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A Re-assessment of Road Accident Data-Analysis Policy

Applying Theory from Involuntary, High-Consequence, Low-Probability Events like Nuclear Power Plant Meltdowns to Voluntary, Low-Consequence, High-Probability Events like Traffic Accidents

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HUMAN-CENTERED TECHNOLOGY TO ENHANCE SAFETY AND MOBILITY

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This report examines the literature on involuntary, high-consequence, low-probability (IHL) events like nuclear power plant meltdowns to determine what can be applied to the problem of voluntary, low-consequence, high-probability (VLH) events like traffic accidents. Five closely related literatures on IHL events are examined: "normal" accident theory, system reliability theory, highly reliable organizations theory, complexity and tight coupling theory, and a theory of feedback and learning (band-of-accident theory). Based on this literature we develop and test a series of propositions to explain traffic injuries and fatalities. To explain motor vehicle accidents, we carry out logistic regression analyses, examining driving conditions and decisions drivers make as factors that can lead to fatalities and injuries. Then, we characterize and describe the models that traffic safety officials use for understanding fatalities and injuries. These models are found in state crash data publications. We compare these models with the instructional material that is used in state driving educational manuals in order to investigate how to improve the collection and use of road traffic safety data based on analysis of the existing data and its use.

A Re-assessment of Road Accident Data-Analysis Policy

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EXECUTIVE SUMMARY

More people are injured and die annually from motor vehicle accidents than from less commonly occurring events like nuclear power plant meltdowns. Unlike motor vehicle accidents, however, incidents at nuclear power plants and in commercial aviation are thoroughly scrutinized and analyzed, and the information fed back to operators, to determine how such disasters can be prevented. Roughly parallel systems should be in place in the traffic safety system, where both the professional driver and the average driver need to be more aware of road hazards and the decisions they should make to avoid them.

This report examines the literature on involuntary, high-consequence, low-probability (IHL) events like nuclear power plant meltdowns to determine what can be applied to the problem of voluntary, low-consequence, high-probability (VLH) events like motor vehicle accidents. It examines five closely related literatures on IHL events: "normal" accident theory, system reliability theory, high reliable organizations theory, complexity and tight coupling theory, and a theory of feedback and learning (band-of-accident theory).

Based on these theories, the researchers developed and tested a series of propositions to explain traffic injuries and fatalities. They carried out logistic regression analyses, examining driving conditions and decisions drivers make as factors that can lead to fatalities and injuries, then characterized and described the models, found in state crash data publications, that traffic safety officials use for understanding fatalities and injuries. These models were compared with the instructional material that is used in state driving educational manuals in order to investigate how to improve the collection and use of road traffic safety data based on analysis of the existing data and its use.

Through the investigation, the researchers found that the most significant condition leading to a fatality or an injury was driving on a rural road, and the most significant decision was choosing not to use a seat belt. How factors combine to cause fatalities and injuries was also examined. For example, a combination of risky driver behavior at stop and yield signs was significantly related to both fatalities and injuries. Similarly, a combination of illegal speed and alcohol use was significantly related to both fatalities and injuries. Overall, the fatality model explained about 2 percent of the variance and the injury model explained about 12 percent of the variance.

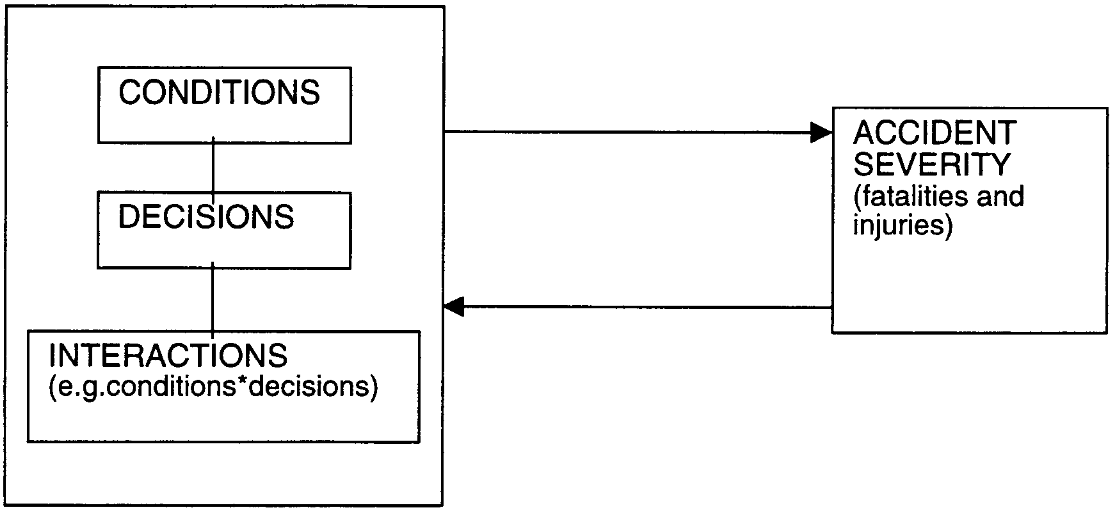
In the investigation of state driving instruction manuals, the researchers discovered that about one-third of the pages in a typical manual were devoted to factors that traffic safety officials consider to be the main reasons for fatalities and injuries. Although the current data collected in Minnesota, when analyzed, provided a number of powerful predictors of fatalities and injuries relating to the conditions a driver faces and the actions that drivers take, overall the data's ability to explain crash severity could be better. Improved theory can inform data collection and result in more powerful predictive models that could be used in programs to educate drivers.

INTRODUCTION

More people are injured and die annually from voluntarily undertaken, low-consequence, high-probability (VLH) events like motor vehicle accidents than from involuntary, high-consequence low-probability (IHL) events like nuclear power plant meltdowns. Nonetheless, psychological research (Slovic and Fischoff, 1976) has shown that people tend to treat VLH events more lightly than IHL ones. People may believe that they are personally immune from VHL events happening to themselves, though they readily acknowledge in the abstract that these events are a major hazard.

In this paper, we examine five closely related literatures on IHL events: "normal" accident theory, system reliability theory, high reliable organizations theory, complexity and tight coupling theory (this is closely linked to normal accident theory), and a theory of feedback and learning (band-of-accident theory). Though there are important differences in approach and emphasis among these theories (Sagan, 1996), our intent is to treat them as an almost seamless framework (see Figure 1)—one that starts with the phenomenon itself (fatalities and injuries) and then moves to examining its causes relative to the conditions that lead to accidents, the decisions that operators make, the interactions between these conditions and decisions, and the systemic or recursive properties of warning and feedback.

Figure 1
A Theory of Safety



THE LITERATURE

Normal Accidents

Heinrich (1959) determined that in a group of 330 precursor incidents, 300 typically resulted in no injury, 29 yielded minor injuries, and one resulted in a major loss of life (p. 26). The idea that not all incidents result in major loss of life has found its way into many safety and loss control programs, including those used in the aerospace, nuclear, and hazardous materials industries. The aim is to prevent ordinary incidents from escalating into injuries, and from injury-causing accidents to escalate into loss of life. In the analyses that Heinrich (1959) did, the chance that an incident would involve injuries was about 9 percent, and the chance that an incident with injuries would involve loss of life was about 3 percent.

With respect to VLH events like motor vehicle accidents, it is also the case that not all crashes result in injuries and not all crashes with injuries yield deaths (see Table 1).

Compared to IHL incidents (Heinrich, 1959), the chance of injury appears to be greater (>30% compared to about 9%) and the chance of fatality lower (<1% compared to 3%). These differences may be a result of reporting threshold, which may be higher for motor vehicle crashes than for industrial accidents. Differences in reporting threshold also may explain differences in state reported crashes. Otherwise, it makes no sense for Michigan, with fewer people than Illinois, to show more than twice the number of crashes (more than 400,000 for Michigan, compared to less than 200,000 for Illinois).

Table 1
Motor Vehicle Accidents, Injuries, and Fatalities in a Number of Midwestern States

	Illinois 1996	**Iowa 1995**	**Kansas 1996**	**Michigan 1997**	**Minnesota 1998**	**Nebraska 1998**	**Dakota 1998**	**Dakota 1998**	**Wisconsin 1998**
Accidents	166,450	76,240	73,872	425,793	92,926	48,183	14,420	19,735	125,831
Injuries	65,950	38,992	31,342	137,548	45,115	30,581	4,920	7,723	62,236
Injury to Accident Ratio	.42	.51	.42	.32	.49	.63	.34	.39	.49
Fatalities	1,477	527	490	1,283	650	315	90	165	709
Fatality to Injury Ratio	.022	.014	.016	.009	.014	.010	.018	.021	.011

With respect to industrial accidents, Perrow (1984) maintains that minor incidents are nearly *"normal,"* that is, they occur regularly and on a continuously. At the typical industrial facility, there is likely to be more than one such incident per day, but incidents that involve injuries are far less common, perhaps taking place only once every two to three months, and very serious accidents involving major loss of life are exceedingly rare (Perrow, 1984, p. 65). Though these events resulting in fatalities are rare, Perrow (1984) considers them to be normal—that is, he believes that they are inevitable and that very little can be done to prevent them. Applying this logic to motor vehicle safety, it would be extremely difficult to predict crashes that involved fatalities.

