# Hazardous Materials Routing Study Phase II

*Analysis of Hazardous Materials Truck Routes in Proximity to the Dallas Central Business District*

October 1985

North Central Texas
Council of Governments

## The North Central Texas Council of Governments

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Funding to conduct this project was provided by the Texas State Department of Highways and Public Transportation in cooperation with the Federal Highway Administration as part of the Texas Traffic Safety Program.

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# Abstract

TITLE: <u>Hazardous Materials Routing Study Phase II: Analysis of Local Routes in Proximity to the Dallas Central Business District</u>

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SUBJECT: An evaluation of freeway and arterial routes for hazardous materials shipments near the Dallas Central Business District.

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ABSTRACT: This report summarizes the findings from the second phase of a two-part analysis of hazardous materials truck routes in the Dallas-Fort Worth area. Phase II of this study analyzes the risk of transporting hazardous materials on freeways and arterial streets in proximity to the Dallas Central Business District. The risk assessment approach is based upon the FHWA report, <u>Guidelines for Establishing Criteria to Designate Routes for Hazardous Materials.</u> Included in this report are results from an industry survey, a vehicle counting program, a review of hazardous materials truck accidents, the risk assessment study, a field survey of alternative routes, proposed safety improvements, and recommendations for further research.

# Acknowledgements

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# Executive Summary

In response to concerns for the potential consequences on an accident involving the release of hazardous materials on congested freeways near the Dallas CBD, the City of Dallas designated a set of arterial hazardous materials truck routes to bypass the freeway system. Particular concern was noted by the City in regard to elevated and depressed below grade canyon-type facilities in which motorists have no adequate means of escape and emergency response access would be difficult in the event of an accident involving the release of a hazardous material.

To evaluate this routing strategy the FHWA risk assessment approach Guidelines for Applying Criteria to Designate Routes for Transporting Hazardous Materials was implemented. This methodology is based upon examining accident probability and potential accident consequences along alternative routes to estimate the relative risks of each routing alternative.

In order to establish information on the types and frequency of hazardous materials shipments in proximity to the CBD, two data collection efforts were completed. The first of these efforts was a survey of 1,400 local industries and transporters requesting specific information about hazardous materials being shipped on the alternative routes in question. To support this data, a series of hazardous materials vehicle counts were completed on freeways approaching the Dallas CBD. Based upon information gained from the industry survey and vehicle counts, it is apparent that a significant number of hazardous materials shipments occur daily on the facilities being evaluated.

The results of the FHWA risk assessment approach indicated that the freeway system represented less risk overall than the arterial street routes due to higher arterial accident rates and greater exposure levels on the arterial segments. A further analysis of the arterial routing system for factors not fully quantified in the risk assessment identified special populations, retail and recreation areas, local businesses and industries located directly adjacent to the arterial routes which would likely be impacted by a hazardous materials accident. Further use of the arterial routes involve freeways to arterial ramps, at-grade intersections and railroad crossings, undivided narrow streets, tunnels, and facilities with a high frequency of curb cuts, all of which increase the likelihood of accidents.

Based upon the results of the risk assessment and field survey of the arterial routes, the findings from this study do not support the use of the arterial routes for hazardous materials shipments to improve overall public safety. Significant concerns remain however, regarding the potential risks to motorists in the event of an accidental release of hazardous materials on the freeway system.

Safety programs involving hazardous materials truck driver training, licensing and certification, vehicle inspection and maintenance, freeway operations and safety design, emergency response personnel training, equipment acquisition, and police enforcement should be further evaluated to reduce the risk of hazardous materials shipments and improve the safety of the freeway system.

# CHAPTER I

## INTRODUCTION

In 1978 the Dallas City Council amended existing city codes to prohibit trucks transporting hazardous materials from using depressed and elevated portions of Interstate Highways 30 and 45 near the Dallas Central Business District (CBD). The ordinance was developed in response to concerns about the potential consequences of a hazardous materials spill in areas where emergency vehicle access would be limited, and motorists could be trapped with no adequate means of escape.

The restricted Interstate facilities shown in Figure 1 include:

1) the depressed section of Interstate Highway 30 (R. L. Thornton Freeway) from Interstate 35E (Stemmons Freeway) to the Oakland Overpass; and

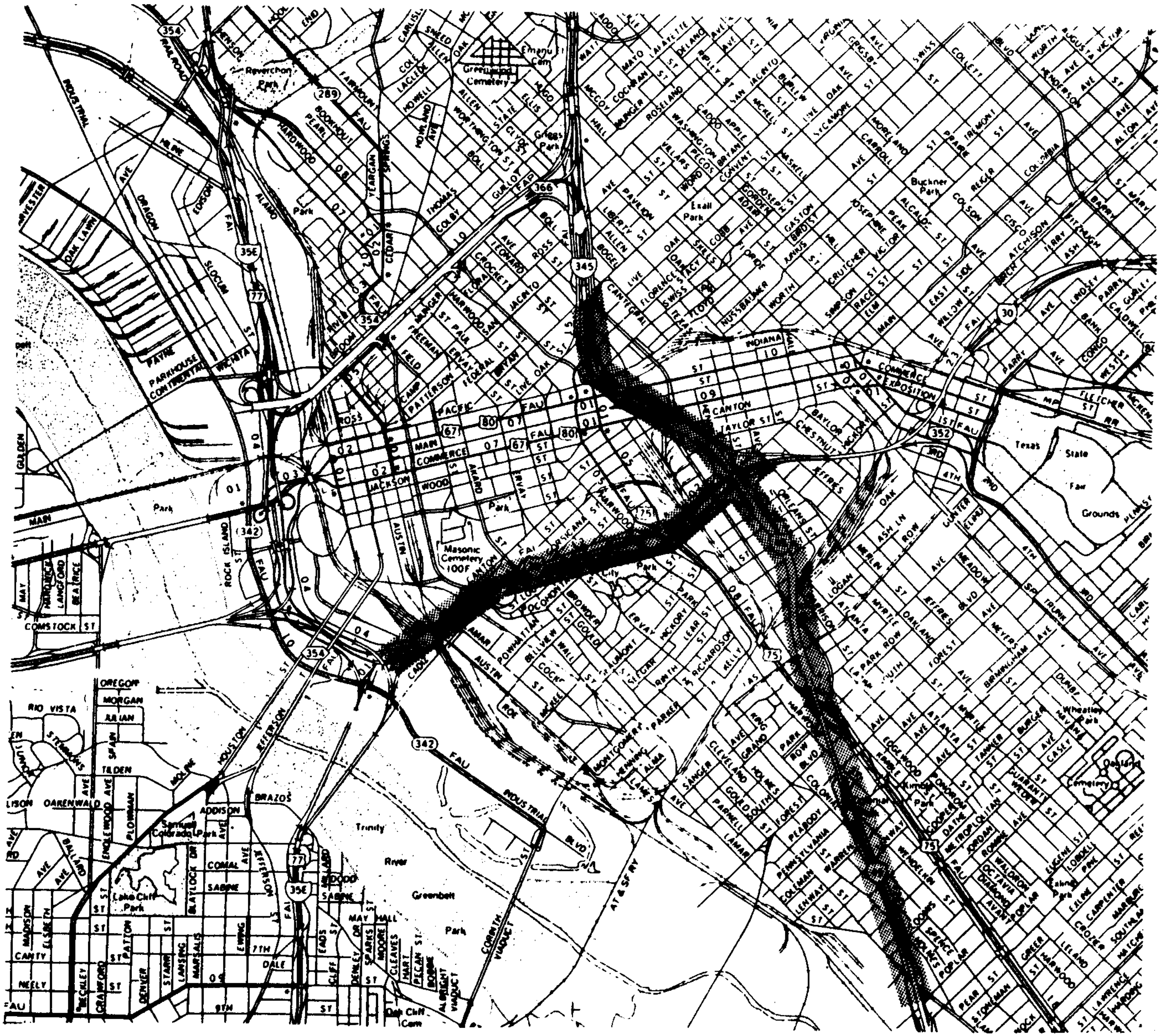
2) the elevated portion of Interstate 45 (Julius Schepps Freeway) from Bryan Street Underpass to Lamar Street Underpass.

In order to facilitate the movement of hazardous materials near the Dallas CBD, the City of Dallas specified a set of arterial routes to bypass the restricted Interstate facilities. These routes are shown in Figure 2.

In September of 1982 the City of Dallas began signing, monitoring, and enforcing hazardous materials routes. The hazardous materials truck route ordinance established by the City of Dallas also specified that *through* shipments of hazardous materials should use the outer loop of Interstate

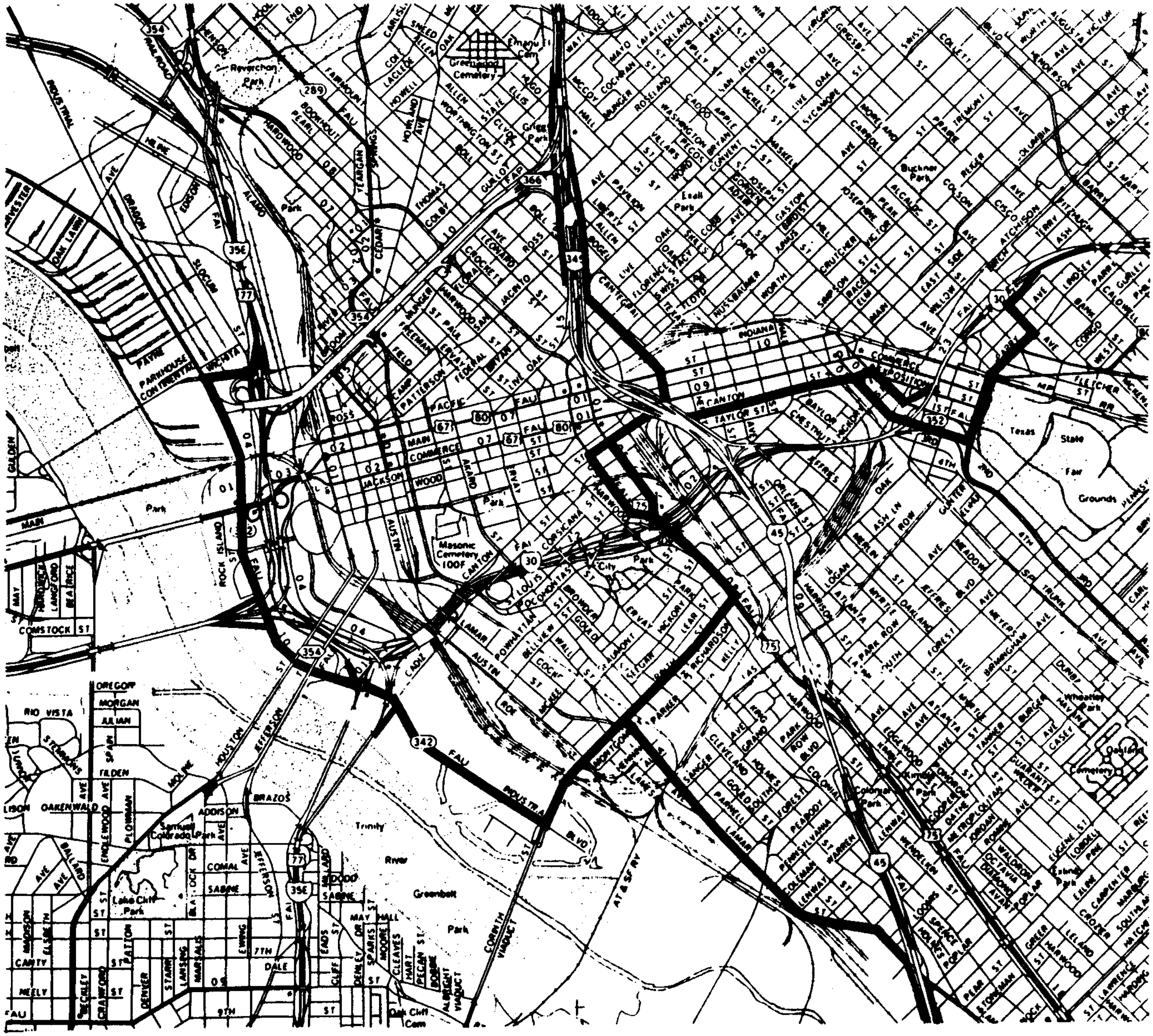
# FIGURE 1

PROHIBITED FREEWAY SECTIONS



<u>FIGURE 2</u>

ARTERIAL ROUTES



Highways 635 and 35E and the connecting freeway segments of Loop 12 and Spur 408.

Work completed in January of 1984 on the Phase I study, Development of Regional Hazardous Materials Truck Routes, supported the previous actions by the City of Dallas in selecting the outer freeway loop for through shipments in Dallas County. A copy of the Dallas Routing Ordinance is provided in Appendix A.

The purpose of this study is to utilize the risk assessment approach as outlined in the Federal Highway Administration Report Guidelines for Applying Criteria to Designate Routes for Transporting Hazardous Materials to analyze and compare the risk associated with hazardous materials shipments on the restricted Interstate highways to the arterial bypass routes near the Dallas CBD.(1)

It is important to note that while the Dallas city ordinance only specifies I.H. 30 and I.H. 45 as the prohibited freeway sections, the current signing in place effectively prohibits shipments on all of the freeways surrounding the Dallas CBD. This includes I.H. 35E (Stemmons), I.H. 30 (R. L. Thornton), U.S. 75/I.H. 345, I.H. 45, and S.H. 366 (Woodall Rogers).

The analysis conducted for this study estimates the risk associated with all of the freeways surrounding the Dallas CBD relative to the arterial bypass routes.

## Study Approach

The FHWA Guidelines, as with the Phase I Regional Through-Routing Study, provided the basic framework for evaluating the alternative routes near the Dallas CBD. Due to the complexity of issues regarding the selection of routes near downtown Dallas, several enhancements were made to the FHWA risk assessment approach. These improvements included both modifications to the risk assessment algorithm and the collection of detailed information regarding the types and quantities of materials being shipped in proximity to the Dallas CBD. Seven project tasks were completed as part of this analysis. These included:

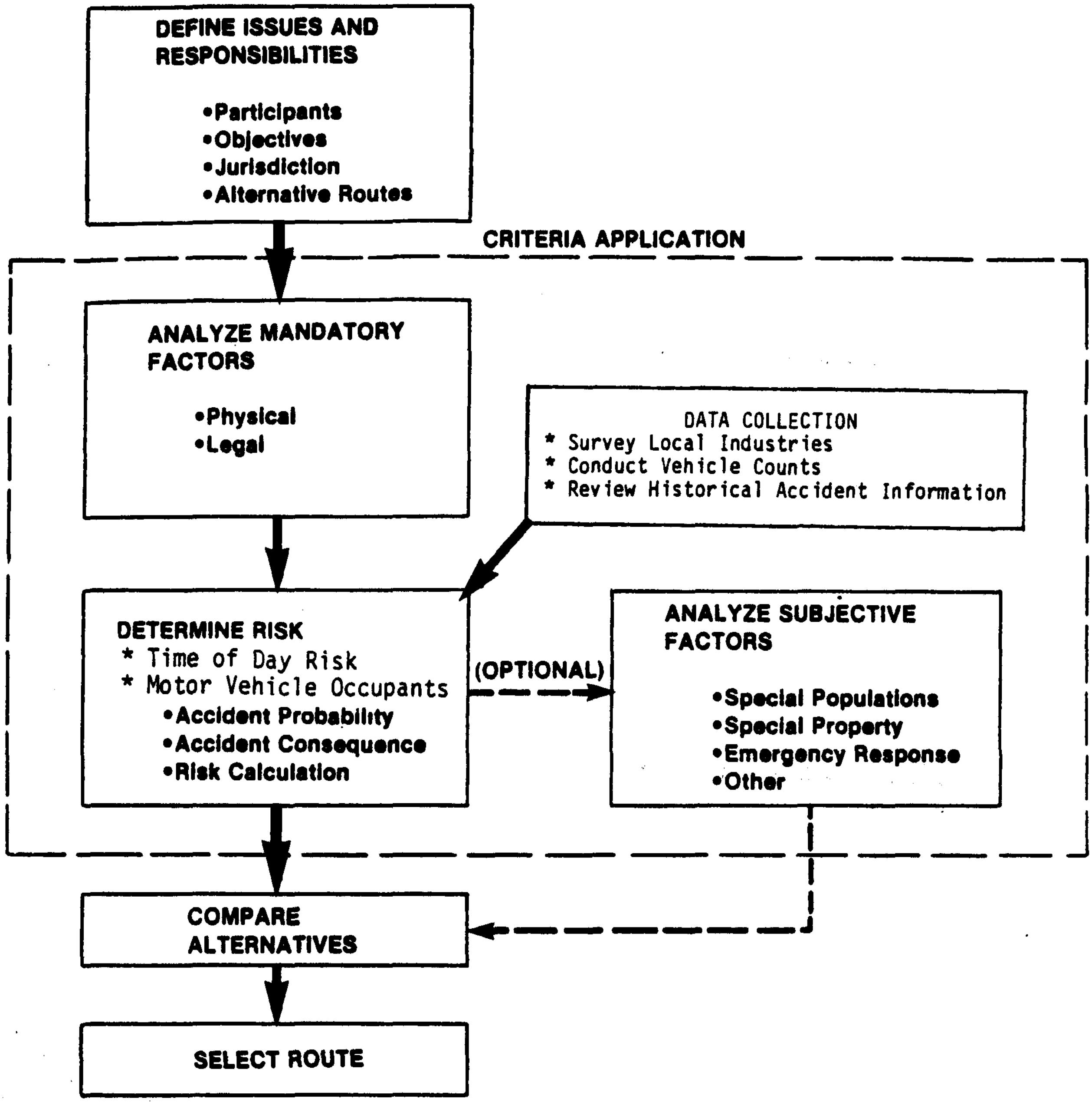
1) Enhancement of the Risk Assessment Algorithm;
2) Inventory/Survey of Industries Shipping Hazardous Materials in Dallas;
3) Hazardous Materials Vehicle Counts;
4) Review of Hazardous Materials Truck Accidents Information;
5) Implementation of Risk Algorithm;
6) Review of Subjective Routing Factors; and
7) Recommendations for Safety Improvement Programs and Further Analysis.

A project flowchart designated by the FHWA Guidelines and used for this analysis is provided in Figure 3. The enhancements made to the study process are also included in the flowchart.

In order to assist in the implementation of this effort, a technical review committee was assembled from various City of Dallas departments: Police, Fire, Emergency Preparedness, Transportation, and Streets and Sanitation. The committee also included a representative from the Dallas Chamber of Commerce subcommittee on hazardous materials. This group reviewed the initial study design, industry survey, preliminary findings regarding the data assembled, and the final study results.

FIGURE 3

FHWA HAZARDOUS MATERIALS ROUTING PROCEDURE




Source: FHWA-IP-80-15 Implementation Package Guidelines for Applying Criteria to Designate Routes for Transporting Hazardous Materials. U.S. Department of Transportation, Federal Highway Administration. Washington, D.C., November, 1980.

* Additional tasks completed for Dallas Phase II Study.

# CHAPTER II

## ENHANCEMENT TO THE RISK ASSESSMENT ALGORITHM

The risk associated with transporting hazardous materials as defined by the FHWA Guidelines can be calculated by combining the estimated probability of a hazardous materials accident with the potential consequences of that accident should it occur. For both the Regional Through-Routing Study and this analysis, the probability of a hazardous materials truck accident was calculated by using an average annual number of semi-tractor/trailer accidents and average annual traffic volume. The two values for each analysis segment were combined to estimate the probability of a truck accident per million vehicle miles. The regional analysis used truck accident data for three years, 1980 through 1982, provided by the State Department of Highways and Public Transportation. This analysis is based upon an expanded data base of five years, 1980 through 1984. The average annual semi-tractor/trailer accident data for the freeway segments was again provided by the SDHPT. Data for the arterial street segments were gathered for the same time period from the City of Dallas annual accident summaries. Since both of the data sources are built from the same accident reports, the data are believed to be comparable.

Accident consequence is defined as the number of individuals who live or work within a potential impact area of a hazardous materials accident. For this application two significant modifications were made to the consequence algorithm to address specific issues of this analysis.

A major concern regarding hazardous materials being shipped on the Interstate facilities near the Dallas CBD was the potential for motorists to be trapped either on elevated portions of the freeway or in the depressed canyon-type segments of the freeway without a means of escape. This analysis included an estimate of the potential number of motorists within a potential impact area of a hazardous materials accident, as well as the population and employment within that impact area.

Due to the significant differences in the amount of activity (employment) and travel during the day versus night in downtown Dallas, the risk assessment algorithm was modified to examine potential accident consequences for both the day and night periods. Several cities have developed truck routes with time of day restrictions. This analysis examines the alternative routes by time of day.

A more detailed description of the motor vehicle occupant exposure algorithm and time-of-day analysis is provided in the risk assessment implementation section of this report.

# CHAPTER III

## INVENTORY OF INDUSTRIES SHIPPING HAZARDOUS MATERIALS IN DALLAS

In order to establish the types and quantities of hazardous materials being shipped in proximity to the Dallas CBD and, in turn, to arrive at a better understanding of the magnitude of risk and potential impacts of the routing alternatives, three data collection efforts were carried out.

The first of these was to assemble information from industries in Dallas and the surrounding communities about the type, quantity, and frequency of hazardous shipments by local industries on the freeway and arterial segments being analyzed in this study.

The inventory began by assembling available information from local, state, and federal agencies. Initial emphasis was placed on working with the City of Dallas Fire, Emergency Preparedness, Streets and Sanitation, and Water Utility Departments to assemble data which had been collected locally into a single data base. This information was augmented by available data from state and federal sources, including the Texas Department of Water Resources, the U. S. DOT Materials Transportation Bureau, and the U. S. Environmental Protection Agency. Private sources of information regarding the transportation of hazardous materials were not available.

The data were screened to identify the most useful information for this effort. Much of the information available through public agencies was of limited use since it was collected to fulfill regulatory and reporting requirements of the respective agencies, rather than the identification of the hazardous materials being transported. This necessitated contacting local industries and shipping firms to secure additional information.

In order to acquire this information industries in the Dallas area were asked to participate in a survey. The following sources were reviewed to create the master list of approximately 10,000 firms, from which a sample of industries were selected to receive a survey;

1) Information obtained from meetings with City of Dallas Fire Department personnel;
2) Dallas Water Utilities' Master List of industrial waste dischargers;
3) NCTCOG's Regional Industrial Waste Management Study;
4) Texas Department of Water Resources Registration Master File of hazardous waste generators;
5) D/FW Council of Safety Professionals;
6) Dun and Bradstreet Employment Data; and
7) Southwestern Bells' Yellow Pages for the City of Dallas.

From this list of firms, 1,400 establishments in the Dallas-Fort Worth area were selected to receive the survey.

The majority of firms were located in Dallas or Dallas County. Table 1 lists the type of firms as classified by the Standard Industrial Classification Codes (SIC) which were surveyed. Also shown in Table 1 is the size of firms and the geographic location of firms included in the survey. For example, all firms in the SIC group 07 through 40 listed in Table 1 with more than 100 employees and located in Dallas County were surveyed. All the firms in the SIC group 10 (Motor Freight Transportation and Warehousing) with more than 10 employees, located in the Dallas-Fort Worth metropolitan area were surveyed. A copy of the survey form mailed to the local industries is provided in Appendix B.

TABLE 1

SUMMARY OF INDUSTRIES SURVEYED FROM
DUN & BRADSTREET DATA

| Industry Type | SIC Code | Number of Employees | Location |
|---|---|---|---|
| AGRICULTURAL SERVICES | 07 | >100 | Dallas County |
| MANUFACTURING | | >100 | Dallas County |
| Food & Kindred Products | 20 | >100 | Dallas County |
| Tobacco Manufacturers | 21 | >100 | Dallas County |
| Textile Mill Products | 22 | >100 | Dallas County |
| Apparel & Finished Products | 23 | >100 | Dallas County |
| Lumber & Wood Products | 24 | >100 | Dallas County |
| Furniture | 25 | >100 | Dallas County |
| Paper & Allied Products | 26 | >100 | Dallas County |
| Printing & Publishing | 27 | >100 | Dallas County |
| Chemicals & Allied Products | 28 | >100 | Dallas County |
| Petroleum & Refining | 29 | >100 | Dallas County |
| Rubber & Miscellaneous Plastics | 30 | >100 | Dallas County |
| Leather & Leather Products | 31 | >100 | Dallas County |
| Stone, Clay, Glass & Concrete | 32 | >100 | Dallas County |
| Primary Metal Industries | 33 | >100 | Dallas County |
| Fabricated Metal Products | 34 | >100 | Dallas County |
| Machinery | 35 | >100 | Dallas County |
| Electrical Equipment | 36 | >100 | Dallas County |
| Transportation Equipment | 37 | >100 | Dallas County |
| Instruments | 38 | >100 | Dallas County |
| Miscellaneous | 39 | >100 | Dallas County |
| RAILROAD TRANSPORTATION | 40 | >100 | |
| MOTOR FREIGHT TRANSPORTATION & WAREHOUSING | 42 | > 10 | Dallas-Fort Worth Area |
| PIPE LINES | 46 | >100 | Dallas County |
| TRANSPORTATION SERVICES | 47 | >100 | Dallas County |
| ELECTRIC, GAS, & SANITARY SERVICES | 49 | >100 | Dallas County |
| WHOLESALE TRADE NON-DURABLE GOODS | | >100 | Dallas County |
| Chemicals & Allied Product | 516 | > 10 | Dallas-Fort |
| Petroleum & Petroleum Products | 517 | > 10 | Worth Area |
| AUTOMOTIVE DEALERS & GASOLINE SERVICE STATIONS | 55 | >100 | Dallas County<br>Dallas County |
| AUTOMOTIVE REPAIR, SERVICE & GARAGES | 75 | >100 | Dallas County |

From the 1,400 surveys mailed, approximately 300 industries responded. One hundred of these responses provided detailed information regarding the types and quantities of hazardous materials shipped by the firm into or through Dallas.

While this survey effort did not provide a complete set of information on the type and quantity of materials being shipped near downtown Dallas, it did provide information about specific operations of many of the major hazardous materials transporters in the region.

For example, several of the major oil companies provided detailed information on their frequency of gasoline shipments near the Dallas CBD. This data helped to identify the potential magnitude of this problem. Combining the responses from two of the major oil companies indicated that as many as 25-30, 9,000 gallon shipments of gasoline from these two companies alone are traveling on the routes in question near the Dallas CBD each day. The survey mailing list of industries included 15 to 20 firms which transport gasoline on a daily basis in the Dallas area.

The survey indicated, as well, that many different types of materials are being shipped along the routes in question. A summary of the hazardous materials and U.S. Department of Transportation classes of the materials which were reported in the survey responses is provided in Table 2.

Finally the survey provided a forum for interaction with local industries regarding the transportation and routing of hazardous materials. A number of industries provided comments regarding the alternative routes as well as suggestions for the analysis. The survey also provided an opportunity to meet

## TABLE 2

## U. S. DOT CLASSES AND HAZARDOUS MATERIALS REPORTED IN SURVEY

| DOT CLASS | SHIPPING NAME |
|---|---|
| Explosives: | |
| Class A | Military Type |
| Class B | Fireworks, Special |
| Class C | Fireworks, Common |
| Blasting Agent | N/R |
| Combustible Liquid | Kerosene |
| Corrosive Material | Acetic Acid<br>Alkaline Corrosive, Liquid N.O.S.<br>Battery Acid<br>Cleaning Compound, Liquid<br>Corrosive, Solid, N.O.S.<br>Hydrochloric Acid<br>Hydrofluoric Acid<br>Hypochlorite Solution<br>Liquid Cement, N.O.S.<br>Nitric Acid<br>Sodium Hydroxide<br>Sulfuric Acid |
| Flammable Liquid | Acetone<br>Alcohol<br>Engine Starting Fluid<br>Ethanol<br>Fuel Oil<br>Gasoline<br>Hexane<br>Iron Chloride Solution<br>Paint Waste<br>Petroleum Oil<br>Resin Solution<br>Spent Solvents<br>Trichloroethane |
| Flammable Gas (Compressed) | Nitrogen |
| Non-Flammable Gas | Chlorine<br>Formaldehyde<br>Oxygen |
| Flammable Solid | Potassium Metal |
| Organic Peroxide | N/R |
| Oxidizer | Aluminum Sulfate<br>Copper Sulfate<br>Ethyl Acetate |
| Poison A | Sodium Cyanide |
| Poison B | N/R |
| Irritating Material | N/R |
| Etiological Agent | N/R |
| Radioactive Materials | Radioactive Materials |
| ORM-A | Trichloroethylene |
| ORM-B, C, D, E | N/R |

N/R - Not Represented in Survey Results

directly with a number of industries including the petroleum bulk terminal operators, which was done as a follow-up to the mailing of the survey to collect additional survey responses.

This effort highlighted the need for additional information and the difficulties in obtaining the data. Future efforts should be made toward establishing a single, uniform data source regarding both storage and transportation of hazardous materials. Establishing this data would undoubtedly provide a clearer understanding of the potential risk due to hazardous materials shipments both in Dallas and the entire Dallas-Fort Worth area.

# CHAPTER IV

## HAZARDOUS MATERIALS VEHICLE COUNTS

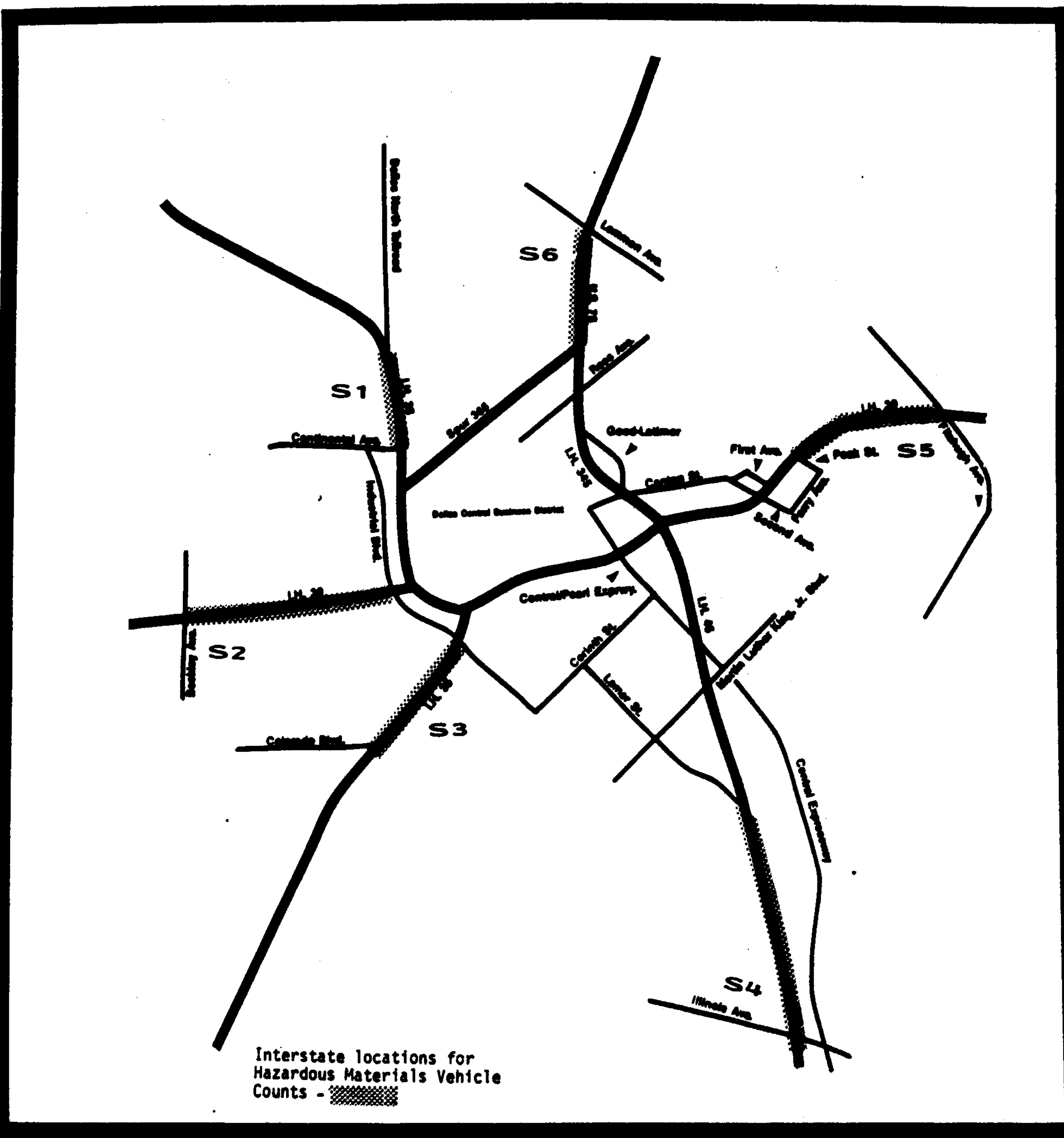
While the industry survey provided detailed information regarding specific hazardous materials shipments, it failed to provide a complete picture of the potential number of shipments near the Dallas CBD. Hence, the decision was made to pursue a series of hazardous materials vehicle counts on freeways leading into the Dallas CBD area. The purpose of these counts was to establish an estimate of the frequency and type of hazardous materials shipments being shipped in proximity to downtown Dallas. This information, as with the industry survey, was needed in order to address the magnitude of the problem and to establish general knowledge regarding the characteristics of the potential shipments on the routes being analyzed.

As shown in Figure 4, six locations were established on the freeways surrounding the Dallas CBD. The six survey points were located outside restricted Interstate facilities and prior to the entry or exit ramps to the arterial (freeway bypass) routes. At these locations all vehicles entering and exiting the CBD area on the freeway system would be counted. No effort was made to establish if vehicles were utilizing the arterial (freeway bypass) routes.

Four survey teams of two to three men conducted the windshield survey vehicle counts over 10, four-hour periods on the freeway system. All of the counts were taken on weekdays over a several week period. In order to sample as much of a 24-hour day as possible the counts were done during different time periods. Counts were completed for 20 hours of a 24-hour period.

FIGURE 4

HAZARDOUS MATERIALS VEHICLE COUNT LOCATIONS



The survey teams recorded for each vehicle (defined in this analysis as a semi-tractor/trailer, tandem trailer or tank trailer displaying a hazardous materials placard), the vehicle type, the U. S. DOT placard on the vehicle, the commodity identification number, the carrier name, direction of travel, and the time the vehicle passed the survey location. A copy of the form used to record the vehicles and a summary of one four-hour vehicle counting session is provided as Appendix C.

In order to establish a percentage of hazardous materials truck shipments in relationship to all trucks, the survey teams also recorded the total number of trucks passing the survey locations for two of the four hours in which the vehicle counts were done.

Table 3 provides a summary of the total number of hazardous materials shipments observed and the average number of shipments per hour for each survey location. Based on the average of 11 shipments per hour per facility, it is apparent that a significant number of hazardous materials shipments will be on the routes in question each day.

Table 4 illustrates the percentage of truck shipments carrying hazardous materials. As shown, the results of the vehicle counts indicated that 5.2 percent of the trucks observed on freeways near the Dallas CBD were transporting hazardous materials. According to discussions with the American Trucking Association, the national U.S. average for trucks carrying hazardous materials ranges between 5-15 percent depending on the area of the country.(2) Hence, the 5.2 percent value observed near the Dallas CBD appears reasonable.

In 1983 the City of Dallas estimated that approximately 11,000 trucks a day travel on I.H. 35E; 14,000 on the common section of I.H. 30 and I.H. 35E and

## TABLE 3

## AVERAGE SHIPMENTS PER HOUR BY LOCATION

| Facility | Location | Total HazMat Truck Volume | Hours Counted | Average No. of Shipments Per Hour |
|---|---|---|---|---|
| I.H. 35E | S1 | 103 | 8 | 13 |
| I.H. 30 | S2 | 128 | 8 | 16 |
| I.H. 35E | S3 | 84 | 8 | 11 |
| I.H. 45 | S4 | 59 | 8 | 7 |
| I.H. 30 | S5 | 51 | 4 | 13 |
| U.S. 75 | S6 | 30 | 4 | 8 |
| Total | | 455 | 40 | 11 |

## TABLE 4

## PERCENTAGE OF SHIPMENTS CARRYING HAZARDOUS MATERIALS BY LOCATION

| Facility | Location | Total HazMat Truck Volume* | Total Truck Volume* | % HazMat* |
|---|---|---|---|---|
| I.H. 35E | S1 | 55 | 1,247 | 4.4 |
| I.H. 30 | S2 | 56 | 980 | 5.7 |
| I.H. 35E | S3 | 37 | 761 | 4.9 |
| I.H. 45 | S4 | 28 | 518 | 5.4 |
| I.H. 30 | S5 | 32 | 599 | 5.3 |
| U.S. 75 | S6 | 21 | 229 | 9.2 |
| Total | | 229 | 4,334 | 5.2 |

* Based on twenty-hour count.

8,900 on I.H. 30 between I.H. 35E and I.H. 45.(3) Applying the value of 5.2 percent to these estimates of 24-hour truck volumes would indicate the potential for over 570 hazardous materials trucks on I.H. 35E, 720 on I.H. 30 and I.H. 35E, and 460 on I.H. 30 per day.

Extrapolating the hazardous materials hourly vehicle count average for each facility into a 24-hour period results in a similar magnitude of hazardous materials truck shipments. For example, the hourly rate of 13 vehicles per hour on I.H. 35E results in a 24-hour total of 312 shipments per day. On I.H. 30 west of downtown Dallas the 16 vehicles per hour translates into 384 shipments per day.

With regard to the type of vehicle and materials observed in the vehicle counts, 74 percent of the vehicles recorded were semi-tractor/bulk tank trailer vehicles. Of those tank trucks, over 70 percent were observed as placarded combustible liquid 1203 (gasoline).

According to the National Tank Truck Carriers Conference, 60-70 percent of the hazardous bulk tank shipments are gasoline.(4) These numbers correspond to the shipments observed in Dallas.

A number of the DOT classes of hazardous materials, as well as specific substances, were observed in the vehicle counts. Table 5 provides a breakdown of the percentage of shipments observed in Dallas by U. S. DOT Class. As illustrated, flammable liquids dominated the observation. The most commonly transported hazardous substances in the United States, in order of frequency of transport, are listed in Table 6. These numbers reflect similar findings to those materials observed in the vehicle counts.

## TABLE 5

## HAZARDOUS MATERIALS OBSERVED BY CLASS IN PROXIMITY TO THE DALLAS CBD

| U. S. DOT Class | Percent of Observation |
|---|---|
| Flammable Liquid | 64.09% |
| Dangerous (Class C Explosives, or Irritants) | 13.65% |
| Corrosive | 10.68% |
| Non-flammable Gas | 3.26% |
| Poison | 2.67% |
| Flammable Gas | 2.67% |
| Flammable Solid | 0.89% |
| Organic Peroxides | 0.59% |
| Combustible Liquid | 0.30% |
| Oxidizer | 0.30% |
| Explosives | 0.30% |
| Non-flammable Liquid | 0.30% |
| Radioactive Material | 0.30% |

## TABLE 6

### MOST COMMONLY TRANSPORTED HAZARDOUS MATERIALS IN THE UNITED STATES

| | |
|---|---|
| Gasoline and jet fuel | 56% |
| Distillate fuel oil | 34% |
| Anhydrous ammonia | 4% |
| Liquified petroleum gas | 2% |
| Paints and allied products | 2% |
| Industrial gases (compressed and liquified) | 1% |

Source: David M. Baldwin, P.E., Regulation of the Movement of Hazardous Cargoes, Final Report, May 1980.

Close to 25 percent of the shipments recorded occurred in semi-tractor/trailer or tandem trailers. The majority of these shipments were being hauled by common freight carriers, displaying only U. S. DOT warning placards. Identification of the material in the shipments beyond the class of material was not possible.

Table 7 provides a list of the types of materials observed in the survey. As observed in the industry survey, a wide variety of types of materials are transported in proximity to the Dallas CBD.

As was mentioned, the vehicle counts were taken at various times of the day in an attempt to make an assessment as to when the majority of shipments were occurring. Responses from the industry survey regarding time of shipments varied dramatically. A large number of the responses indicated that shipments only occurred between the hours of 8 a.m. and 5 p.m. due to the need for pick up/delivery during work hours. The bulk gasoline shippers indicated, however, that their shipments are made 24 hours a day.

With only 40 hourly observations it is difficult to make a full assessment regarding the frequency of shipments by time of day. The vehicle counts indicated, however, that the highest frequency of hazardous materials shipments were observed during the midday period while significant volumes were also registered across the 24-hour day. Figure 5 illustrates the total number of observed shipments by location and hour.

In summary, the vehicle counting program conducted as part of this study revealed that, indeed, significant numbers of hazardous materials shipments are traveling in proximity to the Dallas CBD. The highest percentage of bulk

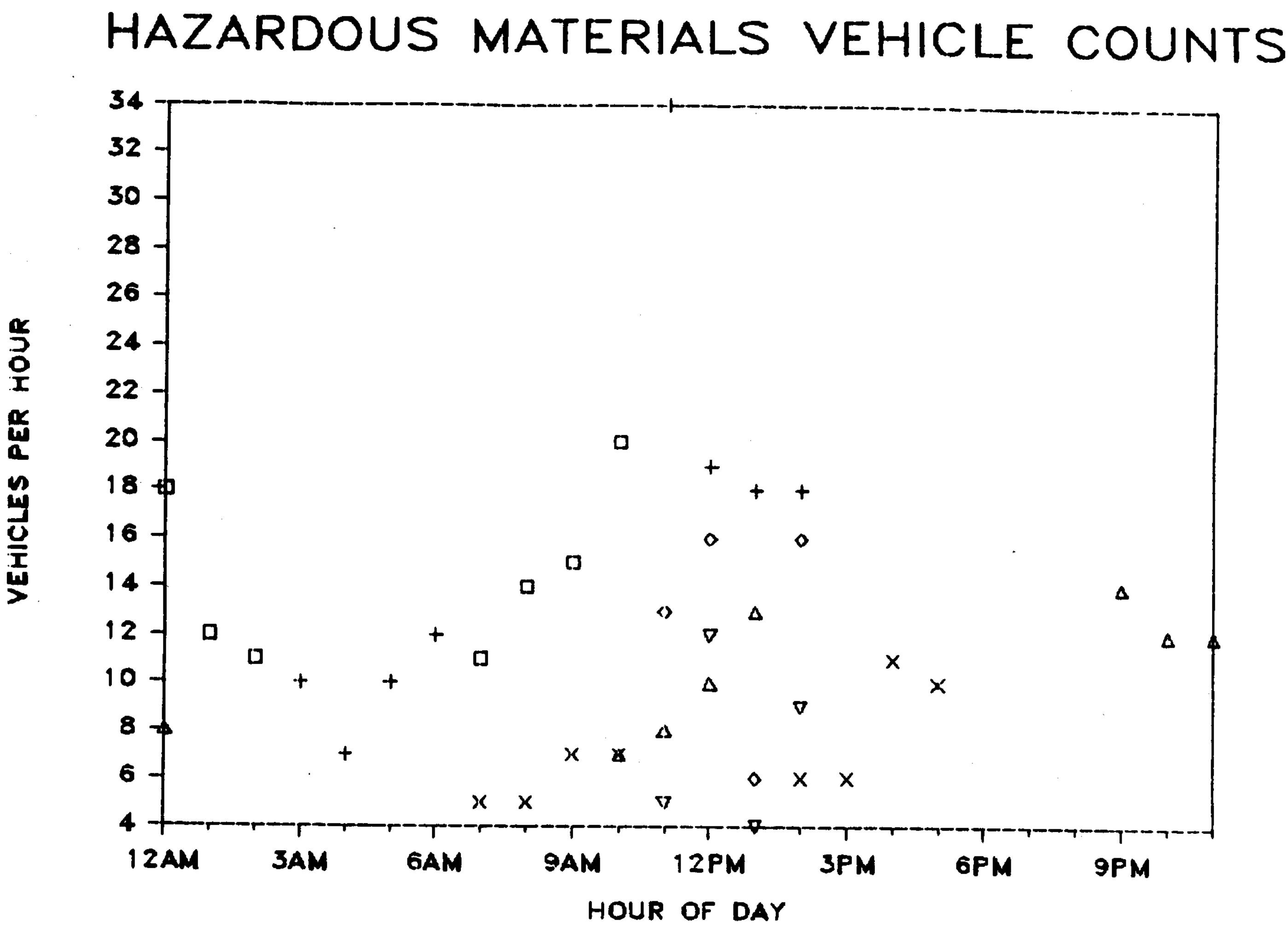
## TABLE 7

## HAZARDOUS MATERIALS OBSERVED IN PROXIMITY TO THE DALLAS CBD

| |
|---|
| Gasoline |
| Nitrophenol |
| Benzoyl Peroxide |
| Nitro Sulphuric Acid |
| Carbon Dioxide |
| Isobutylamine |
| Naptha, Petroleum |
| Sodium Hydrate |
| Tolovene |
| Paint |
| Phosphorus Trisulfide |
| Drier |
| Trifluorochloroethane |
| Dimethylamine |
| Benzoic Derivative |
| Zinc Ammonium Nitrite |
| Hydrogen Liquid |
| Antimony Trifluoride |
| Acetylene |
| Dicyclopentadiene |
| Resin Solution |
| Octanoyl Peroxide |
| Isopropanol |
| Propanoic Acid |
| Cymene |
| Isopropyl Alcohol |
| Nitrogen |
| Liquid Carbon Dioxide |

## FIGURE 5

OBSERVED HAZARDOUS MATERIALS
VEHICLE COUNTS BY HOUR OF DAY BY LOCATION




| | | |
|---|---|---|
| □ | IH 35E | Location S1 |
| + | IH 30 | Location S2 |
| Δ | IH 35E | Location S3 |
| x | IH 45 | Location S4 |
| ◇ | IH 30 | Location S5 |
| ▽ | US 75 | Location S6 |

shipments are gasoline or petroleum supply related. The data collected in this effort appeared to coincide with national statistics regarding hazardous materials shipments.

