Transportation of Hazardous Wastes in Arizona: Development of a Data Base Management System for Basic Analysis

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ABSTRACT

A data base management system for hazardous waste movements in Arizona was developed for the years 1983 and 1984. The data were taken from the full manifest system provided by the Arizona Department of Health Services. A total of 5,053 manifests were reviewed for the 2 years, and a microcomputer software (DBASE III) was used for data storage, retrieval, and analysis. The computer system provided statistical reports by month of year, day of week, chemical number, and other attributes selected by the user for the year 1984. An origin-destination analysis of the data was conducted to trace the flow of waste shipments on all highway routes and links. Results of this analysis provided some insight on the distribution of origins and destinations of shipments within and outside urban areas. Data generated from the origin-destination analysis together with other accident, traffic volume, and population information were used to conduct a risk analysis.

The transportation of hazardous materials and the risk involved with such activity has been identified as a serious problem in the United States. It has been estimated that at least 250,000 shipments of hazardous materials are made each day, totaling at least 4 billion tons per year, and this volume is expected to double every 10 years (1). The U.S. Department of Transportation estimates that between 5 and 15 percent of all trucks on the road at any time carry hazardous materials (2).

When considering the transportation of hazardous materials, it is important to differentiate between hazardous materials and hazardous wastes. All hazardous wastes are hazardous materials, but only a small fraction of hazardous materials shipped are hazardous wastes.

It is currently estimated that somewhat less than 4 percent of the total of all hazardous materials shipped are in the hazardous waste category. In the United States, 160 million metric tons of hazardous wastes are generated each year as part of the industrial process. These wastes include organic chemicals, pesticides, acids, caustics, flammables, and explosives (3).

Statistics have shown that in 1980, all modes of transportation contributed to a total of 16,115 hazardous material incidents--resulting in 619 injuries, 19 fatalities, and $10.7 billion in property damages. Of those incidents, 90 percent were in the highway mode (4). More than 8,000 incidents of hazardous material spills involving truck travel were reported in 1981, of which 84 incidents involved hazardous wastes. Although the number of hazardous waste incidents is small, the hazardous waste shipment share of the total hazardous materials shipped is also small (4 percent). The incident rate, number of incidents per million shipment miles, would be an appropriate measure by which to judge the magnitude of the problem.

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BACKGROUND INFORMATION

In response to a growing concern about the management of hazardous wastes and their impact on the population and environment, the Resource Conservation and Recovery Act (RCRA) was enacted in 1976. RCRA authorized the Environmental Protection Agency (EPA) to establish a hazardous waste control program for the nation, which includes the identification and classification of hazardous wastes, requirements for owners and operators of hazardous waste facilities, and guidelines for state programs developed under the act.

As the transportation of hazardous materials is emerging as a national concern, attempts are ongoing to assess the risks of potential accidents. An early study conducted by Russell et al. (5) provided a comprehensive review and an excellent summary of existing methods used to estimate the risks of hazardous materials transport. The methods reviewed are (a) enumerative indices, (b) regression models, (c) network and distribution models, and (d) probabilistic risk assessment models. The basic concept of all methods is to develop a risk index per transportation route using the probability of hazardous material incidence.

In a recent study conducted for the Office of Solid Waste of the EPA, attempts were made to assess the releases and costs associated with truck transport of hazardous waste (6). Three streams of data were found necessary to conduct the risk analysis:

1. Truck accident and volume data,
2. Hazardous waste shipment information, and
3. Hazardous waste incident data.

Accident and volume data over 5-mile sections were obtained from Texas, California, and New Jersey. Some states have implemented a manifest system for recording hazardous waste shipments. Waste shipment data were obtained from California, Texas, Massachusetts, and New York. The hazardous waste in-

cident data were obtained from the HAZMAT file prepared by the U.S. Department of Transportation's Materials Transportation Bureau (MTB).

