Risk Modeling For Commercial Goods Transport

Final Report

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Abstract

This study presents a risk analysis of goods movement along the Los Angeles County's transport corridors, specifically, I-710, I-5 and I-10. Geographic Information Systems (GIS) tool is used in the analysis. The analysis involves a comparison of truck and passenger car accidents, estimation of accident rates, identification of segments with high potential for accidents, and calculation of risk associated with goods transport. Results of the analysis enable identification of high-risk locations. Various limitations, especially, with respect to data availability make it difficult to obtain a more accurate estimate of risk. The results of the study serve as a foundation for further developing risk models that could be used to estimate risks associated with goods transport and developing policy measures related to goods movement in Southern California. The model can be expanded to include hazardous materials transportation risk and emergency preparedness assessments.

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1 Introduction

This study aims to model the risk of transporting commercial goods along interstate and major highways, specifically I-710, I-5, and I-10 in Los Angeles County. The risk of transporting commercial goods is evaluated based on the accident history along these transport corridors. Geographic Information System (GIS) is used to develop the database and support the risk modeling process.

Modeling efforts in the area of commercial goods have been taking place since the passage of Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991. This act, which mandates states to include a freight component in developing transportation plans, subsequently led to the development of various statewide planning tools that address commercial goods movements. These planning tools are used to forecast origins and destinations of various types of commercial goods, distribute trips to various zones, estimate modal distribution, and load these trips onto the transportation network. An example of such tools is the GIS-based Intermodal Transportation Management System (ITMS) planning tool developed by the California Department of Transportation (Caltrans).

While safety, along with mobility and other performance measures, is used to evaluate freight movement, very little was done to model the impact of an accident on the delivery of commercial goods in general. Most safety studies and modeling efforts have focused on the impact of an accident involving only hazardous materials in transport using risk-based analyses. Although an accident involving hazardous materials is rare, greater attention has been given in this area because of its serious and often costly social consequence. In most planning analytical processes, commercial goods movement are often addressed primarily in the context of mobility.

Like traffic congestion, an accident affects the reliability of delivery of shipment of commercial goods. Reliability of delivery is crucial in reducing the risk of perishability of goods (Vilain and Wolfrom, 2000) and reducing the total transport cost. While traffic congestion is a recurrent event that could easily be factored in the delivery time and transport cost estimates, an accident is a non-recurrent event that is more difficult to predict. An accident may incur cost due to damaged goods and due to a delay in delivery on the parties involved, and a non-recurring traffic delay to other motorists. A study by Miles and Buis in 1992 showed that in Melbourne Australia, congestion cost is estimated at $1.3 billion per year, two-thirds of which is incurred by commercial vehicles, mainly trucks (Czerniak, 1996). The cost of an accident involving non-hazardous commercial goods and the cost of delay associated with an accident may also contribute significantly to the total cost of transport, although they may or may not be the largest costs involved.

The increasing freight activities and demands for “just-in-time” delivery of goods make it relevant to develop a framework for carefully assessing the impact of an accident on commercial goods transport or to apply an existing risk model in commercial goods transport. Such a model could be used to support routing decisions and identification of measures needed to reduce the occurrence of an accident and minimize its negative

impacts, such as increased transportation system delay, increased transportation cost, and others.

Succeeding discussions address the status of goods movement and truck-related accidents in California and Los Angeles County, and the actual risk modeling process on the Los Angeles transport corridors.

1.1 Significance of the Study

This study enables development of a framework for assessing the impact of commercial goods movement on the highway transportation system, application of an existing risk model, and identification of existing databases that could be used to support risk analysis. Results of risk estimates will enable identification of critical locations which may lead to subsequent identification of the affecting factors such as weaknesses in geometric design, deterioration in pavement surface, excessive truck activities and others. These types of information are useful for planning, operations and maintenance activities of a transportation agency such as Caltrans. The identification of critical locations may also facilitate evaluation of emergency preparedness in these areas. This study will also benefit agencies involved in transportation planning activities such the Southern California Association of Governments (SCAG) and other local metropolitan planning organizations, shippers, researchers, emergency responders, and communities that have significant freight activities.

While some data are available, such as accident data, these are not maintained in a friendly format to support risk analysis. Other data, especially those dealing with truck shipments are proprietary in nature and may not readily be available. This study identifies the state of such databases which subsequently may encourage standardization of data collection and maintenance procedures to facilitate data sharing. Future enhancements to the model may include interfacing with a hazardous materials database and population database to evaluate the risk of hazardous materials shipment along the Los Angeles transport corridors in terms of affected population. The emergency preparedness along the transport corridors, especially in areas with unusually high truck traffic or high accident frequency, may be evaluated by interfacing the risk estimates with the emergency response database (e.g., response times). This may be of significance due to the current threats of terrorist attacks on public facilities, such as the transportation system.

1.2 Study Site

As mentioned earlier, this study focuses on freeways I-710, I-5, and I-10 in Los Angeles County, California as shown in Figure 1. I-710 is a 27-mile freeway which serves most truck traffic going inbound and outbound traffic from the Ports of Long Beach and Los Angeles. It begins south in Long Beach and ends north in Pasadena. I-5 spans 88.6 miles beginning south from Orange-Los Angeles county line and ending north to Kern-Los Angeles county line. I-10 is 48 miles and begins west from Santa Monica to San Bernardino-Los Angeles County line.

In California, goods transported annually by road have increased by 22.4 percent from 5.26 billion tons in 1993 to 6.44 billion tons in 1997. (U.S. Census Bureau, 1999). The shipment distances have also increased by 7 percent from an average of 212 miles per shipment in 1993 to 227 miles per shipment in 1997. Truck shipments account for 67.7 percent of all shipments and account for 82.7 percent tons of shipments based on 1997 Commodity Flow Survey. Most of these shipments (57.1 percent) are made at distances less than 100 miles. Increasingly, goods movement are being seen as an important part in the operation of our transport system, especially with the implementation of North American Free Trade Agreement in 1994 and the proliferation of electronic commerce. NAFTA has increased imports and exports activities from the United States to Mexico and Canada, and vice-versa while e-commerce has increased demands for delivered goods.

The total commodity flow data for California are shown in Table 1. Shipments originating from California are 7 percent of the U.S. total shipments of 11.1 billion tons and account for around 8.7 percent of the U.S. total ton-miles of 2.66 billion or around 11.6 percent of the U.S. total value of shipments of 6.9 billion dollars based on the 1997 Commodity Flow Survey data. Shipments with California as a destination are around 7.4 percent of the U.S. total tons of shipment and account for 5 percent of the U.S. total ton-miles or 11.2 percent of the U.S. total value of shipments. These values include all shipments within California.

Table 1. 1997 Commodity Flow Survey Data for California

Shipments	Tons, million	%US Total	Ton-Miles, million	%US Total	Value, $million	%US Total
California Origin*	778805	7.0	133347	8.7	777276	11.6
California Destination*	823934	7.4	232294	5.0	802192	11.2

* Includes shipments within California

The population in California is projected to increase by 43 percent from 1994 to 2020. According to Census 2000, Los Angeles County has a population of 9,519,338 reflecting a 7.4 percent increase from 1990. Similarly, regional volumes of commercial goods are projected to increase more than 40 percent. (SCAG, 1998). The number of trucks on most freeways is projected to exceed 40,000 a day by year 2020.

