A Practical Low Cost Semi – Quantitative Method for Road Risk Assessments for Conveying Hazardous Chemicals

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The conveyance of hazardous chemicals by road for long distances is a common activity in most countries. In South Africa, where there is a large range of different environments along the road boundaries, there are varying risks from a vehicle incident depending on the nature of the incident and the type of environment along the road.. The need for road risk assessment (RRA) has often arisen from EIAs (Environmental Impact Assessments) for new projects. Two questions require to be answered in road risk assessments:

- Are there any unacceptable risk levels anywhere along the route?
- Amongst alternatives, which is the safest route amongst alternatives to deliver hazardous raw materials or products?

To meet a need for a quick, low cost and practical answer to a number of requests for transport risk assessments, the author and another experienced chemical engineer, Debra Mitchell, worked together to develop novel methodology to carry out semi-quantitative modelling for road risk assessments. This has been successfully applied to a number of applications.

The methodology combines the basic approach taken for major hazard analysis and the actual road route conditions / surrounding land use. The route is divided into zones adjacent to the route under evaluation using the HSE (UK) vulnerability rankings. Typical release scenarios are developed for the vehicles / type of hazardous substance. A series of "static" release models are developed for the different land types adjacent to the road and release mechanism. A picture of the changing risk profile can then be built up for the route. The capability of the local emergency services is built into the profile. Comparison of two or more routes is aided by the risk assessments although other information is added for evaluation as well. The method has been used in the Cape area and the route from Pretoria to the diamond mines in Botswana. Hazardous substances have included hydrofluoric acid, nitric acid and chlorine. Results have been well received by clients, authorities and "interested and affected" people going to public meetings.

The semi – quantitative methodology is quick, relatively cheap but does rely on judgements by experienced people. In the paper more details will be given of the methodology and actual applications will be illustrated

KEYWORDS: Risk Assessment, Road Transport, Emergency Planning, Major Hazards

Introduction

The conveyance of hazardous chemicals by road for long distances is a common activity in most countries including South Africa. Many incidents have occurred which have led to release of toxic substances, fire or an explosion. Whilst the risks posed by major hazard installations in fixed plant are covered by legislation (Major Hazards Installations Regulations 2003) there is no such specific legislation for the transport of hazardous chemicals. There have been several requests from companies manufacturing and supplying hazardous chemicals to carry out a "road risk assessment" to try and dimension the risk posed the transportation of hazardous chemicals. This need has often arisen from Environmental Impact Assessments (EIAs) for new projects.

Origins of the need for Road Risk Assessments (RRA)

In one case a major Botswana diamond company requested a RRA as part of the company's assessment of risks associated with all its operations.

As part of an EIA for a new chlorine depot 80 km from Cape Town a quantified RRA was requested by the company carrying out the EIA. The new depot means that the delivery of bulk chlorine from Gauteng (1400 km away) has to follow new routes. The delivery routes to customers in the Western Cape would also change with material being delivered from the new Depot. There are options of different routes for delivery of bulk to the depot and delivery of cylinders and bulk tanks to Western Cape customers.

A further RRA was requested as part of an EIA for the impact of a proposed new chlorine production plant at Saldhana Bay some 80 km north of the depot which is now in operation. The routes to be assessed included receipt and despatch of bulk chlorine to and from Johannesburg and despatch of chlorine to the depot.

Differences between Transport Hazards and Fixed Plant Hazards

There are significant differences between transport and fixed plant hazards. The main differences are:

- There is a large amount of kinetic energy in the vehicle carrying the hazardous material as well as in other vehicles on the road.
- The transport environment is subject to far less management control against a variety of external threats compared to that of a fixed plant.
- There is a great variety of locations that the vehicle may pass through with varying concentrations of exposed people.
- The environments through which the vehicle may pass may change over a period of months. In particular, informal housing may spring up with no notice.
- Emergency response is much more difficult due to:

- Responsibility is not vested with only one municipal district / emergency service and command structures may be complex / confusing
- There is an added delay in response time due to the distance that needs to be covered to reach the scene of the incident
- The location of an incident cannot be predicted so planning is very generic e.g. unknowns will be what approach roads are available, resources such as water available in the area, population in the area.

Applicable South African Legislation

Major Hazard Installation Regulations

The MHI Regulations do not apply to the transport of hazardous materials. However the principles behind the Regulations and in particular the consequence modelling of hazardous events can, in principle, be applied to transport situations. If the individual or societal risks of transportation are calculated they can be compared to accepted criteria used in MHI assessments to decide on acceptability of the risk. The Major Hazard Installation Regulations falling under the Occupational Health and Safety Act of 1993, were promulgated on 16 January 1998. Although these regulations were revised in July 2001, the fundamental requirements remain in force.

