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# Truck Transport of Hazardous Chemicals: Isopropanol

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The transport of hazardous materials by all modes is a major concern of the U.S. Department of Transportation. Estimates place the total amount of hazardous materials transported in the United States in excess of 1.5 billion tons per year. Highway, water, and rail account for nearly all hazardous materials shipments; air shipments are negligible. Fuels, such as gasoline and diesel, account for about half of all hazardous materials transported. Chemicals account for most of the remainder.

The principal purpose of this report is to present estimates of truck shipments of isopropanol, one of 147 large-volume chemicals that account for at least 80 percent of U.S. truck shipments of hazardous chemicals.

All of the reports in this series are based on the best available information at the time the research was conducted. The U.S. chemical industry, however, operates in an environment in which markets, production processes, and distribution requirements can change substantially from year to year. The information in this report on (a) chemical producers and their plant locations, (b) consuming plants and their locations, and (c) the estimated traffic flow from producers to consumers, is thus subject to change.

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## PREFACE

The transport of hazardous materials by all modes is a major concern of the U.S. Department of Transportation (U.S. DOT). Estimates place the total amount of hazardous materials transported in the United States in excess of 1.5 billion tons per year.[1] Highways, water, and rail account for nearly all hazardous materials shipments; air shipments are negligible. Fuels, such as gasoline and diesel, account for about half of all hazardous materials transported. Chemicals account for most of the remainder.

Because of the intermixture of freight and passenger vehicles on the Nation's roads and highways, and because hazardous materials are frequently transported through residential and commercial areas, incidents involving truck movements of hazardous materials may pose a risk to the general population. The U.S. DOT has extensive data on highway incidents involving particular hazardous materials, but does not have comparable volume data with which to establish failure rates (i.e., the percentage of shipment involved in incidents). Moreover, little is known about the routes over which particular hazardous materials are transported. Consequently, Federal and state authorities lack critical information they need to formulate hazardous materials policies and programs regarding enforcement of regulations, training for dealing with hazardous materials incidents, etc.

This document is one of a series of reports being prepared on the bulk shipments of large-volume manufactured or processed non-fuel substances that together account for at least 80 percent of U.S. truck shipments of hazardous chemicals. It was sponsored by the Office of Hazardous Materials Planning and Analysis, Research and Special Programs Administration (RSPA), U.S. DOT. The report was prepared by the Environmental Engineering Division, Volpe National Transportation Systems Center, U.S. DOT, with contract support from TDS Economics, Menlo Park, California.

It should be emphasized that all of the reports in this series are based on the best available information at the time the research was conducted. The U.S. chemical industry, however, operates in a dynamic economic and technological environment in which markets, production processes, and distribution requirements can change substantially from year to year. The information in this report on (a) chemical producers and their plant locations, (b) consuming plants and their locations, and (c) the estimated traffic flows from producers to consumers is thus subject to change.

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[1] Office of Technology Assessment, Congress of the United States, *Transportation of Hazardous Materials*, 1986; Research and Special Programs Administration, U.S. Department of Transportation, *Truck Transportation of Hazardous Materials, A National Overview*, 1987.

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# 1. INTRODUCTION

The principal purpose of this report is to present estimates of bulk shipments by truck of isopropanol, one of the 147 large-volume chemicals that account for at least 80 percent of U.S. truck shipments of non-fuel hazardous chemicals. Appendix A contains a complete list of the 147 chemicals.

The following sections of this report describe the physical characteristics of isopropanol, its uses, and its domestic producers and consumers. Because there is so little direct evidence on the specific routes over which isopropanol is shipped, and in what quantities, the routes and flows are estimated by the use of models. Two widely used models of interregional commodity flows have been used: a gravity model and a linear programming model, each generating its own set of results. Both sets of results show the quantities of isopropanol flowing from and to individual states.

Unfortunately, there are insufficient data on actual flows of isopropanol to test the estimation results for accuracy. Both sets of results, however, are compared for consistency with Research and Special Programs Administration (RSPA) data on incidents involving bulk truck shipments of isopropanol.

# 2. CHARACTERISTICS OF ISOPROPANOL

Isopropanol is a flammable, low-boiling liquid. It is poisonous if swallowed, and its vapors can irritate the eyes, nose, and throat. The *1996 North American Emergency Response Guidebook* recommends that emergency responders use its Guide No. 129 (UN 1219) in the case of a spill involving isopropanol. Additional information about isopropanol is given in Table 1.

# 3. USES OF ISOPROPANOL

Solvent applications account for much U.S. consumption of isopropanol. Other significant uses are in the manufacture of chemical intermediates, in household and personal products, for the synthesis of acetone, and in the manufacture of pharmaceuticals.

# 4. PRODUCTION

Total U.S. production capacity for isopropanol in 1992 was estimated to be 943 thousand short tons, of which 937 thousand short tons were available for shipment to offsite consumers. Isopropanol is produced in four plants located in two states. Three plants in Texas account for about two-thirds of isopropanol production. The remaining production occurs at a plant located in Louisiana.

**TABLE 1. ADDITIONAL INFORMATION ON ISOPROPANOL**

| | |
|---|---|
| Common Synonyms | Isopropyl alcohol<br>Dimethylcarbinol<br>IPA<br>Rubbing alcohol<br>2-Propanol<br>sec-Propyl alcohol |
| Formula | $(CH_3)_2CH\ OH$ |
| UN Number | 1219 |
| DOT Hazard Class | 3 (Flammable and Combustible Liquid) |
| CAS Number | 67-63-0 |
| Description | Watery, flammable liquid<br>Colorless<br>Alcohol odor |

Sources: *CHRIS Manual, Vol. 1, A Condensed Guide to Chemical Hazards*, 1992; National Tank Truck Carriers, Inc., *Hazardous Commodity Handbook*, Tenth Edition, 1994; and Gale Research, Inc., *Hazardous Substances Resource Guide*, 1993.

Isopropanol is used in the manufacture of other chemicals at some of its producing plants. The quantities of isopropanol used for this purpose are not available for shipment elsewhere. Production for intraplant use is termed "captive production." To calculate captive production, downstream chemicals produced within the same plant as isopropanol are identified and the amount of isopropanol needed in their production is estimated. The difference between total capacity and captive production defines the amount available for offsite shipments. It is the potential amount of production available for offsite consumption that is of interest to this study. Table 2 shows net production capacity available for offsite consumption, by producing plant, in 1992.

Producers may ship isopropanol to plants at other locations owned by the same parent company. These shipments are termed "captive shipments." The one producer believed to make captive shipments is identified in Table 2.

