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U.S. Department of Transportation
Research and Special Programs Administration

Guidance for Conducting Hazardous Materials Flow Surveys

Final Report
January 1995

U.S. Department of Transportation
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Cambridge, MA 02142-1093

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This report provides guidance on how to conduct a commodity flow study for hazardous materials moving by highway. It discusses the need for this type of study and details how to review baseline information and design the study. It includes examples and instructions for collecting the data via field studies, analyzing the results, and applying these results back to the purpose of the study. Descriptions of selected recent state and local hazardous material flow studies are provided. A case study example is included that illustrates how to conduct and complete ahazmat flow survey from beginning to end.

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PREFACE

This report was prepared by the U.S. Department of Transportation's Research and Special Programs Administration (RSPA), Volpe National Transportation Systems Center. The effort was supported by RSPA's Office of Hazardous Materials Planning and Analysis under the Associate Administrator for Hazardous Materials Safety. This report provides step-wise guidance for conducting commodity flow studies for hazardous materials moving by highway.

The technical advice of Joseph Nalevanko, Ann Mazzulo, and Richard Hannon of RSPA is gratefully acknowledged.

METRIC/ENGLISH CONVERSION FACTORS

ENGLISH TO METRIC		METRIC TO ENGLISH	
LENGTH (APPROXIMATE)		**LENGTH (APPROXIMATE)**	
1 inch (in)	= 2.5 centimeters (cm)	1 millimeter (mm)	= 0.04 inch (in)
1 foot (ft)	= 30 centimeters (cm)	1 centimeter (cm)	= 0.4 inch (in)
1 yard (yd)	= 0.9 meter (m)	1 meter (m)	= 3.3 feet (ft)
1 mile (mi)	= 1.6 kilometers (km)	1 meter (m)	= 1.1 yards (yd)
		1 kilometer (km)	= 0.6 mile (mi)

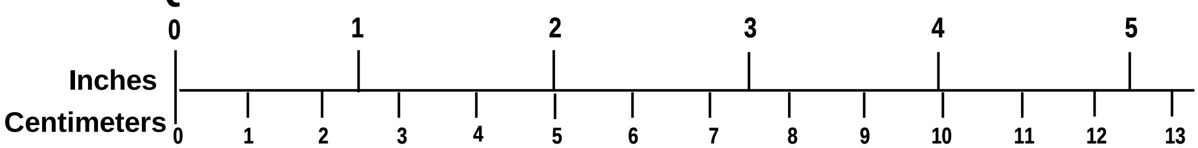
ENGLISH TO METRIC		METRIC TO ENGLISH	
AREA (APPROXIMATE)		**AREA (APPROXIMATE)**	
1 square inch (sq in, in^2)	= 6.5 square centimeters (cm^2)	1 square centimeter (cm^2)	= 0.16 square inch (sq in, in^2)
1 square foot (sq ft, ft^2)	= 0.09 square meter (m^2)	1 square meter (m^2)	= 1.2 square yards (sq yd, yd^2)
1 square yard (sq yd, yd^2)	= 0.8 square meter (m^2)	1 square kilometer (km^2)	= 0.4 square mile (sq mi, mi^2)
1 square mile (sq mi, mi^2)	= 2.6 square kilometers (km^2)	10,000 square meters (m^2)	= 1 hectare (ha) = 2.5 acres
1 acre = 0.4 hectare (he)	= 4,000 square meters (m^2)		

ENGLISH TO METRIC		METRIC TO ENGLISH	
MASS - WEIGHT (APPROXIMATE)		**MASS - WEIGHT (APPROXIMATE)**	
1 ounce (oz)	= 28 grams (gm)	1 gram (gm)	= 0.036 ounce (oz)
1 pound (lb)	= 0.45 kilogram (kg)	1 kilogram (kg)	= 2.2 pounds (lb)
1 short ton = 2,000 pounds (lb)	= 0.9 tonne (t)	1 tonne (t) = 1,000 kilograms (kg)	= 1.1 short tons

ENGLISH TO METRIC		METRIC TO ENGLISH	
VOLUME (APPROXIMATE)		**VOLUME (APPROXIMATE)**	
1 teaspoon (tsp)	= 5 milliliters (ml)	1 milliliter (ml)	= 0.03 fluid ounce (fl oz)
1 tablespoon (tbsp)	= 15 milliliters (ml)	1 liter (l)	= 2.1 pints (pt)
1 fluid ounce (fl oz)	= 30 milliliters (ml)	1 liter (l)	= 1.06 quarts (qt)
1 cup (c)	= 0.24 liter (l)	1 liter (l)	= 0.26 gallon (gal)
1 pint (pt)	= 0.47 liter (l)		
1 quart (qt)	= 0.96 liter (l)		
1 gallon (gal)	= 3.8 liters (l)		
1 cubic foot (cu ft, ft^3)	= 0.03 cubic meter (m^3)	1 cubic meter (m^3)	= 36 cubic feet (cu ft, ft^3)
1 cubic yard (cu yd, yd^3)	= 0.76 cubic meter (m^3)	1 cubic meter (m^3)	= 1.3 cubic yards (cu yd, yd^3)

ENGLISH TO METRIC	METRIC TO ENGLISH
TEMPERATURE (EXACT)	**TEMPERATURE (EXACT)**
[(x-32)(5/9)] °F = y °C	[(9/5) y + 32] °C = x °F

QUICK INCH - CENTIMETER LENGTH CONVERSION



QUICK FAHRENHEIT - CELSIUS TEMPERATURE CONVERSION

°F	-40°	-22°	-4°	14°	32°	50°	68°	86°	104°	122°	140°	158°	176°	194°	212°
°C	-40°	-30°	-20°	-10°	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°

For more exact and or other conversion factors, see NIST Miscellaneous Publication 286, Units of Weights and Measures. Price $2.50 SD Catalog No. C13 10286

Updated 1/23/95

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CHAPTER 1
INTRODUCTION

1.1 NEED FOR DOCUMENT

The primary purpose of a commodity flow study is to identify the types and amounts of commodities transported through a specified geographic area, such as a single community, a state, or large urban area, and the routes used for transporting these commodities. A commodity flow study identifies the chemicals transported, either specifically or by hazard class (see Exhibit 1), as well as the routes on which they are transported. It is important for any jurisdiction to understand the flow of hazardous materials through its area to analyze current traffic patterns, better match planning programs to existing needs within communities, and reduce the potential for releasing incidents to occur. These needs can be met in part through the use of a commodity flow study.

This guidance focuses on how to conduct a commodity flow study for hazardous materials. Upon completion of a commodity flow study, planners will have a better understanding of hazardous materials transportation patterns and can use these data to conduct planning and estimate risks facing the jurisdiction. Depending on the specific type of study that is designed and the resources and time available, a commodity flow study can be used to assess total truck traffic, daily and seasonal variations in traffic, awareness and training of drivers and emergency response personnel in the area, and frequently used transportation routes.

The U.S. Department of Transportation (DOT) anticipates increased interest in commodity flow analyses as a result of two sections of the Federal hazardous material transportation law (Federal hazmat law), 49 U.S.C. 5101 et seq. (formerly the HMTA, 49 App. U.S.C. 1801 et seq.), established a grants program for states that wish to address transportation-related risks in emergency response planning and provide training funds for emergency responders. The regulation outlining the requirements of the Federal hazmat law grants program, 49 CFR Part 110, states that "[a]n assessment to determine flow patterns of hazardous materials within a State, between a State and another State or Indian country, and development and maintenance of a system to keep such information current" is one of the activities eligible for funding under the planning grants program. Conducting a commodity flow study could lead to other grant-eligible activities such as assessing the need for regional hazardous materials emergency response teams. More information on the program is available from the grants manager at (202) 366-0001. Second, recent amendments to the Federal hazmat law authorize states to designate highway routes that may be used for the transport of hazardous materials. Prior to designating routes, planners need to analyze the risks associated with hazardous materials transportation within their jurisdiction. Conducting an analysis of commodity flows is an important step in assessing transportation-related hazardous materials risks.

The highway transport of hazardous materials represents about 62 percent of the volume of hazardous materials transported in the U.S., but contributes only a very small fraction of the annual injuries and deaths attributable to hazardous materials transportation incidents. For the 1982-1993 time period, there were a total of 1.5 billion tons of hazardous materials transported in the U.S., 927 million tons of which were shipped by highway. These 927 million tons of hazardous materials were shipped in a total of 467 thousand trucks, which accounted for 93.6 billion ton-miles of hazardous materials traffic. During that time, there were, on average, 6175 incidents per year involving a release of hazardous materials, resulting in approximately 249 injuries. Deaths from hazardous materials incidents totalled an average of 11 per year, including incidents from both vehicular accidents and accidents attributable to other causes (e.g., a faulty valve).

EXHIBIT 1
THE INTERNATIONAL HAZARD CLASSIFICATION SYSTEM

Class numbers represent general categories of chemicals; some classes are further segmented into several divisions to provide a more accurate description of the hazard. Class or division numbers are displayed in the bottom of placards or in the hazardous materials description on shipping papers. Class numbers have the following meanings:

Class 1 Explosive

Class 2 Gas

Class 3 Flammable and

Class 4 Flammable Solid; Spontaneously Combustible Material; Dangerous When Wet Material

Class 5 Oxidizer and Organic Peroxide

Class 6 Poisonous Material and Infectious Substance

Class 7 Radioactive Material

Class 8 Corrosive Material

Class 9 Miscellaneous Hazardous Material

Of the 1.5 billion tons of hazardous materials transported, the majority represent a small subset of hazardous materials and hazard classes. Almost 50 percent of the shipments were gasoline and petroleum products, and approximately 13 percent were chemicals. By decreasing total volume (tons), the major hazard classes/divisions shipped were Class 3 (flammable and combustible liquids), Division 6.1 (poison B), Division 2.3 (poison A), Division 2.1 (flammable compressed gases), and Division 4.1 (flammable solids); by decreasing volume shipped per ton-mile, the hazard classes/divisions were Class 3 (flammable and combustible liquids), Division 6.1 (poison B), Division 4.1 (flammable solids), and Class 8 (corrosives).

A model was recently developed in a study for DOT's Research and Special Programs Administration (RSPA) to allocate commodity flows between producers and consumers. The study was intended to determine whether secondary data sources used in a model could provide estimates of truck movements in the absence of specific data. Using the model, truck movements were estimated for three chemicals, dodecene-1, phosphorus pentasulfide, and 1-butanol. These chemicals were selected from a list of 147 large-volume chemicals that were identified as accounting for at least 80 percent of truck shipments of hazardous chemicals in the United States. Appendix A of this document provides a brief description of the model, a list of the 147 large-volume chemicals, brief overviews of the three chemicals assessed, and graphic displays of the model output for these three chemicals. The results of the three chemicals presented in Appendix A are preliminary. Revised results, which will be presented in subsequent individual reports on the three chemicals, may differ from those reported in Appendix A.

Although such a model may be useful for predicting national trends, state movements of hazardous chemicals can be determined more accurately using a commodity flow study. This guide is intended to assist states in understanding the purposes and uses of commodity flow studies, and to provide assistance in planning and conducting a study. Although the guide focuses on analyzing hazardous materials transportation along highways, area-specific characteristics might require analysis of other modes of transport.

1.2 ORGANIZATION OF DOCUMENT

This guide provides step-by-step guidance to states, Local Emergency Preparedness Committees (LEPCs), and other planners in assessing hazardous materials transportation patterns. Chapter 2 provides guidance for identification of the objectives of the study (e.g., what data are needed?, how will the data be used?), conducting the study, analysis of the data, and application of the results. Information on identifying study needs, collecting baseline data from other sources, determining the data to be collected, considerations for determining survey locations and personnel needs, and analyzing the results of the study are included. Because this guide focuses on the commodity flow study itself, there is only general discussion of the steps for applying the results to the original objective. Chapter 2 also includes a hypothetical example illustrating considerations for designing and conducting a commodity flow study.

The steps for conducting a commodity flow study might be organized as follows:

1. Review Baseline Information,

2. Design Study,

3. Conduct Commodity Flow Study,

4. Analyze the Results, and

5. Apply the Results to Main Objective.

The main objective may be to characterize the commercial transportation of hazardous materials, or it may require further manipulation of the data during the performance of a subsequent routing risk assessment or other analyses for planning purposes.

Chapter 3 presents descriptions of six studies that have been conducted by states and communities. The examples illustrate the variety of studies that can be designed, and the goals and methods used are described. Chapter 3 also provides a limited discussion of the relative advantages and disadvantages of several methods, depending on the specific purposes of a study. Chapter 4 concludes this guidance with a case study example.

CHAPTER 2
STEP-WISE GUIDANCE

2.1 IDENTIFY SPECIFIC PURPOSE OF STUDY

A commodity flow study is the collection of data on transportation patterns within a jurisdiction. There are a variety of activities and survey methods that can be used to perform a commodity flow survey; many include a road-side survey where truck data (e.g., placard type, UN/NA commodity number, route used, truck type) are recorded and some form of driver interview is conducted. Depending on the methods used and goals of the study, some subset of the information listed below can be gathered for a particular hazardous materials commodity flow study:

< Major traffic corridors used.

< Primary origin and destination locations.

< Primary hazard classes transported.

< Actual materials transported.

< Hazardous materials tonnages shipped.

< Number of hazardous materials trucks.

< Fraction of hazardous materials traffic in all truck traffic.

< Truck types used for hazardous materials.

< Container types used for hazardous materials.

< Driver training and awareness.

< Degree of regulatory compliance.

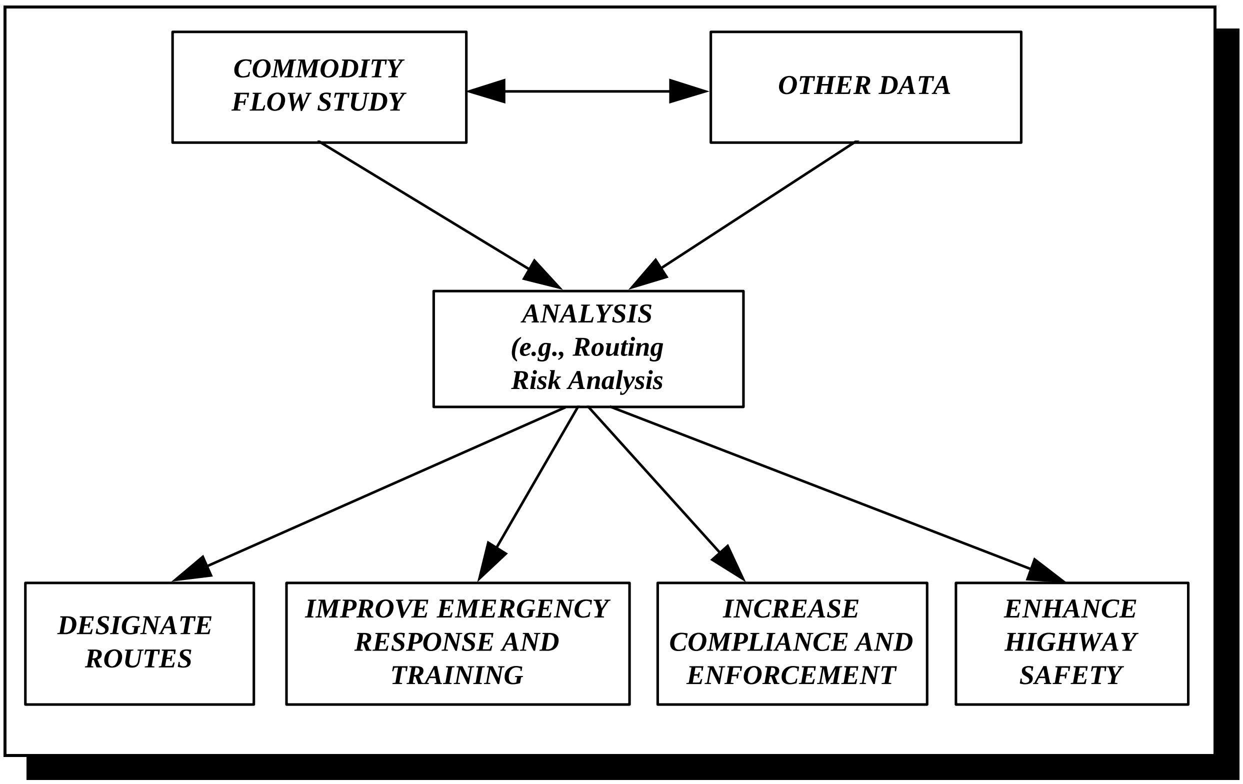
< Peak transportation times and days.

< Seasonal transportation variations.