The increasing population and volumes of goods will further lessen the mobility in the region, especially in Los Angeles which ranked as the most congested area in the United States in 1999 (Schrank and Lomax, 2001). Measures such as the construction of the Alameda Corridor have been implemented to ease traffic congestion and improve truck access and the delivery of goods. The Alameda Corridor is a $2 billion 20-mile rail project spanning across the Ports of Long Beach and Los Angeles to Downtown Los

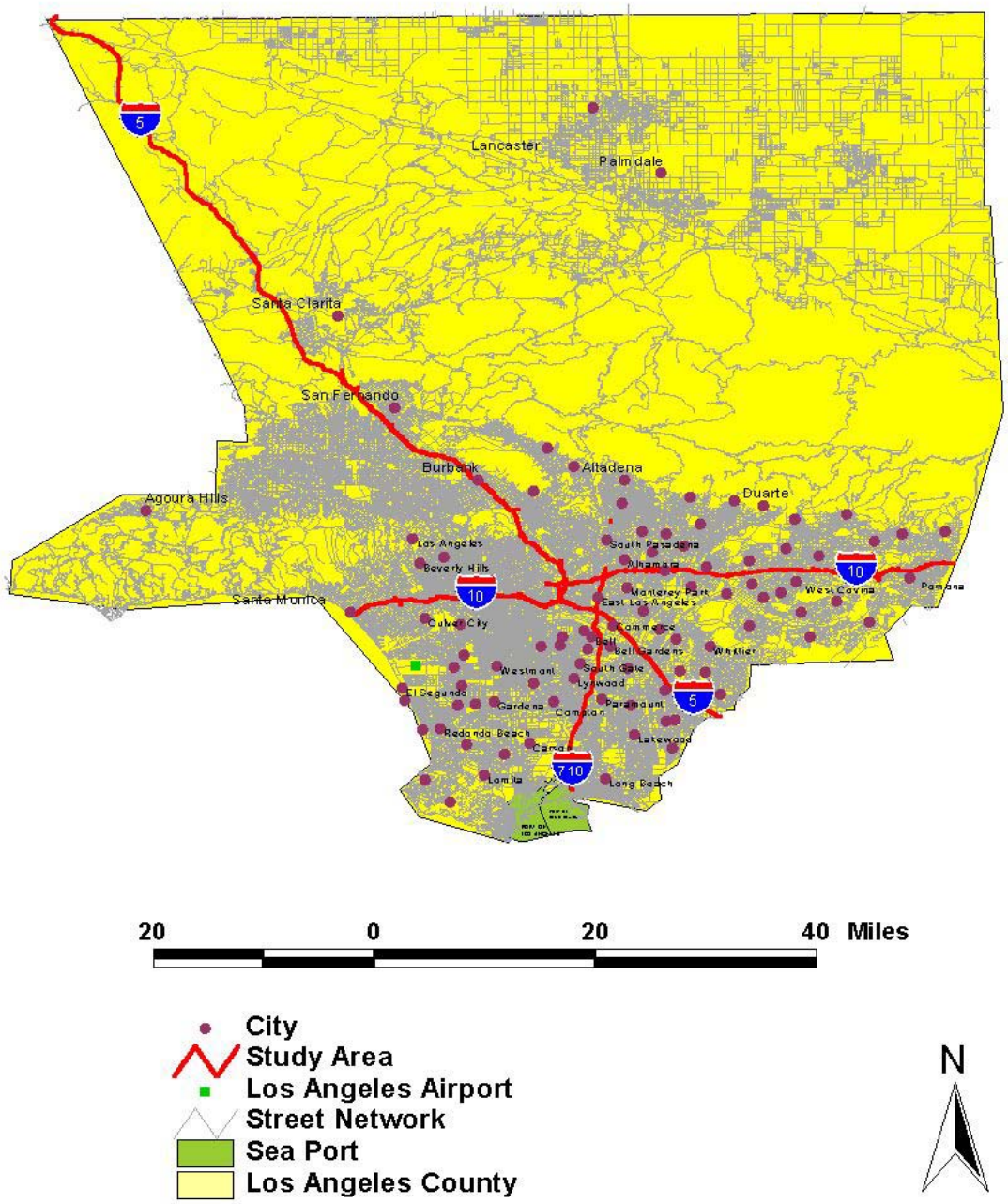

Figure 1. Study Site

Angeles. Other measures include plans to build truck lanes in various segments of I-5, SR-60, I-15 and I-710. Despite these measures, travel delays from either a congestion or traffic accident are expected to remain one of the most challenging issues in the region. The resultant effects of travel delays and accidents will be a further reduction in the quality and reliability of the transport system and an increase in the cost of transporting goods.

According to Czerniak (1996), an efficient freight system within cities is the key to the ability to compete on both domestic and international markets. This could not be truer to Los Angeles County, which is a major economic force in the Pacific Rim and is home to the Port of Long Beach, Port of Los Angeles, and the Los Angeles International Airport. The Port of Long Beach is the nation's busiest container port with around 4.41 million 20-foot equivalent units (TEUs) in 1999 while the Port of Los Angeles is the second busiest with 3.83 million TEUs. A 20-foot equivalent TEU is equal to one 20-foot-long cargo container. Los Angeles airport is the third busiest in the world with air cargo totaling 2.17 million tons in 1999. The regional economy of the region can be sustained only if an efficient transportation system is in place - meaning goods are delivered on time or with minimal delay, safely, and at a minimal cost.

2 Methodology

The study comprised several steps including a comparative review of countywide and statewide accident data, risk modeling, and risk estimation. A review of existing risk models and modeling practices in the shipping industry was performed. The modeling process involves identification of risk variables and data requirements, identification of data availability and sources, data collection and processing, and actual risk estimation. Development of database, data management, and risk analysis were performed using GIS tool, ArcView. This tool is also used to produce graphical results.

2.1 Data Sources

Data used for this study were obtained from the following sources:

- Southern California Association of Governments (SCAG)
- California Department of Transportation (Caltrans), District 7
- California Highway Patrol (CHP) Statewide Integrated Transportation Reporting System (SWITRS)
- National Highway Traffic Safety Administration (NHTSA) State Data System
- NHTSA Fatal Accident Reporting System
- U.S. Bureau of Census 1997 Economic Census and 1997 Commodity Flow Survey

Data on freeways and county boundaries obtained from SCAG are in GIS ArcView format. Traffic and accident data were collected from Caltrans. Accident data came in hard copy formats and had to be scanned, manipulated, and converted into GIS-compatible database. Other data were in digital formats and had to be converted into GIS-compatible formats.

3 Accidents Involving Commercial Operating Vehicles

3.1 Los Angeles vs. Other Counties

Based on a five-year data from 1995 to 1999, fatal truck accidents in Los Angeles County represent around 11 percent of total fatal accident in the state and injury accidents represent 4.3-4.6 percent of total injury accident. In 1999, Los Angeles is the leading county in injury truck collisions, accounting for 28 percent of all injury truck collisions in the state followed by San Bernardino (8 percent) and Orange (6 percent) counties. On fatal truck collisions, Los Angeles County again led the state with 14 percent of state fatal truck collisions, followed by San Bernardino with 11 percent, and Sacramento with 7 percent based on the 1999 data.

The five-year distributions of fatal and injury truck collisions in the state and in Los Angeles County are shown in Figures 2 and 3. It can be noted that the number of injury remains more or less uniform. The number of fatal accidents decreased in both state and county level in 1998 and 1999.

Speed is the primary collision factor for fatal and injury accidents where truck driver is at fault representing 37 percent of all factors. Other significant factors include changing lane unsafely (16 percent), improper turning (13 percent), and auto right-of-way (10 percent). While it appears that most of the factors are related to human errors, measures can be implemented to minimize accident occurrences. Examples of such measures may include stricter enforcement of speed regulations and improvement in sight distances.

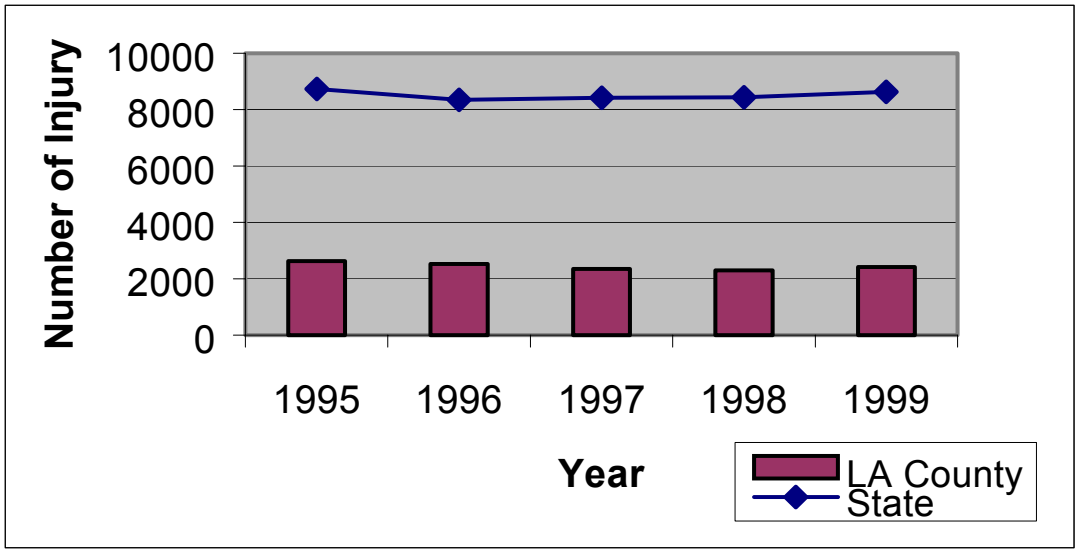

Figure 2. Injury Truck Collisions in California
(Data Source: CHP SWITRS)

