Information Sources for Flow Analyses of Hazardous Materials

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ABSTRACT

As increasing amounts of hazardous materials are transported in the United States, a significant concern has been the associated risk to public safety and the environment. Although a national reporting system for hazardous materials transport incidents exists, a companion data base on hazardous materials movements does not. Thus, it is difficult to monitor the activity level of hazardous materials movements and to assess the safety of the industry. Identified are potential sources of information to perform flow analyses of hazardous materials; the quality and usefulness of these data bases for diagnostic, policy planning, and evaluative needs are assessed. The study scope includes flow, fleet, and network utilization across the major modes of hazardous materials transport. Several important conclusions are reached about the applicability of existing information, in terms of both the way the information is collected and what it represents. Based on these conclusions, recommendations are made on how information reporting policies and practices can be improved to enhance the capability of analyzing hazardous materials transport.

As increasing amounts of hazardous materials cargo are transported in the United States, the associated risk to public safety and the environment has become a significant and growing concern. In 1971, the Office of Hazardous Materials Transport (OHMT) began collecting data on hazardous materials incidents in the United States. Although the data are often criticized as being unrepresentative, a more glaring problem is the lack of comprehensive information on hazardous materials movements. Little information exists about where these moves occur, what vehicles are employed, and what network elements are used. Because of this deficiency, it has been difficult to monitor the activity level of hazardous materials movements and to assess the safety (i.e., accident and incident rates) of this industry as a whole or the relative safety of different modes and containers.

The purpose of this paper is to identify potential sources of information for performing flow analyses of hazardous materials, and to assess the quality and usefulness of these data bases for diagnostic, policy planning, and evaluative needs. The paper concludes with an assessment of the current analysis environment, and suggests reporting modifications that could enhance the capability of performing flow analyses of hazardous materials.

A COMPLEX ARRAY OF SOURCES

Identifying the array of data bases is a complex task. Not only are there three types of data to consider (i.e., flow, fleet, and network) but there are four major vehicular modes involved in transporting hazardous materials: truck, rail, water, and air. Furthermore, many organizations maintain information--including federal agencies, state and local governments, trade organizations, carriers, shippers, and consulting firms.

It would be nearly impossible to describe all of the data bases, especially when carriers and shippers are included; however, it is possible to describe the major ones, particularly those that are publicly available. For the most part, these data bases are kept by federal agencies, state and local governments, and trade organizations.

For many data bases, it is possible to give a synopsis of their characteristics, such as name, sponsoring organization, contents, sources, cross-checks, strengths, and weaknesses. In this paper, the discussion is segmented into flow data bases, fleet data bases, and network data bases.

FLOW DATA BASES

In general, flow data bases contain information on the movement of commodities from one place to another. They can be classified into two tiers, the first indicating whether they include all commodities or a subset only, and the second indicating whether they are multimodal or mode-specific.

Data Bases for All Commodities

Multimodal

Since 1963, the Bureau of the Census has been collecting transportation data every 5 years at varying levels of detail. Most recently, surveys were conducted in 1977 and 1983. The 1977 survey contains four parts: the Commodity Transportation Survey (CTS), the Truck Inventory and Use Survey (TIUS), the National Travel Survey, and the Nonregulated Motor carriers and Public Warehousing Survey (1).

The 1977 CTS contains flow data for commodities shipped by manufacturing establishments selected from each of 456 industries. Each record lists the

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total number of tons shipped from a given origin (state, production area, or Bureau of Economic Analysis region) to a given destination (same basis) for a specific commodity [up to five-digit Standard Transportation Commodity Code (STCC)], the principal mode of transport, weight block, and value block. The data are based on voluntary responses from approximately 16,000 of the 19,500 establishments to which survey forms were sent. The data are checked against the Census of Manufacturers Survey by using the value of shipment information to ensure that the expanded value of shipments made corresponds closely to the value of commodities produced (1).