A jurisdiction will have specific objectives for conducting a commodity flow study based on its particular needs; frequently, a commodity flow study is only one element of a larger study, such as a hazardous materials routing analysis. Most larger studies will require the use of numerous data sources, with the commodity flow study providing a characterization of the traffic and hazardous materials flows within a jurisdiction. There are many other sources of data that can be used in conjunction with the data from a commodity flow study, including databases that provide information on a local, statewide, regional, or national basis, as well as industry associations and state and local planning organizations; potentially available data may include population data, annual accident type and location data, and annual average shipments by hazard class/division.

Exhibit 2 illustrates the interplay of data for a larger study. Both data from a commodity flow study and other sources may be required; in addition, either data set can be used to enhance the other. For example, statewide accident data can be used to identify routes to be surveyed in a commodity flow study. Likewise, an estimate of the average hazardous materials transportation from a commodity flow study can be compared to statewide accident data to determine accident frequencies. Both data sets contribute to the analysis for the main objective. For a routing designation, this objective would be a routing risk analysis; for enhancing highway safety, this could include a comparison of the routes frequently used with data on the physical condition of those routes. The results are then used to implement the objective of the main study, and may result in some variety of emergency response improvement, regulatory compliance increases, route designation, or highway safety enhancements.

EXHIBIT 2
THE USE OF DATA FROM A COMMODITY FLOW SURVEY



In general, hazardous materials commodity flow studies are used for two main highway transportation activities: the designation of transportation routes and the formulation of planning programs.

Within the scope of analyzing transportation patterns, commodity flow studies can be used for routing risk analyses that formulate the basis for route designation. Several applications of commodity flow study data are identified below:

< Origin and destination data collected from a commodity flow study can be used to determine the relative amounts of through traffic (origin and destination out of state) and intrastate traffic (origin, destination, or both in the state). These data could also assist in identifying the locations in need of designated routes.

< Prior to route designation, a state must consider, analyze, and compare feasible alternatives. A commodity flow survey could assist by identifying the current route(s) used.

<	Data from a commodity flow study on the types and quantities of materials carried could be used in the consequence assessment component of a routing risk analysis.

Within the scope of planning, a commodity flow study can contribute to an analysis of current programs and help in assessing future needs. Specific examples are identified below:

<	Used with data on equipment distribution, training and preparedness of response personnel, and accident rates, data on driver training and compliance from a commodity flow study could assist in identification of training needs and staffing requirements for emergency responders and strategic deployment of hazardous materials response teams.

<	A commodity flow study could provide data on the hazard classes and individual hazardous materials being transported through the state; these data could pinpoint specific, extremely high-risk chemicals that require specific training or preparedness efforts.

<	Many commodity flow studies include a review of shipping papers to identify shipment content and destination. This information, compared to Federal, state, and local regulations, could assist in determining rates of shipper compliance with hazardous materials transportation regulations.

<	Data from a commodity flow study on frequency of route usage could be used with accident and roadway conditions data to assist in allocating resources for such measures as highway improvements that enhance public safety.

<	The commodity flow data could be compiled to provide an average daily or annual profile of commercially transported hazardous materials in the jurisdiction. These data could provide the jurisdiction with baseline data that, compared with data from multiple sampling events, could highlight changing transportation patterns and needs.

These goals do not cover the entire range of objectives for which hazardous materials commodity flow studies can be used. However, these examples can be used as a starting point to illustrate the variety of ways in which data from a commodity flow study can be used to fulfill the data requirements for larger analyses.

2.2 REVIEW BASELINE INFORMATION

To select routes to focus on during the study, it is important to determine which roads within a geographic area are capable of supporting hazardous materials and to identify the amounts and types of materials that are being transported over those roads. The information sources discussed in this section support this determination.

2.2.1 <u>Identify Roads Available for Hazardous Materials Transportation</u>

By determining which roads are physically accessible for hazardous materials transportation, the scope of the commodity flow study can be narrowed. Identification of the routes that are capable of carrying hazardous materials can be completed fairly quickly by examining state and county maps, road atlases produced for the trucking industry, and familiarity with the study area. Rand McNally publishes an atlas that shows the legal weight truck route system in each state; communities located on one of these routes can be fairly certain that hazardous materials, particularly gasoline, are passing through at some point during the year. Updated annually, the *Motor Carrier's Road Atlas* is available at retail outlets or by calling Rand McNally at (800) 284-6565.

2.2.1.1 Local Statutes

Some communities have passed legislation restricting the movement of hazardous materials on certain routes. It is advisable to check with local officials to learn about any ordinances that may regulate hazardous materials, particularly for any routes which have bridges or tunnels, which may have restrictions regarding hazardous materials traffic.

2.2.1.2 Highway Performance Monitoring System (HPMS)

The Highway Performance Monitoring System (HPMS) is a joint effort of Federal, state, and local governments. Data are reported by state highway agencies, in cooperation with local governmental units, metropolitan planning organizations, and other organizations. HPMS includes data on lane widths, road capacity, curves and grades, as well as information for all public road and street facilities within each state, including system type (e.g., Federal or state highway) and functional type (e.g., arterial, collector, toll).

> Information regarding the acquisition of data items in the HPMS can be obtained from:
>
> U.S. Department of Transportation
> Federal Highway Administration
> Office of Highway Information Management
> 400 Seventh St., S.W.
> Washington, DC 20590
> (202) 366-0180

These data are used by the Federal Highway Administration to estimate truck volume, as a percentage of traffic, on each link (or segment) in the system. Although truck volumes are not categorized by commodity, a commodity profile (i.e., relative frequency of movement by commodity code) for the area of interest could be matched to these data to estimate roughly annual shipment tonnages by commodity by link.

2.2.2 Highway-Specific Information

After identifying the roads available for hazardous materials transportation, the next step is to assemble data pertaining to those routes. Data on the types of vehicles using those routes, accident histories, and information on the specific commodities transported may be available from public and private organizations at the national, state, and local level. Collecting this information before beginning a field investigation conserves valuable resources by not duplicating data collection efforts. Several of these sources are described below and are summarized in Exhibit 3. Contact the state department of transportation and turnpike authority for more information on data they may have collected.

2.2.2.1 Truck Flow

An essential element to a commodity flow study is the average expected truck volumes for the study area. The following national sources of information can provide data on truck volumes by state (often estimated from national averages), providing indicators of how many trucks and what types of truck (e.g., tank truck, trailer-tractor) are typically traveling through the area.

Commodity Transportation Survey (CTS). The Commodity Transportation Survey (CTS), which is maintained by the U.S. Bureau of the Census, provides the means to estimate market shares and shipment trends of goods manufactured in the United States. The CTS covers all transportation modes, and therefore is not specific to highway shipments. It contains data on shipments only from the point of manufacture to the first destination and does not specifically focus on hazardous materials. Data sources include bills of lading, sales invoices, and other shipping documents for a stratified sample of 19,500 manufacturing establishments drawn from the 1977 Census of Manufacturers.

The Bureau of the Census conducted a Commodity Flow Survey during 1993. This survey features expanded industry coverage relative to its 1977 predecessor. For the first time, flows of hazardous materials (identified by 5-digit Standard Transportation Commodity Classification code) will be flagged and separately tabulated. Survey results are expected to be available in 1995. The data (tons, ton-miles, and value of commodities shipped by manufacturers) are classified by commodity type, means of transport, length of haul, weight, and shipment destinations.

EXHIBIT 3
SOURCES OF EXISTING DATA

Databases and Other Statistical Reports

Commodity Transportation Survey ! Total U.S. flow of each hazardous material by volume shipped

HPMS/FHWA ! Approximate state total truck miles

Truck Inventory and Use Survey ! Hazardous materials carried by trucks registered in state

HMIS ! Hazardous material transportation accident type and location data

Safety Net (OMC 50-T) - Accident information including carrier identification, location, and cargo description

LEPCs and Other Planning Groups

Data provided through TRANSCAER

Substances that originate and terminate locally

Quantities stored locally

Existing Studies

Findings of studies in neighboring or other states

SRI Study (See Appendix A)

Truck Inventory and Use Survey (TIUS). The Truck Inventory and Use Survey (TIUS) is maintained by the U.S. Bureau of the Census, and is part of the Census of Transportation which is conducted once every 5 years. Reports for 1977, 1982 and 1987 are currently available; the 1992 report is expected to be published early in 1995. The TIUS provides data on the physical and operational characteristics of the nation's trucks. Also, hazardous materials truck miles by state are provided. Truck type and truck-mile data for hazardous shipments are included, but origin and destination data are not.

Forms for ordering CTS and TIUS reports can be obtained from Department of Commerce district offices or from:

Customer Services Branch
Data User Services Division
U.S. Bureau of the Census
Washington, DC 20233
(301) 763-7662

The TIUS contains such information as:

< Physical characteristics of each vehicle.

< Operator class.

<   Annual mileage and range of operation.

<   Percentage of miles operated in home state.

<   Commodities carried by hazard class.

<   Percentage of travel miles accounted for by hazardous materials shipments.

Published data from the above two surveys are also available on computer tapes that contain discrete rather than summary data. Depending upon the goals of a study and the quality of data available, the discrete data may be more useful and reduce unnecessary repetitive research.

2.2.2.2 Accident History

Another important data set is the determination of the number, location, and types of accidents occurring in the survey area. The historical record of local transportation accidents and incidents is useful because many carriers are consistent in their routing practices. In other words, if an accident involving a specific substance, occurred during shipment from an origin to a destination, the same route is probably still being used for shipments of that substance, and probably for shipments to other points as well. Even in the absence of detailed records, valuable information can be obtained from newspaper files, from state and local police reports, and from interviews with local emergency responders. The following sources can provide information on highway releases of hazardous materials as well as average accident rates.

Hazardous Materials Incident Reporting System (HMIS). The Hazardous Materials Incident Reporting System (HMIS) became the official Federal record keeping system for hazardous materials release data since 1971, and is maintained by the U.S. Department of Transportation. A release is defined as an unintentional release of a hazardous material during or in connection with its transport. All rail, truck, non-bulk water and air releases occurring during interstate commerce are covered by the HMIS. However, intrastate highway and bulk marine transport are excluded. 49 CFR Sec. 171.16 requires detailed, written hazardous materials incident reports to be submitted, within 30 days of the date of the incident, to the Department of Transportation for each incident that occurs during the course of transportation (including loading, unloading, and temporary storage). HMIS allows isolation of incidents involving specific hazardous materials. Approximately 182,000 records were in the file as of December, 1990. Required reporting categories are listed in Exhibit 4.

> HMIS data for a single year can be obtained on diskette; additional data may require the use of open reel tape. For more information, contact:
>
> U.S. Department of Transportation
> Research and Special Programs Administration
> Information Systems Unit, DHM-63, Room 8112
> 400 Seventh Street, S.W.
> Washington, D.C. 20590
> (202) 366-4555

The HAZMAT (incident record) file includes information about the incident and hazardous material(s) involved. A second file, the HAZCON file, reports details about the hazardous material container(s) involved in each accident (e.g., container type, container capacity, number of failed containers, label or placard, cause of failure).

EXHIBIT 4
INCIDENTS REPORTED IN HMIS

As the direct result of the presence of hazardous materials:

- A person is killed or receives injuries requiring hospitalization.
- Estimated carrier or other property damage exceeds $50,000.
- An evacuation of the general public occurs lasting one hour or more.
- One or more major transportation arteries or facilities are closed or shut down for one hour or more.
- The operational flight pattern or routine of an aircraft is altered.
- Fire, breakage, spillage, or suspected radioactive contamination occurs involving shipment of radioactive material or etiologic agents.
- A situation exists of such a nature that, in the judgment of the carrier, it should be reported to the Department even though it does not meet specific criteria of these categories.
- There has been an unintentional release of hazardous materials from a package (including a tank).
- Any quantity of hazardous waste has been discharged during transportation.

Office of Motor Carriers. Since 1973, the U.S. Department of Transportation, Federal Highway Administration, Office of Motor Carriers (OMC) (formerly the Bureau of Motor Carrier Safety) has maintained a database of accidents involving motor carriers of property.

From 1973 to 1993, accidents were reported to the OMC and reports were filed on Form 50-T. A "reportable accident" was an occurrence involving a motor vehicle engaged in the interstate, foreign, or intrastate operations of a motor carrier that resulted in:

- The death of a human being.
- Bodily injury to a person who, as a result of the injury, immediately receives medical treatment away from the scene of the accident.
- Total damage to all property that aggregates to $4,400 or more based upon actual costs or reliable estimates.

> The 50-T file is available on open reel tape. The Safety Net file is available upon written request. Details may be obtained from:
>
> U.S. Department of Transportation
> Federal Highway Administration
> Office of Motor Carriers
> 400 Seventh Street, S.W.
> Washington, D.C. 20590
> Contact: Linda Giles
> (202) 366-2971
>
> In addition, commercial sources have prepared reports (on a state or national basis) that present and analyze OMC 50-T data.

From 1973 to 1985 the minimum property damage threshold for reporting was $2,000. The minimum damage threshold was raised to $4,200 in January 1986 and to $4,400 in March 1987.

Form 50-T requested carrier identification and address, location of the incident, characteristics of the event, cause, information on the cargo, and consequences of the accident. The carrier identification, cargo description, and certain accident characteristics were recorded, so that users of the HMIS database and the OMC 50-T database might compare data on releases caused by vehicular accidents. In a small percentage of the records, the milepoint data was also included, resulting in more precise accident location determination. The 50-T accident file, which is no longer updated but still available, contains a hazardous materials flag that permits the isolation of vehicular accidents involving hazardous materials.

As of 1993, the OMC no longer collects the Form 50-T. The new **Safety Net** database supersedes the OMC 50-T database. Accident information from March of 1993 on is now collected by the OMC from police accident reports and put into the Safety Net database. The reports include commercial vehicles of 26,000 lbs. or more, that are involved in an accident resulting in a fatality, injury, or tow away. The OMC is collecting these reports from 40 states for the Safety Net database at this time, and the remaining states should be included sometime during 1995.

2.2.2.3 Commodity Type

The above data sources on road type, truck volumes, and accident rates should provide a general overview of the average truck flow within the study area. Information on hazardous materials volumes, usually by hazard class, may also be collected (Exhibit 1 describes the DOT hazard classification system). Planners should keep in mind that these data are general and often based on national averages; this information, however, can help to focus further research on specific truck types or hazard classes passing through the study area. Data sources discussed in this section are for collecting information on hazard classes and specific commodities.

Determining specific or even general types of hazardous materials that are transported through the study area can be one objective of a commodity flow study. Keep in mind, however, that it may be very difficult to identify every single chemical that passes through a jurisdiction. Depending on the nature and amount of hazardous materials traffic, it might be advisable to concentrate on determining which general classes of chemicals (e.g., flammables, corrosives) are being transported. Planners involved in a commodity flow study in the Kanawha Valley region of West Virginia (an area with an extremely high concentration of chemical manufacturers and shippers) learned that there were just too many individual chemicals being transported through the region to study each in depth or to focus planning efforts on each individually. They concentrated on determining general classes of chemicals instead. The following sections discuss several sources of existing information on commodity type.

Information Developed under SARA Title III. The reporting requirements of Title III of the Superfund Amendments and Reauthorization Act of 1986 (SARA) have increased the information that is available about hazardous materials stored in fixed facilities; unfortunately, information on the transport of hazardous materials is neither required nor typically provided to Local Emergency Planning Committees (LEPCs). However, important information can be surmised from the materials submitted to LEPCs.

Information about substances used to produce the final products at a manufacturing plant can be a key indicator of local hazardous materials flow patterns. For example, a chemical plant producing nylon is likely to receive shipments of and/or store significant quantities of furan or furfural. These materials, classified as flammable liquids, are used extensively in processing nylon and are frequently transported by road and rail. Thus, even though data provided by the plant to the LEPC may not explicitly state that such process chemicals are being received from shippers, if they are not produced on site, it may be assumed that they are transported to the plant.

Because each facility must submit information regarding the specific amounts of hazardous materials located on site, both the type and quantity of substances likely to be involved in locally originating and terminating shipments are a matter of public record. LEPC(s) within the study area can provide a list of facilities that report under SARA Title III, including specific substances used on site.

National Associations/Other Sources. Industry associations and other private organizations can be an important resource for collecting existing information. Associations such as the American

Trucking Association, National Association of Chemical Distributors, National Tank Truck Carriers, the American Petroleum Institute, the Chemical Manufacturers Association, and the International Bridge Turnpike and Tunnel Association (IBTTA) may be able to provide data, resources, and/or contacts in a jurisdiction to aid in commodity flow study efforts. Addresses and phone numbers for each of these associations is provided in Exhibit 5.

