEV and its application at Seabrook.

Q. What sources were those?

A. I used the descriptions about I-DYNEV contained in Volume 6 and the other documentary sources referred to there. On page 1-12, Volume 6 of the NHRERP describes I-DYNEV as follows, referring the reader to its Appendices for details:

I-DYNEV consists of these submodels:

An equilibrium traffic assignment model (for details, see Appendix B);

A microscopic traffic simulation model (for details, see Appendix C); and

An intersection capacity model (for details, see Highway Research Record No. 772, Transportation Research Board, 1980, papers by Lieberman and McShane and by Lieberman).

Volume 6 (at p. 1-12) also refers the reader to Appendix D for a description of the procedure for applying I-DYNEV to develop ETEs for the Seabrook Evacuation Plan.

Q. Did you have access to I-DYNEV itself?

A. No, not directly. In obtaining a copy of I-DYNEV from KLD, the Attorney General's office had agreed not to make any copies of it. They gave their one copy of I-DYNEV to Dr. Thomas Adler to do the work he has described in his testimony. Dr. Adler's office is in Vermont, and I was at M.I.T. So I had to travel to Vermont if I wanted to do work using the model. But most of what I needed to know about I-DYNEV was stated in the documentation I have just described.

Q. Could you please list the documentation you reviewed in conducting your analysis for the Massachusetts Department of the Attorney General?

A. Yes, and I will number them for easy reference as I proceed with my testimony. I have carefully reviewed the following materials:

(1) NHRERP, Revision 2, Volume 6, August 1986;

(2) "Description of an Integrated Trip Assignment and

Distribution Model (TRAD) for the I-DYNEV System," KLD Assoc. TR-187, August 1986;

(3) "INPUT Info" to the I-DYNEV Capacity Submodel;

(4) Lieberman, E.B.: "Determining the Lateral Development of Traffic On An Approach To an Intersection," Transportation Research Record (TRR) No. 772, pp. 1-5, 1980;

(5) Lieberman, E.B. and Yadlin, M.: "Development of a Transit-Based Traffic Simulation Model," TRR, No. 722, pp. 6-8, 1980;

(6) Lieberman, E.B. and Andrews, B.J.: "TRAFLO: A New Tool to Evaluate Transportation System Management Strategies," TRR, No. 772, pp. 9-14, 1980;

(7) Lieberman, E.B. and Davila, M.C.: "HYBRID Macroscopic-Microscopic Traffic Simulation Model," TRR, No. 772, pp. 15-17, 1980; and

(8) Lieberman, E.B. and McShane, W.R.: "Service Rates of Mixed Traffic on the Far Left Lane of an Approach," TRR, No 772, pp. 18-23, 1980.

Q. How did you approach your review of I-DYNEV?

A. The review was performed through two perspectives. The first was similar to the perspective I adopt as a referee of various transportation and research journals (e.g., Transportation Research, Transportation Science and Transportation Research Board). The second perspective was aimed at assessing the practical implementation and accuracy level required for predicting real-life situations.

In addition, I conducted a few field tests in the Seabrook Station EPZ (one of them jointly with Dr. Adler) in order to capture certain traffic flow characteristics which may be particularly related to the traffic associated with the EPZ. My comments, reservations and suggestions are organized in the following three sections:

(V) Behavorial Assumptions;

(VI) Adequate Parameters in the I-DYNEV model; and

(VII) Likelihood of Disorderly Traffic Incidents.

V. I-DYNEV's BEHAVIORAL ASSUMPTIONS

Q. Based on your experience, would you please comment in a general way on possible traffic behavior during circumstances similar to that which would exist during an evacuation from the Seabrook EPZ?

A. Traffic disorders are observed during almost every congested traffic situation world-wide. In general, traffic behavior remains stable during these periods due to the anticipated congestion. The same applies to traffic behavior during an anticipated disaster, like evacuating an area because of a hurricane. Nonetheless, during highly congested situations, only one driver needs to behave in an unstable manner to create a significant disturbance across a long line of vehicles. Such behavior can be observed commonly in "rush hour" traffic when a single vehicle, seeking to get through an intersection without waiting for the next green light, occupies part of the intersection and thereby reduces significantly its capacity for the cross-flowing traffic. In other cases, this unstable individual behavior results in an accident which closes part of the roadway and creates a bottleneck.

This individual unstable behavior is also commonly observed when the traffic is dispersing after large public gatherings. I personally observed such behavior again just recently at the July 4th gathering at the Esplanade in Boston. Following the fireworks that evening a mass of traffic sought to leave the area simultaneously. A traffic guide was assigned at each close-by intersection. One could see that often, during this congested movement, one or two vehicles would block part of the intersection due to a spillback of traffic from a downstream intersection.

Apart from the information we have about disorderly traffic behavior from normal rush hours, hurricane evacuations, and large public events, we also know that major traffic disorders have occurred in response to widespread public disorders. In Miami, just after the riots, the traffic moved on open roads with delays of more than 5 hours in contrast to a half hour delay occurring in normal daily congestion. In Washington, D.C., following the assassination of Martin Luther King, traffic delay reached a record of about 6 hours as opposed to about a half hour during daily peak periods. These traffic disorders, too, suggest that a very careful approach is needed to evaluate what will happen to traffic behavior during a nuclear plant evacuation.

Q. Could you please be more specific and comment about the behavioral assumptions used in the I-DYNEV model?

A. Many traffic behavioral questions arise as a result of my review of the articles by Lieberman referenced above and numbered (4) to (8). Although I cannot be sure because I could not review the source code, I-DYNEV apparently was programmed in the manner described in these references. In my opinion it is doubtful that during an evacuation scenario the following model assumptions and procedures mentioned in these references will hold true:

(1) The model assumes that <u>all</u> right turning vehicles will select the outside lane and <u>all</u> left turning vehicles the inside lane. (Article 6, p. 3). In my opinion, however, under congested conditions some vehicles will be switching lanes prior to making turns and will encounter some difficulty in doing so. Therefore, to account for these lane change delays, a traffic merging factor which reduces the average traffic speed should be introduced into the model.

(2) The model assumes that <u>every</u> motorist will select a lane on an approach consistent with his intended turn maneuver and with any specified lane channelization so as to minimize his perceived travel time. (Article 4, p. 21). In my opinion, this is not the case in congested situations in which a motorist is often "forced" to move on an undesired lane.

(3) The model (the Trip Assignment and Distribution model in I-DYNEV) assumes that <u>every</u> motorist will select the optimal routing which minimizes evacuee travel times. (Article

2, p. 3). In my opinion, the actual routing and traffic flow in each route will never follow entirely the so-called "optimal" strategy and, consequently, the actual travel times will be higher than those calculated by the model.

(4) The model assumes that spillback conditions are "properly treated." (Article 6, pp. 11-13). However, this statement is not adequately supported by the analysis provided and more explanation is required. Without this, one cannot assume that spillback conditions are "properly treated". One should bear in mind that two extensive studies have shown that the submodel used in I-DYNEV (an extension of TRANSYT) can not be used for spillback conditions. These studies are: (1) "Traffic Control in Saturated Conditions", Road Research Organizatin for Economic Co-operaton and Development (OECD), January 1981; and (2) Pignataro, L.J., McShane, W.R, Crowley, K.W., Lee Bumjung and Casey, T.W.: "Traffic Control in Oversaturated Street Networks", NCHRP report #196, Transportation Research Board, Washington, D.C., 1978.

All the above behavioral comments emphasize that numerous simplifications of real-world driver behavior have been made in the I-DYNEV model. The important point, however, is that eliminating any of these simplifications will have a tendency to increase the travel time and the vehicle discharging time thereby resulting in longer ETEs. Further comments on behavior from a safety standpoint appear later in my testimony.

Q. Could you also comment on some of the behavioral assumptions contained in the emergency traffic control and management plan?

A. Many behavioral assumptions are also contained in Volume 6 regarding the actual emergency traffic control and management plan. Importantly, <u>these assumptions were not studied thoroughly and their impact on the ETEs may be crucial</u>. It is prudent, therefore, to carefully examine these behavioral assumptions, particularly for the traffic control post locations which are identified as possible bottlenecks. One such bottleneck is at the merging points between Route 110 and Interstate I-95. The traffic control and management arrangements at this point are shown on page I-19 in Volume 6 and also attached to this testimony as Figure 1. (Attachment 3). The assumptions implicit in this traffic control diagram are:

> (i) the traffic moving on Route 110 westbound will be <u>equally divided</u> and will travel at equal speeds via (right turn) the existing on-ramp to I-95 and via (left turn) the off-ramp from I-95 (in the opposite direction!) while merging to another on-ramp to I-95; and
>
> (ii) <u>it is possible</u> for every left-turning vehicle to merge from the off-ramp to the on-ramp leading to I-95 southbound.

The first assumption cannot be true. A field visit to that traffic control post revealed that the left turn from Route 110 westbound onto the I-95 off-ramp can be performed only by making about a 130 degree left turn (around a raised median) followed by a right turn (see the dashed line with arrows in

Attachment 3). This turning movement alone will create larger discharging headways for the left lane vehicles than for the right lane vehicles and, therefore, the traffic flow in a realistic setting is unlikely to be equally divided (i.e., moving at the same speed).

Regarding assumption (ii), my field visit also revealed that there is a curbed median between the off-ramp and the on-ramp which connects the two triangulare islands. This median is shown on Attachment 3 with dashed lines. The Plan calls for the evacuating vehicles to traverse this curbed median onto the southbound on-ramp. In my view, this assumption is unrealistic. All vehicles (particularly during snowy conditions) would not be able to climb the curb, drive across a grass strip, and descend down the curb onto the southbound on-ramp. To get all vehicles across would require constructing an emergency merging lane here. Those vehicles which now can traverse this median will be forced to do so at a very slow speed (e.g., 5 mph).

Taken together, these behavioral assumptions implicit in the model and the traffic control plan result in unrealistic appraisals of the time period in which evacuation could reasonably be accomplished. Changes could be introduced into the model, however, which would address all of my concerns. This would make the model somewhat more complex, but well within the current state-of-the-art in the modeling profession. Prudent planners would make these changes to improve I-DYNEV, in my view, given the importance of having realistic ETEs.

VI. <u>TECHNICAL TRAFFIC ENGINEERING CONCERNS</u>

Q. Do you have any concerns about the I-DYNEV model from a technical traffic engineering viewpoint and, if so, could you briefly express them?

A. I do have some technical concerns about the I-DYNEV model. It should be indicated that the main portions of this model are the result of a considerable effort made under a project for the U.S. Federal Highway Administration. Nonetheless, in addition to the behavioral matters discussed above, the technical reservations I have, would lead prudent planners to doubt the capability of this model to derive realistic ETEs within a reasonable (+ or - 10%) degree of accuracy.

(1) In Article 8, p. 20, the calculation of discharge time at intersections is said to be based on the assumption of exponential distribution for gaps. However, in Gerlough, D.L., Huber, M.J.: "Traffic Flow Theory", TRB special report No. 165, Washington, D.C., 1975; and Gazis, D.C. (Ed.), <u>Traffic Science</u>, John Wiles & Sons Publishing Co., 1974, it is indicated that exponential distributions for gaps are inadequate and other distributions should be selected.

(2) In Volume 6, p. 3, it is indicated that the service volume, Vf, under congested conditions is determined by the formula (capacity X 0.85). In my opinion that formula is

overly optimistic. Based on extensive studies I have conducted on different sections of highways (Ceder, A., & May, A.D.: "Further Evaluation of Single-and-Two Regime Traffic Flow Models," Transportation Research Record 567, pp. 1-15, 1976; Ceder, A.: "A Deterministic Traffic Flow Model for the Two-Regime Approach," Transportation Research Record 567, pp. 16-30, 1976; Ceder, A. & May, A.D.: "Consistency of Maximum FLow Characteristics and Congestion Patterns under Morning Peak Period Conditions on an Urban Freeway," Transportation Research Record 644, pp. 8-14, 1977; and Ceder, A. & Schwartz, A.: "Dynamic Changes of Traffic Flow Characteristics During Morning Peak Period Conditions on an Urban Freeway," Transportation Research Institute, Pub. No. 78-5, p. 137, May 1978) the rate at which traffic can be serviced under congested conditions is less than 1500 vehicles per hour per lane (vphl) for a maximum flow of about 2000 vphl. This can be seen in typical examples in Figures 2 and 3 (Attachments 4 and 5), where the flow of vehicles is simply the number of vehicles passing one point during one hour (or during 5 minutes extrapolated to one hour) and the density is simply the number of vehicles occupying one mile of highway. By inspecting the two-regime models (more accurate than the single-regime models) in Fig. 2 (Attachment 4) and the data in Fig. 3 (Attachment 5), one can see that the peak (5-minute) flow is obtained only when moving from free-flow to congested flow conditions (see Ceder, A.: "A Time-Sequence Analysis for a Two-Regime Traffic FLow Model," The Institute of Systems Science Research, 7th International

Symposium on Transportation and Traffic Theory, Kyoto, Japan, pp. 141-174, August 1977 for more details) and not vice-versa. The example in Fig. 3 (Attachment 5) illustrates the data collected on the Santa Monica Freeway in Los Angeles. The congested situation occuring there after 7:00 a.m. is demonstrated in Fig. 3 by the flow density data points which, at 7:50 a.m., reach the highest density value of about 170 vehicles per mile (vpm) while the flow is less than 1000 vphl. It is more realistic, therefore, to use for the Vf calculation the formula "capacity X 0.75" than the one used in I-DYNEV (capacity X 0.85), i.e., for the freeway capacity the I-DYNEV model uses the value of 1728 vphl as is indicated in Volume 6, pp. 3-10.

