WEATHER-RELATED CRASHES ON PUBLIC LAND

by

Lewis Moore

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DEDICATION

To my Mom, Delia Bernice Ten Eyck Moore, who has never stopped leaning.

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Any errors, omissions or misinterpretations herein are strictly my own.

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LIST OF ABBREVIATIONS/SYMBOLS

AADT: Average Annual Daily Traffic

AIS: Abbreviated Injury Scale

AWS: Advanced Weather Systems

Bureau of Indian Affairs: US Department of the Interior

BLM: Bureau of Land Management, US Department of the Interior

BTS: Bureau of Transportation Statistics, US Department of Transportation

CACoHwyxx: Public Land Section for California in this Analysis

CALTRANS: California Department of Transportation

CAWS: CALTRANS Automated Weather System

CHAMPUS: Civilian Health and Medical Program of the Uniformed Services

CHP: California Highway Patrol

CODES: Crash Outcome Data Evaluation System, NHTSA/USDOT

DOD: US Department of Defense

DOI: US Department of the Interior

DOT: US Department of Transportation (hereinafter USDOT)

EMS: Emergency Medical Services

FARS: Fatality Analysis Reporting System, NHTSA/USDOT

FHWA: Federal Highway Administration, USDOT

FS: US Forest Service. US Department of Agriculture

FLHP: Federal Lands Highway Program, USDOT

FWS: Fish and Wildlife Service, US Department of the Interior

GAO: General Accountability Office, US Congress

GIS: Geographical Information System

GPCoHwyxx: Reference Section of California Roadway between test Sections

GPS: Global Positioning System

HSIS: Highway Safety Information System, FHWA

HTT: Helicopter Trauma Team

ITD: Idaho Transportation Department

ITS: Intelligent Transportation System

KABCO: Five level Accident Severity Scale

LTV: Light Trucks and Vans vehicle classification

MMUCC: Model Minimum Uniform Crash Criteria

NASS--CDS: National Automotive Sampling System – Crashworthiness Data System

NASS—GES: National Automotive Sampling System – General Estimates System

NAT_LND: California HSIS data element for public land identification

NCHRP: National Cooperative Highway Research Program

NCSA: National Center for Statistics and Analysis, NHTSA/USDOT

NHTSA: National Highway Transportation Safety Administration, USDOT

NPS: National Park Service, US Department of the Interior

NWS: National Weather Service, US Department of Commerce

OFCM: Office of the Federal Coordinator for Meteorology, US Department of Commerce

OSDOT: Oregon Department of Transportation

ROR: Run Off Roadway crash

RUCoHwyxx: Rural California reference road section used in this analysis

SDS: NHTSA State Data System

SOIL: Survey of Occupational Injury and Illness by Bureau of Labor Statistics, US Department of Labor

SUV: Sports Utility Vehicle

TRB: Transportation Research Board of the National Academies of Science

VMS: Variable Message Sign

WIST: Weather Information for Surface Transportation, OFCM/National Oceanographic and Atmospheric Administration/US Department of Commerce.

ABSTRACT

WEATHER-RELATED CRASHES ON PUBLIC LANDS

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This research examines weather and road conditions relation to traffic crashes on Bureau of Land Management (BLM) and U.S. Forest Service (FS) land in three states: Idaho, Oregon and California. Crash data for Idaho and Oregon were supplied by the state transportation departments while the California data were obtained from the Federal Highway Administration's Highway Safety Administration (FHWA) .

The results are mixed, probably because of the different methods of data collection: Idaho seems to have particularly severe crashes during bad weather on these public lands when all roads on the public lands are compared with other rural Idaho state and federal highways. Oregon's comparable weather-related crashes do not show such severe crashes in poor weather or road conditions, but Oregon on these federal lands crashes in good weather are very severe as are the "non-weather" crashes on lightly traveled rural highways in the State.

California's FHWA Highway Safety Information System data offered a much more objective test of crashes on the public domain, based on federal and state roadways versus private, rural land roads during "weather" and "non-weather" conditions. In the aggregate, weather-related crash differences appear non-significant for California's public and private lands. The salient finding in California is that on average, "non-weather" crashes on BLM and USFS land are significantly more severe than on comparable rural roadways in the State. Using FHWA projections of crash costs, the BLM and FS crashes produce about 30 percent greater losses.) The latter finding may be a result of more speed with good weather conditions, adverse roadside environments and the increased time required for emergency response to public land crashes.

Future deployments of Intelligent Weather technology for rural California roadways could benefit from the database assembled for this research, especially the weather-related crash analysis for roadway/county/federal or rural land contingencies in Appendix A. Dramatic differences in local crash costs were observed in the limited fine-scale analysis done in this study. Providing weather and location crash cost in a Geographical Information System would further assist management and policy-makers in efforts to reduce rural crash risk.

Chapter 1: INTRODUCTION

This dissertation tests whether remote crashes and weather conditions on U.S. Forest Service (FS) and Bureau of Land Management (BLM) roadways produce different costs compared with other rural areas. It compares the incidence and cost of adverse weather and slick roadway crashes on these federal lands to those in dry weather and on comparable rural, but privately-held areas of the U.S. The results of this study should indicate whether crashes for remote roadways on the public domain are more frequent or severe in various environmental conditions. Also, it could help inform decisions about public access and the use of additional technology for traffic safety on rural roads.

Traffic crashes are a major drain on the U.S. economy despite the notable advances made in highway safety. The Department of Transportation (DOT) projects total U.S. crash costs at several hundred billion dollars per year[1] – comparable to the U.S. Department of Defense budget. The Federal Highway Administration (FHWA) links over half the U.S. crashes with excessive speed, impaired drivers and lack of occupant restraint, but the

[1] U.S. Department of Transportation, National Highway Transportation Safety Administration (NHTSA), "Initiatives to Address Improvement of Traffic Safety Data", Washington: NHTSA, July 2004. p.7. Also at http://www.nhtsa.dot.gov/people/Crash/crashstatistics/TrafficSafetyData_IPT_Report.htm, hereinafter: "NHTSA (2004), Initiatives to Address Improvement of Traffic Safety Data"

causal contributions from those voluntary behaviors are often compounded by drivers' poor information about the roadway environment and vehicle conditions.

Rural travel is disproportionately hazardous; over four-fifths of U.S. roadways are considered "rural", and these roads average almost twice the fatality rate per mile traveled as "urban" areas[2]. Montana (with a population of one million in an area the size of Japan) has nearly triple Massachusetts' road deaths per kilometer traveled. When compounded by the fact that Montanans motor about a third more than the Massachusetts citizens, Big Sky Country's risk of vehicular death is quadruple that of the Bay State[3]. In 2005, the U.S. recorded 9.07 traffic deaths per billion kilometers driven; this rate has diminished at about the same rate as the distance traveled has increased, so the U.S. annual fatality count has remained near 43,000 traffic deaths for the last decade. The excessive death rate for rural travel has remained relatively constant, owing in large measure to the "fatal four" driver behavior factors[4]: lack of restraint, driver fatigue, alcohol and speed - coupled with the predominately two-lane, unpaved rural roads through hazardous terrain, and the use of many high-profile, four wheel-drive vehicles prone to rollover accidents.

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[2] Various sources define "rural" differently – usually in terms of people in a particular political unit, but these population thresholds vary by an order of magnitude, from 50,000 in the UK to 5,000 in Virginia. The author has chosen to use Kon's "rural" definition of 5,000 or less population in this research: "The definition of rural area can be derived from the definition of urban areas. Officially, an urban area has a population more than 5,000 within the boundaries set by state or the local government. Rural areas are those areas outside the boundaries of urban areas." Tayfun Kon, "Collision Warning and Avoidance System for Crest Vertical Curves", (Master's Thesis), Blacksburg, VA: Virginia Tech, May 1998, (Appendix A).

[3] Environmental Working Group (EWG), "Blind Spot", Surface Transportation Policy Project, Washington: EWG, November 20, 1997. This study found the average Montana family drove 26,025 miles annually while Massachusetts families averaged 19, 443 miles.

[4] C., M. Veitch, M. Sheehan, R. Turner, V. Suskind, and D. Paschen, "The Economic, Medical and Social Costs of Road Traffic Crashes in Rural North Queensland: a 5-Year Multi-Phase Study", Alice Springs: 8th National Rural Health Conference, March 10-13, 2005. hereinafter Veitch (2005)

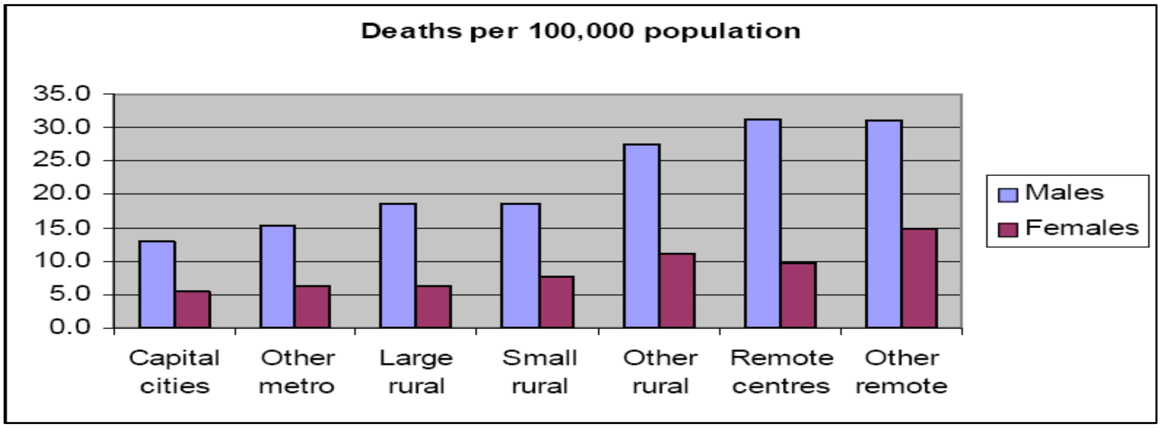

Figure 1: Australian Traffic Fatality Rates 1992-96, by Residence Location and Sex, Source: Inst. Of Health & Welfare[5]

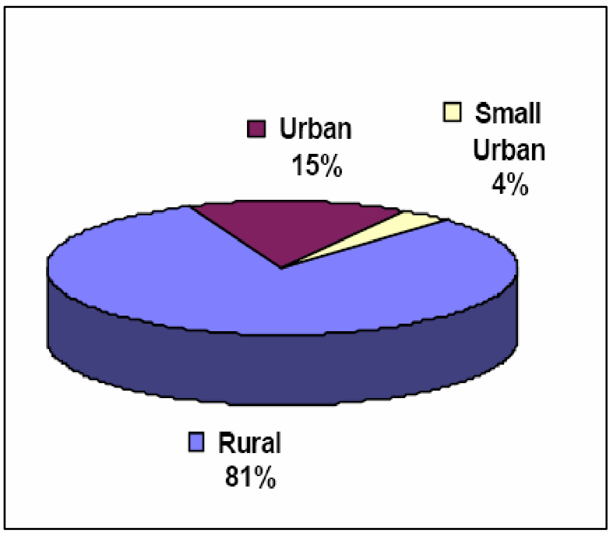

Figure 2: U.S. Roadway Distribution, Per California Department of Transportation (CalTrans) and JHK & Associates

While speed, driver impairment and lack of restraint are the most important contributory factors in raising the risk for rural travel, drivers' lack of information about other environmental conditions undoubtedly elevates the probability of sudden surprises and tragic consequences[6]. Two-lane, unpaved roadways, prevalent on the

[5] Australian Institute of Health and Welfare, 1998. Note that definitions of "urban" and "rural" vary with political jurisdiction and author. Rural is variously defined as an area having less than [Virginia – 5,000] or [Washington – 50,000] people living within a political boundary. Other ranges of urbanization include "urban", "dense rural", "sparse rural" and "frontier". In R.L. Muellerman and K. Mueller, "Fatal Motor Vehicle Crashes: Variations of Crash Characteristics within Rural Regions of Different Population Densities", *Journal of Trauma-Injury Infection & Critical Care*, 41(2):315-320. August 1996.

[6] David Smith, FHWA Senior Transportation Specialist, "FHWA and Safety", Address to the 21st International Forum on Traffic Records & Highway Safety Systems, Buffalo, NY, August 2, 2005.

public domain, have been shown to be particularly dangerous, especially for young drivers and others who run off the roadway[7].

Adverse weather and slick roadways are especially problematic for rural travelers because these hazardous conditions can develop very rapidly, and frequently without much warning. Icy roadway and sudden storms imperil travelers unprepared for adverse weather consequences. Even passing showers can be hazardous; some studies have indicated that the risk of fatal crashes may increase several times with wet pavement – especially when it follows a prolonged dry period[8].

Providing effective roadway warnings as conditions change generally requires Intelligent Transportation Systems[9] (ITS) and Advanced Weather Systems[10] (AWS), deployed in extensive interactive networks. Rural roads cannot generally compete for ITS resources with heavily traveled urban and Interstate arterials, since highway safety allocation policy requires project cost be balanced with expected benefits for future technological systems.

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[7] D. Prubhakar and M. Qu, "Why is it so risky to drive on the Roadways where the Posted Speed limit is 50 MPH?", Presentation to the 31st International Traffic Records Forum, Buffalo NY: July 31-August 4, 2005.

[8] H. Brodsky and A. Hakkert, "Risk of Road Accident in Rainy Weather", *Accident Analysis and Prevention*, Vol. 20, No. 3, 1988, 161—176.

[9] ITS has a variety of facets: USDOT's Intelligent Transportation Systems Joint Program Office (ITS JPO) sponsors weather and surface transportation programs including Integrated Vehicle Based Safety Systems, Cooperative Intersection Collision Avoidance Systems, Next Generation 9-1-1, Mobility Services for All Americans, Integrated Corridor Management Systems, Nationwide Surface Transportation Weather Observing and Forecasting System -- Clarus, Emergency Transportation Operations, Universal Electronic Freight Manifest, and Vehicle Infrastructure Integration (VII). Source: http://www.clarusinitiative.org/fhwa.htm

[10] AWS takes a variety of forms, depending on the nature of the weather condition that poses a problem for the road or situation to be monitored. Basic instrumentation monitors temperature, dew point, wind direction and velocity and atmospheric pressure, but most traffic applications require information about the present weather, visibility and road surface. The latter conditions require more sophisticated sensors, analogous to what is used for airports. See, for example: A.J.,Khattak, P. Kantor, and F. M.Council, "Role of Adverse Weather in Key Crash Types on limited-access roadways", *Transportation Research Record*, No. 1621, 1998. p.10.

While it does not appear that widespread deployment of ITS and AWS will become affordable for many rural road networks, policymaking would be better justified if there were more information on crash incidence, consequences, and driver behavior in this sparsely populated land. Also, there may be ways of preventing some weather-related crashes by providing better tailored advice on environmental conditions through radio, internet or media yet to be employed for travelers on remote roadways. Satellite data relay and remote sensing techniques may eventually keep travelers in continuous contact with weather forecasters who may correspondingly have direct real-time information coming from critical roadway segments on the public domain. Obviously, the net effect of future innovations will ultimately depend on drivers' receptiveness and response to any new information.

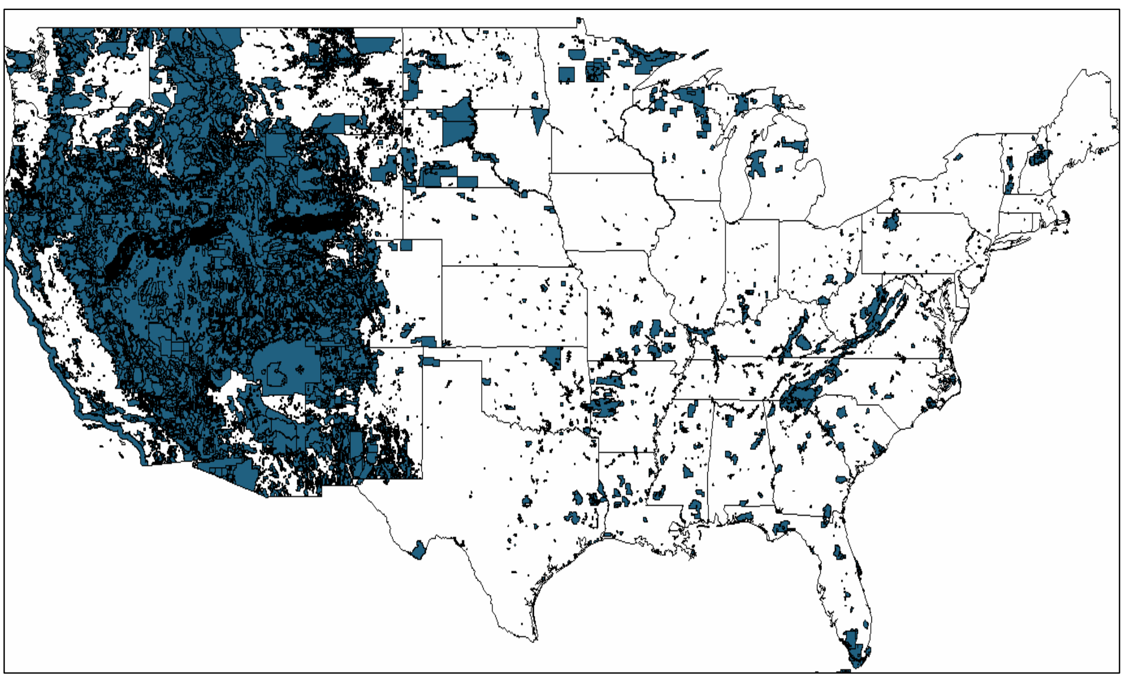

Figure 3: Federal lands in the contiguous U.S.

A. Public Lands

The federal government reserves a third of the U.S. territory from private ownership. While most of these lands are nearly devoid of population, nearly all are transited by major roadways connecting urban centers. Also, land management agencies have constructed prodigious networks of service roads on their domains; these roadways attract an increasingly mobile citizenry in search of recreation.

Despite many roads on federal lands being closed to the public, most of these remote roadbeds remain intact and can not be effectively controlled. Modern "recreational" and "all-terrain" vehicles, limited law enforcement, and the popular desire to "get away from it all" make keeping public land visitors on "designated" roadways virtually impossible.

Table 1: Federal Lands by Department/Agency

Department of the Interior	72%	
Bureau of Land Management		(43%)
Fish and Wildlife Service		(12%)
National Park Service		(10%)
Bureau of Indian Affairs		(7%)
USDA/US Forest Service	25%	
Department of Defense	3%	

Two federal land management agencies, the U. S. Forest Service (FS) and the Bureau of Land Management (BLM) administer a quarter the U.S. There are approximately a million kilometers of various classes of roadways on all federal public lands[11] and the National Forests alone contain about two-thirds of those roadways, enough to circle the earth 17 times. Neither FS nor BLM has very reliable figures for the total extent of encompassed roads, the number and consequences of traffic

[11] David Havlick, No Place Distant: Roads and Motorized Recreation on Americas Public Lands, Washington: Island Press, 2002. Hereinafter: Havlick (2002).

crashes, or total road budgets for its part of the public domain[12]. The FS admits there may be another 100,000 km. of undocumented or "ghost" roads in its Forests[13]; these "unauthorized" roads would give FS a total roadway length equal in distance to a round trip to the moon (800,000 km).

The government encourages travel to the "federal frontier" and the federally-preserved remnants of natural habitat attract 2 billion visits per year. And, while FS and BLM lands have traditionally been viewed as natural resource areas, the dominant land use is now recreation. The officially recognized "value" of FS and BLM land is increasingly shifting to recreation and preservation as environmental needs are recognized and the public is enabled to visit many federal lands[14]. Although recreation and preservation do not generate many direct returns to the federal treasury, it is also recognized that natural resource extraction from public lands has historically been heavily subsidized by the government and has created serious environmental impacts[15].

Since 1950, visitor days to FS land have increased over 20 fold and the century-old agency now views its contribution to the national economy as overwhelmingly recreational rather than as a supplier of forest products. Likewise the BLM, which was formed from the Grazing Service and General Land Office in 1946, has been increasingly directed toward preservation and recreation missions rather than just range management.

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[12] E-mail from USFS National Road System Operations, January 26, 2006.
[13] Havlick (2002), p. 160.
[14] J.G. Laitos & T.A. Carr, "The Transformation on Public Lands", *Ecology Law Quarterly*, 22(2), p. 160-161.
[15] C.F. Wilkinson , Crossing the Next Meridian: Land, Water, and the Future of the West, Boulder: Island Press, 1992.

Federal land managers generally have no liability for visitors on or traveling across the public domain, and, with no comprehensive records of crash incidence and outcomes, FS and BLM administrators have no direct way of knowing the magnitude of property and human damage sustained by the public traveling their domains[16]. Likewise, the U.S. Department of Transportation (DOT), assembles extensive records and performs analyses for all kinds of traffic crashes, but has few special studies of crashes on public lands and apparently none for FS and BLM.

States do have records of traffic crashes, deaths and injuries, but they do not generally have a mandate, resources or perhaps the interest in many keeping records for federal lands. While states and local governments do assume maintenance responsibilities over many roads across the public domain and have the primary role in caring for accident victims, they get varying degrees of federal support, depending upon circumstances. The lack of literature about traffic crashes on FS and BLM land may suggest that it is not a significant issue, or conversely, that the most legally defensible posture for road custodianship may be for the federal government to avoid change – least governmental immunities be eroded by new judicially construed duties to provide specific functions or safety standards.

[16] "Unfortunately, record keeping regarding crashes on National Forest System roads is poor to nonexistent. Responsibility for it is assigned to Forest Supervisors, but most Forests don't do it. There is no national process for entering data about crashes and reporting it. There are no national procedures for obtaining state and local law enforcement authority crash data regarding FS roads." Electronic mail from John Bell, USFS Headquarters, Office of Engineering, August 11, 2004. A search for BLM crash records in the Department of the Interior similarly showed no crash records were being maintained for BLM land. In related electronic mail with the DOT (FHWA &NHTSA) in early 2006, it appears that both agencies' principal crash fatality data bases are likely incomplete and/or significantly incorrect with regard to traffic accidents on public lands.

Extrapolation of the crash records for all rural roadways onto public lands might be a reasonable assumption, but there is little direct evidence to substantiate this assumption for FS and BLM. Crashes anywhere in the U.S. burden society, but public health research suggests traffic fatalities and complications from injuries increase with distance from urban centers as a function of the severity of crashes and delays in providing emergency medical services. Delay in responding and transporting accident victims to medical facilities is a particularly negative aspect of being injured in a remote area. Weather and road conditions further complicate this situation if the weather and slick roads hinder crash discovery and response. These uncertainties raised questions of whether weather-related crash outcomes are different for travelers on FS and BLM land.

By default, the state and local governments, law enforcement and health care centers have largely inherited the job of responding to crashes on the FS and BLM land. It is the records from these local governments, traffic officials and emergency responders which can address questions about crash incidence and outcomes federal lands, with the help of DOT agencies which collect and consolidate most U.S. local crash information.

The incidence and consequences of public land crashes may have significant effects on local governments because of the uneven distribution of federal land and the obligations assumed by local authorities in providing help to crash victims. Forest Service and BLM reservations often cover major portions of counties; few, if any, permanent federal staff is stationed on most of these lands, and the limited emergency services available typically reside in adjacent towns. When the neighboring federal lands have extensive remote roadways and lack effective communications, local authorities may be severely challenged to provide life-saving services and to minimize crash injury consequences[17].

In view of potential risk for travelers and the services borne by local governments, more information about crashes and their economic impact could be useful from a policy and public health standpoint. Federal forests and rangelands are penetrated by numerous kinds of roadways; strict enforcement of road closures is impossible as modern sports and recreational vehicles realistically can reach all these roads; and consequences of remote crashes, on or off-road, can be even more severe than in more populated regions.

Weather is the focus of this research in remote crashes because it is an important environmental variable which can be sensed and predicted to varying degrees. Although there is usually uncertainty as to actual causation in many severe and fatal crashes the general effect of weather is to curtail travel and presumably the severity of crashes as motorists reduce speed. Nevertheless, the abrupt presence of ice, dense fog or heavy precipitation is a definite and immediate threat to motorists who are unprepared for surprised by adverse weather or slick roads. Advanced prediction or detection of these hazardous weather variables depends upon policy decisions by roadway managers who are attempting to balance benefits with the limited resources available to save lives.

[17] Nevada is over 90 percent federal land and has the longest rural crash response times in the Nation, averaging 65 minutes (about 20 minutes more than the national average.) J. Sloan and S. Timko, “65 minutes from crash to hospital: Nevada’s rural response times are worst in U.S”, *Reno Gazette-Journal*, March 26, 2006.

B. Data for this Research

Isolating traffic crash casualty data for FS & BLM is a challenge since state data collectors and federal record keepers typically have not differentiated federal lands within state borders. The DOT has been moving to require precise spatial data in its crash reports, but historic reports on federal land crashes are rare or perhaps done with regard to a single agency[18]. Several attempts are now being used to geo-reference crashes: the National Highway Transportation Safety Administration (NHTSA) has incorporated global positioning system (GPS) in its Fatal Accident Reporting System (FARS); also, the Federal Highway Administration (FHWA) and several states are improving their linear referencing systems for milepost analysis data[19].

Accurate spatial information from GPS should offer an important addition to traffic record analysis capability because it can link accidents to specific land domains roadway locations. Having police accident reports with a precise location of crashes, rather than the customary data compartmentalization by political jurisdiction will add value to crash data because it offers the possibility of better focusing the potential causation questions.

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[18] K. Poindexter, "Fatal Motor Vehicle Crashes on Indian Reservations 1975-2002", DOT HS 809 727, Washington: DOT/NHTSA National Center for Statistics & Analysis, April 2004. This report states that the 5,962 fatal crashes on Indian Reservations constitute 65 percent of all fatal crashes on federal land.

[19] C.,Reider, J. Dildine, J. Tomlinson, and T. Pacheco, "Nevada DOT's New Multi-Level Linear Referencing System Offers Safety Engineers State-of-the-Art Crash Analysis", Buffalo: 2005 Traffic Records Forum, August 4, 2005. http://www.atsip.org/images/uploads/Session_48_Nevada_DOT_Multi_Level_LRS_Reider_part_1.pdf

Geographical information system (GIS) referencing files will allow the sorting of crash records for only those crashes happening in specific areas of land, such as a federal reservation. With crash latitude/longitude coordinates, proximity to other locations of significance can be calculated; also buffering techniques can mask crashes occurring near borders or areas which may not be representative of a selected sample. Spatial data editing should allow more discriminating analysis in associating events, geographical features, spatial relationships, and to negate border data, which may not fairly represent various domains being investigated.

Weather conditions at the time of serious rural crashes are often enigmatic. Extrapolation of crash weather "reports" or observed conditions from the National Weather Service (NWS) records is impractical for FS and BLM land because the variable terrain on the public land creates its own weather. Reliable local weather and road condition information generally isn't being taken for most of these federal reservations and remote sensing with satellites and radar may miss significant events in remote mountainous regions.

The few manned and occasional automated weather observing sites on FS and BLM land are scattered and seasonally operated; consequently, information on immediate conditions for public land roadway is mostly anecdotal or generalized from a sparse data collection network. Forecasts which do exist are usually very general and made for towns and airports in river valleys rather than higher and more weather-adverse stretches of road where the most severe crashes are likely.

Weather Data

Owing to the lack of weather observations and the difficulty in extrapolating weather and road conditions, the data gathered by the crash investigator probably create the best estimate of the conditions at the time of the crash on public lands. Most traffic safety researchers use the police crash reports as a basis for defining environmental conditions while the minority, using official meteorological observations, tend to be studying crashes in more heavily populated areas. For severe crashes in remote crash sites, police crash reports would seem to be more accurate when long distances and varied terrain separate the crash from the nearest weather observation site, and when crash witnesses aren't available.

All crash reports contain weather and roadway conditions and probably offer the best evidence of what environmental conditions contribute to remote crashes; the trained official completing a crash report is generally required to describe the weather from a list of weather conditions and indicate road condition with a single character or digit[20]. Weather and road surface information is documented in crash reports along with perhaps a hundred or more other variables describing crash, roadway and vehicle conditions.

[20] National Highway Traffic Safety Administration, "Model Minimum Uniform Crash Criteria (MMUCC) Guideline", Elements C-11 and C-13, http://www-nrd.nhtsa.dot.gov/pdf/nrd-30/NCSA/MMUCC/2003/intro.html

Adverse weather and/or slick roadways are assumed to be the leading environmental variable for drivers and they are present during 28 percent of all U.S. crashes[21].

The incidence of crashes during bad weather and/or slick roadway is proportionately higher than the fraction of time either or both of these adverse conditions are present for all drivers; consequently, it is generally believed that weather is a significant cause of many crashes. There is no uniform estimate of weather's contribution to crashes; over 50 years of research indicate the effects of weather events and attendant slick road conditions highly variable, depending on the density of traffic, driver knowledge and/or response to developing conditions.

The increase in crashes actually caused by weather is debatable, in part because of the multiplicity of causal factors and the lack ability to control for driver response to specific weather events. Also there is usually not much continuous road condition information measuring such critical factors as road surface temperature, wind velocity, visibility and braking efficiency, so the weather-related condition's contribution must be estimated[22]. Except for a very few special instrument installations[23] and roadway sections under

[21] Office of the Federal Coordinator for Meteorology (OFCM), "Weather Information for Surface Transportation: National Needs Assessment Report", FCM-R18-2002, Washington: Department of Commerce/National Oceanic and Atmospheric Administration (NOAA), December 2002, p.1-3.