EXHIBIT 5
ADDRESSES FOR SELECTED NATIONAL ASSOCIATIONS

American Trucking Associations
2200 Mill Road
Alexandria, VA 22314
703-838-1700

National Association of Chemical Distributors
1101 17th Street, N.W.
Suite 1200
Washington, D.C. 20036
202-296-9200

National Tank Truck Carriers Inc.
2200 Mill Road
Alexandria, VA 22314
703-838-1960

American Petroleum Institute
1220 L Street, N.W.
Washington, D.C. 20005
202-682-8000

Chemical Manufacturers Association
2501 M Street, N.W.
Washington, D.C. 20037
202-887-1100

International Bridge Tunnel and Turnpike Association
2120 L Street, N.W.
Suite 305
Washington, D.C. 20037
202-659-4620

State agencies can provide information on industries, transportation routes, accident histories, and other data within a specific geographic area. The state transportation department may be able to provide information on transporters registered in-state, depending on state law. The state department of environmental protection or natural resources as well as state and local health departments may be able to provide information on known health risks and accident rates, as well as sensitive populations that may require protection (e.g., homes for the elderly, schools) during an incident. State economic development agencies or the state department of environmental protection may have data on facilities registered in-state, including information on materials manufactured or stored on-site. Through the state turnpike authority, the IBTTA can assist collecting original data.

Transportation Community Awareness and Emergency Response (TRANSCAER) is a nationwide community outreach program developed by the Chemical Manufacturers Association (CMA) and implemented by CMA-member firms that ship hazardous materials. Its purpose, in part, is to encourage partnerships between citizens and industry to develop mutual understanding about the transport of hazardous materials and to help community emergency planning groups identify hazardous materials moving through their communities. Industry representatives work with the LEPC and/or local responders and planners to improve awareness and response capabilities by providing information and resources. Additional information can be obtained from CMA (see Exhibit 5).

2.3 DESIGN THE STUDY

By comparing the data collected from the sources discussed above with the project goals, it should be possible to determine whether a field investigation should be undertaken. Because the existing data may prove to be out of date or the study's goals might require more specific data than is already available, it may be necessary to collect original data. For example, if the goal of the study is to quantify the level of awareness of drivers carrying specific high-risk chemicals, additional analysis and/or field surveys that supplement existing data will probably be necessary.

2.3.1 Survey Locations

If a hazardous materials flow study can be made part of a routine function, such as port-of-entry and weigh-station checks, collecting original data can be minimally disruptive and less likely to burden the carrier. However, such data will largely reflect interstate movements and may therefore miss sizable intrastate shipments.

> IDAHO - Peak Transportation Times. Idaho's risk assessment was conducted by surveying truck traffic at eight sites. To obtain data representative of weekly information, each location was surveyed for three days, once in July, and once in August. A total of 46 survey events, all over three days of the week (Sunday - Tuesday) occurred. Although the survey did not cover the entire week, the data gathered did allow initial conclusions to be made about which days and hours in the first part of the week are peak transportation times. These data can be useful for emergency response planning and scheduling.

Many states conduct random safety checks of heavy trucks in transit through their jurisdictions, occasionally utilizing rest stops that afford a safe location for extensive vehicular examination. Shipping paper information can be recorded during the safety examination. Because rest stops are distributed throughout a state's highway network (though chiefly on the Interstate system), they are better than points of entry or established weigh stations for surveying of intrastate movements. In general, survey teams should set up wherever there are appropriate combinations of the following:

- High truck volumes.
- Adequate space for safe pullover and isolation of up to about five trucks from the flow of traffic.
- Good visibility along the highway, in the event it becomes necessary to allow trucks to pass by because of long queues without recording shipping data. In this case, placards could still be read and noted.
- Absence of legal restrictions on survey activity.
- At least one other valid reason (e.g., cargo check, safety check, or weight check) for pulling the vehicle off the highway.

The study should keep in mind that truckers may evade the survey point either to save time or to conceal something. Alternate routes in a corridor are generally few in number and easy to identify. As a contingency, an individual should be stationed on each of these alternate routes to record the placards of drive-by trucks.

One type of easily accessible location for surveying trucks is points of entry, that is, state line crossings. States commonly locate a rest area just before or after state line crossings. Establishing a survey location at one or more of these rest areas (points of entry) would include trucks just as they were entering or exiting the state, and could provide information on the percentages of trucks that are passing through, importing to, or exporting materials from the state. These locations would not, however, survey all truck shipments that both originate and terminate within the state.

Depending on the purpose of the study, it may be useful to divide the routes being studied into segments or "links" to track commodity movements between specific points. Typically, this type of survey would require a large commitment of resources and would be conducted for a survey of an entire state because it requires a large number of survey locations and/or extensive interviews with drivers. Using links is useful because it provides more information on travel between two sites on the same (or adjoining) roads, rather than general information on truck volume on a particular route. For example, by using links, it would be possible to determine that truck volume is higher on a segment of an east-west highway between interchanges with two major north-south highways. It may be useful to consider Points A and B as the end points of the east-west highway interchanges X and Y with 2 north-south highways in between them. If the east-west highway is surveyed only at endpoints A and B, the traffic using the highway only for the connecting link between interchanges X and Y and the north-south highways would be missed. Under these circumstances, it would be important to collect data between interchanges X and Y.

NEVADA ! Links. By locating survey sites throughout the state and dividing the roads into links, Nevada was able to create an overview of statewide hazardous materials transportation. To obtain an average daily profile of commercially transported commodities via Nevada's highway system a total of 45 statewide information collection sites were used, including 19 points of entry, scattered across the state. The routes were divided into 95 "links" to track commodity movement.

At the conclusion of the study, each of the 95 links was analyzed to determine the average daily volume of hazardous materials, and the links were mapped accordingly. Using links identifies frequencies along specific route segments, instead of frequencies along an entire route, which can misrepresent traffic volumes. The mapping method employed is also useful because it creates a reference to identify at a glance the routes used most frequently, as well as the connector roads or segments of roads used as feeders to the major highway system, without having to know and compare exact volumes shipped over different routes.

The routing plans of highway common carriers tend to favor the interstate system because this network offers the most direct, fastest, and safest alternative. Nevertheless, legal-weight carriers are restricted to routes designated by the requirements of the Surface Transportation Assistance Act (STAA) of 1982 which are numerous in some states. Carriers may avoid an Interstate option if the delay, including weight, cargo, safety, and shipping paper checks, is less on another route with a lower classification.

2.3.2 Seasonal/Repetition

To obtain the most representative data, it is advisable to conduct field studies using numerous repetitions during multiple seasons. Using a continuous survey of truck traffic on consecutive days during at least two distinct seasons of the year may well represent a minimally acceptable standard for overcoming the sampling difficulties as discussed in section 2.5 below. Surveying for an entire week during

OREGON ! Multiple survey events and seasons. Oregon spread its survey over eight months to identify seasonal variations in transportation. The entire survey was completed in three phases, over a total of 18 days consisting of periods that began on a Monday or Tuesday at 12:01 am and continued for 72 hours (3 days). Phases one and two were conducted in March and August at seven sites outbound from Portland. In phase three, hazardous materials shipments entering Oregon through four border ports of entry were surveyed during the third week of November.

The use of three survey periods assists in identifying seasonal differences in truck traffic and hazardous materials shipments. Ideally, a survey to identify seasonal variations would be done at the same sites for each of the multiple events. Despite the fact that Oregon's third phase was conducted at different sites, the data from the seven sites surveyed twice can be used to make initial conclusions about seasonal traffic variations.

more than one season may be somewhat better, though undoubtedly more resource intensive. The selection of survey weeks should take into account the relevant economic characteristics of the area being studied (e.g., agricultural cycles, heating oil stockpiling, and industrial production schedules). To contain costs and collect data that are statistically reliable, it may be preferable to conduct field studies for two full weeks in a given month (not necessarily consecutive weeks) with identical follow-up surveys within four to six months after the initial surveys.

2.3.3 Personnel Needs

Law enforcement personnel, technical staff of state administrative departments, and college students have all been employed to collect hazardous materials flow data. No particular technical qualifications are required to perform field duties beyond the ability to read and record verbal or printed information accurately. However, technical qualifications would be required for interpreting and analyzing the data. All survey staff should attend at least one training session in survey procedures to facilitate data collection. This session should precede actual data collection by no more than one week and should include opportunities for personnel to demonstrate their competence. Survey staff can also participate in dry runs at the survey site that involve transport trucks and interactions with persons playing the role of driver. It is also very important that an individual understand and appreciate the survey's purpose. The goals of and rationale for conducting the survey should be central themes of the training sessions.

Staffing needs (in person-hours) will vary with the scope of the survey, irrespective of staff qualifications. If a survey is expected to reflect daily and seasonal fluctuations in hazardous materials flows at locations across a state, the person-hours required for data collection and transcription will be much larger than if a survey is intended only to reflect an average one day truck flow. If there are multiple sampling points in a state with a dense network of designated legal truck routes or a large number of origins and destinations of hazardous materials, the required person-hours will probably be much larger. Personnel considerations for surveys that have been conducted (and are discussed in more detail in Chapter 3) include the following:

< Idaho's study was conducted predominantly in daylight hours and spanned seven calendar months, three of which were survey months. The 1,520 person-hours involved in this study indicate that survey staff worked an eight-hour day at each of two locations.

< By contrast, Oregon's 3,460 person-hour effort involved continuous 72-hour monitoring periods at 11 sites; thus, each of the study's three phases required at least 99 eight-hour (two-person) shifts. The effort expended by the truck inspectors added to the total.

< In the case of the Dallas/Ft. Worth survey, the 100 person-hour commitment was probably appropriate for the spot survey procedure adopted, that is, no truck pullovers, no interviews, and no examination of shipping papers. However, the vigilance required to spot, record, and count all passing placarded trucks dictated shifts no longer than four hours. Accuracy is important, especially in the transcription of placard codes and verbal lading descriptions.

2.3.4 Study Design and Resources

Prior to conducting the commodity flow survey, it will be necessary to ensure that the goals of the survey can be achieved by the study method, and that the method requirements can be met by the resources allocated to the survey. It is important to take some time to review the study and determine whether any modifications are required and determine whether the study needs can be met by the resources available. Budget resources, personnel, equipment, and time restrictions imposed upon the survey must all be considered. If the needs cannot be met by the resources allocated, it may be

necessary to restrict some portions of the survey. For example, a survey may require three surveys to be conducted over a period of one year, using three people at each of 25 locations for each survey. If seasonal variations are more important than obtaining detailed statewide information, it might be appropriate to reduce the number of survey locations while keeping the three survey seasons. Likewise, if statewide variations are vital, having only two surveys at each of the 25 sites may be more practical. Reviewing the survey objectives and study design side by side is an important step in ensuring that the survey results are achieved within the resources allocated for that purpose and that they are meaningful in achieving the stated goal of the survey.

2.4 COLLECT ORIGINAL DATA - FIELD SURVEYS

Field surveys provide the additional data necessary for a more thorough analysis of transportation-related hazardous materials risks. There are several different methods that can be used for collecting data in the field, each requiring a varying degree of effort. This section discusses various methods for collecting original data in the field as well as issues regarding data recording and data storage. Exhibit 6 reviews the specific information to be collected. The applicability of each method (listed in increasing order of the resources required to complete the effort) to the study's design and overall goals should be considered. These various methods may be used in combination, as appropriate, to maximize the amount of data collected.

EXHIBIT 6
INFORMATION TO BE RECORDED DURING FIELD SURVEYS

SOURCE	MINIMAL DATA	ADDITIONAL DATA
SURVEY PERSONNEL	T Date and time sample record was taken	
VEHICLE	T Truck type T Cargo type T DOT placard T Four digit UN/NA ID #	Ú Tank or trailer rated capacity
SHIPPING PAPERS	T Any routing instructions T Four digit UN/NA commodity T ID # (Compare with placard) T Destination of shipment (city and state)	Ú Four digit STCC code number Ú DOT shipping name Ú Quantity of lading (weight or volume) Ú Origin of shipment (city and state)

2.4.1 Data Collection Methods

The following data collection methods will provide, at a minimum, the placard color and type and the four-digit ID code. These data should be recorded and then checked for consistency with shipping paper information. Recording the rated capacity of each tank or trailer provides an indication of the total quantities of specific substances (or hazard classes) being transported and the potential magnitudes of spills or releases in the event of an accident.

2.4.1.1 Placard Surveys

It is relatively easy to determine the hazard class of the contents of a properly placarded truck trailer (see Exhibit 7 for examples of placards and identification numbers). Survey personnel note the material's identification number displayed on trucks moving past a survey point. Binoculars, of course, can assist in reading the four digit ID number, which is displayed either on the placard itself, on an orange panel below the placard, or on the side of the vehicle.

Sheriff's deputies or local law enforcement personnel on routine patrol may be able to conduct these informal checks if they are stationed at or near road arteries passing through the community. Properly trained volunteers (e.g., students, environmental groups) can also provide valuable resources. It is important to select a location for personnel that is safe and has a clear line-of-sight to the right-of-way.

2.4.1.2 Review of Shipping Papers

Each vehicle's shipping papers contains precise information on the quantities and types of hazardous materials being transported. The shipping papers for vehicles transporting hazardous materials must contain:

< Number of packages of lading.

< DOT shipping name of lading.

< DOT hazard class of lading.

< UN/NA four-digit ID number.

< Package weight or volume for each product carried.

In addition, virtually all bills of lading identify either the shipper or forwarding carrier from which the consignment was received, the point of origin of the shipment (or location of receipt), and the shipment's point of destination. There may also be special handling instructions for the driver and recipient, as well as a routing plan for the driver. This plan may be spelled out in some detail, but in general provides only the sequence of routes to be followed (e.g., US 45 north to I-65 north to I-90 east). Comparing the routing instructions with the points of origin and destination can provide a quick quality assurance check.

As trucks pull into the survey area, survey personnel should ask the driver for the shipping papers, which should be readily available. For any hazardous materials shipment, a copy of the shipping papers and any other relevant documents must be placed in the cab before starting the haul.

Survey personnel could be tasked to photocopy the shipping papers while the truck is stopped at a toll booth or weigh station and additional information from the vehicle is recorded. Minimizing the delay to the driver, this approach allows for a detailed examination of the information on the shipping papers away from the site after the field surveys are complete. It is important to note that shipping papers are not standardized; the review process, therefore, could prove lengthy. In addition, the cost of maintaining portable copiers at the survey locations may be prohibitive to some jurisdictions.

2.4.1.3 Driver Interviews

Driver interviews provide "hands on" information. A list of questions should be prepared and survey personnel should be briefed on the types of information to look for. The survey goals will point to the correct questions to ask, for example: If the driver works for a particular company often, does

EXHIBIT 7
EXAMPLES OF PLACARDS AND IDENTIFICATION NUMBERS

he/she typically use the same route? Does he/she usually have the same destination? If so, what is that destination? Is it in-state? Out of state? Is the driver familiar with the material being transported? What type of safety training has he/she received?

2.4.1.4 Facility Survey

If resources allow, distribute a questionnaire to facilities within the study area to obtain precise shipping data. These facilities can be polled to determine specific trends in the amount of hazardous materials transported, the exact mode and route of transport, and the usual hours and days of the week for shipping and receiving. Time must be allowed for conducting follow-up telephone calls to clarify information that may be unclear. Telephone calls can also help increase the rate of response.

> DALLAS CBD ! Facility Survey. The Dallas CBD inventoried local industries to identify the types of hazardous materials transported locally, the routes used, and the frequency and time of day for the shipments. An industry survey was sent to 1,400 Dallas and Dallas County industries and transporters that were selected based on SIC code and identified from several information sources, including Federal, state, local, and private agencies.
>
> From the inventories, it was possible to determine that the majority of bulk shipments were gasoline or petroleum-related, and a number of other materials were regularly being shipped through the area. The data indicated that as many as 25-30 9,000-gallon shipments of gasoline traveled in proximity to the Dallas CBD each day. By obtaining these data prior to conducting a field survey, it is possible to save effort and resources by narrowing the focus of the field study to specific areas and commodities.

2.4.2 Recording Procedures

All data gathered should be accompanied by the date and time they were recorded and should reflect visual inspection of the truck or tractor/trailer as well as examination of shipping papers. Total truck time at the weigh scale, rest stop, or pullover point should not exceed three minutes, unless a safety inspection is also being conducted. A simple tally sheet, with rows or columns for the 25 or 30 most common four-digit hazardous materials codes (plus space to enter any additional codes observed) may be developed to ease analysis after the data have been recorded.