An exercise on the data plotted in Fig. 3 can be made for the congested hour between 7:00-8:00 a.m. There are twelve data points for this hour where each data point represents 5 minute measurements converted to an hourly flow rate. By summing up all the 5-minute flows the result is about 1300 vphl. In the I-DYNEV model Vf is calculated by (capacity X 0.85) or Vf = 1728 X 0.85 = 1468 vphl. By replacing the 0.85 factor by 0.75 factor the result becomes more realistic: Vf = 1728 X 0.75 = 1296 vphl. This means that the Vf factor used in I-DYNEV is 13% too high. It should be noted that the capacity level considered needs to be an average maximum flow across all lanes for the entire 60 minutes of highway operation. Moreover, the authors of Volume 6 consistently claim that they are adopting a <u>conservative</u> approach for the ETE computation (see for example p. 3-6, 1st line). These points further support the finding that the Vf value must be reduced by changing the 0.85 factor to 0.75. This will affect the discharging rates at the bottleneck locations and hence will increase the ETEs.

(3) The manner in which I-DYNEV handles traffic flow through congested intersections is also not conservative. In Volume 6, pp. 3-4, it is indicated that the saturation discharge headway for intersections used in the I-DYNEV is 2.4 seconds per vehicle. Volume 6 claims that this is a conservative value (pp. 3-3). I disagree, and so do others in the profession. Saturation discharge headway is a concept which describes the number of seconds required for a single vehicle to travel to the location of the vehicle just in front. In Salter, R.J.: "Highway Traffic Analysis and Design," Addison Wesley Publishing Co., Inc., 1974, for example, one can find that this headway for an observed 80 vehicles was found on the average to be 2.63 sec/veh. Again if a conservative perspective is to be achieved, this headway should be increased from 2.4 to 2.7 sec/veh, which in turn would increase the ETEs if a critical intersection is a bottleneck. In addition, the remark made on p. 3-3 of Volume 6 (and marked by double asterisks) to explain why the saturation discharge headway (h sat) is a conservative estimate may very well turn out to be a reason for reducing intersection capacity by increasing the probablility of accidents, as is detailed in later parts of my testimony.

(4) Another technical parameter in I-DYNEV which is less than conservative is the flow rate for two lane roads. In Volume 6, pp. 3-8, it is indicated that the flow rates for two lane roads are based on the 1985 Highway Capacity Manual at Level of Service (LOS) E. But the definition of LOS-E is "unstable flow, with yet lower operating speeds and, perhaps, stoppages of momentary duration, volumes at or near capacity." (emphasis supplied.) In other words, by using LOS-E I-DYNEV discharges the evacuee at approximate capacity level -- an "idealized discharging" system. In my opinion, in an evacuation from Seabrook it would be more realistic to assume a system with several bottlenecks in which the flow rate is fluctuating between free-flow and congested-flow regimes at lower levels of flow than "capacity." That is, the anticipated flow rates are likely to alternate between LOS-E and LOS-F, where LOS-F is defined as:

> "forced flow, low volumes. Both speed and volumes can drop to zero. Stoppages may occur for short or long periods. These conditions usually result from queues of vehicles backing up from a restricted downstream."

Without using these more realistic flow rates, I-DYNEV's ETEs tend to be shorter than could be reasonably expected in a real-world evacuation.

(5) In Article 2, p. 9, it is stated that the link travel time is expressed in a "BPR Formula" while adopting a certain function for this computation. In my opinion a certain function can be selected only after evaluating different function forms using real world data while using a

goodness-of-fit measure. There is no indication that the above formula was selected in this way.

(6) In Article 2, p. 10, it is indicated that the calibration parameters "a" and "b" are based on (unspecified) experimental data. The experimental data used, however, may not fit the traffic flow characteristics around the Seabrook Station.

(7) In Article 2, p. 11 it is assumed in the network example that all links have the same values of capacity, length, and free-flow travel times. In my opinion this is not a good basis to draw generalized conclusions for use in the model. Instead, different values should be assigned for a more realistic evaluation process.

(8) In Article 8, p. 19, it is indicated that "some refinements are possible but were judged unnecessary for the precision with which the model would be used. For instance, duration for the A model is actually a random variable, but a simple deterministic computation is done to estimate its duration. Likewise a weighted average headway is used in the B model to simplify the formulation and the computations" (emphasis supplied). My judgment differs, because when random variables (stochastic elements) rather than average values are introduced, the delay at intersections will always increase and may effect the ETE if these intersections become bottlenecks. (Note that models A and B represent certain behavior at intersections.)

Q. As a result of the technical concerns you have just detailed, are you able to draw any overall conclusions about the accuracy of the ETEs that I-DYNEV generated for Seabrook?

A. Yes. It is likely to produce ETEs which err on the low side. I say this because the technical parameters in I-DYNEV about which I have concern, have an effect, or a potential effect, which directly or indirectly causes the model to move cars through the simulated roadway network faster than cars in the real-world are likely to travel. The model itself, therefore, in my opinion, cannot be described as "conservative."

VI. LIKELIHOOD OF DISORDERLY TRAFFIC INCIDENTS

A. Yes. In my opinion such incidents are very likely to occur. Prudent evacuation planners should, therefore, anticipate that during the evacuation process road accidents or road incidents will occur and serve to delay the evacuating traffic at key points. Yet the ETE study described in Volume 6, which uses the I-DYNEV model, does not anticipate even a single road accident or incident which delays traffic at a key point. My opinion about the frequency of such incidents during an evacuation stems, first, from viewing the traffic safety circumstances during the evacuation process as being analogous to the circumstances which commonly exist during construction/maintenance work, and, second, from estimating the probability of accidents occurring at one bottleneck section which is critical to an evacuation of the Seabrook EPZ.

Q. Why do you believe that the evacuating traffic will face a situation analogous to that encountered by a stream of vehicles moving along or through construction zones?

A. Volume 6 suggests a set of traffic control and management tactics in order to expedite the movement of evacuating traffic during an evacuation. The traffic is facilitated or discouraged by means of traffic guides, traffic cones and traffic barricades. This creates a change in the customary traffic pattern analogous to that experienced by traffic during construction or maintenance work. Therefore, in my opinion, traffic safety circumstances during the evacuation process can be viewed, generally, by analogy to those in highway work zones.

Q. What is known about traffic safety during construction work?

A. The on-going activities in the vicinity of traffic barriers and lane closures create substantial hazards to both traffic guides and motorists. A review of the research on this topic stresses the need for effective action to address these hazards in highway work zones. See, for example, Anderson, R.W.: "Improving Safety in Highway Work Zones -- a Matter of Ethics," Proceedings 20th Conference of American Associatin for Automotive Medicine, Atlanta, GA, 1976; and Ceder, A. & Dressler, O,: "A Note on the X 2 Test with Application and Results of Road Accidents in Construction Zones," Accident Analysis and Prevention Journal, Vol. 12, pp. 7-10, 1980. The first work noted here reported that in ten construction zone studies in California accident rates increased about 2.5 times during the construction period. Also, a National Transportation Safety Board study found that accidents resulting in injury had more than doubled during construction/maintenance periods. The second work noted above indicates that on roadways with average daily traffic greater than 10,000 vehicles, the number of accidents during construction/maintenance periods is significantly greater than during other (normal) operation. In "Highway Construction Zone Safety -- Not Yet Acheived," General Report to the Secretary of Transportation, Report No. CED-78-10, Dec. 23, 1977, a comprehensive report was prepared for the Secretary of Transportation covering 79 construction projects with more than 20,000 road accidents. The results show that the safety level significantly deteriorated during construction periods.

The importance of these safety issues was recognized by the Federal Highway Administration while preparing the "planning and scheduling work zone traffic control" implementation package ("Planning and Scheduling Work Zone Traffic Control," FHWA-IP--81-6, User Guide, prepared by Abrams, C.M., Wang, J.J., JHK Associates, San Francisco, U.S. Department of Transportation, October 1981). In that user manual, accident factors were derived for different roadways along with a speed decrease table (see Table 1) (Attachment 6) and other delay characteristics.

From Table 1 (Attachment 6) it is interesting to note that if one lane out of 2 lanes is closed, the average speed is dropped by a factor of 5 (from 30 to 6 mph). In addition, one should bear in mind that markings and signs similar to those used commonly throughout the world for construction projects (see for example Fig. 4, from the user manual) (Attachment 7) are not to be provided during the evacuation process for Seabrook Station. These markings and signs do help, from a safety perspective, in construction zones. Their absence here suggests that the accident rates experienced in an evacuation from Seabrook may well be higher than those commonly experienced in construction zones.

Q. Could you provide some statistical evidence that a safety factor should be introduced into I-DYNEV, or any other simulation model, used to compute ETEs for an evacuation from the Sebrook EPZ?

A. I have evaluated the safety level at the bottleneck location shown in Fig. 1 (Attachment 3), the intersection at which Route 110 merges with Interstate I-95. This may shed some light on the importance of introducing a safety factor into I-DYNEV to reflect the likelihood of traffic disorders and delays due to road incidents, particularly if one seeks to adopt a truly "conservative" approach. Here is how I conducted this evaluation:

Step 1) The critical segment of roadway leading to the bottleneck stretches from the intersection between Routes 1, 1A, and 110 to the merging points between the on-ramps from Route 110 to I-95. Its length is about 2.65 miles.

Step 2) According to Volume 6, p. 3-11, the anticipated traffic flow for the one-lane on-ramp during congested conditions is Vf = Ve X R = 1170 X 0.85 = 994 vph. A density of 100 vpm can be considered for the congestion situation. This leads to an average speed of 994/100 = 9.94 mph or about 10 mph. It is an average (space mean) speed of stop-and-go traffic.

Step 3) The time required for a single vehicle to traverse the critical bottleneck segment of 2.65 miles is therefore about 16 minutes or 0.265 hours.

Step 4) The total vehicle-hours during the evacuation process is the amount of vehicles assigned to that segment times 0.265 hours or 11400 X 0.265 = 3021 vehicle-hours, where 11400 vehicles are used in Volume 6 for the ETE calculations.

Step 5) An example of the relationship between accidents and traffic flow can be found in Ceder, A. & Livneh, M.: "Relationships Between Road Accidents and Hourly Traffic Flow: I Analysis and Interpretation,: Accident Analysis and Prevention Journal, Vol. 14, No. 1, pp. 19-34, 1982; and Ceder, A,: "Relationships Between Road Accidents and Hourly Traffic Flow: II, Probabilistic Approach," Accident Analysis and Prevention Journal, Vol. 14, No. 1, pp. 35-44, 1982. Figures 5 and 6, (Attachments 8 and 9) from these articles, represent the relationships for both free-flow and congested-flow traffic situations, where the traffic flow, designated q, is associated with 2-lane one-way roadways. The accidents presented in Fig. 5 (Attachment 8) were basically collected during an 8-year period. Only injury-producing and fatal accidents occurring during good weather conditions (no snow, ice or heavy fog) were counted. While Fig. 5 shows the relationships between the accident rate and 2-lane traffic flows, Fig. 6 illustrates the probabilities of having at least one accident for various traffic flow conditions and amount of vehicle-hours travelled. The 3021 vehicle-hours at the bottleneck segment described above can be applied to Fig. 6 for the congested situation and for a flow rate of 994 X 2 = 1988 vph (about 2000 vehicles per hour per 2 lanes). This results in a probability close to 100% that a serious multi-vehicle accident will occur during the evacuation process on this bottleneck segment. This is certainly a conservative figure because it is based on only injury-producing and fatal accidents and for good weather conditions.

Step 6) The traffic control arrangement at this bottleneck point appears in Fig. 1. This arrangement of 3 traffic guides, traffic cones and barricades, some conflicting traffic and difficult maneuvers creates a situation similar to highway work zones (as is mentioned earlier). Importantly, the anticipated number of accidents usually are <u>doubled</u> during such traffic control arrangements.

Step 7) An attempt has been made to collect accident data from the Massachusetts Department of Public Works (MDPW) on various state and interstate highways in order to assess the weather factor on road accidents (in the EPZ). The results of the 1983 data (1983 was chosen because it was the latest year for which both accident and traffic flow data were available) are presented in Table 2 (Attachment 10). These results are arranged in terms of the number of accidents per day during good (dry and wet) and bad (snowy and icy) road surface conditions. The ratio between the number of accidents associated with bad and good weather conditions is also indicated in Table 2. In order to be on the conservative side, the five highest ratios (noted on Table 2 with asterisks) were deleted along with a single zero ratio. Overall it results in an average of 3.53 more accidents during bad than good weather conditions.

Step 8) All in all, for this bottleneck exercise the number of expected accidents during the evacuation process may range between 2-7 accidents. In addition to possible accidents, other road incidents may occur, e.g., vehicle breakdowns due to overheated engines or empty gas tanks or mechanical failures. In each of these cases the following disorder scenarios are possible (at the bottleneck described):

- the entire 2-lane roadway is closed
- the entire on-ramp(s) is closed
- the road is partially closed
- the vehicle is located on the shoulder or side of the 2-lane roadway or the on-ramp.

The time to clear the incident or accident depends on the type of incident (accident) and type of car(s) involved as well as on the availability of tow trucks.

In my opinion such incidents (accidents) will have some cumulative effect on the evacuation times. Furthermore, in my opinion, prudent planners would simulate an evacuation in such a way as to introduce accident reduction factors for different disorder scenarios and clearance times. Such simulations would produce more realistic (and certainly more conservative) evacuation time estimates for Seabrook Station.