[22] Even major highways don't have very good weather data; as a result, dangerous conditions are often first perceived when there is a sudden increase in crashes. By comparison, controlled airports, where most weather observations are taken, have instantaneous automated weather observation data available to aircraft controllers; also, ground crews, clearing snow and ice, frequently report runway "braking action" for pilots.

[23] Weather data collection and forecasting that is performed on the public domain is generally for some special purpose such as fire protection and the benefit of headquarters offices. National Weather Service surface observations are generally made only at city airports and weather radar coverage is limited in many parts of the Western U.S because of the interference of mountain ranges and long distances between radars.

some kind of surveillance, the police crash reports, reconstructed from evidence at the accident site, are the primary evidence of any environmental factors leading to a crash.

Modified driving patterns and habits during adverse weather make comparative measures of crash rates and risk difficult to assess. Altered driving habits and some deferral of trips during bad weather result are driver behavior modifications that would be expected to distort probabilities for crashing. (The known threat of encountering patches of dense fog or black ice at night should have a chilling effect on speed.) Consequently, crash data during good and bad weather periods is biased to an unknowable extent, depending on hazards being known to drivers in advance of encountering them, or forecasts of adverse weather, received in time for reconsideration of a discretionary trip.

The consensus remains that adverse weather conditions cause many crashes, but there is much less confidence in attributing specific crash deaths and injuries entirely to weather[24]. While a disproportionate number of crashes occur with bad weather and/or slick pavement, some populations of crash data yield opposing evidence for certain regions or classes of roadways subjected to research. Crash reports define the severity of crashes, the reported weather and surface conditions at the time of a crash, and the immediate consequences in terms of killed and severely injured travelers, with

[24] Wang and Kockelman (2005) found that bad weather seemed to be safer for occupants in both one and two-vehicle crashes which they suggest is due to increased driver caution in bad weather conditions. See: Xiaokin Wang and Kara M. Kockelman, "Occupant Injury Severity using a Heteoscedastic Ordered Logit Model: Distinguishing the Effects of Vehicle Weight and Type" Preprint of paper presented to the 2005 Annual Meeting of the Transportation Research Board, Washington: National Academy of Sciences, January 2005, p. 10

uniformity: however, the selection of particular weather events, regions, and the type of roadway can yield test results which are counter-intuitive.

Unfortunately, there are few records of traffic volume and specific diver behavior on remote roads. When severe crashes occur, it is often very difficult to re-create the exact sequence of events and attribute causation to a single factor; consequently, researchers and traffic analysts have segregated classes of accidents according to the environmental conditions present and/or the features of the roadway at the time of the crash. By comparing the statistical characteristics of classes of accidents, inferences can be drawn as to the additional risk produced by weather or other hazards.

Spatial Analysis

Since research suggests that severe rural crash rates vary inversely with population, an important question to be addressed here is whether more violent accidents are happening on remote regions of the public domain. Because the more remote accidents would generally deprive severely injured victims of immediate care, the consequences of delayed medical help may be compounding the consequences of injury accidents. Adverse weather and slick roadway are only a part of the chain of factors which can lead to crashes, so aggregate analyses in spatial context helps discover the more important behavioral and environmental factors which cause crashes.

Defining crash trends, modeling crash consequences and recognizing patterns or events unique to crashes can be revealing. The lack of certainty in antecedent conditions requires that analyses proceed as statistical studies which assess many cases and attribute causation to variables with a specified degree of confidence. Applying spatial crash analysis to roadway management is customarily directed toward discovering risk and application of remedial measures.

The most obvious and direct use of crash coordinates is in targeting intervals of roadway with higher populations of crashes ("black spots"). Concentrations of certain kinds of crashes often illuminate particular hazards, such as ice-prone bridge decks or deer crossings - which may be partially ameliorated by warning signs or more active preventative measures.

Other, less obvious roadway hazards and risk factors can be discovered with a variety of statistical tools which associate crash data and define risk. This broader consideration of all crash, vehicle and driver information can lead to identification and association of common risk themes such as inexperienced and aging drivers, high profile vehicles and injury type, roll-overs and lack of driver restraint, and road characteristics which contribute higher rates of risk.

Linked crash response data such as medical records, disability payments, and payroll information can potentially offer powerful insights into crash consequences, but some of this data is privileged and not generally available to researchers. However, some of these privacy concerns can be avoided if economic models can be applied to such indices as the severity of crashes, Emergency Medical Service (EMS) response times, and distance to critical care facilities. Crash injury reports have been incorporated into models which are used to compute estimated cost for specific crashes. From the practical standpoint, it is important to use these more generic data which can project consequences beyond crash fatalities and hence better estimate the aggregate cost of populations of crashes.

C. Economic Consequences (Loss)

The DOT has conducted long-term research efforts on the economics of road safety. State and federal health and transportation agencies are continually trying to mine crash and medical outcome data in order to make more accurate appraisals of the consequences of traffic accidents. Crash reports vary in the extent to which they document injuries and subsequent health and economic consequences of an accident, so actual costs of the crashes as well as the contribution of environmental conditions must be estimated.

The NHTSA-sponsored Crash Outcome Data Evaluation System (CODES) is an attempt to link crash victims' recovery and rehabilitation expenses with specific accidents while maintaining the privacy of individuals and their medical records. CODES gathers data from EMS providers and medical facilities while state authorities control the use of this data in order to insure patient privacy[25]. Accounting for crash costs in specific cases serves to validate the average cost of injuries of a particular kind; these qualified

[25] CODES is a decade old program that was originally developed to track the consequences of motorcycle crashes and the effect of state helmet laws; it has subsequently been expanded to include all traffic fatalities and extended to about 30 states Researchers apply this data in anonymous linkages which are not traceable back to specific accidents, vehicles or locations. However, because of the need to preserve victims' privacy, access to CODES files is limited and compartmentalized by state.

estimates can then be used to adjust a aggregate cost estimates created by more generic models.

For large-scale studies, statistical estimates of the economic consequences of injury accidents are the most expeditious means of projecting total injury cost estimates. Models of crash outcomes assume certain consequences result from the injury codes in crash reports and by the emergency medical service personnel. These injury codes are scales for estimating consequences and costs of trauma, generated by first responders with initial crash and medical reports. Indices, such as the Abbreviated Injury Scale (AIS) and the KABCO Scale[26], are used to estimate the extent (costs) of a particular set of injuries and can be used to aggregate the estimated cost of a population of crashes.

While the popular perception of traffic crashes may fixate on fatalities, the consequences for the more seriously injured victims are a huge financial burden for society[27]. In remote regions, serious injuries of crash victims may be further complicated where there are delays in reporting crashes and in getting victims to an appropriate medical treatment facilities. Shared or limited jurisdiction at the site of accidents, funding shortages, local priorities, distance and weather can limit the resources available to overlapping authorities in providing emergency services. A potential for this situation exists in the

[26] Injury severity categories are labeled in accordance with the KABC0 scale (K - fatality, A - incapacitating injury, B – non-incapacitating evident injury, C - possible injury, 0 - no injury). From Winnicki, J., "Ejection mitigation using advanced glazing status report II" Washington: NHTSA, 1996, p 18.

[27] Medical expenses have escalated dramatically for auto insurance companies in Great Britain so that insurers are setting up their own medical clinics, primarily to treat accident victims. This revival of self-care by insurance companies has come as bodily injury claims have soared 250 percent in five years for British automobile insurers. Fleming, C. "Car Accident Victims Get a Body Shop: British Auto Insurer's Pilot Program Offers In-House Medical Treatment", ***The Washington Post***, December 28, 2005, p. D4.

"public" or federal lands where the local governments are expected to attend to traffic crashes despite the title to the surrounding land being retained by the U.S.[28].

D. Agenda

The purpose of this dissertation is to learn whether remote roadways and weather contribute different traffic hazard risks on FS and BLM lands as compared with other rural lands with similar terrain and climate. While it is not possible to find surrogate rural land with population patterns matching the extensive frontier of federal land administered by FS and BLM, there are sections of same-state highways which are very sparsely populated and are used in a manner similar to FS and BLM reservations. The assumption here is that matched samples can be selected; that for example, forest roadways on privately-owned land share comparable crash risks with the highways through national Forests in Oregon and Idaho. Also, that traveling risks on the private prairie lands are not greatly different from the federal rangeland managed by the BLM.

The questions to be answered are (1) do weather-related crashes (with adverse weather and/or slick roadway) on FS and BLM lands differ in frequency and severity from those experienced in surrogate areas, and (2) Do KABCO[29] severity estimates of casualties and projected costs differ significantly between these two crash domains.

[28] Sec. 101, 43 U.S.C. 170, Federal Land Policy and Management Act of 1976.

[29] KABC0 is the National Safety Council (NSC) and American National Standards Institute (ANSI) standard a scale used to report severity of crash injuries from the scene of the accident: Fatal: one or more deaths (commonly signified by K: A-level injury: incapacitating injury preventing victim from functioning normally (e.g., paralysis, broken/distorted limbs, etc: B-level injury : non-incapacitating but visible injury (e.g., abrasions, bruising, swelling, limping, etc.: C-level injury: probable but not visible injury (e.g., sore/stiff neck): property-damage only is(commonly signified by 0)

Chapter 2: REVIEW OF THE LITERATURE

The following chapter discusses the traffic safety literature, focusing on what is known about the crash contributions of driver behavior, the environmental variables, and vehicle characteristics; it then shifts focus to the crash response variations attendant to crashes in remote areas. Finally, the statistical tools used to analyze and model incidences and consequences of crashes are reviewed with the objective of focusing on the techniques for extending knowledge about crashes on FS and BLM lands.

The material reviewed included several fields of safety research: analysis of risk, governmental liability, uncertainty, a search for appropriate crash data, analyses of the environment's contribution to vehicle accidents, resources available from the DOT and the National Academy of Sciences Transportation Research Board and presentations made to the National Safety Council's Traffic Records Forum.

Each of the above interrelated literature topics and sources of information lent to an understanding of how, where, when, and why crashes happen, how they are aggravated by happening in remote locations, and why governments and businesses need to explore ways of reducing the crash loss to themselves and society. The most relevant topics addressing the specific objectives of this research were risk studies of driving in rural rather than urban environments, the archival and classification schemes for crash data, the indexing injuries codes to victim outcomes, the consequences of delayed medical treatment and the financial accountings of crash injury outcomes.

These areas of concern are large, but the end goal is narrowly defined: to identify a class of crashes occurring with adverse weather or slick roads and to make summary economic comparisons of these non-weather and weather-related crashes on the public domain as well as for crashes on privately-owned rural territories.

A. Attributing Causation

Four main factors are identified by the General Accountability Office as contributing to rural road fatalities: human behavior, roadway environment, vehicles and the response in caring for victims after the crash[30]. Road environment and subsequent care of the victims are the two foci most pertinent to this dissertation; however, driver behavior and vehicles driven are integral factors in any crash analysis picture.

Table 2: Factors Contributing to Rural Crashes

Behavior	**Environment**	**Vehicle**	**Response**
Distraction	**Weather**	**Stability**	**Discovery**
Drowsiness	Traction	Crashworthiness	**Distance**
Drugs	Road Geometry	Mechanical	**Communication**
Restraint	Terrain	Condition	Cost
Speed	***(Bolded Items are of special interest for public lands)***		

[30] U.S. General Accounting Office, "HIGHWAY SAFETY: Federal and State Efforts to Address Rural Road Safety Challenges", GAO-04-663, Washington: GAO, June 1, 2004, p. 11.

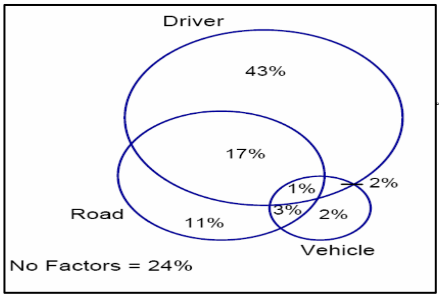

Figure 4: WA Crash Factors & Weights, McCormack & Legg (1999)

Contributing Crash Factors	Rural Safety Issue	% of Vehicles in Rural Crashes in Washington
Human	Unsafe Speed or Exceeding Speed Limit	22 %
	Inattention or Sleeping	9 %
	Judgment Errors	16 %
	Drug or Alcohol	5 %
	Other Human Factors	> 0.5 %
Road	Weather	23 %
	Wildlife Collisions	5 %
	Work Zone	3 %
	Other Road Hazards	> 0.1 %
	Pedestrian or Bicycle Involvement	0.7 %
	Railroad Crossings	> 1 %
	Rural Intersections	28 %
Vehicle	Truck (over 10,000 lb.) Involvement	7 %

Figure 5: Crash Causes & Weights, McCormack & Legg

Because contributory crash causation is a multiple function of behavior, roadway environment and the vehicle it is impossible to isolate or control these concurrent variables in actual traffic situations. Researchers use various statistical techniques and models to assess individual factors' contributions to crashes, as discussed later in this chapter. As may be expected, these results are varied in the cases of adverse weather and roadway condition variables.

The crash reports made by first responders are the most valuable documentation of the facts and circumstances preceding a particular traffic accident. Assigning the cause or the contributing factors of a crash is heavily dependent on the reconstruction of factors antecedent to the incident; this is especially true for rural crashes which are often single vehicle accidents and tend to be more severe. Rural crashes also have less probability of having any continuous surveillance, roadway environment data, or eye witnesses.

Thus, rural accident investigations are deficient in information more common in urban scenes.

Because isolating a single “cause” of a specific crash is often impossible; crash reports typically list several contributing factors and in some cases fail to disclose a proximate cause. Figure 4 is conceptual diagram illustrating the commingled nature of many traffic crashes. While a majority of U.S. crashes are thought to be exclusively caused by human factors, only a few percent are believed to be caused entirely by either environmental or vehicle problems.

Washington State investigated the feasibility of ITS to reduce the severity of crashes on rural roads for 1993-96; this study assigned factors contributing to individual crashes as summarized in Figure 5. Weather was found to be the most common environmental factor linked to crashes (23 percent), but the driver alone was assigned sole responsibility in over 40 percent of the crashes[31]. McCormack and Legg (1999) found driver behavior contributes to (or directly causes) possibly 60 percent of all crashes, while environment and vehicles respectively contribute to roughly 30 and 10 percent of total crashes[32].

Other crash causation studies confer a very large crash responsibility to driver behavior: The Indiana Tri-Level study (Treat, et. al., 1979) found driver errors were a definite or

[31] Edward McCormack and Bill Legg, “The Potential if ITS as a Tool to Address Rural Safety: An Evaluation in Washington State”, Research T9903, Task 89, Seattle: Washington State Transportation Center, February 1999, http://depts.washington.edu/trac/bulkdisk/pdf/460.1.pdf, p. 8-14.

[32] Ibid..

probable cause of 93 percent of crashes[33] and the Zein and Navin (2002) analysis suggests driver cause or contribution leads to 95 percent of all crashes[34].

The degree to which vehicle and roadway environment are responsible for crashes is controversial because, if proven, causation connotes possible liability for vehicle manufacturers and/or contributory negligence on the part of governments responsible for maintaining the roads. By U.S. law, manufacturers have to “recall” vehicles to fix identified defects[35]. Faulty vehicle design or manufacture typically results in product liability suits with huge damage claims against automakers.

Governments, by comparison, are more immune from highway environment lawsuits than vehicle manufacturers are from product liability, because governments enjoy sovereign immunity and they have few legally binding roadway maintenance standards. Also, environmental conditions, particularly weather changes, are considered to be inherently unpredictable in most Federal Tort Claims Act suits[36].

Before reviewing crash determinants and research findings, it is useful to review the available data, the various types of crash records, their particular focus on antecedent conditions, and recorded vehicle, occupant and total crash outcomes.

[33] J. R. Treat, N. S. Tumbas, S. T. McDonald, D. Shinar, R. D. Hume, R. E. Mayer, R.L. Stansifer, and N. J. Castellan, “Tri-level study of the causes of traffic accidents: Final Report. Volume I, Causal factor tabulations and assessments”, Bloomington, Indiana: Indiana University, Institute for Research in Public Safety; 1979.

[34] R.Z Zein, and F.P.D. Navin, “Improving Traffic Safety: The C3-R3 Systems Approach, Paper submitted to the 2003 Traffic Research Board Conference, Vancouver: University of British Columbia, July 23, 2002.

[35] 15 USC 50 protects the buyers of products with a written warranties and provides for legal recourse including warranty suits and the award of attorney's fees.

[36] The Federal Government enjoys the protection of the Discretionary Function Exception (DFE) to the Federal Tort Claims Act (28 USC § 2680). The DFE does not apply where a government employee is performing an “operational” task (e.g. following a checklist or administering anesthetic) in which there is no room for discretion; however, in many cases where the government has the “discretion” as to when and how to perform mundane tasks such as maintenance and hazard abatement, courts have consistently ruled against plaintiffs who seek damages for government negligence. See: Robert Klein and Roger Pielke, “Bad Weather? Then Sue the Weatherman!”, Bulletin of the American Meteorological Society, Vol.83: Nr. 12, p.1791-1807.

Accident reports provide the major insights into the epidemiology of crashes. To varying degrees, states, counties and cities archive information about the conditions surrounding traffic accidents, but in order to have uniform records and to learn from these unfortunate incidents, the federal government encourages certain local record keeping and mandates some reports. In determining what conditions existed in rural areas, crash reports of the investigating officers need to specify all the reliable information about conditions precedent to the accident. The U.S. Department of Transportation (USDOT) subsidizes state record keeping, provides research tools and publishes statistics describing the census of crash data.

The source of national crash data is in individual state databases. States consolidate their crash reports which categorize the location and circumstances of the individual crash, the contributory causes, facts about the provision of emergency services and the number and extent of injuries and fatalities (if any). From these state databases, the (US)DOT National Highway Transportation Safety Administration (NHTSA), The Federal Motor Carrier Safety Administration (FMCSA) and the Federal Highway Administration (FHWA) extract and compile several national databases; other organizations also create databases to serve their specific needs. The federal DOT agencies issue reports containing summaries of accident reports for all states.

From the various data systems it is sometimes possible to isolate accident report data for specific land areas, depending upon the data collection scheme and geographical information system (GIS) in use. NHTSA's National Center for Statistics & Analysis (NCSA) consolidates and compartmentalizes data by political unit, (but does not differentiate according to adjacent land tenure). Since this research requires differentiating crashes according to land ownership, it lead to an examination of the entire spectrum of data and information systems which are summarized below[37].

- State Data Files All states compile crash records, but formats, data entries and the degree of linkage vary. State data files originate with police accident reports (PARs) completed by police officers at the crash scenes and contain information about the crash, the vehicles, and people involved. Access to these files also varies state-by-state; data files vary in completeness and accuracy and specific records may or may not be in electronic form. Custody of these state data files varies by state, being maintained variously by the state Police, the state Highway Safety Department, or the state Department of Transportation.

- **NHTSA State Data System (SDS)** In addition to individual state government records, the NHTSA/NCSA established a State Data System in 1987 to collect state data from 17 states for its own internal analyses. This NHTSA database is also divided into crash, vehicle and person subsets. The NCSA retains the coding used by each state, but applies some standardization to help researchers. NCSA obtains state crash data from the state

[37] Certain restricted databases such as the injury-based Trauma Registry and Emergency Medical Services files are not reviewed here, nor are specialized bridge, rail crossing and roadway construction databases.

agencies and converts them to Statistical Analysis System (SAS) data files. NHTSA is currently expanding SDS to a total of 30 states.

- Fatality Analysis Reporting System (FARS) FARS is a national database (1975 – present) consisting of over 100 variables which all states collect from police accident reports and other sources including driver, vehicle, hospital, coroner and emergency medical services (EMS) records. FARS is maintained by the NHTSA /NCSA with the assistance of state analysts who quality control the data in each state. NHTSA funds 125 data collectors who work in the state motor vehicle agencies; these collectors encode annual state data in a standard format and transmit it to NHTSA/NCSA within 6 months of the end of each calendar year. Any accident resulting in a fatality is reported to NHTSA within 30 days[38]. NCSA quality controls this data and publishes an annual FARS summary[39].

This federal database is used for national and jurisdictional studies with its emphasis on fatalities, but it also contains some information on injuries. FARS should enable the location of crashes according to land tenure with a common geospatial reference system and access to individual crash reports. Since 2000, NHTSA has collected geospatial information in its fatal crash reports[40].

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[38] General Accounting Office, "HIGHWAY SAFETY: Research Continues on a Variety of Factors that Contribute to Motor Vehicle Crashes", GAO-03-436, Washington: GAO, March 2003.

[39] National Transportation Safety Board, "Safety Report: Transportation Databases", NTSB/SR-02/02, Washington: NTSB, September 11, 2002, p. 8.

[40] Per Ken Rutland of NHTSA, briefing the Traffic Records Forum, Nashville, TN, July 28, 2004.

- Highway Safety Information System (HSIS) HSIS is an 9-state database for crashes, roadway inventory variables and traffic flows on "homogenous sections" of the state highway systems in California, Illinois, Maine, Michigan, Minnesota, North Carolina, Ohio, Utah and Washington. (These states were chosen by the FHWA for their data quantity, quality, data variety and overall representative nature of their data[41].) The HSIS contains annual average daily traffic (AADT) data and can be used to identify particular problems as well as modeling particular types of crash risks over uniform expanses of roadway.

- **National Automotive Sampling System - General Estimates System (NASS-GES)** Since 1968, this NHTSA database has created estimates for crash-related safety problems by random sampling of approximately 50,000 crash reports in 60 areas and 400 police jurisdictions. There are 90 separate GES data elements used to track changes and identify problems on a national basis.

- National Automotive Sampling System – Crashworthiness Data System (NASS-CDS) Since 1979, this NHTSA system has sampled approximately 5,000 of the most severe crashes for specific studies. (not a random sample) This is the most comprehensive of all national crash databases, with engineering drawings, photographs,

[41] Forrest Council, "Module 7: Existing Databases- What and How Important are They?", (Unpublished Paper), Chapel Hill, NC: UNC Highway Safety Research Center,. (Ohio was added to HSIS in 2005.)

computerized data and interviews with crash victims - intended to thoroughly analyze each selected crash.

- Crash Outcomes Data Evaluation System (CODES) Beginning in 1992, (and initially focusing on motorcycle crashes and helmet laws) this NHTSA-funded effort has sponsored state databases that relate the medical consequences of the police-reported crashes. CODES provides a follow-up accounting of the "outcomes" (costs) of injuries sustained. Currently, CODES databases are actively being collected in about 60 percent of the states. These data remain under the control of state authorities who protect the privacy of accident victims.

- Motor Carrier Management Information System Since 1989, the Federal Motor Carrier Safety Administration has maintained a record of accidents involving at least one truck or bus with (1) a fatality(s), (2) injury(ies) requiring transportation to a medical facility, and/or (3) damage requiring at least one vehicle be towed from the crash site. This information system contains census, crash, inspection, enforcement and compliance review information. Data are published annually as the "Large Truck Crash Overview".

B. Environment Effects

State and local governments can improve traffic safety by analyzing crashes, conducting investigations of the roadway, vehicles and drivers, and employing statistical systems to highlight where and how accidents are happening, their consequences, and what might be done to prevent them. Structural modifications of highways and bridges, guardrails, arresting devices, as well as changing speed limits and traffic patterns are common methods of crash and injury prevention by altering in the roadway environment. Warning of unexpected hazards, local traffic behaviors, distractions and improving signage are usually very cost-effective ways to eliminate some of the problems for drivers; additionally, advisory services and forecasts to help drivers plan future actions will improve the driving environment and reduce the number of crashes.

As depicted in the causation diagram, Figure 4, the distinction among environment, behvior and vehicular factors is blurred. The traffic environment includes the physical roadway system with varying overlays of distractions, dynamic traffic situations and road conditions, as well as changing weather. For purposes of this analysis, “environment” will include roadway geometry and its surroundings, the state of the weather and weather’s effect on road surface condition, and the externalities that differentiate the “rural” versus “urban” environments.

Roadway Geometry

The majority of U.S rural roads are two lane “secondary” routes which are maintained by the counties or states and handle a limited amount of traffic – depending on local needs. Most of these roads are unpaved and many were originally built for low speed or even horse-drawn vehicles. In the subsequent years, many secondary roads have been incrementally upgraded, but most retain many adjacent hazards, have frequent speed restrictions, and variable roadbed construction which requires drivers be alert and frequently adjust their vehicle's operation to accommodate local conditions. Considerable effort continues to be expended in identifying hazardous conditions on these roads and modifying them for safer vehicle operations, but the backlog of needed improvements is enormous[42].

Montash University (Austrailia) published a 2004 inventory of cost-effective measures for making improvements in the infrastructure of rural roads. This survey found up to two-thirds of the world's traffic crash fatalities occur on rural roads as a result of high speed, hazardous roadsides, poorer roadway design than urban roads, multiple uses and lower rates of traffic law enforcement. Since single-vehicle crashes are much more common on rural roads, the report recommends remedial measures including speed reduction; road surface and shoulder improvements; lane, bridge and culvert widening; improved delineation of roadway centerlines, edges and lanes; roadway geometry improvements in curves and eliminating roadside hazards[43]. Realistically, these improvements would be difficult to achieve because of limited road maintenance resources and the extreme expanse of rural road networks.

While not examining the expected costs and benefits of infrastructure improvements for rural roads, the Monash study does synthesize much current understanding of the rural

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[42] Forest Service currently has an unfunded backlog of $10 billion in road maintenance. Other federal agencies such as Bureau of Indian Affairs and National Park Service have similar "deferred maintenance" totals which exceed their agency budgets by an order of magnitude. Havlick (2002) p. 74.

[43] Oxley, Jennifer , Bruce Corben, Sjaanie Koppel, Brian Fildes, Nisha Jacques, Mark Symmons and Ian Johnston, "Cost-Effective Infrastructure Measures on Rural Roads", Monash Report No. 217 for the Swedish National Road Administrator, Clayton, Victoria: Monash University Research Centre, April 2004, p. iii.

Australian road safety issue: Rural roads are typically un-surfaced, two-lane, variable geometry byways with lots of adjacent hazards. Drivers typically speed, tend to use higher profile vehicles, are more likely to ignore restraints and to be impaired by alcohol and other drugs. As contrasted with urban collisions, rural injury crashes are typically 30-40 percent single-vehicle run off roadway (ROR) incidents resulting in collisions with fixed object and/or rollovers. Because of the higher speeds and impact with rigid objects, rural injuries are more severe and less likely to be ameliorated by the crashworthiness features in modern vehicles[44].

Improving Roadways and Results of Efforts

In 2004, Texas Transportation Institute completed an effort to identify common types of engineered safety countermeasures at 50 sites within the State. These improvements range from steps as basic as cutting grass and trees to structural modification in adding turn lanes and illumination. Results after 3 years indicated only a 15 percent reduction

[44] Ibid, p. xiv

for preventable crashes in the test sections, but a 31 percent reduction of preventable injury accidents[45].

Some infrastructure for roads on public land is provided through the Federal Lands Highway Program (FLHP) and Defense Access Roads among other funding authorities. FLHP is authorized by various Transportation Equity Acts (TEAs) providing for Federal surface transportation. Appropriations for FLHP projects create partnerships between the FHWA, the five civilian land management agencies and Department of Defense. Figure 6 gives a summary of agency land area and funding received under the FLHP. Federal Lands Highway Program provides funds to promote recreational travel and tourism, protection and enhancement of natural resources, and economic development for rural areas[46]; FS uses its FLHP funds to upgrade existing roads. In addition to roadways improved with the FHWA/FLHP, the federal land management agencies obtain funds for building and maintaining other roads in other ways.

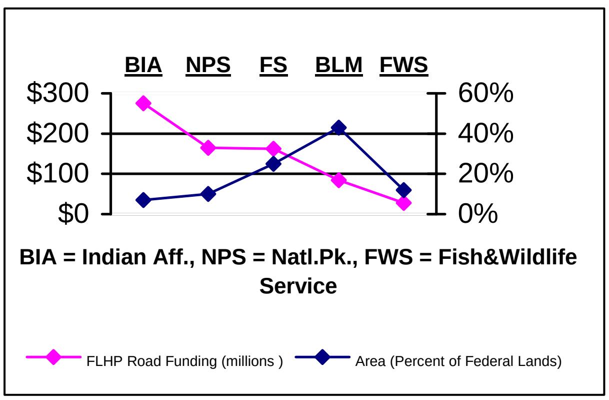

Fig 6: FLHP Funding and Federal Agency Land Area, 2000-2003

[45] Kay Fitzpatrick and Marcus Brewer, "Summary of Treatments for Crashes on Rural Two-Lane Highways in Texas", Project Summary report 0-4048-5, http://tti.tamu.edu/documents/0-4048-5.pdf

[46] U.S. Department of Transportation, "Transportation Equity Act for the 21st Century: A Summary", p.20

Figure 7: Example of an Extremely Dense Forest Road Network in Clearwater National Forest Idaho: Forest Road density is about 25 km. roadway per square kilometer of Forest area. (Very light lines are terrain contours.) The total length of roads in US National forests is approximately 800,000 kilometers. Source: Havlick (2002)

Currently about 50,000 km. of Forest Highways have been upgraded and paved under the FLHP, while a total of 145,000 km of roadway improvements have been sponsored in all federal agencies. The Bureau of Indian Affairs (BIA) receives about half of all FLHP civilian agency funds, followed by the National Park Service (NPS), FS, BLM and the Fish and Wildlife Service (FWS). BIA lands are home to about a million Native Americans and the National Parks are the foci of much of the recreational tourist travel.