Exhibit 8 reviews the advantages and disadvantages of the data-recording procedures that can be used in surveys. On-site keying in with later confirmation from a copy of the shipping paper is, overall, the best means of recording. The data-processing resources for such quality assurance, however, may not be available. Similarly, both verbal and written communications to a data recorder on site provide an important accuracy check, but may necessitate the use of three-person teams. If data are to be keyed in later in an office rather than at the site, then both the survey transcription and a copy of the shipping paper should be available for a consistency check before final data entry.

If two-person teams are conducting the survey, two options are possible: (1) one person records the placard information and examines the truck exterior while the other transcribes the shipping paper data, or (2) one person collects all data and immediately provides them to the other person, who keys them into a computer data file. If data are to be entered into a computer at the survey site, some additional planning is necessary. Even with a laptop or portable personal computer (PC), AC power would likely be needed at the survey site. In addition, the recording location must be sheltered from the weather. A data-entry template should be prepared in advance and already coded into the software for easy and consistent keying of records.

EXHIBIT 8
ADVANTAGES AND DISADVANTAGES OF VARIOUS DATA RECORDING PROCEDURES

Pros	**Cons**
1. Hand Record for Remote Entry	
No need for electrical or telecommunications links	Requires considerable paper processing and tracking
One-person survey team feasible	Subsequent verification of shipping paper data not possible
Resource requirement relatively low	Long per-vehicle survey time
2. Hand Record for On-Site Entry	
Immediate verification and accuracy check feasible, especially if data screen has same format as check sheet	At minimum, two person team required Subsequent verification of shipping paper data not possible
3. Copy Shipping Paper	
One-person survey team feasible	Heavy-duty portable copier required
Fast (survey taker notes placard, copies bill, and sends trucker on his or her way)	Excessive paper handling and tracking required
Easily piggy-backed onto weigh station operations	No explicit check of placard/shipping paper consistency
4. Dictation Key-In	
Data recorder reports each value verbally to data entry specialist	
Instantaneous data recording	No paper record for subsequent verification
Fast processing of each vehicle	
5. Combining (2) and (3)	
Best verification and quality control option	Requires data entry and checking both during and after survey (i.e., more costly)
Data record in computer file is given same ID as shipping paper copy, assuring no mismatch or miscoding	
6. Combining (3) and (4)	
Faster than (5) and potentially as accurate	Same as (5)
7. Inclusion of Driver Interview	
May provide added insight on shipment frequency for a commodity of interest	Time consuming; increases survey cost, increases mean truck delay, and may require four-person teams

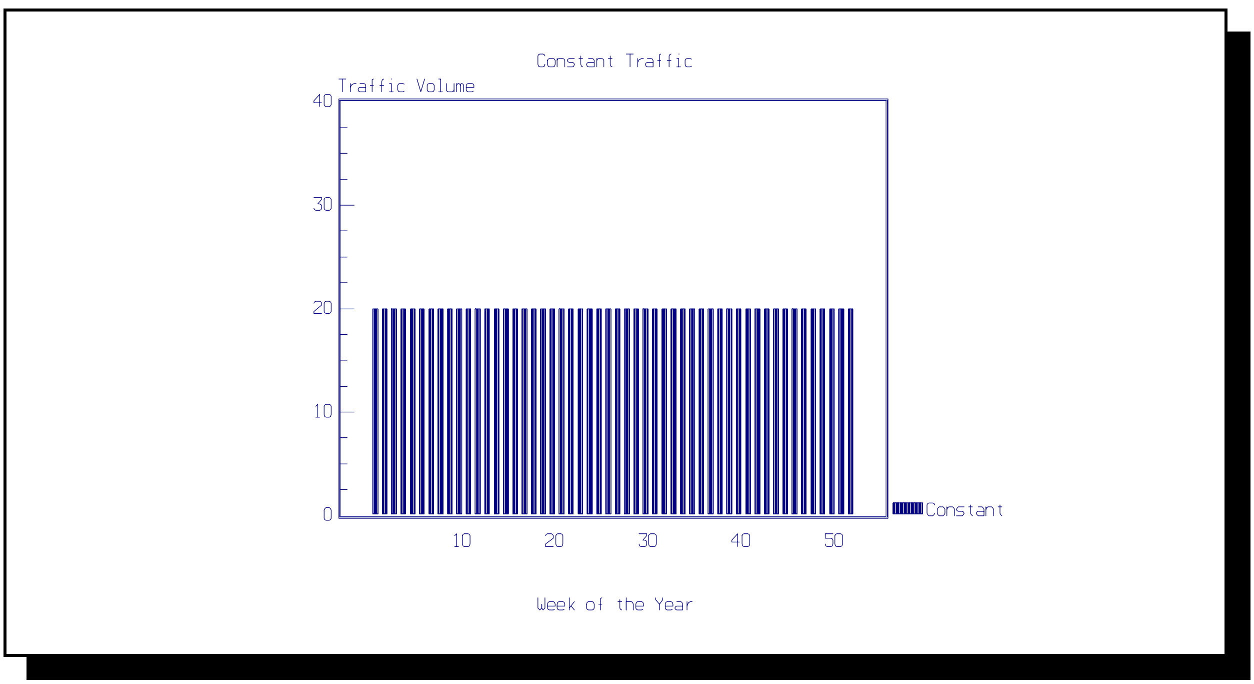
2.5 ANALYZE RESULTS

This section introduces the application of appropriate sampling techniques to the collection of highway hazardous materials flow data. It reviews some basic but important principles of sampling theory that are relevant to the planning of any survey of road traffic. Understanding the points covered is crucial to understanding why some surveys work while others do not, and why even a well-planned survey can sometimes yield erroneous, incomplete, or misleading results.

2.5.1 Statistical Considerations

The field of statistics uses models to predict reality. In this section, traffic flow is assumed to follow a Poisson distribution, which is a specific mathematical model used when discrete events (such as the movement of a truck carrying hazardous materials) occur randomly in time and space. To use the Poisson distribution, one must know the average number of occurrences per unit of time or space. This average number of occurrences is also referred to as the "expected value." For discussion purposes, assume weekly traffic flow is to be surveyed, although the discussion presented below holds for any time period (e.g., random event) chosen. Exhibit 9 represents traffic volume (y-axis units) that is constant for each week of the year (x-axis units). If traffic of a particular type were truly constant, then a survey could be conducted any week of the year and the results used to determine fortnightly, monthly, seasonal, or annual traffic flow. Actually, weekly traffic flow is random, although it may have the same expected average value each week of the year.

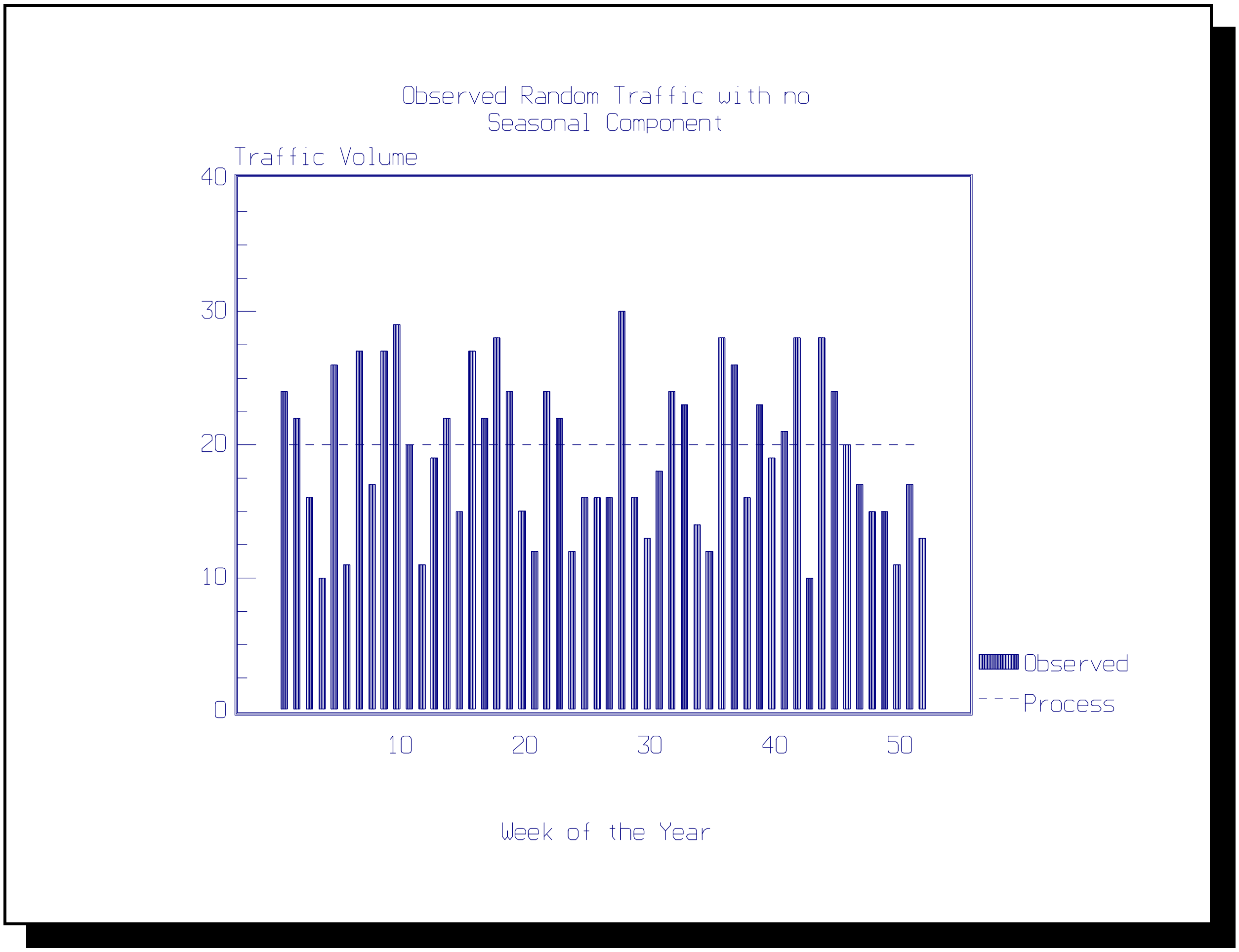
EXHIBIT 9
HYPOTHETICAL CONSTANT TRAFFIC FLOW



The bars of varying heights in Exhibit 10 depict random traffic levels per week. The dashed line at 20 units implies that the *expected* value of traffic each week is constant. The observed value varies around the expected value with probabilities established by the Poisson distribution.

EXHIBIT 10

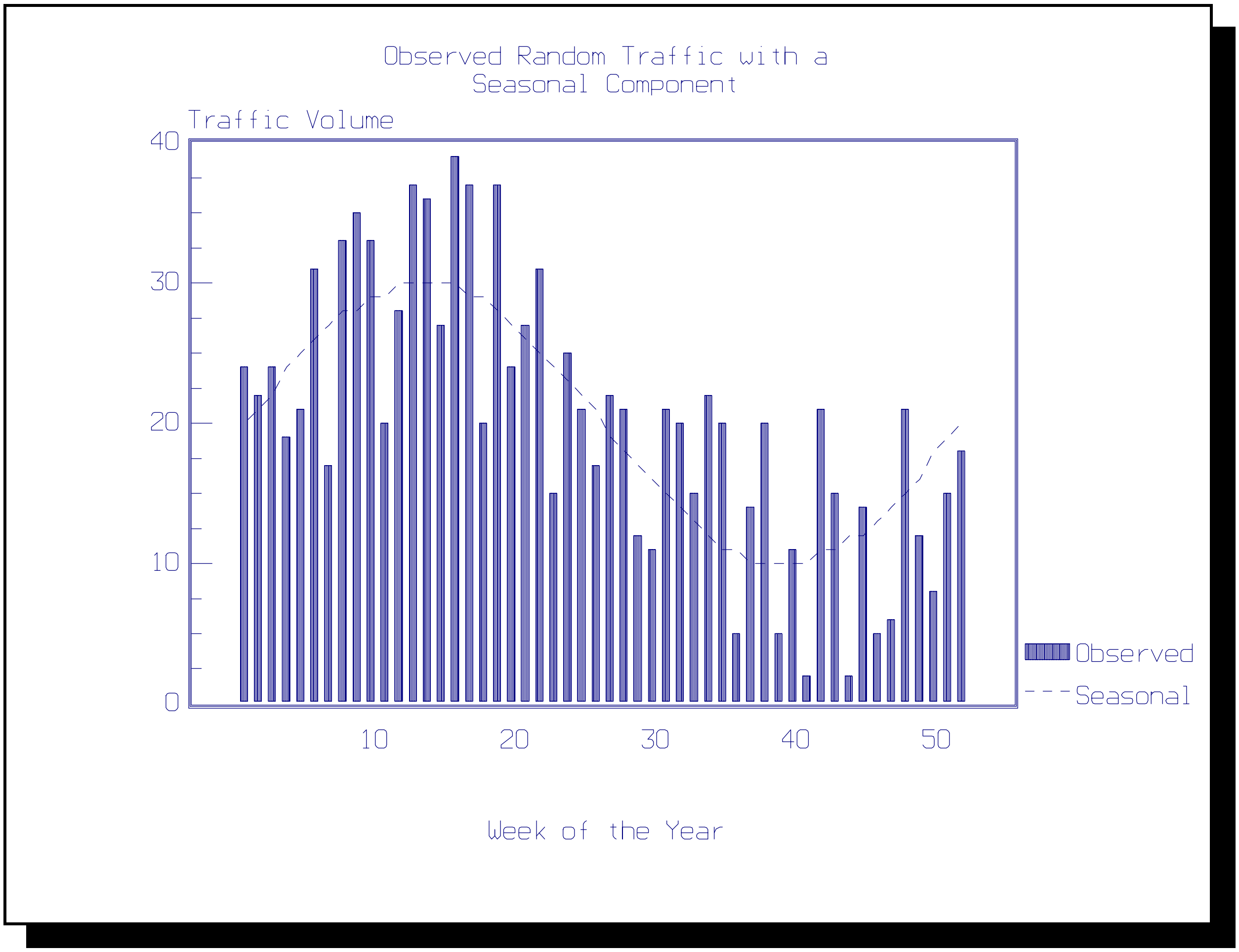
WEEKLY TRAFFIC FLOW PATTERN THAT IS RANDOM WITH NO SEASONAL COMPONENT



The researcher generally does not know the expected value, but only knows the observed value. If a survey were conducted during a random week, the researcher would have to be careful in drawing conclusions about periods other than the week in which the survey was conducted; it could lead to an incorrect estimate of the annual number of vehicles. For example, if the survey were conducted during a week when the observed value was 10 units and these results were used to estimate an annual flow of 520 units, annual flow would be underestimated by a factor of two (i.e., expected value of 20 times 52 weeks is 1,040 units). In real life, this may be acceptable. However, the point being made is that the results of a single survey may not be appropriate from a planning perspective and may need to be supplemented by other information about traffic flow, such as that obtained or inferred by LEPCs or through TRANSCAER.

Although the depiction in Exhibit 10 is more realistic than the previous one, it still is not precise because *expected* traffic volume is likely to vary throughout the year. The case shown in Exhibit 11 is more realistic, although still an oversimplification. The dashed curve represents this time-dependent variation in expected value, and each bar represents the random traffic level associated with the corresponding expected value. In Exhibit 11, the expected value changes every week of the year and the random variation in observed values makes the problem even more complex.

EXHIBIT 11
WEEKLY TRAFFIC FLOW PATTERN THAT IS RANDOM WITH A SEASONAL COMPONENT



Because of the nature of random traffic, what is seen at a particular observation point at any one location or any one time may not necessarily be a good indicator of overall average conditions. For example, if a traffic survey conducted over a week observes 100 shipments of a particular type, what can be reliably assumed about the actual number of shipments of this type at that specific location and time of year? First of all, unless other information is known, the average intensity of traffic flow (e.g., the expected value) can be assumed to be 100. However, the actual intensity may be higher *or* lower than 100, with 100 shipments having been observed simply by chance.