The data collected were used, in association with the RCRA risk/cost analysis model, to calculate the risks and costs involved with all possible combinations of a list of wastes, technologies, and environmental (WET) settings. The most important result of this study as reported by the investigators was that the release rates associated with transporting hazardous wastes by truck appear to be as large as the potential releases at treatment and disposal sites. For some WET combinations, transport may be a more dangerous activity.

A critical review of the literature resulted in the following observations:

1. Most statistics related to hazardous waste shipments cited by different agencies are based on estimates derived from surveys.
2. Those states that have implemented a manifest system for recording hazardous waste shipments have not, to the best of the authors' knowledge, reported on the shipments transported through their state by different category such as
   a. Time period (month of year, day of week);
   b. Hazard class (corrosive, explosive, etc.);
   c. Transportation route;
   d. Urban versus nonurban areas; and
   e. Chemical number, as defined by United Nations Classification System.

RESEARCH SCOPE

The Center for Environmental Studies and the Center for Advanced Research in Transportation at Arizona State University were awarded a research grant, sponsored by the Arizona Department of Transportation (ADOT), to develop a data base management system (DBMS) for hazardous material transport within and through the state of Arizona. One of the objectives of this research was to computerize the hazardous waste manifests for the years 1983 and 1984. To successfully meet this objective, the following tasks were outlined:

1. To use a microcomputer DBMS software to generate a hazardous waste information system for Arizona.
2. To utilize the DBMS for generating statistics related to hazardous waste shipments by transportation routes, time period, origin cities, destination cities, chemical number, chemical class, or any combination of these categories.
3. To identify the most hazardous routes in the state by means of conducting a risk analysis.

Described in this paper are the data collection process, design of the DBMS, the statistical results for 1984, and the risk analysis approach.

Data Collection Process

The Arizona Department of Health Services made available to the research team the original manifests as filed by the generators and the transporters of hazardous waste. Data were collected for the years 1983 and 1984. The manifest allows up to four chemicals to be listed. If more than four chemicals are transported per shipment, a continuation form is attached to the main form.

A total of 2,539 manifests were recorded for 1984, of which 18 shipments contained empty drums. Initial processing of 1983 data revealed that the numbers of shipments during both years are almost equal.

Design of the DBMS

During the early stage of the research, microcomputers were chosen as the data processing tool instead of mainframe computers for two reasons: (a) they are available and accessible by most state agencies, and (b) the transferability of the data base on mircrocomputers is easier and more convenient than on mainframe computers. An IBM-PC/XT with 640 K Random Access Memory was utilized for data processing and an external peripheral (Bernoulli Box) was used to back up the data on a cartridge disk. DBASE III was used to generate the data base. A sample record of the file developed is shown in Figure 1 (note: the computer record shown in Figure 1 has been retyped). A set of programs was developed to permit the user to add more manifests to an existing file, check the EPA identification number for generators and transporters, and search for all possible routes between each origin city and all possible destination cities. They are considered as utility programs to assure accurate data development.

The statistics report option allows the user to query statistics according to the following criteria:

1. By time period:
   - Year (1984, 1983, etc.),
   - Month (January, February, etc.),
   - Date (4/13/1984, etc.),
   - Day of week (Sunday, Monday, etc.);
2. By origin (city) of the chemical;
3. By destination (city) of the chemical;
4. By chemical number (9189, 1760, etc.);
5. By company (EPA identification number);
6. By chemical class (explosive, corrosive, etc.); and
7. By transportation route (any route of the 82 routes identified).

```
                    ****MANIFEST OF WASTE MATERIAL****

                                                  MANIFEST No. 84055
                                                     SHIP DATE 06/18/84

GENERATOR EPA id        AZD054408794
TRANSPORTOR EPA id      CAD008302903        OTHER TRANSPORTOR
     T/S/D EPA id       CAD008302903

              NAME      LB      GAL       CLASS
CHEMICAL      1593       0       676      ORM-A

              2831       0      1140      ORM-A

              9189       0      1300      ORM-E

                                                                    TAG
```

FIGURE 1 Sample of DBMS computer record.