Although the main strength of the census is its multimodal nature, inasmuch as it provides ways to estimate market shares and trends in a wide variety of situations, it does have limitations. The most important of these are as follows. It does not contain data on waste shipments, or agricultural or raw material shipments such as crude petroleum and natural fertilizers. The shipments that are present are only from point of manufacture to first destination, often a warehouse; they do not reflect movements in the entire distribution chain. Data submission is voluntary, creating unknown biases due to nonreporting. In addition, the data are collected only every 5 years, the scope of the survey is heavily dependent on federal budget priorities, and the questions asked are not consistent, making trend analyses difficult. Finally, the Census Bureau typically takes at least 2 years to release the data; as of the publication date of this paper, the 1983 data have yet to be released. Moreover, the data are released at the state-to-state or production area-to-production area level and are carefully screened to release data only on those respondents whose confidentiality can be maintained. Consequently, some flows are omitted at the higher levels of detail. Finally, there is no specific focus on hazardous materials. Therefore, one is limited to the data contained in the commodity flows, and if the detail is weak or suppressed, it is impossible to determine--especially at the two-, three-, and four-digit levels of detail--what percent of the shipments are hazardous.

To demonstrate these problems, only the differences between the CTS data collected in 1983 and those collected in 1977 need be considered. Although the 1977 CTS provides true commodity flow data, the 1983 CTS does not. In 1983, the respondents were asked to identify their line of business by four-digit Standard Industrial Classification (SIC) code and then report the number of tons they shipped to each state and the modal shares, giving no direct indication of commodity. Thus, it is impossible to determine exactly what commodities were shipped and what percent of the tonnage constituted hazardous materials.

Despite these problems, the CTS is the only multimodal data base available. Other organizations, such as state and local governments, do not collect similar information. They rely either on the CTS directly or its interpretation and enhancement by consulting firms for their multimodal flow information. Consulting firms using the CTS supplement it heavily with other modal sources, described later, to improve the quality of the data (2).

Truck

Virtually no truck (highway) flow data exist. There is no evidence that a federal agency maintains this information explicitly; the Interstate Commerce Commission (ICC) does not keep it, nor does the FHWA, U.S. Department of Transportation. The only source of information is the CTS described earlier.

However, three tangentially related data bases are worthy of discussion. The first is the TIUS collected by the Bureau of the Census. The 1977 TIUS contains data on the character and use of approximately 117,000 trucks, drawn from an estimated universe of 28 million. The sampling rate is skewed toward large trucks to enhance that portion of the data, but the sample size is still small. More than one-half of the states have samples of about 1,600 large trucks; for the largest states of Texas and California, the sample size reaches 3,000 (3).

The TIUS contains information on each vehicle's registration (vehicle identification number), physical characteristics (size, type of body, engine size, transmission type, braking system, etc.), operator class (ICC-certified common carrier, contract carrier, etc.), range of operation (e.g., short range), annual mileage, percent of mileage in home state, principal and secondary commodity carried, and the percent of time hazardous materials were carried. It is based on voluntary responses from the owners of the vehicles selected. It has no cross-checks except the state registration files from which the survey vehicles were selected.

The significance of the TIUS from a hazardous materials standpoint stems from it showing what percent of the time (1977) or miles (1982) a vehicle was used to haul hazardous materials. Through the answer to this question and several others, such as the annual mileage statistics, it is possible to estimate various measures of transport activity, such as annual truck-miles by commodity group and carrier category. In addition, through the range of operation and state base of operation, it is possible to develop rudimentary spatial information.

The second source is the Motor Carrier Census (MCCS) maintained by the Bureau of Motor Carrier Safety. It contains a profile on approximately 250,000 motor carriers. Although the data base is used primarily to monitor carrier safety, it can be used to develop activity measures and simple spatial flow indicators. The data base contains each carrier's base-of-operations state, the states served, the type of commodities carried, and--for hazardous materials--the kind of container and tank or package used to carry commodities in each of the hazard classes designated by the U.S. Department of Transportation. Also, it contains information on the carrier's classification (e.g., ICC common, ICC exempt, private), number of miles operated, number of drivers, and numbers of trucks, truck tractors, and trailers, segmented by type of ownership (owned, leased, or trip leased).