Q. Dr. Ceder, the Nuclear Regulatory Commission Licensing Board which conducted hearings regarding the Shoreham nuclear plant on Long Island found that the "DYNEV" model, used in 1983 to develop ETEs for Shoreham, was conceptually sound for the purpose of estimating evacuation times and that it has been subject to reasonable validation in the past. First, what is the DYNEV model? Is it the same as I-DYNEV?

A. No, it's similar, but it is not the same. I-DYNEV is supposed to be a more "advanced" version of DYNEV.

Q. Well, doesn't this mean that I-DYNEV, as the more "advanced" model, must be conceptually sound too?

A. No, not at all. Standards and capabilities in the profession are constantly changing as research gives us more knowledge about traffic behavior and computer models become more sophisticated. This is a rapidly changing area. What was conceptually sound just a few years ago may no longer meet current-day standards in the profession. So, it would not be prudent to judge I-DYNEV's "conceptual soundness" by looking at its parents. One needs to judge it by applying current professional standards.

Q. In your professional opinion, Dr. Ceder, is I-DYNEV "conceptually sound" judged by current professional standards for the purpose of estimating evacuation times?

A. No, it is not, not in the form it was in when Seabrook's ETEs were compiled, because it can not provide realistic ETEs within a reasonable degree ($\pm$ 10%) of accuracy. The I-DYNEV model does not represent the current state of knowledge in transportation science. As a professional who is familiar with the literature, I can definitely say that better, more accurate models can be developed for the purpose of simulating a nuclear plant evacuation. I am not suggesting that a new model needs to be developed here to meet current standards. It may be that if the deficiencies with respect to the traffic engineering parameters I have identified in my testimony were corrected in I-DYNEV, and a series of appropriate behavioral assumptions and accident factors were introduced into the model, then I-DYNEV might be a reasonably accurate tool for estimating evacuation times in general. Because I have not been able to review the source code, I cannot say whether these changes in I-DYNEV will suffice or whether a new model should be developed. Of course, this is not to say that the ETEs generated then would be accurate. As Dr. Adler has pointed out in his testimony, there are three major potential sources of error or uncertainty in using I-DYNEV to estimate realistic evacuation times for Seabrook:

- the calculations made by I-DYNEV;
- the values of inputs to I-DYNEV; and
- the overall assumptions made about the behavior of evacuees and of evacuation personnel.

This testimony has dealt primarily with the first of these three potential sources of error, the calculations about traffic flow and capacity made by I-DYNEV. So, merely making the changes to I-DYNEV that I have suggested or even producing a new model, does not mean that the ETEs then produced will be as reliable as can reasonably be made. In fact, those other two sources of error are probably more critical in that they can easily lead to much larger errors in ETEs than can, say, a 15% error in vehicle flow rates. Nevertheless, without making the changes as I have suggested, I-DYNEV simply cannot produce accurate and "conservative" ETEs (longer that would be experienced in the real world). Instead, in my opinion it produces overly optimistic times which are likely to be shorter than would actually be experienced.

In conclusion, as I have noted, the state-of-the-art knowledge in transportation science (e.g., stochastic models) is not reflected in I-DYNEV. By spending more development time, the model will be somewhat more complex, but more importantly, it will then produce ETEs which have some reasonable possibility of being reliable and accurate. According to the standards in the profession today, we do not have such ETEs yet.

UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

Before Administrative Judges:
Helen F. Hoyt, Chairperson
Gustave A. Linenberger, Jr.
Dr. Jerry Harbour

In the Matter of PUBLIC SERVICE COMPANY OF NEW HAMPSHIRE, ET AL. (Seabrook Station, Units 1 and 2)	Docket Nos. 50-443-444-OL (Off-site EP) September 14, 1987

ATTACHMENTS

TO

TESTIMONY OF AVISHAI CEDER ON BEHALF OF THE ATTORNEY GENERAL FOR THE COMMONWEALTH OF MASSACHUSETTS ON SAPL 31 AND TOH III (EVACUATION ROADWAY CAPACITIES)

Department of the Attorney General
Commonwealth of Massachusetts
One Ashburton Place
Boston, Massachusetts 01208-1698
(617) 727-2265

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ATTACHMENTS

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Attachment 1	Professional Qualifications of Avishai Ceder
Attachment 2	Town of Hampton Contention III
	SAPL Contention 31
Attachment 3	Figure 1: Traffic Control Post for Route 110/I-95
Attachment 4	Figure 2: Typical Single- and Two-Regime Models
Attachment 5	Figure 3: Flow-Density Data Plot
Attachment 6	Table 1: Typical Speeds in Congested Freeway Work Zones
Attachment 7	Figure 4: Construction Project Signs and Markings
Attachment 8	Figure 5: Data and Regression Models for Free-Flow and Congested-Flow Conditions
Attachment 9	Figure 6: Accident Probabilities
Attachment 10	Table 2: Accident Rates

ATTACHMENT 1

July 1987

AVISHAI CEDER

Curriculum Vitae

PERSONAL	Present Address: 463 Concord Ave., Lexington, MA 02173 Date of Birth : 18th May, 1946 Place of Birth : Haifa, Israel Marital Status : Married, three children
ACADEMIC DEGREES	B.Sc., Technion - Israel Institute of Technology, Haifa, Israel. Faculty of Industrial & Management Engineering, 1967-1971. M.Sc., University of California, Berkeley, USA, Faculty of Civil Enginerring, Major: Transportation Engineering, 1971-1972. Ph.D., University of California, Berkeley, USA, Faculty of Civil Engineering, Major: Transportation Engineering, Minors: Operations Research and Human Factors, 1972-1975.
ACADEMIC APPOINTMENTS	o Research Assistant in Transportation Engineering, University of California, Berkeley, USA, 1972-1973. o Lecturer (Adjunct), Technion - Israel Institute of Technology, Faculty of Civil Engineering, 1975-1979. o Senior Research Fellow, Technion - Israel Institute of Technology, Faculty of Civil Engineering, 1979-1980. o Senior Lecturer, Technion - Israel Institute of Technology, Faculty of Civil Engineering, 1980-present. o Visiting Associate Professor, Massachusetts Institute of Technology (M.I.T.), USA, Faculty of Civil Engineering, 1981-1982. o Visiting Associate Professor, M.I.T. Faculty of Civil Engineering, 1985-1987.
TEACHING EXPERIENCE	Faculty of Mechanical Engineering, Technion - Israel Institute of Technology, Teaching Assistant in Technical Drawing & Planning (Undergraduate), 1969-1971. Faculty of Civil Engineering, Technion - I.I.T., teaching the following courses, 1976-1985.

1. Planning and Operationg of Public Transportation (Graduate - 019712)
2. Quantitative Methods in Manmagement and Engineering Systems (Graduate - 019006).
3. Traffic Flow Characteristics & Models (Graduate - 019722).
4. Seminar in Traffic Engineering & Public Transportation (Undergraduate - 014700).
5. Projects in Traffic Engineering & Public Transportation (Undergraduate - 014004).
6. Systems' Analysis (Introduction to Operations Research) (Undergraduate - 014004).
7. Urban and Interurban Transportation Services (Undergraduate - 014711).

Faculty of Civil Engineering, M.I.T., USA, during 1981-1982; and presently (1985-) teaching the following courses:

1. Mathematical Optimization Techniques (#1.143J/13.622j)
2. Traffic Flow: Theory and Applications (#1.209/1.215)
3. Public Transportation (#1.258/1.214)
4. Advanced Topics in Public Transportation (#1.964)
5. Microcomputer Application in Transportation (#1.27)
6. Transportation Systems Analysis (#100J/1.201J/1.20)

Seminars Abroad:

1. University of California, Berkeley, U.S.A., "Human Factors in Transportation," 1974.

2. University College London, England, "Traffic Flow: Macro- and Microscopic Phenomena," August 1977.

3. University of California, Berkeley, U.S.A., "The Operational Process of a Bus Company," May 1979.

4. Massachusetts Institute of Technology (M.I.T.), U.S.A., "Computerized Deficit Function Approach for Bus Assignments," October 1981.

5. Massachusetts Institute of Technology (M.I.T.), U.S.A., "Traffic Behavior Control (at alternate one-way sections) During Lane Closure Periods on a Two-Lane Road," November 1981.

6. University of Pennsylvania, U.S.A., "A Man-Machine Interactive Method for Bus Scheduling," April 1982.

7. M.I.T. summer course (Boston, U.S.A.), "Public Transportation Service and Operations Planning," August 1983.

8. Massachusetts Institute of Technology (M.I.T.), U.S.A., "Methods for Setting Bus Time'‹' 'es," January 1984.

9. Massachusetts Institute of Technology (M.I.T.), "Optimization of a Portable Two-Traffic Light System", 1987.

10. M.I.T. summer course (Boston U.S.A.), "Public Transportati·n Service and Operations Planning," August 1984, 1985, 1986, and 1987.

RESEARCH EXPERIENCE

Master Candidate in the Faculty of Civil Engineering - Transportation Field, University of California, Berkeley, U.S.A., Research on Traffic Flow, 1971-1972.

Doctoral Candidate in the Faculty of Civil Engineering-Transportation Field, University of California, Berkeley, U.S.A., Research on Traffic Flow Models & Man-Machine Ssytems, 1972-1975.

Senior Research Engineer at the Transportation Research Institute and Road Safety Centre, Technion Research & Development Foundation Ltd. Research in the Public Transportation, Road Safety, Operations Research & Human Factors Fields, 1975-present.

PROFESSIONAL EXPERIENCE

1968-1971: Transportation Planning of Bus Routes & Schedules (while frequently serving as a bus driver to obtain valuable first-hand experience): EGGED Bus Company Ltd., the Israel National Carrier.

1975-1985 A Senior Advisor to EGGED Bus Company Ltd. Working on Transit Management Research and projects regarding:

(i) Computerized and man-computer interactive systems for bus scheduling;
(ii) dynamic changes in bus travel time (as an essential input for the planning process);
(iii) data collection systems for buses;
(iv) optimum locations of bus stops;
(v) route and network design;
(vi) methods and appraisal to set bus frequencies (headways) and to create alternative timetables;
(vii) passenger behavior: the walking distance, the waiting time, and travel time criteria;
(viii) methods, policies and criteria of the allocation of land-oriented facilities for public transport; and
(ix) bus priority schemes.

1982 Operations Research Analyst at the Transportation Systems Center (U.S. Department of Transportation), Cambridge, Massachusetts. Work in Projects regarding scheduling methods and data collection and analysis in conjunction with the Automatic Vehicle Monitoring (AVM) system in Los Angeles.

1982-1985 Consultant to Multisystems (Multisystems), Inc., Cambridge, MA. Work in projects regarding crew scheduling at New Jersey Transit Corporation, and preparation of Bus schedules in conjunction with Automatic Data Collection Systems (ADCS) in the U.S.A.

1984- Consultant to BEFAG Transport AG, ZUG, Switzerland. Work in projects regarding development of software to Transit companies about network and route design and vehicle and crew scheduling procedures.

1986- Consultant to ABT Associates, Inc., Cambridge, Massachusetts. Work in developing new projects in the areas of Transit, Traffic Engineering, Logistics and Airport and Aviation. Also involved in projects of the the Department of Justice.

1987- General Attorney Office, Massachusetts, U.S.A. Consultant (including testimonies) work regarding the analysis of the evacuation time of the Seabrook power plant at New Hampshire.

ADMINISTRATIVE (a) Road Safety Centre, Technion - Israel Instituet of Technology

1. Senior Researchers Committee (1976-1981).

2. Responsibility and Organization of National Seminars (1978-1980).

(b) Department of Civil Engineering, Technion - Israel Institute of Technology.

1. Secretary of the Civil Engineering Faculty Council (1980-1981).

2. Member of various Graduate and Undergraduate Committees.

(c) Chairman of the IATR - Israel Association of Transportation Research. (From 1987).

(d) Member, Committee on Bus Transit Systems, Group 1, Section E, A1E01, Transportation Research Board, Washington, D.C., U.S.A. (From 1981).

(e) Member, Editorial panel of Transportation Research Journal. (From 1982).

(f) Member, Committee on Transit Management and Performance, Group 1, Section E, A1E05, Transportation Research Board, Washington, D.C., U.S.A. (From 1984).

AWARDS AND HONORS

1. Technion - Israel Institute of Technology, Faculty of Industrial and Management Engineering, Scholarship (1970).

2. Road Safety Centre - Technion Res. & Dev., Foundation, Ltd., (Ministry of Transport of Israel), Grant for Ph.D. studies (1971-1975).

3. University of California, Berkeley, U.S.A., Scholarship & Fellowship (1973-1974).

ACTIVE PARTICIPATION IN INTERNATIONAL CONGRESSES

1. The 54th Annual Meeting of the Transportation Research Board, Washington, D.C., U.S.A., January 1975. Three papers were presented (see publication list).

2. The International Conference on Pedestrian Safety, Haifa, Israel, December 1976. Two papers were presented (see publication list).

3. The 56th Annual Meeting of the Transportation Research Board, Washington, D.C., U.S.A., January 1977. One paper was presented (see publications list).

4. The 7th International Symposium on Transportation & Traffic Theory, Kyoto, Japan, August 1977. One paper was presented (see publication list).

5. The 13th Conference of the Information Processing Association (IPA), together with the 3rd Jerusalem Conference on Information Technology, August 1978. One paper was presented (see publications list).

6. The Joint International Meeting of the Institute of Traffic Engineering (ITE) on: The Integration of Traffic & Transportation Engineering in Urban Planning, Tel Aviv, Israel, December 1978. One paper was presented (see publications list).