The user may use the AND and OR options with the criteria just listed. The AND option provides a cross tabulation of two or more criteria. For example, a report can be created for the month of May and by chemical number 1760. This report will contain information related to shipments containing only number 1760 and shipped during the month of May. The OR option sums up the data of two criteria. For example, a report can be created for Saturday OR Sunday. Such a report will contain the total weekend shipments.

The statistics report contains the total weight (in pounds), the total volume (in gallons), the number of manifests being processed, and the number of shipments, totaled for the selected criteria. No conversion factors were made to convert volumes to weights. Figure 2 shows a display of a sample run of the data base (note: the sample run shown in Figure 2 has been retyped).

Statistical Results for 1984

Fifty links and 82 routes were identified for hazardous waste shipments. The annual truckloads of hazardous wastes by route were derived and are shown in Figure 3. As the plot indicates, Interstate 10 west of Phoenix, between Ehrenberg and Phoenix, carries the highest number of truck loads. This is as expected because almost all hazardous waste shipments travel on this highway en route to California, where most of the disposal facilities used by Arizona firms are located. The link that connects Tucson and Phoenix is second in ranking because waste generated from Tucson's industries has to go through Phoenix either for reprocessing or en route to California.

The program was used to generate statistical reports by time period and chemical numbers for the year 1984. The total number of loaded shipments was found to be 2,521 shipments--totaling approximately 9,457 tons and 2,464,767 gal. Figure 4 shows a display of the total number of shipments by month of year. It was observed that July and August had the highest number of shipments; their shares were 9.9 percent and 11.3 percent of the total year shipments, respectively.

The distribution of the number of shipments by day of week was derived, and the plots (shown in Figure 5) showed that Tuesday had the highest number of shipments (25.1 percent of the total number of shipments) and the weekend had the lowest. Statistics of this type could be of assistance to the Department of Public Safety in scheduling enforcement programs on the state highway system.

The distribution of shipments by chemical number was developed, and it was concluded from the results that chemical number 9169 and chemical number 1993 collectively constituted almost two-thirds of all the shipments (Figure 6). According to the 1984 Emergency Response Guidebook, chemical number 9169 is defined as hazardous waste in general, whereas chemical number 1993 included 11 different types of chemicals such as combustible liquid, weed killer, cosmetics, creosote, ethyl nitrate, flammable liquid, fuel oil, insecticide, solvent, tar, and wax (7). The guidebook provides instructions on how to handle a hazardous spill and lists emergency action that should be implemented by the HAZMAT team regarding fires, evacuation of the public, and other necessary activities. Statistics provided by the DBMS related to the most frequent chemical being transported on the highways can aid in planning a successful emergency response program.

An origin-destination analysis was conducted to trace shipment flows within and out of Arizona. It was found that shipments originating and terminating within the metropolitan areas of Phoenix and Tucson amounted to 1,082 and 116 shipments for 1984, respectively, which represented approximately 48 percent of all shipments. These intraurban movements represent shipments generated from a company and transported to a processing storage facility before they are sent out to be disposed.

The origin-destination analysis showed that 754 shipments originated from Arizona and were sent outside the state (internal-external), 40 shipments represented external-internal movements, 10 shipments were external-external movements, and 1,623 shipments represented internal-internal movements. As mentioned earlier, intraurban shipments (Phoenix and Tucson) were responsible for 1,198 out of the 1,623 shipments in the internal-internal categories (74 percent of the total).

Closer examination of shipments originating or terminating in Phoenix indicated the following:

- A total of 539 shipments left Phoenix for out-of-state destinations.
- A total of 385 shipments left Phoenix for in-state destinations.