Exhibit 12 summarizes three confidence intervals (90%, 95%, and 99%) about a specific set of observed values. The middle column lists the observed values. Any particular confidence interval about a specific observed value is listed at the intersection of the appropriate row and pair of columns. The 90% confidence interval about the observed value of 100 is given under the third and fifth columns: namely, 85 to 118. Similarly, the 95% confidence interval is given under the second and sixth columns: namely, 82 to 122; and the 99% confidence interval is given under the first and seventh columns: namely, 77 to 129. When a researcher has an observed value, but does not know the expected value, Exhibit 12 can be used to determine the range of possible expected values that would be consistent with the one observed value. In other words, the 90% confidence interval (the range of plausible expected values 90% of the time) about the observed value of 100 is 85 to 118. In fact, there is a 5% chance that 100 or fewer shipments

EXHIBIT 12
CONFIDENCE INTERVALS VERSUS NUMBER OBSERVED

99% Confidence Interval							99% Confidence Interval						
	95% Confidence Interval							95% Confidence Interval					
		90% CI							90% CI				
LCL3	LCL2	LCL1[b]	N[a]	UCL1[c]	UCL2	UCL3	LCL3	LCL2	LCL1[b]	N[a]	UCL1[c]	UCL2	UCL3
0	0	0	0	3	4	7	176	183	187	210	235	240	251
0	0	0	1	4	6	9	185	193	197	220	246	251	262
0	1	1	2	6	7	10	194	202	206	230	256	262	273
1	1	1	3	8	9	12	203	202	206	240	256	262	273
1	2	2	4	9	10	13	212	221	225	250	277	283	294
2	2	2	5	10	12	15	222	230	235	260	288	294	305
2	3	3	6	12	13	16	231	240	244	270	298	304	316
3	3	4	7	13	14	18	240	249	254	280	309	315	327
3	4	5	8	14	16	19	249	258	263	290	319	325	337
4	5	5	9	15	17	21	259	268	273	300	330	336	348
5	5	6	10	17	18	22	268	277	282	310	340	346	359
5	6	7	11	18	20	23	277	287	292	320	351	357	370
6	7	7	12	19	21	25	286	296	301	330	361	368	380
6	8	8	13	20	22	26	296	306	311	340	372	378	391
7	8	9	14	22	24	28	305	315	321	350	382	389	402
8	9	10	15	23	25	29	314	325	330	360	393	399	412
8	10	11	16	24	26	30	324	334	340	370	403	410	423
9	11	11	17	25	27	31	333	344	349	380	413	420	434
10	11	12	18	26	28	33	342	353	359	390	424	431	444
11	12	13	19	28	30	34	352	363	368	400	434	441	455
11	13	14	20	29	31	35	361	372	378	410	445	452	466
19	21	22	30	40	43	48	370	382	388	420	455	462	476
27	29	31	40	52	54	60	380	391	397	430	465	473	487
35	38	40	50	63	66	72	389	401	407	440	476	483	497
43	47	49	60	74	77	84	399	410	416	450	486	494	508
52	55	58	70	85	88	95	408	420	426	460	497	504	519
60	64	67	80	96	100	107	417	429	436	470	507	514	529
69	73	76	90	107	111	118	427	439	445	480	517	525	540
77	82	85	100	118	122	129	436	448	455	490	528	535	550
86	91	94	110	129	133	141	446	458	465	500	538	546	561
95	100	103	120	139	143	152	493	506	513	550	590	598	614
104	109	113	130	150	154	163	540	554	561	600	642	650	667
113	119	122	140	161	165	174	588	602	609	650	693	702	719
122	128	131	150	172	176	185	635	650	658	700	745	754	772
131	137	141	160	182	187	196	683	698	706	750	796	806	824
140	146	150	170	193	198	207	730	746	755	800	848	857	876
149	156	159	180	203	208	218	778	795	803	850	899	909	928
158	165	169	190	214	219	229	826	843	852	900	951	961	981
167	174	178	200	225	230	240	874	891	901	950	1002	1012	1033
							922	940	949	1000	1053	1064	1085

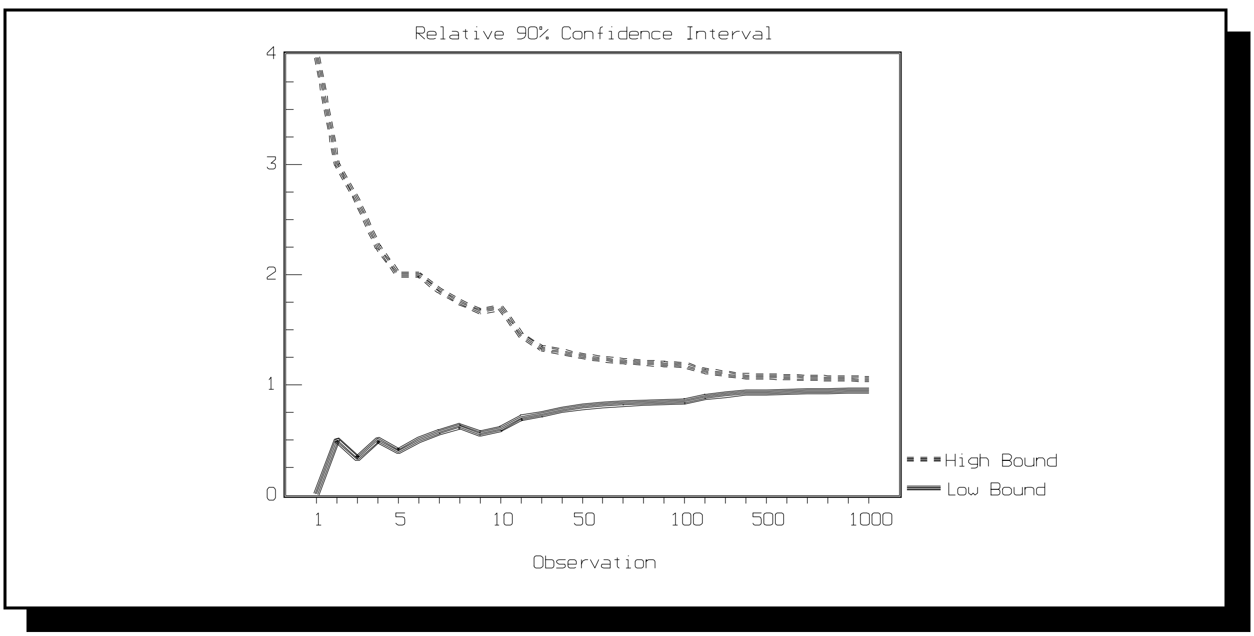
[a] N is the number observed.
[b] LCLn is the lower confidence limit (the probability is (1 - CI)/2 that the "true" intensity is **less** than the LCL for that CI).
[c] UCLn is the upper confidence limit (the probability is (1 - CI)/2 that the "true" intensity is **greater** than the UCL for that CI).

would be observed, even if the expected value was 118. Similarly, there is a 5% chance that 100 or more events would be observed, even if the expected value were 85.

It is possible to use Exhibit 12 to compare two observed values. For example, a community suspects that one of the four seasons has a high commodity flow, one has a low, and the other two have moderate levels of transport. This pattern is similar to the one illustrated in Exhibit 11, but unfortunately the dashed line in the exhibit, that indicates the expected transport flow, is not known before conducting a commodity flow survey. The goal of the commodity flow study is to determine whether there is a statistical difference in seasonal traffic. Before designing the study, an investigator knew that week 10 should have the highest weekly traffic and week 30 should have the lowest weekly traffic. After conducting the study and compiling the data, the investigator determined traffic flow was 30 units in week 10 and 16 units in week 30. The ranges that include a 90% confidence interval for these two values are 22 to 40 in week 10 and 11 to 24 in week 30. These ranges overlap. Both would be consistent with a "true" traffic intensity of 22, 23, or 24. This example illustrates the difficulty of using data developed from commodity flow studies to make meaningful, statistically accurate comparisons.

The size of a particular confidence interval increases as the observed value increases: for the observed values of 10 and 100, the 90% confidence interval sizes are 11 (the difference between 6 and 17) and 33 (the difference between 85 and 118), respectively. But, with respect to the observed value, the confidence interval *ratio* is decreasing (17 is 1.7 times 10 and 6 is 0.6 times 10; 118 is 1.18 times 100 and 85 is 0.85 times 100). Exhibit 13 illustrates this relationship for the 90% confidence interval. Similar results hold for the 95% and 99% confidence intervals. Thus, as sample size (N in Exhibit 12) increases, the proportional amount of error decreases.

EXHIBIT 13
CONFIDENCE INTERVAL VERSUS
NUMBER OF OBSERVATIONS



2.5.2 Implications for Study Design

The major lesson to be learned from this discussion is that there are dangers associated with trying to make inferences based on a small number of surveys or on any comprehensive survey of short duration. Traffic flows for longer or different periods of time may be grossly miscalculated and incorrect conclusions drawn. For example, statistical theory reveals, as shown in Exhibit 12, that 5% of the time when the observed value of a particular traffic type is 0, the expected value may be three. In this instance, it could be concluded that none of this type of traffic is ever present when in fact it may be present sometimes.

It is possible to make inferences based on small samples if the characteristics of the sample population are well known (i.e., if the expected value is known in advance of the survey). The known characteristics allow statisticians to adjust the observed results. For example, forecasts of economic indicators are made early in the year because the observations can be "seasonally adjusted" on the basis of historical data.

Thus, if reliable use is to be made of one or two surveys, information must be obtained about historical traffic patterns (e.g., peak periods, slack periods, and typical periods), and fixed sources of hazardous materials as well as the traffic flow from these sources (e.g., volumes, seasonality, and delivery routes) must be identified. LEPCs and public-use data bases (as described in section 2.2.2) can potentially provide this information.

Given the inherent difficulties and potentially high costs of traffic surveys, the following conclusions are generally applicable.

< Surveys should be done at the state level; that is, surveys should not be conducted unilaterally by local jurisdictions because it would not be valid to extrapolate data from a local survey to state-level conclusions, and components in state-level analyses should be based on consistent methods and data sources;

< Surveys should be carefully designed to ensure obtaining valid and useful results;

< Because when more "events" are observed the proportional size of the confidence range decreases, it may be more effective to sample for fewer time periods of longer duration; and

< Strange or unexpected results should be investigated further so that reasonable explanations can be found.

2.6 APPLY RESULTS TO PURPOSES

The results of the commodity flow study can be used to improve preparedness, prevention, and response capabilities by designating specific routes to be used for the transportation of hazardous materials and other focused planning efforts. For example, it may be useful to display the data on a map (or a series of maps) to obtain a picture of hazardous materials transport. Compare the data and conclusions that have been drawn from the study against the project goals identified at the beginning of the process in order to develop action items and a schedule for implementing the results. The study data and conclusions should be compared to the project goals identified at the beginning of the process. For example, if the study shows that a particularly large amount of a specific chemical is transported on a specific route, emergency responders along that route could benefit from training in the properties and effects of that substance. Equipment purchases could also be made with this information in mind.

> DALLAS CBD ! Statistics. After tallying the field and questionnaire data, several sources of information (MTB data, National Transportation Safety Board (NTSB) accident reports, and a DOE report on the risk of transporting gasoline by truck) were reviewed to better understand the causes and results of hazmat accidents. By reviewing these other sources of data and applying the information to local data, the Dallas CBD saved time and effort through its application of national trends to local realities. The Dallas CBD used statistics to determine how the national trends correlated to local data; this enabled the Dallas CBD to develop sound conclusions from its data without having to come up with its own complex methodology or hypotheses.

In some cases, those who develop and analyze the results of the commodity flow study might not be the most appropriate agent to take action on a particular recommendation. To implement the action items resulting from the study, it might be necessary to work with the state legislature, local governing bodies, or any one of the various state and federal agencies with responsibilities in transportation and environmental planning and emergency response.

CHAPTER 3
STATE AND LOCAL SURVEYS

Several states and one local community have conducted surveys to determine the types and quantities of hazardous materials transported on their highways. Each survey is briefly described in the sections below, and the chapter concludes with a comparison of the survey experiences.

3.1 COLORADO

Colorado Senate Bill (SB) 156, the Hazardous Materials Transportation Act of 1987, was passed in recognition of increasing concern about the potential for serious problems resulting from hazardous materials transportation accidents. One provision of SB 156 directed the State Patrol to designate which Colorado roads can be used for hazardous materials transportation. A truck survey was conducted from December 1987 to May 1988 to learn more about the types and quantities of hazardous materials that were being transported and patterns of hazardous materials movements throughout the state.

Trucks were surveyed at ten sites throughout the state, including selected weigh stations, roadways, and ports of entry. Truck placards were counted, shipping papers were examined, and drivers were interviewed to determine the types and quantities of hazardous materials as well as shipment origin and destination. Ports of entry officers, who deal with trucks on a full-time basis conducted the truck surveys.

Data collected at the survey sites indicated that:

< Ten percent of the shipments surveyed carried hazardous materials, 90% of which consisted of petroleum products.

< Sixty-three percent of the hazardous materials shipments surveyed were flammable and combustible liquids, 27% were flammable gases, 4% were nonflammable gases, 3% were corrosives, 2% were miscellaneous hazardous materials, and 1% were oxidizers.

< Of the hazardous materials shipments surveyed, 52% had both origin and destination within the state, and 45% percent had either origin or destination within the state. Only 3% of the shipments were passing through the state.

Other analyses that were conducted included comparing the placards and interview information over the same 7-day period to identify any differences. In addition, the state looked at accident rates on the highway system. Unlike many other investigations, Colorado looked at accident rates on all roads, not just on those used by truck traffic. This provided an opportunity to contrast accident rates on the routes typically used by trucks to all other traffic accident rates.

Colorado used this information to help identify routes to be designated for hazardous materials transportation. This survey, however, was only one of several methods used to identify hazardous materials routes.

3.2 IDAHO

The goal of this study was to identify factors involving transportation of hazardous materials to determine the health risk to motorists in Idaho. The first phase of the study determined the types and quantities of hazardous material being transported across the state. The second phase assessed the emergency response capabilities of statewide agencies.

The assessment was conducted through surveys of the actual truck traffic on several days during July and August 1987. All trucks at eight ports of entry were counted and, if trucks carried hazardous materials, drivers were interviewed for further information on the types and quantities of materials, shipment origin and destination, driver's training and knowledge of hazardous materials permits and endorsements.

Out of the 11,335 trucks counted, 424 (3.7%) trucks were stopped for interviewing. Hazard placarded trucks ranged from 1.9% to 9.2% of total truck traffic at the different ports of entry surveyed; on average 4% of all trucks on Idaho highways carry hazardous materials, and on average 1% carry a high hazard material, such as radioactive material. Gasoline and other fuel products accounted for the most frequently shipped hazardous materials. Most of the shipments originating outside of Idaho had origins in the neighboring states of Utah, Washington, and California; a majority of the shipments with destinations outside of Idaho were also destined for neighboring states: Montana, Oregon, Washington, and Utah. The highest frequency of hazardous materials traffic occurred on Tuesdays, and peak hours every day occurred between 8:00 a.m. and 3:00 p.m. Fifteen percent of the drivers reported no training for hazardous materials transportation, 12% did not know they needed a hazardous material endorsement, while 25% did not have an endorsement.

> Hazardous Material Transportation Monitoring and Capability Study for the Purpose of Assessing Risk to the Public, January 1988 by College of Health Science, Boise State University
> Idaho Department of Law Enforcement
> Idaho State Police
> 6050 Corporal Lane
> Boise ID 83704
> (208) 327-7180

Seventy-nine (74%) of the 107 agencies interviewed responded to the agency inventory questionnaires. Among the major findings were that 33% of the agencies did not have a copy of the State Disaster Plan, 17% of the agencies were unaware of the State Emergency Management System Communication System, and there was general confusion as to who had responsibility for response to any hazardous materials incident in a specific county.

All the data collected was entered into a computer database and given to the Idaho State Police for further study and use. The study concluded that it is apparent from the numbers of hazardous materials shipments occurring each day and the lack of awareness among agencies regarding state hazardous materials response procedures that motorists in Idaho may be at significant risk from a hazardous materials accident. Some agencies have already taken steps to improve their hazardous materials training and response capabilities, and the Idaho Legislature and other agencies are taking steps to improve training and preparedness and ensure that the public is adequately protected from any hazardous materials incidents in Idaho.

3.3 NEVADA

The purpose of the Nevada DOT (NDOT)'s *Nevada Commodity Report* was to present an average day profile of all commodities, including those classified as hazardous materials, being commercially transported via Nevada's highway system. Final results analyzed total truck traffic, and provided a separate analysis of hazardous materials shipments.

Formulas were developed to convert survey numbers to average daily numbers. Factors looked at included an adjusted average daily volume for commercial trucks; each

> This information is used to gain further understanding of commodity movement throughout Nevada, both for use in hazardous materials routing as well as for other general highway planning requirements.
>
> Commodity Report
> January 1993
> Nevada Department of Transportation
> Research Division
> 1263 S. Stewart Street
> Carson City, NV 89712
> (702) 687-3452

commodity type by vehicle type; and net weight by vehicle type and commodity type.

Hazardous materials tonnages are reported even though the perceived degree of public safety regarding the potential for hazardous materials incidents is more closely related to exposure (frequency) than to the amount (tonnage) of hazardous materials involved. For this reason, the analysis of hazardous materials movements emphasizes frequency rather than tonnage.