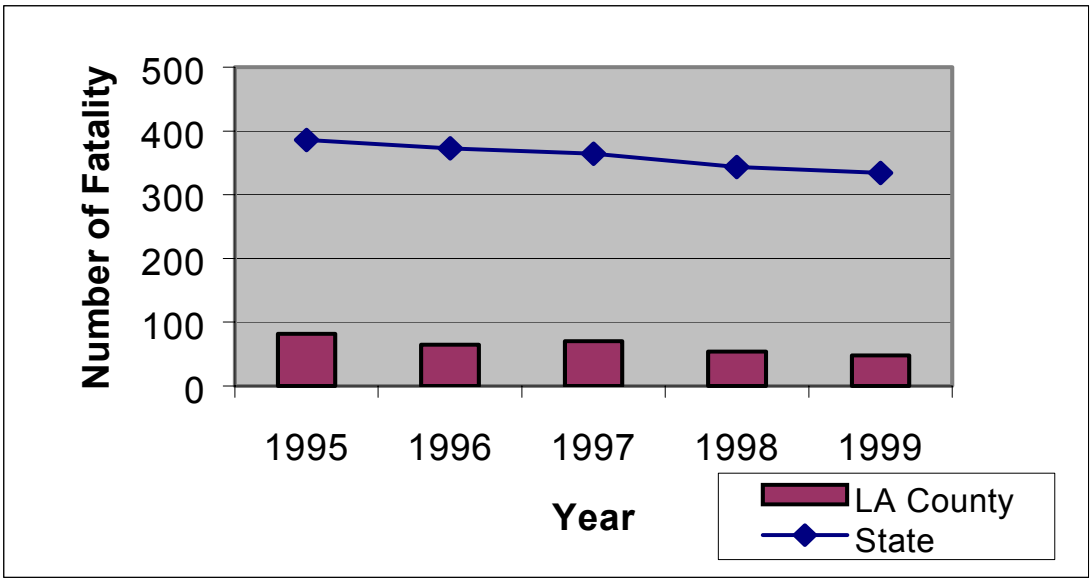

Figure 3. Fatal Truck Collisions in California
(Data Source: CHP SWITRS)

3.2 California vs. Other States

According to a report by the National Highway Traffic Safety Administration (NHTSA), one out of eight traffic fatality in 1999 resulted from collisions involving large trucks or those vehicles weighing 10,000 pounds or more. Figure 4 shows the five leading states in terms of fatality in large truck accidents based on 1989-1994 data. Except in 1989 and 1993, California consistently rank highest in terms of the number of large truck occupants killed in traffic crashes. Figure 5 shows that California has the highest number of large trucks involved in fatal crashes based on 1989-1994 data.

In 1999, Texas leads large trucks involved in fatal crashes with 384 (8 percent of total vehicles) followed by Florida with 327 (7.8 percent of total vehicles) and California with 319 (6.9percent of total vehicles).

In terms of vehicle involvement in traffic crashes, large trucks represent only 4.2 percent of all traffic crashes. Passenger cars have the highest involvement with 61.7 percent, followed by light trucks with 32.7 percent, and the remaining 1.3 percent involved motorcycle, bus, and other vehicles. Despite low involvement, large trucks are more likely to result in fatality than other modes (NHTSA, 1999). Of all traffic fatalities in 1999, 49.3 percent were attributed to passenger cars, 35.1 percent to light trucks, and 8.6 percent to large trucks. The fatality data on large trucks is more than two times higher than the large truck involvement in an accident. In 1994, the total economic cost of motor vehicle crashes was $150.5 billion. This represents the direct cost of accidents involving fatality, injury, or property damage. (Blinscoe, 1994).

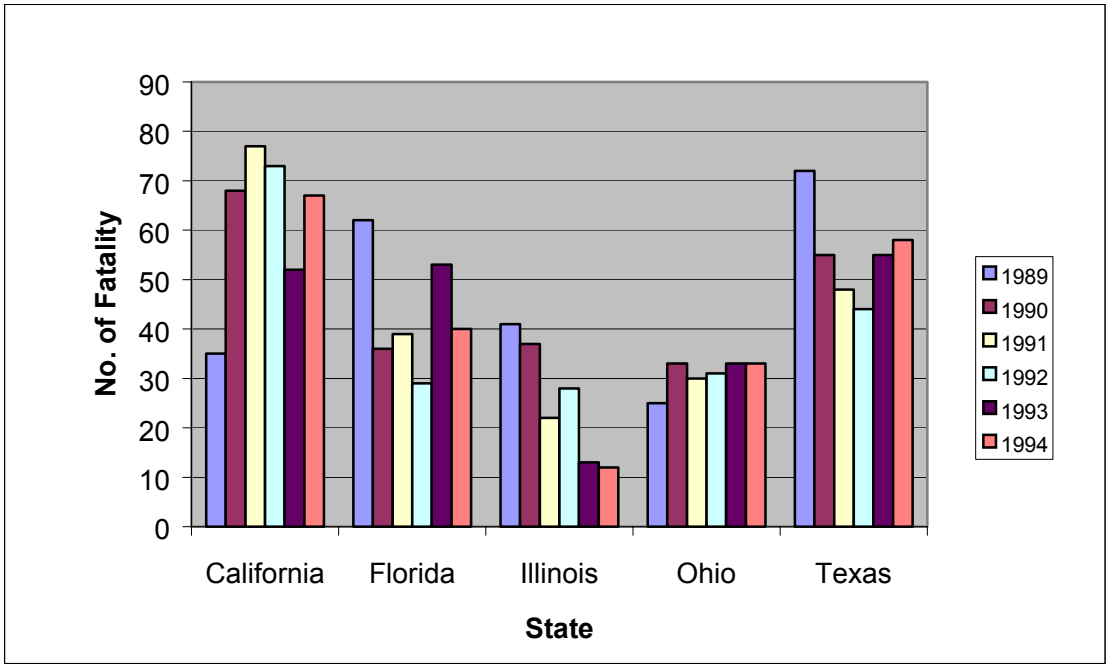

Figure 4. Large Truck Occupants Killed in Motor Vehicle Traffic Crashes by State (Data Source: NHTSA Statewide Crash Data)

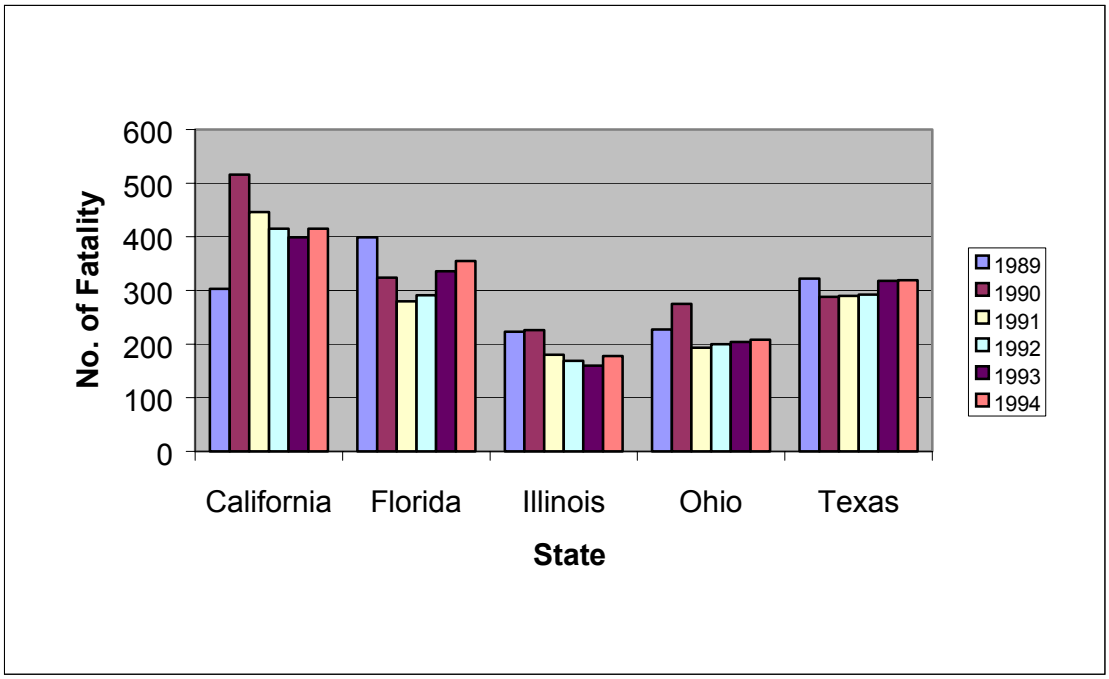

Figure 5. Large Trucks Involved in Motor Vehicle Traffic Crashes by State – Fatal Crashes (Data Source: NHTSA Statewide Crash Data)