Proposition 1*: It will be harder to predict motor vehicle fatalities than to predict motor vehicle injuries.*

System Reliability

Perrow (1984) is critical of methods engineers use to increase system reliability. There are many such tools (U.S. Nuclear Regulatory Commission, 1981) that are only partially adequate, with none being able to identify all potential failure modes and hazard scenarios. To compensate for these limitations, designers regularly build redundancies into IHL systems. The theory is that reliability can be enhanced by parallel configurations—standby components that are in place to operate should the primary components fail (O'Connor, 1991). Not all of the critical points of exposure and of vulnerability, however, can be covered, as safety is a compromise between requirements and economic necessity (Petroski, 1994, p. 122). The level of risk tolerated therefore depends on a

> ...utilitarian calculus that safety is desirable but costly and that organizations choose a level of safety by balancing the benefits of safety reduction against the costs of safety improvement. (Marcus and Nichols, 1996, p. 5)

The level of safety achieved is not the highest technically and humanly possible, but rather, depends on resource availability.

Engineering judgment and economic logic also play a role in VLH events. For road hazards, engineering reliability translates into efforts to improve driving conditions. Roads have to be built so that drivers are separated from objects with which they can collide (other cars, trains, pedestrians, animals, and fixed objects, for example). Roads have to be constructed to adjust for how much traffic they will bear. Curvature has to be limited so that roads can be safely navigated. Lighting has to be in place to assure the safety of nighttime driving. Traffic signals and other signs have to be set up. There is a large body of traffic safety literature that deals with these factors (for example, see Hughes and Stewart, 1998; Bonneson and McCoy, 1997; Wang, Hughes, and Stewart, 1998; Forkenbrook, Foster, and Pogue, 1994; Zhou and Sisiopiku, 1997; Markovitz and DeRobertis, 1998; Graham, Paulsen and Glennon, 1977; and Taylor and Thompson, 1977).

Proposition 2: *Engineering and system reliability (factors like separating drivers from objects with which they can collide, the curvature of a road, traffic signals, and so on) are likely to affect the incidence of motor vehicle injuries and fatalities.*

Highly Reliable Organizations

Those in the high-reliability school place great emphasis on eliminating errors by operators. This school is based on empirical observations of the air traffic control network, electric power system, and aircraft carriers. Roberts' observational research shows how the Navy overcomes risks associated with carrier-based air operations by relying on operator training and flexible exercises (Roberts, 1993). Accidents come from breakdowns in operators' comprehension and social processes (Weick and Roberts, 1993). Those in the high-reliability school emphasize eliminating operator errors by means of anticipation, simulation, and continuous training (Sagan, 1993).

Erroneous assumptions by operators are considered to be the cause of many accidents. (Turner and Pidgeon, 1997). Weick (1995) and Turner and Pidgeon (1997) have focused on operators' lack of pre-crisis cognition and situational sense making. Weick, Sutcliffe, and Obstfeld (1999) have suggested that proper training achieves a greater level of "mindfulness." A high percentage of traffic crashes also have been attributed to operator error and lack of attention (Marcus and Bromiley, 1988; Minnesota Crash Facts, 1998). It is well known that driver judgment can be impaired by alcohol use. Attention to formal precautions, like wearing seat belts and obeying traffic rules such as the speed limit, is important. There is a large body of literature in this area (for example, see French, West, Elander, and Wilding, 1993). Using a variety of research approaches, many studies have tried to understand risky human driving behavior (Evans and Schwing, 1985; Rothe, 1993; Klien, 1994).

Proposition 3: *Impaired decision making by drivers (inattention to formal precautions like seat belts, violation of traffic rules, speeding, and the use of alcohol) is likely to increase the incidence of motor vehicle injuries and fatalities.*

Complexity and Tight Coupling

According to Perrow (1984), IHL systems are complex and tightly coupled, and therefore difficult to manage. Complexity is not simply a matter of the number of parts, components, or subsystems, but of particular paths, loops, and jumps (p. 75) that yield "baffling interactions" not found in the design. Such interactions are not the kind that operators can easily anticipate, nor can operators completely guard against them.

Driving has many of the characteristics of a complex, tightly coupled system. Not everything can be anticipated in advance. To the driver, there are baffling interactions. The complexity of the driving environment puts stress on the driver's cognitive abilities and information processing and the driver is at risk if he or she does not adapt adequately (Brehmer, 1994). Under such conditions the driver has to be extremely careful to exercise restraint and judgment.

Tight coupling adds to the difficulty. In an IHL system, it eliminates the time an operator has to exercise judgment and make decisions. In the face of continuous, rapid processes that have gathered momentum, the operator does not have the luxury to carry out careful analysis or exercise reasoned judgment. Tightly coupled processes move in a single direction with little slack. The buffers are limited. The type of condition that prevails in chemical processing plants and petroleum refineries (Woodward, 1980; Perry, 1997) also can take place on highways where events, once set in motion, cannot be easily brought to a halt. The mechanisms by which processing moves from automated to deliberative leaves the driver with "no spare capacity to cope with the unexpected" (Brehmer, 1994, p. 544).

According to Perrow (1984), management requirements associated with complexity and tight coupling are at odds. Complexity requires that the people in charge step back and take another look at the situation. On the other hand, under tight coupling, there is no time to deliberate and reconsider routines.

Proposition 4: *Interactions such as those between the conditions drivers face and the decisions they make are likely to increase the incidence of motor vehicle injuries and fatalities.*

Despite the potential importance of interactions as a potential cause of traffic accidents, few studies have examined this factor (for an exception, see Wolverton and Mounce, 1996).

Feedback and Learning

Drawing on the work of Rasmussen (1994), Marcus and Nichols (1996) have advanced the concept of a "band of safety." Organizations typically drift within an acceptable performance range, receiving warnings of impending danger based on indicators used to track events. The band of safety is established by the frequency and the clarity of the signals the organization receives. The problem is that the signals are not always that frequent or clear:

> Organizations have goals in addition to safety and though the conditions they may be trying to avoid are obvious ones (a nuclear power plant meltdown or chemical plant explosion), the preconditions that lead to these states seldom are as clear. (Marcus and Nichols, 1999)

According to Marcus and Nichols (1999), the rules for safety cover known dangers that encapsulate theory and lessons of the past, but theory in use often is incomplete, and the future does not perfectly replicate the past, thus making it difficult to accurately perceive problems and take appropriate action.

Methods to reduce incident frequency and accident severity require loops that feed the information back, thus allowing for adjustment and enabling learning and adaptation (Wiener, 1948)—but such systems do not always function as well as they should. For example, Starbuck and Milliken (1988) discuss loss of awareness in an analysis of the Challenger incident. A history of success produced increased confidence in current operations, narrowed attention, and restricted the search for solutions to well-known problems. Organizations that have had past success may improve their competencies within a narrow set of routines. Indeed, systems for detecting and correcting problems are socially constructed, and the average driver receives nothing close to the training and preparation of a pilot, air traffic controller, or operator of a nuclear power plant, nor is the system of feedback loops constructed with the same degree of thoroughness.[1]

Proposition 5: *There is likely to be a loose fit between the information collected about motor vehicle crashes and the use of this information in programs like driver education.*

TESTS OF THE PROPOSITIONS

To test these propositions, an empirical examination of the system for road accident data analysis used in Minnesota was carried out. The advantage of concentrating on one state is that the data are relatively homogeneous, and thus fewer factors have to be controlled. At the end of 1998, 3,526,041 people held Minnesota driver licenses and 3,903,334 motor vehicles were registered. Vehicles traveled over 48.5 billion miles; 650 people died and 45,115 people were injured. The cost of motor vehicle crashes was estimated to be $1.6 billion (Minnesota Motor Crash Facts, 1998). Traffic accident fatalities and injuries rates had declined in the last 20 years in Minnesota and other states as innovations like seat belts, air bags, and improvements in cars and road design resulted in better traffic safety. Yet current levels of fatalities and injuries remained high, and identifying further improvement areas was needed.

The 1999 Minnesota Department of Public Safety crash data file contains all collected information for Minnesota in 1999. About 500 state patrol troopers, 87 county sheriffs, and

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[1] Tamuz (2000) describes how these systems function in commercial aviation. The government sponsors a system that monitors operational errors among air traffic controllers. A second system tracks pilot deviations, a third documents midair collisions, and a fourth collects voluntary confidential reports from pilots about safety-related events. The Airline Pilots Association also sponsors an inter-organizational safety monitoring system. Moreover, there are various airline-specific systems for recording and monitoring potential dangers both in the United States and abroad. Each systems labels potential dangers in a different way and uses the information and analyses differently.