7. Automatic Vehicle Monitoring (AVM) Conference, Dublin, May 9-10, 1979.

8. An International Workshop on Urban Passenger Vehicle & Crew Scheduling, the University of Leeds, England, July 15-18, 1980. One paper was presented (see publication list).

9. The 60th Annual Meeting of the Transportation Research Board, Washington, D.C., U.S.A., January 1981. One paper was presented (see publication list).

10. The Joint International CORS/TIMS/ORSA Meeting, May 3-6, 1981, Toronto, Canada. One paper was presented (see publication list).

11. The 8th International Symposium on Transportation & Traffic Theory, June 24-26, 1981, Toronto, Canada. One paper was presented (see publication list).

12. Frontiers in Transportation Equilibrium and Supply Models. An international Symposium, November 11-13, 1981, Montreal, Quebec. Invited as a discussant.

13. The 61st Annual Meeting of the Transportation Research Board, Washington, D.C., U.S.A., January 1982. One paper was presented (see publications list).

14. First Conference and Workshop on Bus Reliability and Transit Service, UMTA, August 22-25, 1982, Hidden Valley, New York, U.S.A. Invited to participate.

15. The 62nd Annual Meeting of the Transportation Research Board, Washington, D.C., January 1983. One paper was presented (see publication list).

16. The 3rd International Workshop on Transit Vehicle & Crew Scheduling, University of Montreal, June 27-30, 1983. Two papers were presented (see publication list). Invited to serve as chairman of one session.

17. The 63rd Annual Meeting of the Transportation Research Board, Washington, D.C., January 1984. one paper was presented (see publication list).

18. The Annual Meeting of the Operations Research Society of Israel (ORSIS), Beersheva, May 28-29, 1984. One paper was presented (see publication list). Invited to serve as chairman of the Transportation Session.

19. The 3rd International Symposium on Location Decisions (ISOLDE III), Boston, Mass., June 7-12, 1984. One paper was presented (see publication list).

20. The 9th International Symposium on Transportation and Traffic Theory, July 11-13, 1984, Delft, Holland. One paper was presented (see publication list).

21. The 64th Annual Meeting of the Transportation Research Board, Washington, D.C., January 1985. One paper was presented (see publication list).

22. The 65th Annual Meeting of the Transportation Research Board, Washington, D.C., January 1986.

23. Transportation Research Board joint Mid-Year Public Transportation Meeting (section E committees meeting), University of Washington, Seattle, Washington, August 17-20, 1986.

24. Council of Logistics Management 1986 Conference, Anaheim, CA., October 5-8, 1986.

25. The 9th Annual Chaim Weizman Conference on: "Israeli Science, Technolgoy and Medicine", March 1, 1987, Boston, USA. Invited to give presentation.

26. The 10th International Symposium on Transportation and Traffic Theory, July 8-10, 1987, M.I.T. Boston, USA. Invited to serve as a session chairman.

27. The Fourth International workshop on computer-aided scheduling of public transport, Hamburg, Germany, July, 28-31, 1987. Three papers were presented (see publications list).

PROFESSIONAL SOCIETY MEMBERSHIP

1. Israel Association of Engineers & Architects.
2. Operations Research Society of Israel (ORSIS).
3. Transportation Research Board (TRB).
4. Israel Association of Transportation Research (IATR).

AVISHAI CEDER

(publications)

a. THESES

Ceder, A.: "From Car-Following to Speed-Volume Density Relationship." Individual Research for M.Sc. degree. University of California, Berkeley, November 1972. 90 pages.

Ceder, A.: "Investigations of Two-Regime Traffic Flow Models at the Micro- and Macroscopic Levels." Ph.D. Dissertation, University of California, Berkeley, November 1975. 392 pages. (The Abstract of this thesis in in the Bibliography section, Transportation Research Journal, Vol. 10, Page 218, 1976).

b. PAPERS IN PROFESSIONAL JOURNALS

1. Ceder, A. & May, A.D.: "Further Evaluation of Single-and-Two Regime Traffic Flow Models." Transportation Research Record 567, pp. 1-15, 1976.

2. Ceder, A.: "A Deterministic Traffic Flow Model for the Two-Regime Approach." Transportation Research Record 567, pp. 16-30, 1976.

3. Ceder, A.: "Drivers' Eye Movements as Related to Attention in Simulated Traffic Flow Conditions." Human Factors Journal, Vol. 19, pp. 571-581, 1977.

4. Ceder, A. & May, A.D.: "Consistency of Maximum Flow Characteristics and Congestion Patterns under Morning Peak Period Conditions on an Urban Freeway." Transportation Research Record 644, pp. 8-14, 1977.

5. Ceder, A.: "A Time-Sequence Analysis for a Two-Regime Traffic Flow Model." The Institute of Systems Science Research, 7th International Symposium on Transportation and Traffic Theory. Kyoto, Japan, pp. 141-174, August 1977.

6. Ceder, A. & Livneh, M.: "Further Evaluation of the Relationship Between Road Accidents and Average Daily Traffic." Accident Analysis and Prevention Journal, Vol. 10, pp. 95-109, 1978.

7. Ceder, A.: "Drivers' Behavior, Traffic Flow and Road Safety Studies," Hazard Prevention Journal, Vol. 15(1), pp. 24-26, September/October 1978.

8. Ceder, A.: "A Two-Regime Traffic Flow Model and the Consistency of Its Parameters," Applied Mathematical Modelling Journal, Vol. 2, pp. 261-270, December 1978.

b. PAPERS IN PROFESSIONAL JOURNALS (continued)

9. Ceder, A.: "The Accuracy of Traffic Flow Models--A Review and Preliminary Investigation." Traffic Engineering and Control Journal, Vol. 19, pp. 541-544, December 1978.

10. Ceder, A. & Livneh, M.: "A Safety Evaluation Approach for Road Improvement Projects." Traffic Engineering Journal, pp. 26-30, December 1978.

11. Ceder, A.: "A Stable Phase Plane and Car-Following Behavior as Applied to a Macroscopic Phenomenon." Transportation Science Journal, Vol. 13(1), pp. 64-79, 1979.

12. Ceder, A.: "An Algorithm to Assign Pedestrian Groups Dispersing at Public Gatherings Based on Pedestrian/Traffic Modelling." Applied Mathematical Modelling Journal, Vol. 3, pp. 116-124, April 1979. (An invited extended abstract appears in Zentralblatt fur Mathematics, Fol. 403, 90031).

13. Ceder, A. & Dressler, O.: "A Note on the X^2 Test with Application and Results of Road Accidents in Construction Zones." Accident Analysis and Prevention Journal, Vol. 12, pp. 7-10, 1980.

14. Ceder, A.: "A Note on a Graphical Interpretation of Wave and Shockwave Velocities of a Traffic Stream." Transportation Research Journal, Vol. 14B, pp. 257-259, 1980.

15. Ceder, A. & Gonen, D.: "The Operational Planning Process of a Bus Company." UITP Review Journal, Vol. 29(3), pp. 199-218, 1980.

16. Ceder, A.: "Practical Methodology for Determining Dynamic Changes in Bus Travel Time." Transportation Research Board 798, (Bus Planning and Operation), pp. 18-22, 1981.

17. Stern, H.I. & Ceder, A.: "A Deficit Function Approach for Bus Scheduling: in Computer Scheduling of Public Transport: Urban Passenger Vehicle and Crew Scheduling, A. Wren (Ed.), North-Holland Publishing Company, pp. 85-96, 1981.

18. Ceder, A. & Stern, H.I.: "Deficit Function Bus Scheduling with Deadheading Trip Insertions for Fleet Size Reduction." In Transportation Science Journal, Vol. 15, No. 4, pp. 338-363, 1981.

19. Ceder, A. & Livneh, M.: "Relationships between Road Accidents and Hourly Traffic Flow: I. Analysis and Interpretation." Accident Analysis and Prevention Journal, Vol. 14, No. 1, pp. 19-34, 1982.

b. PAPERS IN PROFESSIONAL JOURNALS (continued)

20. Ceder, A.: "Relationships between Road Accidents and Hourly Traffic Flow: II. Probabilstic Approach." Accident Analysis and Prevention Journal, Vol. 14, No. 1, pp. 35-44, 1982.

21. Ceder, A. & Stern, H.I.: "Graphical Interactive Approach for Bus Scheduling." Transportation Research Record 857, pp. 69-74, 1982.

22. Stern, H.I. & Ceder, A.: "The Garage Constrained-Balance Vehicle Schedule Minimum Fleet Size Problem." University of Tronto Press, 8th International Symposium on Transportation & Traffic Theory, V.F. Hurdle, E. Hauer & G.N. Stewart (Eds.), Ontario, Canada, pp. 527-556, 1983.

23. Ceder, A., Prashker, J. & Stern, H.I.: "An Algorithm to Evaluate Public Transportation Stops for Minimizing Passenger Walking Distance." Applied Mathematical Modelling, Vol. 7, pp. 19-24, 1983.

24. Stern, H.I. & Ceder, A.: "An Improved Lower Bound to the Minimum Fleet Size Problem." Transportation Science Journal, Vol. 17, No. 4, pp. 471-477, 1983.

25. Ceder, A.: "Bus Frequency Determination Using Passenger Count Data," Transportation Research Journal (part A), Vol. 18A, No. 5/6, pp. 439-453, 1984.

26. Marguier, P.H.J. & Ceder, A.: "Passenger Waiting Strategies for Overlapping Bus Routes." Transportation Science Journal, Vol. 18, No. 3, pp. 207-230, 1984.

27. Ceder, A. & Stern, H.I.: "Optimal Transit Timetables for a Fixed Vehicle Fleet." VNU Science Press, the 9th International Symposium on Transportation & Traffic Theory, pp. 331-355, 1984.

28. Ceder, A. & Stern, H.I.: "The Variable Trip Procedure Used in the AUTOBUS Vehicle Scheduler." Computer Scheduling of Public Transport 2, J.M. Rousseau (Ed.), North Holland Publishing Company, pp. 371-390, 1985.

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ATTACHMENT 2

TOH Revised Contention III to Revision 2:

The Evacuation Time Estimate Study (ETE) prepared by KLD Associates, Inc., Revision 2, Volume 6, is based upon inaccurate and biased factual data and unreasonable or misleading assumptions, fails to comply with NRC regulations, and fails to provide reasonable assurance that adequate protective measures can and will be taken, or that adequate facilities, equipment, or personnel will be provided to the Town of Hampton, in the event of radiological emergency. 10 CFR § 50.47(a)(1), (b)(1)(10) NUREG-0654, App. 4.

Appendix, Board's Order & Memorandum, May 18, 1987

Admitted Bases:

The KLD ETE is based upon the following inaccurate, unreasonable, or misleading facts or assumptions:

1. The KLD ETE unreasonably estimates vehicle counts within the EPZ, including beach areas, utilizing data obtained on only two weekends, and the intervening work week, in August, 1985. KLD Progress Report #1 (hereinafter KLD #1) Appendix E-13. KLD relies upon these limited vehicle counts as part of "the basis for computer analysis of an Evacuation Plan and computation of ETE." KLD #1, pp. 5,6. KLD concedes, however, that this traffic data was gathered during a period of "occasional rain," KLD #1, p. 7, "this period of time was not particularly appealing to beachgoers," KLD #1, Appendix E-13, "The data will not reflect peak conditions" . . . and there is "some uncertainty" on the accuracy of the data. On its face, therefore, the KLD ETE admits to an inadequate factual base to provide reasonable projections for traffic counts and movements during an evacuation within the EPZ, and particularly the beach areas. Additionally, since even this limited data was obtained by KLD during poor beach weather, it must be assumed that KLD's vehicle counts, and therefore ETE projections, are unreasonably low.

2. The KLD ETE unreasonably relies upon a telephone survey to estimate the time

required for notification of an emergency, elapsed times to commence evacuation trips, and the total population to be evacuated from the EPZ. KLD #1, p. 7, KLD #2, p. 9. Those persons surveyed constitute less than one percent of the individuals residing within the EPZ, KLD #1, Appendix F-6, there is absolutely no showing by KLD that this minimal percentage of residents is in any way representative of the EPZ population as a whole, and therefore the telephone survey represents an inadequate factual base from which to make these ETE projections. For example, while KLD concedes that "we know of no survey which has accumulated empirical information describing the rate at which notification information is received," KLD #2, p. 7, it nevertheless baldly claims that the telephone survey can provide "a reasonable estimate of a notification time frame." KLD #2, p. 7. The Town suggests, however, that limited information obtained by telephone from an apparently nonrepresentative segment of the EPZ population is wholly inadequate to make these significant ETE projections. Based upon the admitted deficiencies in its data base, therefore, the KLD ETE necessarily fails to provide reasonable assurance on the accuracy of these ETE estimates.

3. The KLD ETE computes the number of vehicles to be evacuated from the beach areas merely by counting parking spaces and parking capacity. KLD #1, p. 15, 20. The KLD ETE therefore fails to account for the virtual bumper to bumper traffic that routinely, and continually, travels through the beach areas during the summer. These vehicles in transit represent not only a significant additional number of vehicles to be evacuated, but also present a substantial impediment to all parked vehicles attempting to leave the EPZ. See also KLD #1, Appendix E-4, 5; KLD #2, p. 9.

4. The KLD ETE erroneously assumes that local officials, including police and fire department personnel, will be available to implement the State evacuation plan. KLD #2,

p. 40. Since the Town of Hampton has stated it does not intend to provide this assistance or implement the State RERP, the KLD ETE fails to provide reasonable assurance that adequate personnel are available to implement the evacuation plan. Additionally, even assuming that the State could timely provide an equivalent number of State personnel to fulfill these local functions, the KLD ETE recognizes the local personnel are uniquely qualified to determine potential traffic problems and bottlenecks, which may not be readily apparent to State personnel unfamiliar with the local area. KLD #2, p. 40.