4 Risk Modeling

4.1 Risk Definition

Risk is defined as the potential for realizing undesired impacts. In evaluating the risk of being involved in a fatal crash, risk is commonly defined as the ratio between the number of fatal crashes associated with a specific set of conditions and the amount of travel performed under the same conditions (Cerrelli, 1997).

Various models have been developed to quantify risk and most of them are related to hazardous materials (HazMat) transport (Parentela, 1996). The conceptual approach to modeling HazMat transport risk involves combining probability of occurrence of an event and its consequence and expressed as:

$$Risk = P(Event) \times P(\mathrm{Re}lease) \times Consequence$$

Where:

P(Event) = probability of an event, such as an accident or an incident
P(Release) = conditional probability of HazMat release

A similar definition of risk could be applied in the context of commercial goods. However, the event would be limited to an accident only and the direct consequence would be the undesired impacts to the party or parties involved in an accident as described in the subsequent discussions. The physical condition of the road affects the probability of an accident while the presence of emergency responders who could provide timely response to an accident affects the consequence.

For HazMat transport, three types of events are identified: a normal event where a vehicle operates under normal condition, an accident such as a collision involving a vehicle carrying HazMat, an incident such as an overturned HazMat vehicle or fractured tank. Consequence is often defined in terms of fatalities, injuries, and population exposure.

4.2 Risk Assessment Process

Risk assessment is a multi-step process as illustrated in Figure 6. The first step involves defining risk. A model could not be developed unless there is a clear understanding of its definition and identification of issues involved in the process. Once risk has been defined, measures that could be used to estimate risk can be established as stated in the next step. The subsequent steps include the actual development of a risk model, GIS-based risk estimation, and evaluation of results. The results would enable identification of various risk reduction strategies, which is the next step to the process. The ultimate goal of risk assessment is to select the best strategy or sets of strategies that can be implemented in order to minimize risk. The process involves a cycle of risk estimation, evaluation of risk estimates, identification of risk reduction strategies, and implementation of risk-reduction strategies.

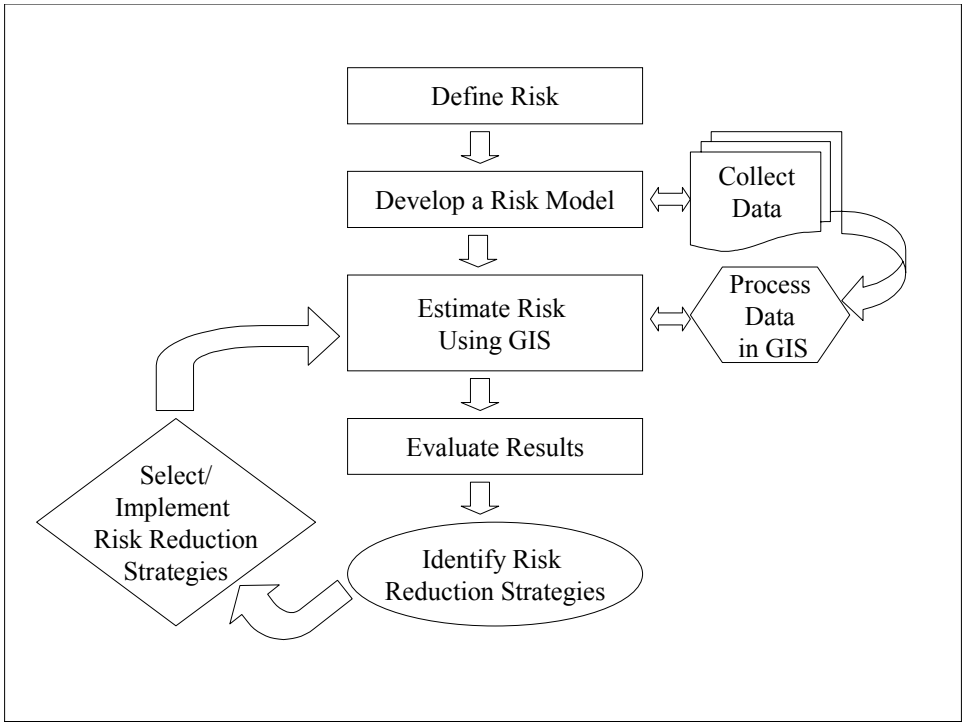

Figure 6. Risk Assessment Process

4.3 Modeling Framework

Movement of commercial goods may be affected by the occurrence of an accident on the road. Two scenarios are possible. The first scenario may be an accident involving vehicle(s) other than trucks, while the second scenario may be an accident involving a truck carrying either non-perishable, perishable, or dangerous goods as illustrated in Figure 7. In the former case where an accident involves other vehicle(s), the truck experiences non-recurrent delay in addition to recurrent congestion delay that is normally factored in the transport cost. In the latter case where an accident involves a truck, the truck not only experiences delay, but also experiences a more serious and costly consequence. Depending on the severity of an accident, such may include damage to perishable goods, delay on the delivery of demand-sensitive goods, leak of gaseous and other harmful substances, injury to the driver or other motorists, or fatalities. In a worst-case scenario where a truck carries dangerous goods including radioactive substances, the surrounding population may also be affected thus leading to a catastrophic result. The impact of an accident varies depending on the severity of an accident as well as the type of goods being moved.

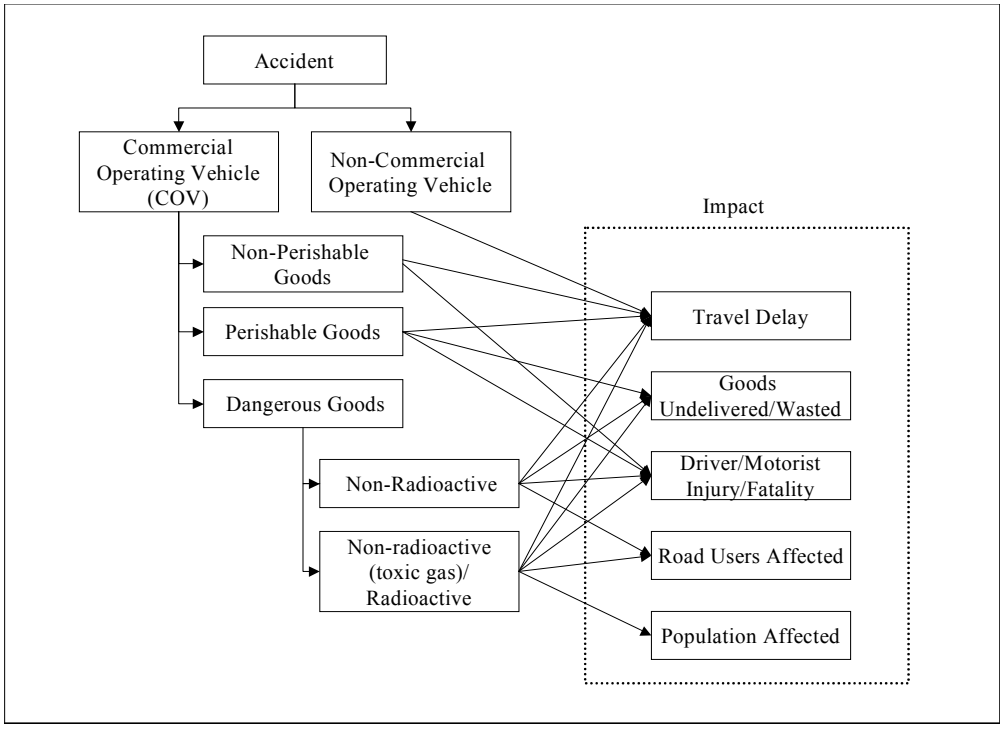

Figure 7. Impact of an Accident Involving a Commercial Operating Vehicle

4.4 Development of Risk Model

The following discussions describe the methods involved in developing a risk model for commercial goods transport. While there are many factors affecting risk estimates, efforts have been made to arrive at a simplified model. A simplified model is one that reduces to a minimum the number of variables needed to evaluate risk.