## TABLE 2. MAJOR PRODUCERS OF ISOPROPANOL, 1992

| Company | Plant Location | Offsite Availability† (Thousands of Short Tons) | Captive Shipments‡ |
|---|---|---|---|
| Exxon | Baton Rouge, LA | 325.0 | No |
| Lyondell | Channelview, TX | 33.0 | No |
| Shell | Deer Park, TX | 300.0 | No |
| Union Carbide | Texas City, TX | 279.0 | Yes |
| **Total Offsite Availability** | | 937.0 | |

† Offsite availability is the amount of the product available for shipment after intraplant consumption is accounted for.

‡ Captive shipments are shipments of the chemical from a producing plant to a consuming plant owned by the same company. Companies with captive shipments are ones with corporate affiliations to net consumers listed in Table 3.

Sources: Based on information from industry sources.

## 5. CONSUMPTION

Sixty-five manufacturing plants that receive bulk shipments of isopropanol have been identified. None of these plants produces isopropanol. Consumption estimates for the 65 plants are given in Table 3. The derivative chemical products that are produced using propanol at each of the consuming plants are also identified in Table 3.[2]

The consuming plants in Table 3 are located in 25 states. Most of these states have only one or two plants. States with more than two plants are Alabama, California, Georgia, Illinois, Michigan, New Jersey, Ohio, and Texas. Of these, Ohio has the most consuming plants (10), followed by California (with 8 plants) and Michigan (with 7 plants). The five plants in Illinois, it might be noted, consume significantly more isopropanol than the listed plants in any of the other states.

In addition to the plants listed in Table 3, there are hundreds of other small-volume consumers of isopropanol in the U.S. These consumers often use isopropanol as a solvent in various industrial applications. Because these consumers generally receive the product in less-than-truckload (LTL) shipments, and not in bulk shipments, they are not covered in this report.

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[2] The production and consumption estimates given in Tables 2 and 3 were developed from publicly available data and telephone interviews with representatives of producer and consumer firms. Implied shipments based on these estimates were found to be consistent with origin and destination data contained in the 1992 ICC Waybill Sample (rail cargoes) and the Army Corps of Engineers Waterborne Commerce reports (barge or ship cargoes).

## TABLE 3. MAJOR CONSUMERS OF ISOPROPANOL, 1992

| Company | Plant Location | Estimated Net Product Requirements (Thousands of Short Tons) | Derivatives† |
|---|---|---|---|
| **Companies Receiving Shipments by Truck** | | | |
| Advanced Chem. Tech. | Anaheim, CA | 0.2 | SOLV |
| AKZO | Columbus, OH | 3.2 | SCS |
| Alpha Metals | Alpharetta, GA | 0.2 | SOLV |
| BASF | Spartanburg, SC | 0.2 | SOLV |
| BASF | Anaheim, CA | 2.8 | SCS |
| BASF | Detroit, MI | 2.8 | SCS |
| BASF | Greenville, OH | 2.8 | SCS |
| Bay Chem Supply | Kennesaw, GA | 0.2 | SOLV |
| Caschem | Bayonne, NJ | 0.7 | FAE |
| Dalden | Southlake, TX | 0.2 | SOLV |
| DuPont | Mt. Clemens, MI | 0.9 | SCS |
| DuPont | Flint, MI | 1.4 | SCS |
| DuPont | Fort Madison, IA | 1.4 | SCS |
| DuPont | Front Royal, VA | 1.4 | SCS |
| DuPont | Parlin, NJ | 1.4 | SCS |
| DuPont | Toledo, OH | 1.4 | SCS |
| Eastman | Kingsport, TN | 5.0 | IPAC |
| Elf Atochem | Riverview, MI | 4.6 | IPAM, DIPAM |
| Essex Group | Columbia City, IN | 0.2 | SOLV |
| Exxon | Casper, WY | 0.2 | SOLV |
| Grow Group | Cleveland, OH | 1.3 | SCS |
| Grow Group | Louisville, KY | 1.4 | SCS |
| Guardsman | Little Rock, AR | 0.8 | SCS |
| Guardsman | Grand Rapids, MI | 0.8 | SCS |
| Guardsman | South Gate, CA | 0.8 | SCS |
| Guardsman | High Point, NC | 0.8 | SCS |
| Hitchiner Mfg. | O'Fallon, MO | 0.2 | SOLV |
| Hoechst | Bishop, TX | 5.0 | IPAC |
| Holloway Tool | Dover, OH | 0.2 | SOLV |
| ICI | Cold Creek, AL | 0.3 | BEN |
| ICI‡ | Huron, OH | 2.8 | SCS |
| ICI‡ | San Francisco, CA | 2.8 | SCS |
| Inolex | Philadelphia, PA | 0.7 | FAE |
| James River | Newnan, GA | 0.2 | SOLV |
| Lilly Ind. Coatings | Dallas, TX | 1.6 | SCS |

TABLE 3. MAJOR CONSUMERS OF ISOPROPANOL, 1992 (CONTINUED)

| Company | Plant Location | Estimated Net Product Requirements (Thousands of Short Tons) | Derivatives† |
|---|---|---|---|
| Lilly Ind. Coatings | Dothan, AL | 1.6 | SCS |
| Nalco | Cudahy, CA | 0.2 | SOLV |
| No. Hand Protection | Charleston, SC | 0.2 | SOLV |
| Platte Chemical | Greeley, CO | 0.2 | SOLV |
| PPG | Circleville, OH | 2.1 | SCS |
| PPG | Delaware, OH | 2.1 | SCS |
| PPG | Oak Creek, WI | 2.1 | SCS |
| PPG | Torrance, CA | 2.1 | SCS |
| Pyroil | Hernando, MS | 0.2 | SOLV |
| Richard-Allan | Kalamazoo, MI | 0.2 | SOLV |
| Scher | Clifton, NJ | 0.2 | DIEST |
| Sherwin-Williams | Richmond, KY | 0.5 | SOLV |
| Sherwin-Williams | Baltimore, MD | 4.7 | SCS |
| Sherwin-Williams | Bedford Heights, OH | 4.7 | SCS |
| Sherwin-Williams | Chicago, IL | 4.7 | SCS |
| Tenneco | Cartersville, GA | 0.2 | SOLV |
| Unichema | Chicago, IL | 0.7 | FAE |
| Union Camp | Dover, OH | 0.9 | DIEST, FAE |
| Union Carbide | Institute, WV | 7.6 | ACET, MIBK, MISC |
| Valspar | Rochester, PA | 1.6 | SCS |
| Valspar | Baltimore, MD | 1.6 | SCS |
| Whittaker | Gardena, CA | 0.2 | SOLV |
| Whittaker | Los Angeles, CA | 0.2 | SCS |
| **Total Truck Shipments** | | 81.9 | |
| **Companies Receiving Rail, Barge, or Ship Shipments** | | | |
| Air Products | St. Gabriel, LA | 21.6 | IPAM, DIPAM |
| AKZO | Morris, IL | 13.1 | SOLV |
| AKZO | McCook, IL | 22.2 | SOLV |
| Enenco | Memphis, TN | 19.3 | SOLV |
| Hoechst | Bucks, AL | 9.3 | IPAM, DIPAM |
| Sherex | Mapleton, IL | 10.2 | SOLV |
| Sherex | Janesville, WI | 10.9 | SOLV |
| Union Carbide | Institute, WV | 71.6 | ACET, MIBK, MIBC |

## TABLE 3. MAJOR CONSUMERS OF ISOPROPANOL, 1992 (CONTINUED)

| Company | Plant Location | Estimated Net Product Requirements (Thousands of Short Tons) | Derivatives† |
|---|---|---|---|
| **Total Rail, Barge, and Ship Shipments** | | 178.2 | |
| **Total, All Modes** | | 260.1 | |

† Derivatives listed in the glossary below are chemicals that use isopropanol in their manufacture.