5. The KLD ETE unreasonably assumes that 151 "traffic guides" will be available to implement traffic control procedures during an evacuation, including 25 for the Town of Hampton. KLD #4, p. 11. The KLD ETE wholly fails, however, to demonstrate the availability of these substantial numbers of trained traffic personnel. Additionally, since State Police Troop A has only 31 troopers available for evacuation traffic control throughout the entire EPZ, it is unreasonable to expect that the State can adequately and promptly supplement these personnel deficiencies, particularly in view of the substantial additional duties imposed on Troop A for overall traffic surveillance, KLD #7, p. 28, and as specified in the State Compensatory Plan. See Compensatory Plan, Troop A New Hampshire State Police, Emergency Response Procedures, p. 2. The KLD ETE further unreasonably assumes the availabililty of an additional 27 New Hampshire "traffic guides" to regulate access control posts on the perimeter of the EPZ to restrict traffic entrance into the EPZ during an evacuation;n. KLD #6, p. 13. As set forth above, there is no showing that in fact these trained personnel will be available to perform these specified duties.

6. The KLD ETE unreasonaably assumes that adequate equipment and personnel will be available to plow roads and driveways, and to assure that evacuation routes remain

passable, if evacuation is required during a snowstorm. KLD #2, p. 19, 24. For example, KLD incorrectly assumes that the time to plow the driveways during an evacuation is identical to the time required for snow clearance under non-emergency conditions. The ETE therefore unreasonably fails to account for evacuation traffic congestion which must impede or prohibit a plow truck from reaching certain homes on roads, and unreasonably fails to consider that a substantial number of those private individuals performing snowplow services may elect to promptly evacuate the EPZ rather than complete their routes.

7. The KLD ETE unreasonably assumes that buses will encounter "little impedance" when entering the EPZ to evacuate schools and those without private vehicles. KLD #7, p. 17. This assumption is unsupportable. For example, the State RERP provides that the Timberlane Bus Company of Salem, New Hampshire shall provide 35 buses to evacuate the Town of Hampton during a radiological emergency. These Timberlane buses, however, would be required to maneuver through thousands of evacuating vehicles headed for the "host" communities of Manchester and Salem. KLD #4, Appendix J. It can only be reasonably anticipated that a substantial number of these buses would be greatly delayed, if not prohibited, from reaching the EPZ against the evacuation traffic flow. The KLD ETE further unreasonably assumes that evacuation buses traveling to the EPZ could travel 40 miles per hour on "at-grade primary highways," such as Route 1, and 50 miles per hour on access controlled roads. KLD #7, p. 17. Anyone familiar with the routine bumper to bumper traffic on Route 1 during the year, and particularly the summer months, however, would recognize these estimates as wholly unrealistic. While recognizing that buses and vans evacuating special facilities "will be embedded within the overall traffic streams evacuating the EPZ," KLD #7, p. 19, the ETE further unreasonably fails to account for the additional and substantial impact of these emergency vehicles, often traveling

against the flow of traffic, in delaying the overall evacuation of vehicles from the EPZ. KLD #2, p. 9. Further the KLD ETE unreasonably calculates the time within which buses may travel evacuation routes to pick up passengers by assuming that all buses will travel <u>with</u> the flow of evacuating traffic. KLD #7, p. 18. It must be assumed, however, that many of these buses will be required, albeit unsuccessfully, to travel <u>against</u> the flow of traffic to reach designated pickup locations. The ETE's calculations that buses may therefor be expected to travel through evacuation traffic and to reach and load passengers at special facilities within 40 minutes is plainly unrealistic. KLD #7, p. 18.

8. The KLD ETE unreasonably relies upon inadequate date to compute the number of persons to be evacuated from the EPZ in the event of radiological emergency. First, KLD computes overall population figures based upon a "compromise estimate" of 2.8 persons per vehicle, although KLD concedes that it lacks "definitive data" on this issue. KLD #2, p. 9. Second, as previously discussed, KLD relies upon a telephone survey of less than one percent of EPZ residents, without any determination that this sample is representative, to compute the number of residents and transients without private transportation. Third, KLD concedes that it has made no computations with respect to populations of special facilities or private citizens with medical needs located within the EPZ. KLD #7, p. 1. Fourth, KLD fails to include within its population estimates the substantial number of individuals traveling through the EPZ, including the beach areas, at the time notification of an emergency may be given. KLD #2, p. 9. Accordingly, on its face, the KLD ETE lacks adequate data to compute the number of individuals or vehicles to be evacuated from the EPZ during an emergency. Without such reasonably adequate data, therefore, KLD's computations regarding time estimates to complete evacuation must seriously be called into questiion.

For reasons set forth above, the KLD ETE fails to provide reasonable assurance that adequate protective measures can or will be implemented in the event of radiological emergency.

Revised Contention III of the Town of Hampton to Evacuation Time Estimate Report by KLD Associates, Inc., May 23, 1986, at pp. 4-10, admitted per Board Memorandum and Order of July 16, 1987 at 7.

(A) Population Estimates.

KLD lacks adequate data to compute the permanent and transient population for the Town of Hampton since KLD computes beach population capacities by examining only the beach above the high tide line, Vol. 6, p. 2-12; counts parking spaces rather than motor vehicles, including vehicles in transit, Vol. 6, p. 2-1; counts beach blankets rather than people, Vol. 6, p. 2-12; utilizes a vehicle occupancy rate of 2.4 based upon two "field surveys" performed on weekends of frequent rain and poor beach weather, Vol. 6, p. 1-10; and counts beach populations using a limited number of photographs, of unspecified date or time, although KLD concedes the beach populations vary widely depending on weather, time of day, and day to day. Vol. 6, p. 2-10. KLD thereby unreasonably reduces the actual population for the Town of Hampton and distorts this "critical" factor in computing ETE. Vol. 6, p. 2-1.

(B) Weather Conditions.

While recognizing that weather represents a "major factor" affecting ETE, Volume 6, p. 3-1 and 2, KLD concedes that it has "limited empirical data on the effect of adverse weather conditions to reduce ETE." Vol. 6, p. 3-1. KLD proceeds to arbitrarily reduce the ETE for rain and snow conditions for the Seabrook EPZ by 20 and 25 percent respectively, Vol. 6, p. 3-11, although KLD lacks any site specific data on the extent of delay caused by these road hazards. KLD acknowledges the "issue of ocean fog," yet fails to provide any data on the impact of fog on ETE, Vol. 6, p. 3-11, and fails to respond to RAC concerns regarding wind changes, which may require contingencies for the redirection of evacuation vehicles, New Hampshire Response Actions to RAC Review, August, 1986, Section VI, pp. 7, 12, (hereinafter RAC Review, August, 1986) with additional delay to traffic and an increase in ETE. KLD does not even estimate the effect of ice storms on ETE.

(C) Road Capacities.

When computing the "major factor" of road network capacity, and its impact on the time required to effectuate an evacuation, Vol. 6, p. 3-1, KLD makes numerous and unsupported assumptions including:

1. All roads will remain passable during evacuation. Vol. 6, p. 10-70. This assumption ignores the obvious and anticipated vehicle breakdowns, gas shortages, overheating of vehicles, roadways becoming impassable from snow or ice storms, gridlock between evacuating private vehicles, commuters, and emergency vehicles attempting to enter the EPZ, and snowplow operators who either refuse to plow during radiological emergency or are unable to reach their designated routes due to evacuation traffic congestion.

2. KLD assumes that the "recommended traffic control tactics are in effect." Vol. 6, p. 10-70. This assumption is unsupportable in view of the avowed position of the Town of Hampton, and other towns within the EPZ, not to implement the NHRERP if called upon to do so. The assumption is further unsupportable following RAC Exercise Assessment and Review of the NHRERP which "cast(s) doubt" on the State's ability to provide adequate evacuation transportation. RAC Review, August, 1986, Section VI, p. 9. Finally, the State has failed to demonstrate an ability to provide sufficient law enforcement and traffic control personnel, FEMA, Final Exercise Assessment, 6/2/86 at

p. 46, to compensate for non-participating towns. Accordingly, KLD's reliance upon the State to supply adequate equipment and personnel for traffic control management is without reasonable foundation.

3. KLD assumes that 3,000 "through" vehicles will be traveling through the EPZ at the time of notification of an emergency. Vol. 6, p. 10-3. No support is provided for this assumption, which is rendered absurd by KLD's own calculation of "peak hourly flow" on I-95 of 6,912 vehicles. Vol. 6, p. 3-11. Since I-95 represents only one road within the 200 square mile EPZ, the 3,000 "through" vehicle estimate represents a gross distortion of roadway demand.

4. KLD concedes that its "estimates of available capacity may overstate the actual accessible capacity." Vol. 6, p. 10-70. KLD thereby admits that its highway capacities relied upon to compute ETE, and which represent a "major factor" to calculate the time required for evacuation, Vol. 6, p. 3-1, would generate an unreasonably low ETE, and would not reflect actual conditions.

5. KLD unreasonably assumes that 25 percent of the EPZ population will spontaneously evacuate, Vol. 6, p. 10-3, and estimates Hampton employees who work at the beach, both during the week and on weekends, Vol. 6, p. 5-6, apparently by simple guess work. KLD thereby lacks adequate data to compute road demand for Hampton employees during evacuation or to compute ETE when partial evacuation of the EPZ is ordered.

6. KLD fails to adequately account for the impact of disabled vehicles on reducing ETE. Given the thousands of vehicles to be evacuated, numerous disabled vehicles must be anticipated. KLD's claim that such vehicles will simply be pushed aside by evacuees, without impacting on ETE, is unsupportable. Vol. 6, p. 12-4.

(D) ETE Preparation Time.

Without statistical support, KLD assumes that 90 percent of the EPZ population will be notified of an emergency within 15 minutes, Vol. 6, p. 4-8, assumes that beachgoers will be able to leave the beach and access their cars within 30 minutes, Vol. 6, p. 4-12, although KLD concedes it has "no empirical data to support this distribution," Vol. 6, p. 4-11, fails to allow for "staging area preparation time" as recommended by the RAC in computing ETE, RAC Review, August, 1986, Section VI, p. 10, and grossly underestimates the adverse impact on ETE of 95 percent of workers returning home, within 30 minutes, to prepare for evacuation following notice of radiological emergency. Vol. 6, p. 4-9.

(E) Growth.

KLD recognizes the "significant growth" in employment within the Town of Hampton between 1980 and 1984. Vol. 6, p. 5-1. It is also common knowledge that the southern New Hampshire population, including the population of the EPZ, is one of the fastest growing in the country. In computing ETE, however, KLD has wholly failed to account for this reasonably anticipated and substantial growth in population and motor vehicles within the EPZ, has failed to obtain any data on projected changes in population distribution within the EPZ, and has otherwise presented a plan which, even assuming its accuracy at the present time, will soon be outdated and will not serve as a reasonable basis for emergency planning.

(F) Choice of Host Locations.

KLD unreasonably assumes that evacuees will choose to evacuate to their assigned host communities. The assumption is unsupportable, particularly in view of the large number of beachgoers and transients within the EPZ during the summer who may be wholly unfamiliar with such host communities as Dover or Manchester. But see, Vol. 6, p. 10 ("virtually all drivers" familiar with EPZ roads). Indeed, during the evacuation exercise, even bus drivers under letter agreement "consistently experienced problems in getting to where they should be needed," FEMA, Final Exercise Assessment, 6/2/86 at p. 43, and the RAC has recommended that KLD increase ETE to allow for "drivers getting lost or misdirected." RAC Review, August, 1986, Section VI, p. 12. Accordingly, if Hampton Beach transients chose to evacuate to Massachusetts or to Maine (as might be more logical) rather than to Manchester (as assigned), already crowded evacuation routes would be rendered impassable by the additional traffic and ETE thereby would be substantially increased. KLD has thereby selected a theoretically optimal, yet unrealistic, model to minimize ETE.

Contentions of the Town of Hampton to New Hampshire Radiological Emergency Response Plan Revision 2, October 31, 1986 (Revised Contention III to Revision 2), at pp. 9-16, admitted per Board Memoradum and Order of May 18, 1987 at 15.

Revised SAPL Contention No. 31:

The evacuation time estimate report, as described in Volume 6 of NHRERP Rev. 2 does not meet the requirements of 10 CFR § 50.47(a)(1), § 50.47(b)(10) and NUREG-0654 II.J.2, II.J.10 i, 10 h and 10 l, and Appendix 4 because it fails to account properly for the number of vehicles that would be evacuating the EPZ; relies in part upon unsupported assumptions; relies in part upon potentially biased input data; does not rely upon an extensive enough empirical base; relies upon traffic control personnel not shown to be available; does not appropriately account for travel impediments such as flooding, snow, fog and icing of roadways; does not account for the effect of driver disobedience on evacuation time estimates (ETEs); does not appropriately deal with topographical features; does not deal realistically with the transport of transit dependent persons; in some instances overestimates roadway capacity and, for all of these reasons, underestimates the amount of time it would take to evacuate the EPZ and its subparts ("Regions) under the various scenarios analyzed.

Appendix, Board's Memorandum and Order, May 18, 1987 at p. 4.

