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Disaster planning for transportation accidents involving hazardous materials

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Abstract

Disasters from mishaps and accidents in the transportation of hazardous materials—chemical, nuclear or biological—will become more numerous and worst in the future. We indicate some reasons for this probable trend. Problems in establishing and developing preparedness planning for such kinds of disastrous occasions are then discussed on the basis of findings and observations from social science research studies. In addition, we examine some of the difficulties that exist in mounting an emergency or first response to actual crisis occasions. Particularly looked at are some typical situational contingencies in hazardous material disasters.

The nature of the problem

The problem of planning for transportation accidents involving hazardous materials has increasingly come to the fore in recent decades. Much of the preparedness involves safety measures to prevent or mitigate everyday incidents that may have dangerous effects. This certainly is important and much yet needs to be done to achieve an acceptable level of deterrence and protection.

However, in this paper we have a more selective focus. Our interest is in the more extreme and qualitatively different kinds of transportation mishaps, those that are of a disastrous or catastrophic nature. While these are substantially more infrequent than everyday accidents, their consequences are more severe, resulting in any given occasion in far greater number of deaths and injuries, property damage and destruction, and social and ecological disruptions. Thus our primary focus is on planning for disasters that may stem from crashes, wrecks, spills and the like in the transport of dangerous materials be these chemicals, nuclear matter or biological substances. An exposition is made of what is known from research about the problems associated with preparedness planning for disasters resulting from transportation accidents or mishaps.

We almost exclusively discuss the situation in the United States and Canada. This is mostly a function of the material we primarily use, that is the relevant studies done at the Disaster Research Center (DRC) of the University of Delaware in the last 15 years ([1–5]; examples and research data not otherwise referenced elsewhere are from these sources). But it is our belief that

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disaster preparedness planning issues for this kind of crisis occasion are generally the same everywhere in the world.

The general issue addressed is not a new one. However, currently we face more and worst hazardous material disasters than have occurred in the past. But bad as the situation is at the present it unfortunately will get worse in several ways.

The past

A look at the past shows that some of the worst disasters ever to hit the North American continent have involved transportation accidents of hazardous materials. For example, there was the explosion in the harbor of Halifax, Canada in 1917; two ships collided setting off a munitions explosion which destroyed a two square mile (2.6 km^2) area and killed nearly 2,000 people [6]. In Texas City, Texas in 1947 a freighter carrying 1,400 tons of ammonium nitrate fertilizer exploded after a fire broke out, followed by another ship explosion the next day, which killed 576 people and injured over 2000 [7]. In 1979 over 215,000 persons were evacuated in a suburb of Toronto, Canada as a result of a train derailment threatening a release of chlorine gas [8]. So there have been major incidents in the past.

The present

Until the last decade or so, there were a number of communities in the United States and Canada that had very low probabilities for having any kind of natural disaster impacts. However, with the development of a technologically based society, any community now that is near a railroad track, an interstate or major highway, a commercial airport, or barge/river traffic, is at risk from a hazardous material disaster, even if there are no chemical, nuclear or biotechnology plants in the vicinity.

It is fairly obvious that communities in the most industrialized and urbanized societies are at risk from incidents involving the movement of hazardous materials. But the exact magnitude of the problem is somewhat uncertain since all kinds of varying statistics are cited even in the United States where record keeping is attempted more than in many other societies. Thus, the Congressional Office of Technology Assessment found that damages from hazardous materials transportation accidents appeared to be at least 10 times higher than the annual amount reported to Congress by the U.S. Department of Transportation [9]. Nevertheless, the overall and general picture is clear, even though all the specifics are not.