The third source is the ICC Waybill Sample (see the description under the section on Rail that follows). It contains data on the rail portion of truck shipments that use rail for one segment of the move, usually referred to as container-on-flatcar or trailer-on-flatcar shipments.

At the state level, several data bases are being developed. New York, for example, is computerizing the data collected by its state police during their roving truck inspections. The data base is both clean and complete. Other states with similar information include Virginia (4), New Mexico (5), Washington (6), and Colorado (6).

A few metropolitan areas such as Indianapolis (7), Portland (8), and San Francisco (9) have collected hazardous materials flow data for information and planning purposes. Moreover, the number is growing, partly as a result of pilot projects funded by federal agencies (6). However, the data are focused on local movements and are of little value for national flow analyses.

Trade organizations generally do not keep flow data. The American Trucking Associations (ATA), for example, keeps only aggregate statistics on tons and ton-miles. Moreover, the firms that submit the data are principally less than truckload carriers, so the data lack information about bulk shipments. Occasionally, the ATA's Safety Department collects site-specific data, but only in response to field studies being conducted at specific locations. Shipper organizations, such as the American Petroleum Institute, the Chemical Manufacturers Association, the Petroleum Marketers Association, and the National Association of Chemical Distributors, are in much the same position as the ATA.

Individual firms, however, do keep data on their own movements. Trucking firms generally keep computerized traffic data bases that include origin, destination, commodity (by a variety of codes), shipment weight, and shipment date. Major shippers, such as the large chemical and petroleum companies, also keep computerized data on their truck shipments. They record origin, destination, commodity (often on the basis of some marketing-based coding scheme), shipment weight, and shipment date.

Other types of data are kept by consulting firms, such as Transportation Research and Marketing, which has developed a National Motor Truck Data Base (NMTDB) (10). Started by the Association of American Railroads in 1977, the NMTDB contains information on approximately 36,000 movements per year, some 4,000 of which involve hazardous materials. The data are collected at 18 selected truck stops, typically in the West and Midwest, in an attempt to sample selectively long-haul moves. For the shipments it covers, the data base includes origin city and state, destination city and state, commodity (up to seven-digit STCC), vehicle characteristics, operator characteristics, and an operator profile. It is cross-checked to a limited extent against fuel sales at the truck stops and volume counts on selected Interstates.

Rail

The federal rail data base is the Waybill Sample collected by the ICC (11). Every year, the ICC requires railroads to submit waybills on a certain percentage of the traffic they terminated. The waybill data base for 1984 contains flow data for approximately 6 percent of all rail movements, approximately 315,000 records. It shows origin (city and state), destination (city and state), commodity (seven-digit STCC), number of cars, shipment weight, shipment cost (rail revenue), and the railroad junctions traversed. It is based on carloads terminated by all the Class I carriers and some of the Class IIs and Class IIIs. Since the AAR took responsibility for collecting the waybills and preparing the samples, numerous editing checks and cross-checks have been introduced. Moreover, by working with the roads involved, the AAR has been able to improve the quality of the sample.

The sample size has risen to 6 percent because of a recent ICC proceeding. Historically, the sample was created by collecting waybills ending in 01, which resulted in about a 0.8 percent sample of all car movements because of underreporting for multiple-car shipments. In Ex parte 385 (12), it was decided to alter the sampling method to correct for this problem. For example, for railroads submitting hard copy waybills, three criteria are now involved. For waybills covering 1- to 5-car movements, the 01 rule still applies; for waybills covering 6 to 25 cars, those ending in 1 must be submitted; and for waybills covering more than 25 cars, those ending in 1 and 7 must be submitted.

The data base does, however, have its limitations. For past years, it reflects only movements terminated by Class I carriers, which means that movements terminated by Class II carriers and Class III carriers are missing (reportedly about 6 percent of all movements). Little edit checking was done before 1983. Occasionally, cars with extremely large loads or cars without any shipment weight appear. Sometimes the same car shows up repeatedly, indicating faulty records. In addition, because many multiple-car shipments are missing in the samples before 1983, some commodities, such as coal and grain, are significantly underreported. For determining spatial flow patterns, the sample is generally considered adequate for region-to-region flows, but for state-to-state flows or anything finer, its credibility is hotly debated.