National Road Traffic Act

The National Road Traffic Act (1996) deals with the transportation of dangerous goods and applies to the transportation of chlorine to Atlantis and from Atlantis to customers. A number of standard specifications issued by the South African Bureau of Standards (SABS) have been incorporated into the Act. These cover a variety of design issues, classification of dangerous goods, vehicle inspection requirements, operational requirements, and emergencies.

In Chapter 8 of the Act Transport of Dangerous Goods and Substances by road", the only reference to road routes is that "Routes need to be pre-planned and co-ordinated with relevant authorities for certain substances"

Methodology

Main Steps

1. A preliminary consequence analysis is required to provide an estimate of what distance from the road would be of interest in the practical aspect of the work where the population density needs to be estimated. The distances of interest depend primarily on the substances being studied and the release characteristics.
2. A practical aspect where the actual routes were driven, meetings and discussions were held with the suppliers and local emergency services regarding routes, procedures etc. Some of this data was used in the following quantitative risk assessment but was also used to provide a qualitative more 'hands-on' assessment of the risks.
3. A theoretical element where computer simulations of the possible consequences of hazardous substance (chlorine as an example) releases from typical accident scenarios were undertaken as well as statistical work on the likelihood of traffic accidents and the various possible results. This data was combined to give a quantitative estimation of the risks associated with the various routes and sections
4. The risk of using an individual route or a comparison of routes can be made taking into account information gathered and collected in Steps 1-3 and other relevant qualitative factors.

Preliminary Consequence Analysis

In the three studies carried out the following hazardous substances were to be transported:

- Chlorine (liquid under pressure)
- Hydrofluoric acid (70%)
- Nitric acid (60%)

Preliminary modelling of the consequences of an escape of the substances showed that the distance of interest either side of the road being used was:

- Chlorine - 1 kilometre
- Hydrofluoric acid (70%) – 5 kilometres
- Nitric acid (60%) – 500 meters

Driving of the Actual / Proposed Delivery Routes and Discussion with Services

Meetings were held with the suppliers and transporters of the hazardous materials to establish:

- Actual routes being used and reasons for that choice
- Possible alternative routes
- Type of container and vehicle being used

- Incident / accident history
- Latest substance information (SDSs etc.)

Before driving the routes, maps were studied to understand the road system. Some major aspects of importance like schools, hospitals, mountain passes etc. were also identified at this point.

Google maps were then studied to identify other features not displayed on maps. As the study distance for hydrofluoric acid was 5 kilometres, it was useful to understand what features were present within this distance and plan to observe them when the actual route was physically driven.

Two people carried out the physical analysis of the route – a driver and an observer / scribe. Distance was measured using the car's odometer. This was felt to be accurate enough for the road risk assessment. Observations were made using both binoculars and unaided eyesight. Judgement was exercised in deciding where the 1 and 5 km distances ended.

The following were noted on the actual routes:

- Road
    - Single / double / multiple carriageway
    - Road material / condition
    - Steep sections / mountain passes / sharp bends
    - General traffic conditions
    - Intersections with heavy traffic
    - Lighting for delivering "after dark"
- Features within the calculated distances for a gas cloud
    - Typical type of habitation / land use and population density
    - Wetlands
    - Type of agriculture
    - Schools, hospitals, prisons
    - Areas prone to flooding / fog
    - Towns / cities through which the load would be moved

The observer recorded all the information in draft format. Land use (population density) was recorded using the following table:

Table 1. Categories of Land Use

TYPE OF ACTIVITY	POPULATION DENSITY	VULNERABILITY OF POPULATION
Agricultural / open land	Very low	Moderate vulnerability due to low population density but offset by outdoor occupation affording little protection
Commercial buildings / industrial sites	Moderate	Low vulnerability due to able bodied persons with largely indoors occupation
Residential areas / suburban single dwellings	Moderate	Moderate vulnerability due to largely indoors but with children and elderly persons present
High density formal housing / suburban complexes including hospitals, schools etc.	High	High vulnerability due to high population density and large numbers of infirm persons
High density informal housing / squatter camps	High	High vulnerability due to very high population density and shelters that provides little protection
Long road tunnels	High	High vulnerability due to limited escape routes, limited shelter facilities, limited fresh air ventilation, limited emergency response routes

Observations were found to be easily made as there is much farmland / bush along the routes and that dense population areas are reasonably clearly defined.

Examples of route analyses are shown later in the article.