500 city police departments (and 5,000 police officers) collect these data. Minnesota motor vehicle accident report forms are filled out for each accident with injuries, or when $1,000 or more in damage has occurred. The form includes data on the driver, the vehicle, and the environment in which the accident occurred. Within ten days it must be mailed to the Driver and Vehicle Services office at the Minnesota Department of Public Safety. Aside from the police report, a driver report also is required. The data are processed in two ways. A coder translates the police report to codes, some of which are filled out by the police officer. Locators find the accident's exact place by using coordinates. The data are entered into a Vax computer about 45 days after the accident. Every 30 to 40 days three files are sent to the state IBM mainframe and are transferred to the Minnesota Department of Transportation (Mn/DOT) Information System (TIS) for use by Mn/DOT and the Office of Traffic Safety in the Department of Public Safety (which includes 14 analysts), where the Minnesota Motor Vehicle Crash Facts report is prepared.

Variables

Using data from the 1999 Minnesota Department of Public Safety crash data file, our dependent variables from "normal accidents" theory are whether the crash results in fatalities or injuries (yes or no).[2] The independent variables are the other elements in the IHC framework (see Table 2)—conditions the driver faces (systems engineering), decisions the driver makes (organizational reliability), and various interactions (complexity and tight coupling theory).[3]

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[2] We also did the analyses with continuous variables based on severity of accident, starting from zero injuries to many and from zero fatalities to many, and obtained essentially the same results.

[3] Controls in the analysis are for driver age (<24 years old), sex (male or female), bad weather, and number of people involved in the crash. One of the interactions also is used as a control—drivers' age*drivers' sex.

Table 2
Dependent Variables

Conditions faced (Systems Engineering)

- Two-vehicle collision
- Collision with a train
- Collision with a pedestrian
- Collision with an animal
- Collision with a fixed object
- Rural road
- Non-rush hour
- Curved road
- Late at night
- Weekend
- Traffic signal
- Stop and yield sign
- School zone
- Railroad signs
- No passing zone

Decisions made (High Reliability Organizations)

- No seat belt used
- Alcohol related
- Risky behavior (such as following too closely or improper turn or lane use)
- Defective vehicle
- Illegal speed

Interactions (Complexity and Tight Coupling)

- No passing zone* Rural road
- No seat belt used* Rural road
- Alcohol related* Rural road
- Illegal speed*Rural road
- Risky driver behavior*Rural road
- No seat belt used*Stop and yield sign
- Alcohol related*Stop and yield sign
- Illegal speed*Stop and yield sign
- Risky driver behavior*Stop and yield sign
- No seat belt used*No passing zone
- Alcohol related*No passing zone
- Illegal speed*No passing zone
- Risky driver behavior*No passing zone
- No seat belt used*Alcohol related
- No seat belt used*Illegal speed
- Alcohol related* Illegal speed

Analyses

After computing means and standard deviations and correlating the variables, logistic regression models were used to explain the dependent variables—fatalities and injuries. Gebers (1998) performed a number of regression analyses of driving record variables over a six-year time period (1986–1991) to compare the results obtained from different techniques and found that the different techniques did not lead to different results. The techniques compared were ordinary least squares, weighted least squares, Poisson, negative binomial, linear probability, and logistic regression models.[4] The SAS program is used to calculate the R-squared statistics for the logistic regressions.

To test for Proposition 5, *implicit* models of fatalities and crashes were built based on *Minnesota Crash Facts* and similar reports produced by other states. Examples of these implicit models can be found in Figures 2–4. Minnesota, Nebraska, and Wisconsin have implicit models for accidents in general and for fatal accidents (see Figures 2, 3, and 4). Wisconsin has percentages on the actual number of fatalities and injuries and mentions the interaction between alcohol and speed. Nebraska includes percentages on the decisions drivers make. These models are *implicit* because there is no explicit theorizing about safety or statistical tests of theories in the state reports. The models that the traffic safety officials implicitly use are inferred from how they organize and present the data and then compared with what is found in state driver manuals by counting pages in the manuals devoted to these factors. To arrive at ideas for improvement, we reviewed literature on data collection, analysis, and safety estimation. We also interviewed selected state-level traffic safety experts.

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[4] Using ordinary least squared regression we obtained virtually the same results.

Figure
Minnesota Motor Vehicle Crash Facts (1998)
Implicit Theories of Crashes and Fatalities

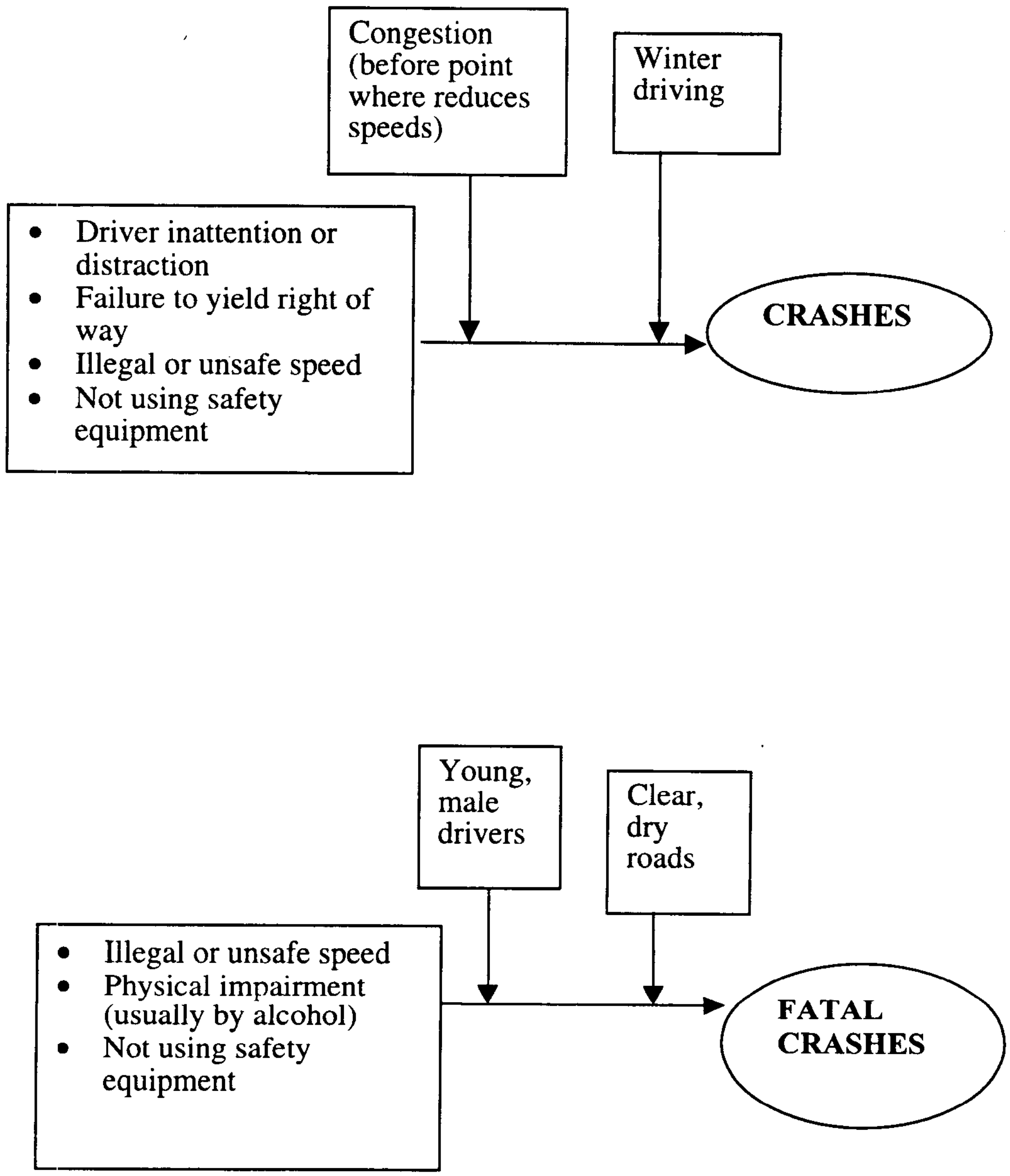


Figure 3
Wisconsin Traffic Crash Facts (1998)
Implicit Theories of Crashes and Fatalities