The FS has about 600,000 km of Forest Roads and Forest Development Roads in addition to about 50,000 km of Forest Highways[47]. Using FLHP funding, the FS is upgrading some of these Forest Roads to Forest Highways -- whereupon maintenance is assumed by state and local governments. The great majority of service roads in national forests were built by FS or for FS by private companies which received "purchase credits" toward timber sales by building the roads they needed to remove logs and forest products.

[47] Havlick (2002) p. 32 and message from FS National Road System Operations & Maintenance Office

Opening, closing or improving roads on public land to permit public access is a politically charged action; more public access generally pleases local businesses and recreation interests, but typically irritates preservation interests which advocate less intrusion on the land[48]. Private sector businesses and employers have an interest in promoting better roads on the public domain because of increased travel, tourism and its revenue potential. Recreational vehicle owners and off-road enthusiasts want more opportunities to use their vehicles; meanwhile, environmental interests such as "Green Scissors[49]", lobby to have FS roadways closed. Overall, most FS roads are lightly traveled; 80 percent of traffic on FS land uses only a fifth of the roads[50]; unfortunately, permanently closing unneeded roads may cost more than their construction.

Federal Lands Highways spending to improve roadways has several potential effects: improving the dirt roads to Forest Highway status can cost many hundreds of thousands of dollars per kilometer and decrease hazards; conversely, these improvements will inevitably increase traffic volume and its speed, thus raising the potential for more severe crashes. Since public land agencies have a tremendous backlog of maintenance on many existing roads, land managers and politicians face the question of whether the public interest is best served by spending to repair all roads, closing marginal roads, or upgrading selected roadways. Recent FS decisions on maintaining or closing roads are

[48] Public Land roads are a highly politicized issue. The Clinton Administration sought to restrict roads while the Bush Administration wants to permit them. Public land agencies struggle to find an intermediate position between motor vehicle advocates and those seeking to ban mechanized travel. See Havlik (2002).

[49] http://www.greenscissors.org/

[50] Havlick (2002) p. 74.

symptomatic of policy reversals during the Clinton and Bush II Administrations; closing and then opening the public lands to road building and certain land uses has created great controversy and several lawsuits.

Weather Studies

Writing for the FHWA, Goodwin (2002, 2003) gives a comprehensive view of the presence of "weather-related" environmental factors in U.S. crashes. She defines weather-related as the presence of "slick pavement" due to water, snow, slush or ice, and/or "adverse weather" as rain, sleet, snow, fog and their combination. Goodwin's application of FARS data below illustrates the magnitude of potential weather-related crashes in the U.S. Crash records show that slick pavement and/or adverse weather was present during about 22 percent of the injury crashes and about 17 percent of the fatal accidents. This depiction does not attempt to differentiate as to the severity of the weather-related problems, nor can it be assumed that the weather event or road condition caused the accident, it is only a condition precedent the crash[51].

An important qualification for Goodwin's findings as well as for all studies of national data is that contributory accident rates are not generally known with slick pavement or inclement weather. One would expect, and traffic counts confirm, that some travelers defer travel plans when the forecast or actual weather and road conditions convey more

[51] Goodwin, Lynette C., "Analysis of Weather Related Crashes on U.S. Highways", December 2002, and "Weather-Related Crashes on U.S. Highways in 2001", Washington: Mitretek Systems, December 2003.

risk. Many travelers who do venture out in bad weather or slick pavement tend to reduce speed and increase the following distance between vehicles, as requested by traffic safety authorities – thereby reducing the capacity and crash potential on slippery roadways[52].

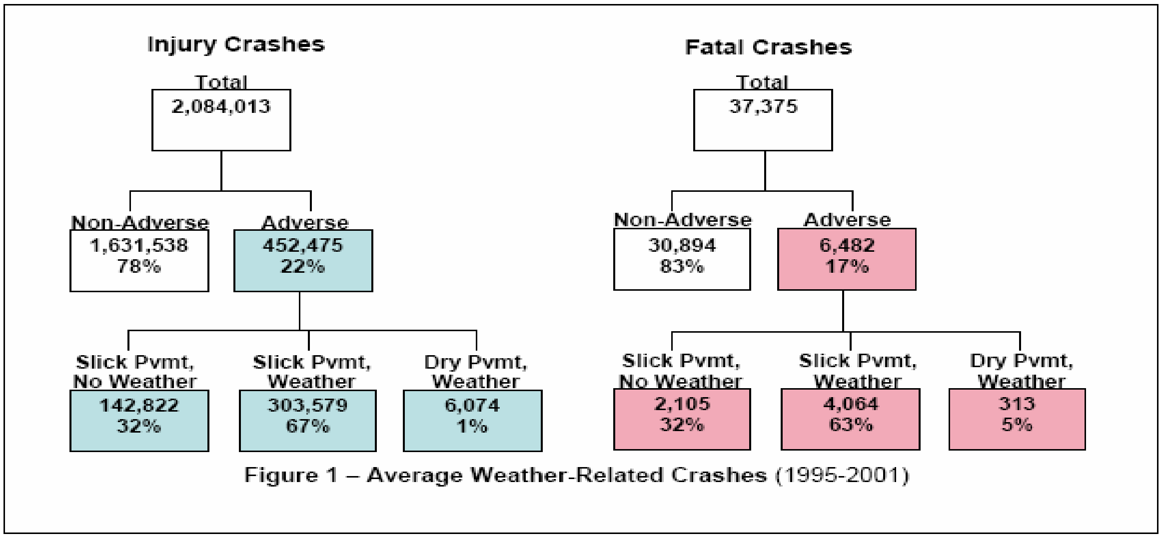

Figure 8: Average U.S. Weather-Related Crashes (1995-2001), Source: Lynette C. Goodwin, "Analysis of Weather Related Crashes on U.S. Highways", Washington: Mitretek Systems Inc., December 2002.

Ongoing Weather-Related Efforts

Several long-term efforts are underway to assess and remedy transportation weather needs on a more comprehensive scale. One significant advance in documenting weather and transportation issues began in 1998, when the U.S. Department of Commerce's Office of the Federal Coordinator for Meteorology (OFCM) and FHWA teamed with other federal agencies in a needs assessment of Weather Information for Surface

[52] Indike Ratnayake, "Identification of Factors Related to Urban and Rural Highway Crashes" Paper for Fall Student Conference, Midwest Transportation Consortium, Manhattan, KS: Kansas State U., Dept. of Civil Engineering, November 19, 2004, p. 10, 14 & 15. The author found that both urban and rural crashes were less severe for wet road surfaces. Hereinafter "Ratnayake (2004)."

Transportation (WIST)[53]. The WIST needs assessment report of December 2002, enumerates the weather elements, thresholds of concern, activities affected, impacts and actions required for both government and the private sector.

In the WIST assessment, the FS lists specific weather needs in almost every weather category – from snow to geomagnetic disturbances. These Forest Service specified needs were linked to protection of campers, recreationists and the FS crews who must travel as much as two days to get to work locations. In most cases, FS indicated it needed immediate weather advisories and forecasts to prevent loss of life and property in the remote and difficult-to-access parts of its extensive National Forest land[54].

Weather Traffic Hazards in Rural Areas

In rural areas or on Forest highways, where traffic is sparse, weather is more hazardous to life and limb because rural driving speeds are not generally restricted by other traffic. Weather and speed kill significantly more people in rural crashes when vehicles leave the roadway with much more kinetic energy than is typical for urban accidents. Because most rural roadways have fewer safety arresting barriers and frequently border trees and embankments, vehicles which do leave the roadway, regardless of weather and road conditions, are more likely to experience rollover and severe impacts with fixed obstructions. In congested urban areas, vehicle speed and roadway capacity are critical

[53] OFCM, “Weather Information for Surface Transportation: National Needs Assessment Report”, FCM-R18-2002, Washington National Oceanic and Atmospheric Administration, December 2002, p. 1-20.

[54] Ibid, Appendix B-1 (Roadway Sector)

factors in avoiding traffic jams; hence, on heavily-traveled roadways, bad weather is typically an inconvenience that slows traffic flow and lengthens commutes.

Since few traffic counters are set up to monitor rural roads, it is particularly difficult to estimate weather's contribution to crash rates; specific information generally exists only for the vehicles which don't make it – and become the subject of a crash report. In some cases, there may be estimates of rural traffic volume, but good average annual daily traffic (AADT) estimates for public lands during bad weather are unlikely for the more remote roadways. Since actual weather-related traveler risk per distance traveled is inversely proportional to the total distance traveled in adverse conditions, if travel is significantly curtailed during bad weather, the actual weather-related risk/distance will be greater than a simple tally of adverse weather crashes or Goodwin's statistics would imply.

The case studies for effects of bad weather on travel, crashes and consequences are not consistent. Adams (1985) found that adverse weather (rain, snow, sleet, fog) reduces travel and speed traveled, but increased crashes - which were less severe[55]. Khattak, et. al. (1998) found that adverse weather significantly decreases crash severity and fatalities, but increases the likelihood of minor injuries. These researchers measured change with the persistence of precipitation as reported from weather stations, rather than using weather data from the crash reports; Khattak found crashes increased on the wettest

[55] J. Adams, Risk and Freedom – The Record of Road Safety Regulations, Nottingham: Bottesford Press, 1985, p. 106

days[56]. Ratnayke (2004) confirmed more severe crashes occurred on rural Kansas roads rather than urban zones, but that rural crash severity was reduced under wet conditions[57]

Rain

The concern with wet weather's effect in restricting traffic is long-standing; however, research results are highly variable due to the diversity of roadway populations sampled, the nature of the weather events investigated and the metrics applied. Stohner measured the speed of automobiles for wet and rainy conditions on rural sections of New York highways during the spring of 1954; after eliminating passenger cars which were following other vehicles by less than 9 seconds, the average speeds in dry and wet conditions were found not to be statistically different[58].

Brodsky and Hakkert (1988), National Transportation Safety Board (NTSB -1980), Sherretz and Farhar (1978), Satterthwaite (1976), and Codling (1974) examined fatalities with wet roadway; all found wet conditions more deadly when compared with dry conditions. The aforementioned studies found the following increases in risk of fatal accidents with wet roads: NTSB (3.9 – 4.5 times dry roadway risk), Brodsky and Hakkert (3.0 – 3.5 times dry risk), Sherretz and Farhar (1.65-2.88 times dry risk), Satterthwaite (1.01-2.33 times dry risk, depending on persistence of rainfall) and Codling (1.5 times

[56] A.J. Khattak, Kantor, P. and Council, F.M., "Role of Adverse Weather in Key Crash Types on limited-access roadways", *Transportation Research Record*, No. 1621, 1998. p.10-19.

[57]. Ratnayake (2004). p.10.

[58] W.R. Stohner, "Speeds of Passenger Cars on Wet and Dry Pavements", Highway Research Board Bulletin, 139, Washington: HRB, 1956, p. 79-84

increased risk with rainfall reported in Great Britain). From these studies, it appears that actual reports of wet pavement at the accident site showed the higher relationship with increased fatal accidents than did the imputation of wet pavement from weather reports of rain in the area of a crash[59].

Many studies for rain's effect have concentrated on urban traffic. Jones et. al. (1970), Kleitsch & Cleveland (1971) and Reis (1981) quantified the decreases in freeway capacity during various adverse weather events in the Midwest[60]. Similarly, Sonka (1976) documented the reduction in urban traffic (and retail sales) accompanying rain in Chicago[61]. Ivey, et.al. (1981) developed a "wet weather safety index" using multiple regression; the associated predictive equations can be used to forecast wet pavement increases in accidents and estimate the contribution of added safety measures[62].

Prevedouros and Kongsil (2003) summarized the results 26 studies of rainy and wet conditions for Austrailia, Great Britain, Canada, Finland, Germany, the Netherlands and the U.S. They found from research performed since 1980, freeway speeds appear to be

[59] Per Harold Brodsky and A. Shalom Hakkert, "Risk of Road Accident in Rainy Weather", *Accident Analysis and Prevention*, Vol. 20, No. 3 (1988), p163.

[60] E.R. Jones, M.E. Goolsby and K.A. Brewer, "The Environmental Influence of Rain on Freeway Capacity", in *Highway Research Record* 321, Transportation Research Board, Washington: National Academy of Sciences, 1970, pp 74-82; D.L. Kleitsch, and D.E. Cleveland, "The Effect of Rainfall on Freeway Capacity" Report TRS-6, Ann Arbor: U. of Michigan, 1971; and G.L. Reis, Impact of Weather on Freeway Capacity", Minneapolis: Minnesota Dept. of Transportation, Office of Traffic Engineering, `Systems and Research Section, 1981.

[61] S.T. Sonka, "The Economics of Weather Modification: A Review and Suggestions for Future Economic Analysis", *Journal of Applied Meteorology* , Vol17, No. 6, p. 778.

[62] D. L. Ivey, et. al. "Predicting wet weather accidents". *Accident Analysis & Prevention* 13: 83-99, 1981.

reduced 5-20 MPH, dependent on the intensity of the rainfall. Similarly, highway capacity was reduced 8-20 percent in direct proportion to the precipitation rate[63].

Snow and Ice

Research on the effect of winter storms on traffic has focused on safety as well as the reduction in highway capacity. As with wet conditions, the results have not been uniform for freezing precipitation, probably because of non-homogenous nature of snow and ice cover, the various types and frequencies of ice and snow removal, and highly variable consequences which hidden ice patches and ROR incidents can produce.

It is difficult to extract any general lessons from crash studied with snow and ice. The FHWA (1977) found increased severe injury crash rates in northern states as compared with warmer southern states[64]. Hanbali (1994) found a significant reduction of crash rates both before and after deicing treatment[65]. Sjogren (1993) found that snow and/or ice was a condition precedent to about a third of the fatal crashes for drivers age 60 and above in Northern Sweden. Other Swedish studies indicated that injury rates on roads with snow and ice are several times greater than those during warm weather conditions.[66]

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[63] P.D. Prevedouros, and P. Kongsil, "Synthesis of the Effects of Wet Condition of Highway Speed and Capacity", Honolulu: University of Hawaii, Department of Civil Engineering, July 21, 2003, p. 11.

[64] J.C. McBride., et al. "Economic Impact of Highway Snow and Ice Control", FHWA Report FHWA-RD-77-95, Washington USDOT/FHWA, December 1977.

[65] R.M., Hanbali, "Economic Impact of Winter Road Maintenance on Road Users", ***Transportation Research Record***, 1442, Washington; national Research Council, Transportation Research Board, 1994, p. 151.

[66] H. Scharsching, "Nowcasting Road Conditions: A System Improving Traffic Safety in Wintertime', proceedings Road Safety in Europe and Strategic Highway Research Program (SHRP), No. 4A, part 5, Sartryck: Swedish Road and Traffic Research Institute (VTI), 1996, p. 142; and H. Savenhed "Relation between Winter Road Maintenance and Safety", Repot No. 214, Sartryck: VTI, 1994.

Altered driving evidence was found by Perry and Symons; while net U.S. crash deaths and injuries increased by only 25 percent on snow days, the rate of these severe crashes for distances traveled was doubling[67]. However, Canadian research indicated while minor crashes were increased by snow and ice, the more severe injury and fatal crash rate actually decreased[68]. Local experience and familiarity may help compensate for weather; Leviakangs (1998) documented the higher accident rate by Russian drivers in Southeastern Finland, attributing part of this increased risk to insufficient wintertime driving experience and inadequate winter equipment[69].

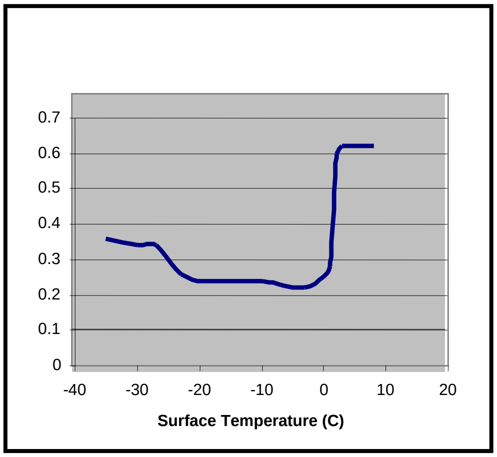

Figure 9: Coefficient of Friction vs. Temperature for Wet Pavement, After D.F. Moore, The Friction of Pneumatic Tyres, Oxford: Elsevier Scientific, (1975)

Freezing Temperature and Traction

Freezing water and frost on pavement and bridge decks is very serious problem in the absence of detection and treatment. Because

[67] A.H. Perry and L. J. Symons, Highway Meteorology, Swansea: University of Wales, 1991.
[68] B Brown and K. Baas, "Seasonal Variation in Frequencies of Highway Accidents a Function of Severity" *Transportation Research Record* 1581, Washington NRC/TRB, 1997, p. 59
[69] P. Leviakangs**.** Accident risk of foreign drivers-the case of Russian drivers in South-Eastern Finland. *Accident Analysis & Prevention* 30: 245-254, 1998.

dramatic surface heat loss can occur in shadows and at night, particularly at high altitudes, the resulting water phase change or accumulation of rime icing can abruptly reduce braking action to near zero. Ice is most dangerous at temperatures near freezing where the pressure of vehicle tires causes a film of liquid water to form on top of the ice.

Drifting snow can also be particularly dangerous when it causes ice to form on otherwise clear highway. A thin plume of blown snow melting and then re-freezing on pavement can be an ambush for drivers who are expecting an uneventful trip on otherwise cold, but dry roads. Tabler (2003) found that a 10 m/sec wind with drifting snow can deposit the equivalent of an 8 cm./hr. snowfall. With typical moisture equivalent, the heat needed to melt this quantity of drifting snow is ten times the average solar heating received in Cheyenne, Wyoming on a typical winter day[70]. A particularly dangerous form of this very low-altitude "ground blizzard" condition comes from otherwise dry pavement being glazed by local katabatic drainage winds which occur in mountain valleys after sunset. At night, motorists, who have unrestricted visibility at eye level, are to likely drive into these unknown conditions before they have a chance to reduce speed.

[70] R. D. Tabler, "Effect of Blowing Snow and Snow Fences on Pavement Temperature and Ice Formation", Niwot, CO: Tabler & Associates, November 24, 2003, p.2.

Weather Visibility Restrictions

All forms of precipitation restrict visibility, but heavy snow, blowing snow, fog, dust and smoke have created massive multiple collisions; in a number of cases more than 100 vehicles have piled up on Interstate highways when drivers were temporarily blinded[71]. Obscuration by heavy snow squalls, ground blizzards and fog can form suddenly; but accurate prediction is very difficult and expensive Advanced notice of very low visibility is critically dependent on observations of temperature, humidity, wind direction and velocity. Therefore, getting timely warning to motorists traveling at a high rate of speed requires sophisticated equipment, reporting data in real-time in order to sense the critical conditions which precede and accompany severe visibility restrictions. The substantial costs and intensive maintenance required for this equipment generally limit its use to critical areas of high volume roadways[72].

ITS Measures for Weather Hazard Warning

Several examples of weather-related ITS deployments are briefly discussed here to illustrate the technology and investment necessary to reduce fog, dust and snow-related collisions. The California Department of Transport (Caltrans) instrumented an accident-

[71] On January 14, 2005, fog caused two huge pileups in Michigan and Indiana, closing both lanes of I-94 and the Indiana Toll Road, CBS: http://www.cbsnews.com/stories/2005/01/13/national/main666586.shtml . And, on February 22, 2001, Virginia Interstates experienced 3 massive chain-reaction crashes in sudden bursts of heavy snow. CNN: http://cnnstudentnews.cnn.com/TRANSCRIPTS/0102/22/bn.05.html

[72] Art MacCarley, “Evaluation of Caltrans District 10 Automated Warning System: Year Two Progress Report”, California PATH Research Report UCB-ITS-PRR-99-28. Berkeley: Institute of Transportation Studies, August 1999.

prone roadway in the Stockton-Manteca area of the San Joaquin Valley in 1996. The automated system consists of 36 speed-monitoring sensors spaced at 0.85 km intervals on Interstate 5 and S.R.120, nine meteorological monitoring systems, similar to automated equipment found at U.S. airports, nine changeable message signs (CMS), and associated communications hubs and computer controllers[73]. In the four years preceding deployment, there were 19 visibility–related crashes in the instrumented area. In two years following the deployment, there were none[74].

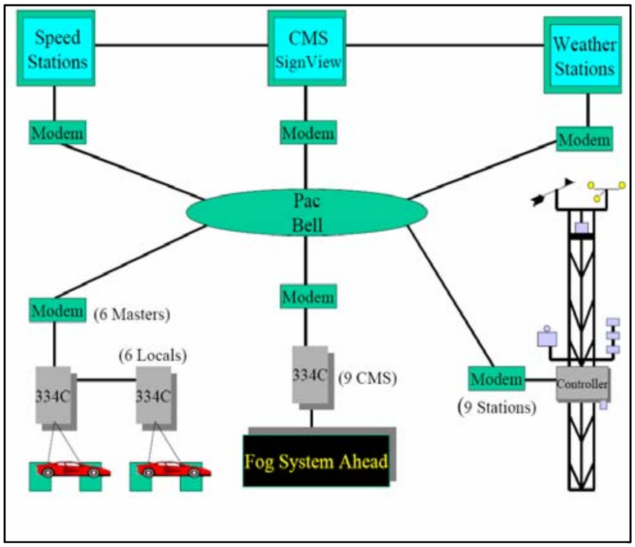

Figure 10: CAWS Schematic, Source: McCarley (1999)

Rural ITS systems have also been deployed in Idaho, Virginia, Washington and other states. Generally these weather and warning networks are designed to serve special problems of risky segments of high volume roadways which become particularly dangerous under hazardous meteorological conditions. The US DOT and Idaho Transportation Department (ITD) initiated a Storm Warning Project in 1993 as a result of the large number of serious crashes on Interstate 84 in Southeastern Idaho. Between 1988 and 1993, 91 vehicles involved in 18 major crashes had killed 9 and injured 46 on a storm-

[73] MacCarley, "Evaluation of Caltrans District 10 Automated Warning System: Year Two Progress Report", California PATH Research Report UCB-ITS-PRR-99-28, San Luis Obispo: California Polytecnic State University, August 1999, p. 9

[74] Lynette C. Goodwin, "Best Practices for Road Weather Management", Version 2.0, McLean, VA: Mitretek Systems, Inc., 2003.

prone area of BLM Land north of the Utah border. Sensors measuring visibility, traffic, roadway and weather data were installed along with video cameras aimed at a row of target signs to verify instrument readings. Four Variable Message Signs (VMS) were installed in the southbound lanes of I-84; they were manually controlled by the ITS.

The Idaho project signs were not effective at getting drivers to slow in fog, when the road was dry, but average speeds dropped over 40 km/hr when the signs warning was accompanied by snow, high wind and slick roadways. For all weather conditions, sign warnings seemed to slow traffic about 10km/hr[75].

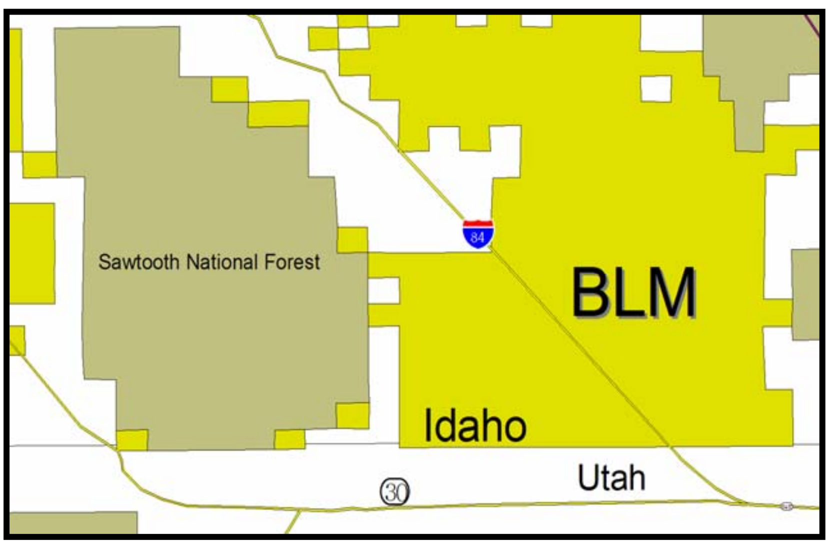

Figure 11: Idaho Storm Warning Project ITS Project Area

Obviously the CAWS and Idaho Storm Warning Project system are very expensive and have significant technical problems including power outages, faulty speed

[75] M. Kyte, P. Shannon & F. Kitchener, "Idaho Storm Warning Systems Operational Test", for Idaho Transportation Department, ITD Report No. IVH9316 (601), Boise: ITD, December 2000, p. 51-60.

detectors, visibility sensors losing calibration, communications and component failures and non-networked computers[76]. ITS deployments such as these require frequent maintenance, human monitoring and are probably economically effective only where the flow of traffic is large and where inclement conditions can cause major pileups in sudden loss of visibility, traction and/or the prospect of major injuries and loss of life. On most public land roads, comparable environmental hazards exist, but average daily traffic is generally so light that these kinds of localized, capital intensive ITS would not be as cost effective..

Reliance on and Responsibility for ITS

The addition of ITS systems brings the possibility of additional liability for the highway authority, despite the good intentions of the transportation authorities. Virginia DOT has tried to provide technology for fog-prone stretches of Interstate highway which have high potential for pile-ups. Ayres (1994) relates how these and other technological remedies for weather and heavy traffic have created more possible liability for the state while it endeavored to give drivers better notice of hazards. In an early attempt to abate fog problems, VDOT installed airport runway lights on the shoulder of I-64 at Afton Mountain, west of Charlottesville. A recklessly-driven pickup subsequently started a 54 vehicle pile-up, closing all lanes of the Afton Mountain Interstate, at a time when part of the fog lighting system had failed and before it could be repaired. As a result, two people

[76] Loragen Corporation, Evaluation of Caltrans Automated Warning System", San Luis Obispo: Loragen, July 2004, http://www.topslab.wisc.edu/resources/NHVC_presentations/Arthur_MacCarley-Caltrans_Automated_Warning_System.pdf

were killed and forty-four were injured and at the time, Virginia was then expecting tort action because of its partially defective efforts to enhance traffic safety.

Another Virginia ITS innovation was installed on I-495 where the Outer Loop of the Capital Beltway joins I-95 and approaches the Woodrow Wilson Bridge from the west. Three electronic signs (VMS) were installed to warn drivers of the raising of the Wilson drawbridge across the Potomac, but District of Columbia bridge operators and VDOT traffic control center routinely did not activate the signs late at night. During one late-night bridge opening, a tractor trailer crashed into a car stopped for the bridge opening, killing the driver of the car. While the VMS signs were not activated because VDOT had closed its operations center for the night, the state nevertheless expected to be sued because it had the potential to provide additional warning and notice to drivers – even though it was under no obligation to do so[77].

Caltrans (1997) notes the large concern about the liability for VMS and other advisory services; specifically, “What happens if the sign turns on when it shouldn’t, giving drivers a false warning?” and “What if the driver has complete confidence in the device and it fails to function, providing a loss of safety to the driver?” The California agency goes on to cite the loss of sovereign immunity in almost every state as judicial decisions

[77] D.R. Ayres, “Tort Reform and “SMART” Hghways: Are Liability Concerns Impeding the Development of Cost-Effective Intelligent Vehicle Highway Systems?”, VTRC 94-R6, Charlottesville: VA Transportation Research Council, March 1994

and legislation have undermined what was formerly a defense to negligence occurring during the discretionary acts of government agencies[78].

C. Rural[79] Road Behavior

There is less traffic, but many more serious accidents in rural areas, owing to narrow 2-lane gravel or dirt roads, higher speeds, more unrestrained vehicle occupants, a preference for higher center of gravity vehicles, less frequent road maintenance and highway patrols, and increased use of alcohol and drugs, prior to and during driving. Also, injuries that do happen in rural settings generally take longer to be discovered and can be further aggravated by the longer distances emergency services have to travel to and from the crash site[80]. Weather events compound the adverse consequences of remote accidents, not only by making the road surface more dangerous, but in obscuring hazards, creating unexpected distractions and delaying the detection of and response to run-off-road (ROR) crashes.

It is widely acknowledged that rural roads have a much higher accident rate and contribute the majority of fatal crashes; Blatt and Furman (1998) have demonstrated that most people killed in these crashes are from rural areas and small towns in the regions of the fatal crashes. In 2004, the General Accounting Office reaffirmed its earlier research

[78] Caltrans (1997) , p. 16.

[79] Tayfun Kon, "Collision Warning and Avoidance System for Crest Vertical Curves", (Master's Thesis), Blacksburg, VA: Virginia Tech, May 1998, (Appendix A). "The definition of rural area can be derived from the definition of urban areas. Officially, an urban area has a population more than 5,000 within the boundaries set by state or the local government. Rural areas are those areas outside the boundaries of urban areas." Other sources define "rural" as less than 10,000 population in Wisconsin to less than 50,000 in some UK studies. The author has chosen to use Kon's "rural" definition of 5,000 or less population in this research.