Consequence Analysis

Typical Causes of Releases Related to Transport (Chlorine example)

- Inadequate design / construction of the road tankers
- Inadequate maintenance to correct defects, wear and tear etc.
- Inadequate operation such as overfilling
- Damage due to fire on or around the vehicle
- Damage due to impact in a traffic accident
- Sabotage, hijacking or vandalism
- Freak accidents such as bridge collapse, floods, aircraft crash, earthquakes etc.
- Failure of preventative systems through human or management systems errors
- Failure of the protective / mitigating systems through human and procedural errors e.g. incorrect emergency recovery procedures

Selection of Incidents for the Transport Risk Assessment

Three scenarios are generally considered for the Studies

- Small hole on container releasing liquid (10mm)
- Large hole on container releasing liquid (50mm)
- Catastrophic failure – complete rupture

Two aspects of the loss of containment need to be considered for estimation of the magnitude of the release. These aspects are the rate of release and the duration of the release. The release scenarios were modelled using PHAST/SAFETI (version 6.53.1)

Likelihood of Hazardous Events

The likelihood of events was based on historic data on past events and some processing of the data. The predicted frequencies have also been tempered with common sense. The data used was essentially generic data from international data sources and road traffic accident data from the Department of Transport. Data was also obtained from the Automobile Association and specialised studies on the main N3 Toll Road from Durban to Johannesburg. The net position is that higher accident rates are experienced in South Africa than most Western countries.

In a transport risk assessment the hazard passes past a particular point on route and the therefore the hazard is transient. In transport risk assessments account needs to be taken of the fact that each person along the route is only exposed for a short period of time.

Using hydrofluoric acid and nitric acid as examples it was concluded that the distances of interest were 2500m for HF and 50m for HNO_3 respectively for downwind of a release. The route was therefore considered in independent segments of 2500m/50m and all transport data and risks were related to a hypothetical 2500m/50m section of the route. So, for example, accident statistics were converted into a likelihood of an accident in 2500m/50m.

A history of rates of failure of tankers has been developed around the world. The rates of failure due to design, construction, maintenance and operations issues is very low and is in the region of 1 failure per million years of operation per tanker. This low likelihood plus the fact that the tanker is only in the each 2500m/50m segments for 120seconds/3 seconds results in an extremely low risk which can be ignored. The more likely event is a road traffic accident resulting in some type of release.

Road Traffic Accidents

Data from the Department of Transport relates to simple average road traffic accident rates. This has to be interpreted and correlated to other information to get:

- A heavy vehicle accident rate
- A chemical vehicle accident rate
- A rate of a chemical vehicle accident involving an actual spill
- Then, for HF only, a rate for a vehicle designed to pressure vessel standards involved in an accident that leads to an actual release
- Then for the various sizes of spills that could result
- Lastly for each of the various types of roads involved e.g. country roads, congested highways etc.

There is no data for high accident zones, steep hills, mist and flooded areas and dangerous intersections. A qualitative assessment has to be made of these aspects. The table below shows a summary of the key data.

Table 2. Summary of Road Traffic Accident rates used in Studies

TYPE OF ROAD	ACCIDENT RATE Incident per chemical transport vehicle kilometre	SPILL RATE Spills per chemical transport vehicle kilometre	RELEASE RATE Release per pressurized gas transport vehicle kilometre	SOURCE OF DATA
Congested and complex highway (e.g. N3 from Durban to Howick, N3 and N1 ring road around Joburg, R24 main road through Krugersdorp)	5.5E-05	3.5E-06	1.8E-07	Midland Incident management data (1996 N3 Midlands - high hazard road)
National highway (e.g. N3 from Howick to Nigel or N4 through Rustenburg, N14)	1.1E-05	7.0E-07	3.5E-08	Midland Incident management data (1996 N3 Berg - low hazard road)
Country Roads (e.g. Route N4, R24 outside Krugersdorp),	4.1E-06	3.0E-07	1.5E-08	DoT data 2007 (and Pietermaritzburg F&E spill to accident ratio) AA Transport Report 1998 accident data Tanker services Data 2001 Natal spill data

The ratio of small events to large events was based on international literature and is shown in the table below:

Table 3 – Percentage of releases in different size categories

RELEASE SIZE	% RELEASES IN SIZE CATEGORY
Small releases	75%
Medium releases	20%
Catastrophic events	5%