State and local governments do not appear to collect rail data. Two states with strong rail divisions, New York and New Jersey, do have data bases, but these are derived from the ICC data. In a few instances, localized data have been collected, for example, in the state of Washington (6) and in Indianapolis, Indiana (7).

The major trade organization, the AAR, maintains a comprehensive data base on railcar movements (13). TRAIN II contains status information on the movement of about 80 percent of all railcars. Its purpose is to allow railroads and shippers to trace their cars regardless of where they are located. Each railroad participating in TRAIN II submits location and status information on all the cars on its lines, both owned and foreign, so that shippers and other roads can determine where their cars are and their respective status. For each car, the data base includes current location (at an origin, destination, or some intermediate point), empty or loaded status, and the commodity being carried (seven-digit STCC).

The AAR currently uses TRAIN II to develop summaries of hazardous material flows. Occasionally, it has prepared tables of carload originations and terminations by STCC code for each state, and tables showing U.S. flows for all hazardous commodities, ranked by total carloadings.

Regarding carriers, most railroads--and certainly the major ones--maintain traffic flow data bases. A few keep times and locations for all events in the car-movement cycle (14). Most keep data that can be captured from the waybill: shipper, consignee, on-line and off-line origins and destinations, cars, tons, revenue, and so forth.

Water

At the federal level, the U.S. Army Corps of Engineers maintains a complete data base on all trade movement of U.S. and foreign vessels in U.S. waters (15) including domestic as well as international shipments. Only data on military cargo moved in U.S. Department of Defense vessels are missing. The following information is provided on each movement: origin district, port, dock, and date; destination district, port, dock, and date; commodity (four-digit code); shipment weight (short tons); operator; vessel description; and the waterways traversed, including entry and exit mileposts. It is based on data submitted by carriers, shippers, and vessel owners. The reporting requirements are comprehensive, and thus it effectively represents a 100 percent sample.

The main weakness of this data base is its commodity classifications. These are based on a four-digit code, but total only 163; as a result, the classifications are broad. Hazardous materials could conceivably fall into 30 of these classifications, but it cannot be determined which ones or to what extent. The level of detail at which one can analyze flows is consequently limited.

Air

No data base on air shipments, hazardous or otherwise, is kept other than the CTS already described. Federal Aviation Administration (FAA) inspectors sometimes perform 90-day record checks, but the only information they keep is the number of hazardous class shipments, not the overall percentage or the total volume.

The situation appears to be much the same for state and local governments. Only Virginia has collected any primary data (4) consisting of information on hazardous materials passing through many of its major airports.

Carriers and shippers maintain traffic flow data bases, including information on hazardous material flows. Generally, they keep track of origin, destination, commodity (again on the basis of a marketing-based code), shipment weight, and shipment date.

Specialized Data Bases

Hazardous Wastes

Environmental Protection Agency (EPA) regulations require every hazardous waste shipment to have a manifest (16). Thus, in theory, a complete flow data base exists detailing hazardous waste movements. In practice, however, the extent of computerization varies from one EPA region to another. An outgrowth of the requirement for manifests is that states generally have good information on waste movements and the carriers involved. In some cases, they are collecting and computerizing the data for EPA. Carriers also appear to have fairly complete data even though they are not technically responsible for preparing the manifests.

Radioactive Materials

The U.S. Department of Energy (DOE) maintains a list of all high-level radioactive shipments, and it conducts surveys of the low-level radioactive shipments. One such survey was conducted in 1975 (17), and a second was recently conducted by SRI International (18).