A total of 924 shipments left Phoenix in 1984. On the other hand, 54 shipments destined for Phoenix from other localities plus the 1,082 intraurban shipments totaled 1,136 shipments. The difference between the 924 figure and the 1,136 figure represents the reduction in number of shipments due to intermediate waste processing or assembly that took place in some of the Phoenix facilities. Furthermore, the 539 shipments that left Phoenix for out-of-state destinations were heading to disposal sites. This figure represents the latent demand for the Mobile disposal facility expected to be opened in Arizona.

The same approach was applied to Tucson; the results were as follows:

- A total of 301 shipments were destined for Tucson from all other cities.
- A total of 116 shipments represented intraurban movement.
- A total of 160 shipments left Tucson for out-of-state destinations.
- A total of 11 shipments left Tucson for in-state destinations.

A total of 417 shipments were destined for Tucson and a total of 171 shipments originated from Tucson, resulting in a reduction of 246 shipments due to processing and storage. The latent demand for the new Mobile site from Tucson is approximately 160 shipments annually.

A final observation resulting from the origin-destination analysis is that the 10 shipments that crossed Arizona without stopping (external-external movement) originated from New Mexico and were destined for disposal sites in southern California.

Risk Analysis Approach

Risk assessment involves the measurement of the probability and severity of harm inherent in exposure to a hazardous object or event. Risk assessment is a scientific activity and should be distinguished from judging safety. By providing objective measures or rankings of risk, it is the purpose of a risk assessment to provide empirical, scientific data so that the subjective process of judging the relative safety of various options can be performed on an informed basis.

```
                                                        MAIN DATABASE : mal
******** Main Menu ********

   1> Statistic Report
   2> Database Diagnosis
   3> Switch Database
   4> Re-index Database
   5> Exit

Is route-links related query involved?
(Say no for fast execution)         N

             1> By Time Period
             2> By Chemical Original City
             3> By Destination City
             4> By Chemical Number
             5> By Company
             6> By Chemical Class
             7> By Shipment Route

Select criteria to be used ->       1

                                                        MAIN DATABASE : mal
                                                               Select time unit
                                                                1> By year
                                                                2> By month
                                                                3> By day
                                                                4> By week day
                                                           => 4
             1> By Time Period     *
             2> By Chemical Original City
             3> By Destination City
             4> By Chemical Number
             5> By Company
             6> By Chemical Class
             7> By Shipment Route

                                                        MAIN DATABASE : mal
Specify Week Day ( 1(Sun),2(Mon),.. 7 )
=>     1

             1> By Time Period     *
             2> By Chemical Original City
             3> By Destination City
             4> By Chemical Number
             5> By Company
             6> By Chemical Class
             7> By Shipment Route

                                                        MAIN DATABASE : mal
-- Current Criteria --
dow(SHIP_DATE) = 1   (Sunday)

             1> By Time Period     *
             2> By Chemical Original City
             3> By Destination City
             4> By Chemical Number
             5> By Company
             6> By Chemical Class
             7> By Shipment Route

Any other criteria to be used ( Y/N ) ?
( Statistic criteria can be multichoosed )
=>     N

                                                        MAIN DATABASE : mal
-- Selected Criteria --
dow(SHIP_DATE) = 1   (Sunday)

Total weight                        235240 lbs
Total volume                        128010 gals
Number of records processed             60
Number of shipments                     60

< Type any key to return to the main menu >
```

FIGURE 2 Sample run of the DBMS.

