Dangerous Goods Route Selection Criteria

by Raheem Dilgir (Vice President) Sany R. Zein (President) and
Al Popoff (Senior Transportation Engineer), Hamilton-Finn

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ABSTRACT

The movement of Dangerous Goods on the roads through a major city represents a challenge to transportation engineers, enforcement officers, and emergency response personnel. One of these challenges is the establishment of a Dangerous Goods Route network. Road safety is a key criterion in the effective selection of Dangerous Goods Routes.

Incorporating safety in the designation of a Dangerous Goods Route Network will be demonstrated using the City of Calgary's network as an example. A research project was conducted in 2003 by Hamilton-Finn for the Centre of Transportation Engineering and Planning (C-TEP) in cooperation with the City of Calgary, to:

- Establish criteria for the selection of dangerous goods routes;
- Review the adequacy of the current network; and
- Identify changes and upgrades using a transparent and repeatable process.

The criteria established for the selection of Dangerous Goods Routes can be equally applicable for other cities in Canada, with minor modifications for local conditions.

The review included the latest research from Europe, Canada and the United States on Dangerous Goods roads transport, and particularly the research related to route selection criteria and methods.

The City of Calgary's existing Dangerous Goods road network was reviewed and discussed with City staff. The City's requirements or expectations from an upgraded Dangerous Goods road network were established. A "what if" scenario analysis was also conducted, examining the alternatives when a designated Dangerous Goods route is blocked due to an emergency, and traffic needs to be diverted.

A new set of criteria and decision support system were established to allow the City to select a logical Dangerous Goods route network using objective, transparent and repeatable measures. Some of the core safety criteria include:

- Minimum crash frequency;
- Insurance premium implications; and
- Catastrophe minimization.

A combination of these and several non-safety criteria form a practical decision support system for the City. An example of the application of the decision support system will be demonstrated. Using the new criteria and decision support system opportunities for changes or upgrades to the City's existing Dangerous Goods network were identified. These included adding/deleting/confirming routes, and suggestions to physically upgrade existing roads to meet dangerous goods designation criteria.

In summary, the movement of Dangerous Goods represents a relatively high-risk road transportation operation, and crashes involving trucks carrying dangerous goods could be catastrophic to the road system and to the surrounding environment. Road safety and public exposure to risk are among the main criteria used in establishing a Dangerous Goods route network.

TEXT

Urban transportation planners are increasingly aware of the magnitude and importance of urban goods movements, truck route systems, and dangerous goods routes. Transportation Engineers work with other disciplines such as police and emergency response personnel to meet the challenges to move dangerous goods safely and efficiently through urban municipalities. There is a growing awareness and concern by the public about the potential accidents or incidents involving hazardous materials (The terms *dangerous goods* and *hazardous material* are used interchangeably).

Dangerous goods routes (DGR) are commonly established to improve public safety. Limiting the movement of dangerous goods to a given route may result in a concentration of risks to certain areas. The routes selected for transporting hazardous materials can affect the amount of risk exposure to the surrounding population and environment. In addition to imposing risk on a select group of people and geographic regions, certain routes may exhibit a higher probability of an accident, due to geometric configuration, weather conditions or other characteristics resulting in the release of hazardous substances.

Road safety is a key criterion in the effective selection and management of dangerous goods routes. The Centre of Transportation Engineering and Planning (C-TEP) located at the University of Calgary, has initiated a research project to determine how to incorporate safety in the designation of a dangerous goods route network. The project will be conducted by Hamilton-Finn in cooperation with the City of Calgary. A need has been identified by the City staff to:

- Establish a new set of criteria to minimize risk of spills on dangerous goods routes;
- Review the adequacy of the current DGR network;
- Identify potential changes and upgrades to the DGR's, using a transparent and repeatable process;
- Develop "what if" scenarios to examine the alternatives to divert traffic when a DGR is blocked due to an emergency;
- Study the issue of high loads and vertical clearances on the network; and;
- Document the implications of allowing new high density developments along designated dangerous goods routes.

The criteria and process established for the selection of DGR's in the study will be equally applicable to other cities in Alberta, with minor modification for local conditions.

What are Dangerous Goods?

The Federal Government passed the Dangerous Goods Act in 1980 to provide uniform definitions of hazardous materials and regulate their movement on those modes which are under Federal jurisdiction. The Province of Alberta passed a Transportation of Dangerous Goods Control Act in 1982 regulates the movement of dangerous goods on provincial roadways.