Risk Model

For commercial goods in general, risk is generally expressed as follows:

$$Risk = P(Accident) \times Consequence$$

<u>Accident probability</u>. The probability of an accident is estimated based on the assumption that an accident is a discrete, random event that can be modeled using Poisson distribution. An accident is measured per unit of time (accident per year) or space (accident per vehicle-mile). In this study, the traditional method of defining an accident rate in terms of number of accident occurrences per unit vehicle-mile is used. The accident rate is estimated using the following equation:

$$R = \frac{Ax10^6}{VMTx365}$$

Where:

R = accident rate, accident per million truck miles
A = number of accidents involving trucks per year
VMT = vehicle miles of travel, defined as a function of truck traffic

Accidents, especially at intersections and high volume truck exits, entrances and interchanges are of interest to transportation planners and engineers. The occurrence of an accident may be influenced by various factors such as the frequency of shipment, volume of truck traffic, travel distance, highway geometry, pavement condition, temporal condition, human factor, and others as shown in Figure 8.

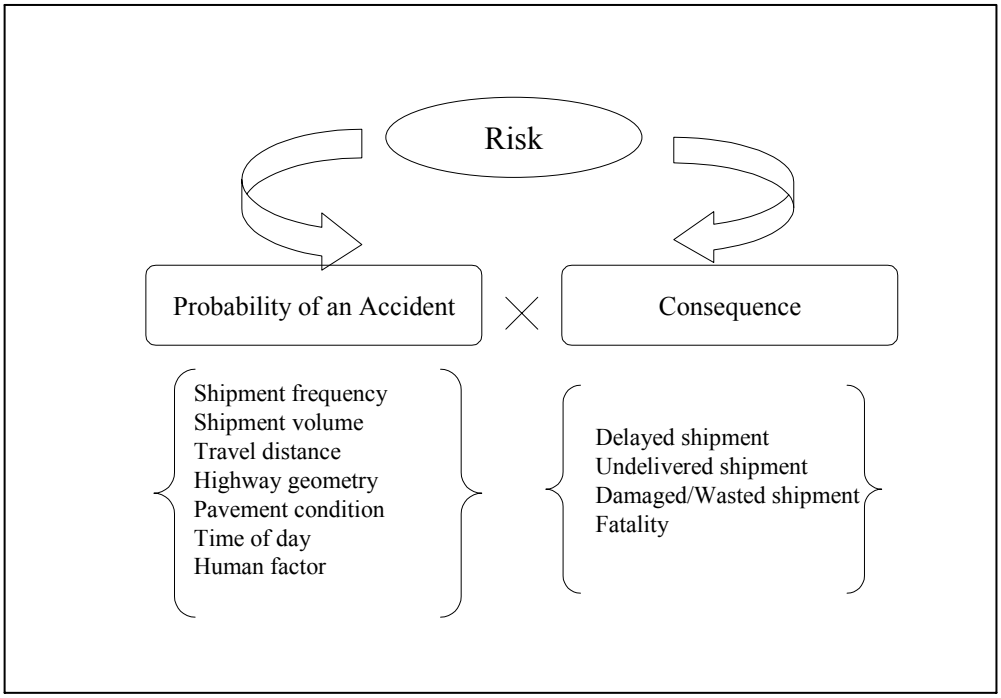

Figure 8. Risk Model

Future risk assessments may include the effects of all the above factors, but for purposes of this analysis, only the shipment frequency and the travel distance is used in the probability analysis.

Consequence. Consequence may be defined in terms of affected shipment such as shipments undelivered on time, undelivered shipments, or damaged/wasted goods. As in hazardous materials, consequence may also be defined in terms of fatalities. Decision on the consequence measure used in the analysis is often influenced by the availability of data and magnitude of data collection effort required. Unfortunately, commercial goods

shipment is an area where not many data are available and most of the available data are proprietary.

In this study, consequence is defined in terms of affected goods and is estimated as follows:

$$Consequence = AADTT \times 365 \times w \times c$$

Where:

$AADTT$ = annual average daily truck traffic, truck/day
w = average weight of shipment, ton/truck
c = unit cost of shipment, $/ton

Substituting this value to the previous equation, risk is expressed as:

$$Risk = P(Acc) \times AADTT \times 365 \times w \times c$$

The unit of measure used to define risk is $/year. At the segment level, the risk from point *i* to point *j* may be defined as follows:

$$Risk_{ij} = P(Acc)_{ij} \times AADTT_{ij} \times d \times 365 \times w \times c$$

Where:

$Risk_{ij}$ = risk in segment *i-j,* $/year
$P(Acc)_{ij}$ = probability of an accident in segment *i-j*
d = directional distribution of truck traffic

This definition of risk is used in the subsequent risk estimation.

Modeling Process

The modeling process involves three main components mentioned in the risk assessment process: development of database, risk estimation, and evaluation of results. GIS is an appropriate tool for this effort because of its ability to handle large data, support spatial analyses, and generate meaningful graphics.

Database development. This is the most time consuming in this process, especially since most data come in various formats and have to be converted into a GIS-compatible format. Extra effort is needed to ensure accuracy during data scanning, conversion and manipulation.

Based on topographic features, the database comprises two types of data: linear data such as the highway network, and point data, which include the traffic volumes and accident locations. The highway network with post mile (PM) attributes serves as a base data. PM's are used to identify and locate traffic count locations and accidents on the network.

Risk estimation. GIS-based analysis can be performed at various levels of detail depending on the need of the user. For example, estimates can be obtained to evaluate

the relative risk of transporting goods on various freeways like I-710, I-5, and I-10. Estimates can also be obtained at the segment level to identify the most critical section of a highway. In this study, risk is estimated at the segment level.

The advantage of risk modeling in a GIS platform is the ease of enhancing the model by simply adding a new variable as an attribute of the network and recalculating risk. For example, human factor can be integrated in the model to account for driver's experience, age, and health.

Evaluation of results. This is an important step required to verify whether or not the analysis provides meaningful results. Any abnormality in the estimate is usually uncovered at this stage.

4.5 Data Requirements for Risk Modeling

The data required for risk modeling are as follows:

- highway network data, including physical and operational characteristics of the transportation system
- truck accident data, including frequency and severity of an accident
- truck traffic flow data, including directional distribution pattern
- freight data, including shipment type, shipment volume

These are all spatial data which may be presented in GIS format. The highway network, truck accident and traffic flow data are readily available from various transportation agencies. However, freight data are rare and difficult to find. Most freight data do not have information that could be used to obtain the desired level of accuracy of risk estimates. The types and values of commodities, as well as the origination and destination of shipments are often available at an aggregate level only.

Other sources of data are various trade associations, industries, and private organizations such as Reebie Associates, based in Connecticut, which maintains the TRANSEARCH database.

4.6 Risk Modeling Issues

Risk modeling of commercial goods in transit can be a powerful tool in decision-making and identifying measures that could minimize the occurrence or impact of an accident. However, issues such as uncertainties in the risk estimates, and lack of comprehensive data complicate the process of risk modeling. Although data limitation is a significant factor, this does not prevent one from developing a theoretically appropriate model.

It is often difficult to obtain reliable risk estimates due to uncertainties involved in the process. Risk estimates are based on probabilities and not on the true values of risks. Thus, the results of risk analysis mainly give insights on the risks involved while

transporting the materials and provide comparisons on whether or not one route or route segment is safer than the other.