ACET=Acetone
BEN=Bensulfide herbicide
DIEST=Diesters
DIPAM=Diisopropylamine
FAE=Fatty acid esters
IPAC=Isopropyl acetate
IPAM=Isopropylamine
MIBC=Methyl isobutyl carbinol
MIBK=Methyl isobutyl ketone
SCS=Surface coatings solvent
SOLV=Solvent use

‡ ICI is now Zeneca

Sources: Based on information from industry sources and the U.S. Department of Transportation's HMIS Database.

## 6. INTERNATIONAL TRADE

U.S. imports of isopropanol in 1992 totaled 43 thousand short tons, 82 percent of which came from Canada. U.S. exports of the chemical reached 196 thousand short tons, or 20 percent of production. Three countries, Mexico, Korea, and Belgium, accounted for nearly half of U.S. exports. International shipments are not included in this study, but data obtained from various sources indicate that rail and ocean transport are the primary modes for international movements.

## 7. DISTRIBUTION AND TRANSPORT

Isopropanol is shipped from producing plants to consumers by rail, water, or truck. The largest consuming plants generally receive isopropanol by rail or water. Trucks are used sometimes to transport smaller bulk shipments to consumers.

Of the 65 consuming plants in Table 3, 58 are likely to receive truck shipments of isopropanol.[3] The volume of isopropanol received annually by each of these plants averages about 1,540 short tons, or about a tank truck delivery once or twice a week. Seven plants in Table 3 are likely to receive shipments via rail or water. On average, these 7 plants receive over 28 thousand short tons of isopropanol per year.

Producers deliver isopropanol directly to the largest consuming plants using rail or water. Direct truck transport is used sometimes for smaller shipments. In addition to direct delivery, producers also use company-owned and public terminals to facilitate their distribution of isopropanol. Table 4 lists public and private terminals known to be used by isopropanol producers. There are, however, numerous other public terminals available. Examples of these additional public terminals are given in Table 5, which shows the marine terminals of GATX Terminals Corporation, the largest marine terminal operator.

Terminals on navigable waterways receive bulk shipments primarily by barge and ship, but rail shipments can be made if waterborne commerce is interrupted for some reason. Other terminals receive bulk and, in some cases, car-load or truck-load drum shipments of isopropanol by rail or truck. Shipments to consumers from both types of terminals are typically made by truck or rail. The use of terminals helps to minimize road transport, with the consequence that truck movements from distribution points to final consumers are generally short distance.

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[3] In the absence of specific information on modal selection from producers or consumers, the following rules are used:

| Estimated Annual Consumption | Mode |
|---|---|
| 150 short tons | Less than truck load |
| 150 to 1,000 short tons | Truck loads (drums) or tank trucks |
| 1,000 short tons | Rail or barge |

Note that consumers may actually use more than one mode; for example, they may generally use rail but rely on truck deliveries if supplies run low.

Producers market some isopropanol to smaller consumers through distributors that maintain bulk storage, drumming, and drum storage facilities throughout the country. Typically, producers ship bulk quantities of isopropanol to distributors by rail or barge. The distributors may make some truck deliveries in bulk quantities from their facilities to consumers (including delivery of more than one chemical using tank trucks with two or more separate tanks). These shipments, however, tend to be limited, because producers prefer to serve large customers directly. The principal business of distributors is the drumming of chemicals received from the producer and the shipment of LTL quantities of drums to customers. Table 6 lists some major distributors of isopropanol and their terminals.

**TABLE 4. TERMINALS USED BY ISOPROPANOL PRODUCERS**

| Producing Company | Terminal Location |
|---|---|
| Exxon | Santa Fe Springs, CA |
| | Carteret, NJ† |
| | Houston, TX† |
| | Channahon, IL† |
| | Fairburn, GA† |
| | Richmond, CA† |
| Shell | Argo, IL† |
| | Atlanta, GA† |
| | Richmond, CA† |
| | Sewaren, NJ† |
| Union Carbide | Carteret, NJ† |
| | Forest View, IL† |
| | South Carleston, WV† |
| | Torrance, CA† |

†Identified as being the possible origin of bulk shipments of isopropanol by truck to consumers.

Note: Public terminals are available to all producers on an as-needed basis. Use may change from year to year.

Sources: Industry contacts and literature.

**TABLE 5. PUBLIC MARINE TERMINALS OF GATX TERMINALS CORPORATION**

| East Coast Terminals | West Coast Terminals | Other Terminals |
|---|---|---|
| Carteret, NJ | Carson, CA † | Argo, IL |
| Paulsboro, NJ | Portland, OR | Galena Park, TX |
| Philadelphia, PA | Richmond, CA | Norco, LA † |
| Staten Island, NY | San Pedro, CA | Pasedena, TX |
| | Seattle, WA | Tampa, FL |
| | Vancouver, WA | |
| | Wilmington, CA | |

†Identified as being the possible origin of bulk shipments of isopropanol by truck to consumers. Some of the other terminals in this list may be among those identified in Table 4 as being possible origins of bulk shipments by truck.

Source: GATX literature.

## TABLE 6. TERMINALS USED BY ISOPROPANOL DISTRIBUTORS

| Distributor | Terminal Location |
|---|---|
| Ashland Chemical | About 50 locations having bulk storage tanks, including: |
| | Argo, IL |
| | Columbus, OH |
| | Dallas, TX |
| | Doraville, GA † |
| | Engelwood/Sheridan, CO† |
| | Newark, CA |
| | St. Louis, MO † |
| | Santa Fe Springs, CA |
| | Willow Springs, IL |
| Chemcentral | 32 locations having bulk storage facilities, including: |
| | Forest View, IL |
| | Louisville, KY |
| Great Western | Portland, OR |
| | Richmond, CA |
| | Torrance, CA |
| Univar Corp., Van Waters & Rogers Subsidiary | 106 locations, many of which have bulk storage facilities, including: |
| | Knoxville, TN |
| | Portland, OR |
| | San Jose, CA |

†Identified as being the possible origin of bulk shipments of isopropanol by truck to consumers.

Sources: Industry contacts and literature.