# CHAPTER V

## LOCATION OF BULK STORAGE TERMINALS

Due to the large percentage of bulk gasoline shipments observed in the vehicle counts and the high frequency of gasoline shipments reported in the industry survey, one further data collection effort was completed. This task identified the location of the bulk gasoline storage facilities in the Dallas-Fort Worth area. As shown in Figure 6, the majority of facilities are located west/northwest of Dallas and north/northeast of Fort Worth. This analysis would indicate that a large percentage of the bulk gasoline shipments traveling in proximity to the Dallas CBD utilize I.H. 30 (R. L. Thornton) and I.H. 35E (Stemmons) when traveling inbound to make deliveries east or south of the Dallas CBD.

Both results of the industry survey response and vehicle counts indicate that the highest number of gasoline shipments are occurring on I.H. 35E and I.H. 30 approaching downtown Dallas.

### Summary of Data Collection Efforts

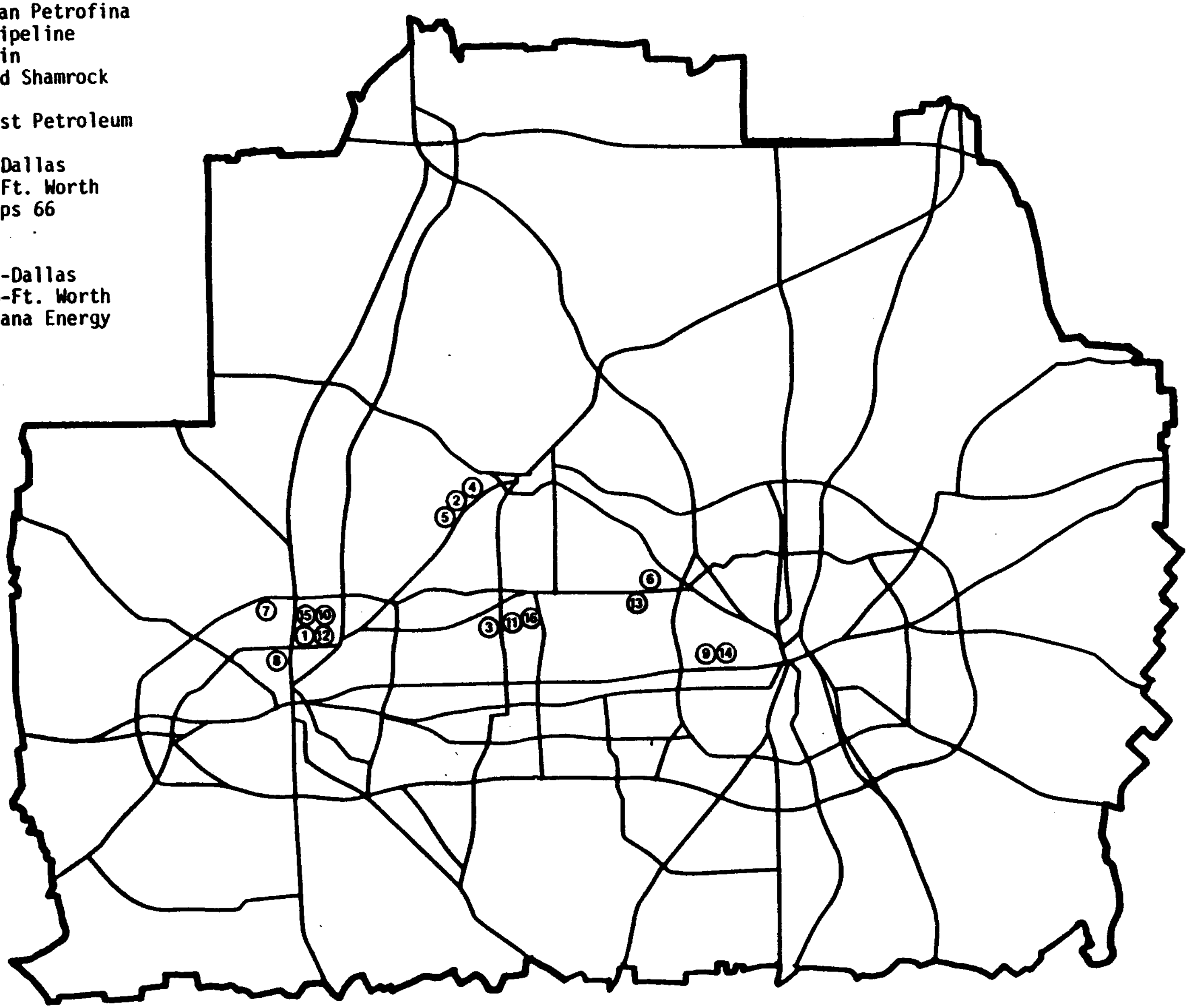
Three separate, yet related, data collection efforts were completed regarding the types, quantity, and frequency of hazardous materials being shipped in proximity to the Dallas CBD. These included:

1) A survey of industries shipping hazardous materials in the Dallas area;
2) Hazardous materials vehicle counts; and
3) A locational analysis of gasoline bulk storage facilities in the region.

FIGURE 6

LOCATIONS OF GASOLINE BULK STORAGE TERMINALS IN THE DALLAS/FORT WORTH AREA

1. Amber
2. American Petrofina
3. Arco Pipeline
4. Champlin
5. Diamond Shamrock
6. Exxon
7. Foremost Petroleum
8. Gulf
9. Mobil-Dallas
10. Mobil-Ft. Worth
11. Phillips 66
12. Pride
13. Shell
14. Texaco-Dallas
15. Texaco-Ft. Worth
16. Tropicana Energy



The results of this analysis indicated that significant numbers of high volume bulk shipments are occurring in the Dallas CBD area as well as a number of small volume shipments being made by common freight carriers.

The majority of bulk materials shipments are gasoline or petroleum related, traveling at all periods of the day, while a number of other types of materials are being shipped on a regular basis through the area.

The most significant implication of these findings is that any routing strategy implemented near the Dallas central business district has the potential for both alleviating and creating risk. For example, the potential routing of several hundred gasoline shipments over a 24-hour period either on the freeway or arterial routes, represents a major shift in levels of risk between facilities as well as travel patterns. Any decisions made regarding the routing, emergency response, and emergency preparedness along these routes should take into account these findings.

# CHAPTER VI

## REVIEW OF HAZARDOUS MATERIALS TRUCK ACCIDENT DATA

Several sources of information were reviewed to obtain a better understanding of the causes of hazardous materials truck accidents, the potential consequences of these accidents and the role in which emergency response capability may play in alleviating risk.

The first type of information gathered for this portion of the study was provided by the Materials Transportation Bureau of the U.S. DOT. This information, in the form of a computer printout, summarized all of the hazardous materials related incidents and accidents for communities in the Dallas-Fort Worth area between 1971 and March 25, 1985. According to the data, 1,916 incidents occurred involving the transportation of hazardous materials via the highway related mode during this time period. An incident is defined in MTB data as an occurrence which results in the spill or release of a hazardous material. This might be a drum rolling off a loading dock and spilling or a truck tank leaking materials.

For the same time period the MTB data reported 17 highway accidents which resulted in the release of a hazardous material in the Dallas-Fort Worth area. An accident is the release of a hazardous material during transport caused by a vehicle accident, such as a multiple vehicle collision or a truck colliding with a fixed object.

While there is considerable concern regarding the completeness of the MTB data due to the several known accidents which have occurred locally during this time period, but which do not appear in the data, a summary of the highway accidents reported for the Dallas-Fort Worth area is shown in Table 8.

# TABLE 8

SUMMARY OF HAZARDOUS MATERIALS ACCIDENTS
AS REPORTED BY THE MATERIALS TRANSPORTATION BUREAU OF
THE US DOT FOR DALLAS-FT. WORTH FROM 1971-1985

| DATE | LOCATION | CARRIER | COMMODITY | CLASS | AMOUNT | INJURIES | DEATHS | COST |
|---|---|---|---|---|---|---|---|---|
| 06/21/75 | ARLIGNTON TX | CONTINENTAL OIL COMPANY | COMBUSTIBLE LIQUID NOS | COMBUSTIBLE LIQUID | NA | 0 | 0 | $8000.00 |
| 10/25/75 | DALLAS TX | AMERICAN FARM LINES | ACID LIQUID NOS | CORROSIVE | NA | 0 | 0 | $3,516.00 |
| 04/16/78 | DALLAS TX | NAVAHO FREIGHT LINES | HYDROCHLORIC ACID | CORROSIVE | 200 GALLONS | 0 | 0 | $0 |
| 11/21/78 | DALLAS TX | OIL TRANSPORT COMPANY | GASOLINE | FLAMMABLE LIQUID | 371 GALLONS | 0 | 0 | $3,832.00 |
| 08/20/79 | DALLAS TX | CONSOLIDATED FREIGHTWAYS | STYRENE MONOMER | FLAMMABLE LIQUID | 10 GALLONS | 0 | 0 | $5.00 |
| 09/25/80 | DALLAS TX | CANGO CORPORATION | ALCOHOL NOS | FLAMMABLE LIQUID | 55 GALLONS | 0 | 0 | $0 |
| 10/17/80 | DALLAS TX | OIL TRANSPORT COMPANY | GASOLINE | FLAMMABLE LIQUID | 1134 GALLONS | 0 | 0 | $1,163.00 |
| 03/07/75 | DALLAS TX | SOUTHLAND DISTRIBUTION | FLAMMABLE LIQUID | FLAMMABLE LIQUID | NA | 0 | 0 | $0 |
| 06/28/77 | DALLAS TX | ASHLAND CHEMICAL COMPANY | FLAMMABLE LIQUID NOS | FLAMMABLE LIQUID | 5000 GALLONS | 0 | 0 | $40,000.00 |
| 01/12/82 | DALLAS TX | GULF OIL COMAPNY USA | GASOLINE | FLAMMABLE LIQUID | 250 GALLONS | 0 | 0 | $0 |
| 03/17/76 | FORT WORTH TX | CHEMICAL LEAMAN TANK LINE | SODIUM HYDROXIDE | CORROSIVE | 20 GALLONS | 0 | 0 | $200.00 |
| 07/21/80 | FORT WORTH TX | GROENDYKE TRANSPORT INC. | GASOLINE | FLAMMABLE LIQUID | 5668 GALLONS | 0 | 0 | $8,500.00 |
| 01/29/82 | FORT WORTH TX | CONOCO INC. | GASOLINE | FLAMMABLE LIQUID | 20 GALLONS | 1 | 0 | $1800.00 |
| 11/20/80 | GRAND PRARIE TX | CHEMICAL EXPRESS CARRIERS | AVIATION JET FUEL | FLAMMABLE LIQUID | 9300 GALLONS | 0 | 0 | $100,000.00 |
| 10/08/73 | IRVING TX | CHEMICAL EXPRESS CARRIERS | GASOLINE | FLAMMABLE LIQUID | NA | 0 | 0 | $371.00 |
| 04/24/75 | IRVING TX | EXXON COMPANY | GASOLINE | FLAMMABLE LIQUID | NA | 0 | 0 | $8000.00 |
| 08/18/76 | PLANO TX | ARKANSAS-BEST FREIGHT | LIQUID CEMENT | FLAMMABLE LIQUID NOS | 1 OZ. | 0 | 0 | $25.00 |

*During the same time period MTB reported 1,913 "Incidents" regarding hazardous materials roadway shipments in the Dallas-Fort Worth area.

**Data reported from 1971 through March 25, 1985

The most significant factor to be noted in this data is that the majority of accidents involved the release of flammable liquids such as gasoline, alcohol and jet fuel. Recalling that these types of materials represented the majority of bulk tank shipments observed in Dallas, the data appeared to coincide with earlier findings regarding hazardous materials shipments.

A second type of information obtained for this study was accident reports provided by the National Transportation Safety Board of the U.S. DOT and press information from recent truck accidents which have occurred locally. The reports describe accidents which involved hazardous material truck shipments. A list of those documents reviewed for this analysis is provided in Figure 7.

A summary of the information examined for each of these reports is shown in Table 9. This information included the type and quantity of the material released; an estimate of the impact area, based upon the spill map or information provided in the report; the result of the spill (fire, gas cloud, etc.); the number of fatalities and injuries; how soon after the incident that the exposure occurred which either killed or injured persons in the area; if an emergency response within five minutes of the accident could have alleviated the fatalities or injuries; and if, as a result of the accident, an evacuation of the area was needed.

The results of this examination with regard to accident consequence and emergency response are clear. In the majority of cases the fatalities and injuries as a result of the accident occurred simultaneously to the release of the material. In each case the release of the material either resulted in severe fires or fumes causing the deaths or injuries.

FIGURE 7

LIST OF HAZARDOUS MATERIALS ACCIDENTS REVIEWED

1. NTSB-HAR-76-04 Surtigas, S. A., Tank-Semitrailer Overturn, Explosion, and Fire, Near Eagle Pass, Texas, 4/29/75.

2. NTSB-HAR-77-01 Transport Company of Texas, Tractor-Semitrailer (Tank) Collision with Bridge Column and Sudden Dispersal of Anhydrous Amonia Cargo, I.H. 610 at Southwest Freeway, Houston, Texas, 5/11/76.

3. NTSB-HSM Map-80-7 Gasoline Release from Highway Tank Truck/Tank Trailer, Los Angeles, California, 3/3/80.

4. NTSB-HZM Map-82-2 Gasoline Release Following Freight Train Collision with Cargo Tank Semi-Trailer, near Charlotte, North Carolina, 10/29/80.

5. NTSB-HZM Map-82-1 Gasoline Release Following Freight Train Collision with Cargo Tank Semi-Trailer, Huntsville, Alabama, 9/15/81.

6. NTSB-HZM Map-83-1 Gasoline Release Following Semi-Trailer Collision with Cargo Tank Semi-Trailer Near Canyon City, Colorado, 10/14/81.

7. NTSB-HZM Map-83-2 Gasoline Release Following Commute Train Collision with Cargo Tank Semi-Trailer, South Hampton, Pennsylvania, 1/2/82.

8. NTSB-HAR-83-1 Multiple Vehicle Collisions and Fire, Caldecott Tunnel, Near Oakland, California, 4/7/82.

9. Gasoline Release Following Cargo Tank Semi-Trailer Collision with Automobile on I.H. 30, Dallas, Texas, 7/2/83, as reported by Dallas Morning News, 6/3/83.

10. Gasoline Release Following Cargo Tank Collision with Dump Truck on S.H. 114, Irving, Texas, 3/17/83, as reported by Dallas Morning News, 3/17/83.

TABLE 9

SUMMARY OF HAZARDOUS MATERIALS ACCIDENTS REVIEWED

| Highway Accident Involving Hazardous Material | Hazardous Material Released | Quantity of Material Released | Consequence of Accident | | | | | | | Source[2] |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Impact Area | Result of Spill[3] | Fatal-ities | Injuries | Time of Fatal-ities/ Injuries[3] | Could Emergency Response Have Saved Lives?[3] | Was Evacuation Needed? | |
| Truck Accident Eagle Pass, TX April 2, 1982 | LPG | 8,748 Gallons | 1,600 Feet | Fire | 16 | 35 | Instan-taneous | No | No | 1 |
| Truck Accident Houston, TX May 11, 1976 | Anhydrous Ammonia | 7,509 Gallons | 2,000 Feet | Fumes | 6 | 178 | 3-5 Minutes | No | No | 2 |
| Truck Accident Los Angeles, CA March 3, 1980 | Gasoline | 8,981 Gallons | 600 Feet | Fire | 5 | 2 | 5 Minutes | No | No | 3 |
| Truck/Train Accident Charlotte, NC Nov. 29, 1980 | Gasoline | 8,800 Gallons | 1,100 Feet | Fire | 1 | 3 | Instan-taneous | No | No | 4 |
| Truck/Train Accident Huntsville, AL Sept. 15, 1981 | Gasoline | 8,986 Gallons | 600 Feet | Fire | 7 | 4 | 7 seconds | No | Yes[1] | 5 |
| Truck Accident Canyon City, CO Nov. 14, 1981 | Gasoline | 8,988 Gallons | 400 Feet | Fire | 8 | 2 | Instan-taneous | No | No | 6 |
| Truck/Train Accident Southampton, PA Jan. 2, 1982 | Gasoline | 7,900 Gallons | 150 Feet | Fire | 1 | 5 | Instan-taneous | No | No | 7 |
| Truck Accident Oakland, CA April 7, 1982 | Gasoline | 8,800 Gallons | 3,300 Feet (Tunnel) | Fire | 7 | 2 | 3 Minutes | No | No | 8 |
| Truck Accident Dallas, TX July 7, 1983 | Gasoline | N/A | 400 Feet | Fire | 2 | 0 | 3-5 Minutes | No | No | 9 |
| Truck Accident Irving, TX March 17, 1983 | Gasoline | 8,220 Gallons | N/A | Fire | 0 | 2 | Instan-taneous | No | No | 10 |

[1] Due to presence of other materials on the train
[2] Corresponds to report numbers listed in Figure 7
[3] Based upon interpretation of the NTSB report or press release

From an emergency response standpoint it also appeared that little, if anything, could have been done to alleviate the deaths or injuries due to the instantaneous nature in which the accidents occurred.

While all of the accidents reviewed in this list involved major releases of hazardous materials, the implications for this analysis based upon these accidents reports are substantial.

A large percentage of the shipments near the Dallas CBD were observed to be bulk gasoline tank shipments, as were those reviewed in this study. Fortunately an accident of the type and magnitude described in these reports has not happened near the Dallas CBD during high volume traffic conditions but the possibility clearly exists. Given the right circumstances, the end results could be even more catastrophic than those listed in Table 9.

An important point to note, however, is that emergency response to the incident, based upon this analysis, would probably not alleviate the immediate injuries or loss of lives. The instantaneous nature of the accident would likely precede any current capabilities or technologies to mitigate the immediate impact of the accident.

Whether an accident happens on the freeways or arterial streets being examined in this study, it is likely that should a major explosion or release of hazardous material occur, injuries and/or deaths will result before any emergency response efforts can be taken. This is not to imply that emergency response to an incident does not play an important role in the control of an incident, including evacuations, containment of the fire, and clean up.

The analogy often used regarding an accident of this type is that hazardous materials release would be similar to that of a bomb exploding. Once the explosion has occurred, little can be done to lessen its impact.

Based upon these findings it is essential that the risk assessment used for this analysis algorithm take into account the potential consequences of this type of accident. The first persons impacted will likely be the vehicle motorist sharing the facility with the trucks. While this problem may be more acute on freeways due to the higher traffic volume and densities, the decision was made to include an estimate of the potential number of motor vehicle occupants which may fall within an impact area of an accident on both the freeway and arterial routes in the consequence exposure algorithm.

A complete summary of the approach used to include motor vehicle occupants in the risk algorithm is provided in the risk assessment discussion.

A second area of concern regarding the potential consequences of an accident lies in the exposure to pedestrians and individuals occupying adjacent properties along the alternative routes. Given the results of this analysis, while motor vehicle occupants may be the initial exposures to an accident, particularly on freeways, pedestrians and people occupying residential, commercial, and industrial establishments directly adjacent to the routes will likely be impacted as well in the event of a major explosion. Due to the existence of these type of properties fronting a large percentage of the arterials being examined in this analysis, this problem is likely to be of greater consequence along the arterial street routes.

While the risk assessment algorithm does take into account population and employment along the routes, it does not specifically address the presence of commercial or recreational type establishments.

Detailed data were not available for this study to quantify this factor in the risk assessment; however, a field survey of properties directly adjacent to the alternative routes was completed. A summary of findings from this field survey is included in this document.

The risk assessment algorithm used for this analysis calculates the probability of all trucks accidents on both freeways and arterials based upon historical truck accident data. A factor of concern not fully accounted for in this study is potential hazardous materials accident severity on freeway routes versus arterial streets. Each of the hazardous materials accidents reviewed for this study occurred either on highway facilities or at railroad crossings and resulted in extensive hazardous materials releases causing major fires or gas clouds.

The question remains with regard to potential accident severity on arterial streets. Arterial street accident probability rates are traditionally much higher due to the presence of intersections, traffic signals, curb cuts, and other factors resulting in traffic conflicts. Average speeds, however, are normally lower on arterial streets due to speed limits, traffic signals, and geometrics suggesting that accident severity may be less on arterial streets.

To address these issues, a report published by the U.S. Department of Energy in 1978 regarding the risk of transporting gasoline by truck was obtained.

Because a large percentage of the hazardous materials shipments observed near the Dallas CBD were transporting gasoline, this report was informative.

It is difficult to summarize all of the information provided in this document, and interested parties are encouraged to examine the report in its entirety. However, the report contains several types of information regarding gasoline releases from tank trucks which address the issues related to the risk on arterial streets versus freeways.

It is estimated in this document that over 90 percent of the accidental gasoline releases occur from tank puncture, impact, or abrasion to the tank vehicle.(5) If vehicle speed is assumed to be a factor which coincides with accident severity, the data regarding relationships between vehicle speed and the threshold levels for the accidental release of gasoline are informative.

The results of research done in the preparation of the DOE report indicated that for a semi-tractor trailer tank to fail and rupture due to the impact of an accident, a velocity change of 23.6 mph in an end-on impact would be required. A velocity change of 18.7 mph is required when the tank is struck from the side.

The report also indicated that speeds ranging from 20 to 32 mph, depending on the road surface and condition of the tank as it comes in contact with road surfaces, would cause tank failure should the tank overturn.

The report further estimates that a tank moving at speeds as low as 1 mph coming in contact with a fixed object of a few inches in length can cause puncture to the tank.

Translating this information into the question regarding speed on freeways and arterial streets, it is apparent that both types of facilities share the potential for release of gasoline due to impact, abrasion, and puncture which may occur in an accident.

Recent estimates of average speeds for both freeways and arterials, as part of the NCTCOG Regional Travel Forecasts, indicate that the average speed on freeways in Dallas is approximately 55 mph, while arterial speeds are 30 mph. Clearly the potential exists for a tank truck traveling on either freeways or arterial streets to collide with a fixed object or a moving vehicle at speeds equal to or in excess of those described in the DOE report.

With regard to the frequency of truck accidents in relationship to vehicle speed, Table 10 provided by the DOE report shows a breakdown of the fraction of truck accidents in various speed ranges. These data represent an analysis of 10,838 truck accidents in the State of Texas. Based upon this information, the frequency of accidents is fairly well distributed over all speed ranges.

In the analysis of specific facility types and type of accidents, again both the freeway and arterials share the likelihood of accidents. Vehicles colliding with tank trucks either from the rear or side could occur on both types of facilities. However, the high number of intersections and curb cuts along the arterial street network increase the likelihood of this type of accident.

Tank abrasion as a result of a vehicle overturn onto the road surface is most likely to occur in higher speed situations in which tank trucks are forced to make rapid changes in direction either to avoid other vehicles or to negotiate

TABLE 10

TRUCK ACCIDENTS AS A FUNCTION OF PRE-ACCIDENT SPEED

| Speed Range | Fraction of All Accidents |
|---|---|
| Stop | 0.058 |
| 1-10 | 0.321 |
| 11-20 | 0.157 |
| 21-30 | 0.156 |
| 31-40 | 0.113 |
| 41-50 | 0.116 |
| 51-60 | 0.072 |
| 61-70 | 0.005 |
| Greater than 70 | 0.0005 |

Source: Prepared for the U. S. Department of Energy, Pacific Northwest Laboratory, An Assessment of the Risk of Transporting Gasoline by Truck, November 1978.

roadway geometrics. While undoubtedly the majority of higher speed situations will occur primarily on the freeway system, overturns often occur on freeway ramps. For example, an analysis of 131 tank truck accidents which occurred in California over a one-year period indicated that 58 percent of the accidents involved overturns.(6) Two-thirds of the tank overturns occurred in turning or swerving maneuvers where centrifugal force as a result of load shifts was a factor. Nearly 50 percent of the accidents involving overturns occurred on curves or freeway ramps. Two-thirds of the ramp accidents occur when leaving the ramp and one-third upon entering the ramp.

Near the Dallas CBD freeway curves and freeway-to-freeway ramp movements have often been cited as locations with difficult geometrics for truck traffic. The need to lower all truck speed limits in this area to avoid vehicle overturns was cited in an earlier study by the City of Dallas.(3)

While vehicle overturns are not likely on the arterial street system itself, in order to use the arterial street network hazardous materials shipments are forced to use a number of freeway on and off ramps. Use of these facilities, particularly for tank truck shipments, is likely to result in an increase of vehicle overturns.

A second type of related information provided in the DOT report is an evaluation of the consequences of gasoline releases. The report considered the relative accident severity and the consequences at three types of accident locations with regard to gasoline spills. These were (1) an unpopulated rural area, (2) an urban freeway and (3) a four-lane urban arterial.

The report estimates that approximately 24 percent of spills from trucks carrying flammable liquids result in a fire.

Data submitted to the Bureau of Motor Carrier Safety in 1975 were analyzed to determine the location of accidents involving spillage of flammable liquids. The data indicated that 68.9 percent of the accidents occurred on rural highways, 22.3 percent in business areas and 8.8 percent in residential areas. Data included in the DOE report from truck accidents in the State of Texas indicated that 32.7 percent of the tank truck accidents occurred on city streets and 18.6 percent on urban freeways.

According to this report however, it is not likely that an equal percentage of gasoline releases will occur on city streets.

In order to further establish accident severity the report examined truck accident data from Washington State which indicated that 2.08 percent of all truck accidents on rural highways result in a fatality while 0.47 percent of the truck accidents in urban areas are fatal. Unfortunately the methodology assumed that the accident environment on a urban freeway was similar to that found on a rural highway, which is questionable.

However, following through on the analysis, the DOE report combined the truck accident data from Texas and Washington State indicating that the probability of a truck accident occurring on a city street equal to (P = 0.327) and is fatal (P = .0047) is equal to $1.54 \times 10^{-3}$. The probability that an accident occurs on a rural highway (P = .0487) and is fatal (P = 0.0208) is $1.21 \times 10^{-2}$ and the probability that an accident occurs on an urban freeway (P = 0.186) and is fatal (P = 0.0208) is $3.87 \times 10^{-3}$.

Assuming an even distribution of truck shipments across facility types the analysis indicates that 9.9 percent of the fatalities from gasoline spills would occur on city streets, 24.9 percent on urban freeways and 65.2 percent on rural highways.

While this information provides some insight into the relative accident severity question, it is difficult to draw any significant conclusions from the analysis due to the questions regarding the assumptions used in the DOE study, the methodology used to estimate accident probability, and the lack of conclusive data to support the findings.

The DOE report also provides estimates of the probability of secondary fires to buildings adjacent to a freeway and an arterial street as a result of a gasoline spill. The results of this analysis indicated a signficantly higher probability level of secondary fires in structures directly adjacent to arterials streets as opposed to freeways.

Again, however applying information from the DOE report to the question regarding as to the relative accident severity of a freeway accident versus an accident on an arterial street is difficult. The problem arises out of the number of assumptions used in the DOE study due to lack of available data and the inability to relate these assumptions to actual conditions on the freeways and arterial streets being evaluated in Dallas.

Based upon the DOE study the following observations can be made:

- Fatalities from gasoline fires are a result of direct exposure to radiant energy from a fire or secondary fires in adjacent vehicles and buildings.

- Average speed of vehicles operating on both freeways and arterial streets in Dallas are in excess of the threshold levels outlined by DOE which would result in tank failure and material release due to tank puncture, impact and abrasion as a result of an accident. While it is anticipated that vehicles traveling at higher speeds would result in more serious accidents with a more likely chance of large explosion and fire, no data were identified to adequately substantiate this premise which could be factored into the risk assessment.

- The DOE report reinforces the need to consider motor vehicle occupants in the risk assessment algorithm and the need to further evaluate exposure to areas immediately adjacent to the arterial routing system due to the likelihood of secondary fires as a result of an accident.

Before turning to the risk assessment approach utilized for this analysis of the Dallas routes, it is important to recognize the potential causes of hazardous materials truck accidents based upon the historical accident information reviewed.

In many instances it is difficult to clearly ascertain the exact causes of the accidents. A dominant characteristic of these accidents however was either truck driver error resulting in failure to negotiate the road conditions or observe the need to take precautions or error on the part of other vehicle operators involved in the accident causing the accident to occur.

This characteristic of hazardous materials accidents as well as all accidents is an important factor to consider in the routing analysis. Areas on freeways with poor signing, vehicle weaving, poor lighting, and difficult geometrics are likely to result in an increase in accidents.

Arterial streets with non-signalized intersections, curb cuts, poor lighting and geometrics, non-signalized railroad crossings, pedestrian traffic, and on-street parking will also likely increase accident rates and the potential for an accident to occur. While the accident probabilities based on historical truck accident data used in risk assessment algorithm are likely to reflect these characteristics, <u>it is important that under any routing strategy, attention should be given to alleviating as many accident prone conditions and areas as possible.</u>

# CHAPTER VII

## IMPLEMENTATION OF THE RISK ASSESSMENT

The Phase I Regional Through-Routing Study detailed the risk assessment approach associated with hazardous materials shipments which is done by combining the probability of a hazardous materials truck accident with the potential consequences of that accident. This concept of measuring risk as outlined in the FHWA Guidelines was utilized for both the Regional Through-Routing Study and this analysis of routing options near the Dallas CBD.

Several enhancements to the risk assessment algorithm were made for the Dallas study. The following discussion summarizes the accident routing alternatives, accident probability, and accident consequence estimates input into the risk algorithm.

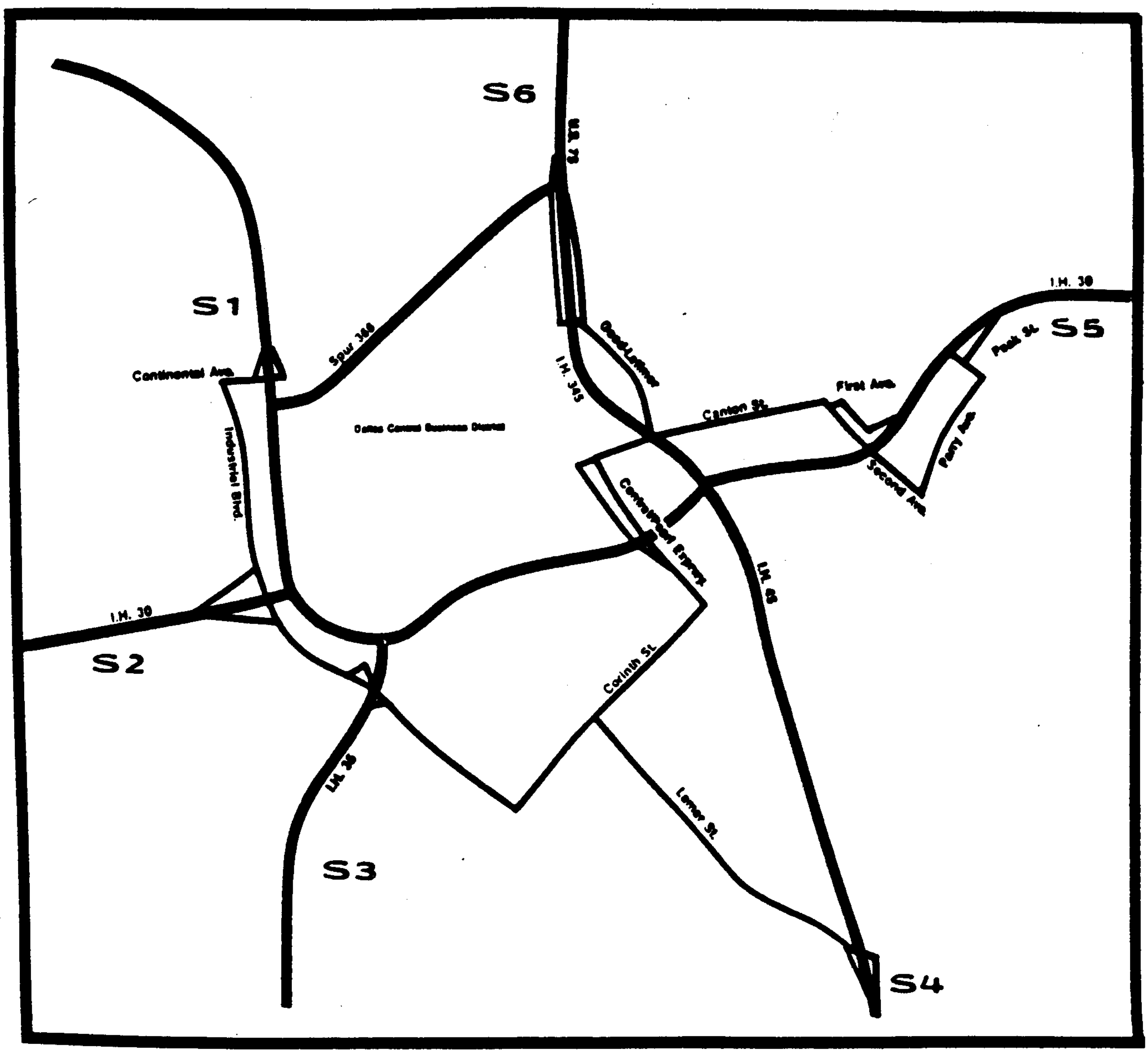
### Route Segments Analyzed

In order to implement the risk assessment approach it was necessary to divide the potential routes into freeway and arterial segments. This allowed for the data to be collected on discrete route segments as recommended by the FHWA Guidelines. The first step of this process was to identify the six locations on the freeways approaching the Dallas CBD in which the entry/exit points to the bypass arterials were established. These points numbered S1 through S6 are shown in Figure 8.

Figure 9 shows the freeway route segments designated for this analysis. Seven freeway segments were created based upon the location of interchanges between the various freeways. Efforts were made to create logical segments that would also correspond to the truck accident data on freeway facilities received from SDHPT.

## FIGURE 8

ENTRY/EXIT POINTS TO THE CBD



# FIGURE 9

FREEWAY ROUTE SEGMENTS

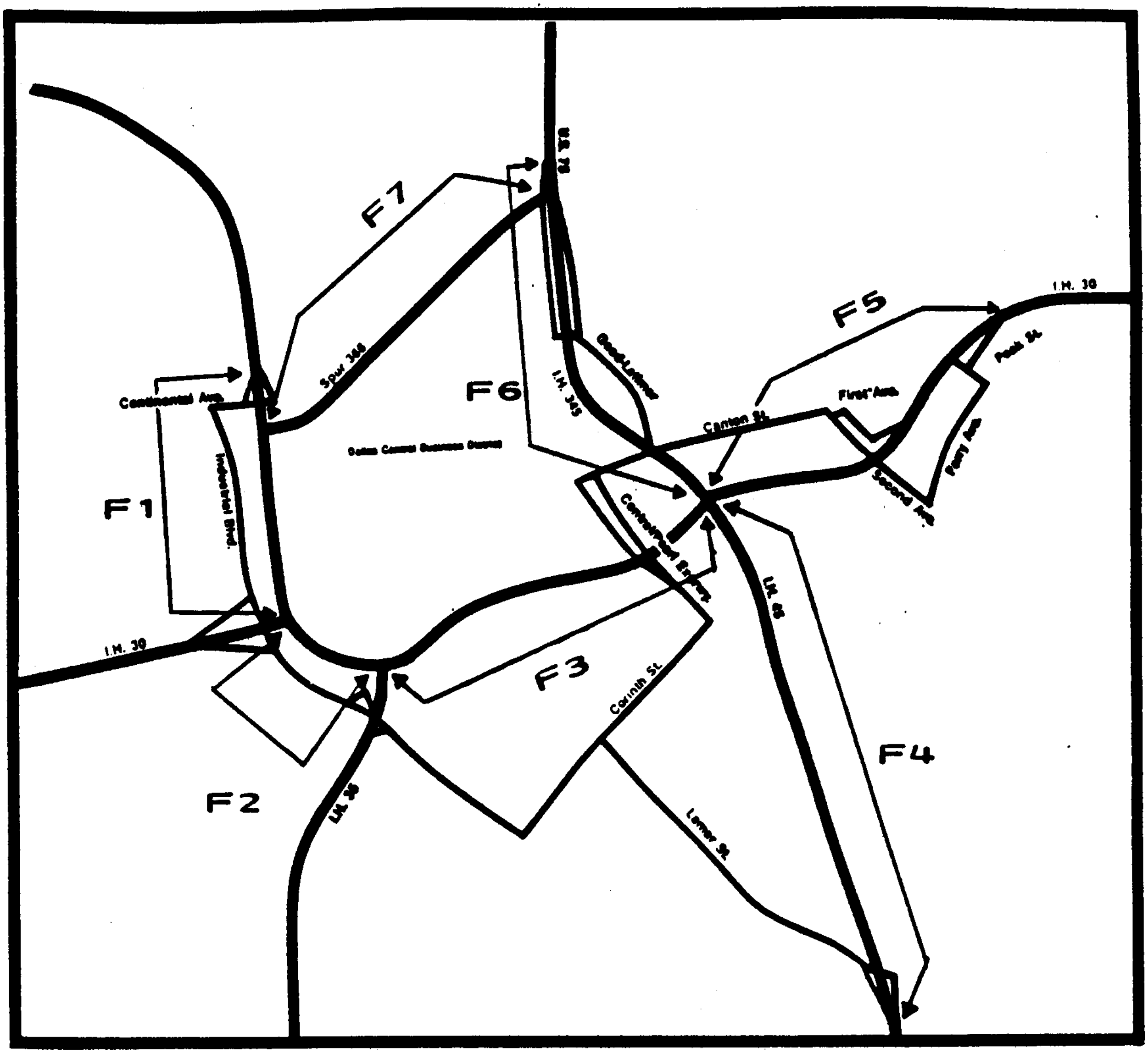


Figure 10 illustrates the arterial street segments developed for this analysis. These segments were also broken out in logical sections for data collection and implementation of the risk assessment.

Once the route segments were established, detailed information for each segment was collected regarding the length of the segment, the average number of lanes, and traffic volume. Information on the length and number of lanes for each segment was compiled from the NCTCOG master thoroughfare link file. Data regarding traffic volumes were compiled from 24-hour traffic counts for the years 1980 through 1984 and the traffic volumes estimated in the 1980 NCTCOG Regional Travel Forecasts.

A detailed listing of information on each route segment is provided in Appendix D. Table 11 summarizes the segment length, average number of lanes, and daily 24-hour traffic volume assumed for each link over the past five years. The traffic volume was used to estimate accident probability and consequences described in the following discussion.

Accident Probability

The probability of a hazardous materials accident is defined as the likelihood or chance that a vehicle carrying hazardous materials will be involved in a roadway accident. As with the Regional Through-Routing Study, this analysis utilizes the formula provided in the FHWA Guidelines to estimate accident probability, once again substituting the average number of accidents for all vehicles with the average number of truck accidents. The resultant formula is:

Probability of an Accident on Segment I = Annual Number of Truck $\text{Accidents}_I$/(Annual Number of $\text{Vehicles}_I$ * Segment Length)

## FIGURE 10

ARTERIAL ROUTE SEGMENTS

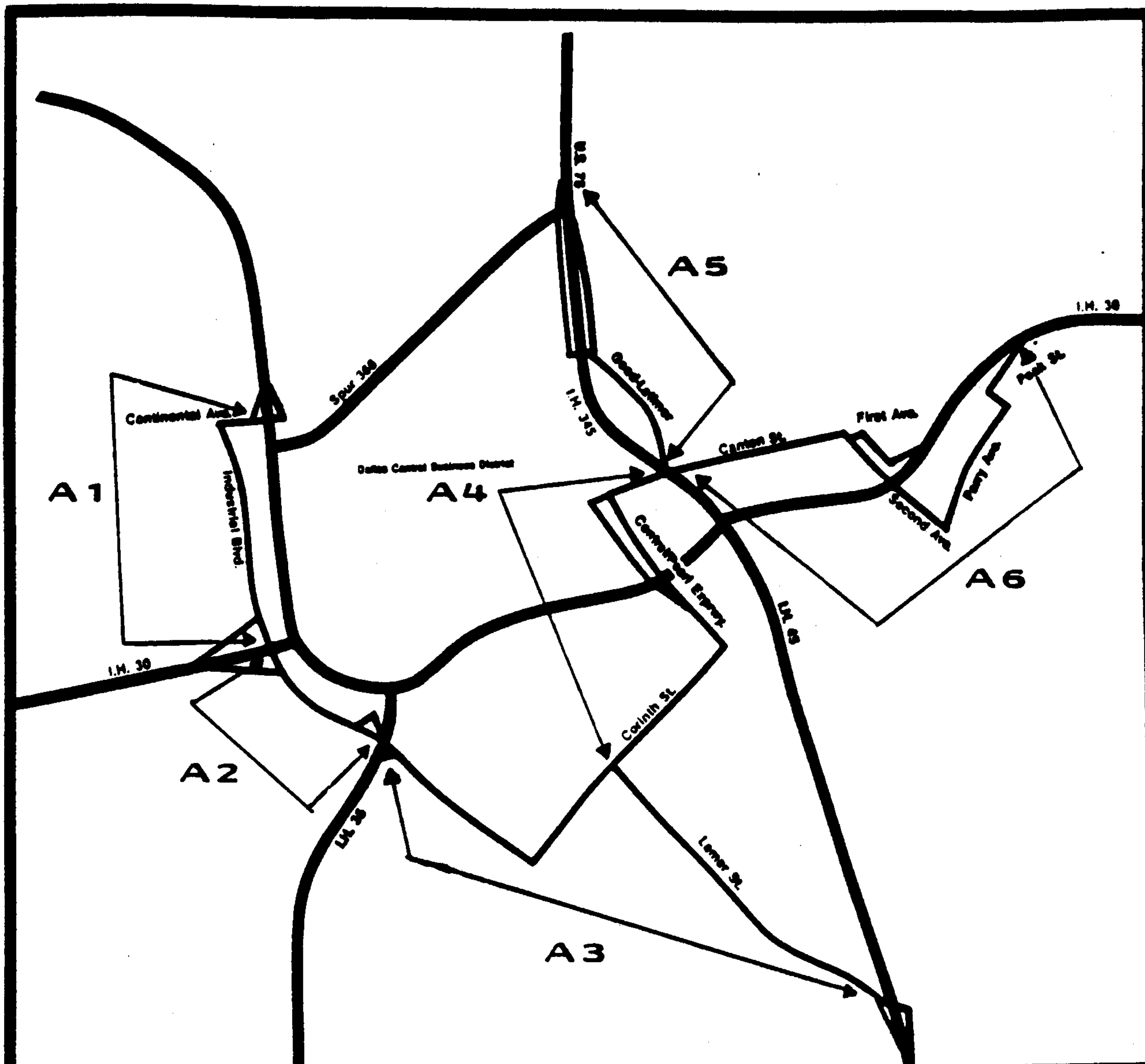


TABLE 11

ROUTE SEGMENT DATA

| Segment | Length (Miles | Number of Lanes | ADT |
|---|---|---|---|
| Arterial Segments | | | |
| A1 | 1.31 | 6 | 22,000 |
| A2 | .70 | 6 | 24,000 |
| A3 | 3.41 | 4 | 18,000 |
| A4 | 1.70 | 4 | 13,000 |
| A5 | 1.52 | 6 | 9,000 |
| A6 | 2.36 | 4 | 8,000 |
| Freeway Segments | | | |
| F1 | 3.18 | 8 | 185,000 |
| F2 | 2.34 | 8 | 184,000 |
| F3 | 4.62 | 6 | 139,000 |
| F4 | 7.0 | 6 | 8,000 |
| F5 | 2.97 | 8 | 128,000 |
| F6 | 4.79 | 6 | 107,000 |
| F7 | 4.45 | 8 | 62,000 |

While there was concern regarding the use of accident data from two sources to compare the routes, it was resolved that the accident reports from each individual accident serve as the data source for both the Dallas and SDHPT data. The accident data provided by the state originates in the City of Dallas and is then reported to the State Department of Public Safety and then on to the SDHPT.

Some questions remain regarding the accident coding and interpretation of the accident reports as to the type of truck that is coded from the accident reports since the truck categories used by the City of Dallas and the SDHPT do not correspond exactly, but this problem was not determined as significant.

Table 12 illustrates the truck accident probabilities by route segment and the value used to estimate the accident rates.

Data regarding truck accidents for the freeway segments were provided for the years 1980 through 1984 from the Traffic Safety Division of the SDHPT. This data consisted of all truck tractor/trailer and truck tractor, semi-trailer accidents summarized in one-half mile segments reported by control section and milepost.

Truck accident data for the arterial streets were collected from the annual mid-block and intersection accident summary reports from 1980 through 1984 from the City of Dallas traffic engineering department. Truck type data were collected on truck or truck tractor, truck tractor and semi-trailer, and other truck combinations, but only the truck tractor, semi-trailer data were used as it appeared to correspond with the data reported by SDHPT.