Risk Levels

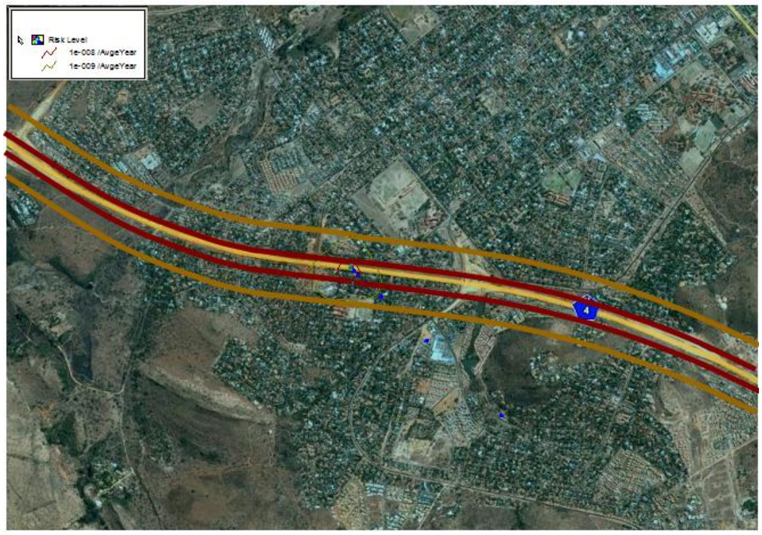
Risk Estimation

Individual risk and societal risk were calculated for the routes. For each of the release events the overall risk was determined by combining the likelihoods and consequences for each road segment. Together these values indicate a risk level to which hypothetical individuals adjacent the route could be exposed as a result of the transport of the hazardous chemical. The units are typically of the order of one chance in a million of death per person per year. At each point the along the route, i.e. for each 2500m/50m segment the risks could be viewed as risk contours around the central point. The map below shows how far certain risks extend or whether the one in a million risk contour extends over certain schools or hospitals etc.

Figure 1. Individual Risk Contours for nitric acid through central Krugersdorp

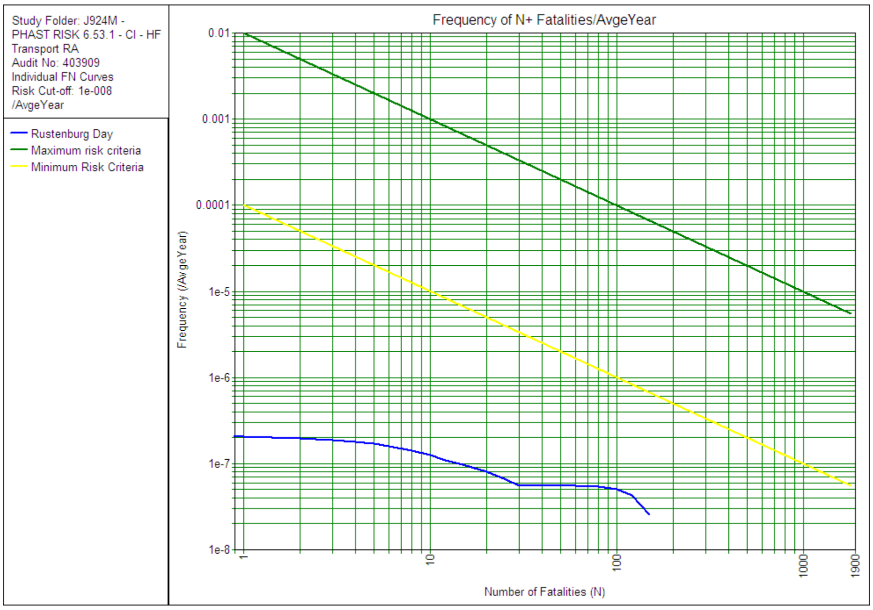
Joining all the 2500m segments together shows the outer edges of the risk contours as parallel lines adjacent to the roads at a particular section of the route.

Figure 2. HF Risk Contours on part of the N4 Highway



Societal risk guidelines from the UK HSE were used in the calculations. The guidelines state that no more than 50 persons can be fatally affected by site accidents more often than once in 5000 years. F – N curves were calculated for HF and nitric acid toxic release at a high population density along each route The Figure below illustrate this:

Figure 3. Societal Risk for the N4 Highway through Rustenburg



Risk Acceptability

There is are no agreed or legislated numerical criteria applicable in South Africa. Over some years the use of the UK HSE's criteria has gained acceptance by the South African authorities.