There were a total of 45 statewide information collection sites, including 19 points of entry; the routes were divided into 95 "links" to track commodity movement. All drivers of trucks with hazard placards were interviewed, including empty trucks with residual materials; shipments by the Department of Defense are not included because the state does not have the authority to stop these trucks. Drivers were questioned as to points of origin and destination, routes traveled within the state, and details on the specific commodities being transported.

Data were collected in 1989, 1990, and 1992, from a total sample of 19,838 trucks. Results of the study indicated that :

< Hazardous materials trucks accounted for 3.6% of total statewide shipments (3.1% on Interstate routes, 5.2% on U.S. routes, and 6.0% on state routes), and 8.9% of statewide tonnage. Daily tonnage of hazardous materials shipments peaked at 3,489 tons per day on I-15, with a total of 13,576 tons being transported daily throughout the state.

< Of all hazardous materials trucks, 32% were passing through the state, 28% were importing shipments, 22% were exporting shipments, and 18% were intrastate shipments.

< On I-15, the route with the largest hazardous materials traffic, flammable liquids made up 61% of the hazardous materials traffic, corrosives accounted for 18%, and gases accounted for 15%. On all the routes together, flammable liquids made up the largest portion of the hazardous materials traffic, accounting for 50% to 80% of the volume, and up to 86% of the tonnage on any single route.

The collected data were analyzed to determine total numbers as well as percentages of individual commodity shipments and frequency of shipments on different routes. These data were used as background information to assist NDOT in highway planning.

NDOT conducts a similar study every other year, so the information is continually being updated. NDOT is compiling a database of this information; so far the number of trucks surveyed have increased during every survey, but the numbers are expected to begin to level off during the next survey scheduled for 1994. NDOT has not changed its survey methods, except to modify survey locations as indicated by travel patterns.

3.4 OREGON

<u>Hazardous Material Movements on Oregon Highways</u>
1988 by the Public Utility Commission of Oregon
and the Oregon Department of Transportation

A study was conducted in response to the December 1986 recommendations of the Oregon Interagency Hazard Communications Council to quantify the level of risk to the state's citizens. The Council requested the Oregon Department of Transportation (ODOT) and the Public Utility Commission (PUC) to undertake a study to gather information on the types and quantities of hazardous materials transported on Oregon highways, as well as on container types, load origins and destinations, routes traveled, and cities and counties exposed to hazardous materials traffic.

Ten truck weigh scale locations in Oregon and one in Washington were chosen for the survey because they provided facilities for separating hazard-placarded trucks from the general traffic. Five of the survey sites were located on the Interstate system, three were on U.S. (primary) highways, and three were on Oregon state highways. In conducting the surveys, ODOT and PUC personnel stopped hazard-placarded trucks to examine shipping papers and to gather information regarding routes traveled. Non-placarded trucks carrying Other Regulated Materials were also included in the survey. Information was collected from a total of 2,511 placarded vehicles.

A preliminary survey was conducted in March to determine placard compliance, which was then used to estimate the reliability of data collected from placarded vehicles only. Two-person teams visited each survey site to selectively examine trucks and cargo; 35 vehicles were inspected, and only one placard violation (3%) was found.

The primary surveys were completed in three phases, over a total of 18 days in 1987, consisting of periods that began on a Monday or Tuesday at 12:01 am and continued for 72 hours (3 days). Phase one was conducted during the second and third weeks of March at seven sites outbound from Portland. During phase two, the same seven sites were revisited during the first and second weeks of August to reveal any seasonal differences in truck traffic and hazardous materials shipments. In phase three, during the third week of November, hazardous materials shipments entering Oregon through four border ports of entry were surveyed.

The results of the study indicated that:

< Hazardous materials movements averaged nearly 2 per hour, ranging from 6.4 movements per hour at Woodburn (southbound from Portland) in August, to less than 1 every four hours at Tillamook (westbound from Portland).

< The heaviest total truck traffic consistently occurred at the Interstate survey sites: three locations on I-5 (the main north-south route through Oregon and Washington) and one location on I-84 east out of Portland.

< For the 7 sites surveyed in both March and August, there was a total increase in hazardous materials movements of 44%. The Brightwood location (eastbound from Portland) showed the largest seasonal change in total truck traffic, increasing 50% in August.

< For all the surveys combined, flammables were most common (54%), followed by corrosives (16%) and dangerous shipments (e.g., a combination of flammables and corrosive materials) (6%). There was a noticeable difference in hazard class breakdowns at the four inbound locations: only 38% were flammable, 21% were corrosives, and nearly 16% were dangerous.

< Petroleum products accounted for 30% of all movements, and averaged 6,000 to 9,000 gallons per shipment. By number of shipments, paint was the most commonly imported commodity, accounting for 14% of inbound commodities, ranging from 3,000 to 5,000 pounds per shipment. A large percentage of total movements were hazardous waste, but this was largely attributed to temporary cleanup activities at a nearby Superfund site.

< Of the traffic originating outside of Oregon, 83% originated in the border states: California, Nevada, Washington, and Idaho.

3.5 VIRGINIA

Multi Modal Hazardous Materials Transportation in Virginia describes two surveys, one conducted in 1977 and one in 1978, that were part of a series of six studies undertaken to identify the nature and volume of hazardous materials flows and the associated accident potential for certain transport modes in Virginia.

The 1977 highway study was based on data collected in July and August, from 8 a.m. to 5 p.m. at 38 locations throughout Virginia: ten weigh stations and 28 locations along the Federal-Aid Primary system. The 1978 study was conducted from April through December on days with two 12-hour shifts, beginning at 7 a.m. at nine weigh stations throughout the state. All trucks were surveyed by examining shipping papers and interviewing drivers. Survey staff for both studies were graduate assistants from the Virginia Polytechnic Institute and State University.

The surveys provided daily estimates of the total number of hazardous materials shipments and the total tonnage of hazardous materials shipped, along with their routing characteristics, for each section of each route on the primary and Interstate systems in Virginia.

The percentage of trucks transporting hazardous materials dropped from approximately 13% in 1977 to approximately 7% in 1978. However, the average load per truck nearly doubled during the same period.

The hazard class breakdowns changed very little between the two studies. In 1977, flammable and combustible liquids, and corrosives accounted for approximately 75% of all hazardous materials transported, of which approximately 64% were flammable and combustible liquids. In 1978, flammable and combustible liquids and corrosives still accounted for approximately 75% of the total, with approximately 62% representing flammable and combustible liquids. Both surveys showed heaviest hazardous materials traffic occurring on the Interstate system, particularly in and around urban areas, although during an average trip, most truck traffic in Virginia uses portions of both the Interstate and primary systems.

Time of day and seasonal variations in hazardous materials flows were determined for the 1978 survey only. Of all the truck traffic, 8% of the trucks carried hazardous materials during daylight hours and nearly 5% transported hazardous materials at night. The percentage of all trucks surveyed transporting hazardous materials was 10% during the spring, 6.2% during the summer, and 7.1% during the fall.

3.6 DALLAS CENTRAL BUSINESS DISTRICT

In 1978, the Dallas City Council amended the city codes to prohibit trucks transporting hazardous material from using depressed and elevated portions of Interstate Highways 30 and 45 near the Dallas Central Business District (CBD) and specified a set of arterial routes to bypass the restricted Interstate segments. As follow-up, Dallas conducted this study to analyze and compare the risks associated with hazardous materials shipments on the restricted highway routes to the designated arterial bypass routes. Concern over the potential for motorists to be trapped in depressed or elevated portions of the highway system during a hazardous materials emergency was a motivating factor for this study.

An initial inventory was conducted by assembling available information from Federal, state and local agencies, including the Dallas Fire, Emergency Preparedness, Streets and Sanitation, and Water Utility Departments, as well as the Texas Department of Water Resources, the U.S. DOT Materials Transportation Bureau (MTB), and the U.S. Environmental Protection Agency. Little of this information was useful due to the regulatory and reporting framework within which it was collected, therefore, Dallas decided to conduct its own data collection activities.

> 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
> Regional Information Center
> P.O. Box 5888
> Arlington TX 76005-5888
> (817) 640-3300

Dallas used the FHWA Report *Guidelines for Applying Criteria to Designate Routes for Transporting Hazardous Materials* as a basic framework to design its study. Several enhancements were made to FHWA's risk assessment approach, including modifications to both the risk assessment algorithm and the information collection regarding the types and quantities of materials being transported.

Three data collection efforts were designed: an inventory of local industries, a visual count of hazard placarded vehicles, and the identification of bulk gasoline storage facilities in the Dallas-Fort Worth area. The inventory sought to identify the types of hazardous materials transported locally, the routes used, and the frequency and time of day for the shipments. An industry survey was sent to 1,400 Dallas and Dallas County industries and transporters that were selected based on SIC code and identified from several information sources, including federal, state, local, and private agencies.

Of the 1,400 industries surveyed, about 300 industries responded; only 100 of these provided detailed information. The majority of bulk shipments are gasoline or petroleum-related, and a number of other materials are regularly being shipped through the area. The data indicated that as many as 25 to 30 9,000-gallon shipments of gasoline travelled in proximity to the Dallas CBD each day.

The vehicle count was designed to complete the picture of local shipments and to establish an estimate of the frequency and types of hazardous materials transported in proximity to downtown Dallas. Six locations for the counts were established surrounding the CBD; all locations were on the freeway system, not on the arterial routes designated by the City Council. Four survey teams of two to three men conducted windshield counts over 10 four-hour periods, all of which occurred on weekdays over several weeks. Counts were completed for 20 hours of a 24-hour period. For about half of the survey time, all trucks passing the survey locations were counted in order to determine the percentage of total truck traffic that was hazardous.

The vehicle counts indicated that hazardous materials account for 5.2% of the total truck traffic, with most shipments occurring during the day. Seventy-four percent of the vehicles recorded were tank trucks; of those, over 70% were carrying gasoline. Most of these counts were consistent with national statistics.

After tallying the data, several sources of information (MTB data, NTSB accident reports, and a DOE report on the risk of transporting gasoline by truck) were reviewed to better understand the causes and results of hazardous materials accidents. These data indicated that a majority of accidents involved flammable liquids (e.g., gasoline), and also that most fatalities or injuries occurred simultaneously with the accident, and thus emergency response actions could have done little to alleviate the fatalities and injuries.

The survey data, the above information, and the fact that the arterial routes selected are more congested with more exposure to the public (e.g., closer to schools, stores, sidewalk traffic) led the Dallas City council to the conclusion that the arterial routes do not decrease the risk to the public, but might actually increase it. Accident probabilities were calculated taking into account potential for tank rupture (perhaps resulting from abrasion), speed, proximity of other motorists, and road geometries; these showed that the highways might actually be safer than the arterial routes. Based upon the data analysis, the city of Dallas has seriously questioned the use of arterial routes for the transportation of hazardous materials and would continue to reevaluate their routing plans. Also, safety, training, inspection, enforcement and other programs are being considered to reduce potential risks to motorists and the public.

3.7 COMPARING SURVEY EXPERIENCES

As described above, several states and at least one major metropolitan area conducted highway hazardous materials flow studies of varying complexity. However, all of these studies were designed to provide specific and reliable information that was previously unavailable or difficult to assemble for decision-making purposes. Because this objective was achieved to an acceptable degree, the survey procedures adopted, with emphasis on key elements of survey design, are discussed below.

All surveys reviewed, with the exception of those in Dallas-Ft. Worth, Nevada, and possibly Idaho, were conducted in ways that revealed important daily and seasonal fluctuations in hazardous materials flows. On average, those surveys spanned eight, but not necessarily consecutive, calendar months and at least two seasons. Oregon's survey (three days of continuous sampling during different seasons) was probably successful in establishing whether fluctuations in flows exist. But the selection of survey sites in Oregon may not be a good model for other states whose objectives encompass a broader (i.e., statewide) base of inquiry. Seven of the ten Oregon survey sites were within 100 miles of the Portland metropolitan area, primarily because flows into and out of Portland were the study's primary focus. It would not therefore be appropriate to term Oregon's survey a statewide effort. Similarly, results of the Dallas/Ft. Worth survey should neither be applied statewide nor necessarily considered representative of other major metropolitan areas in Texas.

Data from the Virginia survey were more comprehensive than Oregon's and likely to include late-week and weekend activity that Oregon would have missed. However, the Oregon interviewers may have observed more about individual trucks and shipments because of their relevant professional experience and because of the selective truck inspections conducted.

Exhibit 14 summarizes the results of five of these hazardous truck traffic studies with respect to the surveyed distribution of hazardous commodities by type and compares these results to the distribution of highway hazardous materials transportation accidents by hazardous materials type in each state for:

< The two-year period 1989-90 based on data reported to DOT/RSPA Hazardous Material Information Reporting System (HMIS); and

< The two-year period 1987-88 from the DOT/OMC 50-T Master File of Accidents of Motor Carriers of Property.

The exhibit shows that considerable insight can be gained from these databases prior to planning and conducting a flow study. Even though the HMIS and OMC 50-T data are compiled from transportation accidents, rather than flows, distribution of incidents in some cases closely parallels the revealed survey share of commodity flow within both state of occurrence and hazardous materials class.

EXHIBIT 14
COMPARISON OF FINDINGS OF FIVE TRUCK TRAFFIC SURVEYS AND STATISTICS FROM PUBLIC USE FEDERAL DATA BASES

State/Hazardous Material	Hazardous Materials Movement as Percent of Total Truck Traffic (or Accidents) in:		Hazardous Materials Traffic (or Accident) Breakdown in Percent	
	State Survey	50-T	State Survey	HMIS
Colorado	**10.0**	**6.2**		
Flammable & Combustible Liquids			63	53
Flammable Gases			27	1
Nonflammable Gases			4	0.4
Corrosives			3	29
Oxidizers			1	3
Idaho	**4-6.0**	**4.5**		
(Results based on ten or more shipments by commodity type)				
Flammable & Combustible Liquids			29	59
Corrosives			10	13
Oxidizers			4	13
Other Regulated Materials, Class E			4	13
Nevada	**8.0**	**9.3**		
Flammable Liquids			59	36
Gases			7	2
Corrosives			22	31
Oxidizers & Organic Peroxides			2	4
Explosives			2	4
Poisonous & Etiologic Materials			1	3
Oregon	**5.5**	**3.4**		
Flammable & Combustible Liquids			54	39
Flammables Gases			4	2
Nonflammable Gases			6	2
Corrosives			16	31
Other Regulated Materials			9	12
Virginia (av. of 2 years)	**10.0**	**3.9**		
Flammable & Combustible Liquids			64	55
Flammable Gases			7	1
Nonflammable Gases			6	5
Corrosives			12	27
Oxidizers			1	2
Organic Peroxides			0.3	1
Explosives, Class B			1	1
Poisons, Class B			1	4
Radioactive Materials			1	1
Other Regulated Materials, Class A			0.5	4
Other Regulated Materials, Class C			2	1

CHAPTER 4
CASE STUDY EXAMPLE

To conclude this guidance, this chapter presents a hypothetical example of how a state designed and carried out a study and the conclusions they reached following the step-wise guidance presented in Chapter 2. The user of this guidance can also consult Chapter 3 for examples of studies that have actually been carried out.

4.1 IDENTIFY PURPOSE OF STUDY

State officials know that several counties lie along a well traveled highway corridor between a major benzene plant and a petroleum refinery complex at which large volumes of premium-grade gasoline are produced. They need to determine whether the quantity of benzene and other aromatic hydrocarbons shipped through the counties warrants new emergency response training for local fire and public safety agencies or whether a state emergency response team headquartered nearby has adequate response capability. To answer the above questions, a flow study is planned at survey locations on the two major highways serving the shipping corridor.

4.2 ASSEMBLE EXISTING INFORMATION

Prior to undertaking the actual survey, available data are examined for possible insights into the flow pattern as it exists. Count data from a Highway Performance Monitoring System (HPMS) surveillance point on the most-travelled (>13,500 vehicles/day) of the two highways indicates a heavy combination truck volume of 6.3 percent in spring and 6.7 percent in autumn, or between 850 and 900 large trucks per average weekday. Expanded to the entire corridor, this estimate could approach 1,600 trucks. The Hazardous Materials Information System (HMIS) data base for 1985-90 shows that four incidents involving hazardous materials releases occurred during truck hauls from the community containing benzene plant to the refinery complex site; all but one involved aromatic hydrocarbons. This statistic is generally consistent with records of the Office of Motor Carriers 50-T database (historically available, but now superseded by the Safety Net database, see page 8) for the same period, although one of the incidents included in the HMIS apparently did not meet the damage threshold for reporting to the DOT Office of Motor Carriers, and another did not involve an interstate-registered carrier. The 50-T indicates that 12 percent of interstate-registered heavy combination truck accidents reported in that corridor from 1985 through 1990 involved at least one vehicle carrying hazardous cargo. Assuming that accidents by cargo type are proportional to flows by cargo type, upwards of 200 trucks per day could be hauling hazmats through the corridor.