For example, there are different figures just as to shipment of hazardous materials. Part of these differences in number stems from what is being counted. Thus in 1981 the National Transportation Safety Board estimated that about 250,000 shipments of hazardous materials were being made ever day, and that this amount was expected to double in 10 years [10]. In turn, the Congressional Office of Technology Assessment had estimated that over 1.5 billion tons of hazardous materials (exclusive of what is sent in pipelines which would more than double the total) are transported annually in the United States, about 60% by truck [9]. In 1989, the railroads alone carried over 1.1 million carloads of poisons, pesticides and other hazardous chemical material [11], up over previous years [12]. But measured any way, these kinds of figures indicate much of a dangerous nature is being moved around in the United States.

There is also some uncertainty about how much of these hazardous chemicals get involved in accidents. Thus, one estimate is that between 1980–1985 there were 420 million pounds (~ 108 tons) of chemical spills in in the United States, but apparently not all of this was in the process of transit [13]. On the other hand, between 1973 and 1983, more than 114,000 hazardous material accidents were reported by the U.S. Transportation Research Board; more specifically there was an annual average of 1.25 incidents per 10,000 shipments for the period indicated [14]. While these figures obviously mean that the overwhelming majority of what is shipped gets to its destination without any trouble whatsoever, nevertheless there is still a fair amount of hazardous material that never gets to its original destination in the form in which it was initially sent.

Certainly there is great potential for problems. A National Transportation Board report noted that there are at least 413,000 tank trucks which regularly transport hazardous materials in bulk [10]. In fact, even more than a decade ago the U.S. Department of Transportation has estimated that 10% of all trucks on the road at any time carry hazardous materials [15]. It is also estimated that there are about 170,000 railroad tank cars, about 10% of all freight cars [3]. The hazardous materials most often transported by rail such as liquified petroleum gas (LPG), chlorine, anhydrous ammonia and vinyl chloride are carried in tank cars with capacities of up to 42,000 gallons or 160 m^3. One review back in 1980 said that about 35% of all manifest train cargoes contain hazardous materials [15]. Single railroad companies alone reportedly move over 100,000 carloads of hazardous substances in just one given year. Between 1984 and 1988, citations by the Federal Railroad Administration against shippers and railroads for hazardous shipping violations rose from 499 to 3,575, more than a 600% increase [9]. Coastal and in-land waterborne volumes of hazardous materials reach 550 million tons annually [14]. No matter what figures are used, the potential for disastrous problems are high.

Even if we take just one specific dangerous chemical item, for instance, it can be impressive insofar as potential risk is concerned. For example, 15.7 billion gallons of liquid propane are shipped every year, around 90% of which are carried in about 25,000 tankers trucks [16]. In 1987, more than 2.36 million pounds of nitrogen tetroxide (N_2O_4), a lethal space shuttle rocket fuel, were shipped across the United States through or near Los Angeles, Dallas, Denver, Albuquerque, Tucson, and Jacksonville among other cities [17].

But it is not just the materials themselves that can be a problem–the ways they are shipped or transported can in themselves create problems or magnify the risks. For example, a special unit of state troopers in New Jersey in 1987 found after stopping 2,000 trucks carrying hazardous materials, that about 720 had to be placed out of service because the trucks were unsafe to drive. In New York State, in 1988, a survey found safety violations in 60% of 40,000 trucks examined. Similar findings were reported earlier by a U.S. Congressional committee examining the matter [18].

The future

Moreover, the situation will get worst in at least two ways. There is continuing increasing production of dangerous materials and therefore increasing transportation of them (Superfund Title III in the United States will probably reduce both somewhat, since it makes sense for plants to have dangerous substances around, but not enough to make a substantial difference). The world also has gone to having 6.5 million chemicals in 1984 from 4.5 million in 1980 (to be sure the great majority are not hazardous in any way).

In 1985 there was 12,900 tons of spent nuclear fuel to ship. By the year 2000 there will be over 47,900 metric tons to ship somewhere; in addition, there are hundreds of shipments of military generated radioactive material. This contrasts with a total of only 1,904 separate shipments of 54,000 pounds (about 25 tons) in 1979 [19] which is partly explained by the growth of commercial nuclear plants at the present time to a total of 113 in the United States out of a total of over 435 in the world.