[80] R.L. Muellerman, and K. Mueller, "Fatal Motor Vehicle Crashes: Variations of Crash Characteristics within Rural Regions of Different Population Densities", *Journal of Trauma-Injury Infection & Critical Care*, 41(2):315-320. August 1996

on traffic safety; it found 60 percent of the U.S. fatalities occur on rural roads. In these rural jurisdictions GAO found the rate of fatalities per mile traveled is approximately twice the national average. GAO emphasized some of the added behavioral risks on rural roads in its 2004 report:

> [During] 2000-2002, rural crashes accounted for about 68 percent of unrestrained (unbelted) fatalities, about 63 percent of all alcohol-related fatalities, and 62 percent of speeding-related fatalities. In addition, over 80 percent of fatalities at speeds of 55 miles per hour or higher occurred in rural areas in 2001….more than 70 percent of the nations fatalities from single-vehicle run-off-the-road crashes occur on rural roads. --(GAO-04-663)

Extensive studies of the Texas roadway system found that low-volume, rural two-lane highways handle less than 8 percent of the state's traffic volume, but create 11 percent of the total crashes. Rural Texas crashes typically happen away from intersections, involve single vehicles running off the road, have a fatality rate triple and an incapacitating injury rate double that of crashes in Texas urban areas[81].

Australian researchers note the much greater risk for rural road travel, yet few specific measures have been instituted to curb rural crashes because policy makers can "reap bigger rewards for dollars invested in urban areas"[82]. Cook University researchers found an inverse relationship between population density and crashes requiring hospitalization. Eighty percent of these rural accidents involved only one vehicle and many of the drivers cited distraction and fatigue prior to the crash. Correspondingly, Parenteau (1999)

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[81] Fitzpatrick, K., A.H Parham, M.A. Brewer, and S. Miaou, "Charachteristics of and Potential Treatments for Crashes on Low-Volume Rural Two-Lane Highways in Texas", Report 4048-1, College Station, TX: Texas Transportation Institute, October 2001, p. 1-1. This study found that structural modifications in 50 test segments of highway had only a modest effect on reducing rural crashes (15 percent reduction), but these modifications reduced injury crashes by over 30 percent.

[82] Veitch (2005)

investigated U.S. rollovers, finding over half of the drivers were asleep or distracted prior to the crash[83].

Falling asleep at the wheel is a hazard which can be produced by the hypnotic effect of long, monotonous drives, as well as curving roadways through forests and on mountains. McCartt et.al. (1996) surveyed New York drivers, finding that over half had driven while drowsy in the past year, almost a quarter had fallen asleep at the wheel and about three percent had crashed by falling asleep. While New York has little federal land, it is not a sparsely populated state, and falling asleep driving is not necessarily a weather-related issue, this research shows drowsiness is a common problem that may be aggravated by driving in snow, rain or fog, especially when travel time is extended by adverse weather and/or slick pavement. Thiffault and Bergeron (2002) performed a driving simulator study showing that monotony decreases overall driver performance[84].

A recent NHTSA continuous video study using100 vehicles equipped with five cameras in the Washington, D.C. area indicates approximately 80 percent of crashes were caused by drivers experiencing drowsiness or distraction. Drivers 18-20 years of age were found to be four times more likely to be involved in inattention-related crashes when compared with adults age 35 years or greater[85]. Some of the more serious factors leading to crashes in this study appeared to be impulsive actions, such as reaching for a sliding purse and dialing cell phones.

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[83] Parenteau, C., M. Shah, and C. Tiemann, "Common Rollover Characteristics in U.S. Crashes", ***Journal of Traffic Medicine***, vol. 27, no. 3-4, p. 97.

[84] P. Thiffault, and Jaques Bergeron. "Monotony of Road Environment and driver fatigue: a simulator study". ***Accident Analysis & Prevention*** 35: 381-391, 2003.

[85] D. ElBoghdady & S. Ginsberg, "Drowsy, Distracted and Driving", ***The Washington Post***, April 21, 2006, p. A1

Queensland, Australia, crashes in 2000 showed a dramatic disparity in rural driving risk from the "Fatal Four" factors of lack of restraint, fatigue, alcohol and speed. It is particularly noteworthy that the voluntary, negligent and illegal actions of driving unbelted, tired, drunk or speeding (or permutations thereof) were killing Australians at a rate at least four times more than in lawfully operated motor vehicles. These alarming fatality rates depicted in Figure 12, are similar to the disparity already cited in contrasting the presumably nominally lawful traffic death rates between Massachusetts and Montana[86].

Some authors theorize that government attempts to legislate traffic safety may be self-limiting due to human nature and willingness to incur additional risk. Adams (1985) and others contend that drivers react to regulation and engineering with "risk homeostasis" or actions which create more risk for themselves and others after the imposition of constraints such as mandatory seat-belt laws or installation of air bags in vehicles[87].

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[86] Veitch, 2005, p. 3.

[87] See J. Adams, Risk and Freedom: The Record of Road Safety Regulation, Cardiff, UK: Transport Publishing Projects 1985; W.N. Evans & J.D. Graham, "Risk Reduction or Risk Compensation? The Case of Mandatory Safety-Belt Laws", ***Journal of Risk and Uncertainty***, Vol. 4 No. 1, January 1991; and J.E.V. Johnson & A.C. Bruce, "Risk Strategy Under Task Complexity: A Multivariate Analysis of Behaviour in a Naturalistic Setting", Journal of Behavioral Decision Making, Vol. 11, No. 1, p1-17.

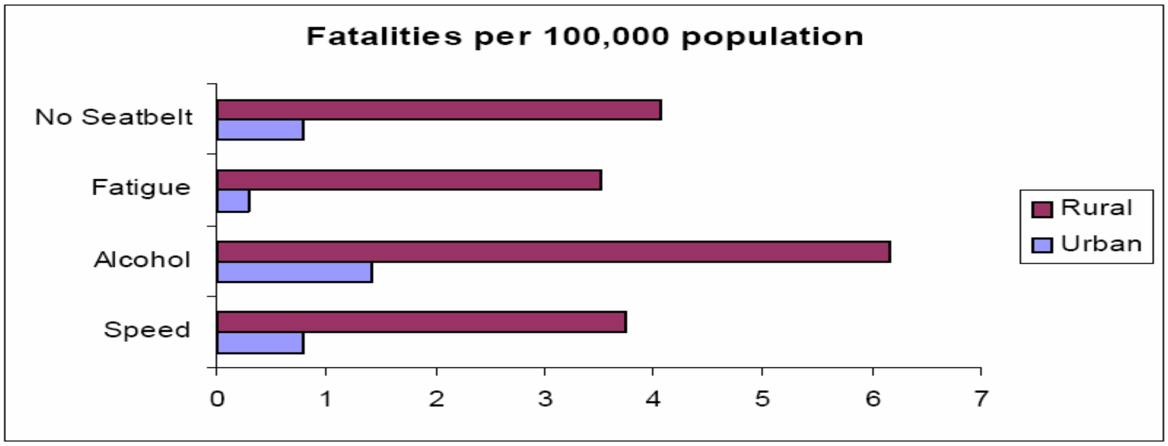

Figure 12: Relative Risk of Death in Crashes, Urban v. Rural Roads, Queensland, AU, 2000[88]

D. Vehicle Characteristics and Accident Type

Vehicle type may play a part in both forming the attitudes of the drivers and shaping the outcome of rural crashes; this is particularly the case in rural areas and on public lands where sports utility vehicles (SUVs) and pickups are usually the desired form of transportation. In 2001, there were 77 million light trucks and 134 million passenger cars on the U.S. roadways as the sales of light trucks and vans (LTVs) first exceeded that of passenger cars[89]. Since 2001, nation's sales of personal vehicles have been dominated by LTVs, collectively classified as "trucks," because these vehicles are heavier and commonly built on a stiffer truck frame.

LTVs

[88] Parliamentary Travelsafe Committee, "Rural Road Safety in Queensland: Final Report", Brisbane, Queensland Legislative Assembly, 2001.

[89] White, M.J., "The 'Arms Race' on American Roads: The Effect of Sport Utility Vehicles and Pickup Trucks on Traffic Safety", *Journal of Law and Economics*, Vol. XLVII, (October 2004), p. 353.

Changing the profile and the frame of passenger vehicles changes the handling characteristics, stability and crashworthiness – for both good and bad consequences.

LTVs “trip” and roll over more easily than passenger cars, but being structurally stronger, they also protect occupants better in comparable crashes.

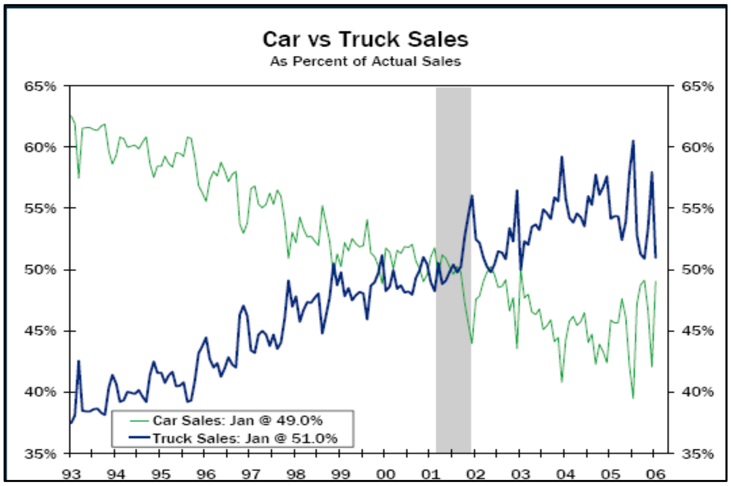

Figure 13: The Rise of the LTV: heavy, high-profile passenger vehicles dominate U.S. market. Source: Wakovia: Economics Group Domestic, January 4, 2007

The conflicting tradeoff between LTV instability and passenger compartment rigidity gets further complicated by the profile and weight differential between LTVs and cars: In collisions between cars and LTVs, the car occupants tend to be much more at risk than in collisions with another car. Side impacts by LTVs on cars are particularly deadly because of the greater weight and higher bumpers of the rigid LTV, and the lack of side-impact protection in most cars.

The graphs in Figure 13 depicts the dramatic increase in sales of larger vehicles, mainly SUVs, vans and pickup trucks, since the early 1990s. These increases in “recreational” vehicles, plus a similar surge in sales of all terrain (off road) vehicles (ATVs), snow machines and jet skis may be driven, in part, by the public’s desire to explore the hinterland and take some risks. Perhaps the appeal of high profile vehicles is more subconscious; many people seem to prefer larger/heavier LTVs, even in urban driving.

Heavier Vehicles, Behavior and Traffic Casualties

While consumers' reasons for purchasing and maintaining the heavier and more expensive LTVs is not clear, driving these vehicles may contribute to increased risk-taking or be indicative of this trait[90]. Anderson et. al. (1998) surveyed drivers in Riverside County, California, finding that pickup drivers were particularly at risk, owing to more reckless driving behavior and lack of restraint use. Pickups were shown to be twice as likely to rollover when compared to other passenger vehicles. Smart et. al. (2004) found that road rage in Ontario was more likely to be perpetrated by urban drivers who drove longer distances on busy roadways in high performance vehicles. Horswill and Coster (2002) found both high performance and greater numbers of vehicle safety features served as an incentive for intentional risk-taking.

LTV occupants do tend to fare better in crashes, and particularly crashes with smaller vehicles. However, the higher profile and less stable weight distribution of SUVs and pick-ups makes them more prone to rollover crashes, particularly when they leave the roadway at high speeds. In roadway collisions, stiffer vehicles offer additional

[90] R. Smart G. Stoduto, R. Mann & E. Aldaf, "Road Rage Experience and Behavior: Vehicle, Exposure and Driver Factors, *Traffic Injury Prevention*, Vol5, No. 4, December 2004, pp. 343-348. The authors found that incidents of road rage were highest in major urban areas and for the drivers of higher performance vehicles.

protection; Kockelman and Kweon (2002) found that occupants of pickups involved in collisions generally fare better than the occupants of the other vehicle, if the other vehicle is a passenger car. However, NHTSA tests show that pickups and SUVs are much more lethal and injurious to passenger cars they strike[91].

In single vehicle crashes, the safer features of LTVs are compromised by their instability. Viner (1995) found that rollovers were the leading cause of death in "ran-off-the-road" crashes and that sloping terrain adds to the complexity of vehicle trajectories. Farmer and Lund (2002) reported that in the four year period, 1995-98, rollovers in the U.S. killed over 14,000 in single-vehicle crashes and injured 78,000 in the same category. Thurman et. al. (1995) studied the incidence of spinal cord injuries in Utah, finding this injury is much more likely to be associated with vehicle rollovers.

There is no obvious winner in the debate about what class of vehicle is safer; while heavier LTVs offer more protection in a crash, they are often very deadly for younger drivers who lack experience in driving high profile machines. White (2004) estimates that for every million LTVs that replace passenger cars, from 34-93 additional car occupants, pedestrians, motorcyclists or bicyclists with die each year[92] Khattak and Rocha (2003) found that SUVs were more likely to roll over, but their occupants also

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[91] NHTSA, "Overview of Vehicle Compatibility/LTV [Light Trucks and Vans]", February 1998, p 2. http://www.nhtsa.dot.gov/cars/problems/studies/LTV/ "… when LTVs strike passenger cars on the left side, the risk of death to the car driver can be 30 times higher than the risk to the LTV occupant. This compares to a driver fatality ratio of 6.6 to 1 in car-to-car left side impact crashes."

[92] Michelle J. White, "The 'Arms Race' on American Roads: The Effect of Sports Utility Vehicles and Pickup Trucks on Traffic Safety",, *Journal of Law and Economics*, Vol. XLVII, October 2004. p 333-355. White found that for every life saved for LTV occupants, a total of 4.3 additional fatalities occur for other crash victims in and on non-LTV vehicles involved in crashes with an LTV.

fared much better in collisions. Overall, SUV occupants were found to be safer than in alternative vehicles, but the collision outcomes for other vehicles were not considered[93].

E. Emergency Care on Public Lands

A great deal of medical research has established the necessity of prompt treatment for traumatic injuries to minimize the resulting disability and death of the victims. Emergency trauma treatment requires appropriately trained technicians getting to the victims, assessing their injuries, stabilizing their conditions and getting them to an appropriate critical care facility or trauma center in the minimum time.

Time to Emergency Care

Because most public lands are frontier territory, uninhabited and far from major trauma treatment centers, geography as well as the bad weather and slick roadways make the public domain a higher risk zone for severely-injured crash victims. Public health literature speaks of a "platinum 10-minutes", the "golden hour" or a "silver day" as critical thresholds in arresting and reversing the effects of severe trauma[94]. Emergency Services providers acknowledge that half the fatalities occur within minutes of severe crashes, another third within hours and the remainder within days to weeks[95].

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[93] A. J Khattak and M.S. Rocha, "Are SUVs 'Supremely Unsafe Vehicles?' Analysis of Rollovers and Injuries", TRB Paper: 03-2567, Washington: Transportation Research Board, April 2003.

[94] Jacobs, L.M., a. Sinclair, A. Beiser and R.B. D'Agostino, " Prehospital Advanced Life Support: Benefits in Trauma", *Journal of Trauma*, 24:8-13; Lerner, E.B., and R.M. Moscata"The Golden Hour: Scientific Fact or Medical Urban Legend?", *Academic Emergency Medicine*, 88:758-760 and Blow, O., L. Magliore, J.A. Claridge, K. Butler and J.S. Young, The Golden Hour and the Silver Day: Detection and correction of Occult Hypoperfusion within 24 hours Improves Outcomes from Major Trauma", *Journal of Trauma, Injury, Infection, and Critical Care,* 7:964-969.

[95] Delmelle, E.M., P.A. Rogerson, M.R. Akella, R. Batta, A. Blatt and G. Wilson, "A Spatial Model of Received Signal Strength Indicator Values", Buffalo: General Dynamics Center for Transportation Injury Research, May 18, 2005. p. 1.

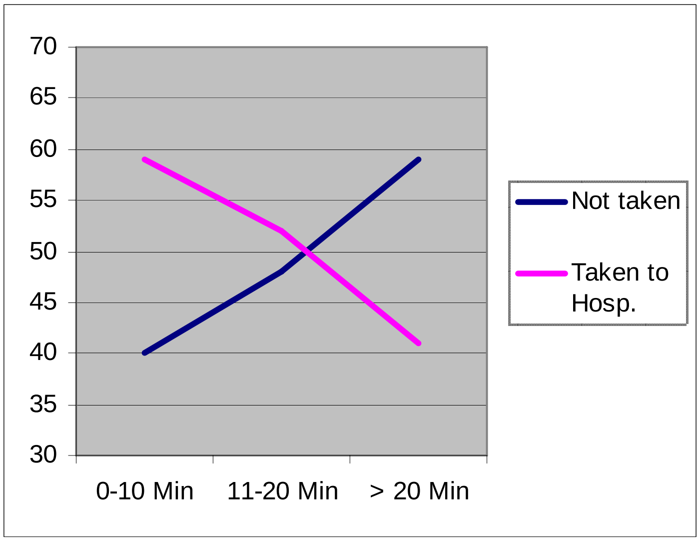

Figure 14: Percent Fatalities taken to Treatment versus EMS Response Time for all Roads

Figure 14 illustrates NHTSA findings for the time dependence of critically injured crash victim survival[96]; between 5 and 25 minutes after the crash, 20 percent of those with critical crash injuries will die if not given immediate care. R.A. Cowley, M.D., has generalized this problem in describing "critical", life threatening injuries: "There is a golden hour between life and death. If you are critically injured you have less than 60 minutes to survive. You might not die right then; it may be three days or two weeks later—but something has happened in your body that is irreparable[97]."

NHTSA estimates that each year 650,000 people suffer severe injuries with consequences ranging from moderately life-threatening to fatal. These victims represent only 12 percent of the estimated 5.3 million total annual injuries in U.S. crashes, but this eighth of

[96] DOT/NHTSA, "CIREN Program Report, 2002" Washington: Crash Injury Research and Engineering Network, October 2002 http://www-nrd.nhtsa.dot.gov/departments/nrd-50/ciren/networkreport/fore.html Hereinafter "CIREN Report (2002)".

[97] Dr Crowley coined the term "golden hour" to represent the critical period for response to life-threatening injuries. http://www.state.me.us/newsletter/backissues/july2000/enhancing_the_chain_of_survival.htm

all crash victims with the most severe injuries will incur 77 percent of economic cost of crash injuries[98].

Like the chances for survival, the extent of injuries for those who do survive will be compounded in proportion to the time it takes to get treatment. Brain and spinal cord injuries are especially time critical when medical intervention may be able to arrest brain swelling and subsequent injuries which can incapacitate, inhibit recovery and kill. Loss of blood, hypothermia, suffocation and dehydration are other hazards of being trapped in a wreck for more than a brief period.

Critical Care vs. Geography

Since a high portion of all injuries do occur in weather-related crashes, any added delays in providing emergency medical care to the victims would be expected to aggravate injuries. The length of time getting EMS at the crash scene and for transporting victims to hospitals is specified in some crash records; consequently it is apparent from analyses that rural crash victims do experience considerable delay in getting medical care and risk more complications from injuries. Also, if weather does increase crashes in rural areas and there is a direct relationship between survival and the speed of providing medical attention, weather delays would tend to make rural crashes more deadly[99].

[98] CIREN Report (2002), p. 9.

[99] Preliminary analysis of Idaho National Forest crash data shows many more injuries in weather-related crashes. State officials in Arizona and New Mexico stated this is a consistent trend.

In the pre-cell phone days, Brodsky (1993) demonstrated a great disparity in the amount of time taken to notify the authorities of rural accidents in Missouri[100]; today those same disparities still exist in remote areas without reliable cell phone service[101]. On public lands, delays in the arrival of crash first response units are obviously more likely in remote crashes with weather delaying both discovery and response.

Baker et. al. (1987) speculated that vehicle type, road conditions, seat-belt use, speed and distance to medical resources all weighed in the equation of traffic fatalities[102]. Muelleman and Miller (1996) used FARS.

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[100] H. Broadsky**,** The call for help after an injury road accident. ***Accident Analysis & Prevention***, 25: 123-130, 1993.

[101] Oregon provided recent examples in how severely snow can delay rescue of motorists. In March 2006, six members of an extended family were marooned in deep snow for 17 days when they tried to drive through an Oregon National Forest. Despite being within a few miles of Interstate 5 and the Oregon Coast, the family's cell phones would not work because of the terrain. And despite being the subject of a widespread search by California and Oregon authorities, two members of the family had to walk for a day and a half -- through deep snow -- until they eventually were rescued by a BLM employee. Fortunately all of the family escaped injury, but had nearly exhausted their fuel by the time they were rescued from their snow-bound motor home. Source: E. Bazar ad W. Welch, "Stranded Family Rationed Food, Kept Wits", USA TODAY, March 21, 2006. On November 25, 2006, the James Kim family was marooned when they attempted to cross Siskiyou National Forest in southwestern Oregon. After nearly two weeks, James Kim's body was found in impassible terrain near the Rogue River. His wife and two small children who stayed in their car survived and were rescued after an extensive search by California and Oregon authorities. Source: "Searchers find missing Dad's Body", San Francisco Chronicle, December 6, 2006.

[102] S.P Baker, R.A. Whitfield and B. O' Neil, "Geographic Variations in Mortality from Motor Vehicle Crashes", ***New England Journal of Medicine***, 316:1384, 1987

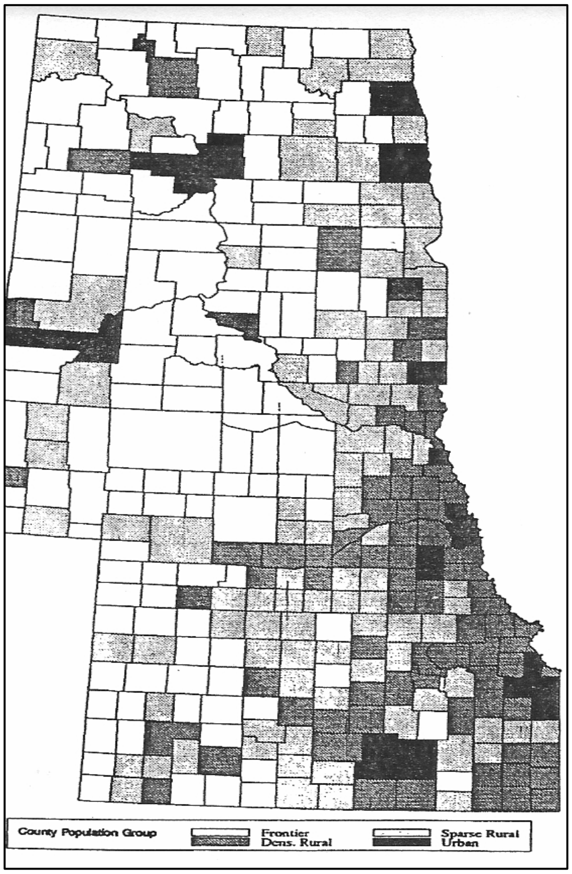

Figure 15: Variation in Crash Response Time, Source Muelleman & Miller (1996)

data to test this proposition for a tier of four Great Plains States [ND-KS]. (Counties were forced into four categories: Urban, Dense Rural, Sparse Rural or Frontier on the basis of population.) Muelleman and Miller documented the inverse relationship of crash fatalities and population density. They found that variables related to the increased fatalities were the use of light and heavy trucks, more alcohol use and intoxication, more frequent single-vehicle [non-collision] crashes on gravel roads, more occupant ejection and delayed medical care[103].

In this analysis, "rural" fatality rates were found to be twice that of "urban" regions. Within the "rural" groups, the "Frontier" counties had the higher fatality rate, almost 3 times that of "Urban" counties. Also the time to medical care was shown to be related to

[103] R.L. Muellerman, and K. Mueller, "Fatal Motor Vehicle Crashes: Variations of Crash Characteristics within Rural Regions of Different Population Densities", *Journal of Trauma-Injury Infection & Critical Care*, 41(2):315-320, August 1996

population; only 56 percent of the injured victims of crashes in the "Frontier" counties got medical treatment within an hour of the crash[104].

Clark (2003) studied U.S. collisions, 1994-98, finding that mortality was inversely proportional to a county's population density[105]. Hendriksson, et. al. (2001) analyzed accidents in a similar fashion for Northern Sweden, finding that in about half the accidents, victims did not receive optimum care because of the distance to hospitals. Absence of first aid was judged to have contributed to deaths in 4 percent of the cases[106].

All traumatic injuries need prompt care, but some are particularly time critical. A study of 155 fatalities in 24 rural Michigan counties found almost 13 percent (20 deaths) were definitely preventable if prompt medical treatment had been available[107]. In an airborne evacuation study, Oppe & DeCharro (2001) analyzed helicopter airlift of crash victims beginning in 1995, finding the greatest Helicopter Trauma Team (HTT) value was getting medical help to victims – rather than getting them to the hospital. In triaging patients according to severity of injury, the authors learned that the greatest outcome benefits of the HTT were for those patients in the intermediate injury group. This finding challenged

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[104] Ibid.

[105] D. E. Clark, "Effect of Population density on mortality after motor vehicle collisions". ***Accident Analysis & Prevention*** 35: 965-971, 2003.

[106] E. Hendricksson, M. Ostrom & A. Eriksson. "Preventability of Vehicle-related Fatalities". ***Accident Analysis & Prevention***, 33: 467-475, 2001.

[107] R.F. Maio, R.E. Burney, M.A. Gregor, and M.G. Baranski, "A Study of Preventable Trauma Mortality in Rural Michigan", [University of Michigan Medical Center, Section of Emergency Medicine] , ***Journal of Trauma***, 41(1), Jul 1996, p.83.

prior assumptions that the most severely injured patients would benefit most from air evacuation[108].

Weather has an additional physiographic linkages which challenge survival for travelers who are injured on the public domain. Local weather prediction is problematic in remote areas because the specific weather events are frequently produced by features of the same mountainous terrain which also inhibit communications. Sections of remote roadways which are customarily dry and clear can become glazed or submerged when convective or terrain-induced weather conditions materialize quickly, but are not generally observed or forecast over a wide area. These localized hazards can cause crashes and the lack of indigenous population and the sparse traffic on public lands can inhibit discovery and reports to emergency responders.

F. Total Costs

Despite the dramatic reduction in the rate of traffic fatalities and safety improvements made in all areas of motor vehicle transportation, crashes are still an incredible drag on the national economy. The Centers for Disease Control cites traffic accidents as the greatest single cause of death and disability for Americans until they reach age 45[109]. NHTSA (2002) estimated total comprehensive costs of U.S. crashes at $346 billion/yr. in 2001 dollars. This figure is the sum of direct costs in injury and property damage and estimated indirect losses in future income and compensation for pain and suffering[110].

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[108] S. Oppe & F. De Charro, "The effect of medical care by a helicopter trauma team on the probability of survival and the quality of life of hospitalized", Accident Analysis & Prevention, 33:1, P138.

[109] T. Litman, "Integrating Public Health Objectives in Transportation Decision-Making" Editorial for the *American Journal of Health Promotion*, 19 March 2003

Miller (1988) estimated the "comprehensive[111]" cost of U.S. Roadway crashes at a third of a trillion dollars – or more than the budget of the Defense Department at the time. He projected the average personal and societal cost of each crash injury at about $30,000 and advocated rational investment to prevent crashes by targeting the most costly injuries. Elvik (2000) made a composite estimation of the cost of road accidents on national economies using a composite of 12 different countries and determined the average to be about 2.5 percent of the gross national product, including loss in the quality of life[112]. (The range was from 0.5 – 5.7 percent of the GNP, depending on the individual country.)

Remote injuries and elapsed time to medical care is very important to total cost because that time is directly related to rehabilitation cost for severe injury victims. Favorable recovery outcomes for trauma victims are inversely proportional to the elapsed required to provide care; this has been repeatedly demonstrated in military operations as well as in highway accidents[113]. While Bull's (1985) study showed that only about 1 percent of the total injuries from crashes result in "serious disabilities" in the U.K.[114], Miller, et. al, (1989) suggests that the severe, nonfatal head and spinal cord injuries in the U.S. are economically more costly than even the fatalities[115].

[110] NHTSA, Fatality Analysis Reporting System: 1999-2001, Washington: DOT 2002, in E. Zaloshnja, E., T. Miller, F. Council and B. Persaud, "Comprehensive and Human Capital Cash Costs by Maximum Police-reported injury severity within selected crash types", *Annuals Proceedings Association of Advanced Automotive Medicine*, 2004; 48:251-263.

[111] Comprehensive costs include loss to the quality of life as well as direct costs.

[112] R. Elvik, How much do road accidents cost the national economy? *Accident Analysis & Prevention* 32: 849-851, 2000.

[113] R. B. Nolan & M. A. Quddis," Improvements in medical care and technology and reductions in traffic-related fatalities in Great Britain", *Accident Analysis and Prevention*, 36:1, January 2004, p. 103.

[114] J.P. Bull, "Disability caused by road traffic accidents and their relation to severity scores". *Accident Analysis & Prevention* 17: 387-397, 1985.

[115] T.R. Miller. "Crash costs and safety investment". *Accident Analysis & Prevention* 21: 303-315, 1989.

Accumulating costs of injury accidents requires considerable effort in tracking the treatment and measuring the progress of victims after the accidents. To be rigorous, this cost data collection requires information which is privileged and private; therefore, it must be protected and be aggregated in order that it not divulge personally identifiable information. The NHTSA Crash Outcomes Data Evaluation System (CODES), managed by a number of states, is the most important effort to track crash injury costs, but from a practical approach, it is too restricted to be used in this dissertation research.