The estimation of risk is complicated by the lack of comprehensive data related to commercial goods transport and analysts have to rely only on what is available. This often results in making simplifying assumptions which may distort the true picture of risk.

Despite these issues, results of risk analyses may be used for transportation planning purposes and for evaluating the emergency preparedness of communities identified as having high-risk potential. Enhancements to various emergency response programs of the shippers and the communities may result from risk analyses.

The impact of an accident may be minimized by the presence of emergency responders who could provide a timely and appropriate response to an accident. This is especially true when dealing, not only with emergencies involving commercial goods in general, but when dealing with those involving hazardous materials in transit.

The September 11, 2001 attack on World Trade Center and the Pentagon raised new concerns on transportation security and safety. Suddenly, every aspect of the transportation system appears to be vulnerable to attacks ranging from airplane hijacking, like what happened on September 11, to possible chemical poisoning of commuters in mass transit stations. The possibility of a sabotage attack on hazardous materials in transit has also become more real. An attack on hazardous materials in transit may bring catastrophic results especially if it occurs on freeway segments that cut across densely populated areas. A risk analysis would be useful in evaluating community vulnerability to such an attack, identifying measures to prevent it from happening, and ensuring that the community is well-prepared to respond to such an emergency. The risk model for commercial goods shipment may be expanded to address the risk associated with hazardous materials shipment. Various risk models on hazardous materials transportation are already available and could be utilized in Southern California as an enhancement to the commercial goods transport risk model.

Results of risk modeling can be used to formulate creative policies that will promote safe and cost effective transportation of goods while limiting environmental and health impacts. Various measures such as the use of dedicated truck lanes in areas with high truck traffic and accident potential, and policy enhancements concerning truck operation may also evolve out of risk estimates. Results of risk modeling can also be used to streamline the risk assessment process by addressing issues involving standardization of a risk model, identification of common risk variables, organization of data bank supporting the model, and others.

5 Case Study: Los Angeles County

The model is used to evaluate the risk of commercial goods transport in Los Angeles County's transport corridors I-710, I-5, and I-10.

5.1 Truck Traffic

Truck traffic is estimated from the 1990 annual average daily traffic (AADT) using a truck factor extracted by comparing historical AADT and annual average daily truck traffic (AADTT).

An investigation of the traffic data showed around 60:40 to less than 45:55 percent directional distributions in I-710, hence, a 60:40 directional distribution was used in the analysis of directional accident. A 70:30 directional distribution was used in I-5 and I-10.

5.2 Accident Frequency

While accidents are normally analyzed using a 3-year accident data, this study presents a one-year analysis period representing the year of 1999. Accident data involving all vehicle types is summarized in Table 2.

Table 2. 1999 Accident Data

Freeway	Length, mi	Total Number of Accidents	Accident Rate per Million Veh-mile[1]	Number of Accidents Involving Trucks[2]	Number of Fatal Accident	Number of Injury Accident	Number of Property Damage Only Accident
I-710	27.19	2134	1.07	755	11	467	1701
I-5	88.61	4834	0.80	1162	18	1194	3622
I-10	48.27	4351	1.15	524	13	1243	3095

[1] - based on all vehicle types

[2] - includes single unit trucks, tractor, truck/tractor with trailer(s), single unit tanker, and truck/tractor with tanker(s)

I-710 had a total of 2134 accidents in 1999. This data is 5 percent higher than in1998, and 10 percent higher than in 1997, reflecting an increasing trend. The data show that around 35 percent of all accidents in I-710 involved large trucks. This is consistent with the percentages of truck accidents recorded in 1998 and 1997. I-5 and I-10 show lower percentages of truck accidents with 24 percent and 11 percent, respectively. I-5, which is the longest freeway analyzed, had the highest number of accidents but its rate of 0.80 accident per million vehicle-mile is the lowest. I-10 and I-710 have greater than 1.0 accident per million vehicle-mile where all vehicle types are involved.

The location of accidents involving all vehicle types and frequency of occurrence are shown in Figure 9 while those involving trucks only are shown in Figure 10.

Speeding is the primary collision factor in 40 percent of all accidents that occurred in I-710, in 50 percent of all accidents in I-5 and in 60 percent of all accidents in I-10. Improper turns and other violations are the second and third most common factor. The most common type of collision is rear-end, followed by side-swipe. The third most common type involved a vehicle hitting an object.

5.3 Truck Accident Rates

The accident rates involving trucks are shown in Figures 11 and 12. The highest accident rate of 13.65 accidents per million truck-mile was observed northbound of I-710 from post mile (PM) 21.92 in Bell City to PM 23.28 in the City of Commerce, at the junction of I-5. This segment also showed the highest accident rate of 8.70 accidents per million vehicle-mile of travel southbound of I-710.

In I-5, accident rates of 7.14 and 6.46 accidents per million vehicle-mile of travel were observed northbound at the junctions of I-710 in Commerce and Route 60 in East Los Angeles. Southbound, these segments also showed the highest rate, although at a much lower value of around 4.5 accidents per million vehicle-mile of travel. In I-10, the highest rate of 6.1 accidents per million truck-mile was observed westbound between PM 14.84 to 18.39, which was at the junctions of I-110 and I-5, both in the City of Los Angeles.

It is to be noted that most of these accidents occurred at or near the junctions or interchanges. This is consistent with the study of Sullivan (1990) who found accidents per vehicle-mile of travel to be related to the number of interchange ramps (Janson, et.al, 1998). The truck accident rates are much higher than the accident rates involving all vehicle types.

The severity of an accident is not factored in the analysis. Each accident, regardless of severity, is treated similarly and counted as a single occurrence. Future evaluation of risks should include an assessment of severity by assigning a higher value to injury accident and a much higher value to fatal accident compared to a property damage only accident.

5.4 Risk Estimates

Based on the 1997 Commodity Flow Survey, the value of shipment made in California is $\$542,598 \times 10^6$ and the total volume of shipment is 644,261,000 tons. Using these data, the value of each ton of shipment is estimated at $842. This value is used to estimate risk. Results of risk estimates are shown in Figure 13.