Also some of the means of transporting hazardous materials have gotten larger. For instance, from 1960 to 1980 not only has the number of tankers doubled, but their shipping tonnage has increased sevenfold. So, increasingly, there is something bigger to spill, explode or burn on waterways. Also not only are there more trucks than ever before, but they are increasingly larger (e.g., including the advent of double trailer trucks). In addition, accidents involving trucks rose 23.4% from 1983 to 1985 from 31,628 to 39,030 [20].

The context also in which accidents can occur will present more opportunities for mass emergencies and disasters. There are simply more people, more inhabited areas, more localities to impact out there. Even if there were no increase in dangerous substances, there is a continual increase of more that can be affected. In many communities the question can be simply asked—given what is known of the community a decade ago and now, is there not more by way of housing, shopping, and office developments, that could be affected by an accident? Given all this, it is not surprising that some scenarios for an LPG explosion in or near a major port area in Southern California have projected a possible 70,000 dead and 325 million dollars of property damage [21].

Problems in preparedness planning

The best way to get a good response at a time of a disaster is to prepare ahead of time. Unfortunately, there are at least four kinds of serious problems in preparing well for hazardous materials transportation accidents. It is not that preparations cannot be made; it is that unlike in the case of other kinds of threats, the planning is relatively more difficult and complicated.

(1) In the case of hazardous materials we are really talking of multiple kinds of risks and threats. For instance, in the instance of chemicals we have reference to substances that can be liquid, gas or solid; we are talking of material that can explode, burn, asphyxiate, poison, corrode and otherwise damage and destroy property, lives or the environment. Put another way, there are multiple ways in which human and other organisms, plant life and fauna, and physical material objects can be destroyed, damaged or otherwise directly negatively affected by a dangerous chemical. In short, a chemical emergency or disaster can involve many perilous happenings unlike a typical earthquake or a volcanic eruption. The referents of the term "chemical" are multiple. So preparations and managements of many hazardous occasions have to vary, along some although not all lines, rather drastically depending on the specific chemical involved. Agents of a hazardous biological nature can also vary considerably.

(2) In the case of hazardous materials transportation incidents we are talking of something that may occur almost anywhere. Of course it is not true that the problem can arise at absolutely any place; roads and railroad tracks are at certain geographical points and locations. But unlike the estimates that can be made, e.g., about where a hurricane tidal surge will come in at a shore or bay, or what particular buildings are likely to be affected by an earthquake, it is in a real sense very difficult to develop specific models of hazardous material transportation risks. In principle it would be possible to compute traffic load, accident rates, hazardous cargos and arrive at a risk probability (see, e.g., [22]), but it is not a very practical thing to do in most cases (This does not deny that in particular communities, it is possible in a less statistical way, to undertake very educated guesses where it is probable that there will be hazardous transportation problems).

Furthermore, the risk is not only likely to appear almost anyplace, but again, unlike in the instance of many natural disaster type agents, the point of impact and the point of later consequences may be rather distant. For example, in the Crestview, Florida incident, the chlorine gas cloud drifted 28 miles (45 km) from where the train accident occurred. The radiation fallout in 1986 from the nuclear plant at Chernobyl, although not resulting from a transportation accident, also illustrates well the possible impacts far from the initial source of the disaster.

(3) Also for a variety of reasons, transportation accidents are more likely to occur in either localities that are less well prepared than others (e.g., in rural

or semi-rural areas that because of financial and other circumstances are less likely to have good emergency preparedness and response capabilities for any kind of emergency and disaster), or in localities that are often in very complicated legal jurisdictions (the extreme would be harbors and airports, but this also applies to railroad yards or interstate highways that are often both formally and informally the responsibilities of more than one local emergency agency—e.g. city police, county police, the sheriff's department, the state police, private security forces, etc). In fact, the tendency to build nuclear, chemical and other industrial plants away from residential and other of commercial areas, while highly laudable from one point of view, frequently means they are located in geographic areas that have poor everyday emergency services.