A Potpourri of Codes

It is surprising, because federal data collection is not new, that numerous hazardous materials commodity codes are used by the different federal agencies. At least 10 exist, not counting those used internally by carriers and shippers. These include the codes used in the U.S. Department of Transportation's OHMT Hazardous Materials Incident Reporting system data base; the EPA codes (16); the United Nations/North American (UN/NA) codes (19); the STCC (20), of which two versions exist; the standard codes (01 through 48) and the 49 series of codes specifically established for hazardous materials; the National Motor Freight Classifications (NMFC) (21); the U.S. Army Corps of Engineers codes (15); several Bureau of the Census codes; the Transportation Commodity Codes for domestic shipments (1977 Census) (22); the SIC codes for the 1983 census (technically speaking, the SIC codes are developed and maintained by the Bureau of Economic Analysis, U.S. Department of Commerce) (23); the Schedule A codes for imports and the Schedule E codes for exports.

These codes are all used simultaneously, yet few cross-reference tables have been developed for them, either for hazardous materials or any other type of commodity. The tables include the conversion file from series 49 STCCs to regular STCC codes and UN/NA codes maintained by the AAR (24); the STCC-to-SIC code conversion table at the four-digit SIC level maintained by the AAR, which is in hard copy only (24); the NMFC-to-STCC conversion table maintained by the ATA (25); the U.S. Army Corps of Engineers conversion file between their commodity codes for water to Bureau of the Census Standard International Trade Classification (SITC) codes (it appears that these SITC codes are used only for translation purposes); and the SITC, SIC, Schedule A, and Schedule E translation files maintained by the Bureau of the Census. It is interesting to note that UN/NA numbers appear only once and OHMT or EPA numbers do not appear at all.

FLEET DATA BASES

Highway

For the highway mode, no useful fleet data base exists. There are data bases for trucks, meaning single-unit trucks and truck tractors, but no similar data base for trailers. Yet trailers are clearly the main highway vehicle for hazardous materials.

At the federal level, the only potential sources of information are the TIUS and the MCCS data bases described previously in the section on Flow Data Bases, but neither of these is adequate. The former is only a small sample, and its focus is on single-unit trucks and truck tractors, not trailers. The latter contains counts of trailers for each carrier, but no information on trailer characteristics, and a dry van is indistinguishable from a stainless steel tank.

The situation is much the same at the state level. Although the states have some information about the trailers they register and inspect, the level of detail is low. The data bases indicate only such details as whether the trailer is a tank or a dry van, and so forth; they do not differentiate between an MC301, MC302, MC306, or MC331, not do they show whether the trailer is being used to carry hazardous materials.

The trade organizations do not maintain fleet data bases. Trailer manufacturers are required to report their production statistics to the Bureau of the Census (26), but the level of detail is aggregate. For example, only 4 categories of tank trailers are indicated, while 10 or more are listed in the OHMT's incident data base. Furthermore, these categories vary from year to year.

Rail, Water, and Air

Relatively comprehensive fleet data are kept for these three modes. The AAR maintains a master file called the Universal Machine Language Equipment Register (UMLER file) on all cars and locomotives in use in the United States (27); the U.S. Army Corps of Engineers keeps a master file on all vessels involved in commercial shipping in the United States; and the FAA keeps records on all aircraft in use in the United States.

However, none of these data bases has flags indicating whether the vehicle is used to carry hazardous materials. One can only infer such information by analyzing the commodity flow and accident and/or incident data bases, and determining the types of vehicles that are typically used for hazardous materials for each mode. It is then possible to extrapolate fleet sizes by reflecting these findings back into the fleet data bases.