## 8. THE USE OF MODELS TO ESTIMATE TRUCK FLOWS

The major producers of isopropanol and their plant locations are identified in Table 2, along with the amount of the chemical each has available to consumers. Table 3 lists consuming companies, their plant locations, and the estimated amounts of isopropanol each received by truck delivery in 1992. The terminals used in the distribution of isopropanol are listed in Tables 4 and 6, and additional terminals available for use in that distribution are listed in Table 5. This section explains how the information in these tables is used to identify the routes over which bulk shipments of isopropanol are transported from producers to users and in what quantities.

Because there is so little readily available direct evidence on the flows of isopropanol over the Nation's highways, those flows must be estimated. For this report, that task was accomplished through the use of two widely used models of interregional commodity flows: a gravity model and a linear programming model. Using data presented previously, both models allocate truck flows from the producing plants and terminals to consuming plants. The basic features of these models are described in Appendix B.[4]

Both models have been adjusted to take into account some real-world features of the distribution of hazardous chemicals:

- Some shipments are made to captive consumers; that is, to consuming plants owned by the same parent company that owns the producing plant.

- A producer may serve a consumer with shipments from either a production facility or a terminal.

- Regulations mandate the use of two drivers for trips over 230 miles in length, which adds to the per mile cost of trucking.

There appears to be no consensus as to which model provides the more accurate estimates of routes used for truck shipments of hazardous chemicals. The gravity model approach, however, is clearly more inclusive in identifying routes over which commodities are transported by truck. For this reason, its results are presented in the main body of this report. The results of the linear programming model are presented in Appendix C.

[4] A more detailed, technical explanation of the models is found in "Alternative Modeling Approaches for Allocating Truck Flows of Hazardous Chemicals," a draft report prepared for RSPA's Office of Hazardous Materials Safety by RSPA/Volpe Center and TDS Economics, July 1994.

## 9. GRAVITY MODEL ESTIMATION RESULTS

The gravity model results for bulk truck shipments of isopropanol are shown in Table 7. As can be seen in the table, an estimated 18 million ton-miles of isopropanol moved by truck in 1992. About 17 percent of those ton-miles occurred in Indiana, a state with a large consumer volume of isopropanol. Another 16 percent occurred in Ohio and 12 percent occurred in Michigan, also states with a large volume of isopropanol consumers. Texas, with the fourth largest number of ton-miles, and is a state with producers, consumers, and terminals. Together, these top four states account for over half of the ton-miles estimated by the gravity model.

Bulk truck shipments of isopropanol are estimated to move through 31 states. Twenty of those states have producers, large volume consumers, or terminals handling isopropanol. The ton-miles for the 20 states range from 2,786 thousand in Ohio to 6 thousand in Missouri. Most of the states have less than 400 thousand ton-miles of isopropanol traffic, and half have less than 300 thousand ton-miles of traffic.

Isopropanol traffic in 11 states is entirely pass-through. Each of those 11 states, however, has one or more neighboring states in which there are producers, consumers, or terminals. The states with the most pass-through traffic are Tennessee, which has 905 thousand ton-miles, and Maryland, which has 387 thousand ton-miles. All other pass-through states have less than 110 thousand tons-miles of isopropanol traffic.

The estimation results indicate that the average length of haul for shipments of isopropanol is about 218 miles. The extensive use of terminals helps to keep truck movements short haul. Without terminals, average trip length would be considerably higher. The Chemical Manufacturers Association also finds that the average length of haul for truck shipments of chemicals is about 200 miles.[5] The use of terminals is important not only because they lower total transportation costs, but also because of increased consumer demand for flexibility and quick delivery associated with just-in-time (JIT) inventory management.

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[5] Chemical Manufacturers Association, *U.S. Chemical Industry Statistical Handbook*, 1993.

## TABLE 7. GRAVITY MODEL ESTIMATES OF BULK-TRUCK SHIPMENTS OF ISOPROPANOL, BY STATE, 1992

| State | Producer, Terminal, or Consumer | Ton-Miles (Thousands) | Truck-Miles† (Thousands) |
|---|---|---|---|
| Alabama | Consumer | 238 | 12 |
| Arkansas | Consumer | 134 | 7 |
| California | Consumer, Terminal | 359 | 18 |
| Colorado | Consumer | 34 | 2 |
| Delaware | | 106 | 5 |
| Florida | | 39 | 2 |
| Georgia | Consumer, Terminal | 788 | 39 |
| Illinois | Consumer, Terminal | 1,428 | 71 |
| Indiana | Consumer | 2,997 | 150 |
| Iowa | | 100 | 5 |
| Kansas | | 40 | 2 |
| Kentucky | Consumer | 253 | 13 |
| Louisiana | Producer | 211 | 11 |
| Maryland | | 387 | 19 |
| Michigan | Consumer | 2,169 | 108 |
| Mississippi | Consumer | 155 | 8 |
| Missouri | Consumer | 6 | 0 |
| Nebraska | | 101 | 5 |
| New Jersey | Consumer, Terminal | 782 | 39 |
| New York | | 5 | 0 |
| North Carolina | Consumer | 91 | 5 |
| Ohio | Consumer | 2,786 | 139 |
| Oklahoma | | 25 | 1 |
| Pennsylvania | Consumer | 381 | 19 |
| South Carolina | Consumer | 113 | 6 |
| Tennessee | | 905 | 45 |
| Texas | Producer, Consumer, Terminal | 1,818 | 91 |
| Virginia | | 263 | 13 |
| West Virginia | Terminal | 1,055 | 53 |
| Wisconsin | | 59 | 3 |
| Wyoming | Consumer | 45 | 2 |
| Total | | 17,872 | 894 |

† Truck-miles are calculated by dividing the number of ton miles by 20 short tons, or the average size of a tank truck load.

## 10. COMPARISON OF MODEL RESULTS WITH INCIDENTS DATA

Table 8 shows estimates of the expected annual number of highway truck accidents involving isopropanol in 1992. These estimates, calculated using 1992 truck-miles (see Table 7) and an RSPA estimate that one highway accident occurs about every million truck-miles, are shown in the "Estimated Accidents" column of the table. Using an RSPA estimate that about 15 percent of highway accidents result in a release or spill, the "Estimated Year/Spill" column shows the expected number of years between spills for each state.

The estimates in Table 8 indicate that, in 1992, the states with the highest risk of both truck accidents and spills were Indiana, Ohio, Michigan, Texas, and Illinois. These states, of course, also rank highest in ton-miles and truck-miles of isopropanol. For the nation as a whole, the expected annual number of truck accidents involving vehicles carrying isopropanol was 0.89, and the expected number of years between spills was 7.