(4) Increasingly so, because of the increased production, transportation and storage of hazardous substances of all kinds, natural disaster agents such as earthquakes or floods which in the past would have simply been natural disasters can now create technological disasters [23]. Train derailments, for example, have followed earthquakes. Floods have spread hazardous chemicals. The convergence of a tornado and a radiologically active cloud could pose a very threatening situation. Among other things, this suggests that preparedness planning for hazardous material occasions should not be totally independent of that for other kinds of disasters.

It is also clear that for these and other reasons that planning and response to fixed compared to hazardous transportation incidents can be simpler and tend to be better.

At fixed sites, there are almost always, at least initially, only company related personnel who are knowledgeable about the chemicals or nuclear substances involved. Whereas in transportation accidents, community emergency agencies with varying and often limited knowledge of threats will be involved. Fixed site accidents generate responses specific to the particular chemical, nuclear or biological hazard involved. Transportation accidents often initially trigger general *accident* response measures rather than hazardous *disaster* responses. Emergencies in plants tend to lead to actions to contain if not to prevent the threat from developing, whereas in transportation accidents measures are mostly to protect the community. Plant accidents are almost always on private property, whereas transportation accidents while they may involve a private carrier, usually occur in what normally is viewed as a public setting. The latter are more socially visible and difficult to hide like many plant accidents are hidden. Accidents in plants often occur where there is at least some prior planning for handling emergencies while transportation accidents may or may not occur there has been much prior planning.

Finally, accidents in plants usually involve only plant personnel; transportation accidents sometime leads to automatic involvement of various governmental agencies–any significant pollution of any body of water in the United States can lead to the activation of the national contingency plan for such events and the active participation of the U.S. Coast Guard, regardless of the local and state plans and the activities of community and state agencies. Nuclear accidents and mishaps trigger an even greater involvement of non-plant social actors; in fact, they will lead to a mass convergence of organizations at all levels, from the federal to the local.

Problems in emergency responses

First, it can be noted that the importance of the initial response, at least in a chemical emergency, is widely recognized. One major chemical manufacturer produced a safety training film entitled "Those Vital First Minutes" to emphasize the necessity of proper and quick actions during the period immediately following a mishap or accident that involves chemical substances. It is often the actions taken in the first few minutes, just before a release or just following a spill, that determine whether there will be a minor nonchemical mishap or the threat or actual occurrence of a chemical disaster.

We should also note that there are relatively more problems with accidents on roads and highways than on railroads; this is because many although not all railroads in the United States have undertaken far more elaborate planning for transporting hazardous materials. Also, some estimates are that 75–90% of all incidents involving release of hazardous materials occur on highways.

Now in the abstract there are all sorts of safeguards and measures that either ought to prevent hazards from appearing or if they appear indicate their nature. Take the matter of placards about hazardous material. State enforcement officials and the police have found that 25–50% of placards on hazardous material shipments are incorrect [9]. One systematic study of trucks in the state of Virginia found that 41% of the trucks stopped for inspection were violating placard requirements for hazardous materials; either they had no placards or improper ones [24]. In an unpublished report from a railroad, its own study showed that required placards were in place on only 77% of the railcars.

However, even when placards and symbols are in place and readable after an accident, they are not automatically recognized. For one, first responders do not always note the signs that identify hazardous materials, and even if aware of them, they do not always fully understand their meaning. Also first responders seldom have easily accessible manuals or booklets that would define the symbols or indicate how they should respond to the incident acording to the type of dangerous substance, identified by the placard, that is involved. While increasingly in many American communities there are specialized "haz mat" teams with trained personnel and special equipment, they are not necessarily always the first emergency responders arriving at the disaster site.