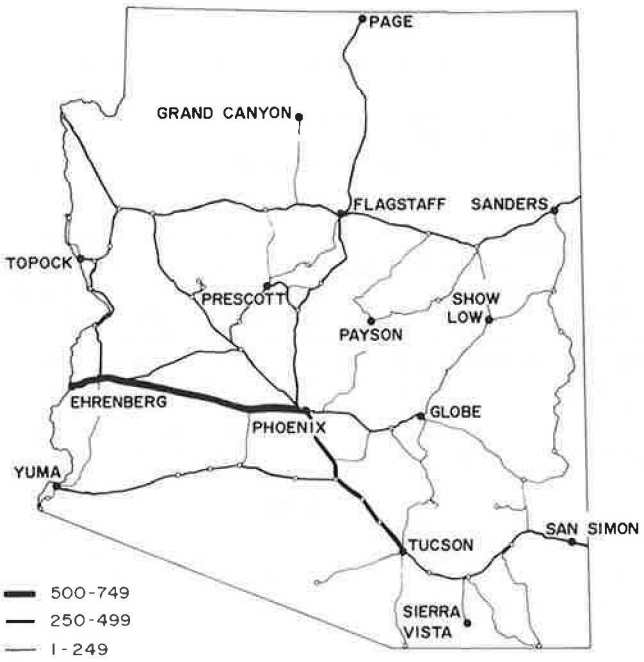

FIGURE 3 Total annual truckloads of hazardous wastes for 1984.

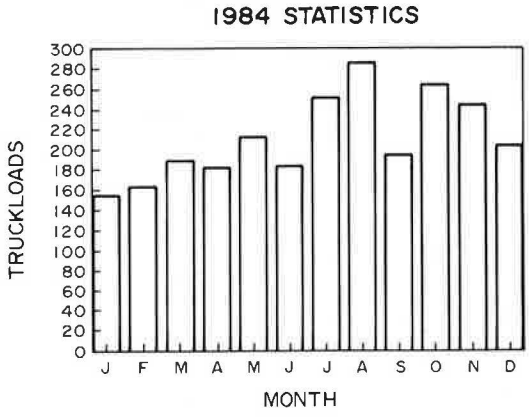

FIGURE 4 1984 shipment classification by month of year.

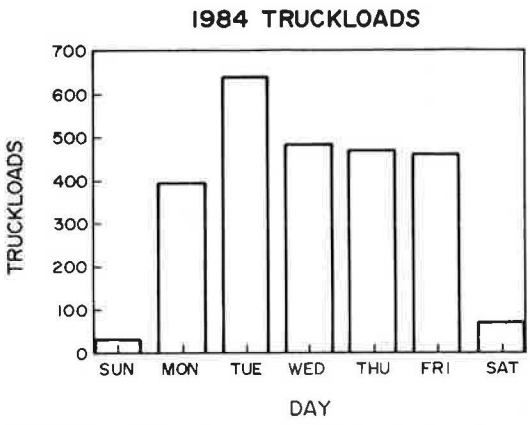

FIGURE 5 1984 shipment classification by day of week.

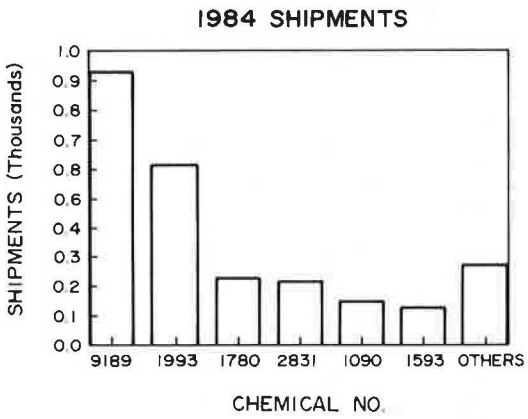

FIGURE 6 1984 shipment classification by selected chemical numbers.

In this section, an empirical risk analysis of transporting hazardous wastes on Arizona highway routes is presented. The objective is to determine risk ratings for routes under study so that transportation routes can be comparatively evaluated regarding level of risk. Such evaluation is crucial for good and sound response planning and implementation to hazardous waste incidents at the state level.

Two factors are identified and used to calculate a risk factor for each route: the first factor represents the probability of a hazardous waste accident for commercial vehicles; the second factor captures the population-at-risk due to a hazardous waste incident. In the next section, the calculations of the two factors and the definition of the final ratings will be described.

Hazardous Waste Accident Probabilities

Four pieces of information were gathered:

1. Highway section length in miles (LENGTH),
2. Daily commercial vehicle traffic volume for 1984 (TRVOL),
3. Number of annual hazardous waste shipments for 1984 (CHEM), and
4. Number of annual commercial vehicle accidents for 1984 (ACCD).