G. Research Methodologies

The following is a cursory review of analytical methods employed in studies of related traffic safety issues. They are presented here as a brief introduction to the kinds of methodologies used in better defining causation and estimating the significance of the factors leading to and produced by traffic crashes. A variety of statistical tools have been used to collect information, assess traffic safety relationships and to infer causation.

Tools vary with the kind of task to be addressed; some outputs are simply descriptive; other situations require measures of exposure; while the more complex questions may require modeling of discontinuous phenomena The following examples were illustrative of research methods used in analysis of issues related to the present research effort.

Transportation Data Collection

In addition to the various crash databases and accident statistics reviewed earlier in this chapter, a number of surveys have collected a vast amount of basic information on transportation in the US. During the 1990s, the Bureau of Transportation Statistics[116] (BTS) and the National Academy of Sciences Transportation Research Board focused on the lack of information on transportation "flow" in the nation. As a result, BTS began taking censuses of the long-distance travel habits of Americans, beginning in 1995. The latest American Travel Survey of 2001-2002 was performed by telephone interviews of approximately 66,000 households to provide policy makers with detailed information on long-distance transportation by all modes. The basic data collected in these Surveys provides a meaningful sample of information about how many Americans are traveling, how, when and where they are going, and how this varies by location and time[117].

Descriptive Statistics

Other research is performed in the context of interpreting data. For example, the American Automobile Association (AAA) contracted with the University of North Carolina to identify the major sources of distractions contributing to crashes. This research employed the NHTSA Crashworthiness Data System (NASS-CDS) statistics which are based on intensive analysis of approximately 5000 severe crashes. The UNC researchers performed a descriptive analysis of the sources of distraction for drivers and the contribution of distraction to crashes in the CDS database.

[116] BTS was created in DOT by the Intermodal Surface Transportation Act of 1991 (ISTEA), to compile, analyze, and publish statistics and to make them comprehensible.

[117] "National Household Travel Survey: Pre- and Post- 9/11 Data Documentation", Washington: Bureau of Transportation Statistics, http://www.bts.gov/programs/national_household_travel_survey/pre_and_post_9_11_data_documentation/pdf/entire.pdf

While acknowledging the possible biases and limitations in data collection methods used, the AAA study focused on the current interest in cell phone distraction, but found little evidence that it was increasing over time as a factor in crashes. Documented crashes while using cell phones ranged from 6-10 during the years 1995-1999, but there was no discernable trend in crash frequency. Researchers noted the growing bias against talking and driving and speculated that admission of cell phone use might be biasing what was being reported during the later period of data collection[118].

Probability

In relating delay in emergency medical care to traffic deaths, Walters and Wells (1973) found a 4.2 percent rural mortality rate versus a 1.2 percent urban rate, corresponding mean response times of 32 and 14 minutes[119]. This was more extreme than the differences in mortality rates computed for American forces in World War II and Vietnam (4.5 and 2.4 percent respectively)[120]. Semmlow and Cone similarly (1979) applied the data of the Illinois Trauma Registry to the issue of mortality and treatment delay in the provision of regional EMS, finding that mortality increased linearly at the rate of 2.5 percent per hour of delay in providing emergency care[121].

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[118] J.C. Stutts, D.W. Reinfurt, L. Staplin, and E.A. Rodgman, "The Role of Driver Distraction in Traffic Crashes", Chapel Hill: Highway Safety Research Center, 2001 http://www.aaafoundation.org/pdf/distraction.pdf

[119] J.M. Walters and C.H Wells, The Effects of Modern Emergency Care in Reducing Automotive Crash Deaths", ***Journal of Trauma***, 13: 645-47, July 1973.

[120] L.P. Hacker, "Time and its Effects on Casualties in World War II and Vietnam", ***Archives of Surgery***, 98: 39-40, January 1969. In WW II the average time to get medical care was 1-2 hours; in Vietnam mean response was between 10 and 20 minutes.

[121] J.L. Semmlow and R. Cone, "EMS Access Performance: The Relative Cost of Treatment Delay", ***J. Clin. Eng***, 1979.

Sampling/Randomization Distribution

Miller (1997) linked injury severity codes to cost of sustained injuries by associating the Abbreviated Injury Scale with police reports of severity and crash type from accident reports; this yielded aggregate costs[122]. Zaloshnja et. al. (2004) refined this process by providing unit and total crash costs, based on use of KABC0 crash severity indices and 16 crash types compartmentalized into high and low speed classes[123]. This method used samples of crash type and injury index data taken from the NHTSA National Accident Sampling System (NASS) databases, and medical cost estimation data from the Civilian Health and Medical Program of the Uniform Services (CHAMPUS) fee records. Productivity Losses were based on a Bureau of Labor Statistics 1993 Survey of Occupational Injury and Illness (SOIL) and loss of quality of life costs were based on physicians' estimates and literature review of the functional capacity loss with varying degrees of injury. The resulting cost estimation system is expected to be useful in identifying significant safety issues and for estimating the benefits of ITS and other remedial traffic strategies.

Models

Wang and Kockelman (2005) used a heteroscedastic logit model to examine the vehicle, environmental, roadway and occupant factors on the severity of injuries. This model showed that crashworthiness and "aggressiveness" toward passenger cars were

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[122] T.R. Miller, D.C. Lestina & M.S. Galbraith, "United States Passenger Vehicle Crashes by Crash Geometry", *Accident Analysis & Prevention*, 29:343-352. 1997.

[123] E. Zaloshnja, T. Miller, F.Council and B. Piersaud, "Comprehensive and Human Capital Crash Costs by Maximum Police-Reported Injury Severity within Selected Crash Types", Key Biscayne, FL: *Proc. 48th. Assoc. for Advancement of Automotive Medicine Conference*, October 26-28, 2004, pp. 251-263

characteristic of LTVs; it also indicated that if all passenger cars were to become a half ton heavier, crash injuries would not change much However, if all vehicles were LTVs, incapacitating injuries and fatalities would respectively rise by 26 and 64 percent[124].

Similarly, White 2004) applied GES data with a logit regression analysis to explain fatalities or serious injuries in particular classes of crashes: two vehicle with cars, two vehicle with LTVs crashes with pedestrians, bicyclists, motorcyclists and single vehicles. A striking conclusion of this research was that for every fatality saved for the passengers of an LTV, an additional 4.3 fatalities would be inflicted upon the occupants of cars, bicycles, motorcycles and pedestrians[125].

Khattak and Rocha (2003) approached this problem by only considering the fate of SUV occupants in single vehicle crashes. Using Poisson and negative binomial regression models and CDS data, they confirmed that SUV occupants are safer, even though their vehicles are more likely to roll and to experience more intense rollovers[126].

Krull, Khattak & Council (2000) studied the tripping events and rollovers experienced in rollover crashes while controlling for roadway, vehicle and driver factors employing logistic regression modeling. Applying data from Michigan and Illinois, they assessed

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[124] X. Wang,and K.M. Kockelman, "Occupant Injury Severity using a Heteroscedastic Ordered Logit Model: Distinguishing the Effects of vehicle e Weight and Type", Paper presented to the Transportation Research Board, Washington: TRB, 2005.

[125] M. J. White, "The Arms Race on America Roads: the Effect of Sport Utility Vehicles and Pickup Trucks on Traffic Safety". *Journal of Law and Economics*, vol. XLVII (2004), p. 333-355

[126] A.J. Khattak & M. Rocha, "Are SUVs "Supremely Unsafe Vehicles?" Analysis of Rollovers and Injuries", TRB Paper 03-2567, Chapel Hill: Carolina Transportation Program, April 2003.

the effect of a number of variables on crash outcomes, using the KABC0 scale. One of the notable findings indicated in this study was that slick pavement reduced the severity of injuries[127].

Kockelman and Kweon (2002) used ordered probit models to investigate the severity of driver injuries in four crash categories; they confirmed that rollovers were far more injurious than most other crashes and that the fatal crash rate increased over 50 percent with the raising of the maximum speed limit in 1987 [128]. Ma and Kockelman (2004) later considered all vehicle occupants for a variety of different variables in Southern California crashes; this study indicated injuries were a function of age and sex[129]

Statistical Inference

Eisenberg (2004) applied negative binomial regression to estimate the change in crashes and precipitation during the period 1975-2000, examining both NHTSA FARS and State Data System crashes with both monthly and daily precipitation totals from the National Climatic Data Center. This version of Poisson regression gave the somewhat surprising result of lower crash rates with increased monthly precipitation; however this relationship reversed to a direct correlation when precipitation was measured on a daily basis. By lagging daily precipitation, the correlation again became negative. Eisenberg infers that

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[127] K.A. Krull, A.J. Khattak & F.M. Council, "Injury Effects of Rollovers and Events Sequence in Single-Vehicle Crashes", _Transportation Research Record_, No. 00-0662, pp 46-54.

[128] K.M. Kockelman and Y. Kweon, "Driver Injury Severity: An Application of Ordered Probit Models", _Accident Analysis and Prevention_ 34 (3): 313-321 (2002),

[129] J Ma, KM Kockelman, "Anticipating Injury & Death: Controlling For New Variables On Southern California Highways", _Proceedings of the 83rd Annual Meeting of the Transportation Research Board_, Washington: National Academy of Sciences, January 2004

the added hazard of wet weather comes in the early part of of the precipitation event when accumulated oil and water create the greatest potential for slick pavement; his theory seemed to be verified by subsequent tests which showed that a greater crash potential occurred with longer intervals since the previous precipitation event[130].

H. Summary and Conclusions

This chapter has presented a wide variety of topics needed to understand the traffic records systems: the nature and distribution of crashes with population, importance of driver and vehicular behavior, determination of crash causation, the nature of travel and environmental hazards on public lands, and methods to estimate the consequences of crashes. Spatial analysis of crashes on FS and BLM land is dependent on the methods used to record crash data; hence, locating crashes on the public domain can be a problem unless adequate spatial information is embedded in the police crash report. Likewise, knowing the actual weather and roadway conditions at the time and location of remote roadway crashes is almost entirely dependent on their reconstruction and recording by the investigating officer.

Examining weather-related accidents on the public domain could provide insight into the risk of travel on public land and in determining the social cost of crashes on federal reservations of states having large areas in the public domain. The stake for some states could be significant, especially in four large Western states which are mostly under the

[130] D. Eisenberg, "The mixed Effects of Precipitation on Traffic Crashes", *Accident Analysis and Prevention*, 36 (2004) 637-647

administration of FS and BLM and another four states with 40 percent federal land. Since much of this area is traversed by state and federal highways and many national parks, monuments, and recreation areas are surrounded by FS and BLM land, there are many inducements for travel. Also, federal land managers are being provided Transportation Equity Act funds to upgrade and pave roads originally created for logging and mineral extraction. These improved forest highways create more enticements for those seeking a "wilderness experience" or opportunity to use their recreational vehicles.

The consequences of this traffic in terms of crash deaths and injuries on FS and BLM land has not been documented or defined. Generally, the Federal land managers do not provide traffic law enforcement or emergency services for visitors and employees traveling through the public domain. Since most of these public lands are sparsely populated and sometimes out of range for reliable radio and telephone service, serious traffic crashes may not be promptly reported and injured victims may face a lengthy trip to appropriate medical facilities. The direct responsibility for responding to the crashes on the FS and BLM reservations falls primarily on local governments, regardless of who owns the land.

A disproportionate number of accidents are known to occur with rain, snow, dust and smoke degrading road conditions; these environmental hazards can be forecast or anticipated to some extent. One open question is whether the cost of contribution of weather-related crashes and the potential for abating some them indicate a need for added weather services at the national level. To date, the extent of economic losses to motorists on FS and BLM land during these adverse conditions is undefined. The hope is that the next three chapters will provide useful information for several levels of government which exercise some responsibilities on FS and BLM land.

Chapter 3 focuses on the specific methodology to be applied in Chapter 4 -- to test the null hypothesis of no significance difference in crash incidence and outcome in matched samples of crash data.

Chapter 3: METHODOLOGY

The following chapter details the processes used to address the hypothesis' questions:

(1) Do BLM and FS lands experience a different distribution of weather-related and non- weather crashes from comparable rural areas? and

(2) Are the human consequences of weather related crashes on BLM and FS roadways significantly different from those on comparable rural, but privately-held lands and national averages? The methods uses to answer these questions were:

(a) Obtaining sources of crash data with sufficient detail to address the questions;

(b) Choosing an objective way to compare public and private land crashes;

(c) Developing a uniform way to categorize various weather conditions;

(d) Finding an acceptable means of measuring crash losses; and

(e) Developing a means of spatial referencing that can identify local variations.

A. Inventorying and Organizing Data Bases:

Analysis of crashes on public land and their consequences is limited by the extent to which these accidents can be identified and for which sponsoring agencies will make data available. This research began in 2001 with the acquisition of some Idaho FS data for 1990-2000; these data indicated an average of only 60 crashes per year being recorded in Idaho's National Forests (31 fatalities and 436 injuries in 11 years). In 2004, some

Highway Safety Information System (HSIS) data obtained from FHWA indicated that National Forest roads in California had recorded nearly 4200 crashes for the year 2000 and these crashes resulted in approximately 80 deaths and 2800 injuries. In that year, NHTSA announced it was collecting GPS coordinates for FARS data; consequently, the expectation was that by 2005, a nationwide inventory of public land fatalities could be derived, using GIS software and accumulated FARS data. NHTSA data was later denied.

There are acknowledged problems in the underreporting of crashes, particularly in rural areas[131]; consequently, it is particularly important to have confidence in the governmental crash reporting process. While virtually all the fatal crashes are reported, many injury and property damage only (PDO) crashes are not. Nationwide, over a fifth of injury accidents are estimated to go unreported[132]. A recent Oregon study[133] examined the 51-mile State Route 18 which is a mostly two-lane highway from Salem in the Willamette Valley to the Pacific Coast. Traffic over this route increased one-third from 1995-2000, in part due to tourism and the Indian Casino at Grand Ronde. The study concluded that at least half of the Route 18 crashes were unreported in 2000.

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[131] Reasons for not reporting crashes in remote areas include the inconvenience of filing a report, lack of driver's license or insurance, and the possibility of citation for traffic violations and other illegal activity.

[132] L. Blincoe, A. Seay, E Zaloshnja, T. Miller, E Romano, S. Luchter and R. Spicer, "The Economic Impact of Motor Vehicle Crashes", Washington: NHTSA, 2002.

[133] S. Malik, R.L. Bertini, C. Monsere. Crash Data Reporting and Analysis - An Oregon Case Study. Paper accepted for presentation at the 2003 Annual Meeting of ITE, Seattle, Washington, August 2003. http://web.pdx.edu/~bertini/crash.pdf

FARS proves Unusable for Crash Data

Because fatal crashes are the most severe and are nearly all reported, the NHTSA Fatality Reporting System (FARS) data originally became the priority data base selected for use in this study. The GIS coordinates which NHTSA has been including in FARS data collection should make it possible to precisely locate the lethal crashes. Unfortunately, NHTSA legal counsel restricted the distribution of the FARS crash latitude and longitude in December 2005 and the agency blanked out these data fields from its online data source; this unexpected denial of the nation-wide database eliminated FARS from use as the key spatial resource for this study[134].

Subsequent attempts to use NHTSA State Data System, which collects crash information from 30 states, proved futile because NHTSA does not retain data which might identify crashes on federal lands. These files do specify the county and city (where applicable) of the crash site, but this cannot be used to locate crashes in BLM and FS reservations absent some accurate means of spatial referencing.

[134] ftp://ftp.nhtsa.dot.gov/FARS/2003/DBF/ Earlier 2003 FARS data obtained form NHTSA on disk proved to be unusable because they were provided in township and range units and even these data were erroneous and plotted crashes in locations where no roads exist.

State data requested: CA, ID, NV, UT & WA

Attempts to get data from states with substantial amounts of BLM and FS land by direct requests to state DOTs yielded mixed results; Alaska, Arizona, Idaho, Nevada, Oregon, Utah and Washington were contacted, but only a few states have means to directly identify crashes on FS and BLM lands. However, crash data for both public and private roadways was made available through by the Idaho Transportation Department Office of Highway Safety and the Oregon DOT's Crash Analysis and Reporting Unit – Transportation Data Section. California crash data having both "NAT_LND" and other reference elements was also obtained through the help of the FHWA's contractor, Landis Corporation, at the FHWA office in McLean, VA, and with the guidance of Dr. Forrest Council at the University of North Carolina's Highway Safety Research Center.

Table 3: Percent of State Area in Federal Control, for the 8 major public land states

NV	86%	OR	50%
AK	81%	CA	40%
UT	64%	AZ	40%
ID	64%	WY	40%

California, Idaho and Oregon are particularly useful states for this analysis because these states have compartmentalized their data according to land ownership and because they have huge BLM and USFS reservations. Nevada would have been another excellent state for analysis, but continued inquiries to Nevada DOT indicated that state's linear referencing system was not sufficiently developed to track federal land crashes. Likewise, Alaska's crash records did not distinguish public and private land crashes.

Ohio and Washington were also considered. They have a much shorter length of public land roadways on FS land than do California, Idaho and Oregon, but the former states have incorporated HSIS segments into its GIS system, so that crashes might be accurately located.

Other states listed in Table 3, which have extensive BLM and FS land, either are not among the nine states in the FHWA HSIS data set, or do not yet have geographic data systems which identify crashes on federal lands. Because California is such an important state with aggressive data collection efforts, it was chosen to be the defining test of the question of crash consequences on BLM and FS lands for this research.

Location a Critical Consideration

Location of crashes became a key variable for studying crashes on public land because the federal land management agencies do not have reliable information on crashes on their own land, knowing whether weather is a significant rrisk. States do collect crash information – especially for the more serious traffic accidents, so it was necessary to access the state data, especially for those states which do keep track of crashes on federal land.

Limited HSIS data

The FHWA HSIS provided the most discriminating crash data available because HSIS crash records are localized by short segments of a state's highways for which many descriptive elements are available. Depending on the state, some of the HSIS data is compartmentalized by land ownership. Because crashes on California HSIS segments could be identified by roadway, county and milepost, the co-location of public land borders provided the means to differentiate public vs. private land crashes. HSIS records locate crashes by roadway classification segment and the nearest milepost; therefore, crash site position can be determined along roadway maps where public land boundaries are known and where HSIS records are otherwise accurate and can confirm crash locations[135].

Criteria for Crash Selection:

In order to distinguish public land roadway environments from other rural roadways several criteria were imposed where crash record data provided sufficient information:

- **Chose BLM, FS and Reference "Sections" > 8 km. (5 mi.)**

Samples of roadway included in the HSIS System provided various segment lengths. Where adjacent segments could be totaled into continuous "sections" greater than five miles in length, for either public or private lands, the section was considered as either a

[135] While HSIS specifies accident location in hundredths of mile, the method used in determining that location is important -- hopefully by odometer distance from an actual roadway milepost. In some cases, the investigating officer may be estimating the mileage from a reference point. [Per Discussion with Steven L. Reed, Traffic Investigator Analyst, Traffic Operations Section, Oregon Department of Transportation, May 15, 2006.] Mr. Reed stated that "10 miles (from a nearby town)" is a frequently "observed" reference distance in many Oregon crash reports – suggesting only a crude estimate of crash locations.

test or reference sample. Because some rural roadways are quite short, discontinuous[136], or interrupted by human activity, the samples used in this analysis were limited to continuous segments extending 8km or more, providing criteria could be supported by available data. In Idaho and Oregon, it was impossible to impose this condition, but in California, this distance threshold was used to more clearly differentiate the federal versus private land roadway environments.

- **Reference data selected for comparison:**

State and HSIS reference crash data for comparison with BLM and FS land were selected for comparable highways sections in California, and similar environments in Idaho, and Oregon. Where possible, candidate roads were screened using average daily traffic, distance from urban centers and satellite imagery to confirm that the surrogate roadway sections were relatively free from intensive industrial or commercial activity, settlements or other patterns signaling land use other than forestry or grazing being the dominant economic activity[137]. End points for these reference roadway sections were obtained by consulting state highway records and beginning "rural" road sections outside the limits of towns and urban areas[138].

- **Weather Data limited to present WX and Road Surface Condition:**

Weather and roadway data were extracted from each crash report for distinguishing classes of conditions and associating crash consequences with weather and road

[136] Many roadways end abruptly after entering public land or meander and out of reservations as they follow terrain contours.

[137] Surrogate roadway segments on private land were checked using Google Maps which locates towns and cities and enables connecting roadways to be viewed from archived satellite imagery with approximately 5 meter resolution.

[138] Fortunately, both Idaho and Oregon have data elements for urban and unincorporated towns, so it was possible to eliminate crashes in these zones from otherwise rural roadway samples. Nevertheless, it was difficult to get fair comparison of roadways with average daily traffic samples in these states.

conditions. Police reports code weather with schemes such as "A" (clear), "B" (cloudy), "C" (raining), "D" (snowing), "E" (fog), "F" (other), "F" (wind), "<" (not stated), or "other" ("error/other codes"). Likewise, roadway conditions are coded for "dry", "wet", "snow", "ice", "mud" and other weather-related conditions. It was necessary to develop a common weather and road surface index because of differing state formats.

Table 4: WEATHER AND ROAD SURFACE CRASH ENVIRONMENT CATEGORIES DEVELOPED FOR ANALYSIS OF CALIFORNIA, IDAHO & OREGON DATA

Category	Weather		Rd.Sfc. Cond.
"Non-Wx"	CLEAR	And	DRY
	CLOUDY	And	DRY
"Wx-Related"	RAIN	And/Or	WET
	SNOW*	And/Or	SNO/ICE***
	VIZOB**	And/Or	MUD****

* includes "Sleet/Hail" in ID and "Sleet" in Oregon
** includes "Fog", "Dust", "Smoke" and "Ash" in Oregon
*** includes "Snow" and "Ice" in Oregon
**** includes "Slippery/ Muddy" in California

The various state DOTs have slightly different categories for recording weather and roadway conditions as well as for crash locations and consequences. It was necessary to create common categories for comparison of crash records between the various states. For example, California has six weather categories, Idaho has eight, and Oregon, nine (including four visibility restrictions: "fog", "dust", "smoke" and "ash"). Likewise, California has four road surface conditions, Idaho: six, and Oregon: five.

Table 4 describes the common weather and road condition categories used for this analysis. When data was missing for weather or road condition, the crash record was deleted, because it could not be distinguishes as to being a "weather-related" or "non-weather related".

- Severity Determined by KABC0 scale.

Crash severity data was more universal than weather and road conditions among the states used in this analysis. The KABC0 scale is the National Safety Council (NSC) and American National Standards Institute (ANSI) standard measure used to report severity of crash injuries from the scene of the accident defined as follows: Fatal: one or more deaths (commonly signified by "K"): "A"-level injury: incapacitating injury preventing victim from functioning normally (e.g., paralysis, broken/distorted limbs, etc.), "B"-level injury : non-incapacitating but visible injury (e.g., abrasions, bruising, swelling, limping, etc.), "C"-level injury: probable but not visible injury (e.g., sore/stiff neck), "0" indicates property-damage is the only result of a crash. The latter category of non-injury crashes is also described as "PDO" or property damage only.

Table 5: Comprehensive Crash Costs Used in this Analysis Per Zaloshnja, et. al., FHWA-HRT-05-051, p. 58.

Maximum Crash Injury	Mean Human Capital Cost/Crash	Std. Error	Number of Crashes	Mean Comp. Cost	Std. Error
K	$1,245,579	$15,182	1,378	$4,008,885	$45,148
A	111,376	9,037	9,419	216,059	15,506
B	41,882	3,918	4,757	79,777	8,636
C	28,405	3,143	5,320	44868	4,254
0 (PDO)	6,390	396	11,605	7,428	548

Assignment of economic loss to each crash for this analysis is made using the FHWA Crash Cost Estimates for Maximum Police-Reported Injury Severity[139]. Where more information about speed limits, crash geometry and a variety of other factors is known, crash costs can be adjusted

[139] Zaloshnja, et. al. , FHWA-HRT-05-051

according to more detailed economic estimates. However in this research, where only crash severity is available, the mean comprehensive cost per crash was applied to all crashes[140]. Table 5 lists the estimated total cost of classes of crashes for various degrees of severity, which were expressed in the KABC0 scale for all data used here.

- Associated Data Elements Requested:

Crash records were obtained from state DOTs and the FHWA with a common request for: (1) unique crash identification number, (2) time and date of accident, (3) crash county (4) crash city/place, (5) crash location information, (6) manner of crash or collision (7) date and time of law enforcement notification, (8) weather condition, (9) roadway surface condition, (10) contributing environmental condition, (11) relation to roadway junction, (12) type of intersection (if any), (13) crash severity, (14) number of vehicles involved, (15) Number of non-fatally injured persons, (16) number of fatalities (if any), (17) authorized speed limit, (18) trafficway description, (19) motor vehicle maneuver action, (20) area of impact, (21 sequence of events, (22) most harmful event, (23) annual daily average traffic, (24) injury status, (25) driver action at the time of the crash, (26) traffic control device at the intersection, (27) time of EMS dispatch, (28) time of EMS arrive at crash site and (29) time of EMS arrival at emergency care facility.

[140] ibid. Table 13, p 58, lists estimated crash costs where no speed limits are posted. These values were generally applied in this study because speed limits were missing for many of the crashes on public land; also, speed limits for most of the comparison rural roadways on privately-owned lands were generally at the maximum allowable on state highway. While Zaloshnja, et. al. do index estimated crash costs on several factors including crash geometry, speed limit, and police-reported severity, the last factor is considered of primary importance in this study owing to the fact that most crashes in these rural roadways are single vehicle, run off the roadway (ROR) accidents.

Neither of the state DOTs nor FHWA could supply all these data fields, but the core data relating to crash severity, location and time, and most of the other variables above were available in all crash reports.

B. Selection of Data:

In the absence of geo-located data from a nation-wide FARS database, state DOTs and FHWA/HSIS data became the only apparent way to locate crashes in FS and BLM reservations. These alternatives limited the extent of the analysis for BLM and USFS land and the varied formats among states required generalizing some weather and roadway data into a common format. However, it was possible to locate crashes on the more important roadways by route designations, mileposts, federal land boundaries, county lines and distance from cities or other reference points. Thus the crash data assimilation task became one of selecting individual roadways, choosing roadway sections for analysis and by locating crashes with respect to federal land boundaries.

Idaho BLM and FS Crash Data

Idaho National Forest and BLM crash records were analyzed for a 16 year period, 1990-2005, using records collected by the Idaho Department of Transportation (IDT) and distinguished according to land tenure. This 16-year period was the maximum for which IDT employees expressed confidence in existing records and they acknowledged that the BLM data may not be as complete as for FS land roadways. The longer duration of the data collection period was obtained because traffic (and hence, the number of crashes) in Idaho is relatively light as compared more populous states such as California.

Data for Idaho BLM and FS crashes were received in June 2006; subsequently, ITD was requested and did supply crash data for remote, rural roadway segments which were not on the public domain. With both samples, some comparisons could be made between made between the nature of crashes on public and private land.

Idaho crash data has some limitations as well as features which could supplement this analysis. While spatial referencing and roadway environment information were limited because of the lack of milepost references and some of the roadway engineering data, Idaho does collect information on the response time of Emergency Medical Services (EMS). Weather, road surface condition, and severity of crashes were recorded in a manner similar to other states.

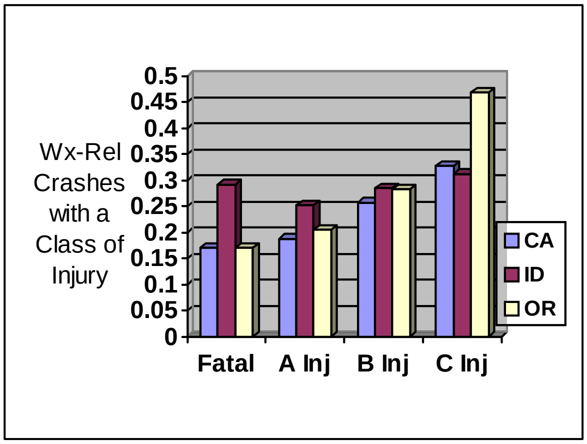

Figure 16: September 2006 Review of BLM & FS Crashes in 3 Western States (incomplete data)

The first step in analyzing the data for Idaho, as well as the other states, was to standardize the weather, road condition and severity data elements in order to make them comparable with other states' data. Weather and road condition converted to the category/conditions listed in Table 4. The second task was to convert crash severity data, generally reported in the KABCO scale, to an economic loss value adopted from the FHWA crash costs in Table 5. Individual crashes were then sorted into "Non-Weather-Related" and "Weather-Related" categories. The economic loss values for weather-related and non-weather related crashes could then be statistically analyzed to determine if significant differences existed for remote rural roads on and off BLM and FS lands.

Idaho Reference Crash Data

After initial analysis of the Idaho public land crash data indicated a disproportionate number of weather-related deaths in crashes on BLM and FS reservations, a further comparison of crashes on rural Idaho highways on privately-owned land was initiated[141].

[141] Idaho BLM & FS data seemed to show that Idaho was experiencing more fatal crashes in bad weather. Per telephone conversation with Dr. Forrest Council, October 11, 2006.

The Idaho Transportation Department, Office of Highway Safety quickly responded to a request for additional data on December 13, 2006, providing edited samples which excluded crashes located in small towns and unincorporated areas along 14 sections of Idaho highway[142] which are enumerated in Table 6.