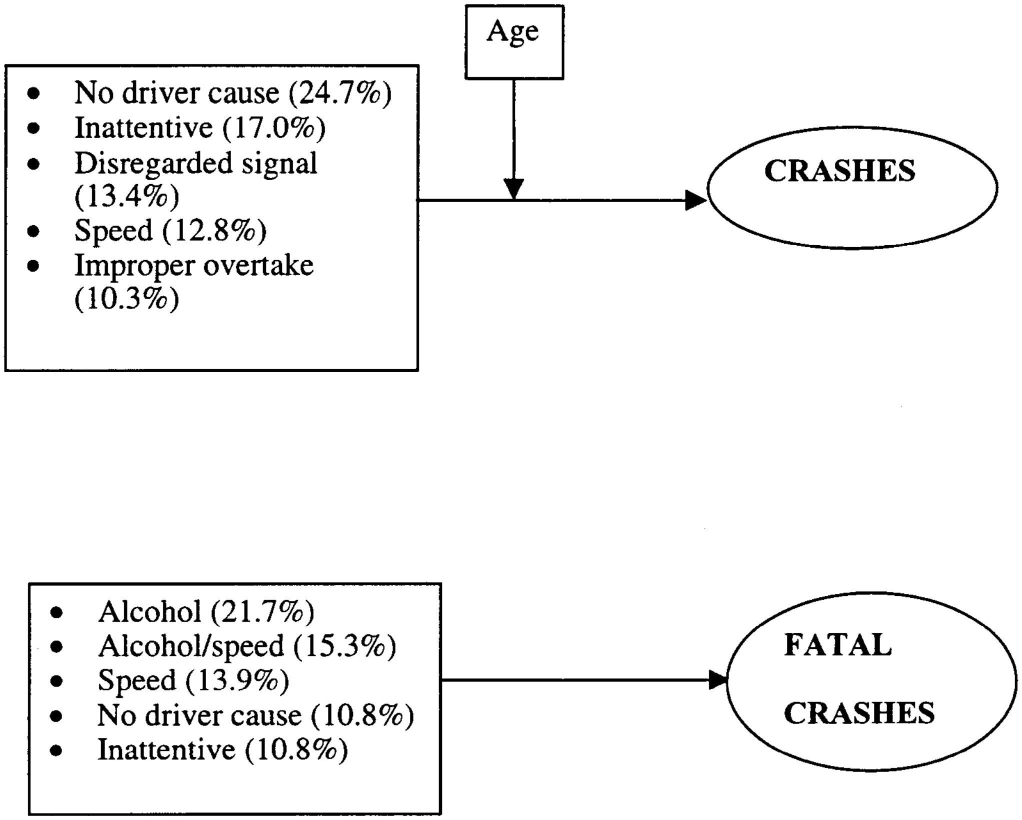
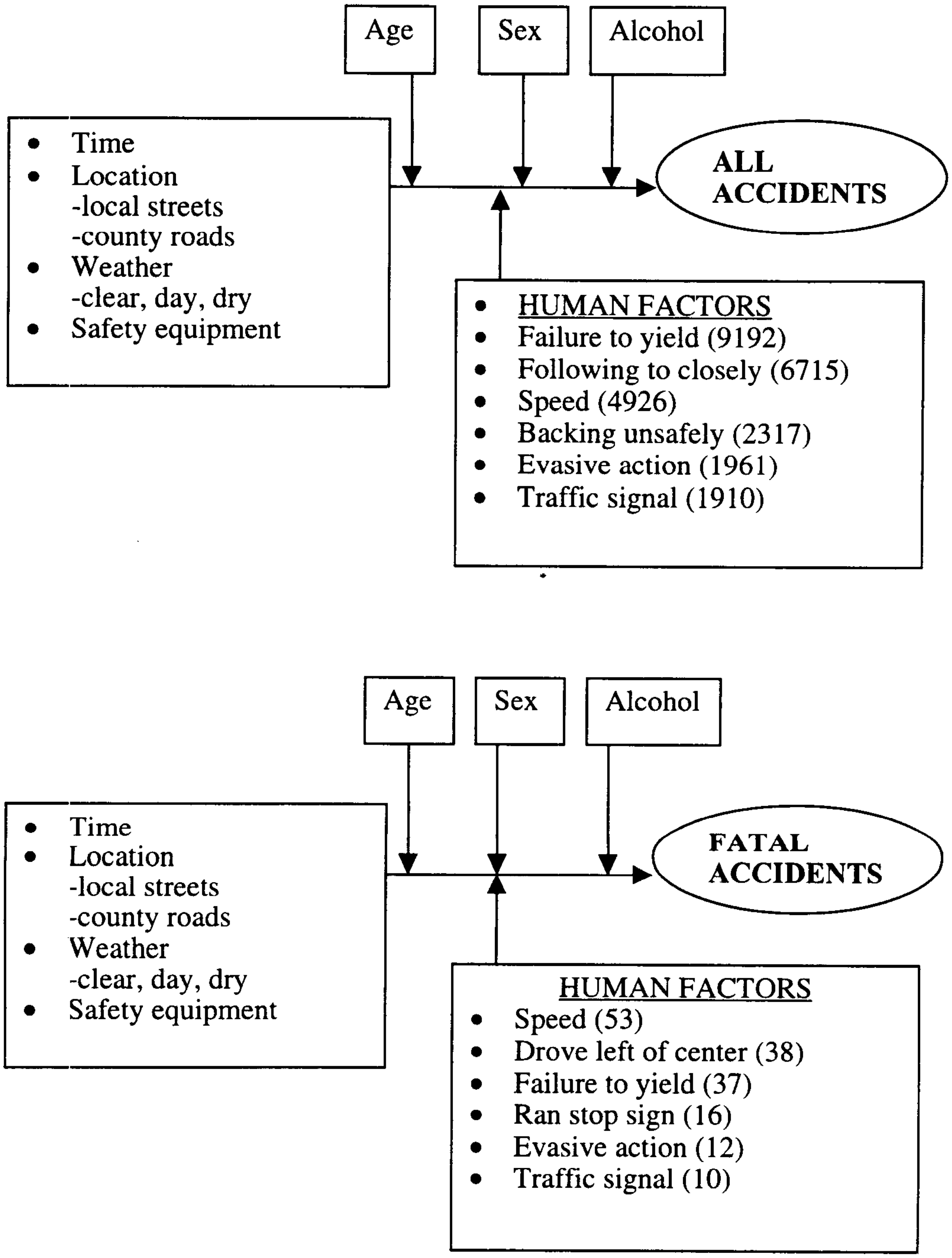


Figure 4
Nebraska Traffic Accident Facts (1998)
Implicit Theories of Crashes and Fatalities



Results

Table 3 is a correlation matrix with the means, standard deviations, and correlations of the variables. It shows that .6% of the accidents involved fatalities and 45% involved injuries. If the sign next to a variable in Table 3 is positive, it means that there is a greater chance of a fatality or injury with that variable, but if the sign is negative it means that there is a greater chance of an accident involving property damage (of > $1,000), but not a fatality or injury.

Table 3

Means, Standard Deviations, and Correlations Between the Variables

		Mean	SD	1	2	3	4	5	6	7	8	9	10
	Condition faced												
1	Two vehicle collision	.72	.45										
2	Collision with a train	.0009	.03	-.05***									
3	Collision with a pedestrian	.025	.15	-.25***	-.005								
4	Collision with an animal	.06	.24	-.41***	-.007*	-.04***							
5	Collision with a fixed object	.11	.32	-.6***	-.01***	-.06***	-.09***						
6	Urban road	.74	.43	.37***	-.02***	.06***	-.32***	-.1***					
7	Non rush hour	.33	.47	.11***	-.006*	.007*	-.07***	-.07***	.05***				
8	Curved road	.13	.33	-.23***	-.009**	-.05***	-.03***	.23***	-.1***	-.04***			
9	Late at night	.06	.24	-.21***	-.002	-.02***	.07***	.17***	-.08***	-.2***	.08***		
10	Weekend	.23	.42	-.1***	.001	-.008*	.04***	.08***	-.07***	-.14***	.03***	.13***	
11	Traffic signal	.2	.4	.23***	-.01***	.03***	-.12***	-.14***	.24***	-.002	-.13***	-.06***	-.02***
12	Stop and yield sign	.15	.35	.17***	-.005	.01***	-.1***	-.09***	.006	.03***	-.05***	-.06***	-.03***
13	School zone	.001	.03	.01***	-.001	.01**	-.006*	-.009**	-.003	.03***	-.002	-.007*	-.02***
14	Railroad signs	.002	.04	-.02***	.55***	-.007*	-.01***	-.002	-.004	-.005	-.009*	-.003	-.004
15	No passing zone	.006	.08	-.04***	-.002	-.006	.01***	.02***	-.08***	-.01***	.07***	.01***	.009**
	Decisions made												
16	No Seat belt used	.11	.31	-.02***	.008**	-.04***	-.07***	.03***	-.1***	-.01***	.03***	.04***	.03***
17	Alcohol related	.06	.23	-.14***	.005	.01***	-.05***	.15***	-.06***	-.11***	.09***	.26***	.13***
18	Risky driver behavior	.52	.5	.35***	.005	.005	-.26***	-.2***	.12***	.07***	-.16***	-.1***	-.05***
19	Defective vehicle	.03	.17	-.08***	-.003	-.02***	-.03***	.08***	-.05***	.002	.04***	-.007*	-.007*
20	Illegal speed	.11	.3	-.15***	-.002	-.04***	-.09***	.2***	-.02***	-.01***	.17***	.05***	.03***
	Controls												
21	Drivers' age (young drivers)	.45	.5	.11***	-.01***	-.07***	-.13***	-.02***	.04***	.004	-.002	.01**	.02***
22	Drivers' sex (male)	.75	.43	.19***	.005	-.08***	-.09***	-.09***	.05***	.002	-.04***	.004	-.002
23	Weather (bad)	.17	.37	-.04***	-.004	-.04***	-.07***	.11***	-.01***	-.007*	.07***	-.002	-.009**
24	Number of persons involved in crash	2.7	2.27	.28***	-.01***	-.02***	-.12***	-.18***	.1***	.04***	-.08***	-.1***	.02***
25	Fatalities	.006	.076	-.03***	.03***	.03***	-.02***	.009**	-.08***	-.003	.007*	.03***	.01***
26	Injuries	.45	.81	.003	.004	.1***	-.11***	-.02***	-.05***	-.004	.03***	-.002	.04***