There are nine major dangerous goods classifications:

Class 1– Explosives (dynamite, caps)
2– Gases (propane, anhydrous ammonia, chlorine, oxygen)
3– Flammable Liquids (gasoline, oil, tars, diesel, kerosene)
4– Flammable Solids (plastics, asphalt shingles)
5– Oxidizing Substances (peroxides)
6– Poisonous and infectious substances (herbicides, pesticide)
7– Radioactive materials
8– Corrosives (acids)
9– Miscellaneous (PCB's, dangerous wastes)

All of the above categories are widely, produced, used, stored, and transported in large urban areas. Each classification and related sub classifications have prescribed placards that must be displayed on the outside of trucks transporting hazardous materials. In the event of an incident, it is important for first responders to know the nature of the dangerous material involved.

Province of Alberta

The Province of Alberta has recognized the importance of having in place workable truck route systems for the movement of goods in urban areas. A 1980 study[1] by the University of Calgary found that the urban goods movement accounted for approximately 50 percent of the total freight bill. The study showed that there was a need for provincial agencies to become more actively involved in assisting municipalities regarding truck routes and that better data was needed about urban goods movement so that urban transportation studies could go into more depth when doing truck route analysis. Uniform infrastructure standards and enforcement measures needed to be applied provincially. The study also recommended that Alberta Transportation develop an innovative technology program and take the lead role in handling the dangerous goods problem.

A 1983 study[2] had the objective to explore the potential for developing uniformity in truck route planning and enforcement for the twelve cities in the province. The study found little uniformity between the cities as to truck route planning and management. The report recommended increased urban goods movement planning, improved forecasting methods, increased expenditures in planning, uniform definitions of heavy trucks, standardization of bylaws and enforcement, improved permitting and route signing.

In July, 2002, Alberta Transportation published *Guidelines for the Establishment of Dangerous Goods Routes in Alberta Municipalities.*[3]*.* The material is meant to be a guide to certain sections of the Transportation of Dangerous Goods Regulations. Municipalities may pass bylaws to govern the movement of dangerous goods in their own jurisdiction. The guidelines can assist municipalities to produce a sensible dangerous goods routing bylaw to enhance public safety. Bylaws require provincial approval to ensure consistency and that the bylaw does not impede the transportation system. The 21 page document provides non-technical information to lead municipal officials through a logical process to produce a workable DGR and an enforceable bylaw. To date Provincial officials have received limited feedback from municipalities on the published guidelines for establishing dangerous goods regulations.

The City of Calgary

The City of Calgary[4] has a roadway network of 3500 kilometres of which 400 kilometres are defined as truck routes and 200 square kilometers are designated unrestricted truck zones. There are 170 kilometers of truck routes designated as dangerous goods routes. The first dangerous goods routes were established in 1979 and have worked reasonably well.

To establish the initial DGR, a multidisciplinary committee gave attention to the following factors:

- Traffic volume (including a breakdown by vehicle type);
- Current accident rate;
- Roadway classification;
- Adjacent land uses (residential development, high occupancy sites such as schools and hospitals);
- Surface and sewer drainage;
- Response capabilities of emergency personnel, and;
- Forecast of primary goods that will be transported.

In 1989 public and City Council concerns developed over some segments of the dangerous goods routes. This necessitated a more in-depth analysis of the safety of the routes.

Incidents involving vehicles transporting dangerous goods on city streets is extremely low and it is not possible to draw any direct conclusions from that data. The City therefore developed a method to assess risk to vehicles transporting dangerous goods. It was assumed that that all traffic would be exposed to similar risks in terms of their involvement in a collision. The City gathered information about the number of vehicles that were transporting dangerous goods along a given route, to supplement the available traffic volumes and traffic accident data

A simple formula was developed to establish the percent of traffic that was carrying dangerous goods which was used to determine the probability of any accident based on the known accident rate.

$$\text{Probability of DG collision} = \frac{\text{No. of placarded vehicles}}{\text{total vehicle count}} (\text{total accident rate})$$

For the purposes of the analysis 1 in 100,000,000 was used as an acceptable rate of probability of a truck carrying hazardous material being involved in a collision. If any location did not meet the criteria, it was examined to determine if the probability could be reduced by engineering solutions. The process identified areas that needed to be reviewed in terms of overall traffic safety and prioritized areas that require more in-depth risk analysis to determine the risk of a spill and the logistics of dealing with the emergency.

The City of Calgary has Bylaw 60M90 that governs truck routes. The bylaw defines the various truck routes, restrictions, and types of trucks. The entrances to the City (near city limits) have truck turnouts and roadside signs that provide truck route information about the movement of dangerous goods in the City.

Applying ITS Technology

Intelligent Transportation Systems (ITS) can enhance the safe transport of hazardous materials. These advanced technologies include vehicle control and driver information systems, heavy vehicle detection systems, and driver/vehicle performance monitoring systems. These systems can provide valuable information to aid in the safe transport of hazardous materials while en route.

A recent study[5] had as its' objective to present the most effective Advanced Transport Technologies (ATT) applicable in hazardous materials fleet management in terms of cost reduction, improvements of levels of service, minimizing of transportation risk, and improvement of drivers' working conditions and safety.