# TABLE 12

## ESTIMATES OF TRUCK ACCIDENT PROBABILITY

Hazardous Materials Routing II - Dallas CBD

| A. Arterial Segments | | | Street Blocks | Total Arterial Truck Accidents | | | | | Average Annual Accidents | Adjusted One-Way Mileage | Annual Traffic Volume | Annual VMT | Accident Probability per million VMT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Segment | Description | | | 1980 | 1981 | 1982 | 1983 | 1984 | 1980-84 | | | | |
| A1 | Continental/ | N Industrial | blocks 100-700 | 0 | 0 | 0 | 0 | 0 | | | | | |
| | Industrial | Continental | blocks 200-400 | 0 | 0 | 0 | 0 | 0 | | | | | |
| | | S Industrial | blocks 100-300 | 4 | 0 | 0 | 0 | 0 | | | | | |
| | | | Intersections | 2 | 0 | 2 | 1 | 1 | | | | | |
| | | | Total | 6 | 0 | 2 | 1 | 1 | 2 | 0.96 | 7480000 | 7180800 | 0.278520 |
| A2 | Industrial | S Industrial | blocks 400-800 | 0 | 1 | 0 | 2 | 1 | | | | | |
| | | | Intersections | 6 | 1 | 1 | 2 | 2 | | | | | |
| | | | Total | 6 | 2 | 1 | 4 | 3 | 3.2 | 0.52 | 8160000 | 4243200 | 0.754147 |
| A3 | Industrial/ | S Industrial | blocks 900-2000 | 2 | 2 | 1 | 1 | 1 | | | | | |
| | Corinth/ | S Lamar | blocks 2100-4100 | 3 | 1 | 3 | 0 | 0 | | | | | |
| | Lamar | Corinth | blocks 200-1000 | 0 | 0 | 0 | 0 | 1 | | | | | |
| | | | Intersections | 2 | 0 | 1 | 0 | 3 | | | | | |
| | | | Total | 7 | 3 | 5 | 1 | 5 | 4.2 | 2.77 | 6120000 | 16952400 | 0.247752 |
| A4 | Corinth/ | Canton | blocks 2200-2600 | 0 | 0 | 0 | 0 | 0 | | | | | |
| | Central/ | Corinth | blocks 1100-2000 | 3 | 0 | 0 | 0 | 0 | | | | | |
| | Pearl Expy/ | S Central Expy | blocks 900-2000 | 2 | 0 | 0 | 0 | 0 | | | | | |
| | Canton | | Intersections | 0 | 3 | 3 | 0 | 0 | | | | | |
| | | | Total | 5 | 3 | 3 | 0 | 0 | 2.2 | 1.7 | 4420000 | 7514000 | 0.292786 |
| A5 | Good Latimer/ | N Good Latimer | blocks 100-700 | 0 | 0 | 0 | 0 | 0 | | | | | |
| | Fr US 75 | N Central Expwy | blocks 1400-1700 | 0 | 0 | 0 | 0 | 0 | | | | | |
| | | S Good Latimer | blocks 100-200 | 0 | 0 | 0 | 0 | 1 | | | | | |
| | | | Intersections | 6 | 4 | 0 | 2 | 2 | | | | | |
| | | | Total | 6 | 4 | 0 | 2 | 3 | 3 | 1.33 | 3060000 | 4069800 | 0.737136 |
| A6 | Canton/ | Canton | blocks 2700-3500 | 2 | 0 | 1 | 0 | 0 | | | | | |
| | First/ | Parry/McCullum | blocks 3400-4200 | 1 | 0 | 0 | 1 | 0 | | | | | |
| | Second/ | S Peak | blocks 700-800 | 0 | 0 | 0 | 0 | 0 | | | | | |
| | Parry/ | 1st Ave | blocks 400-600 | 0 | 0 | 0 | 0 | 0 | | | | | |
| | Peak | 2nd Ave | blocks 400-800 | 0 | 0 | 1 | 0 | 0 | | | | | |
| | | | Intersections | 1 | 1 | 1 | 1 | 0 | | | | | |
| | | | Total | 4 | 1 | 1 | 2 | 0 | 1.6 | 2.02 | 2720000 | 5494400 | 0.291205 |

# TABLE 12
(Continued)

| B. Freeway Segments | | SDHPT Control Sections & Milepoints | Total | Freeway | Truck | Accidents | | Average Annual Accidents | Total One-way Mileage | Annual Traffic Volume | Annual VMT | Accident Probability per million VMT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| F1 | IH 35 Stemmons | cs196-03 | 29 | 28 | 30 | 19 | 17 | 24.6 | 1.59 | 62900000 | 1.0E+08 | 0.245972 |
| | | milepoint 16.2-17.1 | | | | | | | | | | |
| F2 | IH 30 IH 35 Common | cs9-11 mp3.0-3.4 | 14 | 7 | 8 | 9 | 9 | | | | | |
| | | cs1068-04mp13.0-13 | 13 | 7 | 3 | 11 | 11 | | | | | |
| | | cs196-03 mp15.7-16 | 27 | 11 | 23 | 16 | 15 | | | | | |
| | | Total | 54 | 25 | 34 | 36 | 35 | 36.8 | 1.17 | 62560000 | 73195200 | 0.502765 |
| F3 | IH 30 | cs9-11 mp3.5-4.9 | 73 | 52 | 44 | 32 | 38 | 47.8 | 2.31 | 47260000 | 1.1E+08 | 0.437846 |
| F4 | IH 45 | cs92-14 mp17.8-20.5 | 9 | 13 | 5 | 10 | 16 | 10.6 | 3.5 | 27200000 | 95200000 | 0.111344 |
| F5 | IH 30 E. ALT | cs9-11 mp5.0-6.4 | 25 | 22 | 16 | 21 | 22 | 21.2 | 1.485 | 43520000 | 64627200 | 0.328035 |
| F6 | IH 345/ US 75 | cs92-14 mp20.6-21 | 2 | 0 | 1 | 3 | 4 | | | | | |
| | | cs47-07 mp14.0-15 | 5 | 5 | 4 | 7 | 10 | | | | | |
| | | Total | 7 | 5 | 5 | 10 | 14 | 8.2 | 2.395 | 36380000 | 87130100 | 0.094112 |
| F7 | SH 366 Woodall Rogers | cs196-07 mp1.0-2.6 | 0 | 0 | 0 | 3 | 11 | 7 | 2.225 | 21080000 | 46903000 | 0.149244 |

Adjusted Mileage = Arterial Mileage minus Ramps
Annual Traffic Volume = Annual Daily Traffic * 340
VMT= Annual Traffic Volume * One-Way Mileage (Freeways)
Annual Traffic Volume * Adjusted Mileage (Arterials)
Accident Probability = Accident Rate Per Million VMT = (Average Annual Accidents / VMT) * 1000000

Table 13 illustrates accident probabilities based upon the historical truck accident data input into the risk assessment algorithm for this study. While the arterial probabilities were higher overall, these estimates are believed to be extremely conservative relative to freeway accident probabilities. These numbers reflect the likelihood of both non-reporting of accidents on arterial streets and potential problems in the vehicle classification of truck types in the data.

As a means of comparison, Table 13 shows accident probabilities for the same segments, based upon the method outlined in the FHWA Guidelines for calculating accident probability when data is not available. As can be seen, the accident probabilities for the arterial streets are considerably higher relative to the freeways using the FHWA method.

The majority of risk estimates were made using the probabilities based upon the historical accident data. In order to take into account this difference in the accident probability estimates, the FHWA accident probabilities were also input and tested in the risk algorithm to analyze the route segments.

Accident Consequence

The consequences of a hazardous materials accident for this analysis were estimated to equal the sum of total population, total employment and total number of motor vehicle occupants to fall within a specified area of the freeways and arterials.

TABLE 13

COMPARISON OF ACCIDENT PROBABILITIES

| Route Segments | Calculated Truck Accident Probabilities per million vehicle miles | FHWA Default All Vehicle Accident Probabilities per million vehicle miles |
|---|---|---|
| Arterials | | |
| A1 | 0.279 | 8.7 |
| A2 | 0.754 | 6.5 |
| A3 | 0.248 | 6.2 |
| A4 | 0.293 | 11.1 |
| A5 | 0.737 | 11.3 |
| A6 | 0.291 | 11.3 |
| Total Arterials | 0.356 | 9.18 |
| Freeways | | |
| F1 | 0.246 | 3.22 |
| F2 | 0.503 | 2.36 |
| F3 | 0.438 | 5.38 |
| F4 | 0.111 | 5.88 |
| F5 | 0.328 | 2.41 |
| F6 | 0.094 | 4.73 |
| F7 | 0.149 | 2.59 |
| Total Freeways | 0.271 | 3.79 |

## Time of Day Analysis

Several modifications were made to the FHWA consequences algorithm. The first of these was to estimate potential consequences by time of day.

In order to take into account the potential consequences of a hazardous material accident during different times of the 24-hour day, and in turn to assess the impact of potential routing options during different time periods, an estimate of accident consequences during the day from 6 a.m. until 10 p.m. and night 10 p.m. to 6 a.m. was completed. The decision to select these two time periods and the hours of each period was based upon substantially different traffic volumes and employment activity in the Dallas CBD during the day versus night periods. Due to the lack of available employment data by time of day near the Dallas CBD, data from SDHPT permanent traffic recorders located on I.H. 35E Stemmons Freeway, 1.6 miles S.E. of S.H. 356, Station S126, Station 147 on I.H. 30 at the S.H. 78 overpass east of the Dallas CBD, and Station 169, on U.S. 75 1.5 miles north of I.H. 30 near downtown Dallas were analyzed for year 1983 as a measure of overall activity near the Dallas CBD by hour.

The results of this analysis indicated that the percentage of 24-hour daily traffic dropped below 3 percent per hour at 10 p.m. and remained below this level until 6 a.m. when morning traffic builds up in the rush hour to over 7.8 percent at 8 a.m. After the morning peak period, traffic remains above 5 percent per hour, rises again to 7.7 percent per hour at 5 p.m., and gradually falls to 3 percent at 10 p.m. The results of this analysis are shown in Table 14.

## TABLE 14

### 1983 SDHPT TRAFFIC RECORDER DATA
### PERCENT TRAFFIC VOLUME BY HOUR OF DAY

| Hour | Percent Total Volume |
|---|---|
| 12-1 a.m. | 1.2 |
| 1-2 a.m. | .7 |
| 2-3 a.m. | .6 |
| 3-4 a.m. | .5 |
| 4-5 a.m. | .6 |
| 5-6 a.m. | 1.7 |
| 6-7 a.m. | 5.7 |
| 7-8 a.m. | 7.8 |
| 8-9 a.m. | 7.0 |
| 9-10 a.m. | 5.3 |
| 10-11 a.m. | 5.0 |
| 11-12 p.m. | 5.3 |
| 12-1 p.m. | 5.2 |
| 1-2 p.m. | 5.5 |
| 2-3 p.m. | 5.9 |
| 3-4 p.m. | 6.8 |
| 4-5 p.m. | 7.7 |
| 5-6 p.m. | 7.6 |
| 6-7 p.m. | 5.5 |
| 7-8 p.m. | 4.0 |
| 8-9 p.m. | 3.1 |
| 9-10 p.m. | 3.0 |
| 10-11 p.m. | 2.7 |
| 11-12 a.m. (midnight) | 2.0 |

The data are shown graphically in Figure 11 where Station S148 located 0.3 miles north of U.S. 67 south of the Dallas CBD is added. Data for the years 1980, 1981, and 1982 were also analyzed and indicated using similar trends in the percentage of traffic per hour.

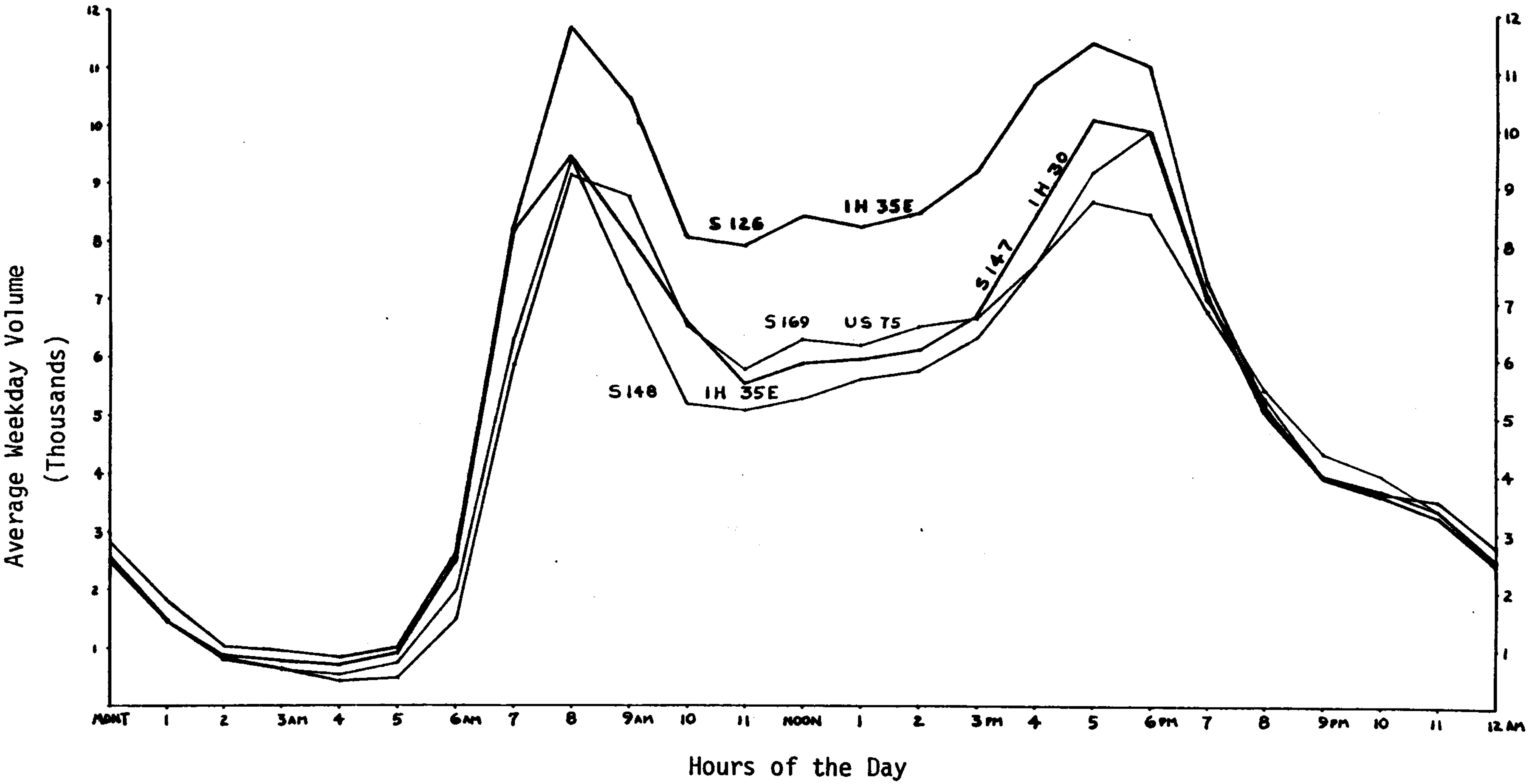
Summing the total percentage of traffic from the 6 a.m.-10 p.m. day period and the 10 p.m.-6 a.m. night period indicated that 84 percent of the traffic on freeways occurred during the day and 16 percent of the traffic occurred during the night. The use of a 6 a.m.-10 p.m., 16 hour day period and 10 p.m.-6 a.m. hour night period also represented time periods when a truck routing system could be implemented and supported the general observation regarding traffic volumes and activity near downtown Dallas.

In order to translate the percentage of travel activity by day and night periods the following calculations were made. It was assumed the 84 percent of employment activity occurred in the Dallas CBD area between the hours of 6 a.m. and 10 p.m., and 16 percent during the night hours.

With regard to day and night population, a review 1980 U.S. Census data from 35 census tracts which fell within a potential impact area of the freeway and arterial routes indicated that 40 percent of the residents of households in the area were employed. The majority of this population resided to the south and east outside of the Dallas CBD; it was not clear as to what percentage of these employees worked in the day versus the night or the work place location. Hence, all of the employees were assumed to work during the day; the day population was defined as 60 percent of the total population or the total population minus the 40 percent employed. The night population was assumed to equal the total population.

FIGURE 11

FREEWAY TRAFFIC VOLUME BY HOUR OF DAY




Source: Texas State Department of Highways and Public Transportation, Permanent Traffic Recorder Data Annual Report, 1983.

A recent study by the Regional Planning Office of SDHPT regarding the number of persons entering and exiting the Dallas CBD at various hours of the day revealed that at the 13 locations counted for a 24-hour period, with data by hour, 94 percent of the trips entering and exiting the CBD occurred between the hours of 6 a.m. and 10 p.m., and 6 percent the night period. The data indicate that the 84/16 percent day to night ratio used for employment in the CBD for this study may be a conservative estimate of this difference; a more appropriate ratio may by 90/10 or even 95/5.

Motor Vehicle Occupants

The second modification made to the FHWA risk assessment approach was to estimate the total number of vehicle occupants that could potentially fall within an impact area of an accident along the freeway or arterial. This value, once calculated for each route segment, is added to the population and employment within the same impact area.

In order to calculate this measure the following steps were followed:

1. The average daily volumes previously estimated (shown in Table 11) were allocated into hourly volumes based upon the annual percentage of daily traffic per hour in 1983 from three of SDHPT's permanent traffic recorders located on I.H. 35E, U.S. 75, and I.H. 30 in proximity to downtown Dallas. (Previously shown in Table 14).
2. The average number of vehicles per hour from 6 a.m. until 10 p.m., (16 hours) and from 10 p.m. until 6 a.m. were then calculated.
3. Given the total number of vehicles per hour by time of day, the average number of vehicles per lane per hour were then estimated.

4. Given the number of vehicles per lane and capacity per lane based upon capacities used in NCTCOG's travel forecasting procedure and traffic impact studies (shown in Table 15), the volume-to-capacity ratio per lane was estimated.

5. Based upon a segment volume-to-capacity ratio, a level of service factor was established for each segment. The factors used are recommended in the <u>ITE Traffic Engineering Handbook</u>. This relationship is illustrated in Figure 12 for freeways and Table 16 for arterials.

6. Once the volume/capacity ratio and the level of service factor for each facility were established, the estimated vehicle density per mile was completed again from Figure 12 for freeways and Table 16 for arterials.

7. The number of vehicles per lane per mile by time of day was then multiplied by the number of lanes on each segment to determine the total number of vehicles per segment per mile by day and night.

8. For each segment the number of vehicles was multiplied by the auto occupancy factor of 1.32 (a calculated average automobile occupancy used by NCTCOG in travel forecasting) to obtain the total number of vehicle occupants per mile per segment.

The results of these estimates are shown for each segment for both day and night in Table 17.

While an estimate of peak period consequences was not included in this study due to the improbability that hazardous materials truck routes or prohibitions would be established for peak periods only, an estimate of the average number of vehicle occupants per mile per hour during the peak periods (7 a.m.-9 a.m. and 4 p.m.-6 p.m.) is included for comparison.

## TABLE 15

### HOURLY SERVICE VOLUME PER LANE*
### (Divided or One-Way Roads)

**FUNCTIONAL CLASS**

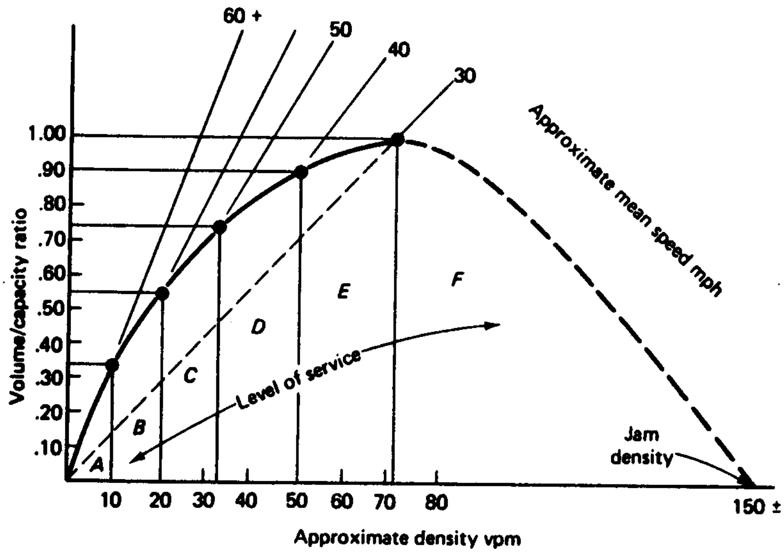
| AREA TYPE | FREEWAY | PRINCIPAL ARTERIAL | MINOR ARTERIAL | COLLECTOR | LOCAL | RAMP | FRONTAGE ROAD |
|---|---|---|---|---|---|---|---|
| CBD | 1800 | 550 | 550 | 450 | 450 | 1100 | 550 |
| FRINGE | 1850 | 600 | 600 | 475 | 475 | 1200 | 600 |
| URBAN RESIDENTIAL | 1875 | 650 | 625 | 500 | 500 | 1250 | 625 |
| SUBURBAN RESIDENTIAL | 1950 | 725 | 700 | 550 | 550 | 1400 | 700 |
| RURAL | 2000 | 800 | 750 | 575 | 575 | 1500 | 750 |

* SERVICE VOLUMES AT LEVEL OF SERVICE E (NCTCOG transportation models require level of service E service volumes. However, continued use of level of service C service volumes for planning purposes is suggested. Level of service C can be obtained by taking 80% of the above level of service E service volumes.)

- If Volume/Service Volume Ratio is <= 0.8 then Level of Service = A, B, or C
- If Volume/Service Volume Ratio is 0.8 < x <= 0.9 the Level of Service = D
- If Volume/Service Volume Ratio is 0.9 < x <= 1.0 then Level of Service = E
- If Volume/Service Volume Ratio is > 1.0 the Level of Service = F

## FIGURE 12

## RELATIONSHIP BETWEEN V/C RATIO, LEVEL OF SERVICE, AND TRAFFIC DENSITY




(a)

## TABLE 16

**Maximum Lane Service Volumes on Urban Arterials Based on 50% Cycle Split and Average Density and Speed Criteria**

| Level of Service | Average Overall Speed | | Density | | Approximate Volume*/ Lane (vehicles/h) |
|---|---|---|---|---|---|
| | mph | km/h | vehicles/mi | vehicles/km | |
| A | ≥30 | ≥48 | 10 | 6 | <300 |
| B | ≥25 | ≥40 | 20 | 12 | 500 |
| C | ≥20 | ≥32 | 30 | 19 | 600 |
| D | ≈15 | ≈24 | 45 | 28 | 675 |
| E | ≈10 | ≈16 | 75 | 47 | 750 |
| F | <10 | <16 | >75 | >47 | Variable |

*The speed–density–volume relationships implicit to this table are correct only if space mean speed is used. Average overall speed as usually measured only approximates this value.

Source: Institute of Transportation Engineers, Transportation and Traffic Engineering Handbook, Second Edition, 1982, pp. 473 and 494.

TABLE 17

SUMMARY OF VEHICLE OCCUPANTS ESTIMATES

| Segment | Day Occupants Per Mile | Night Occupants Per Mile | Peak Hour Occupants Per Mile |
|---|---|---|---|
| Arterials | | | |
| A1 | 79 | 79 | 79 |
| A2 | 79 | 79 | 79 |
| A3 | 53 | 53 | 53 |
| A4 | 53 | 53 | 53 |
| A5 | 79 | 79 | 79 |
| A6 | 53 | 53 | 53 |
| Freeways | | | |
| F1 | 528 | 106 | 792 |
| F2 | 528 | 106 | 792 |
| F3 | 396 | 79 | 594 |
| F4 | 158 | 79 | 396 |
| F5 | 370 | 106 | 370 |
| F6 | 277 | 79 | 396 |
| F7 | 106 | 106 | 106 |

As illustrated in Table 17, due to the relatively low daily traffic volumes, v/c ratios, and higher levels of service on the arterial streets, this analysis did not indicate substantial shifts in the potential number of vehicle occupants per mile by time of day on the arterial segment. A similar situation is shown for the freeway segment F7 (Woodall Rogers S.H. 366). However, for the remaining freeway segments considerable ranges of vehicle occupants occurred in the day versus night comparison.

The implication for this analysis indicates that between the hours of 10 p.m. and 6 a.m. the freeway facilities approach the same number of potential exposures to motor vehicle occupants as do the arterials.

It is imperative to point out that these values represent only estimates of the potential number of vehicle occupants under average daily optimum operating conditions for both types of facilities. Should an accident or disruption of the traffic flow occur, it is likely that these estimates may become much higher due to traffic queuing and the resultant congestion. The values are calculated based upon a step function which explains why many of the same values occur for different segments. While in reality traffic acts as a continuous flow of changing conditions, the numbers do serve to show the relative difference between freeways and arterials by time of day. The results of this analysis were input into the risk consequence algorithm described further.

Impact Area and Consequence Estimates

In order to calculate the population and employment to be potentially impacted by the freeway and arterial routes, the analysis began by assuming a one-half mile impact radius.

The value of one-half mile corresponds to the exposure area impact distance for flammable and combustible liquids in the FHWA Guidelines as well as the U.S. DOT Emergency Response Guidebook for Hazardous Materials Incidents. This value was selected initially due to the high percentage of bulk gasoline shipments observed traveling in proximity to the Dallas CBD.

It should be noted that in the Regional Through-Routing Study a two-mile impact distance was used due to the lack of available information regarding the types of materials being shipped through the metropolitan area. The two-mile area represented a worst case scenario for an accidental spill. While undoubtedly materials with larger impact distances are being shipped near downtown Dallas, based upon the industry survey and vehicle counts, these shipments are likely to be few in number.

The estimates of the amount of the total population and employment were made by plotting the one-half mile exposure areas on maps of the roadway facilities containing traffic survey zones as described in the FHWA Guidelines. The traffic survey zones which fell within each freeway and arterial segment exposure area were then recorded. The total population and employment for each of the zones, based upon population data from the 1980 U.S. Census and NCTCOG's 1980 employment estimates, were then summarized for each route segment and adjusted for time of day as described previously.

The resultant consequence estimate from this analysis for each route segment was equal to the total population and employment to fall within a half-mile area of the route segment plus the total number of motor vehicle occupants within the impact area on the segment, by time of day.

The Regional Through-Routing Study which was based only on exposure to population and employment in consequence algorithm utilized a number of FORTRAN and SAS computer programs to implement the consequence estimates, accident probability measures and total risk assessment. For this application a series of Lotus 1-2-3 spreadsheets were developed to calculate these values and implement the risk assessment. This change in the analysis approach was due to the relative small amount of data needed to implement the Dallas CBD area study as opposed to the regional routing analysis, and the need to analyze a small scale area but under much greater detail. This was accomplished by using the Lotus microcomputer application.

The Summary of Findings section will illustrate a number of different analysis approaches addressed in the study as well as changes to the many of the input parameters in the risk assessment algorithm. The modifications were easily made in the Lotus format.

For each freeway and arterial route segment the accident probability was multiplied by the potential consequence to obtain a total risk measure.

The regional through-routing analysis introduced the concept of exposure miles in which the potential accident consequence (the amount of population and employment exposed) was multiplied by the length of the route segment. This value is then multiplied by the accident probability to obtain a total risk value for each link segment. The total risk for each alternative route can be arrived at by summing the total risk value of all segments on that route. The route with the least amount of total risk can then be identified. This method was used for analysis of routes near the Dallas CBD.

Recent discussions with technicians implementing the FHWA risk assessment approach in other areas of the country, together with material from the Research and Special Program Administration of the U.S. DOT, have indicated that a more appropriate measure for the consequence algorithm (beyond that provided in the FHWA Guidelines which only uses the total population and employment along the route) was the measure of population and employment density.

Therefore, the Dallas Phase II risk assessment was done by examining both exposure miles times accident probability and exposures per mile times accident probability to obtain a total risk estimate. While this analysis allowed for two total risk measures to be tested by time of day in the analysis, this risk assessment study also involved the use of multiple exposure areas and accident probabilities.

With regard to exposure areas, while the one-half mile value represented the most common occurring evacuation distance in the "1984 Emergency Response Guidebook," these evacuation distances represent conservative consequences estimates, meaning that the evacuation distances are greater than most accidents would require for the materials observed near the CBD.

In order to test the sensitivity of this variable in the risk assessment, a one-quarter mile exposure area analysis was completed. The one-quarter mile value was also used in a study of routes in the Portland, Oregon metropolitan area which also utilized the FHWA Guidelines risk assessment approach.(7) As pointed out in the Portland study, the one-fourth mile area realistically reflects the area adjacent to the route which would first and most significantly be affected by an accidental release.

The standard procedure for a fire involving a large quantity of flammable liquid is to first evacuate the area within a radius of 1500 feet (.28 miles). A larger evacuation (one-half mile) may be required if a pressure explosion is anticipated or fumes/smoke threaten downwind areas.

As mentioned previously, accident probabilities based upon historical truck accident data and accident probabilities based upon the FHWA Guidelines were both included in this analysis.

The following is a summary of the results from the risk assessment study.

# CHAPTER VIII

## RISK ASSESSMENT FINDINGS

In order to compare the total risk of freeway routes to the arterial routes, a set of route paths from each of the six entry/exit points to all other entry/exit points was established. This resulted in 15 two-way paths or routes to be analyzed for the freeways and 15 for the arterials. Figure 8 (page VII-2) illustrates again the entry/exit points identified.

For each freeway or arterial path the total risk measures on each route segment making up that path were summed to give the total risk for each alternative route or path. The total risk on the freeway route between two points was then compared to the total risk on the arterial route connecting the same two points.

The results of this comparison begin in Table 18. This analysis is a comparison of freeway versus arterial routes using accident probabilities based on historical accident data, an accident consequence impact area of one-half mile, exposure miles as the consequence measure, and a 24-hour period of analysis.

Each path that was analyzed is listed in the left hand column. For example, the first entry is the path going from point S1 to S2. The total risk for the freeway segment connecting points S1 to S2 is equal to 13578.98. The total arterial risk value is shown to be 8306.81. A ratio of freeway path risk/arterial path risk for each interchange is shown. When this ratio is less than 1, it indicates the freeway route to be of less risk. When this value is greater than 1, the arterial route is of less risk. In this case the arterial is shown to be the least risk path between the two points.

TABLE 18

SUMMARY OF TOTAL RISK ASSESSMENT BASED ON EXPOSURE MILES
1/2 MILE AREA 24 HOUR ANALYSIS

| PATHS | FREEWAY RISK | ARTERIAL RISK | FREEWAY/ARTERIAL RATIO OF RISK |
|---|---|---|---|
| S1-S2 | 13578.98 | 8306.81 | 1.63 |
| S1-S3 | 19840.09 | 12287.73 | 1.61 |
| S1-S4 | 87114.83 | 36840.35 | 2.36 |
| S1-S5 | 73709.70 | 127172.11 | 0.58 |
| S1-S6 | 34405.26 | 163414.18 | 0.21 |
| S2-S3 | 6261.11 | 3980.92 | 1.57 |
| S2-S4 | 73535.85 | 28533.54 | 2.58 |
| S2-S5 | 72635.92 | 118865.30 | 0.61 |
| S2-S6 | 47984.24 | 155107.37 | 0.31 |
| S3-S4 | 67274.74 | 24552.62 | 2.74 |
| S3-S5 | 66374.81 | 114884.38 | 0.58 |
| S3-S6 | 54245.35 | 151126.45 | 0.36 |
| S4-S5 | 34617.01 | 120875.22 | 0.29 |
| S4-S6 | 40204.37 | 157117.29 | 0.26 |
| S5-S6 | 39304.44 | 132302.45 | 0.30 |
| TOTAL/2 | 731086.70 | 1355366.72 | 0.54 |
| TOTAL | 1462173.40 | 2710733.44 | 0.54 |

RATIO OF RISK > 1 INDICATES ARTERIAL TO BE SAFER
RATIO OF RISK < 1 INDICATES FREEWAY TO BE SAFER

The risk values for each of the 15 freeway paths and arterial paths are shown. This analysis indicated that 9 out of 15 times the freeway routes were safer while in six instances arterial routes showed less risk. The sum risk for the 15 path interchanges is shown as total/2. In order to calculate the total two-way freeway versus arterial path risk the total/2 value is multiplied by two.

This is done to represent the total two-way risk value. For instance, the risk value going from S2 to S1 is assumed to be equal to the value from S1 to S2, multiplying the total/2 value by 2 results in the total risk to and from all the interchanges.

Based upon this analysis it is shown that overall the freeway routes represent less risk than on the arterials. Routing trucks onto the arterials represents nearly twice the amount of total risk.

However the analysis also shows that in some instances the arterial routes are indeed safer. In this case when traveling from S1 located on I.H. 35E (Stemmons) to points S2 (I.H. 30 west of CBD) S3 (I.H. 35E southwest of the CBD) and S4 (I.H. 45 southeast of the CBD) the arterial routes are safer. When going on routes beyond S4, the freeway becomes safer. In examining the input data, the accident probability estimates and consequence factors are higher on the arterial segments in A4, A5 and A6 near the CBD. A summary of accident probabilities, consequences and total risk for each route segment is provided in Appendix E. The arterial routes within S1 to S4 such as S2-S3, S2-S4, and S3 to S4 show consistent findings.

It is important to note that the risk assessment showed when traveling from S1 to S5 and S1 to S6 by utilizing the Woodall Rogers, S.H. 366, (freeway segment F7 going north of the CBD) the freeway route showed less risk. No arterial route north of the CBD was analyzed as part of this study.

It must be emphasized that the risk values reported in these tables are <u>not</u> meaningful measures individually. It is the relative risk values between the routing options which are important. This relative risk value between the two routing options for each interchange is developed graphically in Figure 13. The differences in total risk for each path are shown.

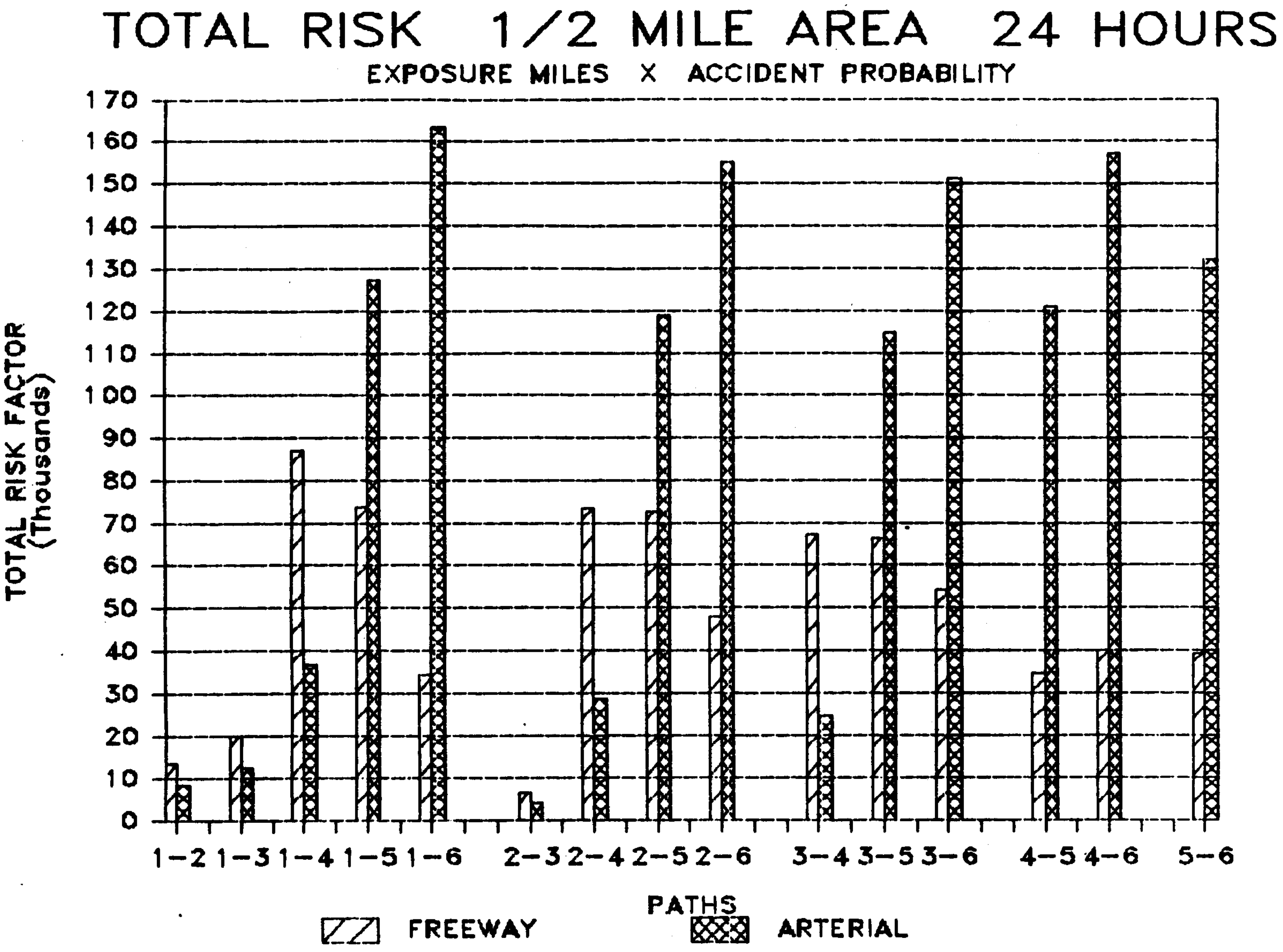
<u>While this summary will report on the findings of a number of risk assessment simulations, the findings shown in this case remained relatively constant throughout the analysis</u>.

A similar analysis was completed by time of day for the day and night periods. As shown in Table 19 the relative risk across routing segments remained similar. Figure 14 graphically displays this analysis. Table 20 and Figure 15 provide the same analysis with similar findings for the night period.

While it was anticipated that the day versus night routing would result in a shift in the total risk between arterials and freeways, <u>the results of this analysis did not support this premise</u>.

On a segment-by-segment basis the difference between risk values for arterial segments as compared to the same freeway segments become less during the night period but only slightly.

FIGURE 13



TOTAL RISK 1/2 MILE AREA 24 HOURS
EXPOSURE MILES X ACCIDENT PROBABILITY
TOTAL RISK FACTOR (Thousands)
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
1-2 1-3 1-4 1-5 1-6 2-3 2-4 2-5 2-6 3-4 3-5 3-6 4-5 4-6 5-6
PATHS
FREEWAY
ARTERIAL

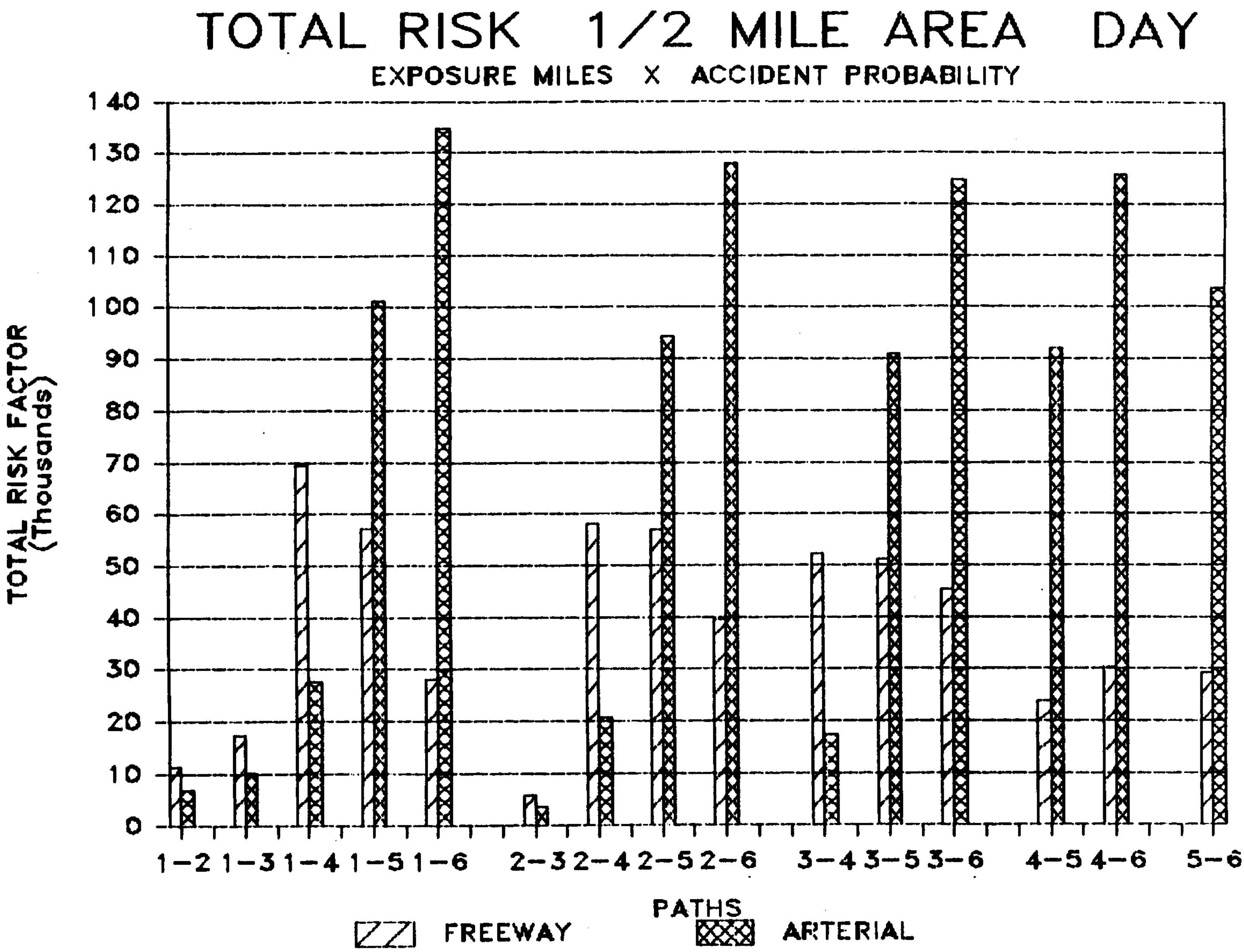
TABLE 19

SUMMARY OF TOTAL RISK ASSESSMENT BASED ON EXPOSURE MILES
1/2 MILE AREA DAY ANALYSIS

| PATHS | FREEWAY RISK | ARTERIAL RISK | FREEWAY/ARTERIAL RATIO OF RISK |
|---|---|---|---|
| S1-S2 | 11423.30 | 6882.59 | 1.66 |
| S1-S3 | 17264.59 | 10232.64 | 1.69 |
| S1-S4 | 69494.22 | 27593.54 | 2.52 |
| S1-S5 | 57259.60 | 101143.25 | 0.57 |
| S1-S6 | 28004.72 | 134874.77 | 0.21 |
| S2-S3 | 5841.29 | 3350.05 | 1.74 |
| S2-S4 | 58070.92 | 20710.95 | 2.80 |
| S2-S5 | 56993.21 | 94260.66 | 0.60 |
| S2-S6 | 39428.02 | 127992.18 | 0.31 |
| S3-S4 | 52229.63 | 17360.90 | 3.01 |
| S3-S5 | 51151.92 | 90910.61 | 0.56 |
| S3-S6 | 45269.31 | 124642.13 | 0.36 |
| S4-S5 | 23815.41 | 92101.57 | 0.26 |
| S4-S6 | 30335.59 | 125833.09 | 0.24 |
| S5-S6 | 29254.88 | 103711.88 | 0.28 |
| TOTAL/2 | 575836.61 | 1081600.81 | 0.53 |
| TOTAL | 1151673.22 | 2163201.62 | 0.53 |

RATIO OF RISK > 1 INDICATES ARTERIAL TO BE SAFER
RATIO OF RISK < 1 INDICATES FREEWAY TO BE SAFER

FIGURE 14


TOTAL RISK 1/2 MILE AREA DAY
EXPOSURE MILES X ACCIDENT PROBABILITY
TOTAL RISK FACTOR (Thousands)
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
1-2 1-3 1-4 1-5 1-6 2-3 2-4 2-5 2-6 3-4 3-5 3-6 4-5 4-6 5-6
PATHS
FREEWAY
ARTERIAL

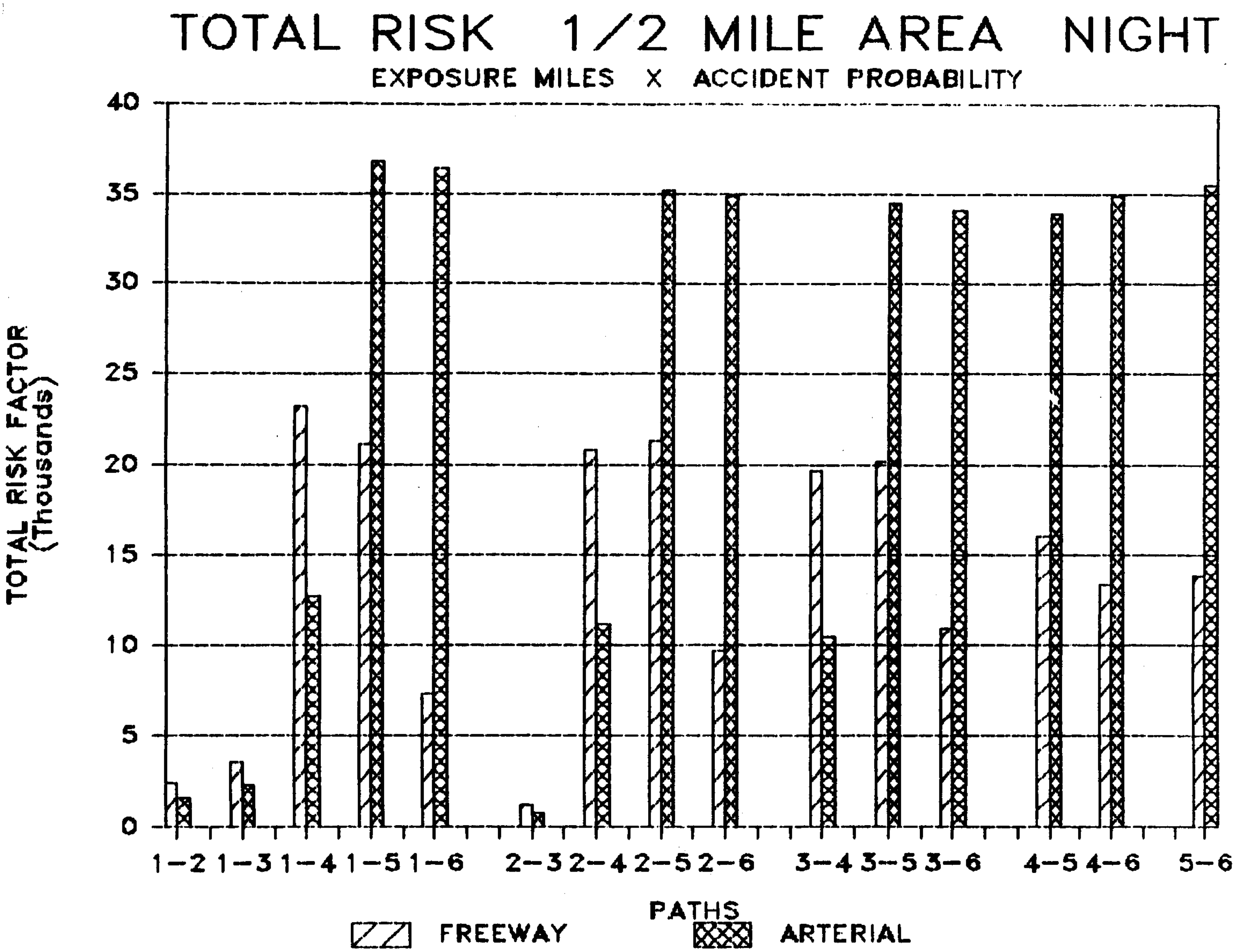
## TABLE 20

SUMMARY OF TOTAL RISK ASSESSMENT BASED ON EXPOSURE MILES
1/2 MILE AREA NIGHT ANALYSIS

| PATHS | FREEWAY RISK | ARTERIAL RISK | FREEWAY/ARTERIAL RATIO OF RISK |
|---|---|---|---|
| S1-S2 | 2408.47 | 1553.74 | 1.55 |
| S1-S3 | 3581.88 | 2289.66 | 1.56 |
| S1-S4 | 23235.16 | 12719.12 | 1.83 |
| S1-S5 | 21118.57 | 36769.10 | 0.57 |
| S1-S6 | 7307.61 | 36425.57 | 0.20 |
| S2-S3 | 1173.41 | 735.92 | 1.59 |
| S2-S4 | 20826.69 | 11165.38 | 1.87 |
| S2-S5 | 21321.98 | 35215.36 | 0.61 |
| S2-S6 | 9716.08 | 34871.83 | 0.28 |
| S3-S4 | 19653.28 | 10429.46 | 1.88 |
| S3-S5 | 20148.57 | 34479.44 | 0.58 |
| S3-S6 | 10889.49 | 34135.91 | 0.32 |
| S4-S5 | 16014.81 | 33927.83 | 0.47 |
| S4-S6 | 13315.67 | 34851.37 | 0.38 |
| S5-S6 | 13810.96 | 35508.29 | 0.39 |
| TOTAL/2 | 204522.63 | 355077.98 | 0.58 |
| TOTAL | 409045.26 | 710155.96 | 0.58 |

RATIO OF RISK > 1 INDICATES ARTERIAL TO BE SAFER
RATIO OF RISK < 1 INDICATES FREEWAY TO BE SAFER

FIGURE 15


TOTAL RISK 1/2 MILE AREA NIGHT
EXPOSURE MILES X ACCIDENT PROBABILITY
TOTAL RISK FACTOR (Thousands)
40
35
30
25
20
15
10
5
0
1-2
1-3
1-4
1-5
1-6
2-3
2-4
2-5
2-6
3-4
3-5
3-6
4-5
4-6
5-6
PATHS
FREEWAY
ARTERIAL

The reduction in CBD employment at night, which reaches its greatest exposure level from the arterial segment A4 (Central/Pearl Expressway - Canton Street), causes the arterial routes to be of less risk at night, thereby causing the freeway versus arterial segments to come closer in their total risk values during the night period.