Table 1 gives the four measures for each of the 50 links being considered. The section lengths were measured from the county maps. Average daily traffic (ADT) data as well as the commercial vehicle percentage for each highway were obtained from the ADOT. It was noticed that, for some highways, more than one ADT existed. The worst scenario was assumed, and the highest ADT was used for calculating the daily commercial vehicle traffic.

Concerning the annual accident number, a computer printout showing all accidents that occurred on all Arizona highways in 1984 was provided by ADOT. Those accidents were reported by location (milepost) and severity level. Data on accidents by vehicle type were not available, and therefore it was assumed that the probability of commercial vehicle accidents is directly related to the proportion of commercial vehicle traffic. Percentages of commercial vehicles were then used in conjunction with the accident numbers to calculate the commercial vehicle accident numbers. The number of annual hazardous waste shipments was derived earlier from the computer DBMS.

TABLE 1 Risk Analysis Input Data

	Highway Section Length (mi)	Daily Commercial Vehicle Traffic Volume (TRVOL)	No. Annual Hazardous Wastes Shipments (CHEM)	No. of Annual Commercial Vehicle Accidents (ACCD)
1	33.69	11,700	2,276	60
2	36.7	4,600	734	33
3	9.71	4,410	711	5
4	27.63	4,800	664	23
5	17.88	9,000	565	29
6	12.8	13,490	774	54
7	3.99	3,150	798	2
8	11.83	2,730	792	6
9	18.72	2,730	792	10
10	74.36	2,520	793	42
11	19.09	3,060	795	2
12	86.47	1,700	50	18
13	19.47	780	50	4
14	12.91	1,275	50	4
15	32.26	1,888	50	5
16	26.65	1,706	50	6
17	14.58	4,840	28	10
18	20.71	3,520	28	17
19	38.15	2,940	28	22
20	50.21	3,395	28	27
21	33.49	480	9	26
22	45.55	2,420	92	33
23	15.39	1,692	4	3
24	18.17	464	7	1
25	39.35	624	4	5
26	35.4	200	4	1
27	23.41	136	8	1
28	46.52	330	8	5
29	31.55	198	2	2
30	70.93	720	2	10
31	61.62	3,300	83	51
32	15.75	2,860	83	12
33	24.68	2,200	64	8
34	89.58	1,820	1	2
35	61.68	1,440	1	8
36	22.96	1,870	2	10
37	51	2,850	39	30
38	62.72	2,646	39	38
39	16.35	1,000	7	2
40	39.78	1,470	7	10
41	40.37	1,710	2	27
42	44.91	750	2	4
43	24.38	33	1	1
44	54.58	378	1	9
45	9.25	1,400	23	4
46	4.02	90	6	0
47	11.7	25	6	0
48	138.91	1,540	24	20
49	80.35	1,330	17	6
50	23.82	1,692	2	15

An index PRO that combines the four measures was developed:

$$PRO = (ACCD \times CHEM)/(LENGTH \times TRVOL)$$

A higher number of accidents and a higher number of shipments produce higher values of PRO. Furthermore, short sections and low commercial vehicle volume produce higher values of PRO, and a higher risk factor should be associated with these conditions. The calculations of the PRO factor showed a range of between 0.000012 and 0.3460. Three arbitrary levels of risk were assumed:

High risk	$PRO > 0.03$
Intermediate risk	$0.03 \geq PRO \geq 0.01$
Low risk	$PRO < 0.01$

To assess the three levels of risk, arbitrary ratios of 1:5:10 were used to represent high, intermediate, and low risk, respectively. A PROB index was assumed to take the values of 70, 35, and 7 for the three levels of risk.