Sometimes first responders to transportation incidents do initiate searches for invoices or other relevant papers. However, even if a search is initiated, it is sometimes difficult to find the invoices or shipping papers for the material that is being transported. Relevant papers are not always carried on the vehicle; one survey found that 23% of trucks carrying hazardous materials failed to carry required shipping papers. Shipping papers are sometimes incomplete or inaccessible. In the New Jersey state police survey mentioned earlier, they issued 900 summonses of which 40% were given to drivers whose documents did not give enough specific information on what they were carrying, their origin or destination; another 30% were for placarding violations.

Personnel from the transporting carrier are sometimes killed injured or disappear from the accident scene, thus precluding questioning by first responders. Of course, such personnel do not necessarily know exactly what type of goods the vehicle has been carrying. There have been cases in which first responders have been unintentionally misinformed by truck or train personnel about the dangerous cargoes that were being carried. Also, DRC observed situations where personnel from the carriers were sometimes reluctant (if not actually uncooperative) to provide relevant information to first responders. In addition, incorrect identification may be diffused to many others through rumor among local officials near the site of a transportation accident.

Thus, for all these reasons, first responders are frequently uncertain about the specific nature of the hazardous threat even after they suspect that the incident is more than a routine accident. It is rare, for example, in chemical emergencies that result from a transportation accident for first responders to learn quickly what they have to face. Also, frequently in accidents that involved multiple dangerous chemicals, responders learn about the range of the hazards long after the incident is over.

Given such circumstances, it is understandable that the responders often remain unclear for some time about the specific nature of the threat. They may recognize that the community is possible endangered and that some, for instance, specific chemicals may be involved but have no specific knowledge about these impressions; in fact, one estimate is that a maximum of 25% of the members of the emergency response network in the United States have received adequate training to meet a hazardous materials emergency [25]. In the face of a very unclear and uncertain threat there is likely to be a delay in doing anything.

There is also a tendency in some kinds of threat situations to overlook two important and dangerous possibilities. First, in almost all cases there is an initial overlooking of possible synergistic chemical effects, for example, the volatile reactions that will occur if water is combined with calcium carbide (ethyn gas will form) and lime in an exothermic reaction; i.e. explosion risk. First responders tend to be oriented to the existence of a single chemical agent rather than a multiple chemical agent. In many cases there are multiple not just one hazardous chemical involved. Shipments often have different chemicals with varying threats to them. In the Crestview accident, besides chlorine there were four other hazardous materials in the derailed cars.

Second, in addition, responders to transportation accidents generally do not recognize the different and various kinds of multiple hazards that might be present. Thus, if a fire is perceived or if one chemical is identified as capable of burning, this is focused on, but explosive, asphyxiating, or corrosive threats that might result from other chemicals involved in the transportation accident are overlooked.

It should also be noted that good planning cannot just stop with first responders. For example, in a survey done in 1987 in New York State it was found that only 29% of hospitals had a list of facilities in their vicinity which handled chemicals and the names of the substances used; a full 68% of emergence room staff had no official contact person to call at nearby facilities which use chemicals to find out what chemicals were released; nearly 63% of emergency room staffs had no special training to treat victims of a toxic chemical accident; only 27% were specifically prepared for a chemical accident. This also has to be seen in the context that a typical hospital can treat an average of less than 10 critically ill patients within 30 minutes of their arrival in the emergency room.

There frequently is an *ad libitum* quality to the pattern of the first response, especially in transportation accidents. Trying to clarify the situation is often a prime initial activity. Defining what is happening and what can and should be done is a large part of the early response, but such definitions are not always correct. There is often a delay in defining a transportation accident as one that has the potential to be a hazardous substance disaster. This is in part because there can be many contingencies present in a potential disaster situation.

Contingencies in emergencies

Different types of contingencies can influence the way in which a response can be handled. Here we shall selectively discuss a few situational contingencies, that is, certain specific social characteristics of the particular social context in which a hazardous material disaster first occurs. A transportation accident does not just happen; it occurs in a particular locality at some social time in the community life. If these possible variations are not taken into account in planning, there will be problems in mounting an effective and efficient response.