An estimate of the exposure miles times accident probability (based upon historical data) was also done for a one-quarter mile impact area. The results of this analysis for the 24-hour period are shown in Table 21. The results are similar to those shown for a one-half mile impact area. While overall the freeway routes represent less risk, once again when traveling S1 between segments S2, S3, and S4 the arterial routes represent less risk. The one-quarter 24-hour analysis did indicate the difference between freeway and arterial risk to be less with a risk ratio of .7 in the one-quarter mile area as opposed .54 in the one-half mile area study. Again this is due to a reduction in the number of residents and employees exposed by the arterial system. These results are shown graphically in Figure 16.

Table 22 provides a summary of the risk assessment simulations completed in this analysis. The left-hand column indicates the simulation number and type. The second column describes the type of accident data used to formulate the probability estimates. The type of consequence measure, exposure/impact area simulated and the time period for each risk assessment simulation are shown in columns 3, 4, and 5 respectively. The far right-hand column provides the total freeway/arterial ratio of risk as previously defined. Risk assessment simulations 1 through 4 correspond to results previously described.

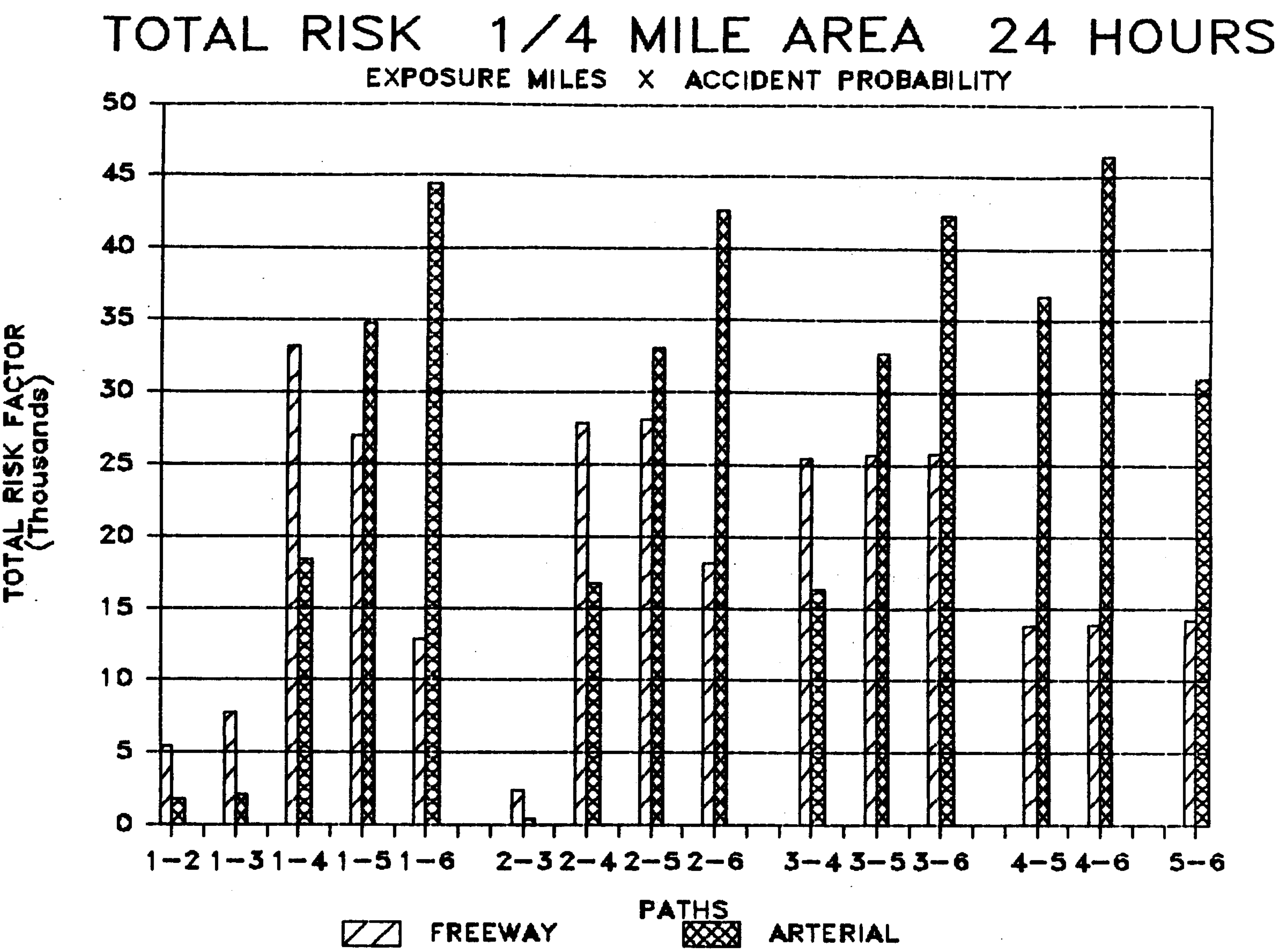
TABLE 21

SUMMARY OF TOTAL RISK ASSESSMENT BASED ON EXPOSURE MILES
1/4 MILE AREA 24 HOUR ANALYSIS

| PATHS | FREEWAY RISK | ARTERIAL RISK | FREEWAY/ARTERIAL RATIO OF RISK |
|---|---|---|---|
| S1-S2 | 5360.86 | 1714.49 | 3.13 |
| S1-S3 | 7728.44 | 2052.35 | 3.77 |
| S1-S4 | 33166.85 | 18442.27 | 1.80 |
| S1-S5 | 26995.21 | 34768.90 | 0.78 |
| S1-S6 | 12851.70 | 44387.74 | 0.29 |
| S2-S3 | 2367.58 | 337.86 | 7.01 |
| S2-S4 | 27805.99 | 16727.78 | 1.66 |
| S2-S5 | 28065.00 | 33054.41 | 0.85 |
| S2-S6 | 18212.56 | 42673.25 | 0.43 |
| S3-S4 | 25438.41 | 16389.92 | 1.55 |
| S3-S5 | 25697.42 | 32716.55 | 0.79 |
| S3-S6 | 25797.83 | 42335.39 | 0.61 |
| S4-S5 | 13784.09 | 36715.69 | 0.38 |
| S4-S6 | 13884.50 | 46334.53 | 0.30 |
| S5-S6 | 14143.51 | 30923.44 | 0.46 |
| TOTAL/2 | 281299.95 | 399574.57 | 0.70 |
| TOTAL | 562599.90 | 799149.14 | 0.70 |

RATIO OF RISK > 1 INDICATES ARTERIAL TO BE SAFER
RATIO OF RISK < 1 INDICATES FREEWAY TO BE SAFER

FIGURE 16


TOTAL RISK 1/4 MILE AREA 24 HOURS
EXPOSURE MILES X ACCIDENT PROBABILITY
TOTAL RISK FACTOR (Thousands)
50
45
40
35
30
25
20
15
10
5
0
1-2
1-3
1-4
1-5
1-6
2-3
2-4
2-5
2-6
3-4
3-5
3-6
4-5
4-6
5-6
PATHS
FREEWAY
ARTERIAL

Risk assessment simulations 5 and 6 summarize the findings of day and night analysis for a one-quarter mile area. The detailed results for route simulations 5 and 6 are provided in Appendix F.

As described previously, a second formulation of the risk measure may be obtained by dividing the total consequence factor (population + employment + motor vehicle occupants) by the length of the route segment to arrive at a density measure of exposures per mile. This value is then multiplied by the accident probability factor to obtain total risk.

<u>The results of this method are similar to earlier findings, however, using this estimate indicates the freeway to be of even less risk overall.</u> A total risk ratio of .37 is shown in Table 22 as simulation 7. In this case the freeways being of less risk, 11 out of 15 times, with the arterial routes representing 2.7 times the amount of total risk.

The results of the risk assessment using exposures per mile times accident probability (based on historical accident rates) for a one-half mile area and a 24-hour analysis for each routes are provided in Appendix F.

Simulations 8 and 9 in Table 22 provide the ratio of risk values for the day and night periods using the risk per mile consequence measure. Again, detailed data by route are provided in Appendix F.

The risk-per-mile times accident probability was also completed for the one-fourth mile impact area, 24-hour, day and night analysis. Here the results again reflected earlier findings showing interchanges S1 through S4 to be of less risk while the system overall favored the freeway segment. The total risk

TABLE 22

SUMMARY OF RISK ASSESSMENT SIMULATIONS

| Type of Simulation | Type of Data Used to Predict Accident Probability | Type of Consequence Measure | Exposure Area | Time of Analysis | Freeway/Arterial Ratio of Risk |
|---|---|---|---|---|---|
| #1 Risk Assessment | Observed | Exposure Miles | 1/2 mile | 24 hour | .54 |
| #2 Risk Assessment | Observed | Exposure Miles | 1/2 mile | Day | .53 |
| #3 Risk Assessment | Observed | Exposure Miles | 1/2 mile | Night | .58 |
| #4 Risk Assessment | Observed | Exposure Miles | 1/4 mile | 24 hour | .70 |
| #5 Risk Assessment | Observed | Exposure Miles | 1/4 mile | Day | .69 |
| #6 Risk Assessment | Observed | Exposure Miles | 1/4 mile | Night | .72 |
| #7 Risk Assessment | Observed | Exposures per Mile | 1/2 mile | 24 hour | .37 |
| #8 Risk Assessment | Observed | Exposures per Mile | 1/2 mile | Day | .38 |
| #9 Risk Assessment | Observed | Exposures per Mile | 1/2 mile | Night | .42 |
| #10 Risk Assessment | Observed | Exposures per Mile | 1/4 mile | 24 hour | .59 |
| #11 Risk Assessment | Observed | Exposures per Mile | 1/4 mile | Day | .55 |
| #12 Risk Assessment | Observed | Exposures per Mile | 1/4 mile | Night | .57 |
| #13 Risk Assessment | FHWA Default | Exposure Miles | 1/2 mile | 24 hour | .42 |
| #14 Risk Assessment | FHWA Default | Exposure Miles | 1/4 mile | 24 hour | .51 |
| #15 Vehicle Occupant Risk | Observed | Vehicle Occupants | --- | Day | 3.79 |
| #16 Vehicle Occupant Risk | Observed | Vehicle Occupants | --- | Night | 1.06 |
| #17 Circuity Measure | --- | Distance | --- | --- | 1.00 |
| #18 Risk Assessment Minus S1-S6 S2-S6 S3-S6 | Observed | Exposure Miles | 1/2 mile | 24 hour | .67 |
| #19 Risk Assessment Minus S1-S6 S2-S6 S3-S6 | Observed | Exposures per Mile | 1/2 mile | 24 hour | .53 |
| #20 Risk Assessment | Observed | Exposures | 1/2 mile | 24 hour | .46 |

ratios are shown in entries 10, 11 and 12 in Table 22. The tables and figures detailing this analysis are included in Appendix F.

In order to represent the accident default rates and resultant probabilities calculated using the FHWA Guidelines, the risk assessment algorithm was implemented using the exposure miles estimate for one-half and one-quarter mile impact area and the accident probabilities based upon the FHWA Guidelines.

Since the accident probabilities for the arterial segment were higher relative to freeways for this analysis, it was anticipated that the total risk measure would favor the freeway beyond previous comparable estimates. This was indeed the result as shown in simulation 13 of Table 22. Using the one-half mile impact area, the arterial segments showed less risk in only 3 out of 15 cases. The overall risk ratio was lowered to .42 from the .54 value calculated in the original one-half mile exposure miles estimate. Again, this indicates the freeways to be over twice as safe as compared to the arterials.

This analysis was completed by a one-quarter mile area in which similar changes in findings were obtained relative to the one-quarter mile area analysis using the historical accident data to estimate probabilities. The detailed results of the one-quarter mile area analysis (simulation 14) are included in Appendix F.

For this study an analysis was completed, of the risk to vehicle occupants. While not part of the total risk assessment, for each route segment the number of vehicle occupants was multiplied by the accident probability for that segment to obtain a total risk value based solely on the exposure to vehicle occupants. This analysis was done for the day and night periods and shown as simulations 15 and 16 in Table 22.

As was expected the risk associated with the freeway routes is significantly higher during the day due to the much higher daily traffic volumes with a resultant risk ratio of 3.79. However, it is interesting to note that during the night period the total risk values approach being equal (1.06) overall, and in some instances are higher on the arterial routes.

While it is not believed accurate to use this measure by itself in the analysis of routes due to the likelihood of exposure to the adjacent populations in the event of a gas-type chemical spill, the findings support the concept of a time of day routing in which trucks would use Interstate facilities at night and arterial routes during the day.

An evaluation of routes was made based upon the FHWA Guidelines to compare the additional route circuity which would occur when using the arterial routes. The results of this assessment indicated the total overall distance for the two routing options is equal. Therefore circuity is not believed to be a major factor. However travel time on the arterial routes is anticipated to be much longer due to speed limits, traffic signals, intersections, and congestion on the arterial network. No further analysis of this factor has been completed in this study.

Concern was noted by NCTCOG staff regarding the lack of bypass arterial routes on the north side of the Dallas CBD. This forced the use of arterial routes around the south side of the CBD when traveling from S1 to S6 on the arterial segments, and in turn raised the overall arterial risk value. An analysis of the freeway versus arterial system without the interchange S1-S6, S2-S6, and S3-S6 portions of the routing system was also done. The results indicated that the freeway system represented less risk overall by similar margins as shown in simulation 18 using the consequence measure of exposure miles and simulation 19 using exposures per mile.

A final risk assessment simulation was completed using the FHWA Guidelines' original method for estimating accident consequence. This approach does not include the length of route segment in the analysis, measuring only exposures as opposed to exposure miles or exposures per mile. The results of the simulation once again indicated similar results as shown in entry number 20 of Table 22. The ratio of risk equalled .46 indicating that arterials have over twice the amount of risk as the freeways. Risk assessment results for each route using this approach again are provided in Appendix F.

## Summary of the Risk Assessment

The results of implementing the FHWA Guidelines risk assessment indicated that overall, the freeway facilities represent less risk. Depending on the size of the impact area, the accident probability estimates used, and the risk measure, the arterials street segment overall risk ranged from 1.4 to over 2.5 times the amount of risk associated with the freeway paths.

With regard to specific path interchanges, in general the arterial route segments connecting the points S1 (I.H. 35E Stemmons) to S2 (I.H. 30), S3 (I.H. 35E) to S4 (I.H. 45) showed less risk. Once the arterial route paths involved arterial sections A4, A5, and A6, the freeway routes were of less risk.

The findings from this phase of the analysis do not support the use of the arterial routes for hazardous materials shipments in proximity to the Dallas CBD. The analysis indicates that the arterials south and west of the CBD may be of less risk, however, it is questionable if the use of these routes alone would fully address the bypass routing originally desired by the City of Dallas. Signing, implementation and enforcement of only these routes for connecting only these points would be extremely difficult and would not appear feasible.

# CHAPTER IX

## REVIEW OF SUBJECTIVE ROUTING FACTORS

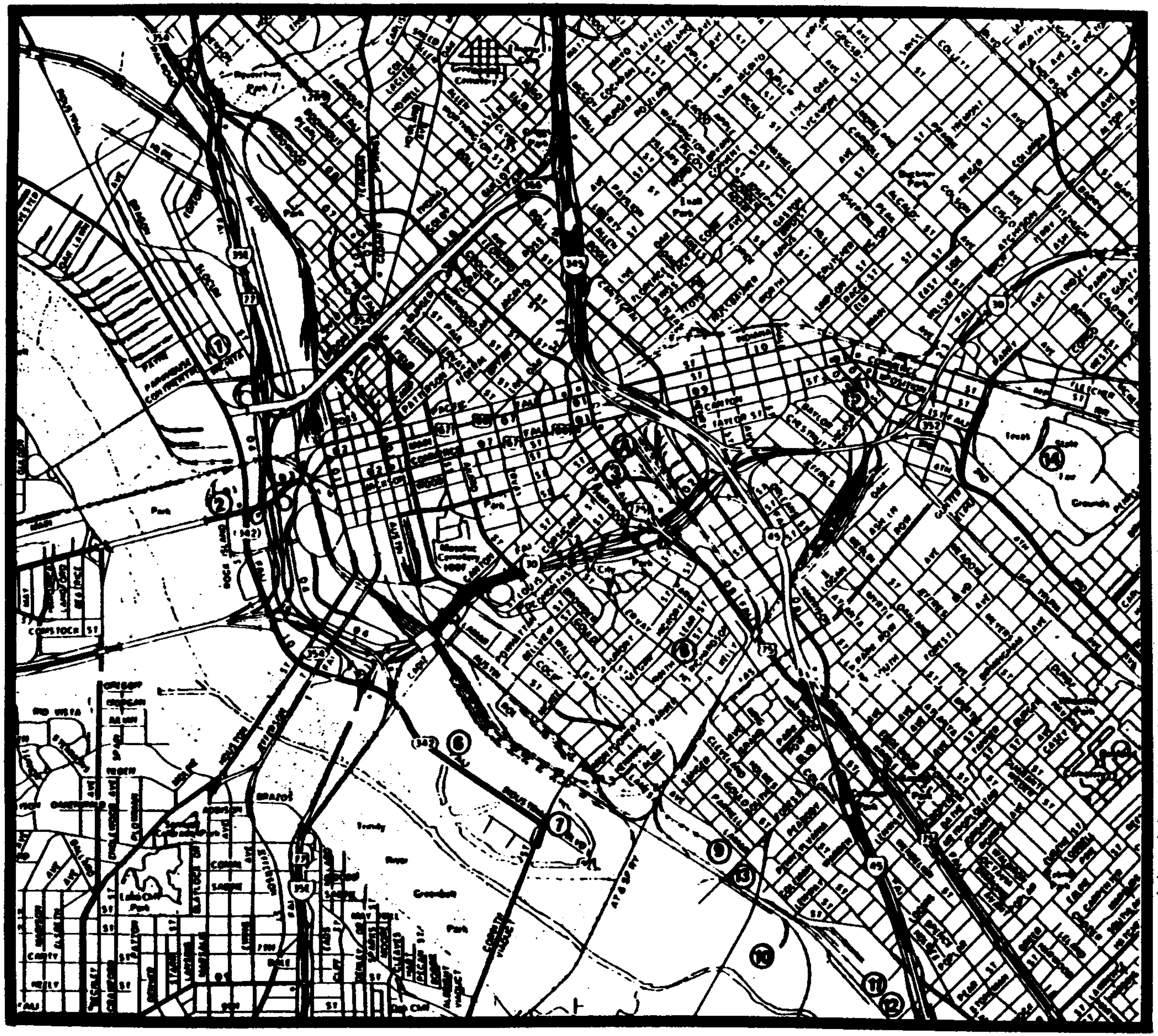
The FHWA Guidelines provide for the optional application of subjective factors. These factors represent the input of considerations which have not previously been quantified in the risk assessment. Further, the FHWA Guidelines suggest the use of subjective criteria for tie-breaking decisions where no alternative is clearly superior to the others. While the freeways represented lower risk levels overall than the arterials, a further assessment of these types of factors was completed.

As was described earlier, the exposure to motor vehicle occupants quantified in the risk assessment algorithm represents the first and most likely initial exposures to hazardous materials accidents. This problem is most acute on the freeway system, particularly in areas that are depressed, canyon-type facilities.

Along the arterial segments, motor vehicle occupants were also considered in the risk assessment, however, exposure to properties and individuals directly adjacent to the routes remain a significant concern. While adjacent properties were not considered directly in the risk algorithm, a field survey along the arterial routes was completed. The results of this survey are shown in Figure 17, illustrating the locations of major facilities along the arterial routes. This is by no means a complete list of establishments, as an estimated 40-50 smaller retail establishments, service stations, and warehouse operations were also observed along the routes as well as some residential areas.

## FIGURE 17

INVENTORY OF ESTABLISHMENTS AND ACTIVITY AREAS
ON THE ARTERIAL STREET NETWORK



1. Dupont Plaza/New Jail
2. Dallas County Jail
3. Farmers Market
4. Dallas Metro Child Care
5. Dallas Public Works
6. Sears Trucking Warehouse
7. Longhorn Ballroom
8. El Centro Job Training Center
9. Coors Plant/Warehouse
10. Diamond Shamrock Terminal
11. Proctor & Gamble
12. Demco Steel
13. Dugan Industries
14. Texas State Fair/Cotton Bowl

Areas of particular concern include facilities such as the Dallas County Jail and Dallas Metro Child Care, where evacuation would be difficult. The Farmers Market and the Fair Park/Cotton Bowl are areas where large crowds assemble on a frequent basis within several hundred feet of the arterial routes. Clearly, consideration should be given to the potential exposure and consequences of a hazardous materials accident in these areas.

<u>The trade-off between immediate exposure to motor vehicle occupants on the freeways versus immediate exposure to pedestrians and occupants of adjacent areas and facilities along the arterials will need to be made in the selection of alternative routes.</u>

In a similar routing/risk assessment study for Portland, Oregon, their analysis concluded that immediate exposure to adjacent areas was indeed an important factor.[(7)] Routes which included a clear space, or a buffer, between the roadway and these type of exposures was preferable, assuming other factors were equal. In one example given, a route prohibiting the U.S. 26 Tunnel would have required bulk gasoline tankers to use city streets which were at the same grade as downtown retail businesses and apartments. The fire department determined that if an accident occurred fire could have easily spread to adjacent structures. A freeway alternative which passed through the identical neighborhood was determined preferable because it was below grade and had approximately 130 yards of clear space separating it from immediately adjacent occupied structures. This problem also exists near downtown Dallas on the arterial routes Dallas being analyzed here. A number of truck warehouses, major industries, retail establishments, and office buildings are directly adjacent to or fall within several hundred feet of the arterial routes.

The trucking warehouses and terminals represent significant levels of congestion, delay and a potential risk for accidents. This is caused by the entry/exit of the trucks from loading docks, often blocking the arterial route while loading and unloading. These problems were particulary acute near the Sears Warehouse facility on Industrial Boulevard and a number of smaller warehouse operations along Canton between Good-Latimer and Second Street.

The presence of on-street angle parking in this section of Canton, combined with trucks at loading docks, at times rendered this facility to only two lanes, one lane, or impassable.

Several large industries including Arrow Chemical, Diamond Shamrock, Austin Steel, and Proctor and Gamble are located on the arterial segments near I.H. 45. These facilities, several of which appeared to have significant quantities of hazardous materials stored on-site, could become involved in major hazardous materials incidents should an accident occur near the plant along the arterial routes.

Roadway geometrics, poor sight-distance, tunnels, and railroad crossings, as well as many curb cuts and uncontrolled intersections are of considerable concern along the arterial routes. Examples of difficult geometrics include the exit ramp from I.H. 30 to First Avenue where there is also a railroad crossing at the end of the ramp. Another difficult area is the merge between southbound traffic on Second Street and eastbound traffic exiting off the I.H. 30 ramp near Fair Park.

Tunnel underpasses on Corinth and Good-Latimer, as well as the Central/Pearl overpass of I.H. 30, represent areas similar to the freeways in which emergency vehicle access would be difficult in the event of an accident.

In a number of instances, hazardous materials tank trucks utilizing the arterial routes were observed unable to negotiate the arterial street intersections. This often resulted in tank vehicles being brought up over the curb on right-hand turns or nearly missing other vehicles at intersections when making left-hand turns. In some instances vehicles had to back up to allow the semi-truck/tank trailers to continue through the intersection.

The intersection of Industrial and the off ramp from I.H. 30, which is not signalized, was noted as particularly dangerous with regard to the number of hazardous materials shipments observed near this location and the difficulty trucks had in attempting to head northbound on Industrial.

Finally, federal regulations regarding hazardous materials (Section 397.9 of Title 49 of the CFR) stipulate, "Unless there is no practicable alternative, a motor vehicle which contains hazardous materials must be operated over routes which do not go through or near heavily populated areas, places where crowds are assembled, tunnels, narrow streets, or alleys. Operating convenience is not a basis for determining whether it is practicable to operate a motor vehicle in accordance with this paragraph."

The regulations are clearly left open for interpretation. A comparison of the freeway routes to the arterial routes shows similar characteristics with regard to the federal regulations. The presence of "heavily populated areas, places where crowds are assembled, tunnels, and narrow streets" on the arterial routes raise serious concerns with regard to the use of the arterial bypass routes.

Emergency response considerations along the routing alternatives are important as well. While the risk assessment considered exposure to motor vehicle occupants, which is the primary concern on the freeway segments, the need to assess emergency response capabilities and issues remains. Under either type of routing strategy, emergency response issues including access, emergency response plans, and evacuation should be more fully addressed once a routing plan is established.

In summary of the subjective criteria, problems do exist on the freeways with regard to geometrics and emergency vehicle access; however, the risks associated with the arterial routes are substantial. Proximity to large crowds, numerous industries, and retail businesses, difficult geometrics for truck movements, narrow streets due to on-street parking and warehouse operations, dangerous intersections, tunnels and grade crossings, and additional travel time likely for shipments to travel through these areas represent conditions of high accident probability and potential tragic consequences. <u>These factors should be considered in the selection of hazardous materials routes</u>.

# CHAPTER X

## CONCLUSIONS

The purpose of this study was to utilize the risk assessment approach, as outlined by the FHWA Guidelines, to analyze and systematically compare the risk associated with hazardous materials shipments on the freeway facilities to the risks on the city-designated arterial street-routing system. A major emphasis of this project was to establish information on the types and frequency of hazardous materials shipments on the freeway system approaching the Dallas central business district. Several enhancements were also made to the FHWA Guidelines in an attempt to quantify the risks to motor vehicle occupants and the analysis of routes by time-of-day.

The results of the industry survey and vehicle counts indicated that significant levels of hazardous materials are being shipped in proximity to the Dallas CBD on a daily basis. The majority of these are bulk gasoline or petroleum related shipments, while a number of other types of materials representing nearly all of the U.S. DOT classes were observed on the freeway system or reported in the industry survey.

<u>The results of this effort support concerns on the part of the City of Dallas to address this problem and the need to further evaluate safety improvements designed to reduce the risks associated with these shipments</u>.

The FHWA Guidelines risk assessment approach was implemented to compare quantitatively the risks of the freeways versus arterial streets. <u>The results of risk assessment indicated the freeway routes represented less total risk overall than the arterial street routing system</u>. Risk values ranged from one and one-half times to over two and one-half times higher on the arterial street routes depending on the type of input data and the risk measures used in the risk algorithm. No significant differences in the relative risk between the freeway and arterial systems were indicated by time of day.

It is important to note that the risk assessment analysis did indicate that the arterial route segments south and west of the CBD had lower risk levels than the corresponding freeway segments. However, it is not likely that the use of these routes alone would address the bypass routing originally desired by the City of Dallas. Further, signing implementation and enforcement of only these routes for connecting the points south and west of the CBD would be extremely difficult and at this point do not appear feasible.

A factor which is not fully accounted for in the FHWA risk assessment approach is the relative severity of an accident occurring on a freeway versus an arterial route. In light of the volume of hazardous materials shipments observed near the Dallas CBD, a further evaluation of routing alternatives may be warranted should data become available to better incorporate this factor into the risk assessment.

As a follow-up to the risk assessment phase of this study, a field survey was conducted along the arterial street system to take into account those factors which should be considered in a routing alternative, but were not fully quantified in the risk analysis. The field survey revealed a number of locations on the arterial street routes with direct proximity to special populations, retail and recreation areas, and local businesses and industries. It is likely that these would be exposed to a hazardous material in the event of a serious accident.

Use of the arterial routes for hazardous materials shipments will result in shipments on facilities with high accident prone characteristics. These include freeway ramps, intersections, undivided narrow streets, tunnels, a high frequency of curb cuts, and at-grade railroad crossings. Using these facilities creates a higher accident probability, exposure risk to local populations, and prolonged travel time for hazardous materials being transported in the CBD area.

<u>Based upon these findings, the results of this study do not support the use of the arterial street routes to improve overall public safety and reduce the risk of hazardous materials truck shipments in proximity to the Dallas CBD</u>.

While the results of this study support use of the freeway system for hazardous materials shipments, significant concerns remain regarding emergency response and the potential consequences of a serious hazardous materials accident on the freeway system near the Dallas CBD. The following recommendations for further study address these concerns.

## CHAPTER XI

### RECOMMENDATIONS FOR FURTHER ANALYSIS

While establishing hazardous materials truck routes is one means of improving public safety by reducing the potential exposure to individuals in the event of an accident, clearly other types of safety programs should be pursued.

It is important to note that routing of the materials may not always result in significant risk reduction. In this study of routing alternatives near the central business district in Dallas, due to the lack of available routing options, no significant reduction in the risk level was achieved.

Throughout the course of this study a number of other types of safety programs have been proposed. Given that the results of the industry survey and vehicle counts indicated that a substantial level of hazardous materials are shipped near the Dallas CBD a number of additional safety programs should be evaluated.

The following discussion provides a summary of safety programs and projects which address the transportation of hazardous materials. These recommendations are based upon proposed safety programs, projects and strategies which have been identified by various individuals and agencies to address the risks of hazardous materials transportation and more specifically the risk of shipments in proximity to the Dallas CBD.

The first of these areas is driver licensing, training, and certification. Undoubtedly the single highest factor with relation to the cause of hazardous materials accidents, as well all motor vehicle accidents in general, relates to driver error. This characteristic in turn is related to other factors such as the lack of adequate driver training, poor driving records or habits, and drug and alcohol abuse while operating motor vehicles.

To address this issue a number of individuals including representatives of the trucking industry have proposed the development by the State of Texas of a special operators license for hazardous materials truck drivers. This license might require a safe driving record, a physical examination, some type of training certification, validation of drivers ability to operate the vehicle and an understanding of the emergency response characteristics of the materials they are hauling. Included in this program is the need for better driver training and enforcement of driver log requirements.

These programs should not be limited to only drivers but also shippers of the material. Training programs which develop knowledge of hazardous materials spill characteristics and appropriate emergency response actions should be pursued. Many private companies provide this type of training today. A statewide or national certification of both the training programs and drivers would be beneficial.

Trucking firms should be encouraged to develop programs to curb on-the-job drug and alcohol abuse as well. Firms should be encouraged to establish salary or hourly pay schedules as opposed to payments by the load to discourage both excessive speed and extended driving times.

Driver training and certification on avoiding vehicle overturns which often occur as a result of difficult roadway geometrics and speeding causing load shifts is an example of the types of training which might be required.

A review of accident reports for the year 1982 used to examine the probable cause of all truck accidents in the Mix Master interchange near the Dallas CBD suggested that two-thirds of the truck accidents in the Mix Master are due to truck driver error. The predominant contributing factors cited were:

1) Failure to maintain control of vehicle (30 percent);
2) Following too closely (21 percent);
3) Failure to yield right-of-way (21 percent);
4) Speeding (18 percent); and
5) Other factors (10 percent).

The second area often cited for safety improvements involves inspection, maintenance, and retrofitting programs for hazardous materials vehicles. The feasibility of establishing a statewide hazardous materials vehicle inspection and maintenance program should be addressed. The program should include enforcement of regulations requiring regular inspection and maintenance of brakes, steering mechanisms, suspension, tires, and electrical systems as well as tank trailer inspections for leaking or cracked tanks, the presence and functioning of all required components and accessories, and the overall integrity of the tank. Further research should be done regarding retrofitting existing tank vehicles and developing new tank designs to improve safety.

The third category of safety improvements is freeway operation improvements. While these improvements would be of particular benefit on the freeway system near the Dallas CBD, similar improvements may also be warranted at other locations in the region. Many of these programs were previously cited as needed by the City of Dallas in the study of traffic operations in the Downtown Mix Master.

The first of these programs is a reduction in the truck speed limit from 55 mph to 45 mph on the freeway system, particularly approaching ramp facilities. While this was cited as a means of reducing all truck accidents, implementing this strategy for all trucks would certainly reduce the risk of accidents involving hazardous materials. The risk of vehicle overturns, often cited as the type of hazardous materials accident resulting in loss of materials and high accident severity, would be addressed by this action. A reduction in speed limits should be coupled with a better system to enforce lower truck speeds.

A detailed examination of the locations of truck accidents in the CBD area on freeways revealed that areas with the highest accident totals were points where there is a high occurrence of weaving and merging. According to the Dallas study accidents occur because drivers are confronted with frequent navigational decisions on roadway sections which require them to abruptly reduce speeds due to the traffic slowdowns.

The Dallas Mix Master study proposes ramp redesign and additional signing to reduce erratic maneuvers and resultant accidents. Both of these strategies should be pursued further to implement existing recommendations and identify locations where these types of actions are warranted. Special attention should be given to signing freeway ramps to indicate difficult geometrics or grade changes which may result in vehicle overturns.

Lighting and pavement surface improvements were two final measures recommended by the City of Dallas Mix Master study to improve freeway operations and safety on freeways near the CBD.

A major concern in using elevated or overhead freeway structures for hazardous materials shipments is the risk of a bulk tank truck breaking through bridge rails and falling onto lower roadways resulting in a major accident and release of materials. An example of this type of catastrophic accident occurred when a truck transporting ammonia struck and penetrated a bridge rail on a ramp connecting Interstate 610 with the Southwest Freeway (U.S. 59) in Houston, Texas on May 11, 1976.

To address this concern Texas Transportation Institute, working with the State Department of Highways and Public Transportation and Federal Highway Administration, recently completed design and testing of a higher, stronger bridge rail to contain and redirect an 80,000 pound tank-type tractor trailer.(8) This is an illustration of the type of safety modifications which might be pursued in Dallas to improve freeway safety of tank shipments.

A related concern with regard to elevated structures is the difficulty in containing a hazardous substance on a bridge structure in the event of an accidental spill in which case hazardous materials would drain down onto vehicles and motorists on lower facilities. Combining guard rail improvements with a gutter or run-off system to contain spilled materials should be more fully evaluated as a potential safety improvement.

Establishing truck lanes on the freeway has often been cited as a means of reducing the conflict between trucks and other motor vehicles. While this may be difficult given the number of interchanges and ramps on the freeways near the CBD, this strategy should be further evaluated from both operational and safety aspects.

Finally, discussions have been raised throughout the course of the Phase II analysis regarding prohibiting hazardous materials shipments on the freeways during the peak-traffic periods. This would partially address the City of Dallas' concern regarding exposure to a large number of motor vehicle occupants on congested freeways in the event of an accidental release of a hazardous materials. While it is likely that hazardous materials carriers avoid traveling during the peak periods on congested facilities due to increased travel time, this strategy should be further evaluated.

A method of increasing overall capacity of the freeway system would be to restrict all truck traffic on certain freeway facilities during the peak periods. Should this strategy be pursued, this would address hazardous materials shipments as well. This approach however, would have far-reaching effects on the trucking industry and requires further evaluation from both economic and operational standpoints.

The fourth major safety improvement area identified from this study is to improve the freeway emergency response characteristics. One of the first steps needed is to develop a detailed emergency response/evacuation plan on a site-specific basis for each of the locations along the freeway system which are below grade, canyon-type facilities, or elevated structures where emergency vehicle access and evacuation are difficult.

From this plan, further efforts should then be made to locate facilities which need water hydrants or perhaps chemical foam supply. The use of fire escape ladders off of elevated structures and out of canyon facilities has been suggested and should be further elevated.

Detailed traffic rerouting plans as well as examination of an emergency vehicle access system using available freeway ramps, frontage roads and contra-flow freeway-type lanes with traffic barriers should be evaluated. A detailed examination of these considerations may also warrant construction of emergency access facilities.

The final area for suggested improvement is to further develop emergency response capabilities and better enforcement techniques.

Fire personnel training for responding to a hazardous materials accident on a freeway should be pursued. The development of hazardous materials response teams as a highly trained, skilled sub-unit of the fire department to deal specifically with hazardous materials incidents have been developed by several major cities in the United States. This may be a useful technique for improving freeway emergency response to a hazardous materials accident.

Additional training coupled with equipment needs should be addressed. Several cities have acquired or developed hazardous material emergency response vehicles which provide special on-site capabilities for better handling of hazardous materials incidents.

These programs represent potential safety improvements which have been identified throughout the course of this study to address the risks of hazardous materials truck shipments. Current plans for future freeway construction may call for the use of additional elevated or depressed below-grade freeway facilities to meet growing traffic demands. Efforts should be made to evaluate future facilities of this type with regard to the risks identifed in this study and the need for additional safety considerations which should be taken into account.

# Hazardous Materials Routing Study Phase II Technical Appendix

## *Analysis of Hazardous Materials Truck Routes in Proximity to the Dallas Central Business District*

October 1985

North Central Texas
Council of Governments

CITY OF DALLAS

December 16, 1985

Dan Kessler, Senior Transportation Planner
North Central Texas Council of Governments
P.O. Drawer COG
Arlington, Texas 76005-5888

Re: Hazardous Material Routing Study Phase II

The Dallas Fire Department has been involved with the Hazardous Material Routing Study Phase II - Analysis of Hazardous Materials Truck Routes in Proximity to the Dallas Central Business District from the onset. Fire Department personnel have attended meetings at which the study was discussed first in concept, later as interim results, and last as a review of the completed study. At each meeting we have expressed concerns with the concept of routing hazardous materials through below grade (in areas where canyon effects are created) and elevated sections of the freeway. The concerns expressed are as follows:

1. Danger of a hazardous material incident trapping motorists in their vehicles and leaving them without any viable escape route. If this scenario were to unfold, tens or perhaps hundreds of motorists could be incinerated or poisoned while still in their vehicle or in the vicinity of their vehicle.

2. Lack of emergency access to the elevated or below grade areas of the freeway system present unique problems for reaching the scene of a hazardous material incident due to traffic congestion. A delayed response to a hazardous material incident could be very costly in terms of lives and property.

3. Lack of fire hydrants in the elevated or below grade portions of the freeway system present problems in obtaining water for controlling a hazardous material incident. Water is the common demoninator in controlling most hazardous material incidents.

FIRE DEPARTMENT CITY HALL DALLAS, TEXAS 75201 TELEPHONE 214/670-4607

4. Elevated portions of the roadway create problems when dealing with hazardous liquid spills. The liquids, whether burning or not, will create another hazardous material incident as they flow to the roadway below.

We have also expressed our concern that consideration should be given to the severity of truck accidents as well as the frequency of truck accidents for determining whether or not an arterial route is safer or more hazardous than the elevated and below grade portions of the freeway system. While we do not dispute the results of the study that show a higher truck accident rate for the arterial routes, we do feel that the likelihood of a rupture that releases cargo is more apt to occur in a freeway accident. Assuming that to be the case, then it is logical that the study would have, in all probability, indicated that the arterial route was safer had the severity of truck accidents been factored in.

Results of the Phase II routing study do not, in the Fire Department's opinion, justify any alteration in our current routing ordinance which bans hazardous materials carriers from below grade freeways and portions of overhead freeways. Therefore, it is our recommendation that the study be expanded to include the severity of truck accidents when exposure factors are developed for routes. In addition, an expanded study could examine other possible arterial routes that would lessen the exposure factor.

R. E. Melton

R. E. Melton, Assistant Chief
Fire Prevention
Dallas Fire Department

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# APPENDIX A

## CITY OF DALLAS HAZARDOUS MATERIALS TRUCK ROUTE ORDINANCE

## BACKGROUND

Accidents on Dallas streets have resulted in major fires, explosions, and hazardous chemical spills. These incidents have caused substantial damage to property, extreme exposure and risk to citizens, and extensive commitment of City of Dallas emergency forces.

Accordingly, the City Council has prohibited **through** shipment of hazardous materials other than on designated routes. Carriers within the city must have a specific point of departure (defined as a "Dallas terminal" in the City Code) or a specific destination (an offloading site).

An explosion and major fire caused by a derailment in February 1977 highlighted problems of hazardous materials transportation in Dallas. As a result, City statutes and procedures governing such transport were strengthened. The Council in October 1978 amended the City Code to designate through shipment routes and to prohibit hazardous materials carriers from using certain freeways and tunnels (Code section printed on reverse). Enforcement of the amended Code reduces the jeopardy to citizens in high-density areas from the through shipment of hazardous materials. The Dallas Fire Department and other City emergency-response agencies have developed and exercised plans to minimize the severity of any hazardous materials incident.

## ROUTES

The map below identifies authorized and prohibited areas for the transport of hazardous materials. Vehicles are permitted on: Interstate 635 and connecting segments of Interstate 20, Spur 408, Walton Walker Boulevard (Loop 12), and Interstate 35E (Stemmons Freeway). Outside this loop to the Dallas city limits, vehicles may operate on state or federal highways which directly connect to the loop.