Population-at-Risk Factor

Two types of population-at-risk were identified:

1. Permanent population living near the transportation route and
2. Drivers and passengers of vehicles on the roads.

The first measure was obtained from the 1980 census data. The boundaries were defined by an evacuation distance of 3 miles on either side of a route and along the route, per mile length. The vehicular traffic at risk was estimated by using basic principles of traffic flow theory. Traffic flow (vehicles per hour) is equal to traffic density (vehicles per mile) times the average operating speed (miles per hour). The ADT per link being known, it was assumed that the peak-hour traffic is 8 percent of ADT. The traffic density was then calculated for each section, and a vehicular occupancy factor of 1.3 was assumed. The two population-at-risk measures, population (POPS) and number of passengers (PSGR), are given in Table 2. The sum of the two measures ranged between 101,273 persons per mile and 11 persons per

TABLE 2 Risk Analysis Results

	Population (POPS)	No. of Passengers (PSGR)	Rating (RTG)	Risk
1	101,070	203	220	1
2	2,419	35	145	2
3	867	36	145	2
4	2,175	42	145	2
5	26,328	78	220	1
6	38,400	123	220	1
7	537	26	145	2
8	675	23	85	3
9	883	23	85	3
10	1,192	21	85	3
11	1,550	31	110	3
12	9,778	17	82	3
13	235	9	50	4
14	790	9	50	4
15	976	10	22	5
16	7,527	10	82	3
17	359	0	22	5
18	1,857	28	82	3
19	3,561	24	82	3
20	2,525	17	22	5
21	2,675	21	110	3
22	509	38	50	4
23	311	10	22	5
24	789	10	22	5
25	1,043	14	22	5
26	786	17	22	5
27	3,535	6	82	3
28	209	6	22	5
29	51	6	22	5
30	688	16	22	5
31	4,816	26	110	3
32	535	24	50	4
33	3,490	19	82	3
34	1,212	23	22	5
35	8,040	28	82	3
36	214	19	22	5
37	6,728	26	82	3
38	4,054	19	22	5
39	5,589	43	82	3
40	5,078	36	82	3
41	2,369	33	22	5
42	2,625	26	22	5
43	62	1	22	5
44	147	3	22	5
45	789	10	22	5
46	233	2	22	5
47	11	0	22	5
48	3,671	24	22	5
49	241	33	22	5
50	591	10	22	5

mile. The same ratio (1:5:10) was applied and a PORSK index was assumed to make the following values:

(POPS + PSGR)	PORSK
< 100	15
100-500	75
> 500	150

Ratings and Risk Factors

The two factors PROB and PORSK were summed to produce RTG, and its value ranged between 22 and 220. Five levels of risk were assumed:

Risk = 1 (high)	RTG $\leq$ 40
Risk = 2	40 < RTG $\leq$ 80
Risk = 3	80 < RTG $\leq$ 120
Risk = 4	120 < RTG < 160
Risk = 5 (low)	RTG $\geq$ 160

The results of the risk levels are given in Table 2. As expected, links 1, 5, and 6 had the highest risk because they are located within the Phoenix and Tucson metropolitan areas. Links 2, 3, 4, and 7 are second highest. Links 2, 3, and 4 represent the route between Phoenix and Tucson on Interstate 10, and link 7 connects Phoenix with California on Interstate 10. Figure 7 shows a display of the risk levels of the 50 links; a comparison of Figure 3 and Figure 7 would show the direct correlation between the number of shipments and the risk level.

SUMMARY AND CONCLUSIONS

Data on hazardous waste shipments in Arizona were collected for the years 1983 and 1984. These data were extracted from official manifests made available by the Arizona Department of Health Services. DBASE III was utilized on an IBM-PC/XT to develop a DBMS for the 1984 hazardous waste data.

The DBMS was utilized to generate statistical reports on month of year, day of week, and selected chemical numbers. An origin-destination analysis was conducted to trace hazardous waste shipments within Arizona.