Table 6: ID Non-public Land Crashes for Reference with BLM & FS

IDT District/Highway		Start Point	End Point	mileage	Land Use
1	US 95/ID 1	Coeur D' Alene, ID	Canadian Border	107	farms & forest
1	ID 41	Jct ID 41 & I-90	Oldtown, ID	39	farms & forest
1	ID 200	Oldtown, ID	MT State Line	63	follows Clark Fk.
1	ID 3/ID 6	St. Maries, ID	Emida, ID	17	forest
2	US 95	New Meadows, ID	Cottonwood, ID	94	forest
3	ID 55	McCall, ID	Smiths Ferry ID	46	forest
3	ID 78	Marsing, ID	Murphy, ID	29	farms & range
4	US 20	7 W. Hill City, ID	Jct. US 20 & ID 46	24	range
4	US 30	Kimberley, ID	Burley, ID	30	farms
5	ID 39	American Falls, ID	Blackfoot, ID	52	farms
5	ID 37	Roy, ID	American Falls, ID	31	farms & range
5	US 30 N.	Bancroft, ID	Montpelier, ID	45	farms & range
5 & 6	US 91	Blackfoot, ID	Idaho Falls, ID	20	farms
6	ID 33	Sugar City, ID	Victor, ID	55	farms & range
			Approx. mileage	**652**	

[142] Electronic mail from Mr.Steve Rich, Research Analyst Principal, Office of Highway Safety, ITD, December 12, 2006.

The comparative data for the rural highways across Idaho's non-federal lands was taken during the period January 1997 – November 2006 and recorded individual injuries or fatalities in 3143 records which were taken from 1337 crashes. Emergency Medical Services responded to 507 of these crashes on private, rural land. This compared with 1952 total crash records on BLM and USFS land, 1990-2005, from 1309 total crashes with 464 EMS responses to those crashes on public land

Of the 1313 crashes sampled on rural Idaho highways for the period 1997-2006, 598 were "weather-related". Of the 1307 Idaho crashes on BLM and FS reservations for 1990-2005, 370 were accompanied by either bad weather, slick roadway, or both of these conditions. From this count, it seems likely that Idaho crash reports include proportionately more crashes having some adverse weather condition crashes on rural highways as compared with BLM and FS lands (45 vs. 28 percent). Correspondingly, weather-related Idaho crashes on the reference rural highways appeared to be much less severe than weather-related BLM and FS land crashes (weather related injuries were about 3 times more "expensive" on the public lands: an estimated $172,982 to $60,015 for individual KABC0 reports).

Oregon BLM and FS Crash Data

Oregon's Crash Analysis and Reporting Unit personnel were contacted in early 2006, when it was learned the state had compartmentalized crash records for federal reservations. The ODOT employees supplied Oregon crash files collected on BLM and FS lands for 2003-2005; this was considered to be the period for the most reliable public land crash data collection in Oregon. In December 2006, ODOT also provided reference crash data for 17 rural roadway segments on non-public lands which were used to compare with the crashes on public land. In January 2007, ODOT Roadway Inventory and Classification Section personnel were again contacted and they supplied additional information on average daily traffic values for public and private lands in the state.

The Oregon privately-owned land reference crash samples extended from 2001-2005 and included crashes in small towns along the 17 routes selected for reference comparison with the BLM and FS land. To remove potential bias due to weather and temporal change, the reference data were sorted to restrict the Oregon private land crashes to the 2003-2005 period and to areas which were not classified as city or urban. This sorting process reduced the initial 3,650 crashes by over 55 percent and resulted in a sample of 1,623 reference crashes during 2003-2005 on 17 rural Oregon road sections.

Oregon crash data have 124 fields with indicators for both cities and urban areas; hence, by restricting the data to the 2003-2005 period and eliminating towns and urban zones, as depicted in Table 6, it was assumed that the remaining 1,623 reference crashes were on rural roadways. The proportionate decrease in fatal and class “A” injuries for the sorted reference sample seemed to indicate that these severe crashes were somewhat evenly distributed; however, it was apparent that many of the reference roadways selected, had much higher traffic volume than the test roadways on federal land.

Table 7: Identification of Reference Oregon Rural Highway Sections for Comparison

A: All OR Non-public Land Crashes for Selected Segments Comparable to BLM & USFS

Highway	Start Point	End Point	mileage	Land Use	Crashes	Crash/Mi	Fatalities	Fat./Mi.
OR206	Wasco, OR	Ruggs, OR	70	range	7	0.10	2	0.03
OR 74	Heppner, OR	US 395	45	range	9	0.20	0	0.00
US 395	Dale, OR	Pendleton, OR	60	Mtns/Rng	124	2.07	4	0.07
OR11	Pendelton, OR	Milton-Freewater, OR	32	farms	128	4.00	2	0.06
OR 206	John Day River	Int OR 207	60	hills/Rng	22	0.37	0	0.00
OR 19/207	Arlington, OR	Service Creek, OR	78	Mtns/Rng	40	0.51	4	0.05
OR 207	Hermiston, OR	Lexington, OR	37	farms/Rng	62	1.68	2	0.05
OR 207	30 N Jct OR 19&207	Heppner, OR	60	range	8	0.13	0	0.00
US 97	Junct US 197	Biggs, OR	68	farms/Rng	167	2.46	13	0.19
US 26	Dayville, OR	Prairie City, OR	42	range	125	2.98	1	0.02
US 26	Unity, OR	Vale, OR	65	range	125	1.92	2	0.03
US 26	Mitchell, OR	Jct. OR 19	32	Mtns/Rng	51	1.59	1	0.03
OR 380	Prineville, OR	Paulina, OR	56	Mtns/Rng	27	0.48	2	0.04
US 20	Newport, OR	Corvallis, OR	41	forest/Fms	505	12.32	24	0.59
US 26	Cannon Beach, OR	Hillsboro, OR	45	forest/Fms	530	11.78	23	0.51
US 101	California Line	Coos Bay, OR	80	forest	852	10.65	15	0.19
US 101	Tillamook, OR	Astoria, OR	40	forest	868	21.70	12	0.30
		Approximate mileage 911		Totals	3650		107	

B: OR Non-public Land Road With Urban Areas Crashes Omitted for the years 2003-2005 (Table 7 Cont.)								
Highway	Start Point	End Point	mileage	Land Use	Crashes	Crash/Mi	Fatalities	Fat./Mi.
OR206	Wasco, OR	Ruggs, OR	70	range	4	0.06	1	0.01
OR 74	Heppner, OR	US 395	45	range	6	0.13	0	0.00
US 395	Dale, OR	Pendleton, OR	60	Mtns/Rng	57	0.95	3	0.05
OR11	Pendelton, OR	Milton-Freewater, OR	32	farms	60	1.88	1	0.03
OR 206	John Day River	Int OR 207	60	hills/Rng	14	0.23	0	0.00
OR 19/207	Arlington, OR	Service Creek, OR	78	Mtns/Rng	26	0.33	4	0.05
OR 207	Hermiston, OR	Lexington, OR	37	farms/Rng	32	0.86	0	0.00
OR 207	30 N Jct OR 19&207	Heppner, OR	60	range	4	0.07	0	0.00
US 97	Junct US 197	Biggs, OR	68	farms/Rng	104	1.53	5	0.07
US 26	Dayville, OR	Prairie City, OR	42	range	58	1.38	1	0.02
US 26	Unity, OR	Vale, OR	65	range	30	0.46	0	0.00
US 26	Mitchell, OR	Jct. OR 19	32	Mtns/Rng	24	0.75	1	0.03
OR 380	Prineville, OR	Paulina, OR	56	Mtns/Rng	16	0.29	1	0.02
US 20	Newport, OR	Corvallis, OR	41	forest/Fms	212	5.17	9	0.22
US 26	Cannon Beach, OR	Hillsboro, OR	45	forest/Fms	326	7.24	12	0.27
US 101	California Line	Coos Bay, OR	80	forest	382	4.78	8	0.10
US 101	Tillamook, OR	Astoria, OR	40	forest	268	6.70	6	0.15
				Totals	1623		52	

Just four of the seventeen reference roadway sections, on US 20, 26 and 101, (the last four, color-coded sections in Table 7), accounted for almost three quarters of the crashes, but less than a quarter of the reference section mileage. These four sections were identified because of their frequency of crashes and the higher density of traffic.

They are generally west of Oregon's coastal mountain range and had roughly an order of magnitude or more crash density than the reference roadway sections to the east.

The review of rural Oregon crashes on and off BLM and FS reservations indicated weather-related crashes did not appear to be abnormally severe when compared with other rural highways. (In Idaho, the public land crashes with adverse weather conditions had caused estimated losses triple those on rural reference highways.) However, Oregon dry weather crashes appeared to be very severe – especially on the federal land where the estimated crash cost averaged almost $320,000. (above incapacitating injury ("A") cost)

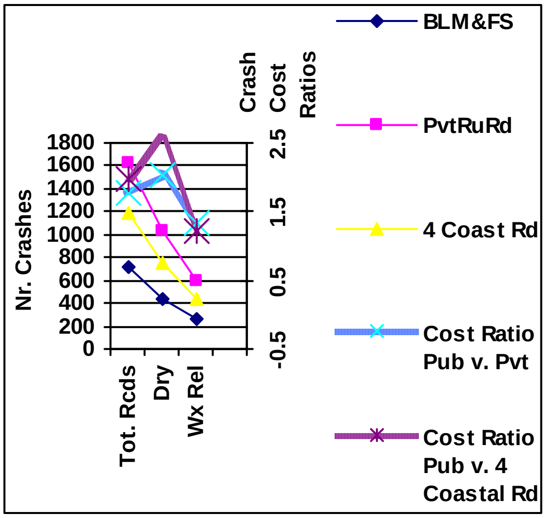

Figure 17: Preliminary Oregon Findings

Figure 17 illustrates some of the survey results of the Oregon analysis when crash results were assessed with the FHWA model. The number of crashes on private rural land, BLM and FS reservations, and the subset of rural crashes on privately-owned land west of the Coastal Range are respectively depicted by magenta, blue and yellow and blue lines. The blue hatched band represents the ratio of estimated crash cost on public land to all private land roadways sampled. The magenta hatched band represents the ratio of estimated crash cost on BLM and FS land compared with the cost of crashes on rural highway samples near the Pacific coast. These observations seem to support the presumption of more severe crashes in the more sparsely populated and less traveled roadways.

California Crash Investigation

The FHWA's Highway Safety Information System (HSIS) Lab in McLean, VA, was first contacted in June 2004 in order to learn what crash data might be available for US public lands. Over the next three years, the HSIS contract staff and Dr. Forrest Council of the University of North Carolina's Traffic Safety Research Center helped explore the potential use of HSIS data to address public land crashes.

California data was used in a pilot study during 2004, but subsequent examination revealed that some of the public and private land crash data, identified then by using the "NAT_LND" variable in the crash file, were either double coded or could not be verified by map inspection. More review and examination was required to insure that data were either BLM, FS or non-federal forest land and that the crash records were not duplicated.

The Need for Exact Crash Location

Analysis of crashes in Idaho and Oregon doesn't address the issue of comparability of roadways which are being used for testing the hypothesis for crashes on public land. Neither state's data could provide exact spatial distribution of the crashes on public lands nor for roads of comparable daily traffic volume. California HSIS data does provide a circuitous means of verifying the location of crashes on public land by restricting test data to state and federal roads and by referencing crashes to a California "roadlog" file.

In California, the CALTRANS Traffic Accident Surveillance and Analysis System collects both roadway inventory information and accident data provided through the

California Highway Patrol (CHPS). These data are subsequently provided to FHWA's HSIS. Roadlog files for the inventory of rural roadways below is of interest because it contains both public and private land. These files are composed of many road "segments" which are homogenous spans of the road differentiated by construction methods and roadway characteristics. Many segments are less than a mile in length and are defined by a beginning and ending milepost.

California crash locations are referenced by roadway mileposts, so with both crash and roadway files, it is possible to link crashes with specific roadway segments. The CHPS crash report specifies the investigating officer report crashes to the nearest hundredth of a mile (16 meters) and to verify this by measuring the distance to mileposts in both directions from the crash[143].

Table 8: HSIS Roadway Mileage by Category, Source: "Guidebook for the California State Data Files" , FHWA, March 2000, p8

California HSIS Highway Category Total	***kilometers***	***(miles)***
Rural Freeways	1002.79	622.85
Rural Freeways , 4 Lanes	2973.72	1847.03
Rural Multilane Divided Non-Freeways	152.64	94.81
Rural Multilane UnDivided Non-Freeways	974.37	605.2
Rural 2 Lane Highways	13670.51	8491
Other	338.84	210.46

After extensive discussion of the possibilities of verifying the FHWA data with Dr. Council, the HSIS Lab supplied an inventory of individual HSIS roadway segments beginning in January 2007.

[143] March 2000 "HSIS Guidebook for the California State Data Files", USDOT, FHWA. http://www.hsisinfo.org/pdf/00-137.pdf

Subsequently, intervals of California roadways were identified as either test or reference “sections” for more intensive analysis of differences which might be present in weather-related crashes on and off the public domain.

Selection of roadways in this study was most elaborate for California, because it was the first state for which HSIS data was available. California is also the only one of the nine HSIS states with a large proportion of public land which reports federal reservations in its crash reports.

California’s system for assigning highway reference points is arcane, in that CalTrans numbers highway mileposts for each of the 58 counties. The milepost count begins as roads enter the individual counties from the south or west or at the roadway’s most southerly or westerly extreme if it begins in a county. (Most states start numbering at state lines.) Currently, California is adopting the more customary federal highway methodology of referencing mileposts from the southern or western state boundaries.

Selecting California Reference and Test Roadway Sections

After receipt of HSIS California roadway segments in January 2007, all of the roadways previously identified as “NATNL FOREST” (FS), “BUREU OF NAT LND” (BLM), or ‘FOREST HIGHWAYS” (non-federal forest) were reviewed. The FHWA contractor provided HSIS segments for 2000, and 2005. For year 2000, there were 6485 HSIS segments coded as BLM, FS or non-federal forest for California. Of these year 2000 segments, 5251 were determined to be within FS and BLM reservations on sections of roadway which were continuous for 5 miles or more within federal land. Of the 5,383 segments supplied by FHWA for the same lands in 2005, 4,687 of met these criteria of falling within continuous sections of roadway on BLM and/or FS land[144].

Dual coding was the reason for rejecting the many of the year 2000 HSIS California data; many of the records were coded to be on both federal and non-federal land. This may have resulted from California's definition of "Forest Highways", which is a also a FS designation. Inspection also showed that many National Park roadways were not coded correctly[145]. Of the 1,234 California HSIS segments for 2000 coded "Forest Highway", only 499 of them did not also indicate they are were on federal land. But of the 695 "Forest Highway" segments for 2005, only 19 were not also have a coded as federal land[146].

When the BLM and FS segments composing a continuous length of 8 kilometers (5 miles) or more on BLM and/or FS reservations had been positively identified by reference to maps and online resources, a more rigorous procedure for testing the hypothesis in California could developed. The test sections of roadway could then be

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[144] FHWA modifies the roadway segments annually, in response to roadway construction and other changes.

[145] Extensive inspection of HSIS California roadway segments and crashes appeared to indicate that only some of the Death Valley National Park roadways were coded as "NATNL MONUMENTS", which is a designated class of lands administered by the National Park Service (NPS). Roadways which entered other large NPS reservations such as Joshua Tree National Monument, as well as Kings Canyon, Sequoia, Yosemite and Lassen National Parks seemed to be coded variously as either FS or "Toll = 2" a "Forest Highway". These suspect segments of roadway were not included in this analysis. Source: March 2000 "HSIS Guidebook for the California State Data Files", USDOT, FHWA.

[146] E-mails from Forrest Counsel and Yusuf Mohamedshah regarding California data, January: There were some overlapping segments in the 2000 and 2005 California HSIS roadway segment file for BLM, FS and "forest Highway". Generally this overlap was less than a mile, but it was a persistent feature in several counties. Additionally, there appeared to be significant HSIS omissions of National Park Service (NPS) roadways for California and some confusion of NPS and "Forest Highway" roadway.

compared with rural reference sections of California highway with similar roadway geometry and daily traffic (AADT) to evaluate crashes which are either in or out of BLM and FS reservations.

On April 13, 2007, FHWA's contractor provided both California HSIS reference segments and crash data for 34 selected highways which transected extensive BLM, FS and private lands of the State. Some of the roadways also requested, such as N3, a mountainous road in Los Angeles County, and an extensive section of old U.S. 66 which is still used in the desert of San Bernardino County, were not available in the HSIS database.

Because California crash records are based on county, rather than the state's boundaries, it was necessary to order HSIS roadway segments by highway, county, and county milepost, and then to identify federal or private land sections over 5 miles long. With the HSIS segment inventory for both public and private lands, Table 8 was constructed to reference the comparable, test and reference sections of California roadway.

Table 9: Selected Sections - California Roadways for Crash Analysis

Hwy	Start Pt.	End Point	Counties in Order	Section ID	Begmp	Endmp
1	Cayucos	Monterrey	S.L. Obispo (40)	RU40001	0	74.32
			Monterrey (27)	CA27001	1.43	21.6
1	Santa Cruz	Princeton	Santa Cruz (44)	RU44001	21.6	34.45
			San Mateo (41)	RU41001	5.746	26
	Olema	Leggett	Marin (21)	RU21001	2.84	50.51
			Mendocino (23)	RU23001	0	105.6
2	Pasadena	Jct CA-138	Los Angeles (19)	CA19002	27	82.3
			San Bernardino (36)	CA36002	0	5.1
4	Stockton	Jct. CA-89	San Joaquin (39)	RU39004	0	38.06
			Stanislas (50)	RU50004	0	7.296
			Calaveras (05)	CA05004	35.7	65.9
			Alpine (02)	CA02004	0	31.7
6	Bishop	NV Line	Inyo (14)	(no P.L.)		
			Mono (26)	GP26006	10.78	16.3
			Mono (26)	CA26006	16.3	32.3
8	San Diego	Winterhaven	San Diego (37)	CA37008	31	57.8
			Imperial (13)	CA13008	12.6	25.11
			Imperial (13)	GP13008	25.11	54.46
			Imperial (13)	CA13008	54.46	92.2
14	Mojave	Homestead	Kern (15)	CA15014	38.5	64.6
25	Jct. CA-198	Hollister	Monterrey (27)	(no P.L.)		
			San Benito (35)	(no P.L.)		
29	Oakville	Jct. CA-20	Napa (28)	RU28029	15.58	27.49
			Lake (17)	(no P.L.)		
32	Chico	Jct. CA-36	Butte (04)	RU04032	15.51	36.6
			Tehema(52)	CA52032	11.3	24.9
33	Jct. US-101	Coalinga	Ventura (56)	CA56033	14.2	56.7
			Santa Barbara (42)	(no P.L.)		
			S.L. Obispo (40)	(no P.L.)		
			Kern (15)	GP15033	9.65	20.2
			Kern (15)	RU15033	31.75	73.74
			Kings (16)	(no P.L.)		
			Fresno (10)	(no P.L.)		

Table 9 (cont.) : Selected Sections - California Roadways for Crash Analysis

Hwy	Start Pt.	End Point	Counties in Order	Section ID	Begmp	Endmp
36	Jct US-101	Susanville	Humboldt (12)	CA12036	42.9	45.7
			Trinity (53)	CA53036	0	41.1
			Tehema(52)	CA52036	80	104
			Plumas(32)	CA32036	0	2.92
			Lassen (18)	CA18036	9	16.8
46	Jct. CA-1	Famoso	S.L. Obispo (40)	RU40046	0.146	60.85
			Kern (15)	(no P.L.)		
50	Placerville	South Tahoe	El Dorado (09)	CA09050	34	80.4
62	Morongo Valley	Parker Dam	San Bernardino (36)	CA36062	45.9	79.48
			Riverside (33)	CA33062	79.5	90.2
				CA36062	90.2	138
70	Pleasant Grove	Hallelujah Jct.	Sutter (51)	RU51070	0.051	8.298
			Yuba (58)	RU58070	0	25.8
			Butte (04)	CA04070	37.5	48.1
			Plumas(32)	CA32070	0	37
			Plumas(32) joins (18)	RU32070	70.1	95.96
			Lassen (18)	RU18070	0	3.888
74	S.J. Capistrano	Palm Desert	Orange (30)	RU30074	1.856	13.7
			Riverside (33)	CA33074	0	11.83
			Riverside (33)	GP33074	11.8	48.3
			Riverside (33)	CA33074	48.3	81.2
78	Escondido	Blythe	San Diego (37)	RU37078	26.93	40.5
			Imperial(13)	CA13078	0	13.17
			Imperial(13)	GP13078	13.17	27.3
			Imperial(13)	CA13078	27.3	75.4
			Riverside (33)	RU33078	0	16.41
79	Descanso	Temecula	San Diego (37)	RU37079	1.66	43.51
			Riverside (33)	RU33079	6.787	39.34
80	Citrus Heights	NV Line	Sacramento (34)	(no P.L.)		
			Placer (31)	CA31080	49.2	69.8
			Nevada(29)	CA29080	9	24.6
88	Stockton	NV Line	San Joaquin (39)	RU39088	13.37	25.37
			Amador (03)	CA03088	45.7	71.6
			Alpine (02)	CA02088	0	20.6

Table 9 (Cont.): Selected Sections - California Roadways for Crash Analysis

Hwy	Start Pt.	End Point	Counties in Order	Section ID	Begmp	Endmp
89	Jct. US-395	Mt. Shasta	Mono (26)	RU26089	0	6
			Alpine (02)	CA02089	0	10.9
			El Dorado (09)	CA09089	0	27.4
			Placer (31)	CA31089	0	21.7
			Nevada(29)	CA29089	0	8.7
			Sierra (46)	CA46089	0	13.3
			Sierra (46)	GP46089	13.3	23
			Sierra (46)	CA46089	23	29.6
			Plumas (32)	CA32089	29.3	37
			Tehema(52)	(joined		
			Shasta(45)	CA45089	0	14.9
			Shasta(45)	GP45089	14.9	21
			Shasta(45)	CA45089	21	33.1
			Siskiyhou (47)	CA47089	0	21.4
			Siskiyhou (47)	GP47089	21.4	26.8
			Siskiyhou (47)	CA47089	26.8	33.5
94	San Diego	Jacumba	San Diego (37)	RU37094	15.36	65.38
96	Weitehpec	Jct. I-5	Humboldt (12)	CA12096	0	45
			Siskiyhou (47)	CA47096	0	103
97	Weed	OR Line	Siskiyhou (47)	CA47097	5.17	16.59
			Siskiyhou (47)	GP47097	16.59	23.4
			Siskiyhou (47)	CA47097	23.4	31.1
108	Chinese Camp	JCT US-395	Tuolume (55)	CA55108	13.4	67
			Mono (26)	CA26108	0	15.1
120	Jct. 395	Benton	Mono (26)	CA26120	0	39.5
120	Manteca	Crane Flat	San Joaquin (39)	RU39120	0.493	21.18
			Stanislas (50)	RU50120	0	10.58
			Tuolume (55)	CA55120	36.5	56.5
			Mariposa (22)	CA22120	41.5	43.7
127	Baker	NV Line	San Bernardino (36)	CA36127	0	41.5
			Inyo (14)	CA14127	0	49.4
139	Canby	OR Line	Modoc (25)	CA25139	3.5	40.5
			Siskiyhou (47)	RU47139	0	5.04
140	Tuttle	El Portal	Merced (24)	RU24140	0	43.98
			Mariposa (22)	RU22140	10.11	28.35

Table 9 (Cont.): Selected Sections - California Roadways for Crash Analysis						
Hwy	Start Pt.	End Point	Counties in Order	Section ID	Begmp	Endmp
168	Clovis	Lake Shore	Fresno (10)	CA10168	29	65.9
168	South Lake	Oasis	Inyo (14)	CA14168	0	14.18
			Inyo (14)	GP14168	14.18	21
			Inyo (14)	CA14168	21	54.7
178	Bakersfield	Jct. CA 190	Kern (15)	CA15178	14.7	40.5
			San Bernardino (36)	CA36178	0.7	14.8
			Inyo (14)	CA14178	28	62.2
199	Jct. US 101	OR Line	Del Norte (08)	CA08199	6.17	36.4
299	Arcata	NV Line	Humboldt (12)	CA12299	32.7	43
			Trinity (53)	CA53299	0	36.8
			Shasta(45)	(No HSIS		
			Lassen (18)	(No HSIS)		
			Modoc (25)	CA25299	6.32	18.3
395	Cajon Pass	NV Line	San Bernardino (36)	CA36395	28.5	73.5
			Kern (15)	RU15395	8.131	36.82
			Inyo (14)	CA14395	3.05	31.5
			Inyo (14)	GP14395	31.5	40.3
			Inyo (14)	CA14395	40.3	47.7
			Mono (26)	RU26395	0	20.58
			Mono (26)	CA26395	20.6	44.87
			Mono (26)	GP26395	44.87	51
			Mono (26)	CA26395	51	71
			Mono (26)	GP26395	71	80.3
			Mono (26)	CA26395	80.3	105
395	Hallelujah Jct.	OR Line	Lassen (18)	RU18395	0	77.36
			Lassen (18)	CA18395	78.1	83.3
			Lassen (18)	GP18395	83.36	88.8
			Lassen (18)	CA18395	88.8	105
			Lassen (18)	GP18395	105	115.3
			Modoc (25)	BLM frag		
			Lassen (18)	CA18395	115.3	119.1
			Lassen (18)	GP18395	119.1	129.3
			Lassen (18)	CA18395	129.3	138

The sections of roadway used as private land reference and BLM and FS test sections (fifth column in Table 9 above) were chosen after direct inspection of 10,291 HSIS segments and the choice of either continuous public land or private land-bounded roadways which were greater than 8 kilometers (5 miles) in length. This inspection verified that the HSIS segments composing each section were all either on public or private land and that the HSIS land designation was consistent with highway maps as well as online data from the Public Lands Information Center[147]. This process enabled spatial referencing of crashes which are linked to HSIS segment in the FHWA database.

Table 10: Sample HSIS Segment for 180 meters of Route 1, San Luis Obispo Co., CA

cntyrte	no_lanes	rte_nbr	begmp	endmp	aadt	toll	nat_lnd	county	rodwycls	county_rte_nbr	ro_seq
05001 40 U	2	1	0	0.11	5400	0		40	8	40001	67000

California HSIS data required that the segments be sorted by roadway and county milepost to insure segments were clearly in the public or private domain. Inspection and elimination of segments in an initial file containing 5383 records gave candidate BLM and FS roadway sections denoted by the “CA”CoHwy code that was assigned to BLM and FS sections. Later inspection of 7072 public land and 3219 private land segments finalized 74 “test” public land sections and 47 rural private land “reference” sections indicated by either “RU”CoHwy or “GP”CoHwy in Table 9.

California crashes supplied by FHWA gave the milepost of the crash and the HSIS segments provided “begmp” and “endmp” locations along each roadway, generally based

[147] http://www.publiclands.org/home.php?SID=

on the distance from the south or west county line. Because HSIS segments also identified any adjacent federal land, it was possible to locate the boundaries of federal reservations on California roadways. When these segments could be identified as forming a continuous section of roadway, greater than eight kilometers (5 mi) in length, with common land tenure and a rural designation, they were designated as either a test or reference section for this research.

The FHWA supplied "rural" California crash records for candidate roadway intervals listed in Table 8 for the years 2003-2005. Using Microsoft Access, the database of 54,584 crashes was sorted for those crashes which fell within the 121 public (test) or private (reference) sections of the roadways. With the specific crashes identified for each section of roadway, it was then possible to accurately locate the crashes and conduct more meaningful comparisons on similar types of roadway with comparable traffic volumes.

Table 11: HSIS Report for an early afternoon sideswipe accident on CA Route 1 in a rural area of Marin Co., 5 km. north of the Golden Gate Bridge; Weather was clear, Road dry, no Injuries

county	*milepost*	*no_lanes*	*ro_seq*	*Highway*	*aadt*	*toll*	*nat_Ind*	*Rodwycls*
21	3	2	158100	1	5600	0		
(first 10 fields)								
acctype	*hour*	*pop_grp*	*loc_typ*	*cause1*	*severity*	*veh_invl*	*rdsurf*	*vtype_at_fault_*
B	1325	9	H	6	0	C	A	G
(next 10 fields)								
tot killed	*tot_inj*	*numvehs*	*weather 1*	*acc_date*	*weather 2*	*cnty_rte*		
0	0	2	A	20051011	-	0400121 U		
(final 7 fields)								

Several initial attempts to analyze the data using Excel failed because the number of the records and the volume of data within each record. By entering the nine different batches of data received from FHWA into MS Access, the unique 21-digit case number ("caseno") was preserved and used as the "primary key" for Access to process the data. A further operation in Access was to associate the separated "non-weather" and weather-related" crash files with each of the 121 specific reference and test sections of highway for statistical analysis. Running queries in Access yielded the following data summary:

Table 12: Receipt, Ingest, Validation and Partition of CA Crashes		
Summary of work: CA HSIS crashes 2003-05	**"Rural" Crashes ("pop-grp" = 9)**	
All Crashes received for CA 2003-05: **54,217** Crashes accepted by Access ("caseno" identified as primary key in import)	**31,777**	
"No Wx" Crash CA 2003-05: **44,302** Crashes w/o Wx or Slick Rd.	**24,882**	
"Wx-Related" Crash CA 2003-05: **9,507** Crashes w/ Wx and/or Slick Rd.	**6,626**	
Private Land Crashes -- All: **11,619** Crashes in Reference Sect.	**7,950**	
Private Land Crash No-Wx: **9,968** No-Wx Crashes	**6,681**	84%
Private Land Crashes--Wx-Rel: **1,518** Wx-Rel Crash.	**1,165**	15%
All BLMFS Crashes -- All Weather Conditions: **6,719** Test Crash.	**6,077**	
BLM&FS Crashes -- No Wx: **4,429** Test Crash. w/o Wx	**3,993**	66%
BLM&FS Crashes --WxRel; **2,241** Test Crash w/ Wx or Slk. Rd.	**2,038**	34%

Manipulation of data design fields in Access enabled the eventual integration and standardization of all HSIS California crashes and reintroduction into Excel for sorting, attributing costs to KABC0 -scaled crashes, and for statistically testing the various classes of crashes.