TABLE 1 Data Base Summary

Data	Highway	Rail	Water	Air
Flows	CTS[a]	CTS[a]	CTS[a]	CTS[a]
	CFIRM-1	CFIRM-1	CFIRM-1	CFIRM-1
	NMTDB[b]			
	TI&U[c]			
	MCS[c]			
	ICC[d]	ICC[e]		
		TRAIN II		
			WCS[f]	
	EPA-1	EPA-1	EPA-1	EPA-1
	DOE	DOE	DOE	DOE
Fleets	TIUS[g]			
	MCCS[h]			
	DMV[i]			
	UMLER[d]	UMLER		
			VMF	
				ARF
	EPA-2	EPA-2		
Networks	DOE/ORNL			
		FRA		
			WMF	
	CFIRM-2	CFIRM-2	CFIRM-2	CFIRM-2

[a] Limited sample; only from point of manufacture to first destination; no wastes or agricultural products.
[b] Only long-haul shipments outside the Northeast.
[c] Level of activity data only, such as truck-miles.
[d] Only for trailers and containers that move via railroads.
[e] No more than a 6 percent sample of all movements.
[f] Limited commodity detail—only 30 classes of hazardous materials.
[g] No specific data on trailers.
[h] Only counts of trailers, truck tractors, and trucks.
[i] No physical characteristics or use indicators for trailers.

NETWORK DATA BASES

Network data bases for highway, rail, and water are each maintained by a federal agency. None is kept for air; the air traffic control system provides national network control. The DOE, through Oak Ridge National Laboratory, maintains an inventory of the principal segments of the U.S. highway network. The Federal Railroad Administration maintains a complete inventory of the line segments in the U.S. network, although it is important to note that the railroads are not directly involved in updating this data base. The U.S. Army Corps of Engineers maintains a complete inventory of the waterway segments in the U.S. waterway network. Moreover, states and some consulting firms keep network data bases that have been derived from these and other data.

Two points are important here. First, the data bases do not contain flags showing which network elements carry heavy volumes of hazardous materials. Second, developing such flags is problematic. In the case of the highway network, the federal standards direct carriers to use the Interstate system, so one can infer general routing patterns with reasonable validity. In the case of the rail network, making inferences is not as easy. Some railroads have more than one way in which they can route a car from point A to point B, and some have special rules for routing hazardous material shipments. In addition, historical movement data are difficult to obtain, and some railroads do not computerize it. Finally TRAIN II does not show a high level of routing detail--just passing times for selected locations within each carrier's network. In the case of water, the vessel movement files show routings in considerable detail, but the commodity data are too weak to draw significant conclusions.

The second problem is that the data bases do not contain the information required to perform risk analyses. In general, their link and node information does not include population statistics, or link condition data such as level of maintenance, accident rates, or historic flow volumes, all of which are key to any method of risk analysis. Fortunately, some private consulting firms have added some of this information to their data bases, but it is not publicly available.

SUMMARY AND CONCLUSIONS

The foremost conclusion is that no single, publicly available data base exists describing the hazardous materials transportation system. An array of data bases is required to develop even crude flow, fleet, and network information, as shown in Tables 1 and 2. The CTS is the only multimodal data base showing flows; however, it is weak from the standpoint of hazardous material flow definition and is 7 years out of date. In addition, when the 1983 CTS is released, it will be of limited value because the survey was small and the flow data do not consist of individual shipments.

Moreover, such a data base cannot be assembled because two of the major components are missing. No comprehensive data base for highway flows is kept, nor is there one for trailers despite the apparent depth in Table 1. Because the highway mode has the most widespread public impact, these are noteworthy gaps. The CTS is helpful for highway flows, but its data are thin. The TIUS and MCCS data bases are helpful, but they provide only the trucks and truck-miles involved in hazardous materials movements, not true flow data. The only other source is the NMTDB, but it has limitations because of its intentional bias toward long-haul shipments and restricted geographic coverage.