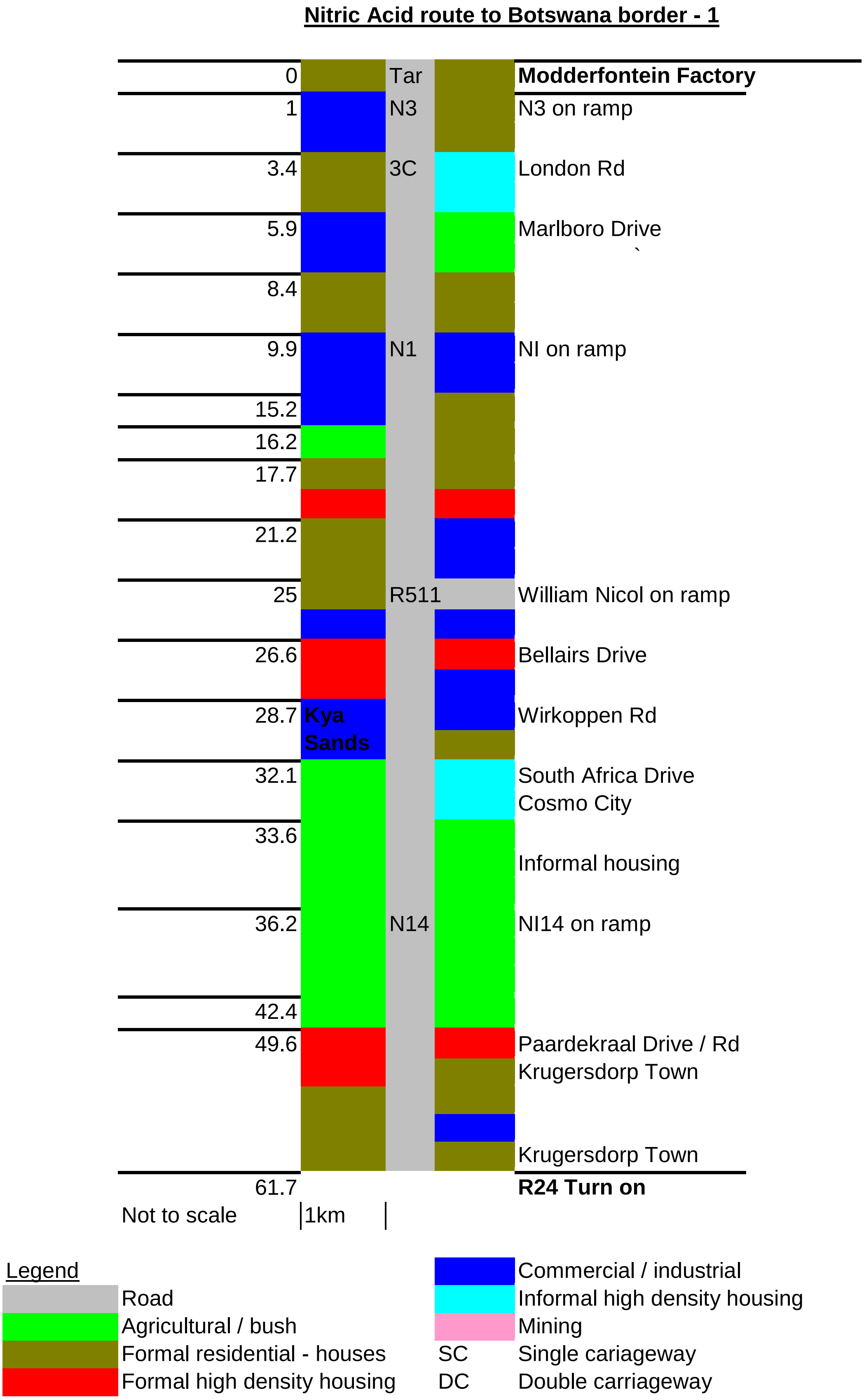
In residential areas, a public risk level of 10^{-6} chances of death per year (10^{-6} d/p/y = one in a million chances of death in one year) is accepted in the UK as being broadly acceptable. In the UK public risk levels in excess of 10-4 d/p/y are considered to be unacceptable and immediate attention should be given to reducing the risk. In the region between 10^{-4} and 10^{-6} risks are tolerable but subject to the ALARP requirements. In industrial areas risks should be similarly low. It has been argued that the risk to employees of an adjacent fixed industrial installation should be below $1x10^{-5}$ d/p/y.

Higher societal risks are related to higher population densities. The greatest societal risk is likely to occur on the roads that have the highest accident rate combined with the highest population density.

Case Study: Individual Risks of Supply of Hydrofluoric Acid

A portion of the route for HF from Pretoria to the Botswana border is shown below.

Figure 4. Portion of the route for HF/Nitric acid from Pretoria to Botswana



The risk along the highways tends to be higher than along country roads because of the higher accident rate. Under normal conditions, there would be a slower response to incidents along country roads. The table below presents some of the risk levels at some points on the HF transportation route. It should be noted that that the residual risks are the unmitigated risks, i .e they assume a potentially exposed individual is at the location 24 hrs a day and cannot escape.