Data from the U.S. DOT's hazardous materials incident database were examined to determine if the gravity model results were consistent with the actual incident experience for the years 1985 through 1993. As Table 9 shows, there were 32 isopropanol highway bulk-shipment incidents reported during the nine-year period.[6] Of these, two involved chemical wastes, which are not covered by this study.[7] Another involved imported product from a shipper located in Canada. Imports moving into the U.S. by truck are also not covered by this study. Of the remaining 29 incidents, seven involved highway accidents. Thus, there is a highway accident about every one to two years. This number differs considerably from the estimate of one incident every seven years given in Table 9. This difference may be due to underestimation of the number of ton-miles of isopropanol moving on the Nation's highways resulting from a difficulty in identifying all industrial solvent users.

Of the highway accidents that occurred, one was in Connecticut, a state that was not identified by gravity model as having isopropanol truck flows (neither was it identified by linear programming as having flows). The destination point for this incident was an unknown plant in Massachusetts. The incident occurred in the 1980's. No likely consuming locations were identified in Massachusetts at the time this report was written. Due to its use as a solvent, and the substitutability of isopropanol with other chemicals for this use, industrial users of isopropanol may vary from year to year.

The remaining highway accidents were spread across six states: Georgia, Nebraska, New Jersey, North Carolina, Ohio, and Pennsylvania. All of these states are shown by the gravity model to have bulk truck flows of isopropanol.

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[6] The data provided in Table 9 represent reported isopropanol incidents involving shipment sizes of 3,500 gallons or greater for the nine-year period from 1985 through 1993.

[7] Chemical wastes are used chemicals that are shipped back to a producer or to a special facility for recycling or other uses. Chemical wastes are not contained in the hazardous chemicals category, but rather in the hazardous wastes category.

### TABLE 8. ESTIMATED NUMBER OF TRUCK ACCIDENTS INVOLVING ISOPROPANOL, BY STATE, 1992

| State | Estimated Accidents‡ | Estimated Years/Spill‡ | State | Estimated Accidents‡ | Estimated Years/Spill‡ |
|---|---|---|---|---|---|
| Alabama | 0.01 | 560 | Missouri | 0.00 | 22,222 |
| Arkansas | 0.01 | 995 | Nebraska | 0.01 | 1,320 |
| California | 0.02 | 371 | New Jersey | 0.04 | 171 |
| Colorado | 0.00 | 3,922 | New York | 0.00 | 26,667 |
| Delaware | 0.01 | 1,258 | North Carolina | 0.00 | 1,465 |
| Florida | 0.00 | 3,419 | Ohio | 0.14 | 48 |
| Georgia | 0.04 | 169 | Oklahoma | 0.00 | 5,333 |
| Illinois | 0.07 | 93 | Pennsylvania | 0.02 | 350 |
| Indiana | 0.15 | 44 | South Carolina | 0.01 | 1,180 |
| Iowa | 0.01 | 1,333 | Tennessee | 0.05 | 147 |
| Kansas | 0.00 | 3,333 | Texas | 0.09 | 73 |
| Kentucky | 0.01 | 527 | Virginia | 0.01 | 507 |
| Louisiana | 0.01 | 632 | West Virginia | 0.05 | 126 |
| Maryland | 0.02 | 345 | Wisconsin | 0.00 | 2,260 |
| Michigan | 0.11 | 61 | Wyoming | 0.00 | 2,963 |
| Mississippi | 0.01 | 860 | Total | 0.89 | 7 |

‡ The number of accidents per year is calculated at one accident per one million truck miles; about 15 percent of these accidents results in a release or spill. These rules of thumb were suggested by RSPA's Office of Hazardous Materials Safety.

In addition to the 7 highway accidents, the 29 highway incidents included 13 incidents caused by human error and 9 caused by packaging failure. All of these incidents occurred in states that were identified by the model as having flows. Most of the incidents caused by human error occurred at origin or destination points. Incidents resulting from highway accidents tend to have the largest releases, generally well over 100 gallons, while incidents resulting from packaging failure or human error tend to have releases well under 100 gallons.

Shipment information included in the U.S. DOT's incidents database substantiates the finding that truck shipments tend to be short distance movements. Most of the origin-destination pairs identified in the database are in the same state or in adjacent states. About five or six of the incidents involved routes that passed through several states, and some of those involved truckload shipments of drums, rather than tank trucks carrying bulk liquids.

## TABLE 9. DATA ON ISOPROPANOL BULK-SHIPMENT INCIDENTS, 1985 TO 1993

| Incident State | Origin State | Destination State | Release Quantity (gallons) | Cause† | Capacity (gallons) | Shipper Type |
|---|---|---|---|---|---|---|
| AL | TX | OH | 5 | 20 | 55 | Unknown |
| CA | CA | CA | 15 | 10 | 7,791 | Terminal |
| CA | CA | CA | 1 | 20 | 5,000 | Distributor |
| CA | CA | CA | 20 | 20 | 6,706 | Terminal |
| CA | CA | CA | 30 | 10 | 6,500 | Terminal |
| CA | CA | CA | 30 | 10 | 7,500 | Terminal |
| CO | CO | CO | 5 | 10 | 8,500 | Distributor |
| CT | NJ | MA | 800 | 30 | 7,500 | Terminal |
| GA | GA | GA | 5 | 20 | 7,600 | Terminal |
| GA | GA | GA | 20 | 10 | 7,600 | Distributor |
| GA | GA | GA | 25 | 10 | 7,500 | Distributor |
| GA | GA | GA | 30 | 10 | 5,200 | Distributor |
| GA | WV | GA | 3,170 | 30 | 5,000 | Terminal |
| IL | IL | IL | 5 | 10 | 4,937 | Terminal |
| IL | IL | IL | 155 | 10 | 9,500 | Distributor |
| IN | IL | IN | 4 | 20 | 5,725 | Terminal |
| KY | PA | KY | 15 | 20 | 4,614 | Waste* |
| MI | IL | MI | 10 | 10 | 7,500 | Terminal |
| MO | MO | MO | 10 | 10 | 7,000 | Distributor |
| MO | TX | IL | 55 | 20 | 55 | Distributor |
| MS | TX | MS | 0 | 10 | 7,600 | Plant |
| NC | NJ | SC | 60 | 30 | 7,000 | Terminal |
| NE | TX | WY | 110 | 30 | 55 | Terminal |
| NJ | NJ | RI | 800 | 30 | 7,500 | Terminal |
| OH | IL | Unknown | 125 | 30 | 7,000 | Terminal |
| PA | NJ | PA | 6,000 | 30 | 7,800 | Terminal |
| SC | NC | SC | 10 | 10 | 6,500 | Distributor |
| TN | TN | LA | 150 | 10 | 6,700 | Waste* |
| TX | TX | NC | 4 | 20 | 6,500 | Distributor |
| TX | TX | TX | 1 | 20 | 7,200 | Plant |
| TX | TX | TX | 10 | 10 | 7,730 | Plant |
| WY | ZZ | TX | 10 | 20 | 55 | Import* |

† Causes: 10=human failure; 20=packaging failure; 30=a highway accident; 40=other causes.
*Waste and import shipments are not included in this study.