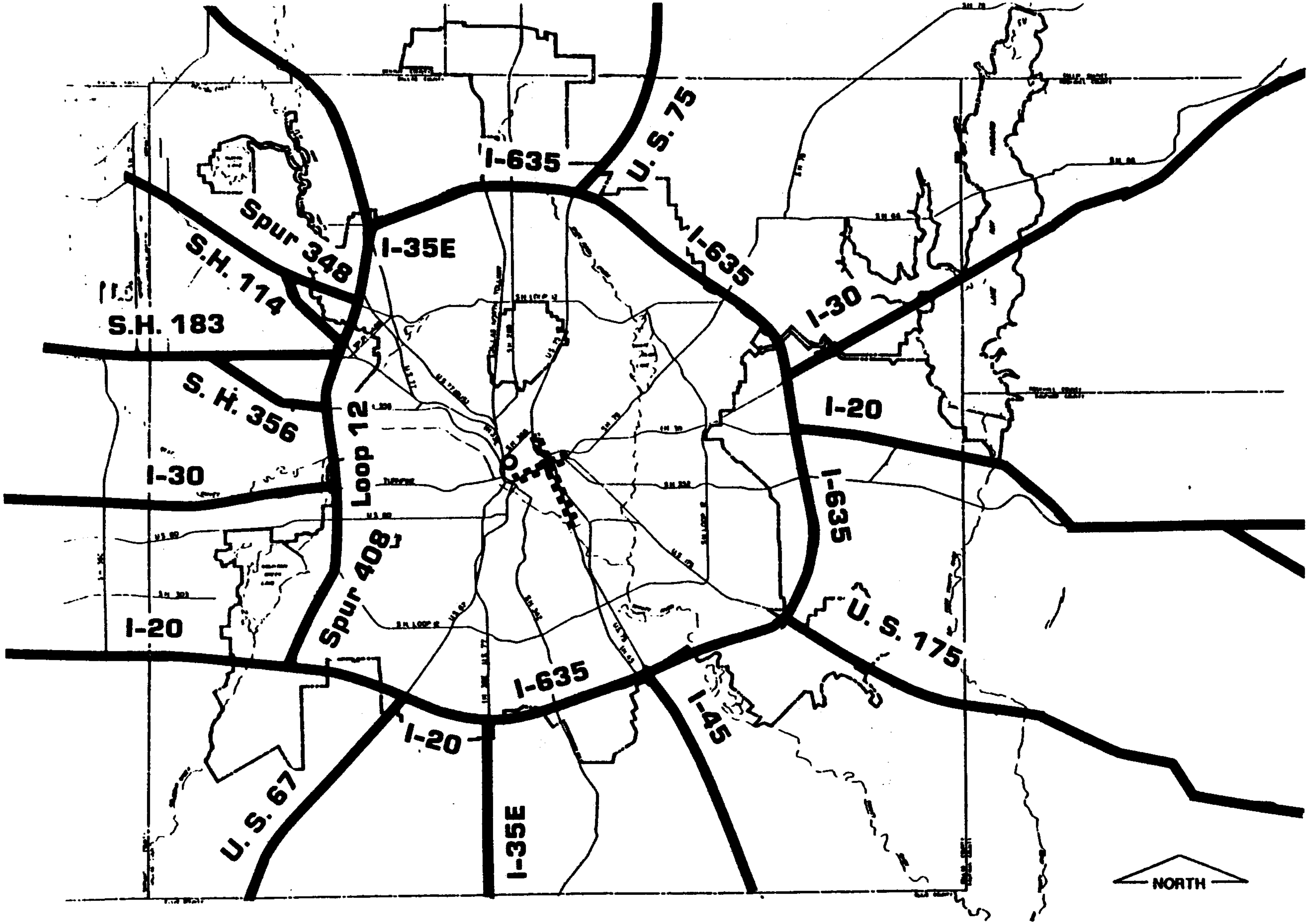
Vehicles are prohibited on: R. L. Thornton Freeway (Interstate 30) from Stemmons Freeway (Interstate 35E) [on the west] to Oakland Avenue overpass [on the east]; the elevated portion of Julius Schepps Freeway (Interstate 45) from the Bryan Street underpass [on the north] to the Lamar Street underpass [on the south]; and in any underground delivery (tunnel) systems.

## ENFORCEMENT

Signs designating hazardous routes are erected on major approaches to Dallas. These signs will read "HAZARDOUS MATERIALS ROUTE." Certain other signs provide directions to authorized routes. Restricted areas are patrolled to enforce the City Code. Noncompliance results in citation to Municipal Court.

## QUESTIONS

For more information call the Dallas Fire Department, Fire Prevention Education & Inspection Division at 670-4628 (2014 Main St. Room 401; Dallas, Texas 75201).




Authorized Routes
Prohibited Routes
o Prohibited Underground Delivery (tunnel) Systems

# THE CITY OF DALLAS HAS A

# HAZARDOUS MATERIALS TRANSPORT ROUTING ORDINANCE

TRANSPORTATION OF HAZARDOUS MATERIALS IN VEHICLES BEARING PLACARDS REQUIRED BY THE U.S. DEPARTMENT OF TRANSPORTATION IS PROHIBITED ON STREETS AND HIGHWAYS WITHIN THE CITY WITH THE FOLLOWING EXCEPTIONS:

1. THE HAZARDOUS MATERIALS MAY BE SHIPPED TO OR FROM A LOCATION WITHIN THE CITY LIMITS OR A DALLAS SHIPPING TERMINAL WITHIN 5 MILES OF THE CITY LIMITS. SUCH SHIPMENTS ARE BANNED FROM ALL "PROHIBITED HAZARDOUS MATERIALS AREAS"*.

2. THE HAZARDOUS MATERIALS MAY BE TRANSPORTED THROUGH THE CITY ON THE LOOP FORMED BY I-635; I-20; SPUR 408; I-35E AND INTERCONNECTING HIGHWAY ROUTES OUTWARD TO THE CITY LIMITS.

*"PROHIBITED HAZARDOUS MATERIALS AREAS" CONSIST OF THE FOLLOWING:

1. JULIUS SCHEPPS FREEWAY (I-45) FROM LAMAR STREET ON THE SOUTH TO BRYAN STREET ON THE NORTH.

2. R. L. THORNTON FREEWAY (I-20) FROM LAMAR STREET ON THE WEST TO OAKLAND AVENUE ON THE EAST.

3. ALL TUNNEL DELIVERY AREAS WITHIN THE CITY.

ORDINANCE NO. 15984

An Ordinance amending Section 16-19.104, "Transportation of Hazardous Chemicals, "of CHAPTER 16, "FIRE PROTECTION," of the Dallas City Code, as amended; regulating transportation of hazardous materials within the city; prohibiting the transportation of hazardous materials on certain segments of public highways and streets; providing a penalty; providing a saving clause; and providing an effective date.

BE IT ORDAINED BY THE CITY COUNCIL OF THE CITY OF DALLAS:

SECTION 1. That Sec. 16-19.104, "Transportation of Hazardous Chemicals," of CHAPTER 16, "FIRE PREVENTION," of the Dallas City Code, as amended, is amended to read as follows:

"SEC. 16-19.104. TRANSPORTATION OF HAZARDOUS MATERIALS.

(a) In this section:

(1) DALLAS TERMINAL means a freight terminal of a motor carrier that handles shipments of materials destined to or from the City of Dallas, so long as the terminal is within the city or within 5 miles of the city limits.

(2) HAZARDOUS MATERIALS means those materials classified as hazardous by the United States Government through the Secretary of Transportation pursuant to his authority under 49 U.S.C.A. Sec. 1801, et seq., (1976), except explosives, blasting agents, and explosive ingredients as defined in this article.

(3) REQUIRING PLACARDS means any vehicle transporting hazardous materials in sufficient quantity to require placarding as set forth in the D.O.T. Hazardous Materials Regulations (49 U.S.C.A. Sec. 1801, et seq (1976)

(4) PROHIBITED HAZARDOUS MATERIALS AREA means the following streets and public highways and segments of streets and public highways:

(A) R. L. Thornton Freeway, from I-35 to Oakland Avenue Overpass;

(B) I-45 Elevated Freeway from Lamar Underpass to Bryan Street Underpass;

(C) Underground tunnel systems.

(b) No person shall transport hazardous materials within the city unless his destination or point of departure is a Dallas terminal or other location within the city.

(c) The prohibition of subsection (b) shall not apply if the hazardous materials are transported on:

(1) Interstate Highway 635 and connecting segments of Interstate Highway 20, Spur 408, Walton Walker Boulevard, and Interstate Highway 35-E; or

(2) State or federal highway directly connecting the foregoing route outward to the city limits.

(d) The prohibition of subsection (b) shall not apply if a vehicle that is used to transport hazardous materials is empty.

(e) The operator of a vehicle used to transport hazardous materials requiring placards shall:

(1) apply and display appropriate placards meeting D.O.T. specifications on each end and each side of the vehicle; and

(2) before operation, inspect the vehicle and determine that:

(A) the brakes are in good working condition;

(B) the steering mechanism is in good working condition;

(C) the electrical wiring is well insulated and firmly secured; and

(D) the vehicle is in a condition adequate to safely transport hazardous materials.

(f) No operator of a motor vehicle transporting hazardous materials as defined in subsection (a) subparagraph (2), and scheduled for delivery to or from a Dallas Terminal shall transport those materials on any street or public highway, or segment of a street or public highway, now or hereafter designated as a "Prohibited Hazardous Materials Area".

SECTION 2. That a person violating a provision of this Ordinance, upon conviction, is punishable by a fine of not less than $150 nor more than $200.

SECTION 3. That CHAPTER 16 of the Dallas City Code, as amended, shall remain in full force and effect, save and except as amended by this Ordinance.

SECTION 4. That the terms and provisions of this Ordinance are severable and are governed by Section 1-4 of CHAPTER 1 of the Dallas City Code, as amended.

SECTION 5. That this Ordinance shall take effect immediately from and after its passage and publication in accordance with the provisions of the Charter of the City of Dallas, and it is accordingly so ordained.

APPROVED AS TO FORM:

LEE E. HOLT, City Attorney

By ______________________
Assistant City Attorney

Passed and correctly enrolled OCT 09 1978, 1978.

0540B/jn

# APPENDIX B

# INDUSTRY SURVEY

NORTH CENTRAL TEXAS COUNCIL OF GOVERNMENTS

TRANSPORTATION OF HAZARDOUS MATERIALS

INDUSTRY SURVEY

Company Name: ______________________________________________

Address: ______________________________________________

______________________________________________

Contact Person: __________________________ Telephone: ____________

Major Standard Industrial Classification Code: ____________________

Hazardous materials of interest in this survey are all materials, including waste materials, shipped or received in quantities and forms which by law require placarding of the vehicle as regulated by the U. S. Department of Transportation.

1. Does your firm handle hazardous materials? Yes _____ No _____
   If no, please return questionnaire.

2. If yes, please specify the following information with regard to your hazardous materials related operations.

Company Type: _______ Manufacturer _______ User _______ Shipper _______ Carrier

_______ Storage _______ Other (Explain) ____________________

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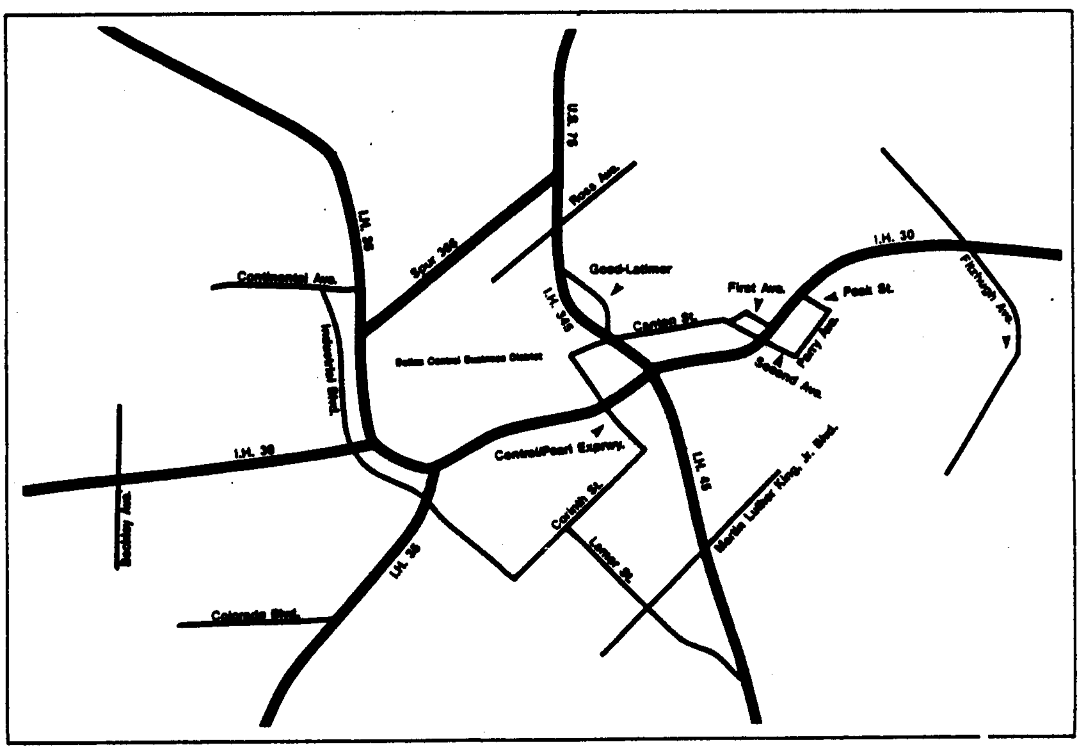
DALLAS CENTRAL BUSINESS DISTRICT AREA



3. If you ship or transport hazardous materials into or in the proximity of the Dallas Central Business District (CBD), please provide the following information. A reference map of roadways in the Dallas CBD area is found on page 1.

| Freeway Facilities (any portion of) | Location | Does Your Company Designate These Routes For Drivers? Yes | No | Proper Shipping Name of Material - Specify UN, NA or STCC Shipping Code and Code Number | How Often Do These Shipments Occur (Specify Daily, Weekly, Monthly, Yearly) | Average Volume Per Shipment | Usual Time of Day |
|---|---|---|---|---|---|---|---|
| Interstate 30 | Between Beckley Ave. (West of CBD) and Fitzhugh Ave. (East of CBD) | | | | | | |
| Interstate 35E | Between Colorado Blvd. (Southwest of CBD) and Continental Ave. (Northwest of CBD) | | | | | | |
| Interstate 45, 345 & U.S. 75 | Between Martin Luther King Jr. Blvd. (Southeast of CBD) and Ross Ave. (Northeast of CBD) | | | | | | |
| Spur 366 (Woodall Rogers Freeway) | Between U.S. 75 (East of CBD) and I.H. 35E (West of CBD) | | | | | | |

Table Continued on Following Page

Attach Additional Sheets If Necessary

| Local Streets Designated as Hazardous Materials Routes by the City of Dallas | Location | Does Your Company Designate These Routes For Drivers? | | Proper Shipping Name of Material - Specify UN, NA or STCC Shipping Code and Code Number | How Often Do These Shipments Occur (Specify Daily, Weekly, Monthly, Yearly) | Average Volume Per Shipment | Usual Time of Day |
|---|---|---|---|---|---|---|---|
| | | Yes | No | | | | |
| Continental Blvd. | Between I.H. 35E and Industrial Blvd. | | | | | | |
| Industrial Blvd. | Between Continental Blvd. and Corinth St. | | | | | | |
| Corinth Street | Between Industrial Blvd. and Central/Pearl Expressway | | | | | | |
| Lamar Street | Between I.H. 45 and Corinth St. | | | | | | |

Table Continued on Following Page

| Local Streets Designated as Hazardous Materials Routes by the City of Dallas | Location | Does Your Company Designate These Routes For Drivers? Yes | No | Proper Shipping Name of Material - Specify UN, NA or STCC Shipping Code and Code Number | How Often Do These Shipments Occur (Specify Daily, Weekly, Monthly, Yearly) | Average Volume Per Shipment | Usual Time of Day |
|---|---|---|---|---|---|---|---|
| Canton Street | Between Central/Pearl Expressway and First Ave. | | | | | | |
| Good Latimer Expressway | Between Canton St. and I.H. 345 | | | | | | |
| Central/Pearl Expressway | Between Corinth St. and Canton St. | | | | | | |
| First Avenue | Between I.H. 30 and Canton St. | | | | | | |

Table Continued on Following Page

| Local Streets Designated as Hazardous Materials Routes by the City of Dallas | Location | Does Your Company Designate These Routes For Drivers? Yes | No | Proper Shipping Name of Material - Specify UN, NA or STCC Shipping Code and Code Number | How Often Do These Shipments Occur (Specify Daily, Weekly, Monthly, Yearly) | Average Volume Per Shipment | Usual Time of Day |
|---|---|---|---|---|---|---|---|
| Second Avenue | Between Canton St. and Parry Ave. | | | | | | |
| Peak Street | Between Parry Ave. and I.H. 30 | | | | | | |
| Parry Avenue | Between Second Ave. and Peak St. | | | | | | |

4. If you ship or transport hazardous materials in the City of Dallas or in the Dallas area, please list routes commonly used to and from your facility and information regarding shipments on those routes.

| Roadway | Location | Does Your Company Designate These Routes For Drivers? | | Proper Shipping Name of Material - Specify UN, NA or STCC Shipping Code and Code Number | How Often Do These Shipments Occur (Specify Daily, Weekly, Monthly, Yearly) | Average Volume Per Shipment | Usual Time of Day |
|---|---|---|---|---|---|---|---|
| | | Yes | No | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |

Attach Additional Sheets If Necessary

See Question 5 On Back

5. Please provide any general recommendations you have for hazardous materials truck routes in the Dallas-Fort Worth area.

PLEASE RETURN THE SURVEY BY MARCH 22, 1985

APPENDIX C

SUMMARY OF HAZARDOUS MATERIALS
VEHICLE COUNTS STATION S1

I.H. 35
6 a.m. - 10 a.m.
April 16, 1985

# HAZARDOUS MATERIALS VEHICLE COUNTING FORM

Roadway Survey Location ______________________________

Date ___________________________

| Time | Vehicle Type | Placard Type and/or Code # (4 Digit) | Vehicle Direction | Carrier Name | Commodity ID |
|---|---|---|---|---|---|
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| | | | | | |

# SUMMARY OF HAZARDOUS MATERIALS
# VEHICLE COUNTS STATION S1

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 134 | IH35 E S1 | 4-16-85 | 6:00 AM | TANK | NA | SOUTH | ISI | NA |
| 135 | IH35 E S1 | 4-16-85 | 6:11 AM | TANK | 1203 | SOUTH | NA | GASOLINE |
| 136 | IH35 E S1 | 4-16-85 | 6:16 AM | TANK | 1203 | SOUTH | NA | GASOLINE |
| 137 | IH35 E S1 | 4-16-85 | 6:21 AM | TANK | 1203 | SOUTH | THOMPSON | GASOLINE |
| 138 | IH35 E S1 | 4-16-85 | 6:30 AM | TANK | NA | SOUTH | NA | NA |
| 139 | IH35 E S1 | 4-16-85 | 6:38 AM | TANK | 1013 | SOUTH | NA | CARBON DIOXIDE |
| 140 | IH35 E S1 | 4-16-85 | 6:52 AM | TANK | 1202 | SOUTH | NA | GAS/OIL |
| 141 | IH35 E S1 | 4-16-85 | 6:52 AM | TANK | 1214 | SOUTH | NA | ISOBUTYLAMINE |
| 142 | IH35 E S1 | 4-16-85 | 7:03 AM | TANK | 1203 | SOUTH | 4C | GASOLINE |
| 143 | IH35 E S1 | 4-16-85 | 7:05 AM | TANK | 1203 | SOUTH | NA | GASOLINE |
| 144 | IH35 E S1 | 4-16-85 | 7:07 AM | TANK | 1203 | SOUTH | EXXON | GASOLINE |
| 145 | IH35 E S1 | 4-16-85 | 7:07 AM | TANK | 1203 | SOUTH | NA | GASOLINE |
| 146 | IH35 E S1 | 4-16-85 | 7:19 AM | TANK | 1203 | SOUTH | THOMPSON | GASOLINE |
| 147 | IH35 E S1 | 4-16-85 | 7:26 AM | TANK | 1203 | SOUTH | NA | GASOLINE |
| 148 | IH35 E S1 | 4-16-85 | 7:37 AM | TANK | 1203 | SOUTH | NA | GASOLINE |
| 149 | IH35 E S1 | 4-16-85 | 7:52 AM | TANK | 1203 | SOUTH | NA | GASOLINE |
| 150 | IH35 E S1 | 4-16-85 | 8:24 AM | TANK | 1203 | SOUTH | EXXON | GASOLINE |
| 151 | IH35 E S1 | 4-16-85 | 8:33 AM | TANK | 1203 | SOUTH | ANDREWS | GASOLINE |
| 152 | IH35 E S1 | 4-16-85 | 8:39 AM | TANK | 1203 | SOUTH | WHITFIELD | GASOLINE |
| 153 | IH35 E S1 | 4-16-85 | 9:00 AM | TRAILER | NA | SOUTH | TRANS CON | NA |
| 154 | IH35 E S1 | 4-16-85 | 9:12 AM | TANK | NA | SOUTH | NA | NA |
| 155 | IH35 E S1 | 4-16-85 | 9:16 AM | TANK | 1203 | SOUTH | ANDREWS | GASOLINE |
| 156 | IH35 E S1 | 4-16-85 | 9:20 AM | TANK | 1203 | SOUTH | THOMPSON | GASOLINE |
| 157 | IH35 E S1 | 4-16-85 | 9:23 AM | TANK | 1203 | SOUTH | THOMPSON | GASOLINE |
| 158 | IH35 E S1 | 4-16-85 | 9:30 AM | TANK | NA | SOUTH | LSI | NA |
| 159 | IH35 E S1 | 4-16-85 | 9:36 AM | TANK | NA | SOUTH | NA | NA |
| 160 | IH35 E S1 | 4-16-85 | 9:33 AM | TRAILER | NA | SOUTH | YELLOW FREIGHT | NA |
| 161 | IH35 E S1 | 4-16-85 | 9:40 AM | TANK | 1203 | SOUTH | NA | GASOLINE |
| 162 | IH35 E S1 | 4-16-85 | 9:48 AM | TANK | NA | SOUTH | CHEMICAL EXPRESS | NA |
| 163 | IH35 E S1 | 4-16-85 | 9:50 AM | TANK | 1203 | SOUTH | NA | GASOLINE |
| 164 | IH35 E S1 | 4-16-85 | 9:53 AM | TANK | NA | SOUTH | LIQUID TRANSPORT | NA |
| 165 | IH35 E S1 | 4-16-85 | 9:55 AM | TANK | 1203 | SOUTH | PTC | GASOLINE |
| 166 | IH35 E S1 | 4-16-85 | 6:09 AM | TANK | DANGEROUS | NORTH | GROENDYKE | NA |
| 167 | IH35 E S1 | 4-16-85 | 6:36 AM | TANDEM TRAILER | CORROSIVE | NORTH | NA | NA |
| 168 | IH35 E S1 | 4-16-85 | 6:36 AM | TANK | 1203 | NORTH | NA | GASOLINE |
| 169 | IH35 E S1 | 4-16-85 | 7:23 AM | TRAILER | CORROSIVE | NORTH | NA | NA |
| 170 | IH35 E S1 | 4-16-85 | 7:29 AM | TANK | NA | NORTH | MCT | NA |
| 171 | IH35 E S1 | 4-16-85 | 7:35 AM | TRAILER | CORROSIVE | NORTH | PIONEER CHEMICAL | NA |
| 172 | IH35 E S1 | 4-16-85 | 7:42 AM | TANK | 1203 | NORTH | WHITE | GASOLINE |
| 173 | IH35 E S1 | 4-16-85 | 7:44 AM | TANK | 1203 | NORTH | PTC | GASOLINE |
| 174 | IH35 E S1 | 4-16-85 | 7:55 AM | TANK | 1203 | NORTH | NA | GASOLINE |
| 175 | IH35 E S1 | 4-16-85 | 8:10 AM | TRAILER | DANGEROUS | NORTH | NA | NA |
| 176 | IH35 E S1 | 4-16-85 | 8:13 AM | TANK | 1203 | NORTH | THOMPSON | GASOLINE |
| 177 | IH35 E S1 | 4-16-85 | 8:16 AM | TANK | 1203 | NORTH | NA | GASOLINE |
| 178 | IH35 E S1 | 4-16-85 | 8:18 AM | TANK | NA | NORTH | MALONE | NA |
| 179 | IH35 E S1 | 4-16-85 | 8:22 AM | TRAILER | DANGEROUS | NORTH | PREFERED | NA |
| 180 | IH35 E S1 | 4-16-85 | 8:27 AM | TANK | 1203 | NORTH | NA | GASOLINE |
| 181 | IH35 E S1 | 4-16-85 | 8:31 AM | TANK | NA | NORTH | CHEMICAL EXPRESS | NA |
| 182 | IH35 E S1 | 4-16-85 | 8:33 AM | TANK | NA | NORTH | AIR PRODUCTS | NA |
| 183 | IH35 E S1 | 4-16-85 | 8:35 AM | TANK | 1203 | NORTH | NA | GASOLINE |
| 184 | IH35 E S1 | 4-16-85 | 8:38 AM | TANK | 1203 | NORTH | NA | GASOLINE |
| 185 | IH35 E S1 | 4-16-85 | 8:48 AM | TANK | 1203 | NORTH | NA | GASOLINE |
| 186 | IH35 E S1 | 4-16-85 | 8:53 AM | TANK | NA | NORTH | NA | NA |
| 187 | IH35 E S1 | 4-16-85 | 9:10 AM | TANK | NA | NORTH | NA | NA |
| 188 | IH35 E S1 | 4-16-85 | 9:17 AM | TANK | NON-FLAM-GAS | NORTH | CARDOX | NA |
| 189 | IH35 E S1 | 4-16-85 | 9:19 AM | TANK | 1203 | NORTH | NA | GASOLINE |
| 190 | IH35 E S1 | 4-16-85 | 9:37 AM | TANK | 1203 | NORTH | NA | GASOLINE |
| 191 | IH35 E S1 | 4-16-85 | 9:37 AM | TANK | NA | NORTH | NA | NA |
| 192 | IH35 E S1 | 4-16-85 | 9:49 AM | TANK | 1203 | NORTH | NA | GASOLINE |
| 193 | IH35 E S1 | 4-16-85 | 9:58 AM | TANK | 1203 | NORTH | WHITFIELD | GASOLINE |

# APPENDIX D

# ROUTE SEGMENT DATA

HAZARDOUSTRANSPORT ROUTINGS II - DALLAS CBD

ARTERIAL AND FREEWAY ANALYSIS SEGMENTS WITH LINKNAMES, NUMBER OF LANES, MILEAGE, AND AVERAGE DAILY TRAFFIC

I. ARTERIAL ROUTES

A1: Continental/Industrial

| | ARTERIAL SEGMENTS' STREET NAME | LINK NAME | OTHER STREET NAMES FROM | NODE A | TO | NODE B | DISTANCE (20) | LANES AB | BA |
|---|---|---|---|---|---|---|---|---|---|
| 1 | RpContS35 | 18760009 | continental | 28700 | S 35Stem | 28703 | 9 | 0 | 1 |
| 2 | RpContN35 | 18760504 | continent | 28701 | N 35Stem | 28702 | 20 | 1 | 0 |
| 3 | Continent | 19131002 | Rp S 35 | 28700 | Rp N 35 | 28701 | 7 | 3 | 3 |
| 4 | Continental | 19130509 | Industrial | 15368 | Rp S 35 | 28700 | 16 | 3 | 3 |
| 5 | Industrial | 19312503 | Continent | 15368 | RpWdlRg | 30680 | 11 | 3 | 3 |
| 6 | Industrial | 19312701 | RpWdlRg | 30680 | Rp Wdl Rg | 30683 | 6 | 3 | 3 |
| 7 | Industrial | 19312800 | RpWdl Rg | 30683 | Commerce | 15400 | 12 | 3 | 3 |
| 8 | Industrial | 19313006 | Commerce | 15400 | Reunion | 28720 | 16 | 3 | 3 |
| 9 | Industrial | 19313501 | Reunion | 28720 | RpWdlIH30 | 28731 | 19 | 3 | 3 |
| 10 | RpIndustrial | 18850008 | Industrial | 28731 | WIH30 | 28730 | 15 | 1 | 0 |

Total Segment Mileage 1.31
Average Number of Lanes 6
Average Daily Traffic 22000

A2: Industrial

| | STREET NAME | LINK NAME | FROM | NODE A | TO | NODE B | DISTANCE | AB | BA |
|---|---|---|---|---|---|---|---|---|---|
| 1 | RpIndustIH30 | 18850503 | EIH30 | 28732 | Industrail | 28733 | 13 | 3 | 0 |
| 2 | RpIndustrial | 19314004 | RpWIH30 | 28731 | RpEIH30 | 28733 | 12 | 3 | 3 |
| 3 | Industrial | 19314509 | RpEIH30 | 28733 | RpSIH30 | 28877 | 40 | 3 | 3 |
| 4 | RpIH35-30 | 13900006 | Industrial | 28877 | SIH35 | 28875 | 5 | 1 | 1 |

Total Segment Mileage .70
Average Number of Lanes 6
Average Daily Traffic 24000

A3: Industrial/Corinth/Lamar

| | STREET NAME | LINK NAME | FROM | NODE A | TO | NODE B | DISTANCE | AB | BA |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Industrial | 18180505 | RpSIH35 | 28877 | Cadiz | 28878 | 15 | 3 | 3 |
| 2 | Industrial | 18181008 | Cadiz | 28878 | Corinth | 16901 | 70 | 3 | 3 |
| 3 | Corinth | 18192005 | Lamar | 15558 | Industrial | 16901 | 44 | 2 | 2 |
| 4 | Lamar | 18165001 | Corinth | 15558 | Grand | 16902 | 41 | 2 | 2 |
| 5 | Lamar | 14680003 | Grand | 16902 | Forest | 16997 | 27 | 2 | 2 |
| 6 | Lamar | 14680508 | Forest | 16997 | Pennsyl | 16916 | 13 | 2 | 2 |
| 7 | Lamar | 14681001 | Pennsyl | 16916 | Metropol | 16920 | 37 | 2 | 2 |
| 8 | Lamar | 14681506 | Metropol | 16920 | RpMetro | 28530 | 16 | 2 | 2 |
| 9 | RpMetro45 | 12790002 | RpMetro | 28530 | RpLamar | 28533 | 33 | 1 | 1 |
| 10 | RpMetro45 | 12791505 | Metropol | 28534 | Lamar | 28532 | 31 | 1 | 1 |
| 11 | Lamar | 14682009 | RpMetro | 28530 | RpMetro | 28532 | 14 | 2 | 2 |

Total Segment Mileage 3.41
Average Number of Lanes 4.0
Average Daily Traffic 18000

A4: Corinth/Central/Pearl/Canton

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Corinth | 18191502 | Akard | 15557 | Lamar | 15558 | 9 | 2 | 2 |
| 2 | Corinth | 18191007 | Ervay | 15556 | Akard | 15557 | 25 | 2 | 2 |
| 3 | Corinth | 18190504 | Harwood | 15628 | Ervey | 15556 | 23 | 2 | 2 |
| 4 | Corinth | 18190009 | Central | 15540 | Harwood | 15628 | 5 | 2 | 2 |
| 5 | Central | 18203505 | Rp Central | 28894 | Corinth | 15540 | 31 | 3 | 3 |
| 6 | Central | 18203000 | RpIH30 | 28891 | RpCentral | 28894 | 19 | 0 | 2 |
| 7 | Central | 18202507 | Canton | 15516 | RpIH30 | 28891 | 30 | 0 | 5 |
| 8 | Canton | 17962507 | Central | 15516 | S GoodLat | 15517 | 21 | 2 | 2 |
| 9 | Canton | 17963000 | S Good Lat | 15517 | N GoodLat | 15518 | 5 | 2 | 2 |
| 10 | Pearl Expwy | 18088500 | FrE IH30 | 28895 | Corinth | 15540 | 27 | 2 | 0 |
| 11 | Pearl Expwy | 18088005 | FrW IH30 | 28890 | RpW IH30 | 28895 | 21 | 2 | 0 |
| 12 | Pearl Expwy | 18087502 | Young | 15493 | FrW IH30 | 28890 | 34 | 5 | 0 |
| 13 | Canton | 00000000 | Pearl Expwy | 15493 | Central EXp | 15516 | 8 | 2 | 2 |

Total Segment Meleage 1.7
Average Number of Lanes 4
Average Daily Traffic 13000

A5: Good Latimer/Fr US 75

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Good Lat | 18042002 | Commerce | 15576 | Canton | 15518 | 7 | 3 | 3 |
| 2 | Good Lat | 18041509 | Main | 15572 | Commerce | 15576 | 6 | 3 | 3 |
| 3 | Good Lat | 18041004 | Elm | 15571 | Main | 15572 | 5 | 3 | 3 |
| 4 | Good Lat | 18040006 | Live oak | 15404 | Elm | 15571 | 34 | 2 | 2 |
| 5 | N Good Lat | 18030551 | Bryan | 15401 | Good Lat | 15404 | 11 | 0 | 3 |
| 6 | Rp Bryan | 13770003 | Bryan | 15401 | N US75 | 28801 | 11 | 1 | 0 |
| 7 | Rp WdlRgr | 13760509 | S US75 | 28790 | FrE WdlRg | 15578 | 8 | 2 | 0 |
| 8 | Fr SUS75 | 13830500 | FrE WdlRg | 15578 | RfE WdlRg | 15360 | 26 | 3 | 0 |
| 9 | Fr SUS75 | 13831003 | FrE WdlRg | 15360 | Ross | 15363 | 4 | 2 | 0 |
| 10 | Fr SUS75 | 13831508 | Ross | 15363 | SanJacinto | 15585 | 11 | 2 | 0 |
| 11 | Fr SUS75 | 13832001 | SanJacinto | 15585 | Routh | 15394 | 11 | 2 | 0 |
| 12 | S GoodLat | 18030007 | Routh | 15394 | Bryan | 15399 | 7 | 3 | 0 |
| 13 | S GoodLat | 18030502 | Bryan | 15399 | Good Lat | 15404 | 11 | 3 | 0 |

Total Mileage for Segment A5 1.52
Average Number of Lanes 6
Average Daily Traffic 9020

A6: Canton/First/Second/Parry/Peak

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Canton | 17963505 | N GoodLat | 15518 | Oakland | 15622 | 28 | 1 | 1 |
| 2 | Canton | 17963703 | Oakland | 15622 | Hall St | 15543 | 20 | 1 | 1 |
| 3 | Canton | 17964000 | Hall St | 15543 | Trunk Av | 15545 | 17 | 1 | 1 |
| 4 | Canton | 17964503 | Trunk Av | 15545 | 2nd Ave | 15546 | 6 | 1 | 1 |
| 5 | 2nd Ave | 18290502 | Canton | 15546 | RpEIH30 | 28912 | 32 | 3 | 0 |
| 6 | 2nd Ave | 18291005 | RpEIH30 | 28912 | Parry | 15552 | 18 | 4 | 0 |
| 7 | SH352 | 38920005 | 1st Ave | 15551 | 2nd Ave | 15552 | 6 | 3 | 3 |
| 8 | Parry-RBC | 18481002 | Exposition | 15550 | 1st Ave | 15551 | 7 | 3 | 3 |
| 9 | Parry-RBC | 18480707 | Commerce | 15670 | Exposition | 15550 | 6 | 3 | 3 |
| 10 | Parry-RBC | 18480509 | Haskell | 15448 | Commerce | 15670 | 9 | 3 | 3 |
| 11 | Parry-RBC | 18480004 | Peak | 15449 | Haskell | 15448 | 14 | 3 | 3 |
| 12 | Peak St | 18262006 | RpEIH30 | 28933 | Parry Av | 15449 | 16 | 0 | 2 |
| 13 | FrE IH30 | 14063309 | Peak | 28933 | Carrol | 15672 | 14 | 3 | 0 |
| 14 | RpPeakI30 | 14030506 | Carroll | 15672 | IH 30 | 28932 | 10 | 1 | 0 |
| 15 | Rp1st Expo | 14011001 | WIH30 RL | 28921 | 1st Ave | 28922 | 10 | 1 | 0 |
| 16 | 1st Ave | 18281501 | Canton | 28922 | RpW IH30 | 15547 | 16 | 0 | 4 |
| 17 | Canton | 17965005 | 1st Ave | 15447 | 2nd Ave | 15546 | 7 | 2 | 2 |

Total Segment Mileage 2.36
Average Number of Lanes 4
Average Daily Traffic 8200

## II. FREEWAY ROUTES

| | FREEWAY SEGMENTS' STREET NAME | LINKNAME | OTHER STREET NAMES FROM | NODE A | TO | NODE B | DISTANCE (00) | LANES AB | BA |
|---|---|---|---|---|---|---|---|---|---|

F1: IH 35 Stemmons

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | S IH35E | 18693507 | RpContinent | 28703 | RpWdl Rg | 30714 | 25 | 4 | 0 |
| 2 | S IH35E | 18693606 | RpWdl Rg | 30714 | RpWdl Rg | 30710 | 4 | 3 | 0 |
| 3 | S IH35E | 18693705 | RpWdl Rg | 30710 | Rp Commer | 28710 | 38 | 4 | 2 |
| 4 | S IH35E | 18694000 | Rp Commer | 28710 | RpWdl Rg | 28742 | 29 | 4 | 2 |
| 5 | RpI30I35 | 18790006 | SIH35E | 28742 | WIH30 | 28741 | 8 | 2 | 0 |
| 6 | WIH30 | 18821553 | RpIndustri | 28730 | RpWIH30 | 28741 | 13 | 0 | 3 |
| 7 | N IH35E | 18695056 | RpE IH30 | 28743 | RpWIH30 | 28744 | 11 | 0 | 4 |
| 8 | N IH35E | 18694554 | Dn NIH35 | 28721 | RpE IH30 | 28743 | 20 | 0 | 4 |
| 9 | RpIH35IH30 | 13903000 | NIH35E RLT | 28743 | RrFrNIH35 | 28747 | 14 | 2 | 2 |
| 10 | N IH35E | 18694356 | RpE IH30 | 15704 | Dn N IH35 | 28721 | 14 | 0 | 4 |
| 11 | N IH35E | 18694059 | RpCommer | 28712 | RpE IH30 | 15704 | 13 | 0 | 4 |
| 12 | N IH35E | 18693754 | RpWdl Rg | 30711 | RpCommer | 28712 | 23 | 0 | 5 |
| 13 | N IH35E | 18693655 | RpWdl Rg | 30713 | RpWdl Rg | 30711 | 21 | 0 | 4 |
| 14 | N IH35E | 18693556 | RpContin | 28702 | RpWdl Rg | 30713 | 15 | 0 | 4 |
| 15 | RpI30I35 | 18791004 | E IH30 | 28740 | RpN IH35 | 15705 | 36 | 2 | 0 |
| 16 | S IH35E | 18694505 | RpW IH30 | 28742 | RpS IH35 | 28724 | 7 | 3 | 0 |
| 17 | RpI35I30 | 13901509 | S IH35 | 28724 | RpS IH35 | 28748 | 15 | 3 | 2 |
| 18 | S IH35E | 18695007 | RpS IH35 | 28724 | RpE IH30 | 28745 | 12 | 3 | 0 |

F1: Total Two-directional Mileage- Segment F1 3.18
Average Number of Lanes 3
Average Daily Traffic 135200

F2: I- 30 IH 35 Common

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | E IH30 | 18821504 | RpIndust | 28732 | RpW IH35 | 28740 | 10 | 3 | 0 |
| 2 | Rp IH30 | 18791509 | E IH30 | 28740 | S I-35E | 28745 | 10 | 2 | 0 |
| 3 | S I-35E | 18696005 | RpE IH30 | 28745 | Dn SIH35E | 28870 | 36 | 4 | 0 |
| 4 | S I-35E | 13880000 | Dn SIH35E | 28870 | E IH30RLT | 28874 | 15 | 4 | 0 |
| 5 | N I-35E | 13880059 | Dn NIH35E | 28871 | W IH30RLT | 28872 | 12 | 0 | 4 |
| 6 | N I-35E | 18696054 | RpW IH30 | 28744 | Dn NIH35 | 28871 | 28 | 0 | 4 |
| 7 | RpI30I35 | 18790501 | N IH35E | 28744 | W IH30 | 28741 | 18 | 0 | 3 |
| 8 | RpI30I35 | 13902002 | Rp SIH35 | 28748 | S IH35 | 28875 | 35 | 2 | 0 |
| 9 | S IH35E | 13890504 | W IH35E | 28872 | RpIH35E | 28875 | 7 | 3 | 3 |
| 10 | RpI-35IH30 | 13903505 | RpFrNIH35 | 28747 | NIH35RLT | 28876 | 44 | 0 | 2 |

F2: Total Two-Directional Mileage 2.34
Average number of Lanes 8
Average Daily Traffic 184000

F3: I- 30

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | N IH35E | 13890553 | Rp NIH30 | 28876 | E IH30 | 28874 | 28 | 0 | 2 |
| 2 | E IH30 RLT | 13870506 | N IH35E | 28874 | Rp Ervay | 28882 | 53 | 2 | 0 |
| 3 | E IH30 RLT | 13871009 | Rp Ervay | 28882 | Rp Griffin | 28900 | 42 | 3 | 0 |
| 4 | E IH30 RLT | 13871504 | Rp Griffin | 28900 | Rp Central | 28893 | 19 | 3 | 0 |
| 5 | E IH30 RLT | 13872007 | Rp Centr | 28893 | Rp N US75 | 28841 | 19 | 3 | 0 |
| 6 | Rp Pocanont | 13970009 | Fr E IH30 | 28902 | E IH30RLT | 28900 | 12 | 1 | 1 |
| 7 | Fr EIH30 | 14063002 | Rp IH30 | 28900 | Rp S US75 | 28845 | 44 | 2 | 0 |
| 8 | Rp US75IH30 | 13824008 | FrEIH30 | 28845 | RpWIH30 | 28846 | 12 | 2 | 0 |
| 9 | Rp US75IH30 | 13824503 | RpWIH30 | 28846 | S IH45 | 28848 | 15 | 2 | 0 |
| 10 | Rp US75 IH30 | 13823505 | FrEIH30 | 28845 | RpN US75 | 28842 | 20 | 1 | 0 |
| 11 | W IH30 RLT | 13872056 | RpCent | 28892 | Bps US75 | 28840 | 42 | 0 | 3 |
| 12 | W IH30 RLT | 13871553 | Rp StPaul | 28901 | RpCent | 28892 | 29 | 0 | 3 |
| 13 | RpStPaul US75 | 13960000 | Rp US75 | 28844 | W IH30RLT | 28901 | 41 | 4 | 0 |
| 14 | W IH30 RLT | 13871058 | Rp Ervay | 28881 | Rp StPaul | 28901 | 13 | 0 | 3 |
| 15 | W IH30 RLT | 13870555 | S IH35E | 28872 | Rp Ervay | 28881 | 73 | 0 | 3 |

F3: Total Two-Directional Mileage 4.62
Average Number of Lanes 6
Average Daily Traffic 139000

F4: IH 45

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | S US75 | 13752506 | Rp Main St | 28830 | RpS IH45 | 28848 | 56 | 3 | 0 |
| 2 | S I-45 | 17770009 | S US75 | 28848 | RpS US75 | 28611 | 46 | 4 | 0 |
| 3 | S IH45 | 17770504 | RpS US75 | 28533 | Rp Lamar | 28533 | 150 | 3 | 0 |
| 4 | N I-45 | 12780052 | RpMetropol | 28531 | RpOverton | 28520 | 216 | 0 | 3 |
| 5 | N I-45 | 17770553 | RpN US75 | 28610 | RpMetropol | 28531 | 83 | 0 | 3 |
| 6 | N I-45 | 17770058 | N US75 | 28849 | Rp N US75 | 28610 | 49 | 0 | 4 |
| 7 | N US75 | 13752555 | RpMain75 | 28831 | N IH45 | 28849 | 47 | 0 | 3 |
| 8 | RpUS75 IH30 | 13825005 | W I-45 | 28849 | RpS US75 | 28847 | 17 | 2 | 0 |
| 9 | RpUs75 IH30 | 13825500 | RpS US75 | 28847 | E IH30 | 28841 | 16 | 1 | 0 |
| 10 | RpUS75 IH30 | 13826003 | RpE IH30 | 28847 | RpStPaul | 28844 | 20 | 2 | 0 |

F4: Total Two-Directional Mileage 7.00
Average Number of Lanes 6
Average Daily Traffic 8000

F5: IH 30 E. RLT

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | E IH30 RLT | 13872502 | RpN US75 | 28841 | Rp2nd Av | 28911 | 38 | 4 | 0 |
| 2 | E IH30 RLT | 13873005 | Rp2nd Av | 28911 | Rp1st Av | 28924 | 24 | 4 | 0 |
| 3 | E IH30 RLT | 13873500 | Rp1st Av | 28924 | Rp Haskell | 28934 | 30 | 4 | 0 |
| 4 | E IH30 RLT | 13874003 | Rp Haskell | 28934 | RpPeak | 28932 | 29 | 4 | 0 |
| 5 | W IH30 RLT | 13874052 | RpPeak | 28936 | RpPeak | 28931 | 63 | 0 | 4 |
| 6 | W IH30 RLT | 13873559 | Rp1st Av | 28921 | RpPeak | 28936 | 29 | 0 | 4 |
| 7 | W IH30 RLT | 13873054 | Rp1st Av | 28910 | Rp 1stExpo | 28921 | 20 | 0 | 4 |
| 8 | W IH30 RLT | 13872551 | RpUS75 | 28840 | Rp1st Av | 28910 | 41 | 0 | 4 |
| 9 | RpUS75 IH30 | 13823000 | W IH30 | 28840 | RpS IH45 | 28846 | 23 | 1 | 0 |

| | |
|---|---|
| F5: Total Two-Directional Mileage | 2.97 |
| Average Number of Lanes | 8 |
| Average Daily Traffic | 128000 |

F6: IH 345/US 75

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | RpUS75 IH30 | 13821004 | RpMain | 15541 | N US75 | 28821 | 28 | 2 | 0 |
| 2 | N US75 | 13751557 | Rp Bryan | 15403 | Rp WIH30 | 28821 | 29 | 0 | 5 |
| 3 | N US75 | 13751052 | RpWdlRg | 30773 | RpBryan | 15403 | 35 | 0 | 4 |
| 4 | N US75 | 13750559 | N US75 | 28793 | RpWdlRg | 30773 | 3 | 0 | 3 |
| 5 | N US75 Central | 13740055 | FrN US75 | 28794 | N US75 | 28793 | 15 | 0 | 4 |
| 6 | N US75 Central | 18594051 | RpWdl Rg | 30776 | FrN US75 | 28794 | 7 | 0 | 3 |
| 7 | N US75 Central | 18593558 | RpWdl Rg | 30776 | RpLemmon | 28783 | 38 | 0 | 3 |
| 8 | S US75 Central | 18594002 | RpWdl Rg | 30770 | RpWdl Rg | 28790 | 4 | 3 | 0 |
| 9 | S US75 Central | 13740006 | Rp FrEWdl | 28790 | S US75 | 28791 | 24 | 3 | 0 |
| 10 | S US75 Central | 13750005 | S US75 | 28791 | FrSUS75 | 15359 | 6 | 2 | 0 |
| 11 | S US75 Central | 13750500 | FrSUS75 | 15359 | RpWdlRg | 30777 | 4 | 2 | 0 |
| 12 | S US75 Central | 13750708 | RpWdl Rg | 30777 | RpWdlRg | 15400 | 32 | 2 | 0 |
| 13 | S US75 Central | 13751003 | RpLiveOak | 15400 | RpBryan | 15477 | 9 | 4 | 0 |
| 14 | S US75 Central | 13751508 | RpBryan | 15447 | RpEIH30 | 28820 | 13 | 4 | 0 |
| 15 | S US75 Central | 13752001 | RpEIH30 | 28820 | RpBryan | 28830 | 35 | 3 | 0 |
| 16 | RpUS75 IH30 | 13821509 | S US75 | 28820 | RpMain | 15632 | 30 | 2 | 0 |
| 17 | RpUS75 IH30 | 13822507 | RpNUs75 | 28843 | E IH30 | 28841 | 28 | 2 | 0 |
| 18 | RpUS75 IH30 | 13821707 | RpMain | 15632 | RpEIH30 | 28843 | 35 | 3 | 0 |
| 19 | RpUS75 IH30 | 13820501 | RpNUS75 | 28842 | RpMain | 15541 | 23 | 3 | 0 |
| 20 | N US75 | 13752050 | RpWfIH30 | 28821 | RpMain | 28831 | 40 | 0 | 3 |
| 21 | S US75 Central | 18593509 | RpFrS75 | 28781 | RpWdlRg | 30770 | 32 | 3 | 0 |
| 22 | RpUs75 IH30 | 13822002 | RpN US75 | 28843 | Rp StPaul | 28844 | 13 | 1 | 0 |

| | |
|---|---|
| F6: Total Two-Directional Mileage | 4.79 |
| Average Number of Lanes | 6 |
| Average Daily Traffic | 127000 |