Preliminary Results of California Analysis

Compartmentalizing the test and reference data into non-weather and weather-related categories for all California roadways being tested initially showed that in the aggregate, there was only an insignificant difference in the average cost of weather-related crashes on BLM and FS land when compared with other rural sections of highway. The aggregate difference in non-weather crashes was significant with crashes on BLM and FS reservations projected as being a third more costly than those on other rural land.

It was obvious that California crashes are a result of widely differing road conditions and environments – from the near wilderness forest highways in the north to the stark deserts of the south – both of these environments being largely in the federal domain. As a result, a means of analyzing California crashes by roadway, county and milepost was sought to learn of significant variations from the above means in local condition. Another Access query design allowed crash records for specific highways and counties to be returned so that regional and local conditions could be extracted.

One early finding with the California data was the curious variation in weather-related crash cost at the extremes of the average daily traffic scale. Based on limited samples of a few hundred crashes, federal land was apparently a safer roadway environment for higher volume roads, but apparently much more dangerous on its low AADT roads. Figure 18 shows that as weather-related, private land rural crashes increased in cost with more traffic, the public land crash cost fell dramatically.

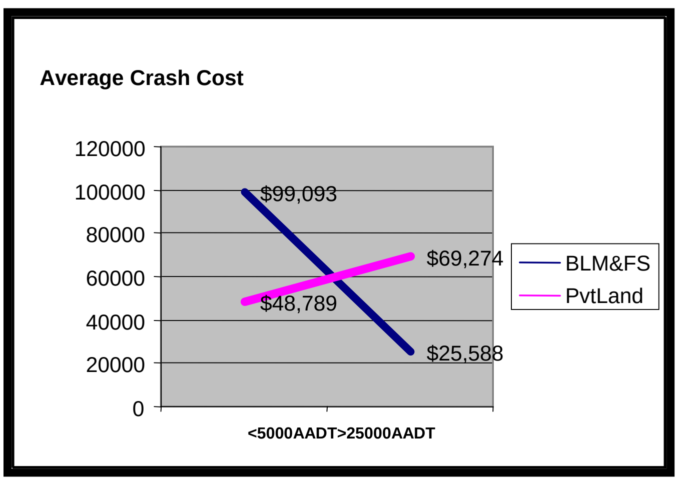

Figure 18: Comparison of CA High and Low Traffic Crashes

While the example above is based on limited samples, it does imply that various driving environments may have a large effect on the kind and severity of crashes. Fortunately

California HSIS data provides enough cases and sufficient spatial information for stratification of crash data to make assessments for particular roadways and regions under different weather regimes. In contrast to the more limited data in Idaho and Oregon, the California HSIS data provides the resource base needed to examine the original question about weather and crashes on BLM and FS land.

Chapter 4: RESULTS

The investigation of crashes on public land was an evolutionary process that included gradually resolving the data acquisition and management issues detailed in Chapter 3 and subsequently proceeding to extract more information and inferences from the crash data available from the three western states. The most definitive tests were restricted to analysis of the California HSIS database with the additional spatial information which could be derived from the FHWA's roadway segment and crash record association. Analysis of Idaho and Oregon crash data was particularly useful in identifying possible associations and trends which could be more rigorously tested with the California data.

Resolution of the question of whether federal forest and rangeland crashes are different from those in other remote rural areas depends on whether sufficient data, tied to accurate location information, are available to statistically demonstrate one or the other conclusions. Idaho and Oregon provided some important insights and contrasts in the severity of crashes in somewhat similar rural environments, but the data available and the results obtained were not consistent enough to formulate any common, significant associations.

Table 13: Idaho Crashes

t-Test: Two-Sample, Unequal Variances

Weather-Related Crashes		
	FS & BLM	***Pvt. Land***
Mean	**$172,982**	**$60,015**
Variance	4.81E+11	7.49E+10
Observations	572	1310
Hypo. Mean	0	
df	650	
t Stat	3.770213	
P(T<=t) one-t	8.90E-05	
t Critical one-	1.647201	
No Weather Crashes		
	FS & BLM	***Pvt. Land***
Mean	$194,762	$213,693
Variance	5.31E+11	6.44E+11
Observations	1312	1803
Hypo. Mean	0	
df	2965	
t Stat	-0.68582	
P(T<=t) one-t	0.246439	
t Critical one-	1.645368	
All Idaho Crashes		
	FS & BLM	***Pvt. Land***
Mean	$187,768	$148,382
Variance	5.15E+11	4.06E+11
Observations	1889	3143
Hypo. Mean	0	
df	3615	

A. Idaho Crashes Compared

The scarcity of rural and public land crashes in Idaho and the lack of more information on roadway conditions limit the significance of this analysis. Idaho is two-thirds federal land, has thousands of miles of forest roads, and seems to have a particularly bad record of crashes during adverse weather. What is not known is the average traffic for remote rural roads, the probability of crashes going unreported, and the consequences of delayed discovery of crashes on the reported accident severity.

From the crash reports obtained from the Idaho Transportation Department, it was apparent that many of the crashes occurred on Forest Service Roads which were unpaved and had a low speed limit. Because a few Idaho crash records indicated accidents on State and U.S. highways within the federal reservations, it was not surprising that only a few of the BLM or FS crashes had any data on average daily traffic. Many of the injury crashes did have time of the crash and time of arrival for EMS, consequently, it was possible to make some estimates of mean emergency response time for victims of crashes on public and private land.

Table 14: Comparison of BLM & FS with Idaho Private Lands for EMS Response Crashes		
Weather-Related Crashes		
t-Test: Tw	***BLM & FS***	***Pvt. Land***
Mean Cost	**$514,676**	**$96,922**
Variance	1.41E+12	7.87E+10
Observatioı	78	207
Hypothesiz	0	
df	80	
t Stat	3.072061	
P(T<=t) one	0.001453	
t Critical on	1.664125	
ID NonWx-Related Crashes with E		
	BLM & FS	***Pvt. Land***
Mean Cost	$472,734	$405,394
Variance	1.26E+12	1.14E+12
Observatioı	220	299
Hypothesiz	0	
df	458	
t Stat	0.690457	
P(T<=t) one	0.245128	
t Critical on	1.648187	
All ID Crashes Sampled with EMS		
	BLM & FS	***Pv.t Land***
Mean Cost	$482,119	$279,076
Variance	1.29E+12	7.24E+11
Observatioı	299	507
Hypothesiz	0	
df	496	
t Stat	2.679687	
P(T<=t) one	0.003807	
t Critical on	1.647932	

When federal and nonfederal land crashes were compared, using the BLM and FS records in contrast to the 14 remote rural segments for private land, the results seem quite significant for weather-related crashes. The Idaho samples indicate decisively more serious weather-related crashes on federal land. Conversely, bad weather crashes on the state highways surrounded by private land appear to be surprisingly modest as compared with either dry weather anywhere in Idaho or adverse weather on public land.

The comparable time for EMS to get to the scene of A major contrast emerged when Idaho crashes were sorted for those requiring an EMS response. Of 299 crashes on BLM & FS land for 1990-2005, and 507 crashes requiring EMS response on Private, rural land 1997-2006, the estimated public land crash cost was over 5 times that of the roadways through the privately-owned, rural Idaho reference areas. These figures need considerable scrutiny because of the lack of information regarding the facts and circumstances of each crash, but the difference in severity of the Idaho's foul weather crashes on public land is certainly justification for directing more attention to the reasons for the disparity.

It is possible that EMS is called more routinely in the case of local rural highway crashes or perhaps that delays in getting EMS on the crash scene in BLM & FS land crashes contribute to the eventual reported severity of the crashes there. Nevertheless, it is clear that in Idaho, EMS responds to much more severe crashes on BLM and FS land than for the rural public highways referenced in this study.

The mean time required for arrival of medical technicians at the scene of severe crashes in Idaho provides evidence that delay in treatment of crash victims is a major contributing factor to the cost differential. A tabulation of time required for EMS to reach crashes on BLM and FS land in Idaho showed that for all EMS responses 1990-2005, the average time for medics to get to the crash scene was an hour and forty-five minutes. The 180 crashes on the referenced rural Idaho highways was 22 minutes. In raw numbers, there is a direct correlation of estimated cost of these classes of accidents and time for EMS response to the crash site.

Oregon Crash Results

Table 15: Comparison of Oregon Cr		
t-Test: Two-Sample Assuming Unequal Vari		
Weather-Related Crashes		
	FS & BLM	***PvtLand***
Mean	$186,335	$146,645
Variance	5.64E+11	4.15E+11
Observatio	270	593
Hypothesi:	0	
df	456	
t Stat	0.751423	
P(T<=t) on	0.226393	
No Weather Crashes		
	FS & BLM	***PvtLand***
Mean	**$319,385**	**$152,733**
Variance	9.67E+11	4.19E+11
Observatio	438	1025
Hypothesi:	0	
df	605	
t Stat	3.257397	
P(T<=t) on	0.000594	
t Critical o	1.647376	
All Oregon Crashes		
	FS & BLM	***PvtLand***
Mean	$266,657	$150,363
Variance	8.10E+11	4.16E+11
Observations	714	1623
Hypothesized Mean D	0	
df	1048	
t Stat	3.117648	
P(T<=t) one-tail	0.000936	
t Critical one-tail	1.646309	

Oregon experiences more public land crashes per year than Idaho and has some additional traffic density information, but it was difficult to meaningfully compare test and reference roadway samples in Oregon because of the great difference in average daily traffic, both among the regions of the state and in federal and other rural areas.

The first attempt to test for differences between public and private land crashes failed to reveal significant differences in the cost of weather-related crashes, but there were huge differences in the "No-Weather" crashes. The average expense of these crashes on federal land was over twice the average for Oregon's reference rural, "private land" routes. Because of this large disparity in estimated cost of the "no-weather" crashes, even the aggregate "all-weather" category of crashes was significantly higher for Oregon's BLM & FS lands.

Crashes on the public lands during dry weather had the highest average estimated cost found anywhere in this study, except for the subcategories of "EMS Response" crashes previously noted in Idaho (Table 14). Nevertheless, the average severity of any "No Weather" crash on BLM and FS owned roadways in Oregon appears to be greater than for the reference sample of "EMS Response" for rural highways in Idaho. ($279,000 for the average EMS response on in rural Idaho vs. about $320,000 for any good weather crash on BLM and FS roads in Oregon)

Table 16: OR Pvt.Land < 1000 AADT

t-Test: Two-Sample Assuming Unequal Variances

OR Pvt Rural < 1000AADT

	NoWx	***Wx-Rel***
Mean	$336,389	$35,965
Variance	1.00E+12	1.80E+09
Observations	88	38
Hypothesized Mean Difference	0	
df	88	
t Stat	2.81546	
P(T<=t) one-tail	0.00301	
t Critical one-tail	1.66235	

Inspection of the limited average daily traffic data available for BLM and FS land in Oregon showed that practically all the crashes identified for these public lands were on roadways traveled by less than 1000 vehicles per day. A comparison of the public land crashes and the lesser-traveled private land roadways was attempted for AADT , 1000. With an AADT file provided by ODOT, it was possible to match traffic volume at various crash sites specified by Oregon's crash file highway and milepost data. Unfortunately, most of Oregon's private land reference roadways had a much higher average daily traffic count than for the public land.

Average daily traffic on the federal lands was not computed due to the uncertainty of data. However, it was assumed that AADT on the BLM and FS reservations was generally less than 1000 vehicles per day, based on a file provided by ODOT[148]. When the reference crashes were sorted, only about 150 of the crashes on private land roads had an AADT less than the highest value indicated for FS and BLM roads[149]. This crash analysis was of limited value because of sample size, but the disparity in the small sample (Table 16) seems to indicate that Oregon's "No Weather" crashes are highly destructive on low traffic highways regardless of who owns the surrounding land.

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148 E-mail from Jennifer K. Campbell, ODOT: January 29 - February 8, 2007, "Here is a file of what we have in our non-state hwy database for volumes on USFS and BLM roads. 98% of these are not numbers that we have collected ourselves, so I can not give you any kind of idea of how valid they are, or even where they came from. If the ADT Year is 2000 - 2006, then it is probably a number that came from a count we did, and can be considered as a non-adjusted volume (i.e., that it was a 24 hour count for whatever day it was taken). I do want to emphasize that these are not adjusted to represent an AADT (annual average daily traffic). I would urge caution in how you use these numbers..."

149 On re-inspection of the Oregon Crash file it was apparent that ODOT's crash records for BLM and FS land included only "Rural County Roadways" and that it's designation of public land crashes did not include state and federal highways passing through the federal reservations.

C. California Crashes

With all the attention given to defining the spatial distribution of crashes in California, it should be expected that some more definitive results might be drawn from the thousand of crashes and dozens of highways inventoried in the development of methodology. The aggregate results were not surprising from what appears in the limited rural weather-related crash literature: weather-related crashes seem to be less severe than in good weather. The aggregate analysis of all the sections indicated that while weather-related crashes were over twice as likely to occur on BLM and FS land in California, those public land crashes tended to be less severe than for the reference roadway sections on private land. A higher proportion of weather-related crashes would be expected on FS land because the same wet weather that sustains the National Forests also means greater durations of precipitation, snow and icy roads. Overall however, there was not a significant difference in the mean crash cost of weather-related accidents in the rural California test and reference sections.

Table 17: Comparison of California Crashes

Weather-Related Crashes		
	BLM&FS	***PvtLand***
Mean	$88,356	$100,346
Variance	2.15E+11	2.55E+11
Observatio	2038	1165
HypoMean	0	
df	2259	
t Stat	0.6658233	
P(T<=t) on	0.252796	
t Critical o	1.6455284	
t-Test: Two-Sample<>Variances		
CA No Weather Cra		
	BLM&FS	***PvtLand***
Mean	$196,126	$150,794
Variance	5.53E+11	4.32E+11
Observatio	3993	6681
Hypothesi	0	
df	7597	
t Stat	-3.180798	
P(T<=t) on	0.0007373	
t Critical o	1.6450542	

While mean weather-linked crash costs on the selected BLM and FS land roadways are somewhat lower than for the selected rural reference sections, both of these categories were far less costly than crashes during favorable weather and road conditions, regardless of land ownership. Most significantly, “No Weather” crashes were much more severe on BLM and FS land, about 30 percent higher in cost and at a 0.0007 level of uncertainty. This was based on a total sample of 10,674 “good weather” crashes reported as “rural” and within the 121 test and reference sections used in this analysis.

Roadways through BLM and FS land in California appear to sustain crashes costing 30 percent more than those on comparable rural highways in good weather.   This result is consistent with the earlier indications in Oregon where public land crashes in good weather were estimated at more than twice the cost of those on private, rural highways. The data is much more reliable in California, because use of the HSIS data is taken from State and federal highways rather than contrasting low volume Forest Service and BLM “test” roads in Idaho and Oregon and “reference” samples on major highways. In California, all the test and reference roadways are maintained by CalTrans and all crash data is compiled by CHPS and CalTrans

The high significance of both the Oregon and California cost estimate differences suggests that roadway hazards in these coastal states may be quite different from Idaho. While Idaho roadways through private land showed much lower crash cost in bad weather, the public land crashes were nearly equal in cost, regardless of the weather.

In an effort to focus on specific counties and roadways, rather than the great variety of terrain, road characteristics and traffic volume represented in the above summary, a rudimentary analysis tool was developed to more thoroughly use the HSIS database. Microsoft™ Access and Excel data analysis capabilities were linked to enable a semi-automated routine for selecting California highways, counties and mileposts and to search for particular crash trends that may exist in various roadways and regions of California. The following two examples are for two highways (U.S. 97 and CA 299) and two Northern California counties (Siskiyou and Trinity, respectively) containing National Forest (test) and rural private land (reference) sections previously developed in Table 9.

Table 18: Focused Analysis of Route 97 Crashes in Siskiyou County, California, 2003-2005 Crashes

t-Test: Two-Sample Assuming Unequal Variances:

SISKIYOU Co. All Crashes			**Weather-Related Crashes**		
	No Wx	***Wx-Rel***	***Pvt Land***	***FS Land***	
Mean	**$276,464**	**$115,792**	**$155,161**	**$46,427**	Mean
Variance	8.83E+11	2.73E+11	4.25E+11	4.01E+09	Variance
Observations	68	58	37	21	Observations
Hyp.Mean	0		0		Hyp.Mean Diff.
df	108		37		df
t Stat	1.208173		1.006303		t Stat
P(T<=t) one-tail	0.11481		0.160403		P(T<=t) one-tail
t Critical one-tail	1.659085		1.687094		t Critical one-tail

Unfortunately, programming limitations have prevented development of a more flexible method for identifying weather and non-weather "hot spots" using GIS software. However, the following examples demonstrate the disparity in crash records for different highways and the need for more concise analysis. From Tables 18 and 19 which represent mountainous forested areas of California, it is evident that crash losses vary considerably and possibly for counter-intuitive reasons.

Table 19: Focused Analysis of Route 299, Trinity Co, California

t-Test: Two-Sample Assuming Unequal Variances: 2003-5 Crashes

TRINITY Co. :	**All Crashes**			**Weather-Related Crashes**		
	No Wx	**Wx-Rel**		**Pvt Land**	**FS Land**	
Mean	**$114,416**	**$47,429**		**$41,245**	**$50,598**	Mean
Variance	2.6E+11	3.5E+09		2.75E+09	3.84E+09	Variance
Observations	240	93		33	62	Observations
Hypo.Mean	0			0		Hypo.Mean Diff.
df	255			75		df
t Stat	2.001893			-0.77564		t Stat
P(T<=t) one-tail	0.023178			0.220201		P(T<=t) one-tail
t Critical one-tail	1.650851			1.665425		t Critical one-tail

The first illustrations of crash cost disparity came in the random selection of two roads (U.S. 97 and CA 299) which run through National Forests in Northern California. Route 299 is a serpentine two lane route through the Shasta- Trinity National Forest, with high speed driving and plenty of opportunities for disaster. It was expected to be a killer, but it obviously is not. Route 299 crash cost estimates for both weather and non-weather crashes are less than half those of U.S. 97 which extends through mountainous forest in

Siskiyou County. U.S. 97 it appears to have much more severe crashes than Route 299, particularly in good weather[150].

Differences in the above crash records led to the more extensive tabulation of roadway and county crash outcomes in Table 22, Appendix A. During the development of that

Table 20: California Public Land Crash Weather Contrast: CA Route 168, within Sierra National Forest, Fresno Co., and U.S. 199, within Six Rivers National Forest and Jedediah Smith State Forest, Del Norte Co.

t-Test: Two-Sample Assuming Unequal Variances

Sierra National Forest, Fresno Co.			6 Rivers & Smith Fst. Del Norte Co.		
CA 168 >	**No Wx**	**Wx-Rel**	**No Wx**	**Wx-Rel**	***<US 199***
Mean Crash Cost	**$192,585**	**$34,244**	**$81,141**	**$230,176**	**Mean Crash Cost**
Variance	5.52E+11	2.58E+09	1.21E+11	7.18E+11	**Variance**
Obs.	138	60	132	147	**Obs.**
Hypo. Mean Dif.	0			0	**Hypo. Mean Dif.**
df	140			198	**df**
t Stat	2.489522			-1.95633	**t Stat**
P(T<=t) one-tail	**0.006981**			**0.025917**	**P(T<=t) one-tail**
t Critical one-tail	1.655811			1.652586	**t Critical one-tail**

table, the additional contrasting samples were discovered. Table 20 demonstrates the huge differences in weather-related crashes within California Forests: crashes during

[150] The analyses above for Siskiyou and Trinity counties was performed before the Access/Excel analysis tool had been fully developed. At the time, it was assumed that the HSIS data included only crashes within roadway ranges provided to FHWA. When it became obvious that crashes at mileposts other than these ranges was included, the highway/county milepost range tool was developed. For this reason, tables prior to Table 20 may include information that does not conform to that presented in Table 21.

good weather on the west slope of the Sierras in Fresno County have estimated costs over five times that of weather-related crashes, at the 0.006 level of significance. Meanwhile, weather-related crash costs on the west slope of the Coastal Range in Del Norte County is estimated to be three times greater than that of good weather crashes at the 0.026 level of significance. Inspection of the crashes within the Forests transected by U.S. 199 revealed only one fatal crash (of 132) during good weather, while there were seven fatal crashes (of 147) during bad weather. Double fatalities were recorded in two of the adverse weather crashes in Del Norte County. These findings leave little doubt as to why thorough analysis is required before any weather-related safety investments are made for California public and rural land.

Table 21: Contrasting Crash Weather Conditions on Two Sections of U.S. 395, Mono Co. California, 2003-2005: Private Land, Milepost 71-- 80.3 (near Lee Vining, CA), and Inyo National Forest, Milepost 20.6 -- 44.9

t-Test: Two-Sample Assuming Unequal Variances

PvtLnd>>	No Wx	Wx-Rel	No Wx	Wx-Rel	<< Inyo Natl. Forest
Mean Crash Cost	$43,120	$15,467	$26,770	$213,866	Mean Crash Cost
Variance	3.4E+09	5.47E+08	1.51E+09	7.18E+11	Variance
Obs.	27	18	54	64	Obs.
Hypo. Mean Dif.	0			0	Hypo. Mean Dif.
df	37			63	df
t Stat	2.212934			-1.76444	t Stat
P(T<=t) one-tail	0.016576			0.041253	P(T<=t) one-tail
t Critical one-tail	1.687094			1.669402	t Critical one-tail

Table 21 demonstrates the variability of crashes and weather conditions along U.S. 395 within Mono County. Although a 15 kilometer section (GP26395b) near Bridgeport, CA, shows the typical bias of more severe crashes in good weather [P (T,=t) one-tail = 0.017], a 40 kilometer section (CA26395a) south of Mono Lake in Inyo National Forest, shows a decided bias toward severe crashes in bad weather [P (T,=t) one-tail = 0.041]. Traffic volume was comparable in both roadway sections. Figure 19 illustrates that contrary to the general trend, bad weather is producing inordinately severe crashes on U.S. 395 as it traverses Inyo National Forest near Deadmans Pass in Mono County California[151].

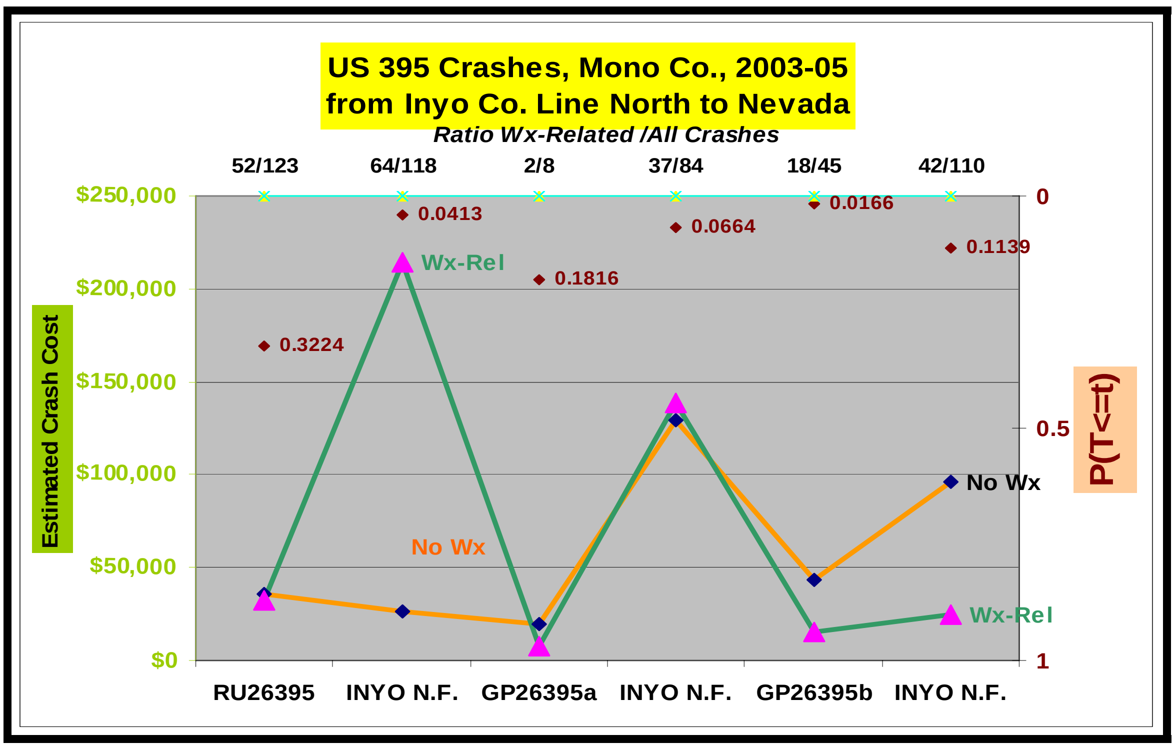

Figure 19: Estimated Crash Costs 2003-5, US 395 crossing Inyo County, California, South to North

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151 Four other sections defined in Mono County did not show significant differences in no weather and weather-related crash distribution at the 0.05 level. See Appendix I, Table 22 for additional information.

It is hoped that continued work with the software and experience gained dealing with the FHWA's HSIS data can yield some useful insights into highway crashes both on federal land and in adjacent rural areas. Appendix A documents the "weather"/"no weather" crash statistics for each of the 121 test and reference sections chosen in California for which data was available. California HSIS data offered the best opportunity to link weather (good or bad) with crashes on public and private rural land because the property domains could be known through a circuitous process. Since the HSIS database contains several hundred data elements for each crash, so there are many ways the sections of public and rural private land defined in this research might be used to test other hypotheses relating to travel on federal reservations.

Chapter 5: CONCLUSIONS AND RECOMMENDATIONS

This dissertation research began as an attempt to find any significant differences in the frequency and severity of crashes during adverse weather on federal land nationwide, but evolved into a slightly broader examination of the differences found in crash costs in all weather conditions, constrained to rely primarily on California crash records.

By selecting the extensive reservations of FS and BLM, it was hoped that these relatively transparent land management agencies, with a combined roadway length to overlay an Apollo mission, would provide a rich source of data. However, as research progressed, it became obvious that reliable and consistent crash data for federal lands is not generally available because of inconsistencies in record-keeping. Many agencies don’t have good records; NHTSA georeferenced FARS crash records have become sensitive; Bureau of Indian Affairs traffic issues have been very political for a long time; and Department of Defense records can also involve various degrees of sensitivity or classification. Because the BLM and FS lands are concentrated in a few western states and because only the FHWA California data seemed to offer a route to a rigorous evaluation process, this analysis relied primarily on the FSIS database and data taken by California authorities to reach its conclusions and form recommendations.

A. Policy Relevance

Public land managers face many conflicting goals: recreational access to public lands, providing maintenance to a huge inventory of "improvements" on the land, permitting resource extraction and enforcing conservation, and providing effective public information. Likewise, county governments in these "frontier" regions have to balance law enforcement and emergency response, the sufficiency of medical services, and adequate two-way communications -- against the limited tax base available to them. Meanwhile the public visitation to federal lands continues to increase as does the aggregate cost of vehicle crashes and search and rescue operations.

Public access to federal land is especially important to those who hike, hunt, or are mechanically empowered to traverse almost any road or trail; conversely, the limited staff and budgets of BLM and FS are generally ineffective in denying any determined RV owner, cyclist or snow machine access to these national reservations. This research was confined to legally accessed BLM and FS roadways in three states and the reports generated by their law enforcement officers. However, BLM and FS are confronted with similar, and often more visible health and safety issues with off-road vehicles riders, boaters, rock climbers, survivalists, as well as drug and people traffickers on public land. These administrative problems are shared, and ultimately largely borne by the counties which contain large areas of these public lands. Because the federal revenue shared with these "host" counties is generally a portion of the natural resource extraction royalties or some formulation of “payment in lieu of taxes”, it is unreasonable to expect these “frontier” counties can or will provide extraordinary protection for out-of-state people traversing the federal domain.

Emergency medical response to crashes is critical to survival and avoiding further complications of trauma, but many of the frontier counties don’t have the crisis care that would be available to accident victims in cities, nor the air evacuation units to provide optimum extraction for the injured. While the issue of emergency response to remote crashes is directly analogous to battlefield medicine, none of the responsible federal agencies or local governments are staffed and funded like DOD, nor will they ever be.

Public information, including roadway information, weather forecasts, signage as well as direct telephone, radio and internet broadcasts, is key to public safety; all these venues are governmental functions which can reduce the risk of crashes and other accidents on federal land. However, insuring the receipt and recognition of this information is contingent on the individual, so creative ways of impressing vital information on a public unfamiliar with hazards of a frontier region are required to reduce risk and provide the optimum protection.