Source: U.S. Department of Transportation

# APPENDIX A. LIST OF 147 LARGE-VOLUME CHEMICALS

| Chemical | 1994 Production (Thousands of Short Tons) | Chemical | 1994 Production (Thousands of Short Tons) |
|---|---|---|---|
| Acetaldehyde | 174 | Chloroform | 565 |
| Acetic Acid, Synthetic | 1,992 | Chloronitrobenzene | 65 |
| Acetic Anhydride | na | Copper Sulfate | 53 |
| Acetone | 1,331 | Cyclohexane | 982 |
| Acetylene | >140 | Cyclohexanone | 552 |
| Acrylamide | 58 | p-Dichlorobenzene | 39 |
| Acrylic Acid | 575 | Dichlorodifluoromethane (F12) | 63 |
| Acrylonitrile | 1,491 | Dicyclopentadiene | na |
| Activated Carbon | 158 | Dimethylamine | na |
| Adipic Acid | 900 | Epichlorohydrin | 253 |
| Aluminum Chloride | na | Ethanol (Synthetic) | 324 |
| Aluminum Sulfate (w/17% $Al_2O_3$) | 1,316 | Ethyl Acetate | 163 |
| Ammonia | 17,256 | Ethyl Acrylate | 182 |
| Ammonium Nitrate | 8,517 | Ethylbenzene | 5,378 |
| Amyl Alcohol | 23 | Ethyl Chloride | na |
| Aniline | 632 | Ethylenediamine | 45 |
| Argon | 800 | Ethylenediamine Tetraacetic Acid | 6 |
| Atrazine | na | Ethylene Dibromide | 13 |
| Barite | 643 | Ethylene Dichloride | 8,380 |
| Barium Sulfide | na | Ethylene Glycol Monobutyl Ether | 195 |
| Benzene | >7,110 | Ethylene Glycol Monoethyl Ether | 29 |
| Benzoic Acid | 60 | Ethylene Glycol Monoethyl Ether Acetate | 23 |
| Benzyl Chloride | na | Ethylene Glycol Monomethyl Ether | 20 |
| Bromine | 215 | Ethylene Oxide | 2,928 |
| 1,3-Butadiene | 1,689 | Ferric Chloride (100%) | 225 |
| 1-Butanol | 739 | Formaldehyde (37%) | 4,082 |
| Butene-1 | 483 | Furfural | 43 |
| n-Butyl Acetate | 155 | n-Heptane | 60 |
| n-Butyl Acrylate | 412 | Hexamethylenediamine | 626 |
| Butyraldehyde | 1,097 | Hexane | 170 |
| Calcium Carbide | 244 | Hexene-1 | na |
| Calcium Hypochlorite | 92 | Hydrochloric Acid (100%) | 3,734 |
| Calcium Oxide | >16,314 | Hydrofluoric Acid | 200 |
| Carbon Black | 1,625 | Hydrofluosilicic Acid | 55 |
| Carbon Dioxide | 12,547 | Hydrogen | 862 |
| Carbon Disulfide | na | Hydrogen Cyanide | 514 |
| Carbon Tetrachloride | 124 | Hydrogen Peroxide | 318 |
| Chlorinated Isocyanurates | 68 | Isobutanol | 70 |
| Chlorine Gas | 12,187 | Isobutyl Acetate | 42 |
| Chlorobenzene, Mono | 109 | Isobutylene | 1,539 |
| Chlorodifluoromethane (F22) | 153 | | |

## APPENDIX A. LIST OF 147 LARGE-VOLUME CHEMICALS (Continued)

| Chemical | 1994 Production (Thousands of Short Tons) | Chemical | 1994 Production (Thousands of Short Tons) |
|---|---|---|---|
| Isobutyraldehyde | 264 | Pinene | na |
| Isoprene | 310 | Potassium Hydroxide (100%) | 27 |
| Isopropanol | 726 | Propane | 31,492 |
| Isopropyl Acetate | 28 | n-Propanol | 625 |
| Isopropylamine, Mono | na | Propionaldehyde | 182 |
| Linear Alkylate Sulfonate | 305 | Propionic Acid | 94 |
| Maleic Anhydride | 239 | n-Propyl Acetate | 44 |
| Methanol | 5,387 | Propylene Oxide | 1,850 |
| Methylamine | na | Propylene Tetramer (Dodecene) | 155 |
| Methyl t-Butyl Ether | 5,515 | Sodium (Metal) | na |
| Methyl Chloride | 500 | Sodium Chlorate (100%) | 559 |
| Methylchloroform | 335 | Sodium Chromate/Dichromate | 132 |
| Methylene Dichloride | na | Sodium Cyanide | 142 |
| Methylene Diphenlyene Diisocyanate | 535 | Sodium Hydrosulfide | 117 |
| Methyl Ethyl Ketone | 600 | Sodium Hydrosulfite | 90 |
| Methyl Isobutyl Ketone | 70 | Sodium Hydroxide | 12,555 |
| Methyl Methacrylate | 659 | Sodium Phosphate, Tribasic | 22 |
| Monoethanolamine | 198 | Styrene | 5,455 |
| Naphthalene | 101 | Sulfur | 12,677 |
| Nitric Acid (100% $HNO_3$ Basis) | 8,611 | Sulfur Dioxide | 229 |
| Nitrobenzene | 720 | Sulfuric Acid | 44,813 |
| Nitrogen | 31,515 | Tetrahydrofuran | 126 |
| Nonylphenol | na | Toluene | >2,895 |
| Oxygen | 25,045 | Toluene Diisocyanate | 419 |
| n-Pentane | na | Trichloroethylene | na |
| Perchloroethylene | 123 | Tripropylene (Nonene) | 328 |
| Phenol | 2,065 | Vinyl Acetate | 1,518 |
| Phosgene | na | Vinyl Chloride | 6,924 |
| Phosphoric Acid ($P_2O_5$ Basis) | 12,792 | o-Xylene | 457 |
| Phosphorus | 255 | p-Xylene | 3,114 |
| Phosphorus Oxychloride | 36 | Zinc Chloride | <10 |
| Phosphorus Pentasulfide | 61 | Zinc Sulfate | 43 |
| Phosphorus Trichloride | 158 | | |
| Phthalic Anhydride | 480 | **Total** | >349,004 |

Notes:

(1) The Acetylene production numbers include production for chemical use only.
(2) The Calcium Oxide, Benzene, and Toluene production numbers do not include production from all sources;
(3) The Zinc Chloride production number includes the zinc content of zinc ammonium chloride.