The State Highway Division follows up with each of the carriers involved in the HMIS incidents to a) verify shipment origin, destination, and location of incident, and b) confirm the nature and cause of the release. The carriers are also asked about how many hazardous shipments per year they handle between the benzene plant and the refineries; two of the three carriers provide complete shipment records for the relevant consignments that cover the year just preceding (the third carrier provides a rough estimate). Finally, the LEPC provides inventories of hazardous materials stored on site submitted to them by the refinery operators under SARA Title III. The quantity of aromatic hydrocarbons available at any one time at the refineries represents about 20 percent of the monthly production capacity of the benzene plant; thus, it is *possible* that the plant is supplying up to 100 percent of the refineries' collective benzene requirements.

4.3 DESIGN STUDY

Survey stations are established at four locations, one near each end of the two corridor routes. For two of the four locations, existing weigh station facilities are available. The other two are set up 1) adjacent to a freeway rest area and 2) by a large restaurant/service station facility catering primarily to truckers. Truck traffic is sampled for sixteen hours a day (6 a.m. to 12 a.m.) in two working shifts over two-week periods in early spring and mid-autumn.

4.4 CONDUCT STUDY

A total of 13,986 (non-duplicate) trucks are surveyed in the spring and 14,777 in the autumn; based on HPMS data, this is believed to represent better than a 60 percent (three-fifths) sample of all truck movements during each recording period. Survey data are processed such that they can be sorted, tabulated or summed on any variable. Results of this (hypothetical) survey are summarized in Exhibit 14.

4.5 ANALYZE RESULTS

Based on the count results only, the Highway Division can interpolate the values in Exhibit 15 to be 99% confident that the survey may have missed as many as 44 trucks carrying combustible liquids during the spring survey period, or over-represented the typical bi-weekly spring flow of such combustibles by as many as 38 trucks. Other confidence ranges by hazmat class are similarly computed.

Although the limited routing data collected from truckers clearly indicate a strong linkage between the benzene producer and the refinery complex, the total volumes of aromatics shipped are not especially high. However, important seasonal and time-of-week variations in the number of shipments are revealed by the survey. Larger quantities of benzene are shipped in the spring than in the fall, as the refineries gear up to produce enough gasoline to meet peak summertime demand. In the autumn, more distillate oil production for winter heating significantly reduces benzene shipments and quantities. Moreover, more benzene is shipped on Mondays, Tuesdays, and Fridays (apparently to accommodate refinery production schedules) than on Wednesdays, Thursdays, and weekends. About 30 percent of this movement is taking place during the nighttime hours.

An unexpected survey finding is that large volumes of highly corrosive metal-processing waste generated in a neighboring state are being shipped along the corridor for disposal in another state. The hazardous waste facility in that state to which the effluent had been sent for disposal for the past 20 years was now closed, creating the need to move the waste much greater distances for disposal.

4.6 APPLY RESULTS TO PURPOSE

On the basis of their analysis of the flow data, the state officials determine that additional preparedness training for an emergency involving aromatics is not needed at the local level. However, additional capabilities and procedures for off-hours notification of the state's hazmat team need to be installed in all local emergency response vehicles and departments in the corridor. The state officials also adjust their estimate of delay between the time of occurrence of a benzene transportation emergency and the hazmat team's arrival at the scene. Its former "worst case" (i.e., late night hours) is now a "probable case." In addition, they decide to increase inventories of chemical neutralizing agents, surfactants, and foams at fire departments throughout the affected counties.

EXHIBIT 15
RESULTS OF HYPOTHETICAL TRUCK TRAFFIC SURVEY

Daily weekday total traffic in corridor from HPMS and state surveillance counts:
SPRING--24,600 **AUTUMN--25,200**
(Extrapolated) share of traffic that is combination trucks:
SPRING--6.3% **AUTUMN--6.7%**
Share of heavy truck volume 6 a.m.-12 a.m.:
SPRING--89% **AUTUMN--84%**
Computed total heavy truck flow during survey period (weekend days = 1/2 weekday):

SPRING: (24,600)(.063)(12)/(0.89) = 20,896; 13,986/20,896 = 0.67
AUTUMN: (25,200)(.067)(12)/(0.84) = 24,120; 14,777/24,120 = 0.61

Truck Traffic

[redacted]		*in State Survey*		[redacted]	
		Spring	*Fall*	*Spring*	*Fall*
	Percent Hazardous Materials Movement	**20.3**	**16.2**		
Class or Division Number	**Description of Hazardous Material**	**Percent**		**Count of Hazmat Traffic Surveyed**	
3	Flammable and Combustible Liquid	60	55	1,704	1,317
2.1	Flammable Gas	14	6	397	144
	Aromatics	*11*	*4*	*312*	*96*
	Non-aromatics	*3*	*2*	*8*	*48*
2.2	Nonflammable Gas	3	5	85	120
8	Corrosive Material	19	24	539	575
5.1	Oxidizers	1	2	28	49
5.2	Organic Peroxide	0.2	1	6	23
1.3	Explosives (with predominately a fire hazard)	0.4	0.3	11	7
6.1	Poisonous Material	1.3	1.5	37	34
7	Radioactive Material	0.8	2.6	23	63
None	Other Regulated Materials-D	0.3	2.6	9	62
	TOTAL	100%	100%	2,839	2,394

APPENDIX A
DESCRIPTION AND OUTPUT OF A COMMODITY FLOW ALLOCATION MODEL
(SRI International, 1993)

A.1 DESCRIPTION OF THE COMMODITY FLOW ALLOCATION MODEL

A commodity flow allocation model was used by SRI International to assign hazardous chemical flows between producers and consumers. The model is a modified gravity model based on the premise that the shorter the distance between an origin-destination pair (e.g., a chemical production facility and a consumer of that chemical), the greater the likelihood of cargo flow between that pair. In this study, the following assumptions were used in the implementation of the gravity model:

- Available supply at each origin (e.g., production location) was set equal to the net production available for truck shipments.

- The total amount demanded at each destination was set equal to the estimated demand for truck delivery.

- The impedance relation was modified to reflect corporate affiliations (captive consumers) and possible use of terminal facilities.

- After discussions with chemical producers, it was discovered that some consuming plants, as a matter of policy, do not purchase from specified companies. For these cases, the flow between origin and destination was set to zero.

To estimate the highway distances between origins and destinations and highway routes used by trucking companies, an off-the-shelf software package called PCMiler is used. PCMiler identifies the minimum distance between two points for specified types of highway (e.g., interstates). ZIP codes were used to identify the locations of producing and consuming plants.

The unaltered gravity model has a tendency to attempt to assign at least a small increment of flow to all possible origin-destination pairs. In reality, such small commodity flows do not occur. The model, therefore, truncates all flows below a minimum threshold value and sets the cell value to zero. The minimum threshold was set equal to 20 tons per year (e.g., the approximate weight of one average-sized bulk truck load per year).

A.2 OVERVIEW OF CHEMICALS STUDIED

Using a generalized gravity flow model, SRI developed a list of 147 large-volume chemicals that account for at least 80% of U.S. truck shipments of hazardous chemicals. Exhibit A-1 lists these chemicals and their estimated production volumes, in decreasing order. Three chemicals were selected for detailed analysis using the model: 1-butanol, dodecene-1, and phosphorus pentasulfide. In the next subsections, brief overviews of the characteristics, uses, and geographical distribution of producers and consumers are presented.

A.2.1 1-Butanol

> DOT Emergency Response Guidebook (ERG). The ERG is not a regulatory guide, but is designed for the sole purpose of aiding emergency responders in the initial phases of an incident.

1-Butanol, which appears in the top one-third of the chemicals listed in Exhibit A-1, is a low-boiling liquid classified as a fire or explosion and health hazard (Guide No. 26 in the DOT Emergency Response Guidebook [ERG]). The chemical is principally used for the production of methacrylate esters, glycol ethers, and butyl acetate, as well as direct use as a solvent.

U.S. production of 1-butanol in 1987 is estimated at 575,000 short tons, of which 450,000 short tons was available for shipment to off-site consumers. All production is in the Texas-Louisiana region, while consumption of the chemical is concentrated in the Chicago, Illinois, New Jersey, and Los Angeles, California areas. There are six producers (five of which have terminals) and 67 major consuming plants.

1-Butanol is shipped by barge, rail, and truck. Most large volume shipments of 1-butanol are made by barge using inland and coastal waterways. Rail shipments are used for large volume movements that do not follow navigable waterways. Truck movements tend to be limited to short haul (i.e., from a terminal to the end-user) or small volume shipments in drums. Companies using 1-butanol as a solvent have it delivered by truck in mixed shipments using compartmented tankwagons or cargo tank trucks. Most tankwagon shipments originate from terminals located near major consuming centers. It is estimated that 83,200 short tons are delivered annually by truck.

A.2.2 Dodecene-1

Dodecene-1, with an estimated 1987 production of 200,000 short tons, is in the middle third of the list of 147 chemicals. It is a high-boiling liquid identified as propylene tetramer and is classified as a fire, explosion, and health hazard (Guide No. 27 in the DOT ERG). Consumption of dodecene-1 is primarily for the production of branched dodecylbenzene, tridecyl alcohol, and dodecylphenol.

Because dodecene-1 is used in the manufacture of other chemicals at its producing plants, the quantities used in captive production are not available for shipment elsewhere. Of the plants producing dodecene-1, four were identified as net producers that ship their product domestically, either directly from their plant or from terminals supplied by barge or other ocean-going vessels. Several additional production plants were eliminated from the analysis because contacts in the industry confirmed that no product was available for off-site shipment by highway.

Thirteen plants were identified as net consumers of the chemical, and of these only eight received shipments by truck. An estimated 15,100 tons are shipped by highway.

A.2.3 Phosphorus Pentasulfide

Phosphorus pentasulfide, with an estimated U.S. production of 70,000 short tons in 1987, is in the lower third of the list of chemicals given in Exhibit A-1. It is a high-melting solid that may ignite in the presence of moisture and produce poisonous gas, as identified in DOT ERG Guide No. 41. Phosphorus pentasulfide is used primarily for production of pesticides and lubricating oil additives. Production and consumption are widely distributed from the Northeast to the Southeast.

Four plants produce phosphorus pentasulfide, and thirteen plants are identified as net consumers of phosphorus pentasulfide. Most consuming plants are located in the Mid-Atlantic and Southern states, and the producing plants are in Illinois, Kansas, Pennsylvania, and Tennessee. One of the consuming plants receives shipments exclusively by rail, and the remaining twelve have an estimated demand of 52,500 tons.

EXHIBIT A-1
LIST OF 147 LARGE VOLUME CHEMICALS

Chemical	Production Volume, 1987 (thousands of Short Tons)	Chemical	Production Volume, 1987 (thousands of Short Tons)
Sulfuric Acid	39,235	Acrylic Acid	550
Propane	26,896	Hexamethylenediamine	543
Nitrogen	24,515	Isobutylene	518
Oxygen	16,669	Hydrogen Cyanide	516
Ammonia	16,100	Methyl Methacrylate	514
Calcium Oxide	15,733	Phthalic Anhydride	508
Sodium Hydroxide	11,486	O-Xylene	470
Chlorine Gas	11,019	Methylene-Diphenylene Diisocyanate	467
Phosphoric Acid	10,685		
Sulfur	10,321	Cyclohexanone	465
Carbon Dioxide	8,307	Barite	448
Ethylene Dichloride	7,878	Aniline	430
Ammonium Nitrate	7,612	Hexane	426
Nitric Acid (100% HNO_3 Basis)	7,225	Phosgene	421
Benzene	5,904	Linear Alkylate Sulfonate	399
Ethylbenzene	4,630	Hydrogen	389
Vinyl Chloride	4,201	Carbon Tetrachloride	374
Styrene	4,007	Acetaldehyde	363
Methanol	3,769	Toluene Diisocyanate	357
Toluene	3,223	Methylchloroform	347
Ethylene Oxide	2,921	Phosphorus	344
Hydrochloric Acid (100%)	2,869	Methyl Ethyl Ketone	336
P-Xylene	2,578	Sodium Chlorate	289
Methyl-T-Butyl Ether	1,757	Tripropylene (Nonene)	275
Phenol	1,676	Hydrofluoric Acid	274
Acetic Acid, Synthetic	1,623	Methyl Chloride	261
1,3-Butadiene	1,465	Methylene Dichloride	259
Ethanol (Synthetic)	1,434	N-Butyl Acrylate	258
Aluminum Sulfate	1,426	Potassium Hydroxide	246
Carbon Black (Furnace Black)	1,362	Perchloroethylene	237
Vinyl Acetate	1,253	1-Butene	231
Acrylonitrile	1,250	Calcium Carbide	230
Formaldehyde	1,232	Sulfur Dioxide	229
Cyclohexane	1,137	Epichlorohydrin	225
Propylene Oxide	1,105	Chloroform	224
Acetone	1,048	Propylene Tetramer (Dodecene)	200
Butyraldehyde	879	Maleic Anhydride	193
Acetic Anhydride	858	Dichlorodifluoromethane (F12)	184
Adipic Acid	795	Acetylene	182
Isopropanol	685	Carbon Disulfide	180
Nitrobenzene	625	Ethylene Glycol Monobutyl Ether	175
1-Butanol	575	Bromine	168
Argon	560	Ethyle Acrylate	162

EXHIBIT A-1
LIST OF 147 LARGE VOLUME CHEMICALS
(Continued)

Chemical	Production Volume, 1987 (thousands of Short Tons)	Chemical	Production Volume, 1987 (thousands of Short Tons)
Hydrogen Peroxide	153	Isoprene	54
Chlorodifluoromethane (F22)	142	Zinc Sulfate	54
N-Pentane	142	Ethylene Glycol Monoethyl Ether	53
Propionaldehyde	140		
Ferric Chloride	137	P-Dichlorobenzene	52
Nonylphenol	137	Dicyclopentadiene	50
Sodium Chromate/Dichromate	128	Hydrofluosilicic Acid	50
Chlorobenzene	123	Benzoic Acid	48
Naphthalene	121	Isobutyl Acetate	44
Monoethanolamine	116	Atrazine	43
Activated Carbon	109	Ethylene Glycol Monoethyl Ether Acetate	42
Ethyl Acetate	107		
Phosphorus Trichloride	102	Ethylenediamine Tetraacetic Acid	41
N-Butyl Acetate	101	Furfural	40
Isobutyraldehyde	99	Sodium Hydrosulfide	40
Trichloroethylene	98	Ethylenediamine	39
N-Propanol	93	Dimethylamine	37
Barium Sulfide	92	Cupric Sulfate	36
N-Heptane	89	Ethylene Glycol Monomethyl Ether	36
Calcium Hypochlorite	88	N-Propyl Acetate	35
Sodium Cyanide	85	Aluminum Chloride	33
Isobutanol	83	Benzyl Chloride	33
Pinene	78	Phosphorus Oxychloride	31
Sodium Hydrosulfite	78	Ethylene Dibromide	30
Ethyl Chloride	77	Zinc Chloride	28
Tetrahydrofuran	77	Isopropyl Acetate	27
Methyl Isobutyl Ketone	76	Isopropylamine, Mono	27
Chloronitrobenzene	73	Methylamine	26
Sodium (Metal)	72	Sodium Phosphate, Tribasic	26
Phosphorus Pentasulfide	70	Amyl Alcohol	25
Hexene-1	61		
Propionic Acid	59	**Total for 147 Chemicals**	**288,792**
Acrylamide	56		
Chlorinated Isocyanurates	55		

A.3 PRESENTATION OF RESULTS

For each of the chemicals studied, a map of the United States presenting the results of the commodity flow allocation model is attached (see Exhibit A-2, A-3, and A-4). These results are preliminary only and may differ significantly from the final results, which will be presented in subsequent reports on each of the three chemicals. GisPlus Map software, developed by the Caliper Corporation of Newton, Massachusetts, was used to prepare the maps. Two kinds of input data are used to produce the maps: point (node) and line (flow) files. The point data file provides the ZIP code location and descriptors for each of the producing and consuming plants. The link file provides the estimated flow (tonnage) of chemicals moving from each producing plant to each consuming plant.