Table 4. Individual risk of the transport of Hydrofluoric Acid

LOCATION	INDIVIDUAL RISK LEVEL (per million or cpm)	ASSESSMENT PER UK HSE CRITERIA	CAUSES OF RESIDUAL RISK
Supply of 70% Hydrofluoric Acid along congested sections with complex driving conditions			
Other road users	0.017	Acceptably low	▪ Large liquid puncture. ▪ Catastrophic rupture. ▪ Small liquid puncture.
Persons living or working immediately adjacent the road (<50m)	0.01	Acceptably low	▪ Large liquid puncture. ▪ Small liquid puncture. ▪ Catastrophic rupture.
Persons over 500m from the road	<0.0001	Negligible	▪ Large liquid puncture. ▪ Catastrophic rupture.
Supply of 70% Hydrofluoric Acid along quiet country roads			
Other road users	0.0015	Acceptably low	▪ Large liquid puncture. ▪ Catastrophic rupture. ▪ Small liquid puncture.
Persons living or working immediately adjacent the road (<50m)	<0.0001	Negligible	▪ Large liquid puncture. ▪ Small liquid puncture. ▪ Catastrophic rupture.
Persons over 500m from the road	<0.000001	Negligible	▪ Large liquid puncture. ▪ Catastrophic rupture.

From the above table the following can be concluded:

1. The risks posed by transportation of 70% hydrofluoric acid from the manufacturing site at Pelindaba (Pretoria) to the Botswana border are acceptably low, i.e. far below 1cpm.
2. Risk in the neighboroughing areas beyond 100m from any of the supply routes can be considered negligible, i.e. less than 0.01cpm and are similar to the chance of an aircraft falling out of the sky and causing fatalities on the ground.

Comparison of Alternative Routes

A desirable outcome of a Road Transport Risk Assessment is to present alternative routes and to recommend the better route based on objective analysis. When public meeting are held (legal requirement) the route options can be tabled with pros and cons including subjective factors. The ability to discuss routes as objectively as possible removes some of the emotionality associated with new route proposals. As stated, sometimes it is not possible to find genuine alternatives to an obvious route.

A study of chlorine distribution in the Cape Province allowed some interesting route comparisons to be made and a rational decision to be reached. A variety of distribution situations were evaluated. One of the interesting comparisons was the transport in 20 ton bulk tankers from the proposed new chlorine plant at Saldhana Bay (about 105 km north of Cape Town) to a common point on the N1 Highway to Johannesburg. This case is briefly discussed below.

The map below show the two major alternative routes. One is clearly a “country route” and the other makes maximum use of highways and is termed the “highway route”.

Figure 5. Chlorine distribution routes from the proposed Saldhana Bay Factory in the Western Cape

Km 0		R27		Saldanha Bay Site
Km 1		R45		Turn on to R45
		good		Fossil Park
Km 9		SC		Flying school on left
Km 30				
Km 31				Hopefield town
Km 46		R311		Turn on to R311
		Bumps		
Km 65		R311		Moorreesburg town
Km 85		Good		
Km 86		SC		Riebeeck West
Km 88				Riebeeck West
Km 91				Riebeeck West
Km 92				
Km 94				
Km 96				R46 turn off to Ceres

DISTRIBUTION ROUTES FOR CHLORINE TO JOHANNESBURG

BULK TO JOHANNESBURG (HIGHWAY)

BULK TO JOHANNESBURG (COUNTRY)

Figure 6. Country route for bulk chlorine from Saldhana Bay to N1 highway

Km 103		R46		
Km 104		SC		High Density RDP houses
Km 124		Good		Nuwekloof Pass (6km) - bends
Km 148				School on left
Km 149		Some		
Km 150		DC		Mitchells Pass (8km) - bends
Km 159				Ceres town – Commercial & Houses
Km 161		R46		Ceres town – Commercial & Houses
Km 163		Steep		Prison
Km 164		SC		
Km 172				Theronsburg Pass (5km) – bends
Km 231				Intersection with NI – 9km to Touws River

Legend	
	Farm / bush
	Formal housing – single dwelling
	Formal housing – high density
	Commercial / industrial
	Informal HD housing
	Railway
SC/DC	Single / double carriageway