Table 3 Continued

	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1															
2															
3															
4															
5															
6															
7															
8															
9															
10															
11															
12	-.21***														
13	-.02***	-.01***													
14	-.02***	-.02***	-.001												
15	-.04***	-.03***	-.002	-.003											
16	-.04***	.03***	-.00006	.007*	.02***										
17	-.04***	-.03***	-.006	.0009	.02***	.13***									
18	.09***	.1***	-.002	.004	-.03***	.06***	-.08***								
19	-.04***	-.02***	-.004	.0003	.003	.005	-.02***	-.15***							
20	-.09***	-.06***	.0005	-.003	.01***	.04***	.06***	-.32***	-.05***						
21	-.001	.03***	.006	-.005	-.009**	.1***	-.02***	.1***	.001	.05***					
22	.05***	.02***	.0005	.006	-.008*	.04***	.04***	.08***	-.02***	.001	.04***				
23		-.04***	-.001	-.001	.002	-.03***	-.03***	-.15***	.06***	.18***	.001	-.006			
24	.1***	.06***	.06***	.00006	-.01***	.05***	-.05***	.15***	-.02***	-.03***	.09***	.09***	-.02***		
25	-.03***	.008**	-.002	.02***	.03***	.1***	.05***	.002	-.0009	.02***	-.01***	.009**	-.01***	.0008	
26	.05***	.06***	-.002	.002	.01***	.27***	.1***	.13***	-.01***	.04***	.06***	-.02***	-.04***	.16***	.05***

Controlling for the other variables (see Tables 4 and 5), Model 1 tests for the effects of conditions faced and decisions made, Model 2 for the effects of decisions made, Model 3 for the effects of conditions faced, and Model 4 for conditions faced, decisions made, and the interactions. The results (based on Model 4) are summarized in Figure 5.

Table 4
Fatalities Models

	Fatalities Model 1	Fatalities Model 2	Fatalities Model 3	Fatalities Model 4
Intercept	-5.06*** (.19)	-5.8*** (.13)	-4.3*** (.16)	-5*** (.22)
Conditions faced				
Two-vehicle collision	.01 (.15)		-.04 (.14)	-.008 (.15)
Collision with a train	.03 (1.22)		.03 (1.06)	.03 (1.25)
Collision with a pedestrian	.21*** (.21)		.17*** (.2)	.21*** (.21)
Collision with an animal	-.32*** (.6)		-.42*** (.58)	-.33*** (.6)
Collision with a fixed object	-.04 (.16)		-.06* (.16)	-.05 (.16)
Rural road	.43*** (.11)		.5*** (.11)	.31*** (.23)
Non-rush hour	.04 (.1)		-.02 (.1)	.04 (.1)
Curved road	.09*** (.12)		.1*** (.11)	.09*** (.12)
Late at night	.09*** (.15)		.11*** (.14)	.09*** (.15)
Weekend	.01 (.1)		.03 (.1)	.01 (.1)
Traffic signal	-.12** (.19)		-.13** (.18)	-.11** (.19)
Stop and yield sign	.02 (.12)		.04 (.12)	-.27** (.45)
School zone	-.26 (2.7)		-.26 (2.9)	-.26 (2.5)
Railroad signs	-.004 (1.2)		.001 (1)	-.004 (1.2)
No passing zone	.02* (.26)		.03** (.26)	.05* (.57)
Decisions made				
No seat belt used	.32*** (.1)	.36*** (.09)		.31*** (.14)
Alcohol related	.04* (.13)	.11*** (.11)		.04 (.23)
Risky driver behavior	.013 (.12)	.06* (.1)		.05 (.16)
Defective vehicle	-.017 (.27)	.02 (.26)		-.017 (.28)
Illegal speed	.08** (.14)	.13*** (.13)		.017 (.25)
Interactions				
Rural road * No passing zone				.01 (1.1)
No seat belt used * Rural road				.03 (.2)
Alcohol related * Rural road				.003 (.27)
Illegal speed * Rural road				.015 (.29)
Risky driver behavior * Rural road				.27*** (.24)
No seat belt used * Stop and yield sign				.014 (.24)
Alcohol related * Stop and yield sign				.016 (.35)
Illegal speed * Stop and yield sign				.04 (.45)

	Fatalities Model 1	Fatalities Model 2	Fatalities Model 3	Fatalities Model 4
Risky driver behavior * Stop and yield sign				.28*** (.44)
No seat belt used * No passing zone				.02* (.54)
Alcohol related * No passing zone				.002 (.6)
Illegal speed * No passing zone				.011 (.63)
Risky driver behavior * No passing zone				.009 (.67)
No seat belt used * Alcohol related				.02 (.24)
No seat belt used * Illegal speed				.005 (.25)
Illegal speed * Alcohol related				.03* (.27)
Drivers' age * Drivers' sex				.04 (.26)
Controls				
Drivers' age (young drivers)	-.17*** (.1)	-.19*** (.1)	-.12*** (.1)	-.21** (.24)
Drivers' sex (male)	.1*** (.12)	.04 (.11)	.13*** (.12)	.09** (.15)
Weather (bad)	-.1*** (.15)	-.1*** (.14)	-.14*** (.15)	-.1** (.15)
Number of persons involved in crash	.03 (.01)	-.01 (.02)	.04** (.01)	.03 (.01)
R Square	.016	.0078	.011	.017
Chi-Square	78***	38.5***	64.7***	421***
N	71828	90441	71828	71828

*p<.05 ** p< .01 ***p< .001 Standard errors in parentheses.

Table 5
Injuries Models

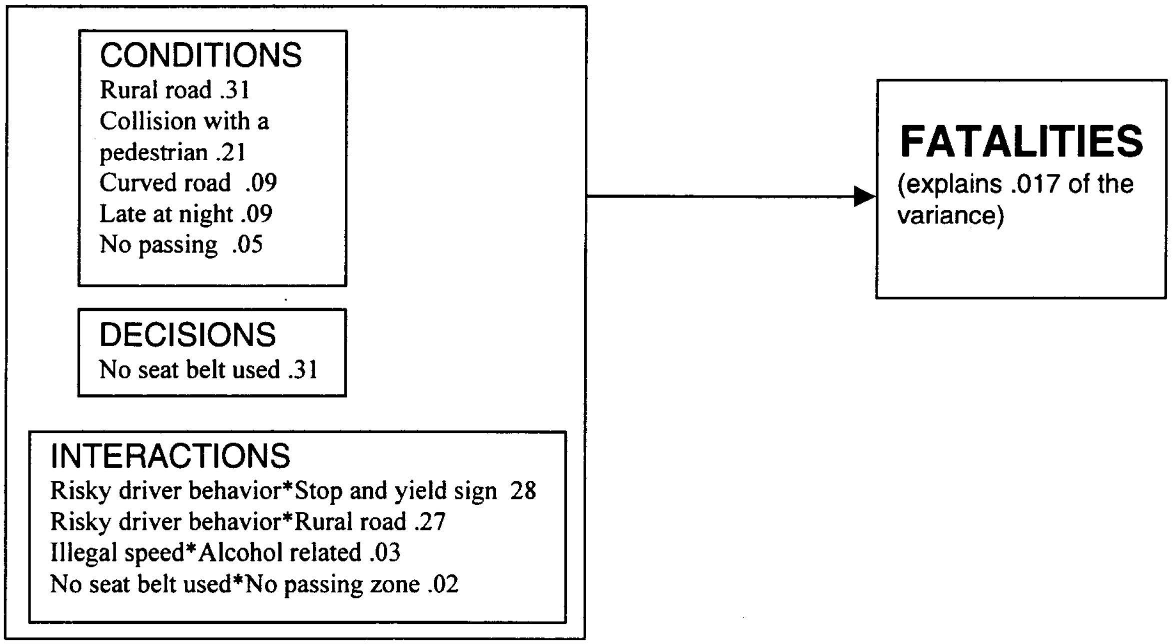
	Injuries Model 5	Injuries Model 6	Injuries Model 6	Injuries Model 7
Intercept	-5.5*** (.06)	-6.25***	-5*** (.06)	-5.5*** (.07)
Conditions faced				
Two-vehicle collision	-.13*** (.03)		-.14*** (.03)	-.13*** (.03)
Collision with a train	-.0005 (.34)		.00005 (.33)	-.0006 (.34)
Collision with a pedestrian	.09*** (.05)		.07*** (.05)	.09*** (.05)
Collision with an animal	-.22*** (.06)		-.27*** (.06)	-.22*** (.06)
Collision with a fixed object	-.09*** (.036)		-.1*** (.03)	-.1*** (.036)
Rural road	.058*** (.02)		.08*** (.02)	.03** (.04)
Non-rush hour	.01* (.017)		.017*** (.017)	.01* (.017)
Curved road	.011** (.025)		.016*** (.02)	.01* (.025)
Late at night	-.013** (.036)		.013** (.03)	-.013** (.04)
Weekend	.022*** (.02)		.03*** (.02)	.021*** (.02)
Traffic signal	.1*** (.02)		.1*** (.02)	.1*** (.02)
Stop and yield sign	.06*** (.02)		.07*** (.02)	.017 (.06)
School zone	-.006 (.26)		-.006 (.25)	-.006 (.26)
Railroad signs	.002 (.22)		.003 (.21)	.002 (.22)
No passing zone	.016*** (.1)		.02*** (.1)	.023* (.19)
Decisions made				
No seat belt used	.24*** (.02)	.24*** (.02)		.25*** (.04)
Alcohol related	.07*** (.03)	.1*** (.03)		.09*** (.06)
Risky driver behavior	.04*** (.02)	.17*** (.016)		.06*** (.04)
Defective vehicle	-.02*** (.05)	.03*** (.04)		-.019*** (.05)
Illegal speed	.03*** (.028)	.1*** (.02)		.033*** (.05)