TABLE 2 Data Bases

Acronym	Data	Organization
ARF	Aircraft registration files	Federal Aviation Administration
CFIRM-1	Flow data bases	Consulting firm
CFIRM-2	Network data bases	Consulting firm
CTS	Commodity Transportation Survey	Bureau of the Census
DOE	Radioactive shipment data bases, high and low level	U.S. Department of Energy
DOE/ORNL	Highway network file	Maintained by the U.S. Department of Energy at Oak Ridge National Laboratory
DMV	Motor vehicle records	State departmens of motor vehicles
EPA-1	Waste shipment manifests	Environmental Protection Agency
EPA-2	Waste carrier permits	Environmental Protection Agency
FRA	Rail network data base	Federal Railroad Administration
ICC	ICC Waybill Sample	Interstate Commerce Commission
MCCS	Motor Carrier Census	Bureau of Motor Carrier Safety, Federal Highway Administration
NMTDB	National Motor Truck Data Base	Transportation Research and Marketing (consulting firm)
TIUS	Truck Inventory and Use Survey	Bureau of the Census
TRAIN II	Rail locator data base	Association of American Railroads
UMLER	Uniform machine language equipment register	Association of American Railroads
VMF	Vessel master file	U.S. Army Corps of Engineers
WCS	Waterborne commerce flow statistics	U.S. Army Corps of Engineers
WMF	Waterway master file	U.S. Army Corps of Engineers

Although the ICC data are adequate for rail flows, they could be enhanced or replaced by the TRAIN II data kept by the AAR, if the latter could be obtained. TRAIN II provides much better information because it represents 100 percent data on at least 80 percent of the rail-based shipments.

The data for water are essentially complete, especially insofar as vessel movements are concerned. The main shortcoming is that the commodity classifications are too broad. This problem could be resolved by expanding the commodity list or by adding a flag that shows whether a given shipment was a hazardous commodity.

The absence of interchangeable commodity codes is an additional and major problem. The OHMT has one set of codes, the EPA another, and there are UN/NA codes, modal codes, and codes used internally by carriers and shippers. The level of detail varies widely between one set of codes and another, and no standard officially recognized or maintained cross-reference tables have been developed.

The current status of reporting hazardous materials movement information suggests that major modifications to existing reporting practices are necessary to enable national hazardous commodity flows to be quantified. These modifications must occur at several levels, beginning with designing adequate procedures for cross-referencing, defining uniform categories of measurement, and implementing enforcement programs regarding reporting requirements and standards. This process is likely to be resource-intensive and require a considerable degree of institutional cooperation.

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Scheduling Truck Shipments of Hazardous Materials in the Presence of Curfews

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ABSTRACT

Locally imposed curfews have been considered as a mechanism for reducing risks associated with movements of hazardous materials through heavily populated areas. However, the imposition of such curfews creates scheduling problems for carriers and the need for consideration of overall policy at the state and federal levels. Simple algorithms for addressing these scheduling issues are presented; their use in doing sensitivity analysis of a hypothetical problem involving shipment of spent nuclear fuel by truck is demonstrated.

Transportation of hazardous materials is an issue of considerable public concern. This concern is most sharply focused when the materials being transported are radioactive, but a wide variety of toxic and flammable chemicals also presents varying degrees of risk to people and property. In the United States, most hazardous materials are moved by truck or rail, and these movements frequently pass through heavily populated urban areas.

The mechanisms used to reduce the risks associated with hazardous materials movements include attempts to reduce both the probability of accidents involving these shipments and the number of people potentially exposed to the consequences of an accident, should one occur. In practice, this has led to consideration of restricting hazardous materials to certain specified routes, restricting their movement during some portions of the day (e.g., rush hour), or both.

Regulation of hazardous materials transportation occurs at the local, state, and federal levels. These regulations are in many cases implemented independently, and in some cases they conflict with each other. This has led some observers and participants in the industry to criticize the hodgepodge of local regulations, while others defend the rights of local governments to control movements within their jurisdictions.

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The focus of this paper is on one important type of movement restriction: the imposition of time-of-day curfews by localities. The objective is to develop analytical tools that can be used for two basic purposes:

1. For a carrier of hazardous materials facing a particular set of curfews in specific cities, an important operational problem is to schedule shipments to minimize total transit time, including delay due to the curfews.
2. For policy analysis, it is important to be able to estimate the total delay imposed by curfews of various types in different numbers of cities in order to determine the aggregate effect of the pattern of local regulations.

Use of the models developed here for operational planning by carriers is important because en route delays imposed by curfews are clearly undesirable. Such delays increase the cost of shipment and, because they increase total time en route, they also increase some elements of risk associated with hazardous materials movement.