Admitted Bases:

1. This latest revision of the KLD Report now notes that 3,000 "through" vehicles will be in the EPZ highway network at the time of the order to evacuate (Vol. 6, pp. 2-27 and 10-3). This estimate of 3,000 through vehicles at any one time is unsupported since in 1985, traffic levels on I-95 alone in New Hampshire exceeded 99,000 vehicles per day, many of which were through vehicles. The size of the Seabrook Station EPZ is roughly 200 square miles (Vol. 6, p. 4-2). It is clear that the number of vehicles chosen by KLD significantly underestimates roadway demand. This error is particularly serious in the beach areas during the summer season. The lack of appropriate consideration of cars in the roadway system contributes to the serious underestimate by KLD of vehicles in the beach area. Though the KLD Report states that a total of 3000 cars were

counted in the roadway from aerial films in Hampton Beach, there is no statement as to when those photographs were taken or by whom they were taken (Vol. 6, p. 10-16). It is not even clear that KLD has factored the 3,000 estimate into its time estimate calculations since the estimate is found in a section captioned "Uncertainties."

2. The KLD Report continues to rely upon NRC estimates compiled in a report by M. Kaltman in February 1981 for estimate of vehicles per dwelling at seasonal housing units (Vol. 6, p. 2-14), the count of overnight accommodation units (Vol. 6, p. 2-17), and numbers of vehicles at campgrounds (Vol. 6, p. 2-17), and numbers of vehicles at campgrounds (Vol. 6, p. 2-20). These numbers are unlikely to have a high reliability given the significant growth that has occurred in the EPZ area over the past 5 years.

3. The KLD Report has failed to make any provision for resident and employee population growth in the area over the plant's projected lifespan. Population redistribution in the area could also markedly affect evacuation time estimates (ETEs) for various regions in the EPZ. At current rates of growth, resident populations will increase over 70% and employment will increase to an even greater degree over this time span. The result will be that the ETEs set out in this report will rapidly be rendered obsolescent, even if one were to assume that they are currently correct.

4. The KLD Study continues unrealistically to assume that traffic management and control measures are in effect at the time the evacuation is ordered (Vol. 6, p. 10-70 and Appendix I). This is a wholly unrealistic assumption even if one were to assume that all local communities were intending to implement the emergency plan. Seven towns did not participate in the graded FEMA exercise on February 26, 1986. Under many plausible scenarios, state resources and manpower, even if adequate, could not be mobilized quickly enough to be in place in the non-participating or even the participating communities before it would be

necessary to order an evacuation. The sensitivity calculation by KLD that an immediate General Emergency would extend ETE by only 20-30 minutes is non-persuasive and the assumptions employed in doing that sensitivity study are not carefully elucidated.

5. The KLD "planning-basis" accident scenario assumes that there are two temporally displaced evacuation stages, i.e., the rest of the EPZ starts to evacuate 25 minutes after those in the beach areas (Vol. 6, p. 4-17). This is not a realistic assumption because many people will choose to leave the areas when they see the beach people going by, particularly given the heightened awareness of radiation health effects resultant upon the extensive news coverage of the Chernobyl accident. There is no empirical basis shown for the KLD Report's 25 percent spontaneous evacuation rate among those within the EPZ but not ordered to evacuate (Vol. 6, p. 10-3). The KLD Report fails to account for those beyond the EPZ who may spontaneously evacuate, taking up roadway capacity beyond the zone and thereby impeding evacuation progress out of the EPZ.

6. The KLD Study relies upon potentially biased input data in that the telephone survey of "heads of households" provides a substantial portion of the data used. This survey involved calls to over 10,000 households, yet resulted in only 1,300 completed responses (Vol. 6, Appendices F and G). Given the low response rate and the fact that no efforts were made to validate the responses, a large non-response bias exists in the completed data sample. There is, therefore, no reasonable basis for assuming that the notification times, estimates of times to commence evacuation trips, estimates of average person occupancy of vehicles evacuating the EPZ or other data derived from the survey are accurate (Vol. 6, p. 2-3, Exhibit 2-1 and Chapter 4).

7. Further, the "Time to Travel Home" data derived from the telephone survey (Vol. 6, p. 4-10) is of limited, if any, utility. Question #9 of the telephone survey asked: Approximately how long does it take Commuter #( ) to travel home from work or college?" This question as

framed elicits a response about how long it takes the commuter to return home under normal circumstances. Under the circumstances of an evacuation, however, commuters will be returning home partly against the direction of evacuating traffic, through intersections with cones blocking desired turning movements, and partly with the flow of evacuating traffic in massive queues. The effect of almost 95 percent of the commuting population attempting to return home within 30 minutes of each other (Vol. 6, p. 4-9) would be a massive rush hour even without an evacuation in progress. The assumption that commuting workers can return home in their normal time frames defies common sense and is insupportable from an analytic standpoint.

8. The KLD Report still relies upon Traffic Guides for Traffic Control Posts (TCP) and Access Control Posts (ACP). 181 local and 10 interstate traffic guides are needed for the TCP, 118 of whom are needed in New Hampshire (Vol. 6, Table 8-6). An additional 130 personnel are needed at the ACP, 28 of whom are needed in New Hampshire (Vol. 6, Table 9-4), bringing the total New Hampshire traffic personnel requirement to 146. The NHRERP still does not support a finding that these personnel will be available in adequate numbers.

9. The KLD Report still continues to assume that all roads will remain passable during evacuation (Vol. 6, p. 10-70). This assumption is insupportable as it denies the realistic potential for vehicle problems either due to mechanical malfunctions or extremes of temperature. The KLD Study acknowledges that temperatures in the EPZ range "from well below zero (F) in the winter to as high as 100 degrees (F) in the summer" (Vol. 6, p. 1-8) and then ignores the implications of the statement for vehicle reliability. The KLD Study assumes that all vehicles with problems can be pushed to the side of the roadway. This ignores the bridges and other choke points within the EPZ, such as the entry onto Route 51 (a major evacuation route from the beach) which could be totally obstructed by one failed vehicle. In those situtations no easy solution could be effected since there is no place to push the vehicle. Even if a vehicle is pushed onto the shoulder,

the Highway Capacity Manual estimates that capacity is reduced by one-third because the roadway's perceived width is reduced. The KLD plan unrealistically assumes that no reductions in capacity or increases in travel times will result from these incidences of vehicle failure. The KLD plan recommends stationery placement of tow trucks at locations specified in Table 12-1. However, the NHRERP does not reflect this specific assignment of tow trucks to specific locations. Further, the KLD Report gives no estimate of how long it would take a tow vehicle to respond to an incident and then return to its assigned location. Only 2 of the recommended tow truck locations are within the EPZ in New Hampshire (Vol. 6, Table 12-1).

Vehicles could also be disabled by exhaustion of fuel supply or accident. The KLD Report assumes that most accidents will involve vehicles traveling at low speeds and that therefore they will not result in vehicle disablement (Vol. 6, p. 12-3). However, the KLD Report does not assume that all traffic flow is low speed in that buses are assumed to travel from 40 to 50 MPH (Vol. 6, p. 11-20). The KLD Report still does not appropriately account for flooding, excessive snow, fog and icing of roadways. It now makes only passing mention of fog (Vol. 6, p. 3-11) and indicates that the capacity reductions for snow and rain are responsive to the problem. The KLD estimates of capacity reduction for rain are, as SAPL stated before, too optimistic. This new version has changed the capacity reduction for snow to 25% from the 30% stated earlier, a move in the wrong direction. The 1985 Highway Capacity Manual cites detailed studies which show capacity reductions of 8% for a trace snowfall plus 2.8% for each 0.01 in./hr. water-equivalent snowfall. For a snowstorm accumulating 6" of snow over 8 hours, the corresponding capacity reduction would be over 40%; substantially more than assumed in KLD's analysis. Flooding could render a section of roadway wholly impassible.

10. [Basis denied by Board Order of May 18, 1987]

11. The KLD Report now does contain maps including topographical features, but the time estimate study does not account for these features other than to make brief mention of them (Vol. 6, p. 1-5). The effect on time estimates of the more hilly topography west of I-95 and the effect of the choke points at bridges over rivers and streams have been ignored.

12. The mobilization time for buses has been modified in this Revision 2 version of the KLD Report. It is now claimed on the basis of a telephone survey of the organizations which own and operate the buses that 50% of available buses (as opposed to the earlier 62%) can be mobilized within one hour of notification, and another 30% within the second hour, with the remainder following in the third hour (Vol. 6, p. 11-19). The survey instrument and the data on the replies are not included in the appendices of the report.

During off business hours, in particular, the response rate could not reasonably be expected to be anywhere near this favorable.

13. The revised KLD Report now computes the number of persons within the EPZ having no vehicles available and requiring transit services at 2,249, or 2.5% of the 91,601 population in the 17 towns in New Hampshire. Again, KLD has moved in the wrong direction in reducing the prior estimate of 3%. The basis of KLD's calculation was the telephone survey, the problems with which were discussed at 6. above. This estimate is now less credible than it was heretofore. In Section VI of the "New Hampshire Response Actions to RAC Review of State and Local Radiological Emergency Response Plans - August 1986," (hereinafter "Reply to RAC"), the RAC commented that the vehicle ownership data should be compared to census data. KLD responded that though the 1980 census data showed that 5.5% of all households have no car available, a 2.65% estimate is reasonable "in light of the expansion of car ownership during the intervening years." (Reply to RAC., p. 3). The RAC rebutted this position with national car ownership statistics and KLD came back with the reply that only site-specific data are relevant

for planning purposes (Reply to RAC, pp. 4-5). KLD's reply is unpersuasive because of the problems noted with regard to the telephone survey at 6. above. Unreliable site specific data are not better than the national data. KLD attempts to shore up its argument by referring to the NHCDA survey, which arrived at a similar number. The allegedly corroborative data has its own reliability problems. SAPL holds that the number of those requiring transport assistance has been seriously underestimated.

14. The revised KLD report now estimates the time for loading passengers at special facilities at 45 minutes (Vol. 6, p. 11-21). They assume that the average elderly or disabled person can board a bus in a 15 second mean headway. SAPL still finds this an unrealistically short period of time for loading special facility populations along with their necessary personal effects and medications. The estimate of time for loading non-ambulatory persons, previously 0.67 hours, appears to have been omitted from this revised KLD Report. There is still no estimate of the number of non-ambulatory persons outside of special facilities.

15. Though the revised KLD Report states that substantial detail on roadway geometrics was collected (Vol. 6, p. 1-10), the rural roads were classified into only 4 crude groups (Vol. 6, p. 3-7 and 3-8). The detailed data collected should confirm that all sections of each roadway included in a given class have minimum widths greater than or equal to those assumed. This has not been demonstrated.

16. [Basis denied by Board Order of May 18, 1987]

17. The calculation increasing the number of people by 6% because the average vehicle is out of service 6% of the time is not correct. A proper calculation would increase the number of permanent residents needing transit by more than 6% (Vol. 6, pp. 11-8 and 11-9) based on data in Figures 2-2 and 2-3.

18. The simulation model employed by KLD appears to have some serious defects:

(a) It is unclear how traffic control information is handled in the actual simulation and produced the results in Appendices I and N. As an example, Appendix N seems to imply that 1,500 cars can enter node #1 (Vol. 6, p. I-49) from each of three directions.

To resolve questions, a sample derivation of link capacities should be included for one simple and one more complex link. A sample of actual flow at a crowded intersection, showing all inputs, outputs and queues should also be included.

(b) Loading procedures are not described in much detail. The full loading results at one major loading point should be included.

(c) It appears that a substantial amount of passing has been assumed since a factor of fd = 0.75 x (0.90) = 0.675 is used to get one way from two way capacity.

(d) Appendix I shows light traffic on many roads. It is not clear how, if at all, these light traffic patterns have been treated in the simulation model.

19. The estimate of 2.6 people per vehicle for permanent residents is unrealistic, particularly for the first hour when people will be returning home or picking up family members (Vol. 6, p. 2-5). The data from the actual counts of vehicle occupancy collected in August 1985 and July 4 weekend in 1986 do not support this estimate (Vol. 6, pp. 4-6 and 4-8).

20. The KLD Report lacks a sufficient empirical base for computing the transient population in the EPZ. KLD should have taken extensive aerial photographs of the area during the height of the beach season. The reliance upon indirect inferences from beach blanket space and parking spaces in indefensible when the real picture could have been taken in a systematic and thorough fashion.

For all of the above-stated reasons, the KLD Report in Volume 6 of NHRERP Rev. 2 fails to provide a sufficient basis for a finding of reasonable assurance that the public can and will be protected in the event of a radiological emergency.

Seacoast Anti-Pollution League's Contentions on Revision 2 of the New Hampshire Radiological Response Plan, Nov. 26, 1986, at pp. 7-17 (Revised Contention 31), as admitted per Board Memorandum and Order of May 18, 1987, at 44.

The KLD study has overestimated the capacity of certain roads and intersections. For example, Route 1A N/S is classified as a "Medium" design road (See KLD Progress Report No. 1, ESTIMATION OF HIGHWAY CAPACITY, P. 46). Route 1A N/S is in some places very narrow, has a steep grade along at lease one section and winds along certain sections. It has at at least two points almost right angle turns. It should be treated as a low design road. The traffic from the beach area of Hampton is to get off the beach by turning left on either Highland Ave. or Church St. and then traveling west bound on Rt 51. Alternate routes for each beach population all involve travel north on Route 1A with left turns at either 101C, 101D, South Road or Washington Road. The capacities of Highland Ave. and Church St. will quickly be overwhelmed so that people will need to go north on 1A in large numbers. The overestimate of the capacity of Route 1A therefore can have very serious implications for accuracy of the ETE.