GisPlus has an auxiliary database that contains descriptors of each of the nation's roads and highways. The descriptors include such items as local, state, or Federal control; paved or unpaved; all year or seasonal operating conditions; and height or weight restrictions. The maps produced assume that hazardous chemicals are not moved on certain types of roads, including restricted, unpaved, or seasonal roads. The GisPlus program tends to select larger, interstate routes, and avoid smaller, winding roads. In addition to the national maps presented in the exhibits, the software is capable of producing maps for individual states, counties, or other specified regions.

A.3.1 1-Butanol

Approximately 30,243 ton-miles of 1-butanol shipments are estimated (see Exhibit A-2). Because a combination of rail and truck shipment is generally less expensive than truck shipments alone, only about 12% of truck movements are estimated to originate at producing plants. Of the total ton-miles travelled, over 40% are accounted for in states where consumption from off-site sources is concentrated, such as California, Illinois, Michigan, and North Carolina. States in which production occurs (Texas and Louisiana) have little if any off-site consumption but capture about 20% of highway miles because of direct deliveries to other states. Only a few states with neither production or consumption facilities are shown to have any truck shipments. These states include Indiana, Arizona, and New Mexico.

A.3.2 Dodecene-1

Of the estimated 11,616 ton-miles of dodecene-1 moved by truck in 1987, nearly 20% occurred in Texas, a major consuming and producing state (see Exhibit A-3). About 14% of ton-miles occurred in Pennsylvania, a state that has neither production nor major consumption facilities. An additional 10% of total ton-miles occurred in Ohio, which has a production facility and a consuming plant that receives 15% of the estimated truck shipments of the chemical. Other states with neither production nor consumption facilities that have relatively large percentages of ton-miles include Alabama, Louisiana, Mississippi, Oklahoma, Tennessee, and Virginia. Because the volume of production and consumption of dodecene-1 is relatively small, terminal facilities have not generally been established to offset the cost of truck movements.

A.3.3 Phosphorus Pentasulfide

Because of the dispersed nature of production and consumption, and the heavy reliance on truck transport, there were an estimated 27,472 ton-miles of phosphorus pentasulfide moved by truck in 1987 (see Exhibit A-4). Nearly a quarter of the ton-miles are in Pennsylvania, a state with a production plant. Other states with about 10% to 15% of ton-miles are Ohio, Illinois, Indiana, Missouri, and Mississippi. Most of these states have either a production or consumption facility.

EXHIBIT A-2

1-BUTANOL FLOWS BY HIGHWAY

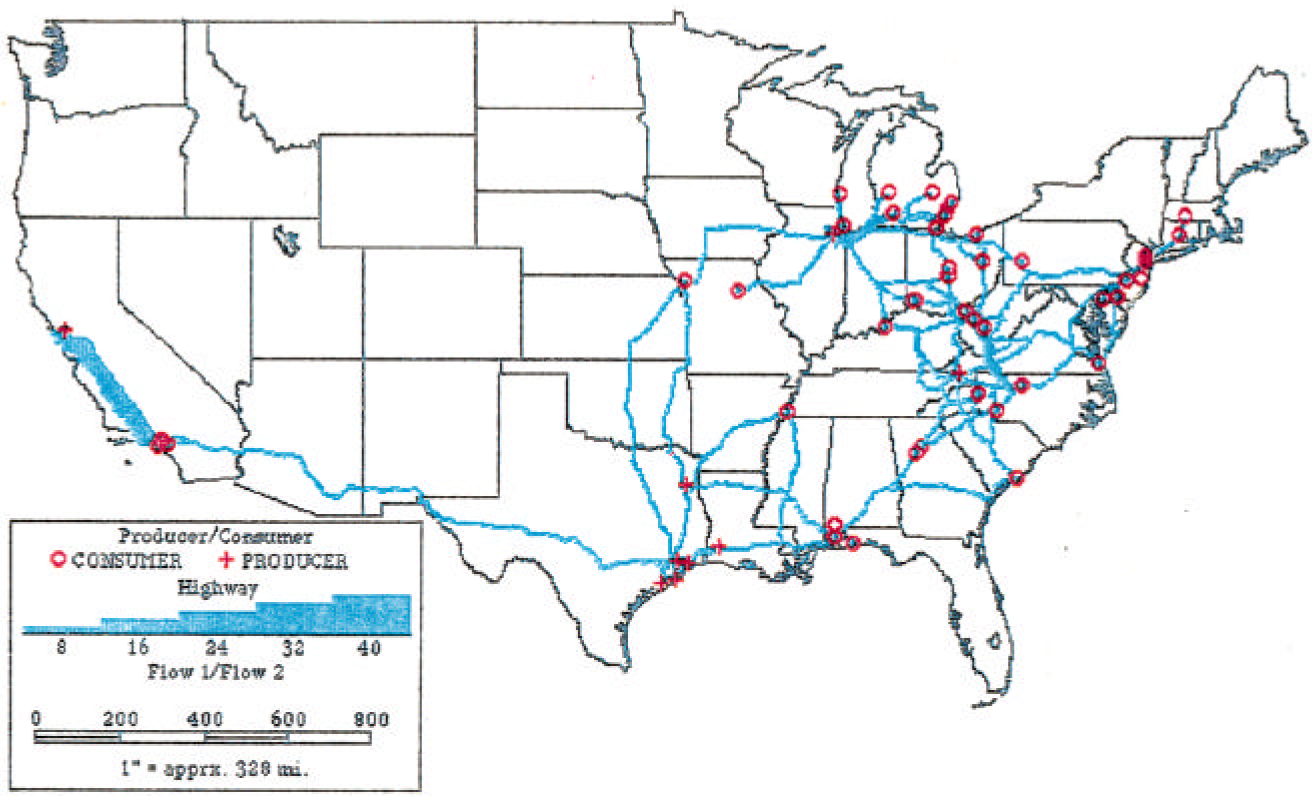


EXHIBIT A-3

DODECENE-1 FLOWS BY HIGHWAY

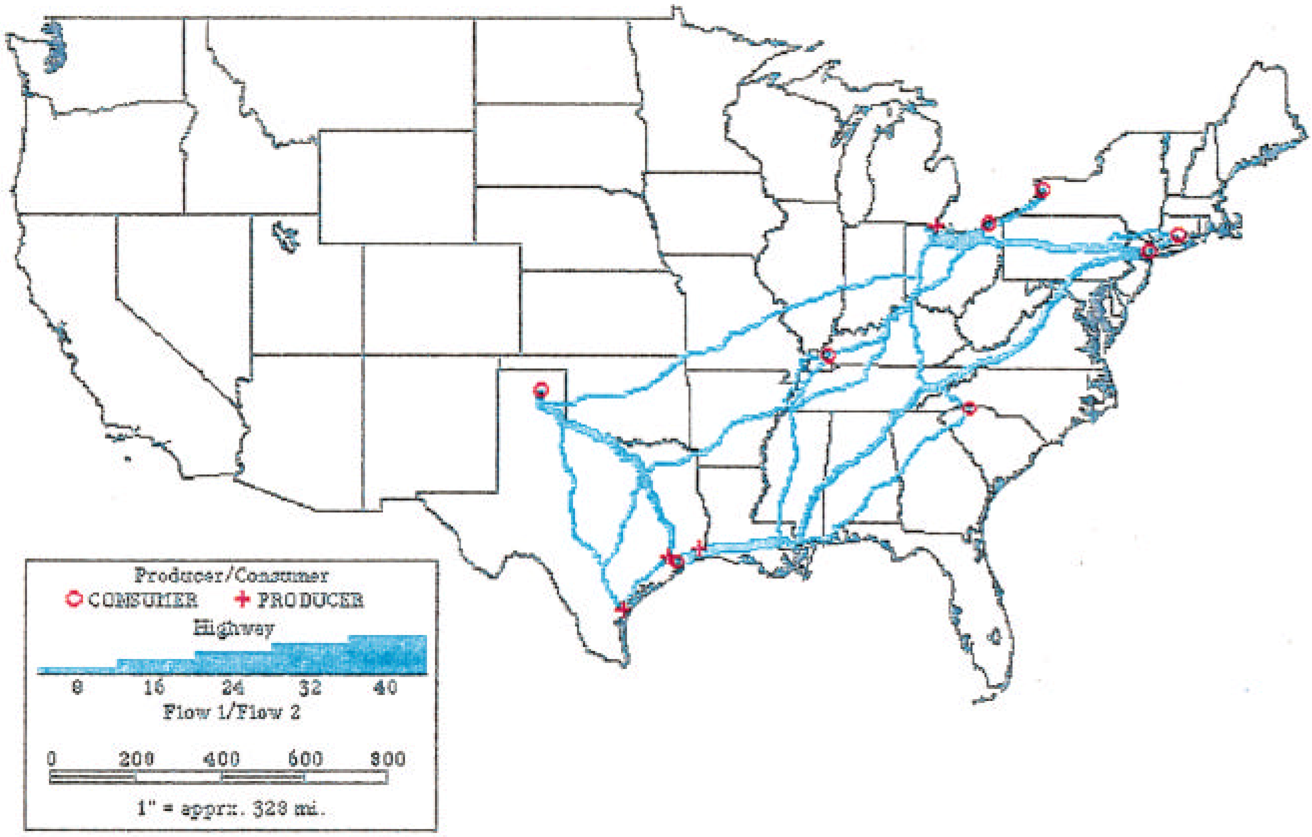
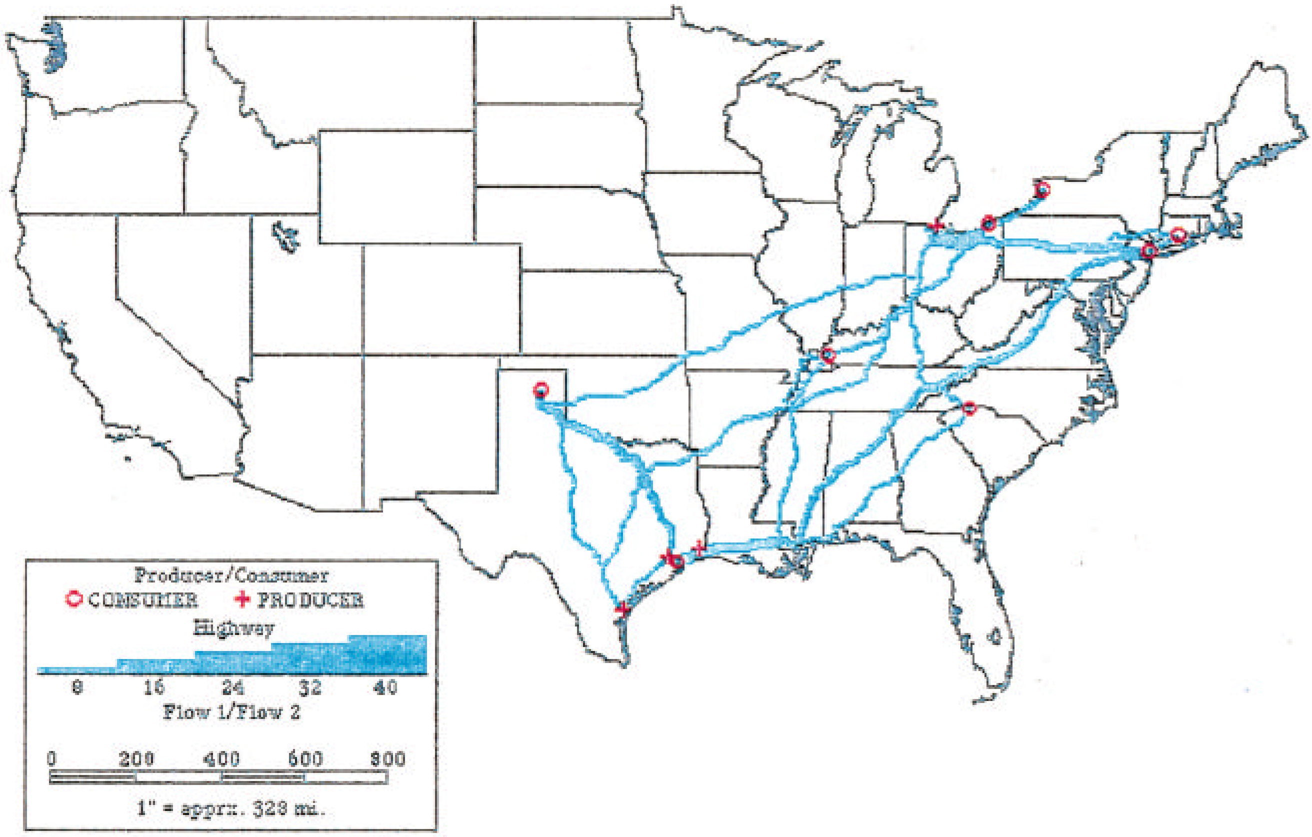


EXHIBIT A-3

DODECENE-1 FLOWS BY HIGHWAY



REFERENCES

Guidelines for Applying Criteria to Designate Routes for Transporting Hazardous Materials, Report Number: DOT/RSPA/OHMT-89-02, Washington, D.C., July 1989.

Guidelines for Selecting Preferred Highway Routes for Highway Route Controlled Quantity Shipments of Radioactive Materials, Report Number: DOT/RSPA/HMS/92-02, Washington, D.C., August 1992.

Kessler, Dan, Hazardous Materials Routing Study Phase II: Analysis of Hazardous Materials Truck Routes in Proximity to the Dallas Central Business District, No. Central Texas Council of Governments, Arlington, TX, October 1985.

Hildebrand, L.K. and Edward J. Barber, Implementation Package: Guidelines for Applying Criteria to Designate Routes for Transporting Hazardous Materials, Report Number FHWA-IP-80-15, Washington, D.C., 1980.

Urbanek, Gary L. and Edward J. Barber, Development of Criteria to Designate Routes for Transporting Hazardous Materials, Report Number FHWA-RD-80-105, Washington, D.C., 1980.

Risk Assessment/Vulnerability Users Manual for Small Communities and Rural Areas, Report Number: DOT/RSPA/DPB-50/81/29, Washington, D.C., October 1981.

Conference on Recent Advances in Hazardous Materials Transportation Research: An International Exchange, Preprint Volume, Transportation Research Board, National Research Council, Washington, D.C., November 1985.

Hazardous Material Transportation Monitoring and Capability Study: Agency Resource Capability, Boise State University, September 1988. Prepared for Idaho Department of Law Enforcement, and Idaho State Police.

Hazardous Material Transportation Monitoring and Capability Study for the Purpose of Assessing Risk to the Public, Boise State University, January 1988. Prepared for Idaho Department of Law Enforcement, and Idaho State Police.

Present Practices of Highway Transportation of Hazardous Materials, Task B Final Report, Literature Review, Report Number: USDOT/FHWA-RD-89-013, McLean, Virginia, January 1987. Prepared by Midwest Research Institute.

Starry, Claire, Kirtland E. McCaleb, and William A. Stock, Study of Truck Transportation of Hazardous Chemicals, SRI International, Menlo Park, California.

Transportation of Hazardous Materials, Report Number: OTA-SET-304, U.S. Congress, Office of Technology Assessment, Washington, D.C., July 1986.

Transportation of Hazardous Materials: Toward a National Strategy, Vols. 1 and 2, Special Report 197, Transportation Research Board, National Academy of Sciences, National Research Council, Washington, D.C., 1983.

Hazardous Material Movements on Oregon Highways, Flow Study, The Public Utility Commission of Oregon and the Oregon Department of Transportation, 1987.

Nevada Department of Transportation, Planning Research Division, Commodity Report Including Hazardous Material Movement, Carson City, Nevada, January 1993.

Transportation of Hazardous Materials Summary, Report Number: OTA-SET-305, Office of Technology Assessment, Washington, D.C., July 1986.

Transportation of Hazardous Materials, Report Number: OTA-SET-304, U.S. Congress, Office of Technology Assessment, Washington, D.C., July 1986.

1986 Route Segment Report: A Report on the Operation and Performance of the State Highways, Vol. 1--selected segments, and Vol.2--route segment listing, California State Highway System, 1986.

A Community Model for Handling Hazardous Material Transportation Emergencies, Report Number: DOT/RSPA/DPB/50/81/30, Washington, D.C., October 1981.

Guidelines for Emergency Response to Hazardous Materials Transportation Accidents, USDOT/RSPA/Materials Transportation Bureau, Washington, D.C., July 1980.

Lessons Learned: A Report on the Lessons Learned from State and Local Experiences in Accident Prevention and Response Planning for Hazardous Materials Transportation, Prepared for USDOT, and USEPA, December 1985.

San Francisco Bay Area Hazardous Spill Prevention and Response Plan, Vol.2: Risk Assessment, USDOT/RSPA, December 1982. Prepared by Association of Bay Area Governments.