The location at which a disaster occurs can significantly affect the response. For example, a chemical or biological incident in North America can occur on private property, a mixed public–private setting, or a public location. There are different implications from these three possibilities. They range from the degree of knowledge about the occasion that is likely to become publically available, to the probable courses of action that responding emergency organizations will take. For example, DRC found that when chemical accidents occurred inside chemical company property, the larger community rarely found out quickly about such happening unless there were immediate casualties or fatalities. In nearly all cases DRC studied there was a delay between the time that an accident on private property was turning into a disaster and when this happening became public knowledge. Until the accident at the Three Mile Island, many internal mishaps in nuclear plants elsewhere never came to the attention of outsiders.

Another locational contingency involves the geographic and demographic setting of the hazardous occasions. For example, importantly affecting the response is whether the incident occurs in a rural or urban setting. An occasion that would have only minor consequences in a sparsely populated farming area could have potentially catastrophic consequences in a metropolitan region with high population density. Similarly, the quantity and quality of the organizational resources that could be mobilized to cope with the threat would vary considerable depending on the social location of the hazardous incident. Both of the possibilities—regarding negative consequences and relevant resources—would be true even through the inherent destructiveness of the hazardous agent might not differ in two different occasions.

Likewise, the social in contrast to the chronological time when a hazardous material disaster occurs also can have an important effect on a response. In every locality there is a rhythm to social life with certain activities ebbing and increasing in particular patterns and cycles which vary and not always directly to the time of the day, the day of the week, and the season. Thus, there are community social phenomena such as the rush hour, vacation times, weekends, and holidays which affect where people will be concentrated and what they will be doing, as well as the state of readiness of emergency organizations and how quickly relevant resources can be mobilized.

The DRC studies, for example, found that even organizations that operate on a shift basis—and most emergency groups are on a 24 hour basis—do not have either the same quantity or quality of personnel available at all times. Some chemical disasters were studied in which the organized response developed slowly because higher level officials were not immediately available because the occasion occurred outside of regular weekday working hours. In a few cases, needed equipment or goods could not be easily located and used because the organizations owning them were closed and it was difficult to find any staff with relevant information on how the resources could be obtained or who had the authority to allow their use. Again, the risks per se from the hazardous material might be identical in two crises, but because of the social time in which the incidents occur there will be rather different situations for the responders and managers to face in the two cases.

Closing comments

Finally, we should note some serious problems DRC found [26] with the Incident Command System (ICS) which is often mentioned as a model to be used in the planning for and managing of hazardous materials incidents. The Incident Command System is often used as a slogan or buzzword which seldom has all the components it is supposed to have in being where ICS is supposedly in place. The recommended shift of command from officers of lower rank to those of higher often leads to loss of information and effective management. The ICS involves primarily *intraorganizational* planning that does not provide for an interfacing or integrating of activities with relevant organizations from outside the community. The planning often gives the impression that the fire department is in charge, but this is an organization which has different degrees of legitimacy for taking overall responsibility in different communities–in some American cities there are often tense if not conflictive relationships between police and fire departments. The ICS does not encourage integration of activities with a variety of local organizations, such as the local emergence management agencies, formal and informal relief groups and organized volunteers. The use of the ICS also often creates serious problems in disasters where the impacts occur in focused, limited spatial areas because it appears to encourage an "overkill" mobilization of forces and resources. In addition, the ICS does not handle very well the intraorganizational problems of communication and coordination that are bound to surface in disaster occasions. Also, unless they are involved in its initial development, the system does not solve the problems of coordination that arise between responding units. Finally, the ICS is based upon classic command and control models of emergency management instead of coordinative and resource management models; studies suggest numerous problems with the former kinds of models [27]. Even the military has increasingly found that command and control in the classic sense is more nominal real in actual operational situations [28]. Given all these problems, there ought to be considerable caution in accepting the ICS as the model to be used for any kind of disaster situation, including transportation accidents involving hazardous materials.

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