F7: Woodall Rogers

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | RpWdl Rgr | 50240506 | E Wdl Rgr | 30712 | S IH35E | 28703 | 48 | 0 | 2 |
| 2 | E Wdl Rgr | 50220508 | RpIH35E | 30712 | RpWdl Rg | 30721 | 22 | 5 | 0 |
| 3 | E Wdl Rgr | 50221001 | RpGriffin | 30721 | RpGriffin | 30724 | 12 | 4 | 0 |
| 4 | E Wdl Rg | 50221506 | RpGriffin | 30724 | RpPearl | 30741 | 25 | 5 | 0 |
| 5 | E Wdl Rg | 50222009 | RpPearl | 30741 | RpPearl | 30752 | 11 | 4 | 0 |
| 6 | E Wdl Rg | 50222504 | RpPearl | 30752 | RpUS75 | 30755 | 25 | 4 | 0 |
| 7 | Rp Wdl US75 | 50291004 | E Wdl Rg | 30775 | S US75 | 30777 | 26 | 1 | 0 |
| 8 | RpWdl Rg | 50290501 | N US75 | 30776 | E Wdl Rg | 30775 | 24 | 0 | 1 |
| 9 | RpWdl US75 | 50292507 | RpUS75 | 30712 | W Wdl Rg | 30771 | 32 | 1 | 0 |
| 10 | W Wdl Rgr | 50223056 | RpRouth | 30760 | RpUS75 | 30771 | 22 | 0 | 4 |
| 11 | W Wdl Rgr | 50222553 | RpPearl | 30751 | RpRouth | 30760 | 3 | 0 | 4 |
| 12 | W Wdl Rgr | 50222058 | Rp StPaul | 30732 | RpPearl | 30751 | 11 | 0 | 5 |
| 13 | W Wdl Rgr | 50221555 | RpAkard | 30730 | RpStPaul | 30732 | 20 | 0 | 4 |
| 14 | W Wdl Rgr | 50221258 | RpGriffin | 30726 | RpAkard | 30730 | 7 | 0 | 4 |
| 15 | W Wdl Rg | 50221050 | RpGriffin | 30720 | RpGriffin | 30726 | 10 | 0 | 4 |
| 16 | W Wdl Rgr | 50220557 | RpIH35 | 30716 | RpGriffin | 30720 | 43 | 0 | 4 |
| 17 | Rp Wdl US75 | 50292002 | N US75 | 30773 | RpWdl Rg | 30772 | 7 | 1 | 0 |
| 18 | RpWdl US75 | 50292507 | RpUS75 | 30772 | RpUS75 | 30771 | 32 | 1 | 0 |
| 19 | RpWdl US75 | 50290006 | S US75 | 30770 | W Wdl Rg | 30771 | 30 | 1 | 0 |
| 20 | RpWdl IH35E | 50241504 | W Wdl Rg | 30716 | S IH35E | 30714 | 17 | 1 | 0 |
| 21 | RpWdl IH35E | 50241009 | W Wdl Rg | 30716 | N IH35 E | 30713 | 17 | 2 | 0 |

| | |
|---|---|
| F7: Total Two-Directional Mileage | 4.45 |
| Average Number of Lanes | 8 |
| Average Daily Traffic | 62000 |

# APPENDIX E

## SUMMARY RISK CALCULATIONS BY ROUTE SEGMENT

Hazardous Materials Routing II - Dallas CBD
Accident Probabilities for the Total 1/2-Mile Exposure Area - 24-hour Analysis

| A. Arterial Segments | | Average Annual Accidents | Total One-way Mileage | Annual Traffic Volume | Annual VMT | Accident Probability per Million VMT | Total Employment | Total Population | 24-hour Vehicle Occupancy | Total Accident Consequence | Accident Consequence per mile | Total Exposure Miles |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A1 | Continental/Industrial | 2 | 1.31 | 7480000 | 7180800 | 0.278520 | 22034 | 630 | 103 | 22767 | 17379.38 | 29824.77 |
| A2 | Industrial | 3.2 | 0.7 | 8160000 | 4243200 | 0.754147 | 7319 | 40 | 182 | 7541 | 10772.85 | 5278.7 |
| A3 | Industrial/Corinth/Lamar | 4.2 | 3.41 | 6120000 | 16952400 | 0.247752 | 19956 | 9016 | 90 | 29062 | 8522.580 | 99:01.42 |
| A4 | Corinth/Central/Pearl | 2.2 | 1.7 | 4420000 | 7514000 | 0.292786 | 109951 | 5539 | 180 | 115670 | 68041.17 | 196639 |
| A5 | Good Latimer/US 75 | 3 | 1.52 | 3060000 | 4069800 | 0.737136 | 70858 | 4236 | 119 | 75213 | 49482.23 | 114323.7 |
| A6 | Canton/1st/n2nd/Parry/Peak | 1.6 | 2.36 | 2720000 | 5494400 | 0.291205 | 51996 | 17765 | 127 | 69888 | 29613.55 | 164935.6 |

| A. Arterial Segments | | Total Risk Factor | Risk Factor per mile | Exposure Miles' Risk |
|---|---|---|---|---|
| A1 | Continental/Industrial | 6341.076 | 4840.516 | 8306.809 |
| A2 | Industrial | 5687.028 | 8124.326 | 3980.920 |
| A3 | Industrial/Corinth/Lamar | 7200.184 | 2111.490 | 24552.62 |
| A4 | Corinth/Central/Pearl | 33866.64 | 19921.55 | 57573.30 |
| A5 | Good Latimer/US 75 | 55442.28 | 36475.18 | 84272.26 |
| A6 | Canton/1st/n2nd/Parry/Peak | 20351.77 | 8623.634 | 48030.19 |

| B. Freeway Segments | | Average Annual Accidents | Total One-Way Mileage | Annual Traffic Volume | Annual VMT | Accident Probability per million VMT | Total Employment | Total Population | 24-Hour Vehicle Occupancy | Total Accident Consequence | Accident Consequence per mile | Total Exposure Miles |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| F1 | IH 35 Stemmons | 24.6 | 1.59 | 62900000 | 1.0E+08 | 0.245972 | 33464 | 634 | 622.25 | 34720.25 | 21836.63 | 55205.[illegible]9 |
| F2 | IH 30 IH 35 Common | 36.8 | 1.17 | 62560000 | 73195200 | 0.502765 | 10111 | 105 | 427.88 | 10643.88 | 9097.333 | 12453.33 |
| F3 | IH 30 | 47.8 | 2.31 | 47260000 | 1.1E+08 | 0.437846 | 43751 | 4577 | 628.89 | 48956.89 | 21193.45 | 113090.4 |
| F4 | IH 45 | 10.6 | 3.5 | 27200000 | 95200000 | 0.111344 | 30324 | 14783 | 461.92 | 45568.92 | 13019.69 | 159491.2 |
| F5 | IH 30 E. ALT | 21 | 1.485 | 43520000 | 64627200 | 0.324940 | 20910 | 13603 | 424.32 | 34937.32 | 23526.81 | 51881.92 |
| F6 | IH 345/US 75 | 8.2 | 2.395 | 36380000 | 87130100 | 0.094112 | 88858 | 10258 | 467.19 | 99583.19 | 41579.62 | 238501.7 |
| F7 | SH 366/Wdl Rogers | 7 | 2.225 | 21080000 | 46903000 | 0.149244 | 97146 | 6219 | 244 | 103609 | 46565.84 | 230530.0 |

| B. Freeway Segments | | Total Risk Factor | Risk Factor per mile | Exposure Risk Factor |
|---|---|---|---|---|
| F1 | IH 35 Stemmons | 8540.242 | 5371.221 | 13578.98 |
| F2 | IH 30 IH 35 Common | 5351.372 | 4573.822 | 6261.105 |
| F3 | IH 30 | 21435.61 | 9279.488 | 49516.27 |
| F4 | IH 45 | 5073.850 | 1449.671 | 17758.47 |
| F5 | IH 30 E. ALT | 11352.55 | 7644.816 | 16858.54 |
| F6 | IH 345/US 75 | 9371.986 | 3913.146 | 22445.90 |
| F7 | SH 366/Wdl Rogers | 15463.04 | 6949.681 | 34405.26 |

Annual Traffic Volume = Average Daily Traffic * 340
VMT=Annual Traffic Volume * (Adjusted Mileage/100) - for Arterials
Annual Traffic Volume * (Total Mileage / 200) - for Freeways
Accident Probability = Accident Rate Per Million VMT = (Average Annual Accidents/VMT)*1000000
24-hour Vehicle Occupancy = weighted Sum of Daytime (67%) and Nighttime (33%) Occupancy Rates
Total Exposure Miles = Total Accident Consequence * Total Mileage
Total Accident Consequence = Sum of Population, Employment, and 24-hour Vehicle Occupancy Rate
Accident Consequence per mile = Total Consequence divided by total mileage
Total Risk Factor = Total Accident Consequence * Accident Probability
Risk Factor per mile = Total Risk Factor / Total Mileage
Exposure Risk Factor = Total Exposure Miles * Accident Probability

Hazardous Materials Routing II- Dallas CBD
Accident Probabilities, Consequence, Exposure, and Risk Factors by Time of Day
I. Daytime Statistics - For the 1/2-Mile Exposure Area

| I.A. Arterial Segments | | Average Annual Accidents 1980-84 | Adjusted One-way Mileage | Annual Traffic Volume | Annual VMT | Total One-way Mileage | Accident Probability per Million VMT | Total Daytime Employment | Total Daytime Population • | Daytime Vehicle Occupancy | Daytime Employment per mile | Daytime Population per mile |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A1 | Continental/ Industrial | 2.0 | 0.96 | 7480000 | 7180800 | 1.31 | 0.278520 | 18508.56 | 252 | 103 | 14128.67 | 192.3664 |
| A2 | Industrial | 3.2 | 0.52 | 8160000 | 4243200 | 0.7 | 0.754147 | 6147.96 | 16 | 182 | 8782.8 | 22.85714 |
| A3 | Industrial/ Corinth/Lamar | 4.2 | 2.77 | 6120000 | 16952400 | 3.41 | 0.247752 | 16763.04 | 3606.4 | 180 | 4915.847 | 1057.595 |
| A4 | Corinth/Central Pearl/Canton | 2.2 | 1.7 | 4420000 | 7514000 | 1.7 | 0.292786 | 93798.6 | 2217.2 | 90 | 55175.64 | 1304.235 |
| A5 | Good Latimer/ Fr US 75 | 3.0 | 1.33 | 3060000 | 4069800 | 1.52 | 0.737136 | 59520.72 | 1694.4 | 119 | 39158.36 | 1114.736 |
| A6 | Canton/First/ Second/Parry/Peak | 1.6 | 2.02 | 2720000 | 5494400 | 2.36 | 0.291205 | 43736.28 | 7050.4 | 127 | 18532.32 | 2987.457 |

| I.A. Arterial Segments | | Daytime Auto Occupancy per mile | Total Daytime Accident Consequence | Accident Consequence per mile | Total Risk Factor | Risk Factor per mile | Total Exposure Miles | Exposure Risk Factor |
|---|---|---|---|---|---|---|---|---|
| A1 | Continental/ Industrial | 107.2916 | 18863.56 | 14399.66 | 5253.888 | 4010.601 | 24711.26 | 6882.593 |
| A2 | Industrial | 350 | 6345.96 | 9065.657 | 4785.791 | 6836.845 | 4442.172 | 3350.054 |
| A3 | Industrial/ Corinth/Lamar | 64.98194 | 20549.44 | 6026.228 | 5091.175 | 1493.013 | 70073.59 | 17360.90 |
| A4 | Corinth/Central Pearl/Canton | 52.94117 | 96105.8 | 56532.82 | 28138.50 | 16552.06 | 163379.8 | 47835.46 |
| A5 | Good Latimer/ Fr US 75 | 89.47368 | 61334.12 | 40351.39 | 45211.64 | 29744.50 | 93227.86 | 68721.70 |
| A6 | Canton/First/ Second/Parry/Peak | 62.87128 | 50913.68 | 21573.59 | 14826.34 | 6282.350 | 120156.2 | 34990.18 |

| I.D. | Freeway Segments | Average Annual Accidents 1980-84 | Adjusted One-way Mileage | Adjusted Annual Traffic | Annual VMT | Total One-Way Mileage | Accident Probability per Million VMT | Total Daytime Employment | Total Daytime Population | Daytime Auto Occupancy | Daytime Employment per Mile | Daytime Population per Mile |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| F1 | IH 35 Stemmons | 24.6 | 1.59 | 62900000 | 1.0E+08 | 1.59 | 0.245972 | 28109.76 | 253.6 | 845 | 17679.09 | 159.4968 |
| F2 | IH 30 IH 35 Common | 36.8 | 1.17 | 62560000 | 73195200 | 1.17 | 0.502765 | 9307.2 | 42 | 581 | 7954.871 | 35.89743 |
| F3 | IH 30 | 47.8 | 2.31 | 47260000 | 1.1E+08 | 2.31 | 0.437846 | 36750.84 | 1830.8 | 752 | 15909.45 | 792.5541 |
| F4 | IH 45 | 10.6 | 3.5 | 27200000 | 95200000 | 3.5 | 0.111344 | 25472.16 | 5913.2 | 553 | 7277.76 | 1689.485 |
| F5 | IH 30 E. RLT | 21.0 | 1.485 | 43520000 | 64627200 | 1.485 | 0.324940 | 17564.4 | 5441.2 | 555 | 11827.87 | 3664.107 |
| F6 | IH 345/ US 75 | 8.2 | 2.395 | 36380000 | 87130100 | 2.395 | 0.094112 | 74640.72 | 4103.2 | 609 | 31165.22 | 1713.235 |
| F7 | SH 366 Woodall Rogers | 7.0 | 2.225 | 21080000 | 46903000 | 2.225 | 0.149244 | 81602.64 | 2487.6 | 244 | 36675.34 | 1118.022 |

| I.D. | Freeway Segments | Daytime Auto Occupancy per mile | Total Accident Consequence | Accident Consequence per mile | Total Risk Factor | Risk Factor per mile | Total Exposure Miles | Exposure Risk Factor |
|---|---|---|---|---|---|---|---|---|
| F1 | IH 35 Stemmons | 531.4465 | 29208.36 | 18370.03 | 7184.466 | 4518.532 | 46441.29 | 11423.30 |
| F2 | IH 30 IH 35 Common | 496.5811 | 9930.2 | 8487.350 | 4992.559 | 4267.144 | 11618.33 | 5841.294 |
| F3 | IH 30 | 325.5411 | 39333.64 | 17027.54 | 17222.10 | 7455.458 | 90860.70 | 39783.07 |
| F4 | IH 45 | 158 | 31938.36 | 9125.245 | 3556.161 | 1016.046 | 111784.2 | 12446.56 |
| F5 | IH 30 E. RLT | 373.7373 | 23560.6 | 15865.72 | 7655.795 | 5155.417 | 34987.49 | 11368.85 |
| F6 | IH 345/ US 75 | 254.2797 | 79352.92 | 33132.74 | 7468.072 | 3118.193 | 190050.2 | 17886.03 |
| F7 | SH 366 Woodall Rogers | 109.6629 | 84334.24 | 37903.02 | 12586.39 | 5656.806 | 187643.6 | 28004.72 |

II. Nighttime Traffic Statistics - the 1/2-Mile Exposure Area

| II.A. Arterial Routes | | Average Annual Accidents 1980-84 | Adjusted One-way Mileage | Adjusted Annual Traffic | Annual VMT | Total One-way Mileage | Accident Probability per Million VMT | Total Nighttime Employment | Total Nighttime Population | Vehicle Occupancy Nighttime | Nighttime Employment per Mile | Nighttime Population per Mile |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A1 | Continental/ Industrial | 2.0 | 0.96 | 7480000 | 7180800 | 1.31 | 0.278520 | 3525.44 | 630 | 103 | 2691.175 | 480.9160 |
| A2 | Industrial | 3.2 | 0.52 | 8160000 | 4243200 | 0.7 | 0.754147 | 1171.04 | 40 | 183 | 1672.914 | 57.14285 |
| A3 | Industrial/ Corinth/Lamar | 4.2 | 2.77 | 6120000 | 16952400 | 3.41 | 0.247752 | 3192.96 | 9016 | 136 | 936.3519 | 2643.988 |
| A4 | Corinth/Central Expwy/ Pearl/Canton | 2.2 | 1.7 | 4420000 | 7514000 | 1.7 | 0.292786 | 17866.4 | 5543 | 90 | 10509.64 | 3260.588 |
| A5 | Good Latimer/ Fr US 75 | 3.0 | 1.33 | 3060000 | 4069800 | 1.52 | 0.737136 | 11337.28 | 4236 | 119 | 7458.736 | 2786.842 |
| A6 | Canton/First/ Second/Parry/Peak | 1.6 | 2.02 | 2720000 | 5494400 | 2.36 | 0.291205 | 8330.72 | 17626 | 127 | 3529.966 | 7468.644 |

II. Nighttime Traffic Statistics - the 1/2-Mile Exposure Area

| II.A. Arterial Routes | | Nighttime Auto Occupancy per mile | Total Nighttime Accident Consequence | Accident Consequence Per mile Nighttime | Total Risk Factor Nighttime | Risk Factor per mile Nighttime | Total Exposure Miles . Nighttime | Exposure Risk Factor Nighttime |
|---|---|---|---|---|---|---|---|---|
| A1 | Continental/ Industrial | 107.2916 | 4258.44 | 3250.717 | 1186.062 | 905.3914 | 5578.556 | 1553.742 |
| A2 | Industrial | 351.9230 | 1394.04 | 1991.485 | 1051.312 | 1501.874 | 975.828 | 735.9185 |
| A3 | Industrial/ Corinth/Lamar | 49.09747 | 12344.96 | 3620.222 | 3058.495 | 896.9193 | 42096.31 | 10429.46 |
| A4 | Corinth/Central Expwy/ Pearl/Canton | 52.94117 | 23499.4 | 13823.17 | 6880.314 | 4047.243 | 39948.98 | 11696.53 |
| A5 | Good Latimer/ Fr US 75 | 89.47368 | 15692.28 | 10323.86 | 11567.35 | 7610.104 | 23852.26 | 17582.38 |
| A6 | Canton/First/ Second/Parry/Peak | 62.87128 | 26083.72 | 11052.42 | 7595.725 | 3218.527 | 61557.57 | 17925.91 |

| II.A. Freeway Routes | | Average Annual Accidents 1980-84 | Adjusted One-way Mileage | Annual Traffic Volume | Annual VMT | Total One-Way Mileage | Accident Probability per Million VMT | Total Nighttime Employment | Total Nighttime Population | Vehicle Occupancy Nighttime | Nighttime Employment per Mile | Nighttime Population per Mile |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| F1 | IH 35 Stemmons | 24.6 | 1.59 | 62900000 | 1.0E+08 | 1.59 | 0.245972 | 5354.24 | 634 | 170 | 3367.446 | 398.7421 |
| F2 | IH 30 IH35 Common | 36.8 | 1.17 | 62560000 | 73195200 | 1.17 | 0.502765 | 1772.8 | 105 | 117 | 1515.213 | 89.74358 |
| F3 | IH 30 | 47.8 | 2.31 | 47260000 | 1.1E+08 | 2.31 | 0.437846 | 7000.16 | 4577 | 182 | 3030.372 | 1981.385 |
| F4 | IH 45 | 10.6 | 3.5 | 27200000 | 95200000 | 3.5 | 0.111344 | 4851.84 | 14783 | 277 | 1386.24 | 4223.714 |
| F5 | IH 30 E. RLT | 21.0 | 1.485 | 43520000 | 64627200 | 1.485 | 0.324940 | 3345.6 | 13603 | 159 | 2252.929 | 9160.269 |
| F6 | IH 345/ US 75 | 8.2 | 2.395 | 36380000 | 87130100 | 2.395 | 0.094112 | 14217.28 | 10258 | 174 | 5936.233 | 4283.089 |
| F7 | SH 366 Woodall Rogers | 7.0 | 2.225 | 21080000 | 46903000 | 2.225 | 0.149244 | 15543.36 | 6219 | 244 | 6985.779 | 2795.056 |

| II.A. Freeway Routes | | Nighttime Auto Occupancy per mile | Total Accident Consequence Nighttime | Accident Consequence Per mile Nighttime | Total Risk Factor Nighttime | Risk Factor per mile Nighttime | Total Exposure Miles Nighttime | Exposure Risk Factor Nighttime |
|---|---|---|---|---|---|---|---|---|
| F1 | IH 35 Stemmons | 106.9182 | 6158.24 | 3873.106 | 1514.760 | 952.6795 | 9791.601 | 2408.469 |
| F2 | IH 30 IH35 Common | 100 | 1994.8 | 1704.957 | 1002.916 | 857.1931 | 2333.916 | 1173.411 |
| F3 | IH 30 | 78.78787 | 11759.16 | 5090.545 | 5148.710 | 2228.879 | 27163.65 | 11893.52 |
| F4 | IH 45 | 79.14285 | 19911.84 | 5689.097 | 2217.074 | 633.4498 | 69691.44 | 7759.761 |
| F5 | IH 30 E. RLT | 107.0707 | 17107.6 | 11520.26 | 5558.953 | 3743.403 | 25404.78 | 8255.045 |
| F6 | IH 345/ US 75 | 72.65135 | 24649.28 | 10291.97 | 2319.796 | 968.5997 | 59035.02 | 5555.912 |
| F7 | SH 366 Woodall Rogers | 109.6629 | 22006.36 | 9890.498 | 3284.321 | 1476.099 | 48964.15 | 7307.614 |

VMT = Annual Traffic Volume * Adjusted One-way Mileage (Arterials)
Annual Traffic Volume * Total One-Way Mileage (Freeways)
Average Annual Accident = (Sum TTST accidents for 1980-1984)/5
Probability of Accidents Per Million VMT = VMT * Average Annual Truck Accidents
Daytime Population = Total Segment Population * .40
Nighttime Population = Total Segment Population
Daytime Employment = Total Segment Employment * .84
Nighttime Employment = Total Segment Employment * .16
Total Accident Consequence = Sum Daytime Population, Daytime Employment, Auto Occupancy
Accident Consequence per mile = Total Accident Consequence / Adjusted Mileage
Total Risk Factor = Accident Probability * (Sum Daytime Population, Daytime Employment, Auto Occupancy)
Risk Factor per Mile = Total Risk Factor / Adjusted Mileage

Hazardous Materials Routing II - Dallas CBD
Accident Probabilities for the 1/4-mile Exposure Area - 24-hour Analysis

| A. Arterial Segments | | Average Annual Accidents | Total One-way Mileage | Annual Traffic Volume | Annual VMT | Accident Probability per million VMT | Total Employment | Total Population | 24-hour Vehicle Occupancy | Total Accident Consequence | Accident Consequence per mile | Total Exposure Miles |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A1 | Continental/Industrial | 2 | 1.31 | 7480000 | 7180800 | 0.278520 | 4593 | 3 | 103 | 4699 | 3587.022 | 6155.63 |
| A2 | Industrial | 3.2 | 0.7 | 8160000 | 4243200 | 0.754147 | 457 | 1 | 182 | 640 | 914.2857 | 448 |
| A3 | Industrial/Corinth/Lamar | 4.2 | 3.41 | 6120000 | 16952400 | 0.247752 | 14120 | 5190 | 90 | 19400 | 5689.149 | 66154 |
| A4 | Corinth/Central/Pearl | 2.2 | 1.7 | 4420000 | 7514000 | 0.292786 | 30521 | 1181 | 180 | 31882 | 18754.11 | 54199.4 |
| A5 | Good Latimer/US 75 | 3 | 1.52 | 3060000 | 4069800 | 0.737136 | 17001 | 972 | 119 | 18092 | 11902.63 | 27499.84 |
| A6 | Canton/1st/n2nd/Parry/Peak | 1.6 | 2.36 | 2720000 | 5494400 | 0.291205 | 13363 | 2010 | 127 | 15500 | 6567.796 | 3658 |

| A. Arterial Segments | | Total Risk Factor | Risk Factor per mile | Exposure Risk Factor |
|---|---|---|---|---|
| A1 | Continental/Industrial | 1308.767 | 999.0594 | 1714.485 |
| A2 | Industrial | 482.6546 | 689.5065 | 337.8582 |
| A3 | Industrial/Corinth/Lamar | 4806.399 | 1409.501 | 16389.82 |
| A4 | Corinth/Central/Pearl | 9334.628 | 5490.958 | 15868.86 |
| A5 | Good Latimer/US 75 | 13336.28 | 8773.869 | 20271.14 |
| A6 | Canton/1st/n2nd/Parry/Peak | 4513.686 | 1912.579 | 10652.30 |

| 9. Freeway Segments | | Average Annual Accidents | Total One-way Mileage | Annual Traffic Volume | Annual VMT | Accident Probability per million VMT | Total Employment | Total Population | 24-Hour Vehicle Occupancy | Total Accident Consequence | Accident Consequence per mile | Total Exposure Miles |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| F1 | IH 35 Stemmons | 24.6 | 1.59 | 62900000 | 1.0E+08 | 0.245972 | 13010 | 75 | 622.25 | 13707.25 | 8620.911 | 21794.5 |
| F2 | IH 30 IH 35 Common | 36.8 | 1.17 | 62560000 | 73195200 | 0.502765 | 3596 | 1 | 427.88 | 4024.88 | 3440.068 | 4709.10 |
| F3 | IH 30 | 47.8 | 2.31 | 47260000 | 1.1E+08 | 0.437846 | 16102 | 1734 | 628.89 | 18464.89 | 7993.458 | 42653.6 |
| F4 | IH 45 | 10.6 | 3.5 | 27200000 | 95200000 | 0.111344 | 10355 | 6536 | 461.92 | 17352.92 | 4957.977 | 60735.2 |
| F5 | IH 30 E. RLT | 21 | 1.485 | 43520000 | 64627200 | 0.324940 | 8810 | 5317 | 424.32 | 14551.32 | 9798.868 | 21608.7 |
| F6 | IH 345/US 75 | 8.2 | 2.395 | 36380000 | 87130100 | 0.094112 | 28833 | 2297 | 467.19 | 31597.19 | 13192.98 | 75675.2 |
| F7 | SH 366/Wil Rogers | 7 | 2.225 | 21080000 | 46903000 | 0.149244 | 37215 | 1243 | 244 | 38702 | 17394.15 | 86111.9 |

| 9. Freeway Segments | | Total Risk Factor | Risk Factor per mile | Exposure Risk Factor |
|---|---|---|---|---|
| F1 | IH 35 Stemmons | 3371.612 | 2120.511 | 5360.864 |
| F2 | IH 30 IH 35 Common | 2023.569 | 1729.546 | 2367.576 |
| F3 | IH 30 | 8084.793 | 3499.910 | 18675.87 |
| F4 | IH 45 | 1932.152 | 552.0436 | 6762.535 |
| F5 | IH 30 E. RLT | 4728.314 | 3184.050 | 7021.546 |
| F6 | IH 345/US 75 | 2973.679 | 1241.619 | 7121.961 |
| F7 | SH 366/Wil Rogers | 5776.048 | 2595.976 | 12851.70 |

Annual Traffic Volume = Average Daily Traffic * 340
VMT=Annual Traffic Volume * (Adjusted Mileage/100) - for Arterials
Annual Traffic Volume * (Total Mileage / 200) - for Freeways
Accident Probability = Accident Rate Per Million VMT = (Average Annual Accidents/VMT)*1000000
24-hour Vehicle Occupancy = weighted Sum of Daytime (67%) and Nighttime (33%) Occupancy Rates
Total Exposure Miles = Total Accident Consequence * Total Mileage
Total Accident Consequence = Sum of Population, Employment, and 24-hour Vehicle Occupancy Rate
Accident Consequence per mile = Total Consequence divided by total mileage
Total Risk Factor = Total Accident Consequence * Accident Probability
Risk Factor per mile = Total Risk Factor / Total Mileage
Exposure Risk Factor = Total Exposure Miles * Accident Probability

Hazardous Materials Routing II - Dallas CBD
Hazardous Materials Routing II - Dallas CBD
The 1/4-mile Exposure Area by Time-of-Day
I. Daytime

| I.A. Arterial Segments | | Average Annual Accidents 1980-84 | Adjusted One-way Mileage | Annual Traffic Volume | Annual VMT | Accident Probability per Million VMT | Daytime Employment | Daytime Population | Daytime Vehicle Occupancy | Daytime Employment per mile | Daytime Population per mile | Daytime Occupancy per mile |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A1 | Continental/ Industrial | 2.0 | 0.96 | 7480000 | 7180800 | 0.278520 | 3203.76 | 1.2 | 103 | 3337.25 | 1.25 | 107.2916 |
| A2 | Industrial | 3.2 | 0.52 | 8160000 | 4243200 | 0.754147 | 383.88 | 0.4 | 182 | 738.2307 | 0.769230 | 350 |
| A3 | Industrial/ Corinth/Lamar | 4.2 | 2.77 | 6120000 | 16952400 | 0.247752 | 11860.8 | 2076 | 180 | 4281.877 | 749.4584 | 64.98194 |
| A4 | Corinth/Central Pearl/Canton | 2.2 | 1.7 | 4420000 | 7514000 | 0.292786 | 25637.64 | 472.4 | 90 | 15080.96 | 277.8823 | 52.94117 |
| A5 | Good Latimer/ Fr US 75 | 3.0 | 1.33 | 3060000 | 4069800 | 0.737136 | 14280.84 | 388.8 | 119 | 10737.47 | 292.3308 | 89.47368 |
| A6 | Canton/First/ Second/Parry/Peak | 1.6 | 2.02 | 2720000 | 5494400 | 0.291205 | 11224.92 | 804 | 127 | 5556.891 | 398.0198 | 62.87128 |

| I.A. Arterial Segments | | Total Daytime Accident Consequence | Accident Consequence per mile | Total Risk Factor | Risk Factor per mile | Total Exposure Miles | Exposure Risk Factor |
|---|---|---|---|---|---|---|---|
| A1 | Continental/ Industrial | 3307.96 | 3445.791 | 921.3346 | 959.7236 | 4333.427 | 1206.948 |
| A2 | Industrial | 566.28 | 1089 | 427.0588 | 821.2669 | 396.396 | 298.9411 |
| A3 | Industrial/ Corinth/Lamar | 14116.8 | 5096.317 | 3497.472 | 1262.625 | 48138.28 | 11926.38 |
| A4 | Corinth/Central Pearl/Canton | 26200.04 | 15411.78 | 7671.025 | 4512.368 | 44540.06 | 13040.74 |
| A5 | Good Latimer/ Fr US 75 | 14788.64 | 11119.27 | 10901.25 | 8196.430 | 22478.73 | 16569.90 |
| A6 | Canton/First/ Second/Parry/Peak | 12155.92 | 6017.782 | 3539.871 | 1752.411 | 28687.97 | 8354.097 |

| I.B. Freeway Segments Daytime | | Average Annual Accidents 1980-84 | Total One-way Mileage | Annual Traffic Volume | Annual VMT | Accident Probability per million VMT | Daytime Employment | Daytime Population | Daytime Vehicle Occupancy | Daytime Employment per mile | Daytime Population per mile | Daytime Vehicle Occupancy per mile |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| F1 | IH 35 Stemmons | 24.6 | 1.59 | 62900000 | 1.0E+08 | 0.245972 | 10928.4 | 30 | 845 | 6873.207 | 18.86792 | 531.4465 |
| F2 | IH 30 IH 35 Common | 36.8 | 1.17 | 62560000 | 73195200 | 0.502765 | 3020.64 | 0.4 | 581 | 2581.743 | 0.341880 | 496.5811 |
| F3 | IH 30 | 47.8 | 2.31 | 47260000 | 1.1E+08 | 0.437846 | 13525.68 | 693.6 | 752 | 5855.272 | 300.2597 | 325.5411 |
| F4 | IH 45 | 10.6 | 3.5 | 27200000 | 95200000 | 0.111344 | 8698.2 | 2614.4 | 553 | 2485.2 | 746.9714 | 158 |
| F5 | IH 30 E. ALT | 21.0 | 1.485 | 43520000 | 64627200 | 0.324940 | 7400.4 | 2126.8 | 555 | 4983.434 | 1432.188 | 373.7373 |
| F6 | IH 345/ US 75 | 8.2 | 2.395 | 36380000 | 87130100 | 0.094112 | 24219.72 | 918.8 | 609 | 10112.61 | 383.6325 | 254.2797 |
| F7 | SH 366 Woodall Rogers | 7.0 | 2.225 | 21080000 | 46903000 | 0.149244 | 31260.6 | 497.2 | 244 | 14049.70 | 223.4606 | 109.6629 |

| I.B. Freeway Segments | | Total Accident Consequence | Accident Consequence per mile | Total Risk Factor | Risk Factor per mile | Total Exposure Miles | Exposure Risk Factor |
|---|---|---|---|---|---|---|---|
| F1 | IH 35 Stemmons | 11803.4 | 7423.522 | 2903.317 | 1825.985 | 18767.40 | 4616.274 |
| F2 | IH 30 IH 35 Common | 3602.04 | 3078.666 | 1810.980 | 1547.846 | 4214.386 | 2118.847 |
| F3 | IH 30 | 14971.28 | 6481.073 | 6555.127 | 2837.717 | 34583.65 | 15142.34 |
| F4 | IH 45 | 11865.6 | 3390.171 | 1321.169 | 377.4770 | 41529.6 | 4624.094 |
| F5 | IH 30 E. ALT | 10082.2 | 6789.360 | 3276.115 | 2206.138 | 14972.06 | 4865.032 |
| F6 | IH 345/ US 75 | 25747.52 | 10750.53 | 2423.154 | 1011.755 | 61665.31 | 5803.454 |
| F7 | SH 366 Woodall Rogers | 32001.8 | 14382.83 | 4776.082 | 2146.553 | 71204.00 | 10626.78 |

Annual Traffic Volume = Average Daily Traffic * 340
VMT=Annual Traffic Volume * (Adjusted Mileage/100) - for Arterials
Annual Traffic Volume * (Total Mileage / 200) - for Freeways
Accident Probability = Accident Rate Per Million VMT = (Average Annual Accidents/VMT)*1000000
24-hour Vehicle Occupancy = Weighted Sum of Daytime (67%) and Nighttime (33%) Occupancy Rates
Total Exposure Miles = Total Accident Consequence * Total Mileage
Total Accident Consequence = Sum of Population, Employment, and 24-hour Vehicle Occupancy Rate
Accident Consequence per mile = Total Conceqence divided by total mileage
Total Risk Factor = Total Accident Consequence * Accident Probability
Risk Factor per mile = Total Risk Factor / Total Mileage
Exposure Risk Factor = Total Exposure Miles * Accident Probability

| II.A. Freeway Routes Nighttime | | Average Annual Accidents 1980-84 | Total One-way Mileage | Annual Traffic Volume | Annual VMT | Accident Probability per million VMT | Nighttime Employment | Nighttime Population | Nighttime Vehicle Occupancy | Nighttime Employment per mile | Nighttime Population per mile | Nighttime Vehicle Occupancy per mile |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| F1 | IH 35 Stemmons | 24.6 | 1.59 | 62900000 | 1.0E+08 | 0.245972 | 2081.6 | 75 | 170 | 1309.182 | 47.16981 | 106.9182 |
| F2 | IH 30 IH35 Common | 36.8 | 1.17 | 62560000 | 73195200 | 0.502765 | 575.36 | 1 | 117 | 491.7606 | 0.854700 | 100 |
| F3 | IH 30 | 47.8 | 2.31 | 47260000 | 1.1E+08 | 0.437846 | 2576.32 | 1734 | 182 | 1115.290 | 750.6493 | 78.78787 |
| F4 | IH 45 | 10.6 | 3.5 | 27200000 | 95200000 | 0.111344 | 1656.8 | 6536 | 277 | 473.3714 | 1867.428 | 79.14285 |
| F5 | IH 30 E. ALT | 21.0 | 1.485 | 43520000 | 64627200 | 0.324940 | 1409.6 | 5317 | 159 | 949.2255 | 3580.471 | 107.0707 |
| F6 | IH 345/ US 75 | 8.2 | 2.395 | 36380000 | 87130100 | 0.094112 | 4613.28 | 2297 | 174 | 1926.212 | 959.0814 | 72.65135 |
| F7 | SH 366 Woodall Rogers | 7.0 | 2.225 | 21080000 | 46903000 | 0.149244 | 5954.4 | 1243 | 244 | 2676.134 | 558.6516 | 109.6629 |

| II.A. Freeway Routes | | Total Nighttime Accident Consequence | Nightime Accident Consequence Per mile | Total Nighttime Risk Factor | Nightime Risk Factor per mile | Total Nighttime Exposure Miles | Nighttime Exposure Risk Factor |
|---|---|---|---|---|---|---|---|
| F1 | IH 35 Stemmons | 2326.6 | 1463.270 | 572.2806 | 359.9249 | 3699.294 | 909.9262 |
| F2 | IH 30 IH35 Common | 693.36 | 592.6153 | 348.5972 | 297.9463 | 811.2312 | 407.8588 |
| F3 | IH 30 | 4492.32 | 1944.727 | 1966.948 | 851.4926 | 10377.25 | 4543.649 |
| F4 | IH 45 | 8469.8 | 2419.942 | 943.0659 | 269.4474 | 29644.3 | 3300.730 |
| F5 | IH 30 E. ALT | 6885.6 | 4636.767 | 2237.410 | 1506.673 | 10225.11 | 3322.555 |
| F6 | IH 345/ US 75 | 7084.28 | 2957.945 | 666.7167 | 278.3785 | 16966.85 | 1596.786 |
| F7 | SH 366 Woodall Rogers | 7441.4 | 3344.449 | 1110.585 | 499.1396 | 16557.11 | 2471.053 |

Annual Traffic Volume = Average Daily Traffic * 340
VMT=Annual Traffic Volume * (Adjusted Mileage/100) - for Arterials
Annual Traffic Volume * (Total Mileage / 200) - for Freeways
Accident Probability = Accident Rate Per Million VMT = (Average Annual Accidents/VMT)*1000000
24-hour Vehicle Occupancy = weighted Sum of Daytime (67%) and Nighttime (33%) Occupancy Rates
Total Exposure Miles = Total Accident Consequence * Total Mileage
Total Accident Consequence = Sum of Population, Employment, and 24-hour Vehicle Occupancy Rate
Accident Consequence per mile = Total Consequence divided by total mileage
Total Risk Factor = Total Accident Consequence * Accident Probability
Risk Factor per mile = Total Risk Factor / Total Mileage
Exposure Risk Factor = Total Exposure Miles * Accident Probability

II. Nighttime

| II.A. Arterial Routes | | Average Annual Accidents 1980-84 | Adjusted One-way Mileage | Annual Traffic Volume | Annual VMT | Accident Probability per million VMT | Nighttime Employment | Nighttime Population | Nighttime Vehicle Occupancy | Nighttime Employment per mile | Nighttime Population per mile | Nighttime Vehicle Occupancy per mile |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A1 | Continental/ Industrial | 2.0 | 0.96 | 7480000 | 7180800 | 0.278520 | 734.88 | 3 | 103 | 765.5 | 3.125 | 107.2916 |
| A2 | Industrial | 3.2 | 0.52 | 8160000 | 4243200 | 0.754147 | 73.12 | 1 | 183 | 140.6153 | 1.923076 | 351.9230 |
| A3 | Industrial/ Corinth/Lamar | 4.2 | 2.77 | 6120000 | 16952400 | 0.247752 | 2259.2 | 5190 | 136 | 815.5956 | 1873.646 | 49.09747 |
| A4 | Corinth/Central Expwy/ Pearl/Canton | 2.2 | 1.7 | 4420000 | 7514000 | 0.292786 | 4883.36 | 1181 | 90 | 2872.564 | 694.7058 | 52.94117 |
| A5 | Good Latimer/ Fr US 75 | 3.0 | 1.33 | 3060000 | 4069800 | 0.737136 | 2720.16 | 972 | 119 | 2045.233 | 730.8270 | 89.47368 |
| A6 | Canton/First/ Second/Parry/Peak | 1.6 | 2.02 | 2720000 | 5494400 | 0.291205 | 2138.08 | 2010 | 127 | 1058.455 | 995.0495 | 62.87128 |

II. Nighttime

| II.A. Arterial Routes | | Total Nighttime Accident Consequence | Nighttime Accident Consequence per mile | Total Nighttime Risk Factor | Nighttime Risk Factor per mile | Total Nighttime Exposure Miles | Exposure Risk Factor Nighttime |
|---|---|---|---|---|---|---|---|
| A1 | Continental/ Industrial | 840.88 | 875.9166 | 234.2023 | 243.9607 | 1101.552 | 306.8050 |
| A2 | Industrial | 257.12 | 494.4615 | 193.9064 | 372.8970 | 179.984 | 135.7345 |
| A3 | Industrial/ Corinth/Lamar | 7585.2 | 2738.339 | 1879.252 | 678.4305 | 25865.53 | 6408.251 |
| A4 | Corinth/Central Expwy/ Pearl/Canton | 6154.36 | 3620.211 | 1801.915 | 1059.950 | 10462.41 | 3063.256 |
| A5 | Good Latimer/ Fr US 75 | 3811.16 | 2865.533 | 2809.346 | 2112.290 | 5792.963 | 4270.207 |
| A6 | Canton/First/ Second/Parry/Peak | 4275.08 | 2116.376 | 1244.927 | 616.3005 | 10089.18 | 2938.028 |

Hazardous Materials Routing II-Dallas CBD
Accident Probabilities for the Total 24-hour Exposure Area - Using default accident rates.
Risk Statistics based on the Total one-way Mileage - VMT based on Adjusted one-way Mileage

| A. Arterial Segments | | Average Annual Accidents | Total One-way Mileage | Annual Traffic Volume | Annual VMT | Accident Probability per Million VMT | Total Employment | Total Population | 24-hour Vehicle Occupancy | Total Accident Consequence | Accident Consequence per mile | Total Exposure Miles |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A1 | Continental/Industrial | 2 | 1.31 | 7480000 | 7180800 | 8.7 | 22034 | 630 | 103 | 22767 | 17379.38 | 29824.7 |
| A2 | Industrial | 3.2 | 0.7 | 8160000 | 4243200 | 6.5 | 7319 | 40 | 182 | 7541 | 10772.85 | 5278. |
| A3 | Industrial/Corinth/Lamar | 4.2 | 3.41 | 6120000 | 16952400 | 6.2 | 19956 | 9016 | 90 | 29062 | 8522.580 | 99101.4 |
| A4 | Corinth/Central/Pearl | 2.2 | 1.7 | 4420000 | 7514000 | 11.1 | 109951 | 5539 | 180 | 115670 | 68041.17 | 19663 |
| A5 | Good Latimer/US 75 | 3 | 1.52 | 3060000 | 4069800 | 11.3 | 70858 | 4236 | 119 | 75213 | 49482.23 | 114323. |
| A6 | Canton/1st/n2nd/Parry/Peak | 1.6 | 2.36 | 2720000 | 5494400 | 11.3 | 51996 | 17765 | 127 | 69888 | 29613.55 | 164935. |

| A. Arterial Segments | | Total Risk Factor | Risk Factor per mile | Exposure Miles' Risk |
|---|---|---|---|---|
| A1 | Continental/Industrial | 198072.9 | 151200.6 | 259475.4 |
| A2 | Industrial | 49016.5 | 70022.57 | 34311.55 |
| A3 | Industrial/Corinth/Lamar | 180184.4 | 52840 | 514428.9 |
| A4 | Corinth/Central/Pearl | 1283937 | 755257.0 | 2182592. |
| A5 | Good Latimer/US 75 | 849906.9 | 559149.2 | 1291858. |
| A6 | Canton/1st/n2nd/Parry/Peak | 789734.4 | 334633.2 | 1863773. |

| B. Freeway Segments | | Average Annual Accidents | Total One-Way Mileage | Adjusted Annual Traffic | VMT | Accident Probabiltiy per Million VMT | Total Employment | Total Population | 24-Hour Vehicle Occupancy | Total Accident Consequence | Accident Consequence per mile | Total Exposure Miles |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| F1 | IH 35 Stemmons | 24.6 | 1.59 | 62900000 | 1.0E+08 | 3.21975 | 33464 | 634 | 622.25 | 34720.25 | 21836.63 | 55205.19 |
| F2 | IH 30 IH 35 Common | 36.8 | 1.17 | 62560000 | 73195200 | 2.36106 | 10111 | 105 | 427.88 | 10643.88 | 9097.333 | 12453.33 |
| F3 | IH 30 | 47.8 | 2.31 | 47260000 | 1.1E+08 | 5.37999 | 43751 | 4577 | 628.89 | 48956.89 | 21193.45 | 113090.4 |
| F4 | IH 45 | 10.6 | 3.5 | 27200000 | 95200000 | 5.88 | 30324 | 14783 | 461.92 | 45568.92 | 13019.69 | 159491.2 |
| F5 | IH 30 E. RLT | 21 | 1.485 | 43520000 | 64627200 | 2.41461 | 20910 | 13603 | 424.32 | 34937.32 | 23526.81 | 51881.92 |
| F6 | IH 345/US 75 | 8.2 | 2.395 | 36380000 | 87130100 | 4.734915 | 88858 | 10258 | 467.19 | 99583.19 | 41579.62 | 238501.7 |
| F7 | SH 366/Wdl Rogers | 7 | 2.225 | 21080000 | 46903000 | 2.5899 | 97146 | 6219 | 244 | 103609 | 46565.84 | 230530.0 |

| B. Freeway Segments | | Total Risk Factor | Risk Factor per mile | Exposure Miles' Risk |
|---|---|---|---|---|
| F1 | IH 35 Stemmons | 111790.5 | 70308.50 | 177746.9 |
| F2 | IH 30 IH 35 Common | 25130.83 | 21479.34 | 29403.08 |
| F3 | IH 30 | 263387.5 | 114020.5 | 608425.3 |
| F4 | IH 45 | 267945.2 | 76555.78 | 937808.3 |
| F5 | IH 30 E. RLT | 84360.00 | 56808.08 | 125274.6 |
| F6 | IH 345/US 75 | 471517.9 | 196875.9 | 1129285. |
| F7 | SH 366/Wdl Rogers | 268336.9 | 120600.8 | 597049.7 |