	Injuries Model 5	Injuries Model 6	Injuries Model 6	Injuries Model 7
Interactions				
Rural road * No passing zone				.01* (.25)
No seat belt used * Rural road				.001 (.04)
Alcohol related * Rural road				.02** (.06)
Illegal speed * Rural road				.004 (.06)
Risky driver behavior * Rural road				.044*** (.04)
No seat belt used * Stop and yield				.0028 (.05)
Alcohol related * Stop and yield				.01* (.09)
Illegal speed * Stop and yield sign				.002 (.09)
Risky driver behavior * Stop and yield				.05*** (.06)
No seat belt used * No passing zone				.009* (.22)
Alcohol related * No passing zone				.003 (.27)
Illegal speed * No passing zone				.004 (.28)
Risky driver behavior * No passing zone				.003 (.22)
No seat belt used * Alcohol related				.01** (.06)
No seat belt used * Illegal speed				.006 (.06)
Illegal speed * Alcohol related				.002 (.08)
Drivers' age * Drivers' sex				.03** (.04)
Controls				
Drivers' age (young drivers)	.001 (.016)	-.001 (.01)	.02*** (.015)	-.02* (.03)
Drivers' sex (male)	-.06*** (.02)	-.08*** (.016)	-.04*** (.02)	-.07*** (.02)
Weather (bad)	-.04*** (.02)	.03*** (.02)	-.05*** (.02)	-.037*** (.02)
Number of persons involved in crash	.11*** (.003)	.09*** (.003)	.12*** (.003)	.11*** (.003)
R Square	.12	.09	.07	.12
Chi-Square	4045***	2503***	4064***	4856***
N	71828	90441	71828	71828

*p<.05 ** p< .01 ***p< .001 Standard errors in parentheses.

Figure 5

A Model of Fatalities Based on the IHL Framework and 1999 Minnesota Statistics



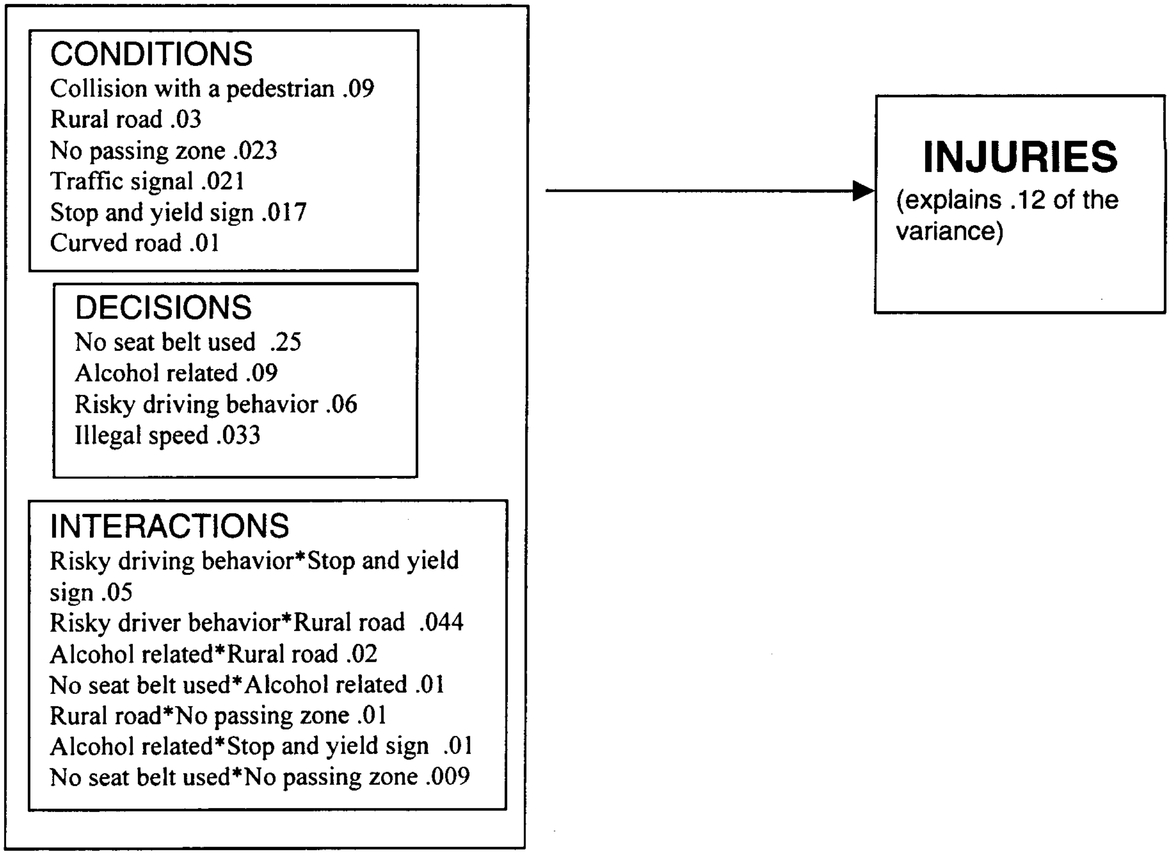
CONDITIONS
Rural road .31
Collision with a pedestrian .21
Curved road .09
Late at night .09
No passing .05

DECISIONS
No seat belt used .31

INTERACTIONS
Risky driver behavior*Stop and yield sign 28
Risky driver behavior*Rural road .27
Illegal speed*Alcohol related .03
No seat belt used*No passing zone .02

FATALITIES
(explains .017 of the variance)

A Model of Injuries Based on the IHL Framework and 1999 Minnesota Statistics



CONDITIONS
Collision with a pedestrian .09
Rural road .03
No passing zone .023
Traffic signal .021
Stop and yield sign .017
Curved road .01

DECISIONS
No seat belt used .25
Alcohol related .09
Risky driving behavior .06
Illegal speed .033

INTERACTIONS
Risky driving behavior*Stop and yield sign .05
Risky driver behavior*Rural road .044
Alcohol related*Rural road .02
No seat belt used*Alcohol related .01
Rural road*No passing zone .01
Alcohol related*Stop and yield sign .01
No seat belt used*No passing zone .009

INJURIES
(explains .12 of the variance)

Propositions 1 through 4. Proposition 1 is supported in that the fatalities model explains less of the variance (.017) than the injuries models (.12). It is harder to predict motor vehicle fatalities than to predict motor vehicle injuries. Proposition 2 is supported in that engineering and system reliability factors have a significant effect on the incidence of motor vehicle injuries and fatalities. Proposition 3 is supported in that inattention to formal precautions such as seat belts, violation of traffic rules such as the speed limit, and impaired judgment from using alcohol are likely to increase the incidence of motor vehicle injuries and fatalities. Note that illegal speed is more important in the case of fatalities and that alcohol is more important in the case of injuries. Proposition 4 is supported in that interactions such as those between the conditions drivers face and the decisions drivers make increase the incidence of motor vehicle injuries and fatalities. The significant relationship between illegal speed and fatalities (Models 1 and 2) is replaced by the interaction between illegal speed and alcohol (Model 4), which suggests that illegal speed is more likely to be fatal when it is combined with alcohol use.

Proposition 5. In addition, the analyses provide evidence to support Proposition 5. For example, though the Illinois driving manual includes extensive discussions of many factors that may be related to safe driving, Illinois does not mention speed in the crash facts analysis (see Figure 6), and some of the factors the analysis does mention, such as work zones, are not discussed in the driving manual. Clearly, in Illinois and the other states, different theories of safe driving govern data collection and driving instruction. The number of pages dedicated to the implicit theories in the state crash facts range from a low of 8.8% in Illinois to a high of 43.3% in Wisconsin (see Table 6). The connection between the information collected about motor vehicle crashes and the use of this information in programs like driver education is a loose one.