Seacoast Anti-Pollution League's Fourth Supplemental Petition For Leave To Intervene, dated May 5, 1986 (contention 31), at p. 11, as admitted per Board Memorandum and Order of July 16, 1987 at 12.

ATTACHMENT 3

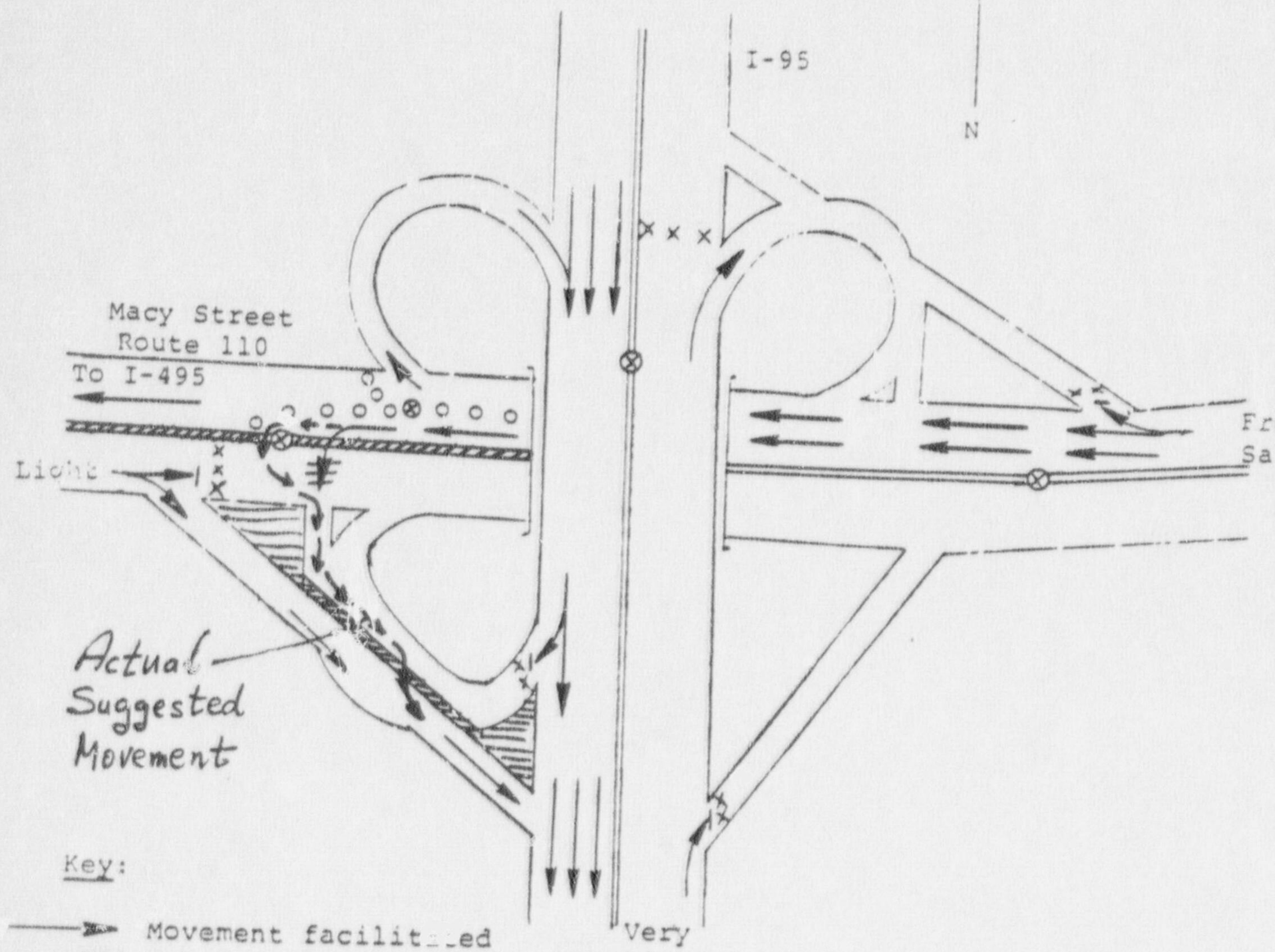
Figure 1. Traffic Control Post No. B-AM-06

ERPA: B

TOWN: Amesbury

LOCATION: I-95 & Route 110

NODE: 253, 255



Key:

Movement facilitated
Movement discouraged
⊗ Traffic guide
○ Traffic cone
× Traffic barricade

DESCRIPTION:

1. Discourage eastbound movement along Route 110 and northbound movement along I-95.
2. Facilitate movement of traffic from Route 110 onto southbound I-95.
3. Permit ~~east~~ west bound movement along Route 110 if Macy Street approach to I-495 is not congested.

MANPOWER/EQUIPMENT

4 traffic guides
10 traffic cones
12 traffic barricades

ATTACHMENT 4

Ceder, A., and May, A.D.: "Further Evaluation of Single- and Two-Regime Traffic Flow Models," Transportation Research Record 567, pp. 1-15, 1976.

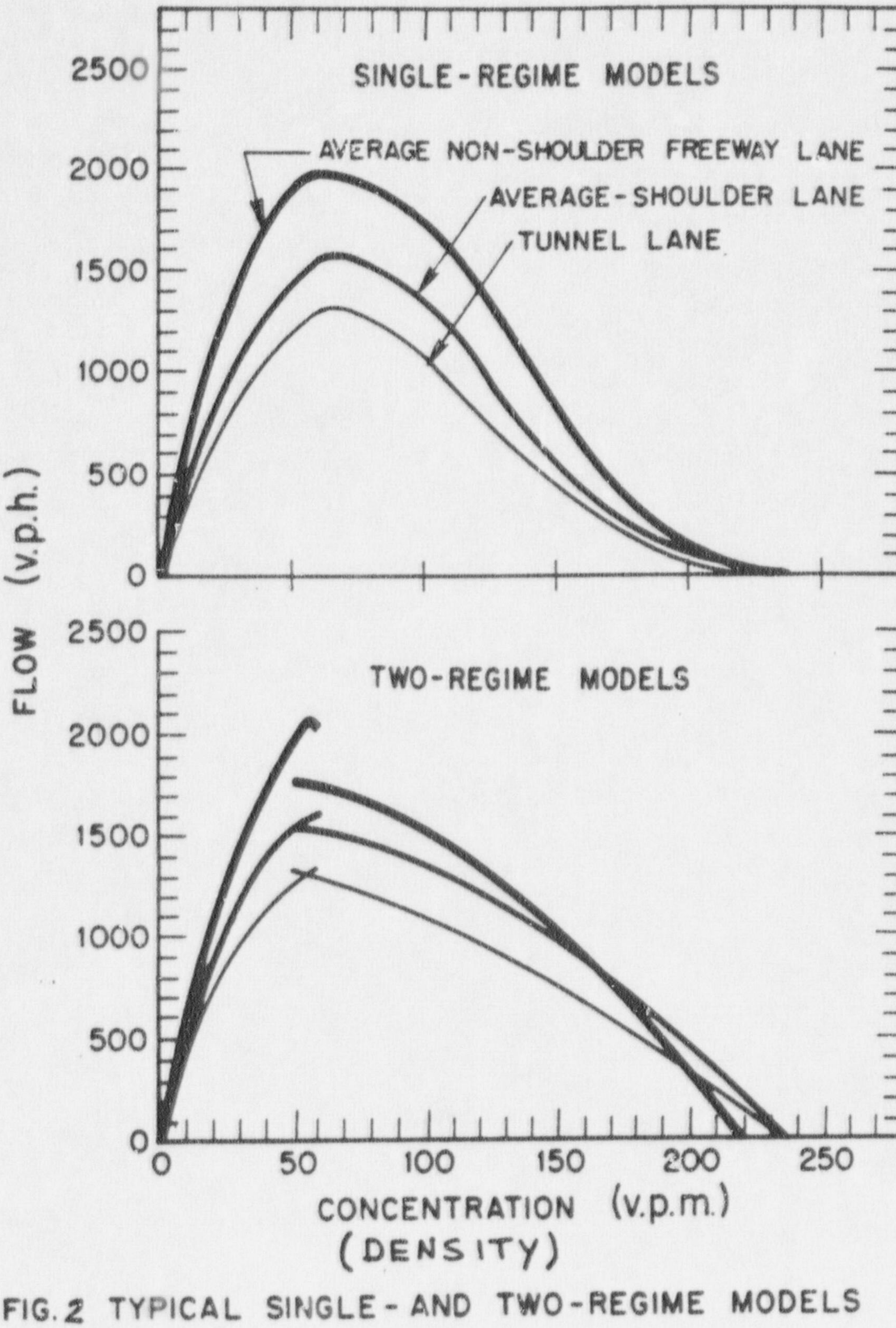


FIG. 2 TYPICAL SINGLE- AND TWO-REGIME MODELS

ATTACHMENT 5

Ceder, A. and Schwartz, A.: "Dynamic Changes of Traffic Flow Characteristics During Morning Peak Period Conditions on an Urban Freeway," Transportation Research Institute, Pub. No. 78-5, p. 137, May 1978.

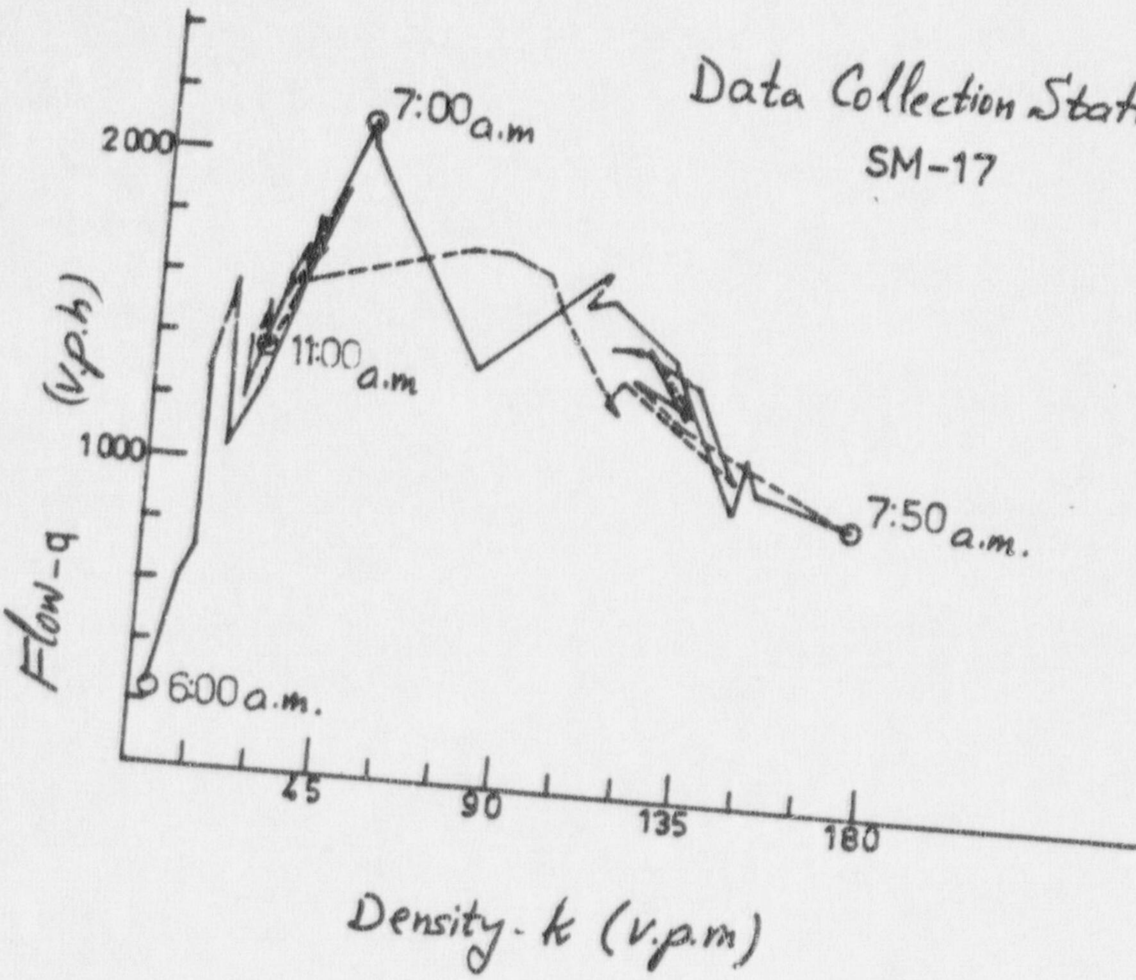


Fig. 3. Flow-Density Data plot.

ATTACHMENT 6

"Planning and Scheduling Work Zone Traffic Control," FHWA-IP-81-6, User Guide, prepared by Abrams, C.M., Wang, J.J., JHK Associates, San Francisco, U.S. Department of Transportation, October 1981.