The main categories of Advanced Transport Telematics for hazardous materials fleet management are:

- Automatic Vehicle Location – vehicle location known in real time;
- Mobile Communication Systems – two way data and voice transmission between driver and dispatcher;
- On-Board Computers – store information related business transactions, location of the vehicle, service hours;
- Routing and Dispatching software – supports the selection of minimum cost routes and the optimum assignment of drivers;
- Vehicle Condition Monitoring – monitor the condition of the vehicle and shipment.

The study developed benefit cost ratios for the above various ATT's. A major finding was that Vehicle Condition Monitoring systems are the most cost/effective ATT technology.

NCHRP Synthesis 261[6] found in their survey that while ITS/ATT applications have potential applications over the next decade to improve the safety of hazardous goods movement, many, like collision avoidance systems, are primarily in the development stage. Lindquist's[7] review reached similar conclusions, namely that there are many potential uses for ITS in the area of hazardous material transport, regulation, incident response, hazard mitigation and risk reduction, but much more work can and should be conducted in the area of technology and risk. Boghani[8] also found that advanced technologies are not the only answer to safety problems. Additional needed improvements include enhanced routing, greater control over allowable travel time, and better training of transportation personnel.

An ITS technology that may have an application to the Calgary study is to use variable message signs at strategic locations to manage traffic in the event of a major spill or road blockage.

A Geographic Information System (GIS) is a collection of information technology, data, and procedures for collecting, storing, manipulating, analyzing, and presenting maps and descriptive information about features that can be presented on maps. GIS is an important tool for solving transportation problems because it can manipulate large quantities of data and present results in a wide range of graphical formats.

Various types of geographical information systems are used by many urban areas and may be a good platform to plan dangerous goods routes. The application of GIS to assess the risks of highway hazardous materials transportation in Arizona[9] was used to demonstrate that vulnerable segments in a state-wide highway system can be identified.

Assessment of Risk

The assessment of risk in the selection of routes in a network along which to transport hazardous materials, takes into consideration the length of time in transit, the probability of a collision and the risk of population exposure in the event of an incident. There are a variety of theories, perspectives, approaches and algorithms that have been put forward to solve multi-objective problems for determining the best routes to transport hazardous substances.

While it is simple to list potential factors that can influence routing decisions such as population density, facility type, material to be shipped, and exposure, the challenge is to convert these factors into specific measurable criteria to apply to specific links in a network and then develop algorithms which can use the estimates to identify the best (safest) routes.

Risk assessment[10] is a process of evaluating the potential consequences resulting from certain events and the probabilities that these consequences will be realized. Risk is governed by incident frequency and incident severity. Quantitative risk assessments can provide information to actively manage risk and to identify and prioritize technology needs and decision making, and provide decision analyses evaluating regulatory alternatives.

Saccommanno[11] has used an interactive model that computes minimum-risk routes in Toronto for the shipment of chlorine. The model developed different routing based on specific strategies such as minimum costs, minimum accident rate, minimum spill damage potential and minimum risk exposure. Bercha and Morrall[12] have applied risk management theory in a number of Canadian studies.

European countries have been actively researching risk assessment models. Much of the interest arose after serious hazardous material incidents in long tunnels. A Quantitative Risk Assessment (QRA) model and a Decision Support Model (DSM) have been developed as working tools[13]. Considerable effort is needed for input data collections which are rarely available in the required format or detail.

Risk is characterized by two aspects:

- Occurrence probability of an event; and,
- Consequences of an occurring event.

Quantification of risk is difficult because probabilities for traffic accidents are low and those involving dangerous goods are even lower, but the consequences of the latter can be enormous.

A Canadian study[14] examined the motorway network on Montreal Island and applied calculation methods used by the insurance companies' probabilistic methods covering a number of risk factors ranging from geometric variables to traffic conditions. Each potentially critical site is weighted according to the likelihood of various risks arising and the impact of such risks.

The method used by insurance companies to calculate premiums is to multiply the cost of compensating for damage by the probability of such damage occurring. As an analogy, the ranking of a road risk as a probability and the ranking of it's risk as a cost in dollars. Twenty four road risks were considered:

- Airplane accidents, railway accidents and road accidents
- Road blockades, adverse weather conditions,
- spills of hazardous materials, rock slides, cave-ins, ice jams, erosion, fire,
- flooding, bridge and dam failures, earthquakes, emergencies in buildings,
- Collapse of high voltage lines, natural gas, interruptions to ship traffic;
- Avalanches and nuclear accidents.

Each sites' strategic ranking is a qualitative assessment of the probability that the risks will occur; the duration of the intervention and the impact should the strategic site be lost.