Figure 6
Illinois Crash Facts (1996)
Implicit Theory of Accidents

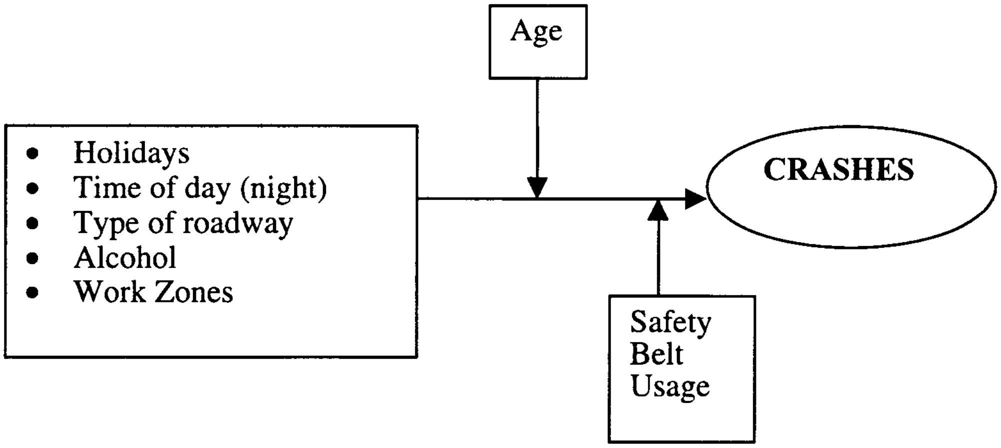


Figure 7
Illinois Drivers' Manual (1999)
Implicit Theory of Crashes

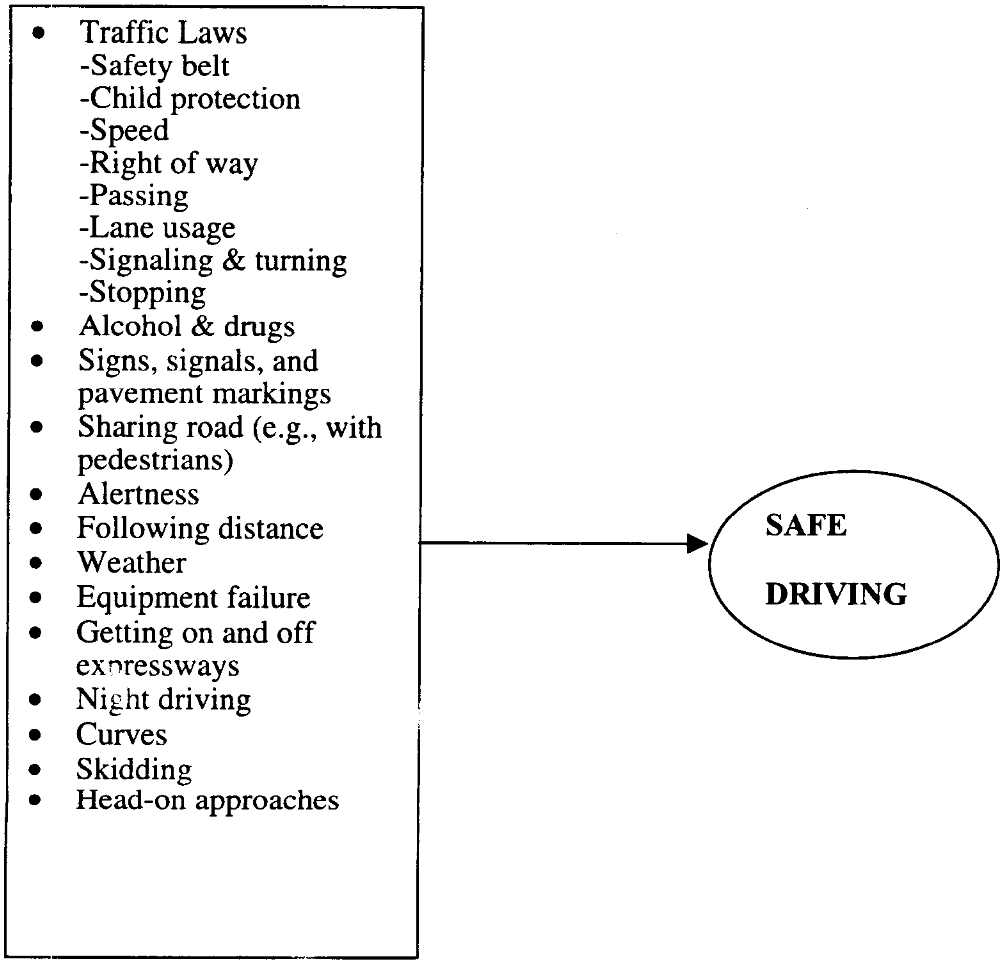


Table 6

Driving Manual Pages Devoted to Crash Causes

	Illinois (1996 Crash Facts & 1999 Driving Manual)	**Iowa** (1995 Crash Facts & 2000 Driving Manual)	**Kansas** (1996 Crash Facts & 2000 Driving Manual)	**Michigan** (1997 Crash Facts & 1999 Driving Manual)	**Minnesota** (1998 Crash Facts & 1999 Driving Manual)	**Nebraska** (1998 Crash Facts & 2000 Driving Manual)	**NDakota** (1998 Crash Facts & 2001 Driving Manual)	**SDakota** (1999 Crash Facts & 1999 Driving Manual)	**Wisconsin** (1998 Crash Facts & 1999 Driving Manual)
Conditions Leading to Crashes	*Holidays *Time of day (night) *Urban /rural roadway *Work zones	*Time of day *County	*Time of day *Roadway type (urban/rural) & condition *Intersections * Stop & yield signs	*Time of day *Roadway type & condition *Weather *Vehicle type	*Stop & yield signs *Congestion	*Time *Location *Stop & yield signs *Traffic signals	* Urban /rural roadway *Time of day, month, day of week * Stop & yield signs	* Urban /rural roadway *County *Holidays *Vehicle type	
Decisions Leading to Crashes	*Alcohol	*Safety equipment *Alcohol	*Restraint usage *Inattention *Speed *Alcohol	*Restraint usage	*Safety equipment *Speed *Alcohol *Distraction, inattention *Following too closely	*Alcohol *Speed *Safety equipment *Risky driving behavior	*Speed *Alcohol *Distraction, inattention	*Safety equipment *Alcohol	*Alcohol *Speed *Inattention *Disregard for signals *Improper overtake
Controls	*Age	*Age	*Age *Sex *Weather	*Age *Sex	*Age *Sex * Weather	*Age *Sex *Weather		*Age *Weather	*Age
Proportion of the Driving Manual Devoted to These Factors	8.8%	18.2%	21.4%	23.1%	27.7%	13. 7%	9.8%	30.3%	45.3%

For Minnesota, we examined earlier driving manuals to see if there was any trend, with more attention being devoted to accident causes over time. If anything, the trend was in the opposite direction, with 36.3% of the driving manual devoted to the causes in 1986, 30.6% devoted to them in 1996, and 27.7% devoted to them in 1999 (see Table 7). As an additional test, we examined the proportion of the driving manual devoted to fatal and injury accident causes identified in the statistical analyses (see Table 8). While this number was higher at 36.5%, the connection between what the data reveal and what is found in the driving manual was still not very tight. One can ask, how much of a driving manual *should* be devoted to accident causes? Other information has to appear in these manuals (for example, how to get a license). Nonetheless, given that the main purpose of the manuals is to provide instruction on safe driving, the evidence suggests that the information collected about crashes is not systematically incorporated into the manuals.

Table 7
Minnesota Driver's Manual Pages Devoted to Accident Causes Emphasized in Crash Facts

	1986 (91 pages)	1996 (141 pages)	1999 (159 pages)
Driver inattention or distraction	p. 27, 69	pp. 44-5 (concentration, fatigue)	pp. 51-3 (concentration, fatigue)
Failure to yield right of way	p. 37,56,65 (yield signs) pp. 77-82 (on freeways) p. 12, 37,59,64 (other)	pp. 97-98 (right of way & yielding) pp. 85, 123-7 (on freeways)	pp. 106-7 (right of way & yielding) pp. 92,136-141 (on freeways)
Illegal or unsafe speed	pp. 53-5,61	pp. 87-8	pp. 46,94-6
Physical impairment (usually by alcohol)	pp. 28-9, 62-3	pp. 48-61 (including drugs)	pp. 56-68 (including drugs)
Not using safety equipment	p. 23,85	pp. 27-30, 108-9, 135	pp. 32-3,35-6,118-9.150
Young, male drivers (inexperience, reduced judgment, increased risk-taking)	p. 30,61 (following distance) p. 65 (reckless & careless driving)	p. 40-2,100 (following distance) p.101(reckless driving)	pp. 47-9 (following distance) p. 110 (reckless driving)
Clear, dry roads (two-lane, two-way)	pp. 57-8 (passing)	pp. 91-4 (passing)	pp. 99-103 (passing)
Congestion (before point where reduces speeds)			
Winter driving	pp. 70-2,76	pp. 115-120	pp.127-32
	33 pages	44 pages	44 pages

Table 8
Minnesota Driver's Manual: Proportion Devoted to Fatal and Injury Accident Causes Identified in the Statistical Analyses

	1999 (159 pages)
CONDITIONS	
Rural road	0 pages
Collision with a pedestrian	7 pages
Curved road	2 pages
Late at night	6 pages
No passing zone	5 pages
Failure to yield right of way	2 pages
Traffic signal	4 pages
Stop and yield sign	2 pages
No passing zone	5 pages
DECISIONS	
No seat belt used	7 pages
Alcohol related	11 pages
Risky driving behavior	3 pages
Illegal speed	4 pages
Total	58 pages
Proportion of the driving manual devoted to these factors	36.5%

IMPROVED METHODS

The Literature

The Bureau of Transportation Statistics (BTS) has published the *Guide to Good Statistical Practice (1999)*. These guidelines have been developed over several years within various organizations and federal statistical agencies such as the U.S. Census Bureau, American Statistical Association, National Center for Education Statistics, and Energy Information Administration. They deal with aspects of data collection and data analysis, sources of data, data accuracy, defining errors in data analyzing, and presenting data. However, they do not deal with the systems in place for interpreting, disseminating, and using the data to derive lessons that will prevent future accidents from occurring.