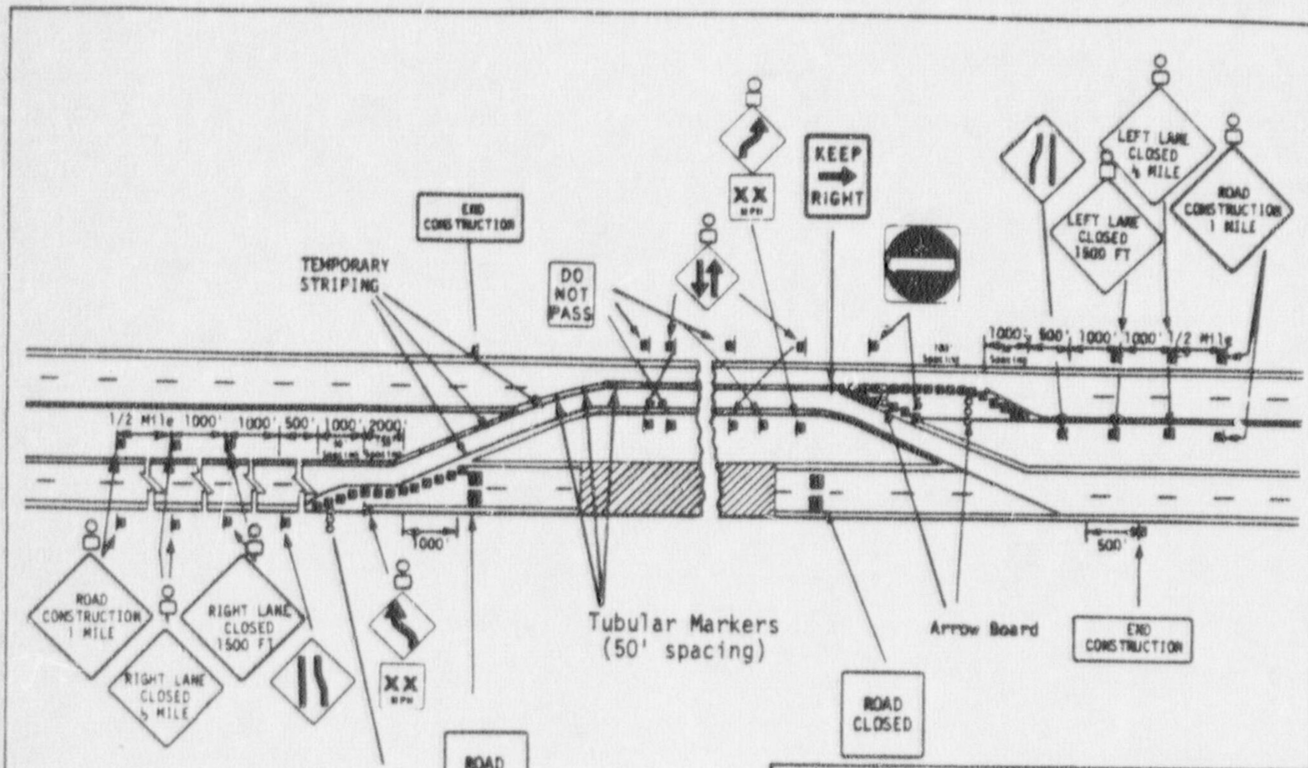
Table 1 . Typical Speeds in Congested Freeway Work Zones

Number of Lanes in Queue Section (Upstream of Bottleneck)	Number of Lanes Closed (at bottleneck)	Average Travel Speed (in mph)	Space Headway (feet/vehicle)
4	0	21	76
	1	9	47
	2	4	38
	3	3	35
3	0	25	85
	1	8	46
	2	3	35
2	0	30	98
	1	6	40

Source: Developed from California Speed-Density Relationship and Work Zone Capacities.

ATTACHMENT 7

"Planning and Scheduling Work Zone Traffic Control," FHWA-IP-81-6, User Guide, prepared by Abrams, C.M., Wang, J.J., JHK Associates, San Francisco, U.S. Department of Transportation, October 1981.



KEY
Type III Barricade

Arrow Panel

Flashers on Signs - Type B

[1]Note. Temporary markings installed by public agency. Cost of constructing the crossover sections not included.

Computation of Traffic Control Costs

Signs

12 - 48" x 48" w/flashers	
Type B @ 3.75	= $ 45.00
4 - 48" x 48" @ 1.00	= 4.00
2 - 36" x 36" @ .90	= 1.80
5 - 30" x 30" @ .75	= 3.75
3 - 24" x 24" @ .50	= 1.50
1 - 48" x 18" @ .75	= .75
2 - 48" x 30" @ .90	= 1.80
5 - 24" x 30" @ .50	= 2.50
2 - 60" x 24" @ 1.00	= 2.00

Channelizing Devices

104 Type III barricades w/steady burn Type C @ 2.00	= 208.00
3 Arrow Boards @ 50.00	= 150.00
186 Tubular Markers with reflective bands @ .50	= 98.00
Total cost per day	$519.10[1]
Use	$520.00/day

Figure 4. Rural Freeway (Speed-55 mph)

ATTACHMENT 8

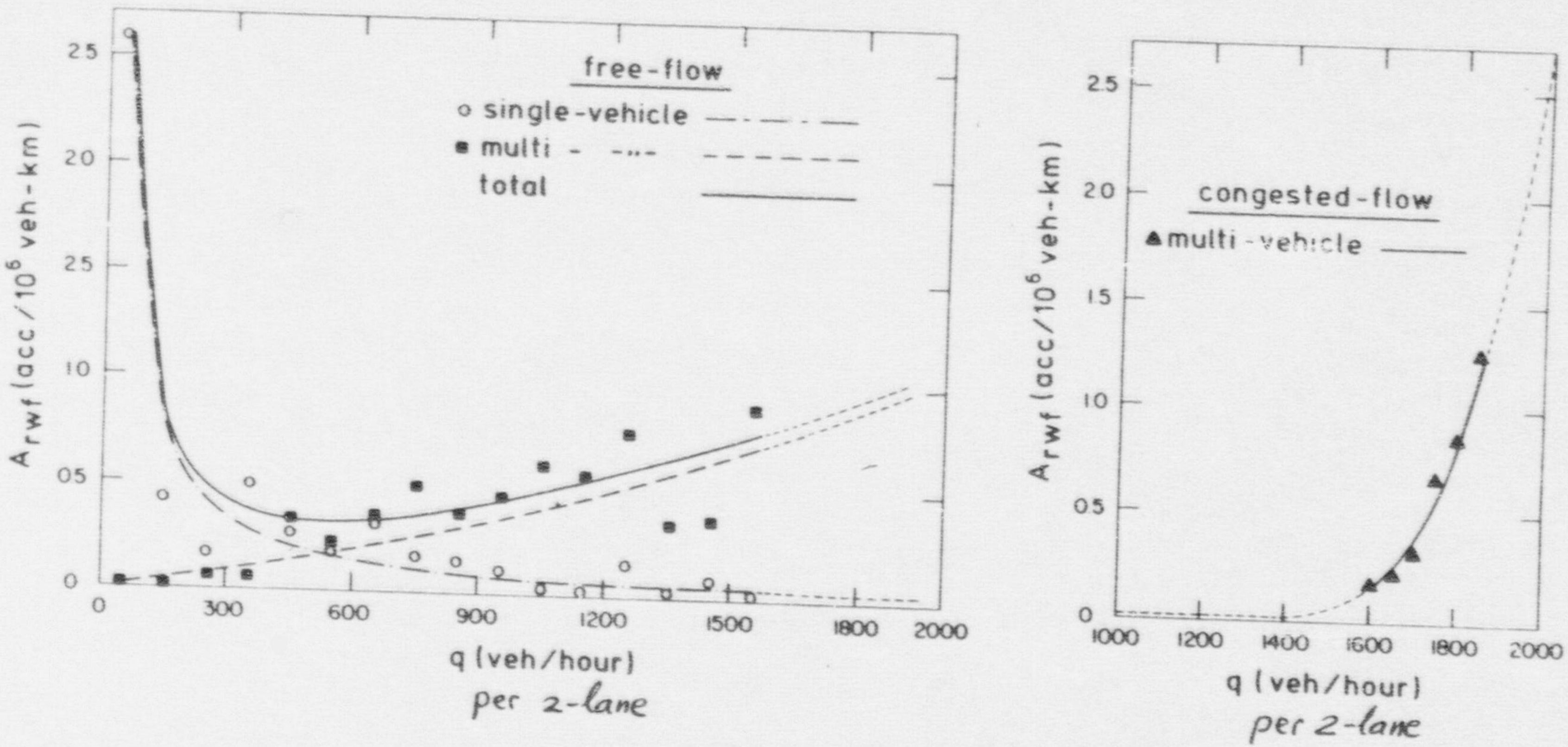


Fig.5 : The data and regression models for free-flow and congested-flow conditions.

ATTACHMENT 9

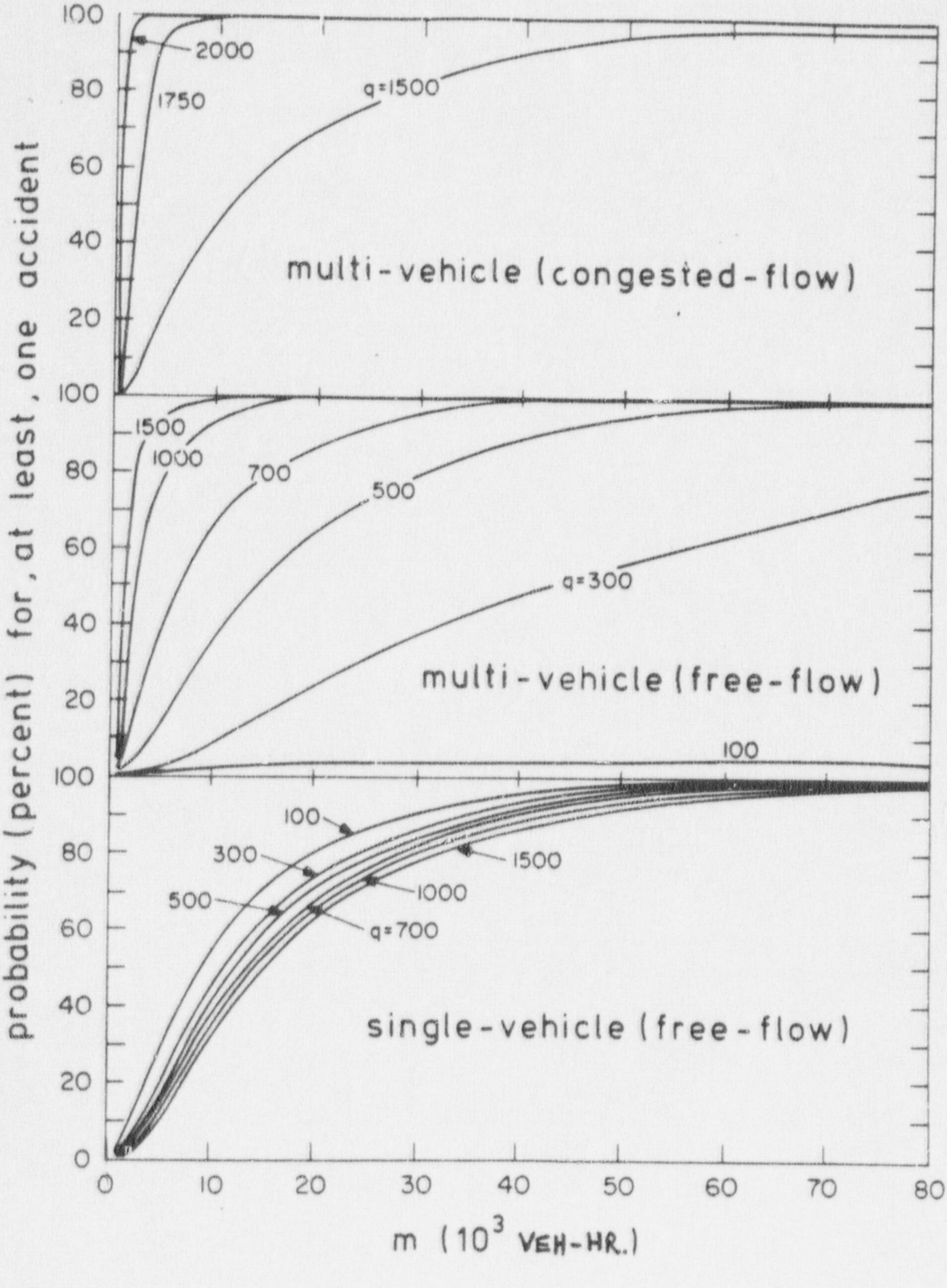


Fig. 6: The resultant relationship between the probability for at least one accident and m for various q (veh/hour) values.

ATTACHMENT 10

TABLE 2. NUMBER OF ACCIDENTS PER DAY (1983 MASS DATA)

		Road Surface Condition		
Location	Station	Good (dry, wet)	Bad (snowy, icy)	Ratio (bad, good)
MASS. STATE HIGHWAYS	Route 12, North of Rt. 62	0.0028	0.1835	(65.5)*
	Route 8 & 9, West of Dalton	0.0706	0.1835	2.6
	Route 202, South Hadley	0.0311	0.0917	2.9
	Route 10 & 202, Southwick	0.5370	0.1835	3.4
	Route 140, Boylston	0.0508	0.0	(0)*
	Route 140, Norton	0.0280	0.0917	(32.7)*
	Route 44, Plymouth	0.0169	0.0917	5.4
	Route 18, East Bridgewater	0.0395	0.0917	2.3
MASS. INTERSTATE HIGHWAYS	I-91, Deerfield	0.0085	0.4587	5.4
	I-495, Bolton	0.0311	0.2752	(8.8)*
	I-95, Georgetown	0.0226	0.4587	2.6
	I-290, Worcester	0.4123	1.2840	3.1
	I-91, Springfield	0.2429	1.6510	6.8
	I-195, Seekonk	0.0537	0.1835	3.4
	I-495, Southborough	0.0028	0.3670	(131.1)*
	I-495, Haverhill	0.1525	1.4680	(9.6)*
	Route 128, Danvers	0.0650	0.0917	1.4
	I-95, Attleboro	0.0960	0.3670	3.8

*Deleted.