Communication is essential to public safety, but line-of-sight transmission is a particular problem in mountainous West where cell phones are often out of range in valleys and over ridgelines. Satellite transmission of emergency calls and vehicle rollover alarms are very desirable, but not available media for most travelers. The consequences of vast areas and limited communications include difficult and expensive searches for missing visitors and accidents victims. Also the extensive networks of public land roads, the low traffic volume and high operating costs, make frequent safety patrols impractical for remote roadways.

These are the general problems of providing more adequate response to crashes and other emergencies in remote public lands: resources are limited, distance and terrain provide difficult challenges, communication is spotty, and the visiting public doesn't always do the right thing. Determining the most reasonable tradeoffs of preparedness, economy of operation, and avoiding potential liability are constant challenges for local, state and federal government; consequently the policy decisions made are highly subject to criticism when an emergency does occur.

B. Findings in Three Western States

The optimum response for lowering the risk of crashes on public lands is to provide effective public information and focus available resources on those areas most likely to create problems for travelers. In this limited examination of public lands, the hypothesis of weather's effect on crashes was neither confirmed nor rejected, because both good and bad weather is accompanied by a variety of crash outcomes. There was an unexpected finding that good weather is generally attended by more severe crashes – inversely proportional to the volume of traffic on all types of rural roads examined here. Also there is statistical confirmation that while less severe crashes are the rule in bad weather, significant local exceptions exist which deserve particular scrutiny by roadway administrators

Idaho

The FS data from 1990 forward strongly indicates that Idaho has a disproportionate problem with weather-related crashes on public land, with snow and/or ice present on roadways in nearly two-thirds of these crashes. Being farther north and having rougher terrain in its National Forests may be determining factors in causing Idaho's public land crashes to show more weather dependence when compared with Oregon (where much more severe public land accidents happen in good weather). Although a comparison of Idaho, Oregon, and California is not realistic based on the differences in data used here, Idaho and Oregon have similar crash data collection methodology which records crashes on FS Roads; in contrast, all the California HSIS crashes were either on state or federal roadways.

Reducing Idaho's public land bad weather crash hazard will be difficult because of the complex terrain and the isolation of many of the FS roads; however, there is new technology and ongoing research which can reduce the crash risk. Federal and State agencies have a long history of developing automated weather stations in Idaho and surrounding states, to warn of hydrologic, seismic and meteorological hazards. There are hundreds of these automated stations in Idaho and close to its borders, but it is difficult to get information for most of them without internet access[152]. Depending upon the sponsoring agency, automated weather station data may or may not be quality-controlled; consequently, providing valid weather information and forecasts to drivers for remote locations remains a challenge. Well-maintained and calibrated automatic sensors can provide remote weather intelligence to help reduce crash casualties caused by unexpected conditions on Idaho's public lands.

Numerous other initiatives could prevent some of the public land crashes in Idaho: The Idaho Department of Education offers driver education videos: "Rural Highway Hazards", "Mountain Driving" and "Rural Road Safety: Drive Smart and Stay Alive". Also the Transportation Research Board recommends Idaho Agencies identify "black spots" or concentrations of crashes for further analysis. The State has also developed a Road Report phone system which drivers can use if their telecommunication companies allow the use of the 511 access number. Idaho Department of Transportation also provides this information on a website, 511.Idaho.gov.

Of course, all of the above remedies are a piecemeal approach to protect the public. The BLM and FS could attempt to close more of their roads, but this would immediately cause a political reaction that neither agency wants to face. Above all, Idaho travelers

[152] An excellent linked inventory of Pacific Northwest surface observation is at: http://www.wrh.noaa.gov/mso/newrgl.php

need to understand the risks they accept when they travel the public domain as these will not likely greatly diminish in the foreseeable future.

Oregon

Oregon crash records indicate a different kind of risk on BLM and FS land, probably indicative of reckless driving in good weather and road conditions. Both the federal reservations and lightly traveled rural Oregon highways seem to share huge mean costs of dry weather crashes. This contrasts with the lower average costs on Oregon's heavily traveled coastal highways where mean dry weather crashes cost only 40 percent of the average fair weather crash on BLM and FS crashes (Fig 17).

Speed limits posted on Oregon's BLM and FS reservations and on the reference highways are 55 MPH or less. Almost half of the 2003-2005 crashes examined on these public lands (312 of 714) cited speed "too fast for conditions" as the primary cause of the crash. This compares with driving left of center (89 of 714), following too close (29), inattention (26), defective brakes (3) and mechanical defect (1). From these descriptions, it is apparent that speeding is a very prevalent precursor to public land crashes in Oregon and that the consequences of speed are particularly destructive crashes. There were also a total of 55 rollovers in the 714 BLM and FS crashes in Oregon of which 40 (73 percent) occurred after the vehicle struck an animal.

Rather than unexpected weather, the high crash costs in Oregon appears to result more from drivers knowingly or unwittingly elevating their risk by speeding and reckless driving on public lands and remote roadways. While traffic is sparse and law enforcement next to non-existent on many of these backcountry roads, kinetic energy still builds as the square of velocity, and it can cause horrific trauma when suddenly dissipated after running off the road.

California

The FHWA HSIS data provided the only opportunity to get an objective test of whether the BLM and FS roadway environment produced a different cost from that of privately-owned land. Because all highways were maintained by the State, average daily traffic is known and a great many variables can be controlled in the analysis; consequently, there is an opportunity to extend the HSIS methodology developed here to a variety of questions and to focus on individual roadways, counties and federal reservations.

The aggregate analysis of California crash data shows BLM and FS land crashes are substantially more severe and costly than those in the referenced rural areas. Unlike the indications from Oregon that crash cost vary in inverse proportion to the with roadway traffic volume, California data indicate that the same rural highways, crossing public and private land will experience more severe crashes during fair weather in the federal sector.

Why might this be so? Are drivers more distracted by the scenery? Might they unconsciously build too much speed on long downgrades? Is the roadside less forgiving than on privately-owned land? Or is the additional delay in getting injured to the hospital the chief reason that these federal lands can be more hazardous to health? These are some of the additional questions that follow the finding that California's fair weather crash potential is different depending on land tenure.

Within the California data there is obviously great variation which needs to be examined. The limited analysis of individual counties and roads shows the variability in frequency and severity of crashes; consequently, the database assembled in this research should be further analyzed to identify the "blackest spots" or most risky locations for highway crashes. The examples illustrated in Del Norte and Inyo Counties (Tables 20 and 21) indicate that there may be unique roadway sections which deserve particular weather safety measures.

It is doubtful that many senior federal land managers are aware of human and financial costs of crashes on their reservations. But the federal government does have the means to coordinate data assimilation and information dissemination, so it is especially important that these managers are cognizant of the crash consequences and do collaborate with state and local highway managers to reduce the toll.

C. Recommendations for Future Research

The knowledge of and remedies for abating roadway risk should be promoted by government, but growing concerns over possible civil liability for their actions or inactions may inhibit government managers from directly addressing risk. The

Transportation Research Board indicated this was an issue in the 2003 National Cooperative Highway Research Program (NCHRP): Synthesis 321:

> The fear of tort liability is an important issue in some local agencies. There is frequently a concern that if safety issues are identified and then not corrected to the latest and highest standards, there will be a resulting liability if a crash occurs. There is also a belief that if a problem is fixed, but not fixed at all similar locations, the potential for liability exists. In general, the documentation of a needed safety improvement is often lacking unless the improvement is underway. Limited understanding of the legal aspects of safety and the prevalence of tort liability has negatively influenced the need for local roadway safety programs[153]

The above passage is a rare reference to the "elephant in the room" with federal land managers, state highway officials and county administrators. It appears that information about and analysis of crash data on public lands is being widely ignored because it would be yet another source of trouble, or worse still, create more legal responsibilities for government agencies. The NCHRP report recommends a strategy for breaking this stalemate by obtaining the crash records, analyzing their distribution and consequences, and developing remedies to reduce future human and financial losses.

Reactive Tools – Situational Awareness

The NCHRP advocates spatially referenced crash analysis and traffic volume documentation as the first step for investigating the risk and identifying higher

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[153] National Academies of Science, Transportation Research Board, National Cooperative Highway Research Program, "NCHRP Synthesis 321: Roadway Safety Tools for Local Agencies, A Synthesis of Highway Practice", Washington: TRB, 2003, pg. 4-14.

distribution of accidents. This cluster analysis or localization of black spots is used to quantify the risk and to select priority areas for remedial efforts.

An important addition to the NCHRP approach for analysis of weather-related factors is the simultaneously inventory the sources of weather and other environmental data which can be linked with the crash reports to yield a more complete record of crash conditions. Environmental monitoring stations and video feeds available online, archived records of warnings and advisories issued by the National Weather Service and State DOTS, and "511" records could be referenced to produce a more comprehensive assessment of crashes when weather is a factor.

Timeline analysis and trend data need to be examined in the crash analysis to emphasize risks which are increasing rather than those which may be diminishing with time and technology. Statistical treatments can also help identify associations, lags and leads which may not be obvious from simple displays of crash data. Finally, results of the analysis should be presented in a form that will aid the decision maker in selecting possible strategies for remedying the identified problems.

Proactive Measures -- Addressing the Problem

Road Safety Audits and Reviews are the NCHRP approach to tailoring response to the risks identified in the reactive crash analysis. This method can be implemented by a team independent of the "custodial" agencies in an effort to enhance objectivity and innovation, but the final responsibility for changes rests with the funding agencies.

The Road Safety Audit Team responsibilities include developing functional classifications of roadways with specific problems to be addressed and to set out an agenda for addressing these problems throughout the domain of the custodial agency. In a future audit of weather-linked crashes, compartmentalization of specific weather and roadway conditions would be required, cross-referenced with highways, counties or federal reservations. Strategies for addressing risk could then be developed, implemented on a pilot basis, and evaluated to determine if wider use is justified.

Hopefully, an independent audit team might create novel, but effective remedies for improving traffic safety; obviously the team should focus on the least-cost approaches in the case of the two largest federal land management agencies. Improved signage might be a bargain in producing beneficial results: "Welcome to (blank) National Forest! Drive Safely; Ambulances are two hours away." Or,"Flooding? Climb to Safety.[154]"

Another incentive for developing a diverse audit team could be the members' experience with different technologies, applications and media. While most government agencies are receptive to new technology, some get bogged down in pursuing "in-house" solutions. Sometimes industry or other organizations have solved similar problems and have off-the-shelf products which can be more effective.

[154] The latter signs were posted in Big Thompson Canyon, Colorado after a surprise flash flood killed 140 campers and motorists there in 1976.

In conclusion, traffic crashes are a serious cost to all parts of the nation, but they are proportionately more dangerous and costly on remote rural roads in general, and particularly on BLM and FS land. Although bad weather and adverse road conditions may defer some trips on public lands or engender more conservative driving practices on most remote roads, California data show that some roads are particularly dangerous in bad weather. Overall however, this analysis indicates that good weather and dry roads apparently invite more risk-taking and yield more severe crashes. Driving on BLM and FS land compounds this risk because these reservations lack prompt emergency response which reduces crash consequences in more accessible rural areas.

Appendix A: California Roadways With Crash Analysis Contingencies
Table 22: CA Roadway Test and Reference Sections* -

Hwy	Start Point	End Point	Counties in Order with CA/HSIS Nr.	Test/Ref Section*	Begmp	Endmp	Nr. No Wx Crashes	Average No Wx Crash Cost	Nr. Wx-Rel Crashes	Average Wx-Rel Crash Cost	P(T<=t) one-tail: No Wx v. Wx-Rel.
1	Cayucos	Monterrey	S.L. Obispo (40)	RU40001CA	0	74.324	517	155231	78	87316	0.1275
			Monterrey (27)	CA2700105	1.43	21.6	35	178661	3	76972	0.2263
1	Santa Cruz	Princeton	Santa Cruz (44)	RU44001CA	21.6	34.451	59	124749	10	453086	0.2157
			San Mateo (41)	RU41001CA	5.746	26	79	91294	11	769266	0.0961
1	Olema	Leggett	Marin (21)	RU21001CA	2.84	50.509	216	53200	28	42972	0.2165
			Mendocino (23)	RU23001CA	0	105.578	293	83290	86	84947	0.4873
2	Pasadena	Jct CA-138	Los Angeles (19)	CA1900205	27	82.3	279	224512	30	176410	0.345
			San Bernardino (36)	CA3600205	0	5.1	43	229952	19	251704	0.4649
4	Stockton	Jct. CA-89	San Joaquin (39)	RU39004CA	0	38.059	416	150376	83	27806	**0.0001**
			Stanislas (50)	RU50004CA	0	7.296	41	243740	6	19486	0.0528
			Calaveras (05)	CA0500405	35.7	65.9	97	122447	95	28797	0.0541
			Alpine (02)	CA0200405	0	31.7	33	199312	4	34875	0.0913
6	Bishop	NV Line	Inyo (14)								
			Mono (26)	GP26006	10.78	16.3	6	25726	3	31544	0.422
			Mono (26)	CA26006	16.3	32.3	14	323442	2	26148	0.157

Hwy	Start Point	End Point	Counties in Order with CA/HSIS Nr.	Test/Ref Section	Begmp	Endmp	Nr. No Wx Crashes	Average No Wx Crash Cost	Nr. Wx-Rel Crashes	Average Wx-Rel Crash Cost	P(T<=t) one-tail: No Wx v. Wx-Rel.
8	San Diego	Winterhaven	San Diego (37)	CA37008	31	57.8	183	279587	69	95487	**0.0216**
			Imperial (13)	CA13008a	12.6	25.11	54	200786	4	16788	**0.0401**
			Imperial (13)	GP13008	25.11	54.46	177	237437	10	39523	**0.0023**
				CA13078 Complete			56	201017	8	12108	**0.0334**
			Imperial (13)	CA13008b	54.46	92.2	126	262170	6	673004	0.2834
14	Mojave	Homestead	Kern (15)	CA15014	38.5	64.6	77	312451	2	2004157	0.2765
25	Jct. CA-198	Hollister	Monterrey (27)	(no P.L.)							
			San Benito (35)	(no P.L.)							
29	Oakville	Jct. CA-20	Napa (28)	RU28029	15.58	27.49	169	125529	23	42104	**0.0409**
32	Chico	Jct. CA-36	Butte (04)	RU04032	15.51	36.6	43	331177	22	41748	**0.035**
33	Jct. US-101	Coalinga	Tehema(52)	CA52032	11.3	24.9	25	219847	18	247585	0.4596
			Ventura (56)	CA56033	14.2	56.7	114	332977	9	502884	0.3562
			Santa Barbara (42)	(no P.L.)							
			S.L. Obispo (40)	(no P.L.)							
			Kern (15)	GP15033	9.65	20.2	12	370572	1	79777	undefined
			Kern (15)	RU15033	31.75	73.74	47	376348	4	16788	**0.0164**
			Kings (16)	(no P.L.)							
			Fresno (10)	(no P.L.)							

Hwy	Start Point	End Point	Counties in Order with CA/HSIS Nr.	Test/Ref Section	Beg mp	End mp	Nr. No Wx Crashes	Average No Wx Crash Cost	Nr. Wx-Rel Crashes	Average Wx-Rel Crash Cost	P(T<=t) one-tail: No Wx v. Wx-Rel.
36	Jct US-101	Susanville	Humboldt (12)	CA12036	42.9	45.7	1	216059	0		undefined
			Trinity (53)	CA53036	0	41.1	24	233272	5	29892	0.1145
			Tehema(52)	CA52036	80	104	24	369871	57	104026	0.1379
			Plumas(32)	CA32036	0	2.92	4	79777	2	43603	0.25
			Lassen (18)	CA18036	9	16.8	17	41128	37	33610	0.3175
46	Jct. CA-1	Famoso	S.L. Obispo (40)	RU40046	0.146	60.85	195	93323	22	23603	**0.029**
			Kern (15)	(no P.L.)							
50	Placerville	South Tahoe	El Dorado (09)	CA09050	34	80.4	289	203257	220	67543	**0.0043**
62	Morongo Valley	Parker Dam	San Bernardino (36)	CA36062	45.9	79.48	27	511871	1	79777	undefined
			Riverside (33)	CA33062	79.5	90.2	19	28704	1	44868	undefined
				CA36062	90.2	138	62	272534	5	51344	**0.0232**
				CA36062 Complete			108	289457	7	54480	**0.0043**
70	Pleasant Grove	Hallelujah Jct.	Sutter (51)	RU51070	0.051	8.298	67	152157	12	28635	0.0725
			Yuba (58)	RU58070	0	25.8	416	155372	102	111085	0.2469
			Butte (04)	CA04070	37.5	48.1	25	210206	9	15748	0.1158
			Plumas(32)	CA32070	0	37	99	175404	59	98256	0.2122
			Plumas(32) joins (18)	RU32070	70.1	95.96	78	43937	27	43213	0.478
			Lassen (18)	RU18070	0	3.888	11	61919	5	36368	0.2064

Hwy	Start Point	End Point	Counties in Order with CA/HSIS Nr.	Test/Ref Section	Beg mp	Endmp	Nr. No Wx Crashes	Average No Wx Crash Cost	Nr. Wx-Rel Crashes	Average Wx-Rel Crash Cost	P(T<=t) one-tail: No Wx v. Wx-Rel.
74	S.J. Capistrano	Palm Desert	Orange (30)	RU30074	1.856	13.7	161	214287	47	128247	0.2095
			Riverside (33)	CA33074a	0	11.83	217	219146	29	32550	**0.0003**
			Riverside (33)	GP33074	11.8	48.3	903	131989	89	254968	0.1097
			Riverside (33)	CA33074b	48.3	81.2	199	152935	49	40804	**0.0067**
				CA33074Comp.			416	187473	78	37735	0
78	Escondido	Blythe	San Diego (37)	RU37078	26.93	40.5	208	76805	29	155200	0.2899
			Imperial(13)	CA13078a	0	13.17	6	31544	3	7428	0.0873
			Imperial(13)	GP13078	13.17	27.3	30	315596	0	undefined	undefined
			Imperial(13)	CA13078b	27.3	75.4	49	221769	5	14916	**0.037**
				CA13078 Comp.			56	201017	8	12108	**0.0334**
		Riverside (33)	RU33078	0	16.41	29	34552	2	26148	0.3658	
79	Descanso	Temecula	San Diego (37)	RU37079	1.66	43.51	145	220653	23	42214	**0.0039**
			Riverside (33)	RU33079	6.787	39.34	509	152412	52	191811	0.3618
80	Citrus Heights	NV Line	Sacramento (34)	(no P.L.)							
			Placer (31)	CA31080	49.2	69.8	261	195427	263	41895	**0.0011**
			Nevada(29)	CA29080	9	24.6	97	63832	89	19457	0.1423
88	Stockton	NV Line	San Joaquin (39)	RU39088	13.37	25.37	161	180877	28	39261	**0.0102**
			Amador (03)	CA03088	45.7	71.6	33	40289	71	36695	0.3561
			Alpine (02)	CA02088	0	20.6	41	526178	79	95830	**0.0236**

Hwy	Start Point	End Point	Counties in Order with CA/HSIS Nr.	Test/Ref Section	Beg mp	Endmp	Nr. No Wx Crashes	Average No Wx Crash Cost	Nr. Wx-Rel Crashes	Average Wx-Rel Crash Cost	P(T<=t) one-tail: No Wx v. Wx-Rel.
89	Jct. US-395	Mt. Shasta	Mono (26)	RU26089	0	6	2	147918	0	undefined	undefined
			Alpine (02)	CA02089	0	10.9	17	100932	1	7428	undefined
			El Dorado (09)	CA09089	0	27.4	90	99776	39	44077	0.1108
			Placer (31)	CA31089	0	21.7	149	119096	102	70255	0.2096
			Nevada(29)	CA29089	0	8.7	16	49571	6	31544	0.2239
			Sierra (46)	CA46089a	0	13.3	25	378525	26	32472	0.0631
			Sierra (46)	GP46089	13.3	23	9	27666	4	7428	**0.0471**
			Sierra (46)	CA46089b	23	29.6	1	7428	2	7428	undefined
			Plumas (32)	CA32089	29.3	37	10	36621	6	37784	0.4748
			Tehema(52)	(joined							
			Shasta(45)	CA45089a	0	14.9	30	169287	10	18660	0.1325
			Shasta(45)	GP45089	14.9	21	5	820589	1	44868	undefined
			Shasta(45)	CA45089b	21	33.1	28	174434	6	66738	0.2326
				CA45089 Cmp			58	171771	16	36689	0.0844
			Siskiyhou (47)	CA47089a	0	21.4	(no data)				
			Siskiyhou (47)	GP47089	21.4	26.8	(no data)				
			Siskiyhou (47)	CA47089b	26.8	33.5	(no data)				
				CA47089 Cmp			58	171771	16	36689	0.0844
94	San Diego	Jacumba	San Diego (37)	RU37094	15.36	65.38	349	235631	49	130116	0.1283
96	Weitehpec	Jct. I-5	Humboldt (12)	CA12096	0	45	99	121343	56	41898	0.082
			Siskiyhou (47)	CA47096	0	103	73	129008	20	432349	0.1441

Hwy	Start Point	End Point	Counties in Order with CA/HSIS Nr.	Test/Ref Section	Beg mp	Endmp	Nr. No Wx Crashes	Average No Wx Crash Cost		Average Wx-Rel Crash Cost	P(T<=t) one-tail: No Wx v. Wx-Rel.
97	Weed	OR Line	Siskiyhou (47)	CA47097a	5.17	16.59	18	259776	2	111744	0.2776
			Siskiyhou (47)	GP47097	16.59	23.4	9	475262	9	27666	0.1699
			Siskiyhou (47)	CA47097b	23.4	31.1	7	68239	19	39551	0.1881
							25	205713	21	46427	0.1635
108	Chinese Camp	JCT US-395	Tuolume (55)	CA55108	13.4	67	98	130862	85	72616	0.2155
			Mono (26)	CA26108	0	15.1	17	61912	1	79777	undefined
120	Jct. 395	Benton	Mono (26)	CA26120	0	39.5	28	206267	4	43603	0.1317
120	Manteca	Crane Flat	San Joaquin (39)	RU39120	0.493	21.18	309	148666	32	21073	**0.0004**
			Stanislas (50)	RU50120	0	10.58	123	138382	16	32009	0.0323
			Tuolume (55)	CA55120	36.5	56.5	22	791291	11	30793	**0.0159**
			Mariposa (22)	CA22120	41.5	43.7	3	1432240	1	7428	undefined
127	Baker	NV Line	San Bernardino (36)	CA36127	0	41.5	52	435112	4	43603	**0.0105**
			Inyo (14)	CA14127	0	49.4	32	175720	2	79777	0.2222
139	Canby	OR Line	Modoc (25)	CA25139	3.5	40.5	18	39256	17	263765	0.1758
			Siskiyhou (47)	RU47139	0	5.04	5	21898	5	29386	0.3623

Hwy	Start Point	End Point	Counties in Order with CA/HSIS Nr.	Test/Ref Section	Beg mp	Endmp	Nr. No Wx Crashes	Average No Wx Crash Cost		Average Wx-Rel Crash Cost	P(T<=t) one-tail: No Wx v. Wx-Rel.
140	Tuttle	El Portal	Merced (24)	RU24140	0	43.98	336	106009	30	31713	0.0059
			Mariposa (22)	RU22140	10.11	28.35	132	28992	22	28709	0.4894
168	Clovis	Lake Shore	Fresno (10)	CA10168	29	65.9	138	192585	60	34244	**0.0069**
168	South Lake	Oasis	Inyo (14)	CA14168a	0	14.18	5	78600	0	undefined	undefined
			Inyo (14)	GP14168	14.18	21	21	83122	4	7428	**0.0002**
			Inyo (14)	CA14168b	21	54.7	12	84335	1	44868	undefined
				CA14168 Cmp			17	82648	1	44868	undefined
178	Bakersfield	Jct. CA 190	Kern (15)	CA15178	14.7	40.5	222	81683	67	36798	**0.0419**
			San Bernardino (36)	CA36178	0.7	14.8	21	95980	3	55661	0.1271
			Inyo (14)	CA14178	28	62.2	13	57063	0		
199	Jct. US 101	OR Line	Del Norte (08)	CA08199	6.17	36.4	102	88441	114	181344	0.1207
299	Arcata	NV Line	Humboldt (12)	CA12299	32.7	43	29	35017	26	38329	0.3723
			Trinity (53)	CA53299	0	36.8	115	79386	61	50691	0.2109
			Shasta(45)	(No HSIS							
			Lassen (18)	(No HSIS)							
			Modoc (25)	CA25299	6.32	18.3	6	19486	10	432222	0.1627

Hwy	Start Point	End Point	Counties in Order with CA/HSIS Nr.	Test/Ref Section	Beg mp	Endmp	Nr. No Wx Crashes	Average No Wx Crash Cost		Average Wx-Rel Crash Cost	P(T<=t) one-tail: No Wx v. Wx-Rel.
395	Cajon Pass	NV Line	San Bernardino (36)	CA36395	28.5	73.5	137	222613	5	813607	0.2505
			Kern (15)	RU15395	8.131	36.82	59	455099	3	31544	**0.0049**
			Inyo (14)	CA14395a	3.05	31.5	52	359593	10	71112	**0.0297**
			Inyo (14)	GP14395	31.5	40.3	35	305439	3	1338580	0.2607
			Inyo (14)	CA14395b	40.3	47.7	11	409398	21	26148	0.1561
			Mono (26)	RU26395	0	20.58	71	36055	52	32084	0.3224
			Mono (26)	CA26395a	20.6	44.87	54	26770	64	213866	0.0413
			Mono (26)	GP26395a	44.87	51	6	19486	2	7428	0.1816
			Mono (26)	CA26395b	51	71	47	129581	37	138665	0.0664
			Mono (26)	GP26395b	71	80.3	27	43120	18	15467	**0.0166**
			Mono (26)	CA26395c	80.3	105	68	96274	42	24774	0.1139
395	Hallelujah Jct.	OR Line	Lassen (18)	RU18395	0	77.36	265	264982	126	72466	**0.0015**
			Lassen (18)	CA18395a	78.1	83.3	3	31544	0	undefined	undefined
			Lassen (18)	GP18395a	83.36	88.8	2	7428	0	undefined	undefined
			Lassen (18)	CA18395b	88.8	105	8	12108	11	412571	0.1456
			Lassen (18)	GP18395b	105	115.3	5	50837	9	23787	0.1105
			Modoc (25)	BLM fragments							
			Lassen (18)	CA18395c	115.3	119.1	9	35704	1	7428	undefined
			Lassen (18)	GP18395c	119.1	129.3	5	29386	3	55661	0.2098
			Lassen (18)	CA18395d	129.3	138	11	779016	17	256812	0.2813

*Sections are 8 km or greater continuous roadway samples which were either entirely on public land or on rural, privately-owned land. Sections were selected by examining HSIS roadway segments and map sources to determine continunity and rural character; they are delimited by county mileposts for California data. The comparison above is a t-test of "no weather" vs. weather-related" crashes for each of the sections for which data were available; those comparisons having a probability level of P(T,=t) one tail distribution less than 0.05 are flagged as having significantly different crash distributions for the same roadway, county and land regime.

The designation"CACoHwyxx" indicates Forest Service or Bureau of Land Management land; "RUCoHwyxx" is a rural section not on public land; and "GP"CoHwyxx" is a "gap" of private land which is bordered by public land sections within the same county. "CA/RU/GPCoHwya,b,c etc" labels designate multiple sections of land in the same county while CACoHwyComp is the collected statistics for all public land segments along a single higyway within the same California county.

APPENDIX B: Cirriculum Vitae for External Reader, Dr. Forrest M Council

TITLE: Senior Research Scientist, UNC Highway Safety Research Center
Senior Research Scientist, BMI-SG
(Director, UNC HSRC, 1993 – 1999)
Adjunct Associate Professor, UNC-CH
School of Public Health, Department of Health
Behavior & Health Education
Adjunct Assistant Professor, UNC-CH Department of City and Regional Planning

EDUCATION: B.S. North Carolina State University (1967)
M.S. North Carolina State University (1969)
PhD North Carolina State University (1992)

MAJOR SPECIALTY: Transportation Engineering

RESEARCH AREAS: Accident Records Research Methodology, Roadway Safety, Driver Education, Occupant Protection

MEMBERSHIPS IN PROFESSIONAL AND HONOR SOCIETIES:

President, National Child Passenger Safety Association (1981-82)

Chair, National Research Council Committee on Research Priorities and Coordination in Highway Infrastructure and Operations Research (2005-2006)

Chair, National Research Council Committee for Review of Federal Motor Carrier Safety Administration's Truck Crash Causation Study (2000-2003)

Chair, Methodology for Evaluating Highway Improvements Committee, Transportation Research Board (1987-93)

Member, Research and Technology Coordinating Committee, National Research Council/ Transportation Research Board (1996-2002)

Member, FHWA Operations CBU Work Zone Steering Committee (2000-2003)

Member, Group 3 Council (Operation, Safety and Maintenance of Transportation Facilities), Transportation Research Board (1993-96)

Member, Association for the Advancement of Automotive Medicine (Past Member, Executive Board; Past Chair, Scientific Program Committee)

Member, Executive Board, UNC Injury Prevention Research Center

Chi Epsilon, Phi Kappa Phi, Tau Beta Phi

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