# APPENDIX A. LIST OF 147 LARGE-VOLUME CHEMICALS (Concluded)

Sources:

(1) List of Chemicals: C. Starry, K. McCaleb, and W. Stock, "Study of Truck Transportation of Hazardous Chemicals," Prepared by SRI International for the U.S. Department of Transportation, 1993.
(2) 1994 Production Numbers: U.S. International Trade Commission, *Synthetic Organic Chemicals, United States Production and Sales, 1994*, USTIC Publication 2933, June 1995; U.S. Geological Survey, *Minerals Yearbook, 1994*; *Chemical & Engineering News*, June 24, 1996, pp. 41-43; U.S. DOE/EIA, *Petroleum Supply Annual, 1995*, Vol. 1; other industry sources; and Volpe estimates based on industry source projections of chemical production or consumption, or on the relationships between the quantities of selected inputs and the quantities of finished chemical product outputs.

## APPENDIX B. MODELING TRUCK FLOWS

Models are used to allocate truck flows from the various producing plants and terminals to consuming plants that receive shipments by truck. The models are designed to estimate most likely origin-destination pairs based on a variety of considerations, as described below:

- The shorter the distance between an origin-destination pair, the greater the likely cargo flow between them.
- The larger the production or consumption of the chemical at the origin or destination, the greater the cargo flow.
- Corporate affiliations are sufficiently strong that if a producing and a consuming plant are both owned by the same company, the effective distance between them can be shortened to one-third the actual distance.
- Minimum shipment volumes of approximately 10 short tons per year are set for any given origin-destination pair. This amount is approximately equal to 3,500 gallons, the minimum requirement for inclusion in the U.S. DOT's Hazardous Materials Registration Program.
- Available supply at each origin is set equal to the net production available for offsite truck shipments.
- The total amount supplied to each destination is set equal to its estimated net product requirement specified for truck delivery.
- Due to regulations, two drivers are required for trips that are over 230 miles in length. An additional driver is estimated for this study to increase the cost per mile by 33 percent.[8,9]

The models start with a set of plants having available for offsite shipment, estimated quantities of the hazardous chemical under study. Those quantities are typically measured in thousands of short tons per year. There are also consuming plants receiving estimated quantities of the chemical. Terminals are included as possible routing opportunities for producers. Each origin-destination pair may be served directly from a producing plant or via a terminal.

The models estimate the quantities of chemicals, termed flows, moving from the producing

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8 Jack Faucett Associates, "The Effect of Size and Weight Limits on Truck Costs," Working Paper Prepared as Part of the Truck Size and Weight and User Fee Policy Analysis Study, U.S. Department of Transportation, Federal Highway Administration, Revised October 1991.

9 Leon Witconis and Ken Stadden, "Cost Per Mile: A View From The Top," *Owner Operator*, September/October 1988.

plants to the consuming plants. The flows can be arrayed in a two-dimensional table, such as the one shown below in Table B-1.

**TABLE B-1. PRODUCTION/CONSUMPTION FLOW MATRIX**

| Consumers<br>Producers | Consumer 1 | Consumer 2 | Consumer 3 | Total Available for Offsite Shipments |
|---|---|---|---|---|
| Producer 1 | $F_{11}$ | $F_{12}$ | $F_{13}$ | Production 1 $\geq \Sigma_j F_{1j}$ |
| Producer 2 | $F_{21}$ | $F_{22}$ | $F_{23}$ | Production 2 $\geq \Sigma_j F_{2j}$ |
| Producer 3 | $F_{31}$ | $F_{32}$ | $F_{33}$ | Production 3 $\geq \Sigma_j F_{3j}$ |
| Producer 4 | $F_{41}$ | $F_{42}$ | $F_{43}$ | Production 4 $\geq \Sigma_j F_{4j}$ |
| Total Consumption Received by Truck | Consumption 1 $\Sigma_I F_{i1}$ | Consumption 2 $\Sigma_I F_{i2}$ | Consumption 3 $\Sigma_I F_{i3}$ | Total Shipped by Truck $\Sigma_{ij} F_{ij}$ |

The F's in the table are the flows to be estimated. For example, $F_{21}$ indicates the flow from producing plant 2 to consuming plant 1. Note that if the flows are summed vertically, they will equal the consumption totals listed across the bottom of the table. In general, however, the production totals will be less than or equal to the production quantities listed to their left in Table B-1, because production may be less than capacity and some of the production may be used internally, exported, or travel by a mode other than truck.

Based on previous research, two models are used to estimate truck flows by state.[10] These models are described below.

### Gravity Model

Gravity models provide a method for filling in Table B-1. They are widely applied and accepted models for freight allocation problems and have been shown to be reasonable predictors of freight movements.[11] They take their name from their mathematical formulation, which is analogous to Newton's Law of Universal Gravitation; otherwise they have nothing to do with gravity.

Unless they are programmed otherwise, gravity models assign the largest commodity flows to those origin-destination pairs that (a) are closest in distance, and (b) have the largest volumes of product available at the origin or demanded at the destination. Gravity models also provide a routing over the actual highway network for these flows. By their mathematical structure, they tend to assign flows in such a way that all of the $F_{ij}$'s are non-zero, although some may be quite small. Because, in reality, companies tend to buy in large quantities, such as truckloads, the model is modified to restrict the $F_{ij}$'s to be at least 10 short tons (approximately 3,500 gallons).[12] Other adjustments, such as giving preferences to flows between producers and consumers owned by the same parent company, are incorporated into the model.

### Linear Programming Model

Linear programming is the second model used for estimating the $F_{ij}$'s.[13] This particular application of linear programming models is part of the "Transportation Problem" in which the model minimizes ton-miles, truck-miles, or some other measure of transportation cost. The same input variables used in the gravity model are required for the linear programming model: information on production available for offsite consumption, demand for truck shipments by consumer, and estimated miles between each producer and consumer.

The linear programming model starts with an objective function, typically to minimize ton-miles or truck-miles traveled:

$$\text{Min } \Sigma_{ij} F_{ij}.$$

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[10] "Alternative Modeling Approaches for Allocating Truck Flows of Hazardous Chemicals," a draft report prepared for RSPA's Office of Hazardous Materials Safety by the RSPA/Volpe Center and TDS Economics, July 1994.

[11] Overgaard, K. Rask, "Traffic Estimating and Planning," *Acta Polytechnica Scandinavica*, Civil Engineering and Building Construction Series No. 37, 1966.

[12] For the purposes of this report, the minimum quantity carried in a truckload shipment of isopropanol is assumed to be 10 short tons.

[13] Kwak, N, *Mathematical Programming with Business Applications*, New York: McGraw-Hill, Inc., 1973.

Due to the mathematical nature of linear programming models, flows are assigned to only a few $F_{ij}$'s; many of the $F_{ij}$'s are zero. The same constraints used by gravity models on the flows—for example, adjustments to favor flows between producers and consumers owned by the same company—are incorporated into the model to reflect the realities of the transportation decision-making process.