Annual Traffic Volume = Average Daily Traffic * 340
VMT=Annual Traffic Volume * (Adjusted Mileage/100) - for Arterials
Annual Traffic Volume * (Total Mileage / 200) - for Freeways
Accident Probability = Accident Rate Per Million VMT = (Average Annual Accidents/VMT)*1000000
24-hour Vehicle Occupancy = Weighted Sum of Daytime (67%) and Nighttime (33%) Occupancy Rates
Total Exposure Miles = Total Accident Consequence * Total Mileage
Total Accident Consequence = Sum of Population, Employment, and 24-hour Vehicle Occupancy Rate
Accident Consequence per mile = Total Consequence divided by total mileage
Total Risk Factor = Total Accident Consequence * Accident Probability
Risk Factor per mile = Total Risk Factor / Total Mileage
Exposure Risk Factor = Total Exposure Miles * Accident Probability

Hazardous Materials Routing II-Dallas CBD- 1/4-mile exposure area
Accident Probabilities for the 1/4-mile Exposure Area Total 24-hour period - Using default accident rates
Risk Statistics based on the Total one-way Mileage - VMT based on Adjusted one-way Mileage

| A. Arterial Segments | | Average Annual Accidents | Total One-way Mileage | Adjusted Annual Traffic | VMT | Probably Accident Mill VMT | Total Employment | Total Population | 24-hour Vehicle Occupancy | Total Accident Consequence | Accident Consequence per mile | Total Exposure Miles |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A1 | Continental/Industrial | 2 | 1.31 | 7480000 | 7180800 | 8.7 | 4593 | 3 | 103 | 4699 | 3587.022 | 6155.69 |
| A2 | Industrial | 3.2 | 0.7 | 8160000 | 4243200 | 6.5 | 457 | 1 | 182 | 640 | 914.2857 | 448 |
| A3 | Industrial/Corinth/Lamar | 4.2 | 3.41 | 6120000 | 16952400 | 6.2 | 14120 | 5190 | 90 | 19400 | 5689.149 | 66154 |
| A4 | Corinth/Central/Pearl | 2.2 | 1.7 | 4420000 | 7514000 | 11.1 | 30521 | 1181 | 180 | 31882 | 18754.11 | 54199.4 |
| A5 | Good Latimer/US 75 | 3 | 1.52 | 3060000 | 4069800 | 11.3 | 17001 | 972 | 119 | 18092 | 11902.63 | 27499.84 |
| A6 | Canton/1st/n2nd/Parry/Peak | 1.6 | 2.36 | 2720000 | 5494400 | 11.3 | 13363 | 2010 | 127 | 15500 | 6567.736 | 36580 |

| A. Arterial Segments | | Total Risk Factor | Risk Factor per mile | Exposure Miles' Risk |
|---|---|---|---|---|
| A1 | Continental/Industrial | 40881.3 | 31207.09 | 53554.50 |
| A2 | Industrial | 4160 | 5942.857 | 2912 |
| A3 | Industrial/Corinth/Lamar | 120280 | 35272.72 | 410154.8 |
| A4 | Corinth/Central/Pearl | 353890.2 | 208170.7 | 601613.3 |
| A5 | Good Latimer/US 75 | 204439.6 | 134499.7 | 310748.1 |
| A6 | Canton/1st/n2nd/Parry/Peak | 175150 | 74216.10 | 413354 |

| B. Freeway Segments | | Average Annual Accidents | Total One-Way Mileage | Adjusted Annual Traffic | VMT | Accident Probability per Million VMT | Total Employment | Total Population | 24-Hour Vehicle Occupancy | Total Accident Consequence | Accident Consequence per mile | Tota Expos Miles |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| F1 | IH 35 Stemmons | 24.6 | 1.59 | 62900000 | 1.0E+08 | 3.22 | 13010 | 75 | 622.25 | 13707.25 | 8620.911 | 21794.52 |
| F2 | IH 30 IH 35 Common | 36.8 | 1.17 | 62560000 | 73195200 | 2.36 | 3596 | 1 | 427.88 | 4024.88 | 3440.068 | 4709.109 |
| F3 | IH 30 | 47.8 | 2.31 | 47260000 | 1.1E+08 | 5.38 | 16102 | 1734 | 628.89 | 18464.89 | 7993.458 | 42653.89 |
| F4 | IH 45 | 10.6 | 3.5 | 27200000 | 95200000 | 5.88 | 10355 | 6536 | 461.92 | 17352.92 | 4957.977 | 60735.22 |
| F5 | IH 30 E. RLT | 21 | 1.485 | 43520000 | 64627200 | 2.41 | 8810 | 5317 | 424.32 | 14551.32 | 9798.868 | 21608.71 |
| F6 | IH 345/US 75 | 8.2 | 2.395 | 36380000 | 87130100 | 4.73 | 28833 | 2297 | 467.19 | 31597.19 | 13192.98 | 75675.27 |
| F7 | SH 366/Wdl Rogers | 7 | 2.225 | 21080000 | 46903000 | 2.59 | 37215 | 1243 | 244 | 38702 | 17394.15 | 86111.95 |

| B. Freeway Segments | | Total Risk Factor | Risk Factor per mile | Exposure Miles' Risk |
|---|---|---|---|---|
| F1 | IH 35 Stemmons | 44137.34 | 27759.33 | 70178.37 |
| F2 | IH 30 IH 35 Common | 9498.716 | 8118.561 | 11113.49 |
| F3 | IH 30 | 99341.10 | 43004.80 | 229477.9 |
| F4 | IH 45 | 102035.1 | 29152.90 | 357123.0 |
| F5 | IH 30 E. RLT | 35068.68 | 23615.27 | 52076.99 |
| F6 | IH 345/US 75 | 149454.7 | 62402.80 | 357944.0 |
| F7 | SH 366/Wdl Rogers | 100238.1 | 45050.86 | 223029.9 |

Annual Traffic Volume = Average Daily Traffic * 34[illegible]
VMT=Annual Traffic Volume * (Adjusted Mileage/100) - for Arterials
Annual Traffic Volume * (Total Mileage / 200) - for Freeways
Accident Probability = Accident Rate Per Million VMT = (Average Annual Accidents/VMT)*1000000
24-hour Vehicle Occupancy = weighted Sum of Daytime (67%) and Nighttime (32%) Occupancy Rates
Total Exposure Miles = Total Accident Consequence * Total Mileage
Total Accident Consequence = Sum of Population, Employment, and 24-hour Vehicle Occupancy Rate
Accident Consequence per mile = Total Consequence divided by total mileage
Total Risk Factor = Total Accident Consequence * Accident Probability
Risk Factor per mile = Total Risk Factor / Total Mileage
Exposure Risk Factor = Total Exposure Miles * Accident Probability

# APPENDIX F

# FURTHER RISK ASSESSMENT RESULTS

LIST OF TABLES

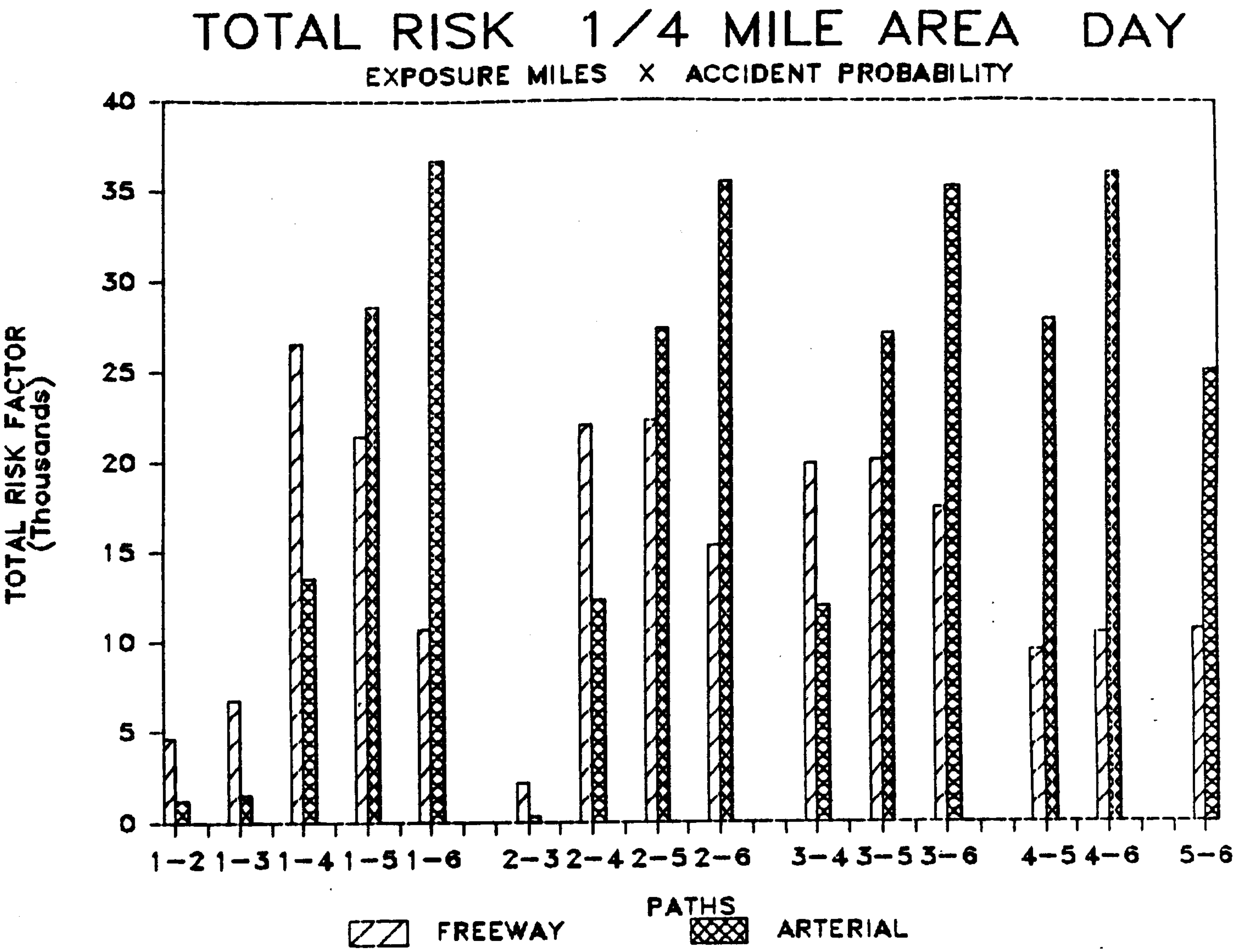
## LIST OF FIGURES

TABLE F-1

SUMMARY OF TOTAL RISK ASSESSMENT BASED ON EXPOSURE MILES
1/4 MILE DAY ANALYSIS

| PATHS | FREEWAY RISK | ARTERIAL RISK | FREEWAY/ARTERIAL RATIO OF RISK |
|---|---|---|---|
| S1-S2 | 4616.27 | 1206.95 | 3.82 |
| S1-S3 | 6735.12 | 1505.89 | 4.47 |
| S1-S4 | 26501.55 | 13432.27 | 1.97 |
| S1-S5 | 21295.26 | 28454.85 | 0.75 |
| S1-S6 | 10626.78 | 36670.65 | 0.29 |
| S2-S3 | 2118.85 | 298.94 | 7.09 |
| S2-S4 | 21885.28 | 12225.32 | 1.79 |
| S2-S5 | 22126.22 | 27247.90 | 0.81 |
| S2-S6 | 15243.05 | 35463.70 | 0.43 |
| S3-S4 | 19766.43 | 11926.38 | 1.66 |
| S3-S5 | 20007.37 | 26948.96 | 0.74 |
| S3-S6 | 17361.90 | 35164.76 | 0.49 |
| S4-S5 | 9489.12 | 27767.10 | 0.34 |
| S4-S6 | 10427.54 | 35982.90 | 0.29 |
| S5-S6 | 10668.48 | 24924.00 | 0.43 |
| TOTAL/2 | 218869.22 | 319220.57 | 0.69 |
| TOTAL | 437738.44 | 638441.14 | 0.69 |

FIGURE F-1



TOTAL RISK 1/4 MILE AREA DAY
EXPOSURE MILES X ACCIDENT PROBABILITY
TOTAL RISK FACTOR (Thousands)
40
35
30
25
20
15
10
5
0
1-2 1-3 1-4 1-5 1-6 2-3 2-4 2-5 2-6 3-4 3-5 3-6 4-5 4-6 5-6
PATHS
FREEWAY
ARTERIAL

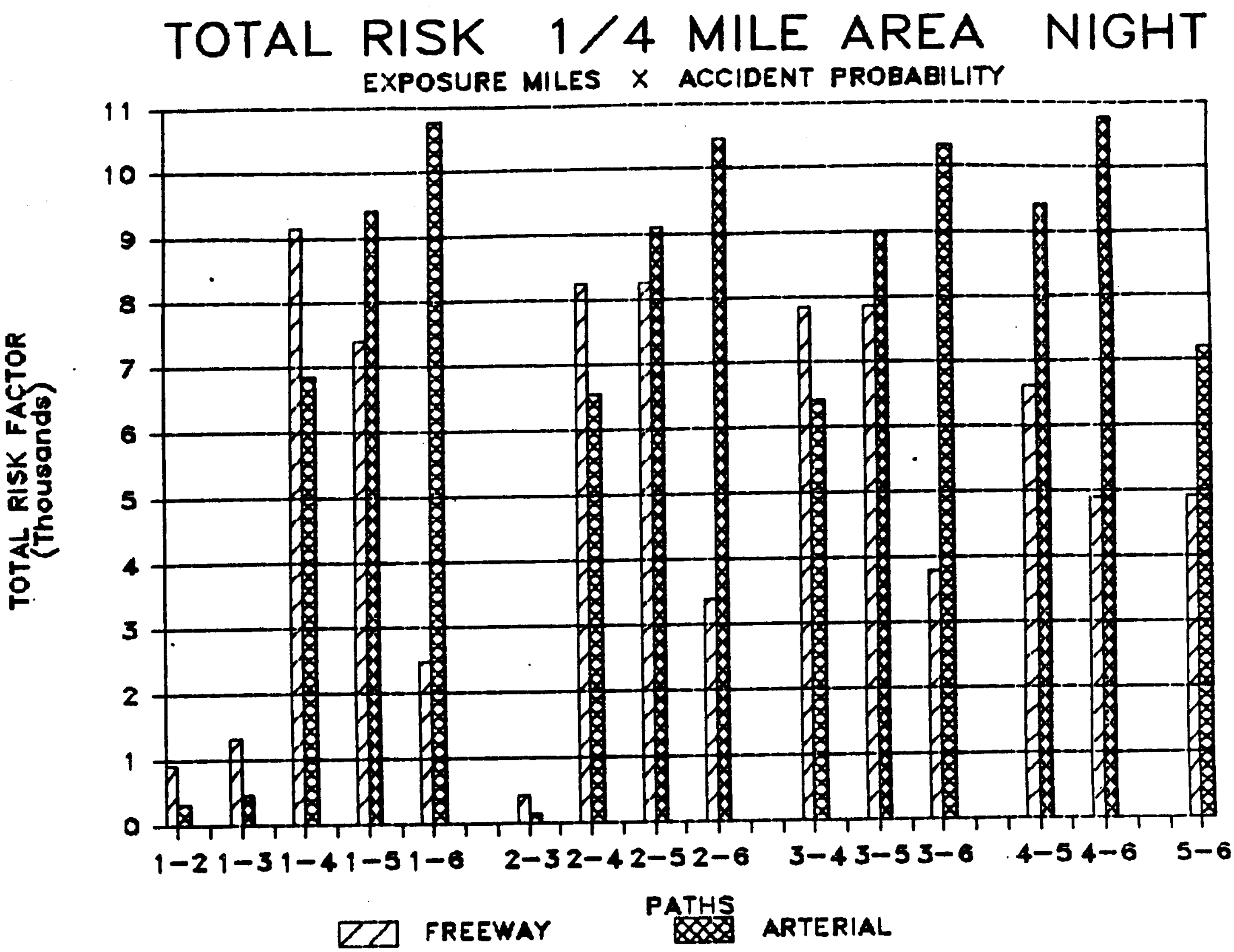
TABLE F-2

SUMMARY OF TOTAL RISK ASSESSMENT BASED ON EXPOSURE MILES
1/4 MILE AREA NIGHT ANALYSIS

| PATHS | FREEWAY RISK | ARTERIAL RISK | RATIO OF RISK |
|---|---|---|---|
| S1-S2 | 909.93 | 306.81 | 2.97 |
| S1-S3 | 1317.79 | 442.54 | 2.98 |
| S1-S4 | 9162.17 | 6850.79 | 1.34 |
| S1-S5 | 7390.40 | 9428.15 | 0.78 |
| S1-S6 | 2471.05 | 10760.33 | 0.23 |
| S2-S3 | 407.86 | 135.73 | 3.00 |
| S2-S4 | 8252.24 | 6543.98 | 1.26 |
| S2-S5 | 8274.07 | 9121.34 | 0.91 |
| S2-S6 | 3380.98 | 10453.52 | 0.32 |
| S3-S4 | 7844.38 | 6408.25 | 1.22 |
| S3-S5 | 7866.21 | 8985.61 | 0.88 |
| S3-S6 | 3788.84 | 10317.79 | 0.37 |
| S4-S5 | 6623.29 | 9425.22 | 0.70 |
| S4-S6 | 4897.52 | 10757.40 | 0.46 |
| S5-S6 | 4919.35 | 7208.24 | 0.68 |
| TOTAL/2 | 77506.08 | 107145.70 | 0.72 |
| TOTAL | 155012.16 | 214291.40 | 0.72 |

RATIO OF RISK > 1 INDICATES ARTERIAL TO BE SAFER
RATIO OF RISK < 1 INDICATES FREEWAY TO BE SAFER

FIGURE F-2



TOTAL RISK 1/4 MILE AREA NIGHT
EXPOSURE MILES X ACCIDENT PROBABILITY
TOTAL RISK FACTOR (Thousands)
0
1
2
3
4
5
6
7
8
9
10
11
1-2 1-3 1-4 1-5 1-6 2-3 2-4 2-5 2-6 3-4 3-5 3-6 4-5 4-6 5-6
PATHS
FREEWAY
ARTERIAL

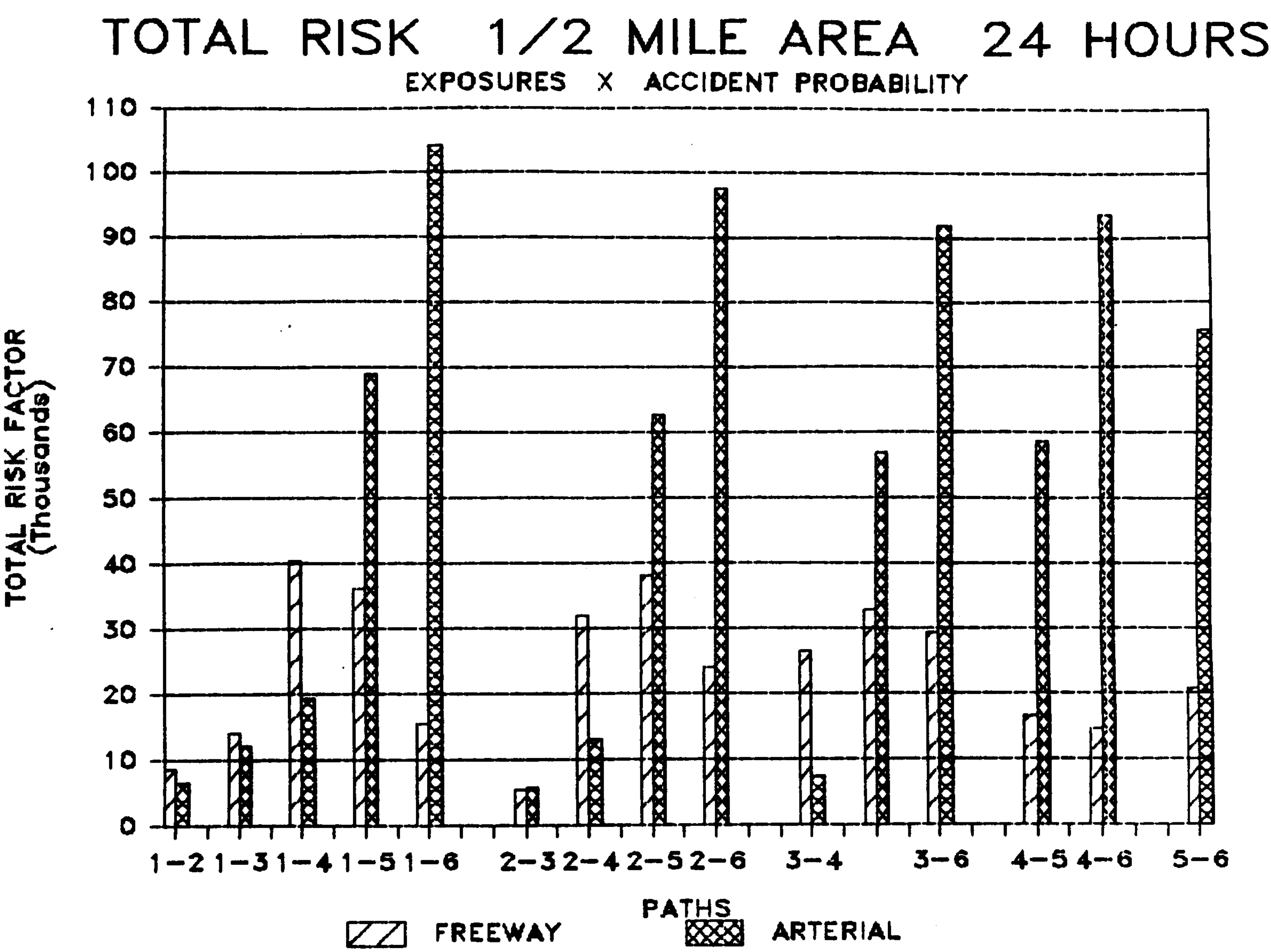
TABLE F-3

SUMMARY OF TOTAL RISK ASSESSMENT BASED ON SEGMENT RISKS PER MILE
1/2 MILE AREA 24 HOUR ANALYSIS

| PATHS | FREEWAY RISK | ARTERIAL RISK | FREEWAY/ARTERIAL RATIO OF RISK |
|---|---|---|---|
| S1-S2 | 5371.22 | 4840.52 | 1.11 |
| S1-S3 | 9945.04 | 12964.85 | 0.77 |
| S1-S4 | 20674.20 | 15076.34 | 1.37 |
| S1-S5 | 18507.65 | 42493.35 | 0.44 |
| S1-S6 | 6949.68 | 70344.90 | 0.10 |
| S2-S3 | 4573.82 | 8124.33 | 0.56 |
| S2-S4 | 15302.98 | 10235.82 | 1.50 |
| S2-S5 | 21498.13 | 37652.83 | 0.57 |
| S2-S6 | 12320.90 | 65504.38 | 0.19 |
| S3-S4 | 10729.16 | 2111.49 | 5.08 |
| S3-S5 | 16924.31 | 29528.50 | 0.57 |
| S3-S6 | 13192.64 | 57380.05 | 0.23 |
| S4-S5 | 9094.49 | 29673.35 | 0.31 |
| S4-S6 | 5362.82 | 57524.90 | 0.09 |
| S5-S6 | 11557.97 | 45098.81 | 0.26 |
| TOTAL/2 | 182005.01 | 488554.42 | 0.37 |
| TOTAL | 364010.02 | 977108.84 | 0.37 |

RATIO OF RISK > 1 INDICATES ARTERIAL TO BE SAFER
RATIO OF RISK < 1 INDICATES FREEWAY TO BE SAFER

FIGURE F-3



TOTAL RISK 1/2 MILE AREA 24 HOURS
EXPOSURES X ACCIDENT PROBABILITY
TOTAL RISK FACTOR (Thousands)
110
100
90
80
70
60
50
40
30
20
10
0
1-2 1-3 1-4 1-5 1-6 2-3 2-4 2-5 2-6 3-4 3-6 4-5 4-6 5-6
PATHS
FREEWAY
ARTERIAL

TABLE F-4

SUMMARY OF TOTAL RISK ASSESSMENT BASED ON SEGMENT RISK PER MILE
1/2 MILE AREA   DAY ANALYSIS

| PATHS | FREEWAY RISK | ARTERIAL RISK | FREEWAY/ARTERIAL RATIO OF RISK |
|---|---|---|---|
| S1-S2 | 4518.53 | 4010.60 | 1.13 |
| S1-S3 | 8785.67 | 10847.44 | 0.81 |
| S1-S4 | 17257.18 | 12340.45 | 1.40 |
| S1-S5 | 21396.55 | 34246.20 | 0.62 |
| S1-S6 | 5656.81 | 57708.35 | 0.10 |
| S2-S3 | 4267.14 | 6836.84 | 0.62 |
| S2-S4 | 12738.65 | 8329.85 | 1.53 |
| S2-S5 | 16878.02 | 30235.60 | 0.56 |
| S2-S6 | 10175.34 | 53697.75 | 0.19 |
| S3-S4 | 8471.51 | 1493.01 | 5.67 |
| S3-S5 | 12610.88 | 23399.25 | 0.54 |
| S3-S6 | 10573.65 | 46891.40 | 0.23 |
| S4-S5 | 6147.47 | 23762.61 | 0.26 |
| S4-S6 | 4134.24 | 47224.58 | 0.09 |
| S5-S6 | 8273.61 | 36026.85 | 0.23 |
| TOTAL/2 | 151885.25 | 397050.78 | 0.38 |
| TOTAL | 303770.50 | 794101.56 | 0.38 |

RATIO OF RISK > 1 INDICATES ARTERIAL TO BE SAFER
RATIO OF RISK < 1 INDICATES FREEWAY TO BE SAFER

FIGURE F-4

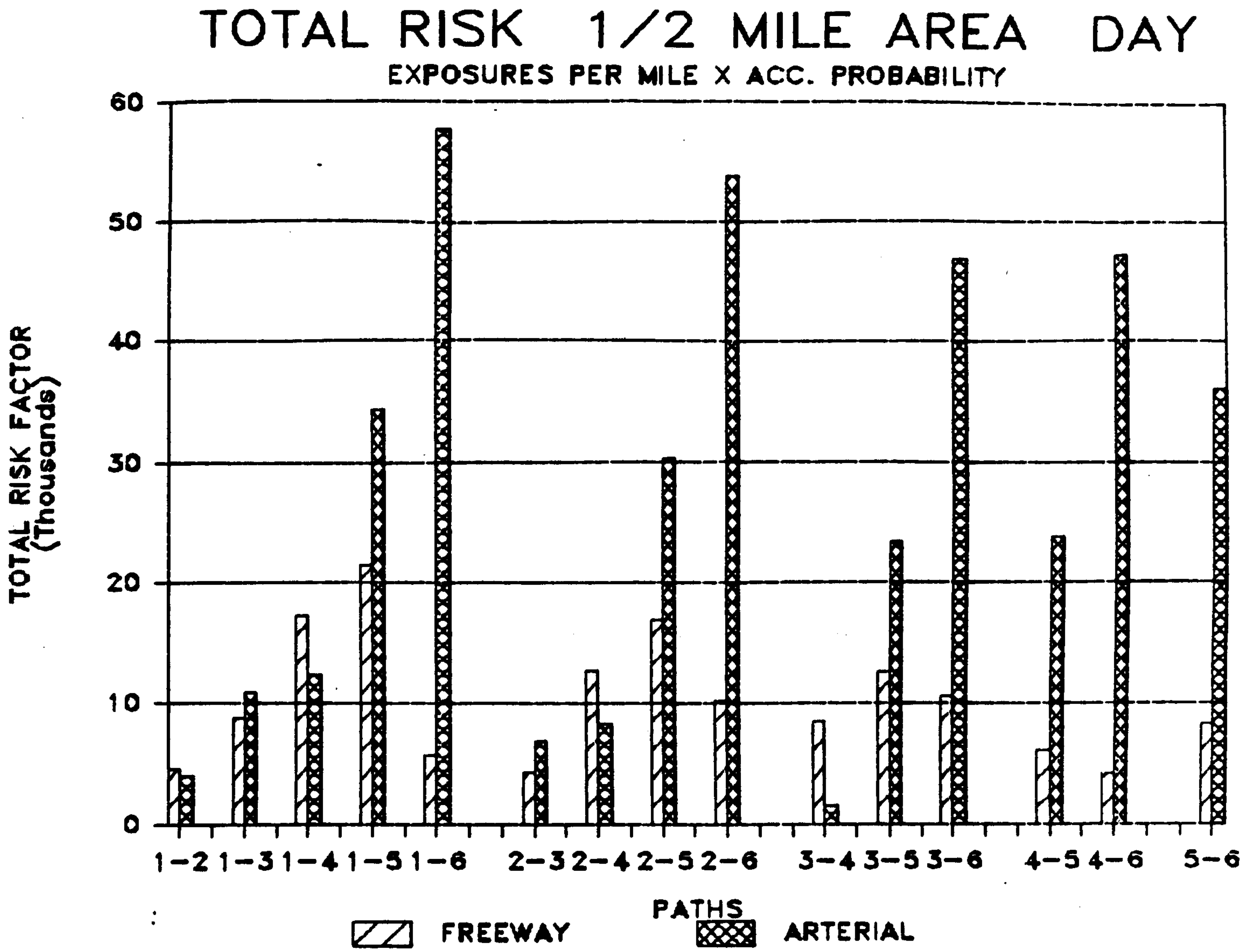

TOTAL RISK 1/2 MILE AREA DAY
EXPOSURES PER MILE X ACC. PROBABILITY
TOTAL RISK FACTOR (Thousands)
0
10
20
30
40
50
60
1-2
1-3
1-4
1-5
1-6
2-3
2-4
2-5
2-6
3-4
3-5
3-6
4-5
4-6
5-6
PATHS
FREEWAY
ARTERIAL

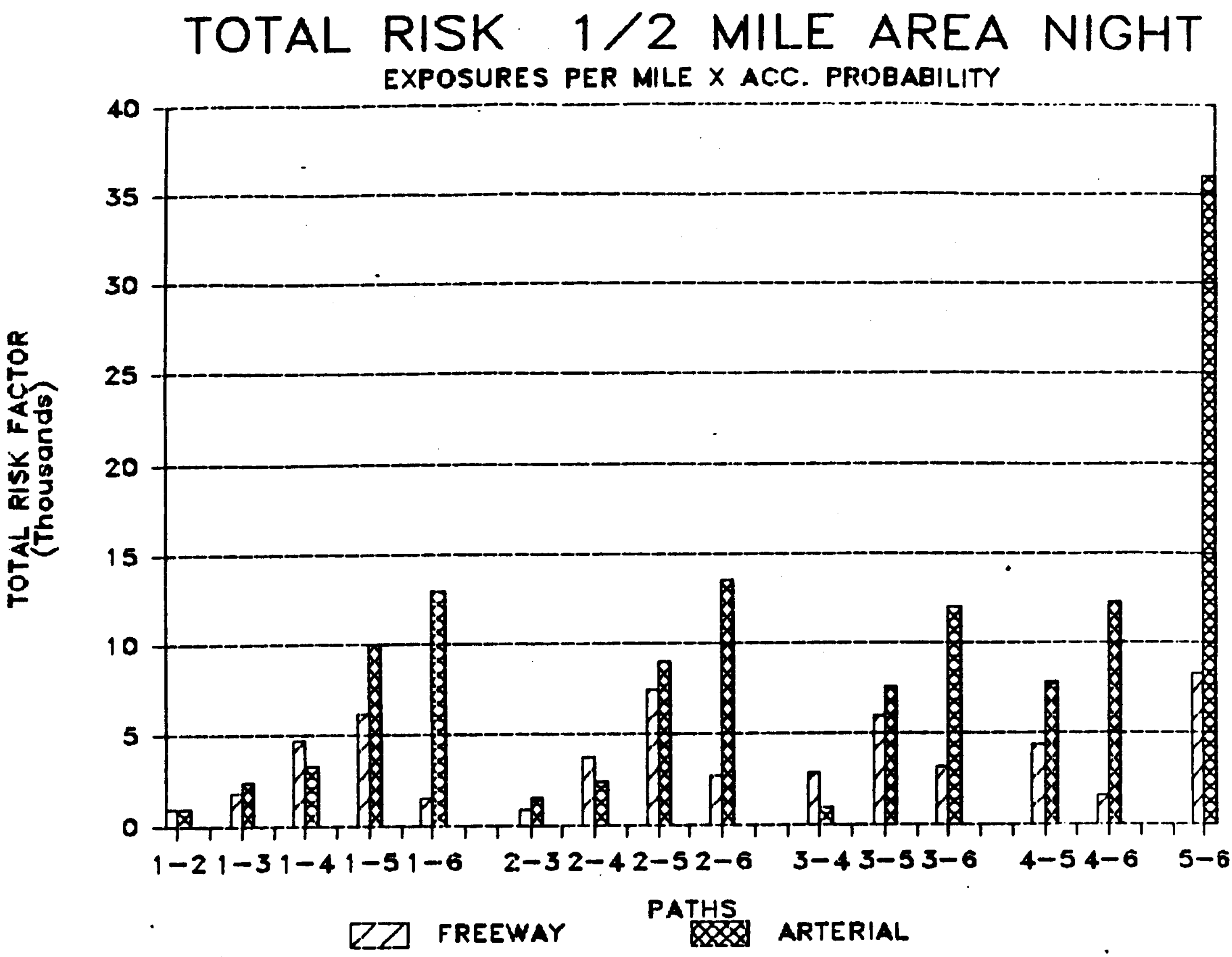
TABLE F-5

SUMMARY OF TOTAL RISK ASSESSMENT BASED ON SEGMENT RISK PER MILE
1/2 MILE AREA NIGHT

| PATHS | FREEWAY RISK | ARTERIAL RISK | FREEWAY/ARTERIAL RATIO OF RISK |
|---|---|---|---|
| S1-S2 | 952.68 | 905.39 | 1.05 |
| S1-S3 | 1809.87 | 2407.26 | 0.75 |
| S1-S4 | 4672.20 | 3304.18 | 1.41 |
| S1-S5 | 6188.10 | 10012.10 | 0.62 |
| S1-S6 | 1476.10 | 12916.95 | 0.11 |
| S2-S3 | 857.19 | 1501.87 | 0.57 |
| S2-S4 | 3719.52 | 2398.79 | 1.55 |
| S2-S5 | 7462.92 | 9016.71 | 0.83 |
| S2-S6 | 2711.58 | 13498.24 | 0.20 |
| S3-S4 | 2862.33 | 896.91 | 3.19 |
| S3-S5 | 5971.28 | 7604.84 | 0.79 |
| S3-S6 | 3197.48 | 11996.37 | 0.27 |
| S4-S5 | 4376.85 | 7823.69 | 0.56 |
| S4-S6 | 1602.05 | 12215.22 | 0.13 |
| S5-S6 | 8273.61 | 36026.85 | 0.23 |
| TOTAL/2 | 56133.76 | 132525.37 | 0.42 |
| TOTAL | 112267.52 | 265050.74 | 0.42 |

RATIO OF RISK > 1 INDICATES ARTERIAL TO BE SAFER
RATIO OF RISK < 1 INDICATES FREEWAY TO BE SAFER

FIGURE F-5


TOTAL RISK 1/2 MILE AREA NIGHT
EXPOSURES PER MILE X ACC. PROBABILITY
TOTAL RISK FACTOR (Thousands)
40
35
30
25
20
15
10
5
0
1-2
1-3
1-4
1-5
1-6
2-3
2-4
2-5
2-6
3-4
3-5
3-6
4-5
4-6
5-6
PATHS
FREEWAY
ARTERIAL

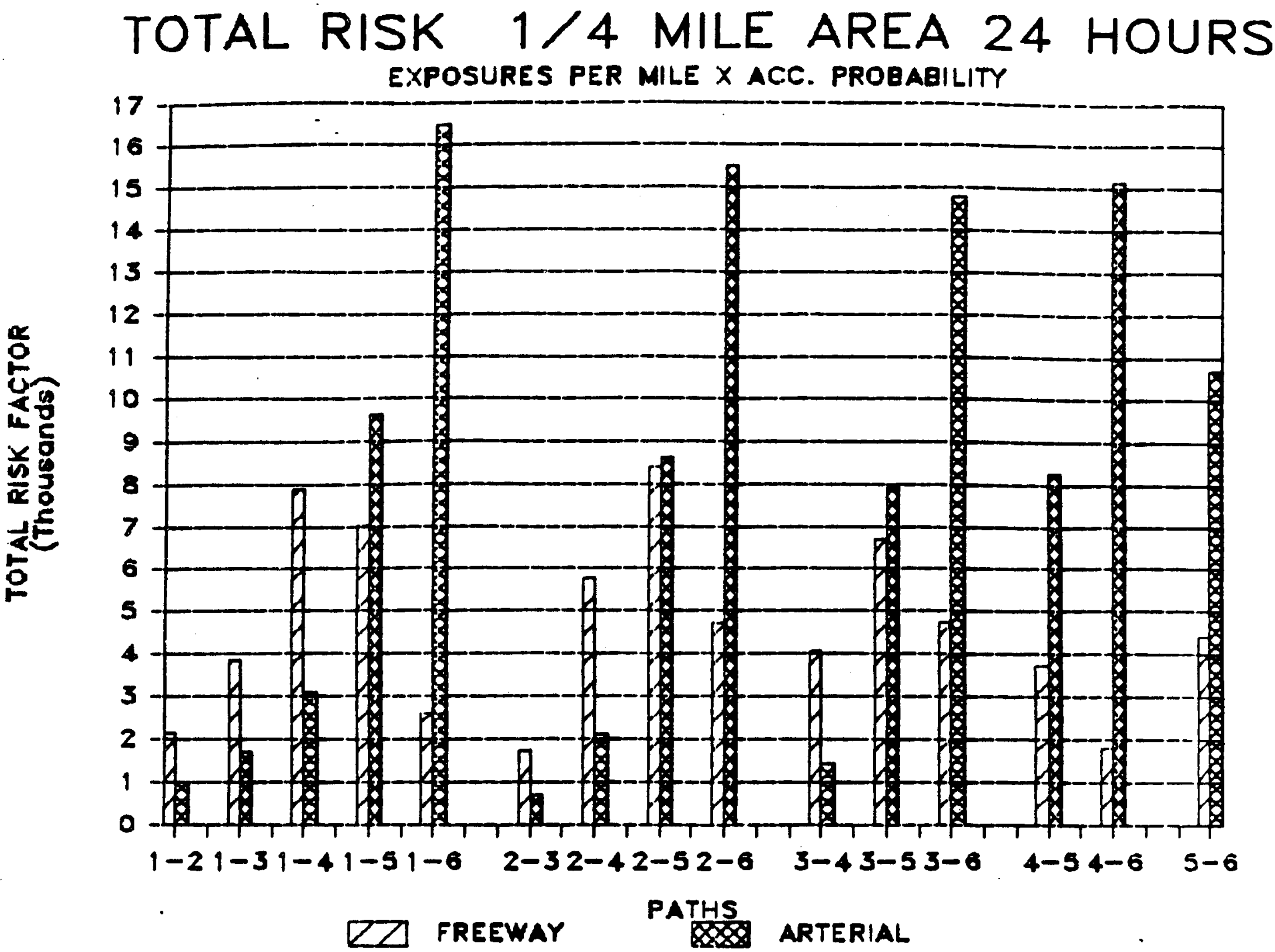
## TABLE F-6

SUMMARY OF TOTAL RISK ASSESSMENT BASED ON SEGMENT RISK PER MILE
1/4 MILE AREA 24 HOUR ANALYSIS

| PATHS | FREEWAY RISK | ARTERIAL RISK | FREEWAY/ARTERIAL RATIO OF RISK |
|---|---|---|---|
| S1-S2 | 2120.51 | 999.06 | 2.12 |
| S1-S3 | 3850.06 | 1688.57 | 2.28 |
| S1-S4 | 7902.01 | 3098.07 | 2.55 |
| S1-S5 | 7021.65 | 9624.90 | 0.73 |
| S1-S6 | 2595.98 | 16486.19 | 0.16 |
| S2-S3 | 1729.55 | 689.51 | 2.51 |
| S2-S4 | 5781.50 | 2099.01 | 2.75 |
| S2-S5 | 8413.51 | 8625.84 | 0.98 |
| S2-S6 | 4716.49 | 15487.13 | 0.30 |
| S3-S4 | 4051.95 | 1409.50 | 2.87 |
| S3-S5 | 6683.96 | 7936.33 | 0.84 |
| S3-S6 | 4741.53 | 14797.62 | 0.32 |
| S4-S5 | 3736.09 | 8280.25 | 0.45 |
| S4-S6 | 1793.66 | 15141.54 | 0.12 |
| S5-S6 | 4425.67 | 10686.45 | 0.41 |
| TOTAL/2 | 69564.12 | 117049.97 | 0.59 |
| TOTAL | 139128.24 | 234099.95 | 0.59 |

RATIO OF RISK > 1 INDICATES ARTERIAL TO BE SAFER
RATIO OF RISK < 1 INDICATES FREEWAY TO BE SAFER

FIGURE F-6


TOTAL RISK 1/4 MILE AREA 24 HOURS
EXPOSURES PER MILE X ACC. PROBABILITY
TOTAL RISK FACTOR (Thousands)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
1-2 1-3 1-4 1-5 1-6 2-3 2-4 2-5 2-6 3-4 3-5 3-6 4-5 4-6 5-6
PATHS
FREEWAY
ARTERIAL

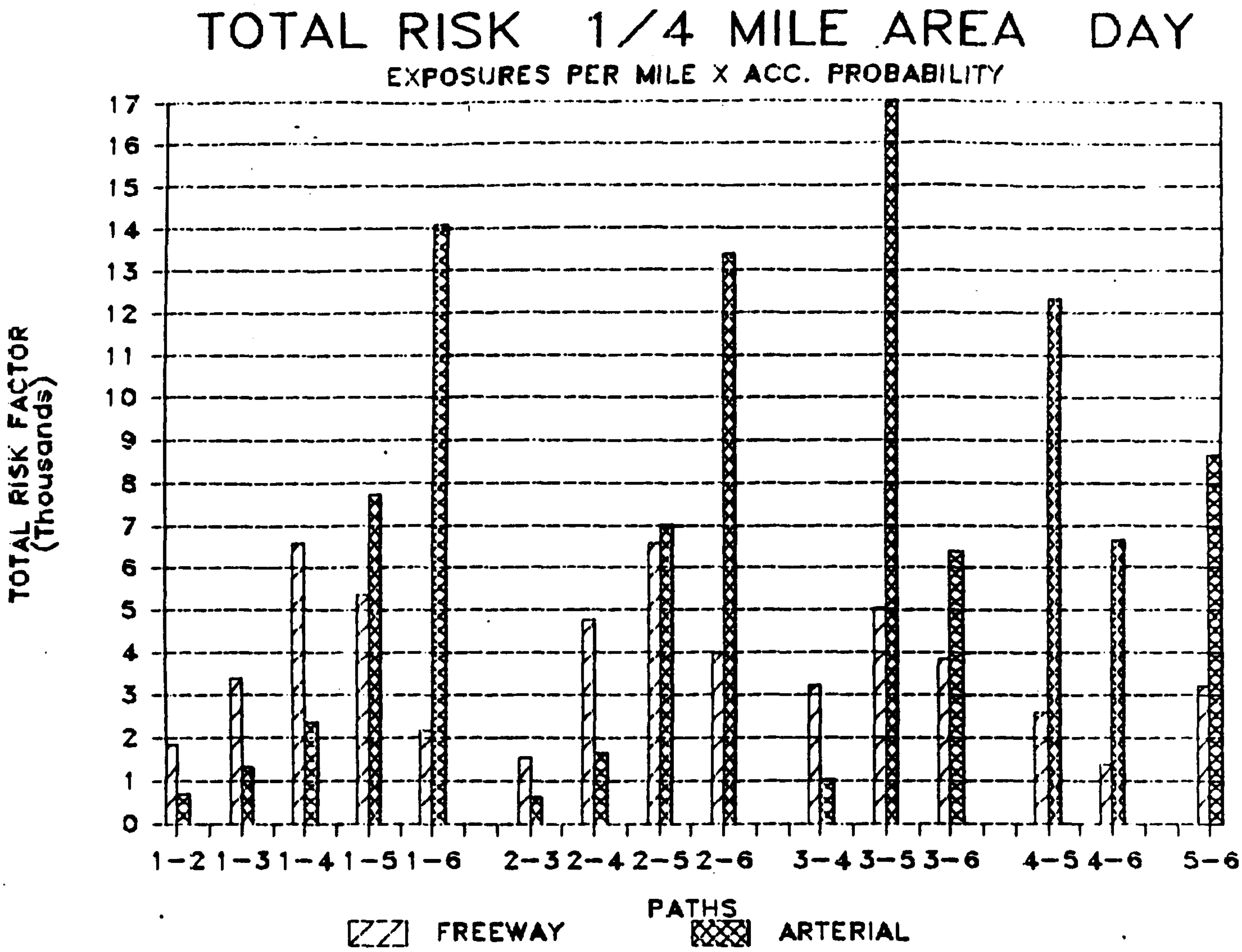
## TABLE F-7

SUMMARY OF TOTAL RISK BASED ON SEGMENT RISK PER MILE
1/4 MILE AREA DAY ANALYSIS

| PATHS | FREEWAY RISK | ARTERIAL RISK | FREEWAY/ARTERIAL RATIO OF RISK |
|---|---|---|---|
| S1-S2 | 1825.98 | 703.30 | 2.60 |
| S1-S3 | 3373.84 | 1313.38 | 2.57 |
| S1-S4 | 6589.04 | 2339.03 | 2.82 |
| S1-S5 | 5364.45 | 7713.40 | 0.70 |
| S1-S6 | 2146.55 | 14088.63 | 0.15 |
| S2-S3 | 1547.85 | 610.08 | 2.54 |
| S2-S4 | 4763.05 | 1635.73 | 2.91 |
| S2-S5 | 6591.71 | 7010.10 | 0.94 |
| S2-S6 | 3972.54 | 13385.33 | 0.30 |
| S3-S4 | 3215.20 | 1025.65 | 3.13 |
| S3-S5 | 5043.86 | 16972.05 | 0.30 |
| S3-S6 | 3849.48 | 6400.02 | 0.60 |
| S4-S5 | 2583.62 | 12322.22 | 0.21 |
| S4-S6 | 1389.24 | 6650.27 | 0.21 |
| S5-S6 | 3217.90 | 8671.83 | 0.37 |
| TOTAL/2 | 55474.31 | 100841.02 | 0.55 |
| TOTAL | 110948.62 | 201682.04 | 0.55 |