(City)

to the

Km 0		R27		Saldanha Bay Site
Km 1		R45		Turn on to R45
		good		Fossil Park
Km 9		SC		Flying school on left
Km 30				
Km 31				Hopefield town
Km 46		R311		Turn on to R311
		Bumps		
Km 65				Moorreesburg town
Km 67				Moorreesburg town
Km 69		N7		Turn on to N7
Km 99		SC		Malmesbury town start
		Good		Malmesbury town
Km 103				Malmesbury town
Km 104				Malmesbury town
Km 107				Malmesbury town end
Km 138				Atlantis turn off to R304
Km 158				Dunoon
Km 159				Bothasig
Km 163				Chevron Oil refinery
Km 166		N1		N7/N1 intersection
Km 167		3 lanes		
Km 170				Karl Bremer Hospital
Km 172				
Km 185				
Km 190				R304 turn off
Km 205				
Km 210		SC		
Km 219		X X X		Huguenot tunnel – 4km
Km 258				School
Km 266				
Km 277				De Doorns
				De Doorns
Km 290				De Doorns
Km 306		bends		Hex River Pass – 6km
Km 324		SC/DC		R46 connection to NI – 9km to TR

Figure 7. Highway route for bulk chlorine from Saldhana Bay N1 Highway

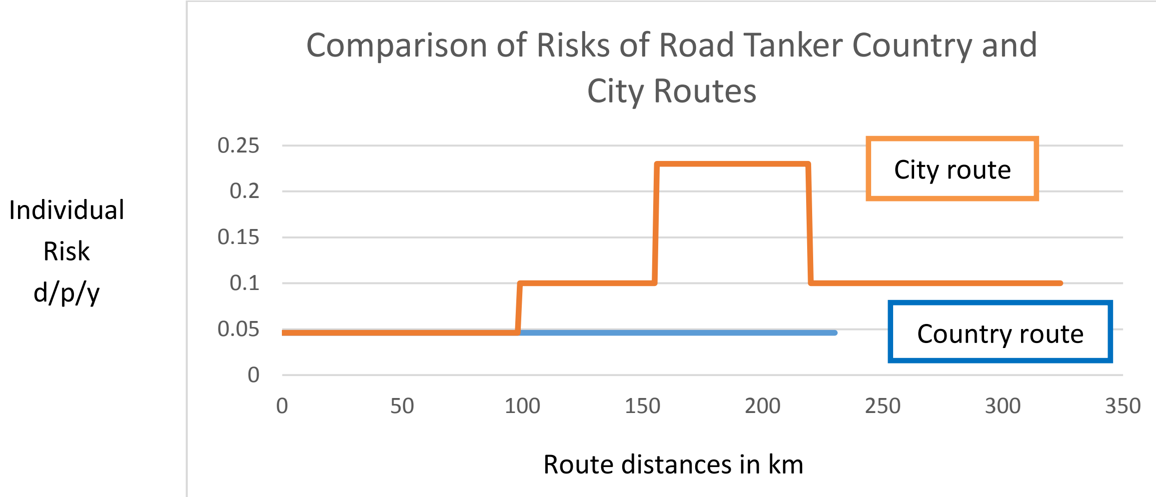
Table 5. Risk levels for the transport of chlorine

LOCATION	INDIVIDUAL RISK LEVEL (per million or cpm)	ASSESSMENT PER UK HSE CRITERIA	CAUSES OF RESIDUAL RISK
Supply of Chlorine in Road Tankers to Gauteng through the N7 and N1 interchange			
Other road users	0.23	Acceptably low	▪ Road tanker small liquid leak ▪ Road tanker rupture ▪ Road tanker large liquid leak ▪ Empty road tanker rupture
Persons living or working immediately adjacent the road (<100m)	0.22	Acceptably low	▪ Road tanker small liquid leak ▪ Road tanker large liquid leak ▪ Road tanker rupture ▪ Empty road tanker rupture
Persons living or working over 100m from the road	< 0.18	Acceptably low	▪ Road tanker small liquid leak ▪ Road tanker large liquid leak ▪ Road tanker rupture ▪ Empty road tanker rupture
Supply of Chlorine in Road Tankers to Gauteng along Country Route Through Ceres to Touws Rivier			
Other road users	0.046	Acceptably low	▪ Road tanker small liquid leak ▪ Road tanker rupture ▪ Road tanker large liquid leak ▪ Empty road tanker rupture
Persons living or working immediately adjacent the road (<100m)	0.04	Acceptably low	▪ Road tanker small liquid leak ▪ Road tanker large liquid leak ▪ Road tanker rupture ▪ Empty road tanker rupture
Persons living or working over 100m from the road	< 0.037	Acceptably low	▪ Road tanker small liquid leak ▪ Road tanker large liquid leak ▪ Road tanker rupture ▪ Empty road tanker rupture

The transport of chlorine in bulk road tankers present lower individual risks on the country route via Ceres versus the city route via the N7/N1 interchange. In general when transporting hazardous chemicals the data indicates that where possible avoid routes that involve travelling on congested highways or highways where driving conditions are complex, e.g. multiple lanes with numerous exits and on-ramps where traffic is changing lanes at high speeds, areas with multiple billboards lots of activity adjacent the high speed highway, areas with lots of curves or hills misty conditions combined with multiple lane traffic etc.