Linear programming ideally suited for the decision process of a single company that is interested in minimizing its transportation costs. It may be less applicable to modeling the decisions of multiple companies that are not all working together to minimize total industry-wide transportation costs.

**Model Comparison**

The two model types, gravity and linear programming, provide alternative methods for analyzing truck flows. The first tends to assign flows to most possible origin-destination pairs, while the other assigns flows to only a few pairs. The results of the two approaches show the range of possible outcomes, which are subject to many factors beyond simple mathematical modeling, such as fuel prices, corporate alliances, and the desire of purchasing companies to have multiple sources of supply.

# APPENDIX C. LINEAR PROGRAMMING ESTIMATION RESULTS

This appendix reports the linear programming estimates of bulk highway shipments of isopropanol and compares them with the estimates of the gravity model presented in the main body of the text. The linear programming results are shown in Table C-1.

The linear programming model estimates 16 million ton-miles of bulk truck movements of isopropanol in 1992. The four states with the greatest numbers of ton-miles are, in descending order, Ohio, Michigan, West Virginia, and Texas. Together, these top four states account for slightly more than 50 percent of the estimated ton-miles. In all, the linear programming model results indicate that 28 states will have bulk highway isopropanol shipments. Movements in eight of these are purely pass-through--that is, the eight states have no producers, no bulk consumers, and no terminals. All eight states have neighbors in which producers, bulk consumers, or terminals are located, however. Tennessee is the only pass-through state with more than 1 million ton-miles of isopropanol; all of the other states, with the exception of Maryland, have less than 110 thousand ton-miles of isopropanol.

The average length of haul for bulk truck shipments is estimated to be about 196 miles by the linear programming model. This is quite close to the 200 miles estimated by the Chemical Manufacturers Association for the average length of haul for truck shipments of chemicals.

Table C-2 presents the estimated numbers of accidents and the estimated years per spill for the linear programming results. The expected annual number of truck accidents for the nation as a whole was 0.80, which was slightly less than the estimate derived from the gravity model results. The expected number of years between spills was eight.

## Comparison of Linear Programming with the Gravity Model Results

The ton-miles estimated by the linear programming model ton-miles are about 10 percent less than those estimated by the gravity model. Furthermore, the linear programming model shows three fewer states with bulk highway movements than does the gravity model.

There was some shift in isopropanol shipments among the states. Many states had more or less the same number of ton-miles under both models. A few, including Indiana, California, and Alabama, had dramatically fewer ton-miles with linear programming than with the gravity model. West Virginia had significantly more ton-miles with linear programming. Because of the shifts in estimated ton-miles, Indiana, which was in the top four states with the gravity model, was not among the top four with linear programming, while West Virginia, which was not in the top four states with the gravity model, was among the top four with linear programming. Overall, the ton-miles by state predicted by the linear programming model are relatively similar to those predicted by the gravity model.

The average length of haul for bulk highway shipments was less with the linear programming model than with the gravity model. Since the total ton-miles were also less with linear programming, this is not at all surprising.

As can be seen by comparing Tables 8 and C-2, accident/spill expectations from linear programming and from the gravity model are similiar, but not identical.

## TABLE C-1. LINEAR PROGRAMMING MODEL ESTIMATES OF BULK SHIPMENTS OF ISOPROPANOL BY STATE, 1992

| State | Producer, Terminal, or Consumer | Ton-Miles (Thousands) | Truck-Miles† (Thousands) |
|---|---|---|---|
| Alabama | Consumer | 175 | 9 |
| Arkansas | Consumer | 127 | 6 |
| California | Consumer, Terminal | 197 | 10 |
| Colorado | Consumer | 10 | 1 |
| Delaware | | 107 | 5 |
| Georgia | Consumer, Terminal | 1,132 | 57 |
| Illinois | Consumer, Terminal | 1,264 | 63 |
| Indiana | Consumer | 1,126 | 56 |
| Iowa | | 90 | 4 |
| Kentucky | Consumer | 248 | 12 |
| Louisiana | Producer | 174 | 9 |
| Maryland | | 377 | 19 |
| Michigan | Consumer | 2,176 | 109 |
| Mississippi | Consumer | 114 | 6 |
| Missouri | Consumer | 7 | 0 |
| Nebraska | | 91 | 5 |
| New Jersey | Consumer, Terminal | 713 | 36 |
| New York | | 5 | 0 |
| North Carolina | Consumer | 95 | 5 |
| Ohio | Consumer | 2,566 | 128 |
| Pennsylvania | Consumer | 141 | 7 |
| South Carolina | Consumer | 134 | 7 |
| Tennessee | | 1,241 | 62 |
| Texas | Producer, Consumer, Terminal | 1,595 | 80 |
| Virginia | | 234 | 12 |
| West Virginia | Terminal | 1,785 | 89 |
| Wisconsin | | 59 | 3 |
| Wyoming | Consumer | 46 | 2 |
| Total | | 16,029 | 801 |

† Truck miles are calculated by dividing the number of ton miles by 20 short tons, or the average size of a tank truck load.

**TABLE C-2. ESTIMATED NUMBER OF TRUCK ACCIDENTS INVOLVING ISOPROPANOL, BY STATE, 1992 (BASED ON LINEAR PROGRAMMING RESULTS)**

| State | Estimated Accidents‡ | Estimated Years/Spill‡ | State | Estimated Accidents‡ | Estimated Years/Spill‡ |
|---|---|---|---|---|---|
| Alabama | 0.01 | 762 | Nebraska | 0.00 | 1,465 |
| Arkansas | 0.01 | 1,050 | New Jersey | 0.04 | 187 |
| California | 0.01 | 677 | New York | 0.00 | 26,667 |
| Colorado | 0.00 | 13,333 | North Carolina | 0.00 | 1,404 |
| Delaware | 0.01 | 1,246 | Ohio | 0.13 | 52 |
| Georgia | 0.06 | 118 | Pennsylvania | 0.01 | 946 |
| Illinois | 0.06 | 105 | South Carolina | 0.01 | 995 |
| Indiana | 0.06 | 118 | Tennessee | 0.06 | 107 |
| Iowa | 0.00 | 1,481 | Texas | 0.08 | 84 |
| Kentucky | 0.01 | 538 | Virginia | 0.01 | 570 |
| Louisiana | 0.01 | 766 | West Virginia | 0.09 | 75 |
| Maryland | 0.02 | 354 | Wisconsin | 0.00 | 2,260 |
| Michigan | 0.11 | 61 | Wyoming | 0.00 | 2,899 |
| Mississippi | 0.01 | 1,170 | | | |
| Missouri | 0.00 | 19,048 | Total | 0.80 | 8 |

‡ The number of accidents per year is calculated at one accident per one million truck miles; about 15 percent of these accidents results in a release or spill. These rules of thumb were suggested by RSPA's Office of Hazardous Materials Safety.