Rank	Criteria	Mean Rating
I	Population density	3.47
2	Location of special populations (schools, etc.)	3.27
3	Accident history	3.00
4	Type of highway	2.93
5	Availability of alternate routes	2.80
6	Type and quantity of hazardous material	2.73
7	Underpass and bridge clearances	2.67
8	Capability of ER teams to contain/suppress releases	2.60
9	Through Routing	2.53
10	Relative impact zone & risks of each type and quantity	2.50
11	Roadway geometric design elements	2.47
12	Congestion	2.47
13	Vehicle weight and size limits	2.40
14	Location of sensitive environments	2.40
15	Proximity of emergency response facilities	2.40
16	Effects on commerce	2.20
17	Degree of access control	2.13
18	Number of lanes	2.07
19	Terrain considerations	1.60
20	Property value risk analysis	1.53
21	Cost to transporter	1.47
22	Median and shoulder structures	1.37
23	Climate considerations	1.27
24	Highway drainage system	0.97

Risk assessment is an appropriate tool to develop an optimal road network for the transport of hazardous material. The challenge is to find workable models that can be integrated with existing geographic Information Systems. Much of the risk assessment work to date is either at the research or experimental level, requires extensive data or is more applicable to larger regional road networks level.

The methodology used in Montreal may be applicable to assess risk for an urban DGR network like Calgary.

Route Selection Criteria

The NCHRP Synthesis 261, *Criteria for Highway Routing of Hazardous Materials, 1998,* identifies how states designate highway routes for the transport of hazardous material. Relative importance of 24 routing criteria are summarized below:

Mean rating: 0 = not important 1 = somewhat important 2 = important
3 = very important 4 = critical

The ranking was carried out by state officials and reflect rural conditions over a large network. An urban survey may have some changes in the emphasis and ranking.

The Safety Issue

A United States study[15] found that on a national basis, the estimated non-hazmat accident rate is more than twice the hazmat tuck accident rate. Further research is needed to understand the meaning of this disparity. It may be that the hazardous material truck accident rate is lower due to better training, equipment and driver selection, as well as greater care due to regulations and the inherent risk associated with the material being transported. It is encouraging that the considerable efforts and costs to provide a high level of safety for the movement of dangerous goods indicate positive results.

The Edmonton Truck Route Study[16] showed that although trucks compose 5 percent of all vehicles, they accounted for fewer than 2 percent of accidents between 1992 and 1994. The truck accident rate was found to be 1.5 accidents per million kilometers of travel which is seven times lower than the comparable automobile rate. It is good news to know that the programs and measures taken to improve truck safety seem to be working. The superior safety record for large trucks may be the fact that they operate in most part on roadway network that has a high degree of safety built into the roadway. In urban areas this can be thought of as truck routes that usually follow the major traffic arteries designed to move traffic more safely and efficiently than collector and local streets. In the same context, dangerous goods routes are normally designated to take advantage of the safest roads available in a community.

It is important to minimize the likelihood that a truck carrying hazardous materials will be involved in a collision that may result in a spill of a dangerous material. This can be achieved by choosing safe routes and making safety improvements on those routes. Traffic safety management tools such as in-service road safety audits can be employed to identify collision prone locations and the appropriate corrective measures;

In the event of a spill of hazardous materials the consequences of the event need to be reduced by a quick response of trained emergency personnel to contain the spill and to evacuate the area if necessary.

A major spill of hazardous materials may close a major traffic route. Contingency plans are necessary to reroute traffic. Trucks carrying dangerous goods need to be directed to the next safest route.

Benefits to Alberta

The following phases will complete this research project:

- Expert interviews and discussions with leading researchers to obtain their latest thoughts about the routing of dangerous goods in large cities;
- Establishment of new criteria and a decision support system. The core criteria is expected to include minimum population exposure, minimum crash frequency, minimum travel distance and catastrophe minimization;
- Identification of upgrade opportunities to the Calgary dangerous goods route system, using the new criteria and decision support system. This phase may include suggestions to physically upgrade existing roads to meet the dangerous goods designation criteria; and,
- Explore the potential for auxiliary “shadow” dangerous goods routes that can be activated by the police when an emergency occurs on the primary dangerous goods route.

The benefits of this research project to Alberta include:

- Recommendations to improve the dangerous goods route network through Calgary, Alberta’s largest City and its main economic base. The recommendations should result I increased road efficiency and safety and public safety;

- A system will be available for objectively establishing a dangerous goods route network that other Alberta communities could adopt, perhaps with minor modifications to suit local conditions. The primary characteristics of this system will be transparency and repeatability. The basis for the system will be logical criteria that balance public safety with dangerous goods mobility.
- A contribution to Alberta's knowledge of the state-of-the-art related to dangerous goods route selection and methods to minimize risk

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