RATIO OF RISK > 1 INDICATES ARTERIAL TO BE SAFER
RATIO OF RISK < 1 INDICATES FREEWAY TO BE SAFER

FIGURE F-7


TOTAL RISK 1/4 MILE AREA DAY
EXPOSURES PER MILE X ACC. PROBABILITY
TOTAL RISK FACTOR (Thousands)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
1-2
1-3
1-4
1-5
1-6
2-3
2-4
2-5
2-6
3-4
3-5
3-6
4-5
4-6
5-6
PATHS
FREEWAY
ARTERIAL

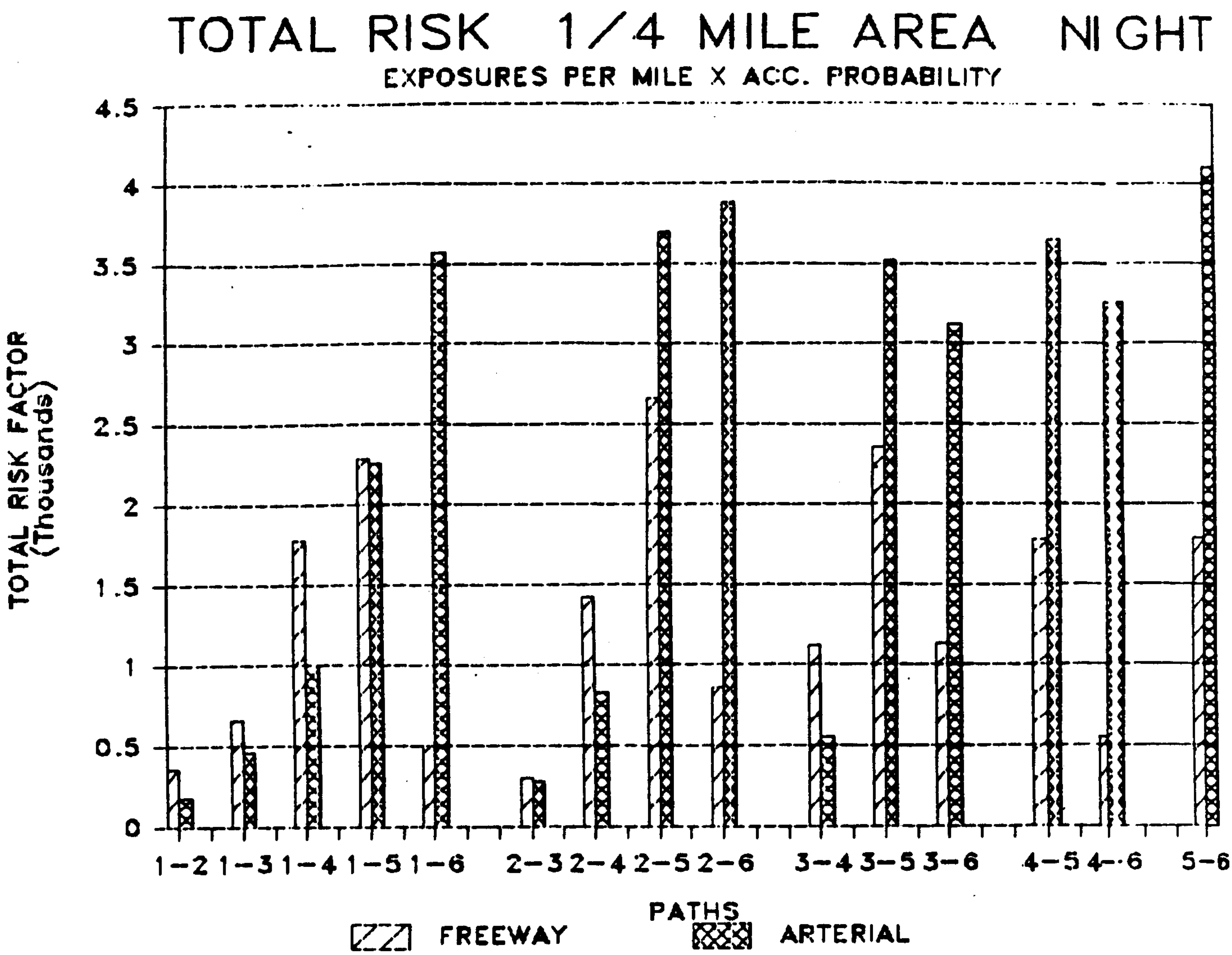
## TABLE F-8

SUMMARY OF TOTAL RISK BASED ON SEGMENT RISK PER MILE
1/4 MILE AREA NIGHT ANALYSIS

| PATHS | FREEWAY RISK | ARTERIAL RISK | FREEWAY/ARTERIAL RATIO OF RISK |
|---|---|---|---|
| S1-S2 | 359.92 | 178.78 | 2.01 |
| S1-S3 | 657.87 | 455.79 | 1.44 |
| S1-S4 | 1778.81 | 1006.89 | 1.77 |
| S1-S5 | 2284.19 | 2251.57 | 1.01 |
| S1-S6 | 499.14 | 3572.31 | 0.14 |
| S2-S3 | 297.95 | 277.01 | 1.08 |
| S2-S4 | 1418.89 | 828.11 | 1.71 |
| S2-S5 | 2656.11 | 3698.62 | 0.72 |
| S2-S6 | 859.06 | 3878.86 | 0.22 |
| S3-S4 | 1120.94 | 551.10 | 2.03 |
| S3-S5 | 2358.16 | 3519.84 | 0.67 |
| S3-S6 | 1129.87 | 3116.52 | 0.36 |
| S4-S5 | 1776.12 | 3654.30 | 0.49 |
| S4-S6 | 547.83 | 3250.98 | 0.17 |
| S5-S6 | 1785.05 | 4099.82 | 0.44 |
| TOTAL/2 | 19529.91 | 34340.50 | 0.57 |
| TOTAL | 39059.82 | 68681.00 | 0.57 |

RATIO OF RISK > 1 INDICATES ARTERIAL TO BE SAFER
RATIO OF RISK < 1 INDICATES FREEWAY TO BE SAFER

FIGURE F-8



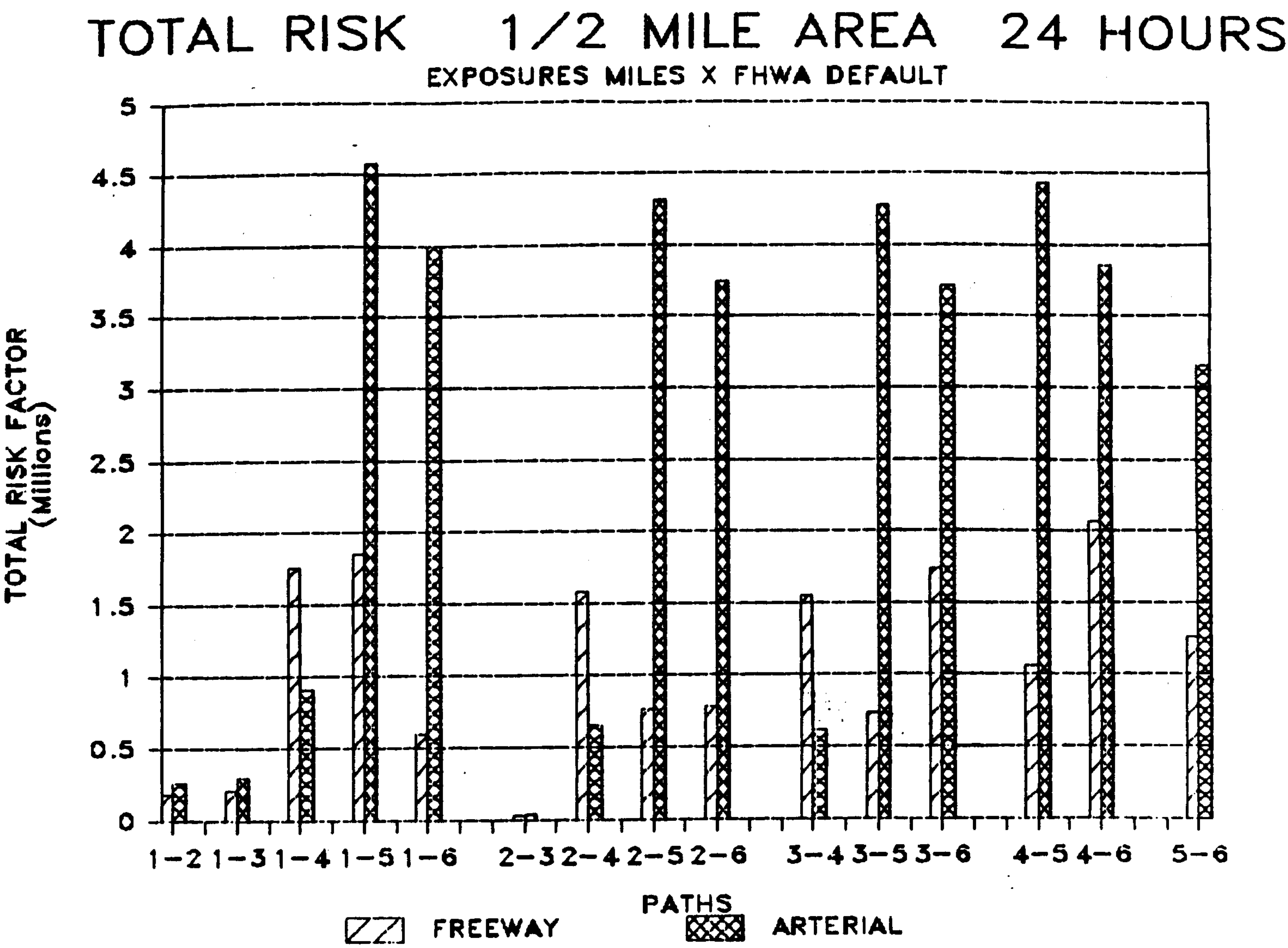
TOTAL RISK 1/4 MILE AREA NIGHT
EXPOSURES PER MILE X ACC. PROBABILITY
TOTAL RISK FACTOR
(Thousands)
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
1-2
1-3
1-4
1-5
1-6
2-3
2-4
2-5
2-6
3-4
3-5
3-6
4-5
4-6
5-6
PATHS
FREEWAY
ARTERIAL

## TABLE F-9

SUMMARY OF TOTAL RISK ASSESSMENT BASED ON EXPOSURE MILES X FHWA DEFAULT
1/2 MILE AREA 24 HOUR ANALYSIS

| PATHS | FREEWAY RISK | ARTERIAL RISK | FREEWAY/ARTERIAL RATIO OF RISK |
|---|---|---|---|
| S1-S2 | 177746.90 | 259475.40 | 0.69 |
| S1-S3 | 207149.98 | 293786.95 | 0.71 |
| S1-S4 | 1753383.58 | 908215.75 | 1.93 |
| S1-S5 | 1851609.30 | 4572506.04 | 0.40 |
| S1-S6 | 597049.70 | 4000591.04 | 0.15 |
| S2-S3 | 29403.08 | 34311.55 | 0.86 |
| S2-S4 | 1575636.68 | 648740.35 | 2.43 |
| S2-S5 | 763102.98 | 4313030.64 | 0.18 |
| S2-S6 | 774796.60 | 3741115.64 | 0.21 |
| S3-S4 | 1546233.60 | 614428.80 | 2.52 |
| S3-S5 | 733699.90 | 4278719.09 | 0.17 |
| S3-S6 | 1737710.30 | 3706804.09 | 0.47 |
| S4-S5 | 1063082.90 | 4428639.71 | 0.24 |
| S4-S6 | 2067093.30 | 3856724.71 | 0.54 |
| S5-S6 | 1254559.60 | 3155631.00 | 0.40 |
| TOTAL/2 | 16132258.40 | 38812720.75 | 0.42 |
| TOTAL | 32264516.80 | 77625441.49 | 0.42 |

FIGURE F-9



TOTAL RISK 1/2 MILE AREA 24 HOURS
EXPOSURES MILES X FHWA DEFAULT
TOTAL RISK FACTOR (Millions)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
1-2 1-3 1-4 1-5 1-6 2-3 2-4 2-5 2-6 3-4 3-5 3-6 4-5 4-6 5-6
PATHS
FREEWAY
ARTERIAL

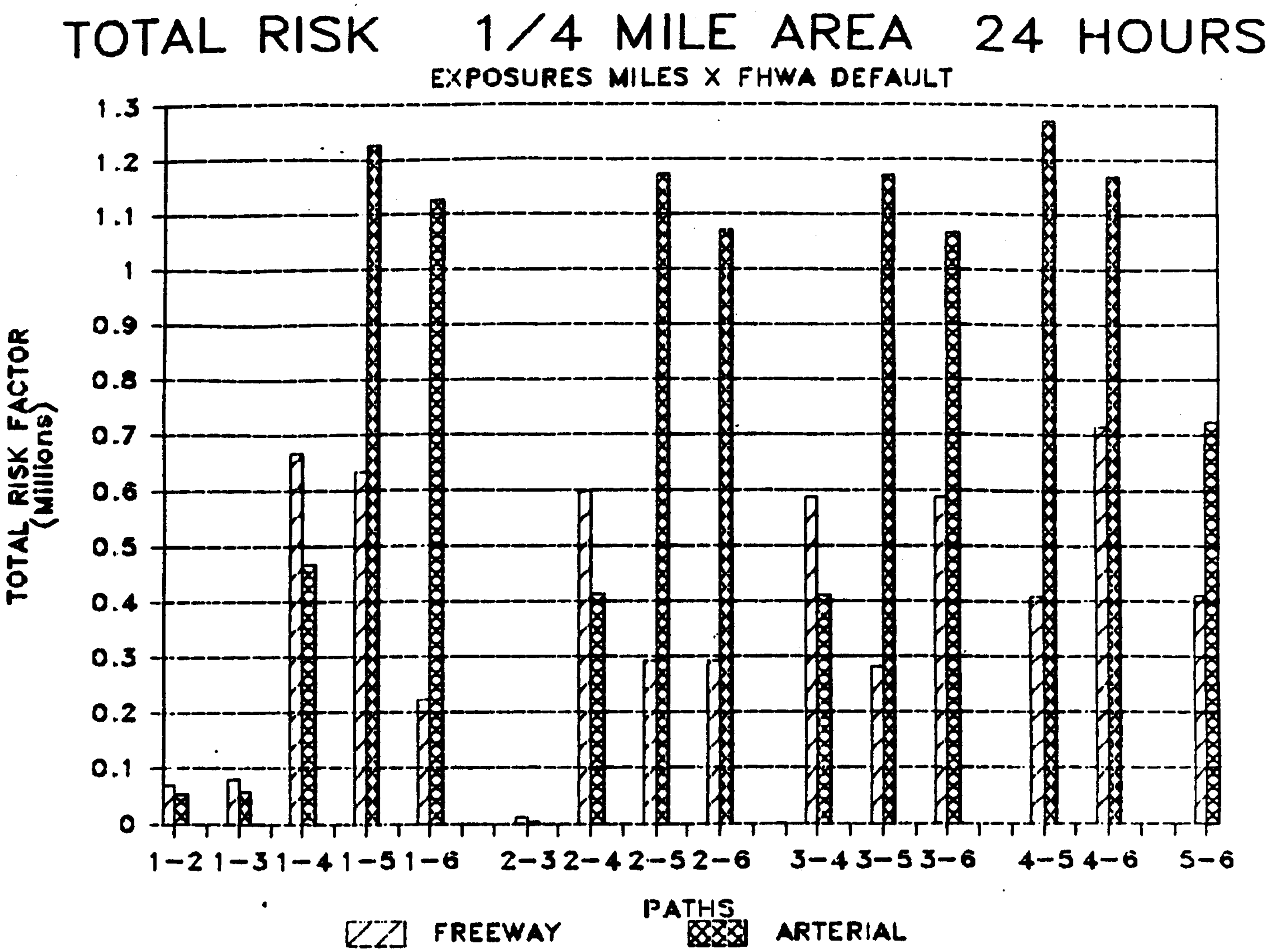
## TABLE F-10

SUMMARY OF TOTAL RISK ASSESSMENT BASED ON EXPOSURE MILES X FHWA DEFAULT
1/4 MILE AREA 24 HOUR ANALYSIS

| PATHS | FREEWAY RISK | ARTERIAL RISK | FREEWAY/ARTERIAL RATIO OF RISK |
|---|---|---|---|
| S1-S2 | 70178.37 | 53554.50 | 1.31 |
| S1-S3 | 81291.86 | 56466.50 | 1.44 |
| S1-S4 | 667892.76 | 466621.30 | 1.43 |
| S1-S5 | 632750.89 | 1226472.31 | 0.52 |
| S1-S6 | 223029.90 | 1123866.41 | 0.20 |
| S2-S3 | 11113.49 | 2912.00 | 3.82 |
| S2-S4 | 597714.39 | 413066.80 | 1.45 |
| S2-S5 | 292668.38 | 1172917.81 | 0.25 |
| S2-S6 | 293208.27 | 1070311.91 | 0.27 |
| S3-S4 | 586600.90 | 410154.80 | 1.43 |
| S3-S5 | 281554.89 | 1170005.81 | 0.24 |
| S3-S6 | 587121.90 | 1067399.91 | 0.55 |
| S4-S5 | 409199.99 | 1270083.59 | 0.32 |
| S4-S6 | 714767.00 | 1167477.69 | 0.61 |
| S5-S6 | 409720.99 | 724102.10 | 0.57 |
| TOTAL/2 | 5858813.98 | 11395413.46 | 0.51 |
| TOTAL | 11717627.96 | 22790826.92 | 0.51 |

RATIO OF RISK > 1 INDICATES ARTERIAL TO BE SAFER
RATIO OF RISK < 1 INDICATES FREEWAY TO BE SAFER

FIGURE F-10



TOTAL RISK 1/4 MILE AREA 24 HOURS
EXPOSURES MILES X FHWA DEFAULT
TOTAL RISK FACTOR (Millions)
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1-2 1-3 1-4 1-5 1-6 2-3 2-4 2-5 2-6 3-4 3-5 3-6 4-5 4-6 5-6
PATHS
FREEWAY
ARTERIAL

TABLE F-11

SUMMARY OF TOTAL RISK ASSESSMENT BASED ON VEHICLE OCCUPANTS
DAY

| PATHS | FREEWAY RISK | ARTERIAL RISK | FREEWAY/ARTERIAL RATIO OF RISK |
|---|---|---|---|
| S1-S2 | 330.48 | 27.54 | 12.00 |
| S1-S3 | 672.24 | 98.91 | 6.80 |
| S1-S4 | 1648.34 | 222.44 | 7.41 |
| S1-S5 | 486.10 | 275.95 | 1.76 |
| S1-S6 | 81.02 | 317.91 | 0.25 |
| S2-S3 | 341.76 | 71.37 | 4.79 |
| S2-S4 | 1317.86 | 194.90 | 6.76 |
| S2-S5 | 1370.16 | 248.41 | 5.52 |
| S2-S6 | 411.50 | 290.37 | 1.42 |
| S3-S4 | 976.10 | 123.53 | 7.90 |
| S3-S5 | 1028.40 | 177.04 | 5.81 |
| S3-S6 | 753.26 | 219.00 | 3.44 |
| S4-S5 | 483.32 | 185.51 | 2.61 |
| S4-S6 | 352.78 | 227.47 | 1.55 |
| S5-S6 | 632.55 | 191.38 | 3.31 |
| TOTAL/2 | 10885.87 | 2871.73 | 3.79 |
| TOTAL | 21771.74 | 5743.46 | 3.79 |

RATIO OF RISK > 1 INDICATES ARTERIAL TO BE SAFER
RATIO OF RISK < 1 INDICATES FREEWAY TO BE SAFER

FIGURE F-11

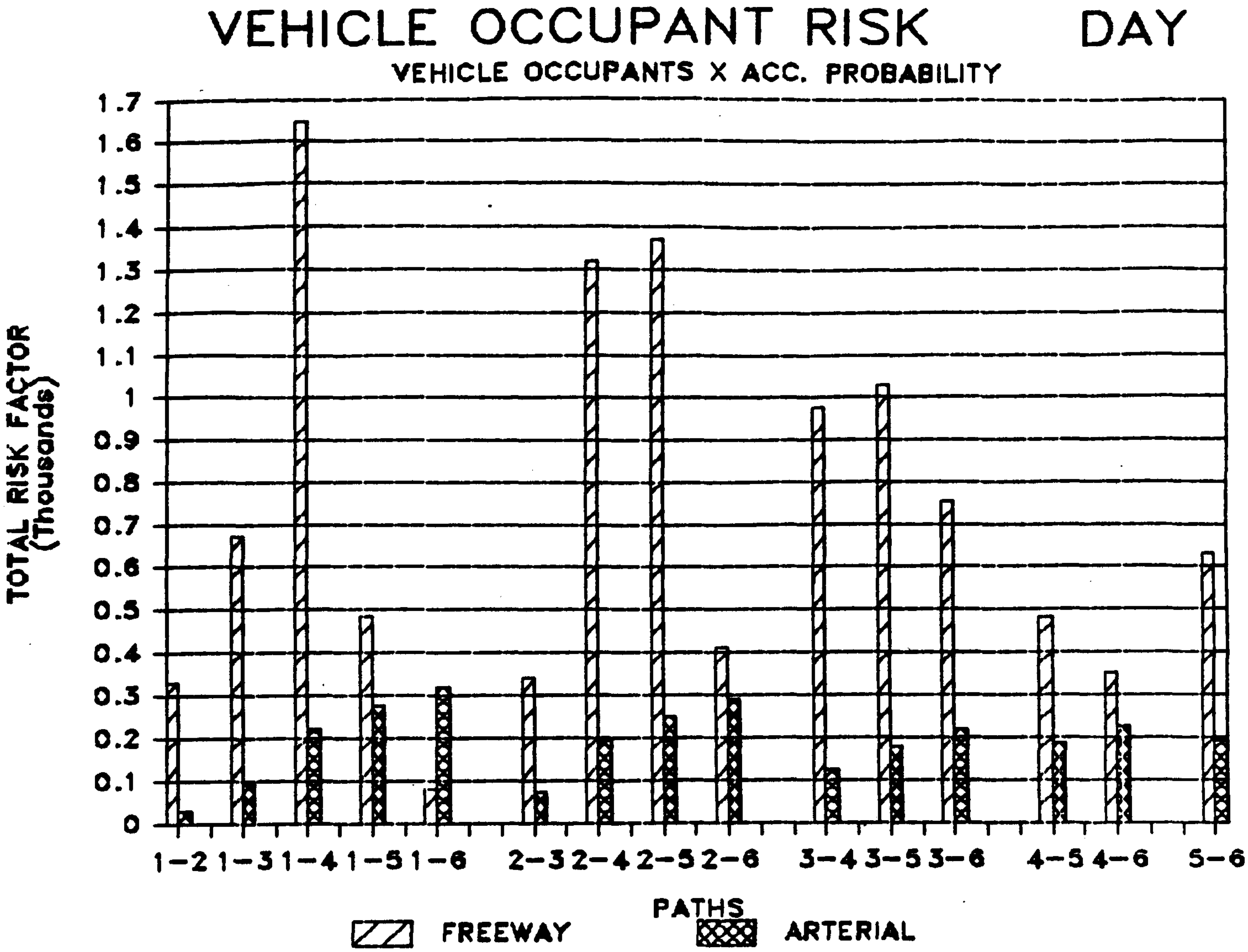

VEHICLE OCCUPANT RISK DAY
VEHICLE OCCUPANTS X ACC. PROBABILITY
TOTAL RISK FACTOR (Thousands)
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1-2 1-3 1-4 1-5 1-6 2-3 2-4 2-5 2-6 3-4 3-5 3-6 4-5 4-6 5-6
PATHS
FREEWAY
ARTERIAL

TABLE F-12

SUMMARY OF TOTAL RISK ASSESSMENT BASED ON VEHICLE OCCUPANTS
NIGHT

| PATHS | FREEWAY RISK | ARTERIAL RISK | FREEWAY/ARTERIAL RATIO OF RISK |
|---|---|---|---|
| S1-S2 | 66.49 | 27.54 | 2.41 |
| S1-S3 | 135.31 | 98.91 | 1.37 |
| S1-S4 | 427.34 | 222.44 | 1.92 |
| S1-S5 | 196.96 | 275.95 | 0.71 |
| S1-S6 | 81.02 | 317.91 | 0.25 |
| S2-S3 | 68.82 | 71.37 | 0.96 |
| S2-S4 | 360.85 | 194.90 | 1.85 |
| S2-S5 | 329.62 | 248.41 | 1.33 |
| S2-S6 | 147.51 | 290.37 | 0.51 |
| S3-S4 | 292.03 | 123.53 | 2.36 |
| S3-S5 | 260.80 | 177.04 | 1.47 |
| S3-S6 | 216.33 | 219.00 | 0.99 |
| S4-S5 | 184.67 | 185.51 | 1.00 |
| S4-S6 | 147.17 | 227.47 | 0.65 |
| S5-S6 | 115.94 | 191.38 | 0.61 |
| TOTAL/2 | 3030.86 | 2871.73 | 1.06 |
| TOTAL | 6061.72 | 5743.46 | 1.06 |

RATIO OF RISK > 1 INDICATES ARTERIAL TO BE SAFER
RATIO OF RISK < 1 INDICATES FREEWAY TO BE SAFER

FIGURE F-12

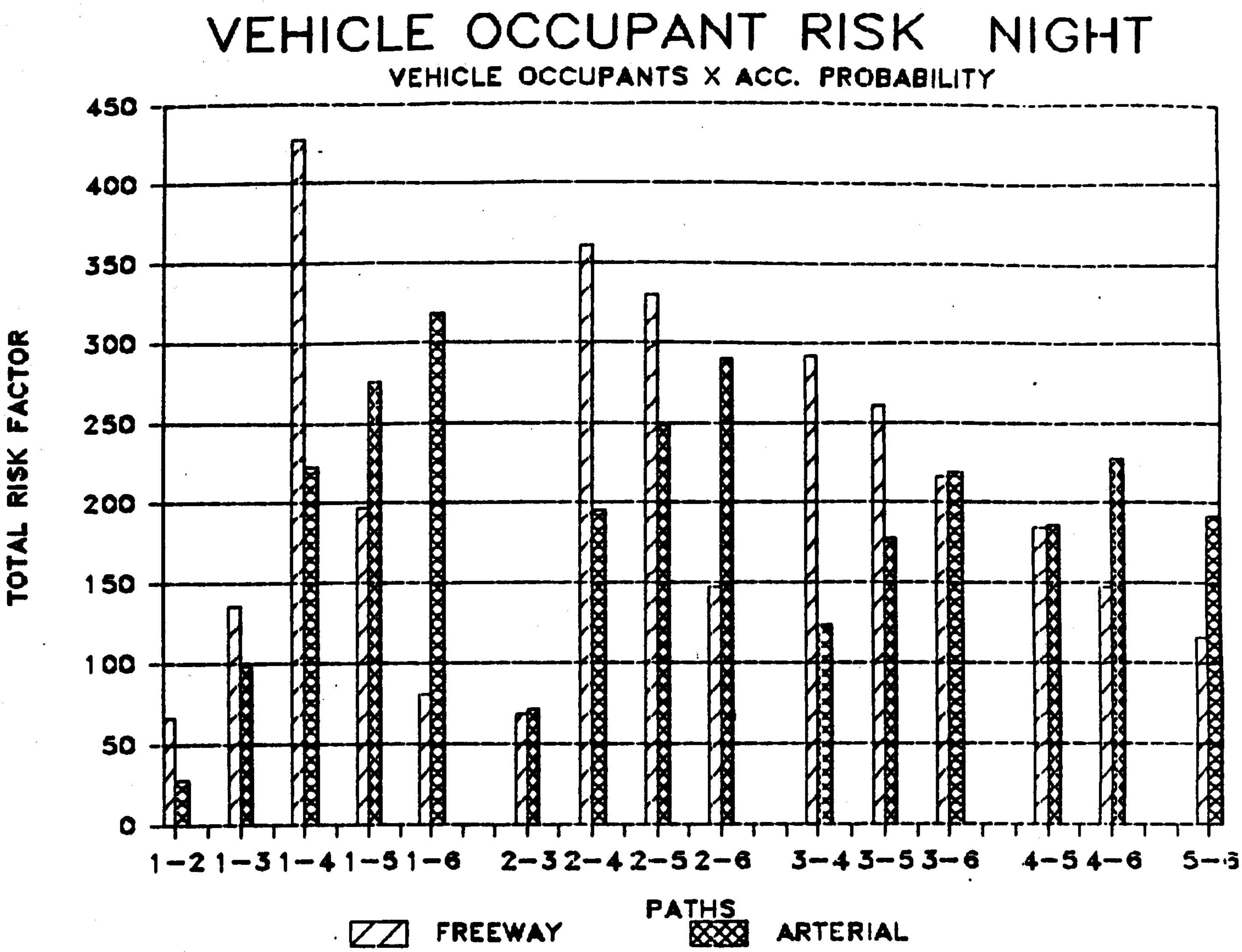

VEHICLE OCCUPANT RISK NIGHT
VEHICLE OCCUPANTS X ACC. PROBABILITY
TOTAL RISK FACTOR
450
400
350
300
250
200
150
100
50
0
1-2
1-3
1-4
1-5
1-6
2-3
2-4
2-5
2-6
3-4
3-5
3-6
4-5
4-6
5-6
PATHS
FREEWAY
ARTERIAL

TABLE F-13

SUMMARY OF TOTAL RISK ASSESSMENT BASED ON CIRCUITY FACTOR
ONE WAY TOTAL DISTANCE

| PATHS | FREEWAY MILES | ARTERIAL MILES | FREEWAY/ARTERIAL RATIO OF RISK |
|---|---|---|---|
| S1-S2 | 1.59 | 1.31 | 1.21 |
| S1-S3 | 2.76 | 2.01 | 1.37 |
| S1-S4 | 8.57 | 5.42 | 1.58 |
| S1-S5 | 6.12 | 7.66 | 0.80 |
| S1-S6 | 2.23 | 6.82 | 0.33 |
| S2-S3 | 1.17 | 0.70 | 1.67 |
| S2-S4 | 6.98 | 4.11 | 1.70 |
| S2-S5 | 4.97 | 6.35 | 0.78 |
| S2-S6 | 3.82 | 5.51 | 0.69 |
| S3-S4 | 5.81 | 3.41 | 1.70 |
| S3-S5 | 3.80 | 4.65 | 0.82 |
| S3-S6 | 4.71 | 4.81 | 0.9[illegible] |
| S4-S5 | 4.99 | 5.88 | 0.85 |
| S4-S6 | 5.90 | 5.04 | 1.17 |
| S5-S6 | 3.89 | 3.88 | 1.00 |
| TOTAL/2 | 67.31 | 67.56 | 1.00 |
| TOTAL | 134.62 | 135.12 | 1.00 |

RATIO OF RISK ) 1 INDICATES ARTERIAL TO BE SAFER
RATIO OF RISK ( 1 INDICATES FREEWAY TO BE SAFER

FIGURE F-13

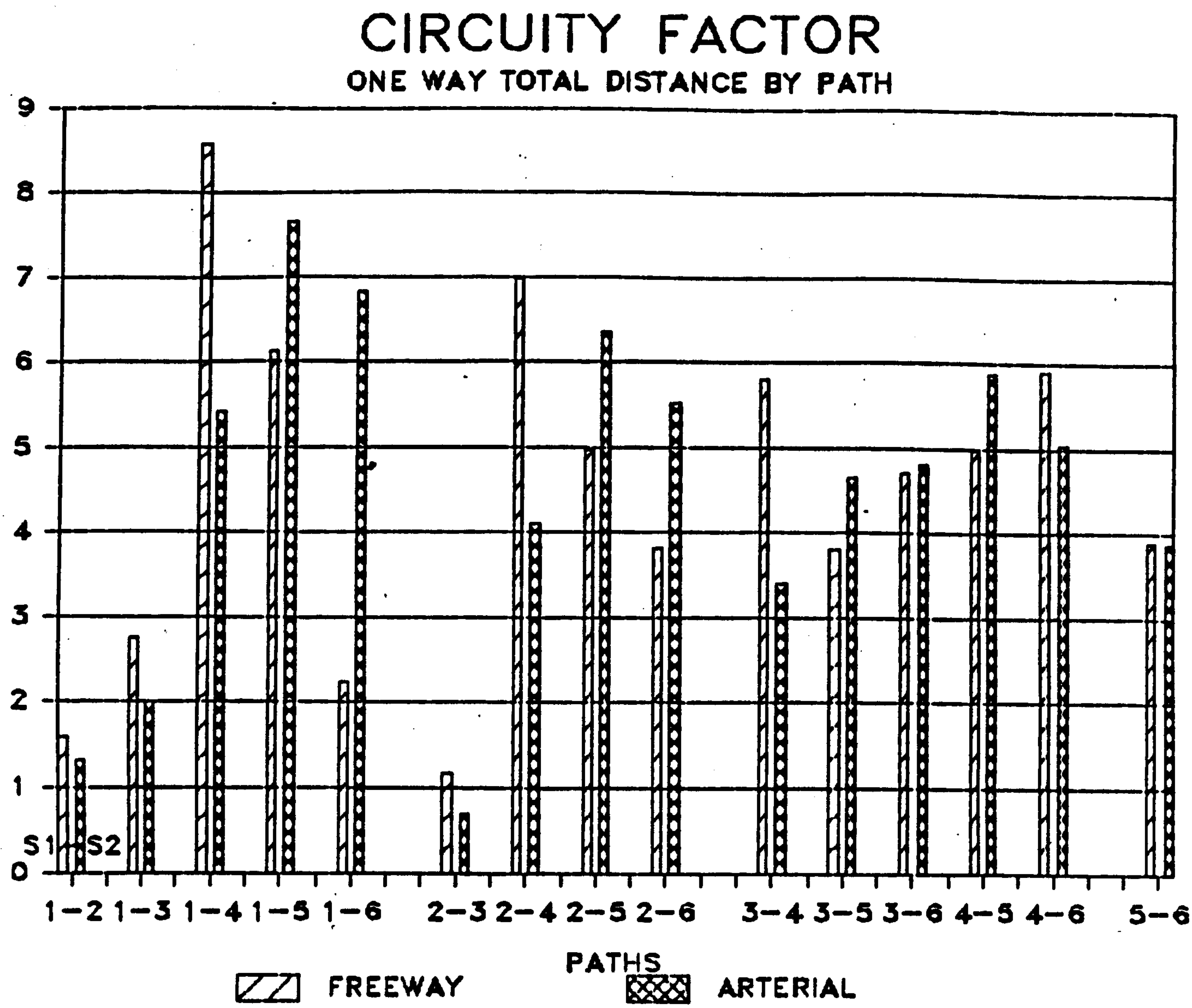

CIRCUITY FACTOR
ONE WAY TOTAL DISTANCE BY PATH
9
8
7
6
5
4
3
2
1
0
S1
S2
1-2
1-3
1-4
1-5
1-6
2-3
2-4
2-5
2-6
3-4
3-5
3-6
4-5
4-6
5-6
PATHS
FREEWAY
ARTERIAL

TABLE F-14

SUMMARY OF TOTAL RISK ASSESSMENT BASED ON EXPOSURE MILES
1/2 MILE AREA 24 HOUR ANALYSIS
S1-S6, S2-26, AND S3-S6 NOT INCLUDED

| PATHS | FREEWAY RISK | ARTERIAL RISK | FREEWAY/ARTERIAL RATIO OF RISK |
|---|---|---|---|
| S1-S2 | 13578.98 | 8306.81 | 1.63 |
| S1-S3 | 19840.09 | 12287.73 | 1.61 |
| S1-S4 | 87114.83 | 36840.35 | 2.36 |
| S1-S5 | 73709.70 | 127172.11 | 0.58 |
| S2-S3 | 6261.11 | 3980.92 | 1.57 |
| S2-S4 | 73535.85 | 28533.54 | 2.58 |
| S2-S5 | 72635.92 | 118865.30 | 0.61 |
| S3-S4 | 67274.74 | 24552.62 | 2.74 |
| S3-S5 | 66374.81 | 114884.38 | 0.58 |
| S4-S5 | 34617.01 | 120875.22 | 0.29 |
| S4-S6 | 40204.37 | 157117.29 | 0.26 |
| S5-S6 | 39304.44 | 132302.45 | 0.30 |
| TOTAL/2 | 594451.85 | 885718.72 | 0.67 |
| TOTAL | 1188903.70 | 1771437.44 | 0.67 |

## TABLE F-15

SUMMARY OF TOTAL RISK ASSESSMENT BASED ON SEGMENT RISKS PER MILE
1/2 MILE AREA 24 HOUR ANALYSIS
S1-S6, S2-S6, AND S3-S6 NOT INCLUDED

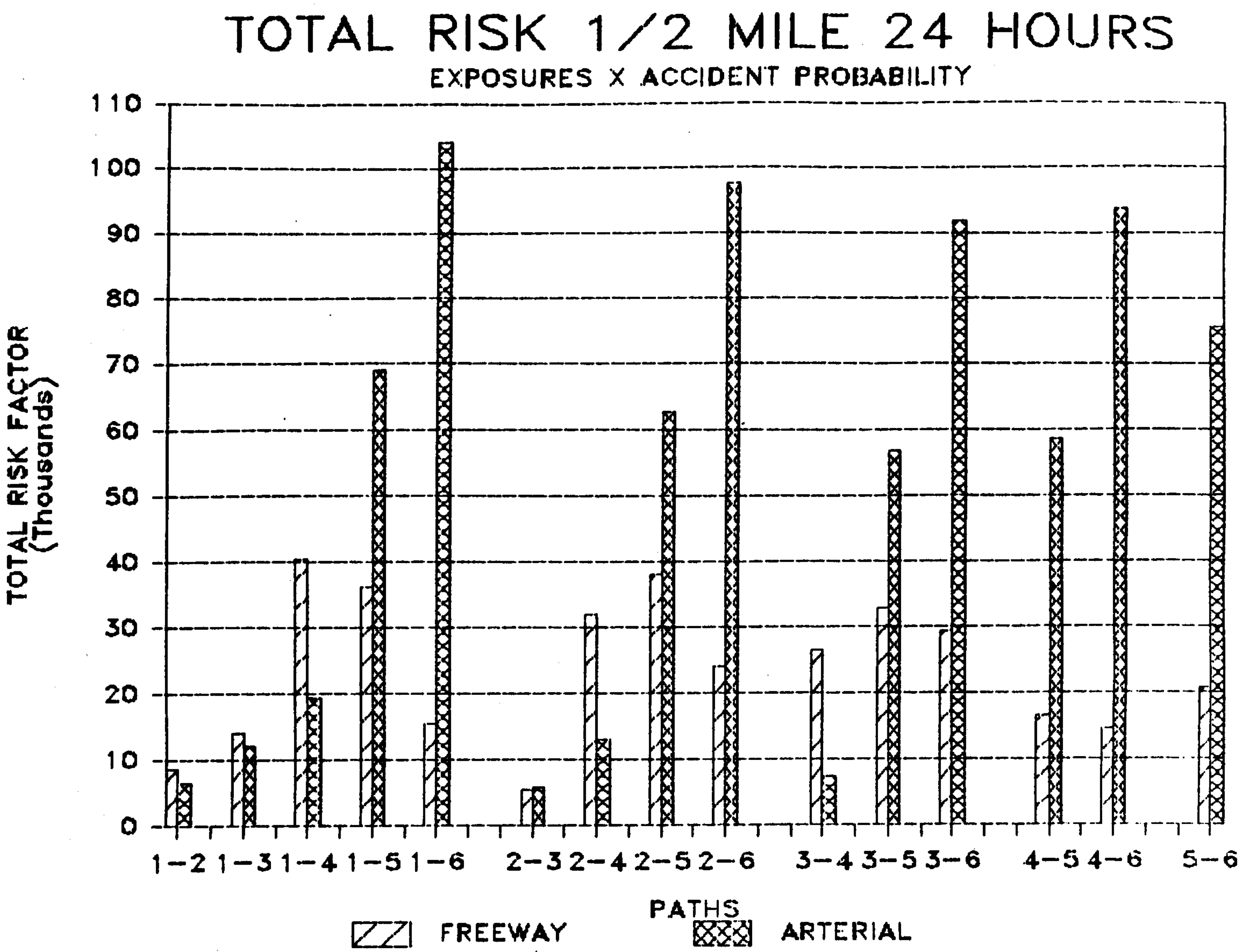
| PATHS | FREEWAY RISK | ARTERIAL RISK | FREEWAY/ARTERIAL RATIO OF RISK |
|---|---|---|---|
| S1-S2 | 5371.22 | 4840.52 | 1.11 |
| S1-S3 | 9945.04 | 12964.85 | 0.77 |
| S1-S4 | 20674.20 | 15076.34 | 1.37 |
| S1-S5 | 18507.65 | 42493.35 | 0.44 |
| S2-S3 | 4573.82 | 8124.33 | 0.56 |
| S2-S4 | 15302.98 | 10235.82 | 1.50 |
| S2-S5 | 21498.13 | 37652.83 | 0.57 |
| S3-S4 | 10729.16 | 2111.49 | 5.08 |
| S3-S5 | 16924.31 | 29528.50 | 0.57 |
| S4-S5 | 9094.49 | 29673.35 | 0.31 |
| S4-S6 | 5362.82 | 57524.90 | 0.09 |
| S5-S6 | 11557.97 | 45098.81 | 0.26 |
| TOTAL/2 | 149541.79 | 295325.09 | 0.51 |
| TOTAL | 299083.58 | 590650.18 | 0.51 |

## TABLE F-16

SUMMARY OF TOTAL RISK ASSESSMENT· 1/2 MILE AREA 24 HOUR ANALYSIS

| PATHS | FREEWAY RISK | ARTERIAL RISK | FREEWAY/ARTERIAL RATIO OF RISK |
|---|---|---|---|
| S1-S2 | 8540.24 | 6341.08 | 1.35 |
| S1-S3 | 13891.61 | 12028.11 | 1.15 |
| S1-S4 | 40401.07 | 19228.29 | 2.10 |
| S1-S5 | 36187.58 | 68968.19 | 0.52 |
| S1-S6 | 15463.04 | 104058.70 | 0.15 |
| S2-S3 | 5351.37 | 5687.03 | 0.94 |
| S2-S4 | 31860.83 | 12887.21 | 2.47 |
| S2-S5 | 38139.53 | 62627.11 | 0.61 |
| S2-S6 | 24003.28 | 97717.62 | 0.25 |
| S3-S4 | 26509.46 | 7200.18 | 3.68 |
| S3-S5 | 32788.16 | 56940.08 | 0.58 |
| S3-S6 | 29354.65 | 92030.59 | 0.32 |
| S4-S5 | 16426.40 | 58696.92 | 0.28 |
| S4-S6 | 14445.84 | 93787.43 | 0.15 |
| S5-S6 | 20724.54 | 75794.05 | 0.27 |
| TOTAL/2 | 354087.60 | 773992.58 | 0.46 |
| TOTAL | 708175.20 | 1547985.16 | 0.46 |

FIGURE F-16


TOTAL RISK 1/2 MILE 24 HOURS
EXPOSURES X ACCIDENT PROBABILITY
TOTAL RISK FACTOR
(Thousands)
110
100
90
80
70
60
50
40
30
20
10
0
1-2
1-3
1-4
1-5
1-6
2-3
2-4
2-5
2-6
3-4
3-5
3-6
4-5
4-6
5-6
PATHS
FREEWAY
ARTERIAL