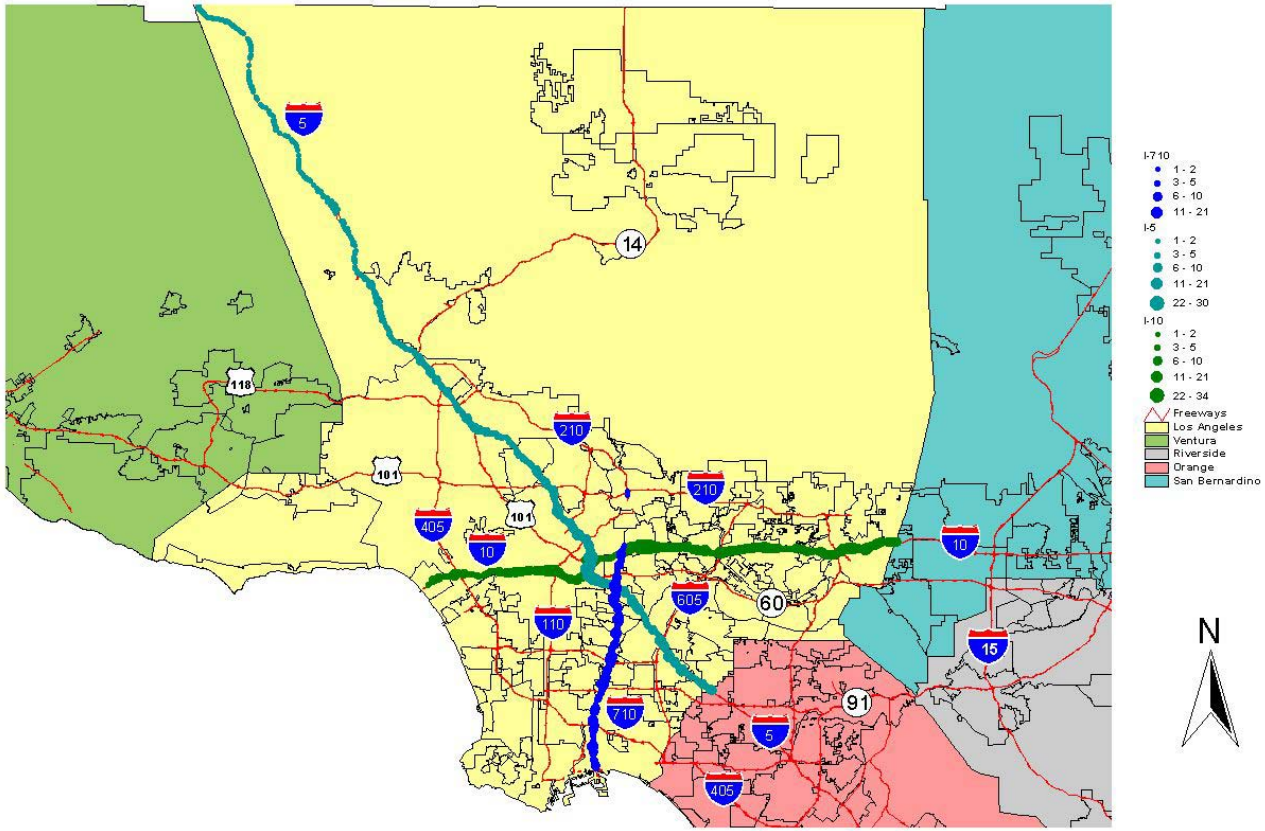

Figure 9. Locations of Accidents Involving All Vehicle Types

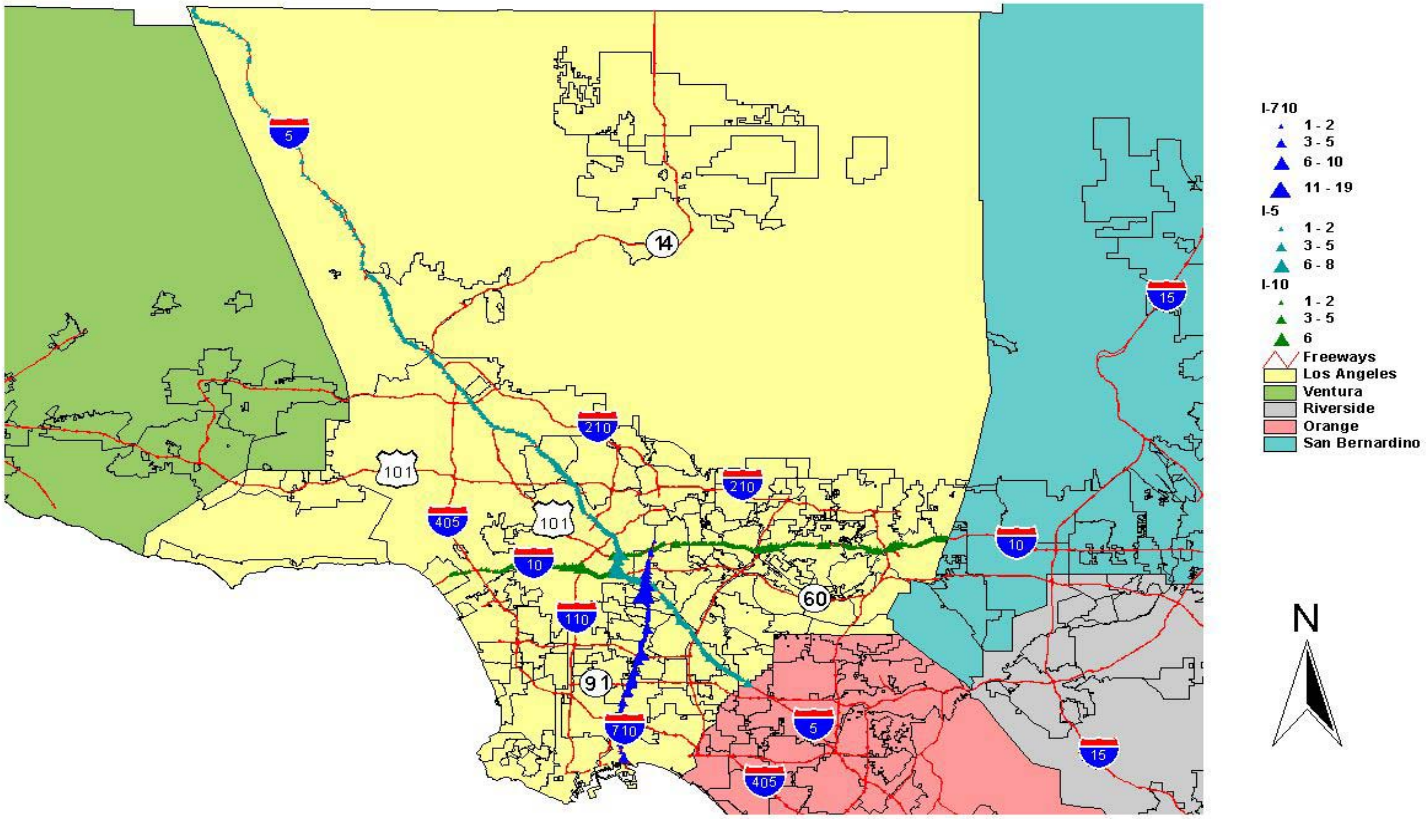

Figure 10. Locations of Accidents Involving Large Trucks

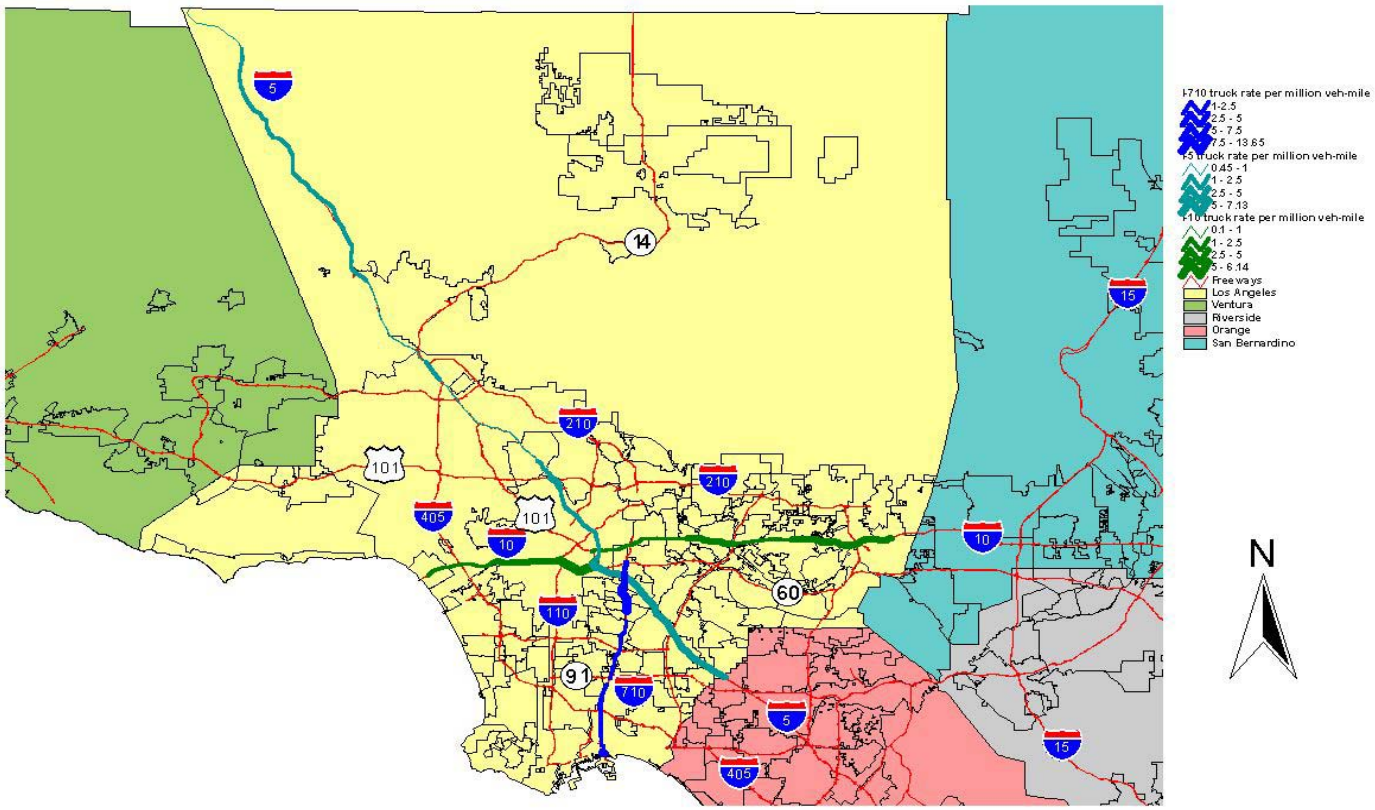

Figure 11. Large Trucks Accident Rates per Million Truck-Miles Traveled

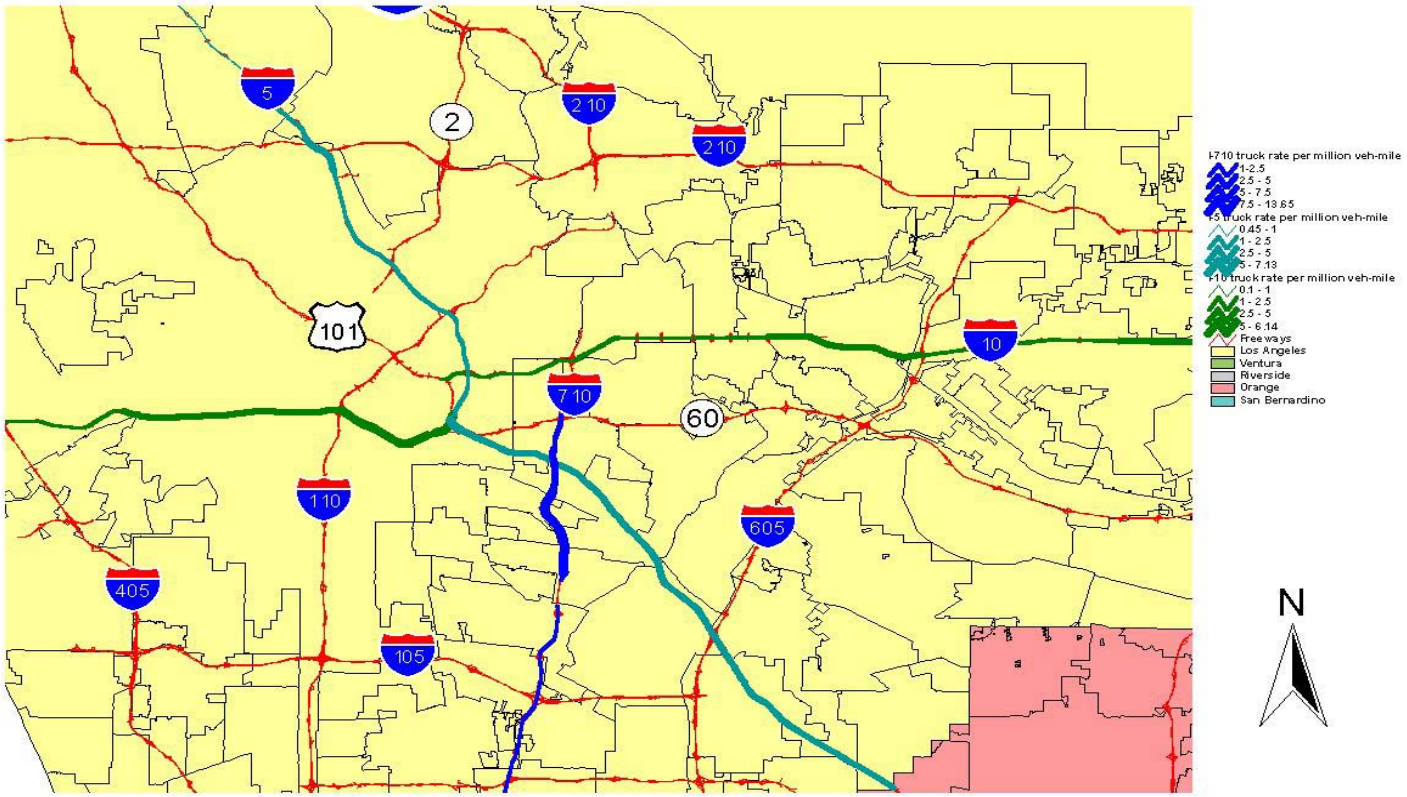

Figure 12. Large Trucks Accident Rates per Million Truck-Miles Traveled – Enlarged Section

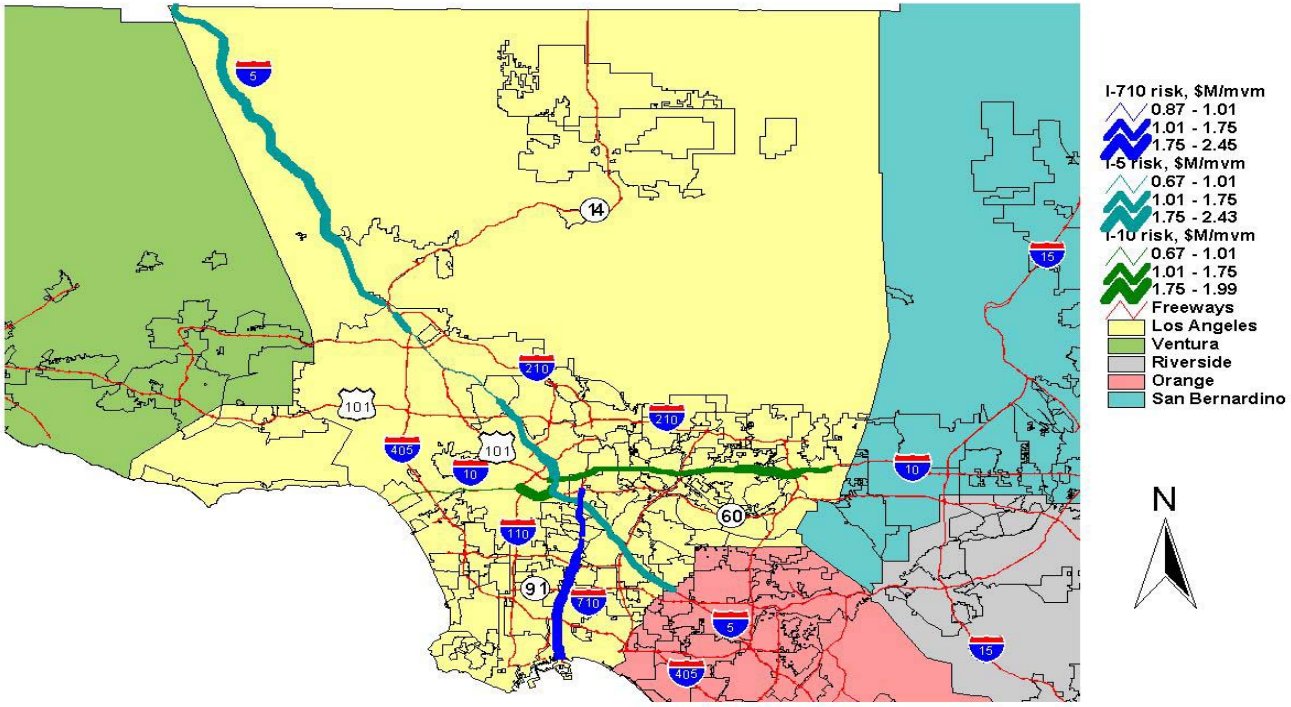

Figure 13. Risk in $/Year

The results indicate that among the three corridors analyzed, I-710 has the highest risk potential. As mentioned earlier, the model did not include other relevant factors such as the severity of an accident.

6 Conclusions

The primary objective of this project is to analyze goods movement in Southern California. Specifically, the analysis focused on I-710, I-5, and I-10. Lack of comprehensive data limit the estimation of risk to the desired level of analysis. Despite this limitation, the results provide relative risk estimates and enable identification of areas that are categorized as "high" risk. The model can be enhanced to provide an option to analyze the risk of transporting hazardous materials and to evaluate emergency preparedness along the transport route. Results of risk modeling efforts can be used to formulate creative policies that will promote safe and cost effective transportation of goods while limiting environmental and health impacts.

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