The more complete a traffic accident record and analysis system is, the more potential for safety improvement. Data should provide a resource to meet the needs of investigators. Research activities in the area of crash data collection must include data file building and maintenance. Systems of software that provide access to the database are a major issue. A number of simple data access functions can interface the system data sets with statistical analysis packages. Miller and Deasy (1998) suggest rules for designing and maintaining web pages on transportation safety.

Only a small fraction of what takes place at an accident finds its way into the official record, however. Uniform, complete, and accurate accident reporting can reveal not only how *many* accidents occur, but what kind of accidents occur, where and when they occur, what the physical circumstances were, which emergency services and enforcement agencies responded, and many other kinds of information. Attempts at improving the quality of data collected and how these data are subsequently interpreted and used must take into account the fact that recording accident data is only part of a police officer's duties at an accident scene. Therefore, it is desirable to find ways to improve the quality of data without adding to the work involved in recording data. The use of emerging technologies, such as mobile computers, Global Positioning Systems (GPS), Geographic Information Systems (GIS), printers, and magnetic stripe and barcode readers has been suggested as a way to improve the quality of traffic accident data.

Hughes, Reinfurt, Yohanan, and McGee (1993) reviewed processes related to the collection and management of motor vehicle traffic accident data. They identified technologies that are most promising in terms of improving the quality, accuracy, completeness, and timeliness of accident data and reducing the demands on police officers, accident investigators, data coders, and data entry personnel. The technologies examined included form readers/optical scanners, laptop and notebook computers, pen-based portable computers, identification technologies including magnetic stripe, bar codes, and smart cards, Automatic Vehicle Identification (AVI), the Global Positioning System (GPS), and location technologies.

Miller (1997) claimed that although advanced technologies have the potential to improve crash records processing, a number of recurring institutional issues must be examined to understand the limits of these technologies. These issues include the diversity of crash-data users and providers, the dynamic nature of crash records, and the lack of a single entity that reaps all the benefits and bears all the costs of crash-record processing. Thus, the system itself for interpreting, disseminating, and drawing lessons from the data is in important ways deficient. These issues contribute to problems with crash-record processing, such as lack of access to crash data, inconsistencies among crash databases, and a disincentive to implement new technologies or organizational changes that would make crash data more accessible, timely, and practical.

During recent years different initiatives for changing the system have progressed, but improvements in the system of data analysis, interpretation, dissemination, and use still need to be made. Miller (1995) has conducted an overview of Virginia's computerized crash system. The University of Michigan Transportation Research Institute (UMTRI) has a study for evaluation of data sources for highway safety. Thielman (1999) has reported on what might be the most significant initiative, the new Federal Highway Administration (FHWA) Expert Systems for Crash Data Collection Program, which the Iowa Department of Transportation has participated in. Despite these advances, questions still remain. To what extent are agencies using the data that exist? What interpretations are they drawing from the data? What lessons are they learning? How are they implementing the lessons they learn?

There is a demand by the highway safety community for better quality crash data to meet a wide variety of needs, but better quality data in and of itself will not solve all problems unless the system for using these data is understood and improved (Hauer, 1997, p. 40). Bier (1998) suggests using sophisticated probabilistic risk analysis techniques for estimating the frequency of accidents. Thomas and Otte (1996) describe the role of real-world crash injury data in the development of safety strategies or regulations. Knoblauch, Moore, Schmitz, and Sommers (1977) have collected and analyzed data to identify potential countermeasures. They discuss countermeasures to apply to each accident type, but are these countermeasures taken? What system is in place to assure that warnings are heeded and that the system responds well to the information it has?

CODES is a collaborative approach to obtain medical and financial outcome information related to motor vehicle crashes for highway safety and injury control decision-making. It has evolved as the result of the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991, which provides funds to the National Traffic Safety Administration (NHTSA) to report to Congress about the benefits of safety belts and motorcycle helmets for persons involved in motor vehicle crashes. Again, the issue is, what happens once this information is made known? How does it affect policy? To what extent is the information used to prevent accidents?

The Experts

The experts we interviewed provided a number of suggestions for improving data collection and use. They experts told us that much information is missing. For instance, data on the placement of signage and its effects is partial. Some of the definitions of the reasons for crashes are too general. No data exist for near misses. Drivers have a disincentive to reveal some of the facts of a case, as they are aware that a full report of how the crash happened might lead to a ticket or higher insurance premium. Insurance companies do not publish data they have—data that might be useful for the learning processes.

The experts maintain that the data are richer than their uses. For example, high-risk groups, such as young drivers, are well known. The main reasons for crashes, such as alcohol, have been identified. Though more intensive and better data collection is needed, it is likely that in dealing with known issues, improvements can be made. All opportunities for learning from the existing data have not been exhausted. Better communication and cooperation is needed among the different organizations that collect and use the data. The current system is complex. It is unclear who the customers for the data are and who uses the data. A sharp and clear definition of customers and users would be useful.

Better learning comes from improved feedback loops. The interviews provide some examples of feedback loops that might be improved:

1. ***Signage.*** How do designers of road signs in industry and state agencies learn? To what extent do they rely on and obtain accurate crash data?

2. ***The release of crash data to the public.*** How should it be communicated? Do ordinary drivers receive information that would improve their driving ability and enable them to avoid crashes?

3. ***Alcohol.*** Who is receiving information on alcohol-related accidents? What sense are they making of it?

4. ***Young drivers.*** How can the learning curve be accelerated among young drivers? Should accident cases and scenarios be used in driver education?

5. ***Big fleets.*** How do the U.S. Postal Service or FedEx® communicate crash information to their drivers and provide them with training to prevent future accidents? What are the learning processes among commercial drivers?

6. ***Auto manufacturers.*** What mechanism do auto manufacturers use for crash data collection? How is this information incorporated into new vehicle design and recall decisions?

7. ***Ambulance drivers and emergency room personnel.*** Could accident data be shared with these groups to enhance their preparedness and increase their ability to save lives?

8. ***Benchmarking.*** Benchmarking different systems would be useful—benchmarking state systems against each other and against systems used in IHL sectors, such as aviation, chemical manufacturing, or nuclear power.

CONCLUSION

This paper has reviewed theories for analyzing incidents in high-risk technologies and applied them to voluntary, low-consequence, high-probability events like traffic accidents. The impact of the conditions drivers face (for example, the type of road) and the decisions they make (for example, the decision to wear a seat belt) have been examined using Minnesota data. The most significant condition leading to a fatality or an injury was driving on a rural road, and the most significant decision was choosing not to use a seat belt. How factors combine to cause fatalities and injuries was examined. For example, a combination of risky driver behavior *at* stop and yield signs was significantly related to both fatalities and injuries. Similarly, a combination of illegal speed *and* alcohol use was significantly related to both fatalities and injuries. Traffic controls, such as traffic signals and stop and yield signs, tended to prevent fatalities but were also the sites of a disproportionately large number of injuries. No passing zones, on the other hand, tended to be the scenes of both a high number of fatalities and a high number of injuries. Overall, the fatality model explained about 2 percent of the variance and the injury model explained about 12 percent of the variance.

Traffic safety officials have their own implicit models of what causes fatalities and injuries. Models were constructed from the Minnesota report, *Crash Facts,* and similar reports of eight neighboring states—Illinois, Iowa, Kansas, Michigan, Nebraska, North Dakota, South Dakota, and Wisconsin. Then, the driver instruction manual for each state was analyzed to determine the extent to which the factors identified by traffic safety officials as being associated with fatalities and injuries were emphasized in the manuals. About one-third of the pages in a typical manual were devoted to factors that traffic safety officials consider to be the main reasons for fatalities and injuries.

Although the current data collected in Minnesota, when analyzed, provided a number of powerful predictors of fatalities and injuries relating to the conditions a driver faces, such as rural roads, and the actions that drivers take, such as failure to use a seatbelt, overall the data's ability to explain crash severity could be better. Improved theory can inform data collection and result in more powerful predictive models that could be used in programs to educate drivers. Accidents at nuclear power plants and chemical plants and in commercial aviation are thoroughly scrutinized and analyzed to determine how disasters can be prevented. This information is fed back to operators and system designers to help them defend against accidents, but more systematic analysis of road accident data is needed for these purposes. In commercial aviation, pilots are *systematically* fed back information about potential incidents and given *explicit* instruction about how to prevent them. Roughly parallel systems should be in place in the traffic safety system, where both the professional driver and the average driver need to be more aware of road hazards and the decisions they should make to avoid them.

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