It may be preferable to route the transportation via the country route instead of along the N1 and N7 (town route). The graph below is a representation of how the relative risks may be reduced by using the 'country route' instead of the 'town route'. The blue country line is shorter indicating a shorter distance and it is below the orange town line indicating lower risk levels. The orange line has three levels of risk representing the distance travelled on congested highway, normal highway and country roads.

Figure 8: Risks of road tanker transport routes



Subjective Aspects of Road Risk Assessment

In addition to the quantitative work, a variety of subjective factors should be taken into account in addition to the "numbers".

Supplier / Transporter Emergency Procedures

The suppliers and transporters of the hazardous chemicals considered in the studies had a varied approach to the issue of dealing with a possible spill or release event. The quality of the initial response to an incident whether it is by SUPPLIER / TRANSPORTER or LOCAL AUTHORITIES can have a significant effect on the consequences of an incident.

It was found that most transporters did not have a written Emergency Plan. In these cases the drivers did have a broad idea of actions to be taken in an incident but there was no reference document.

General requirements for an emergency plan are:

- Priority actions for Driver
- Communication with the Company Control Centre
- Initial spectator "control"

The emergency actions could be spelt out on a simple card.

The suppliers of HF had comprehensive procedures for releases of hazardous materials but not specifically for HF. In one case the Fire Department who would be first responders to an incident did not have a specific HF plan. The identification of the hazardous material being transported was on the vehicle through a HAZCHEM number. Most suppliers had material experts on tap to handle material specific issues. Principles for routes selection by transport companies varied. The bigger companies chose highway routes but tried to avoid hospitals and school. Another chose "country routes" avoiding big towns. However, in South Africa, this is not always possible .No company had a clear plan for a hazardous goods vehicle caught up in a major gridlock and suffering a loss of containment for any reason. This is a real issue as traffic congestion is a major feature of transport in South Africa today.

Local Authority Emergency Services

The speed and effectiveness of the response by Emergency Services can impact directly on the consequences on the incident.

HAZMAT capabilities are available from the major centres (Cape Town, Durban, Johannesburg, Pretoria) and some centres which service routes (Atlantis, Vredenburg) where hazardous chemicals are regularly transported. Around the major centres the various Local Authority Services are well co-ordinated and do not leave gaps in coverage. Moving out from the major centres towards the country areas and borders with neighbouring countries, there are areas where no effective response is available. The Local Authorities stated that SOPs were available but no copies were provide. Discussions with the relevant Services took place on all the Road Risk Assessment Studies. In general, these Services appeared professional and prepared for hazardous substance incidents. Most services used the Canadian HAZMAT manual and the South African SABS Emergency Response Handbook. The approach is to reserve judgement on the material involved and the state of the release scene until direct evidence is obtained. In general, SDSs were not available. In the course of the studies updated SDSs were provided to all the authorities.

The major contribution from the Emergency Services will be when a slow progressive leak is in progress. If a massive leak takes place (e.g. valve knocked totally off) the gas will be released within 10 minutes but may, of course, may settle in low-lying areas nearby.

Whilst centres like Cape Town required proposed routes for hazardous materials to be submitted for consideration, other centres were not interested in becoming involved in issues around hazardous materials.

Environmental Issues

These were not to be found to be significant in any of the studies. Whilst the chemicals are toxic to aquatic organisms, sewage microorganisms, vegetation and aquatic plants, it was established that there was a very small chance of liquid materials entering waterways. On the routes studied no significant waterways were observed.

Conclusions

From the information provided in the paper and the underlying Road Risk Assessments carried out, the following conclusions can be drawn:

- It can be quantitatively determined that the risk level for the transport of a hazardous material along an entire route or on parts of it are unacceptable / acceptable.
- Amongst alternative routes, the safest route can be determined using methods described in the paper. The proposed choice can be well defended if public meetings of “interested and affected” people are held.
- Even if there is no legislation to specify how Road Risk Assessments should be done (as in South Africa), UK legislation and guidelines can be used to good effect.
- Qualitative information such as road surface, availability of emergency services / competence and transporter training / competence should be considered together with the quantitative information in making decisions.
- The proposed routes should be driven and observations made of significant features such as schools / hospitals and informal settlements. Where environments can change quickly this is particularly important. The use of desk studies using Google Earth or Maps can supplement this.
- Basic accident data may not be available for industrial vehicles and particular routes. However, with interpretation of available data and good judgement, reasonable data can be produced.
- The methodology (mix of quantitative and qualitative) is quick, relatively cheap but does rely on judgement of experienced people.

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