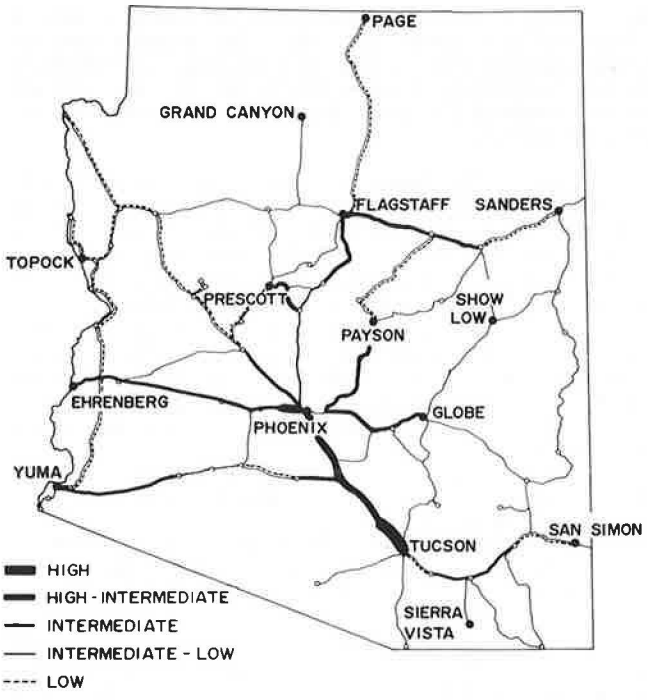

FIGURE 7 Map showing risk levels of the 50 lines.

A risk analysis was conducted to assess the risk levels of selected links on the transportation routes. Data on link lengths, commercial vehicle traffic volume, commercial vehicle accidents, number of hazardous waste shipments, population-at-risk factor, and passenger-at-risk factor were collected for all 50 links to conduct the risk analysis.

Several conclusions were reached:

1. The use of DBMS computer software provided a powerful and easy approach for data storage, retrieval, and analysis.
2. In 1984, 2,521 shipments occurred, totaling 9,457 tons plus 2,464,767 gal of wastes in Arizona for 1984.
3. August and October had the highest number of shipments, with shares of 9.9 percent and 11.3 percent of the 1984 total shipments, respectively.
4. Tuesday had the highest number of shipments, representing 25.1 percent of the total shipments, and the weekend had the lowest share.
5. Chemicals identified as numbers 9189 and 1993 collectively represented almost two-thirds of all 1984 shipments.
6. Intraurban shipments with Phoenix and Tucson metropolitan areas collectively constituted 48 percent of all shipments.
7. The origin-destination analysis of the 1984 data provided valuable information on waste movements within and across Arizona.
8. It was concluded based on the risk analysis that the highway links located within the Phoenix and Tucson metropolitan areas had the highest risk factors. The lines with the second highest risk factors were found to be located on the route between Phoenix and Tucson, and the links that connect Phoenix with California on Interstate 10.

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REFERENCES

1. J. Colle. Federal Activities in Toxic Substances. Environmental Protection Agency, May 1980.
2. D. Doniger. The Law and Policy of Toxic Substances Control. Johns Hopkins University Press, Baltimore, Md., 1978.
3. National Survey of Hazardous Waste Generators and Treatment, Storage, and Disposal Facilities Regulated Under RCRA in 1981. Preliminary Highlights and Findings. Draft Final Report. Environmental Protection Agency, Jan. 1981.
4. Transportation of Hazardous Materials: Toward a National Strategy. TRB, National Research Council, Washington, D.C., 1983, Volume 1.
5. E.R. Russell et al. Risk Assessment Users Manual for Small Communities and Rural Areas. DOT/RSPA DPB/50/81/30. Department of Civil Engineering, Kansas State University, Manhattan, 1980.
6. Assessing the Releases and Costs Associated with Truck Transport of Hazardous Wastes. Office of Solid Waste, Environmental Protection Agency, 1983.
7. 1984 Emergency Response Guidebook. Report DOT P 5800.3. Materials Transportation Bureau, U.S. Department of Transportation, 1984.