Weather-Related Crashes on Public Lands

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By

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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.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

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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George Mason University, 2007

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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.

[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)

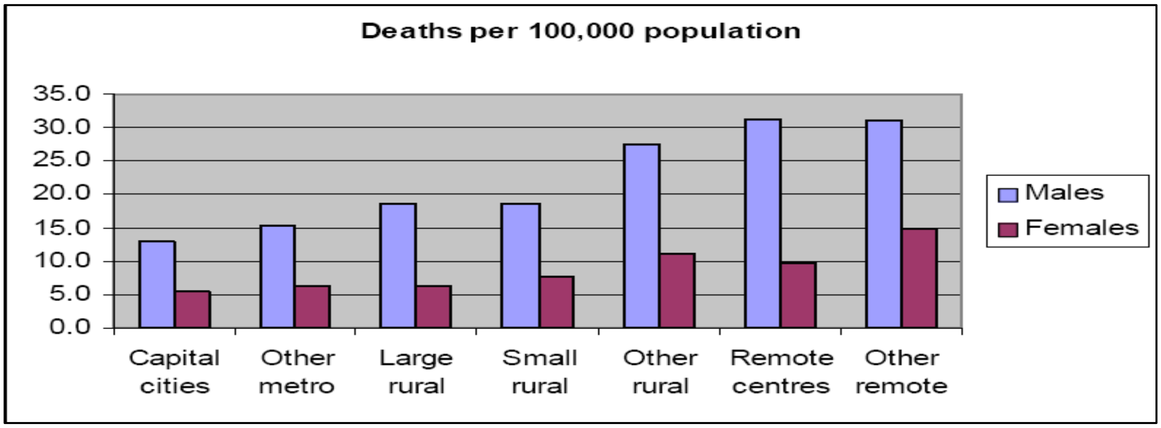

Figure 1: Australian Traffic Fatality Rates 1992-96, by Residence Location and Sex, Source: Inst. Of Health & Welfare[5]

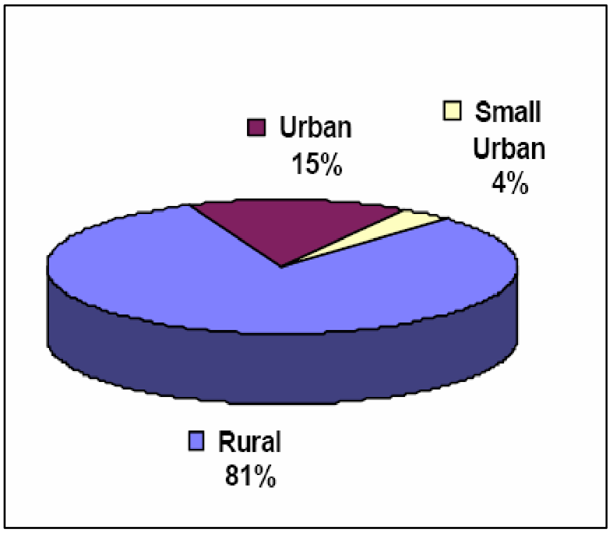

Figure 2: U.S. Roadway Distribution, Per California Department of Transportation (CalTrans) and JHK & Associates

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.

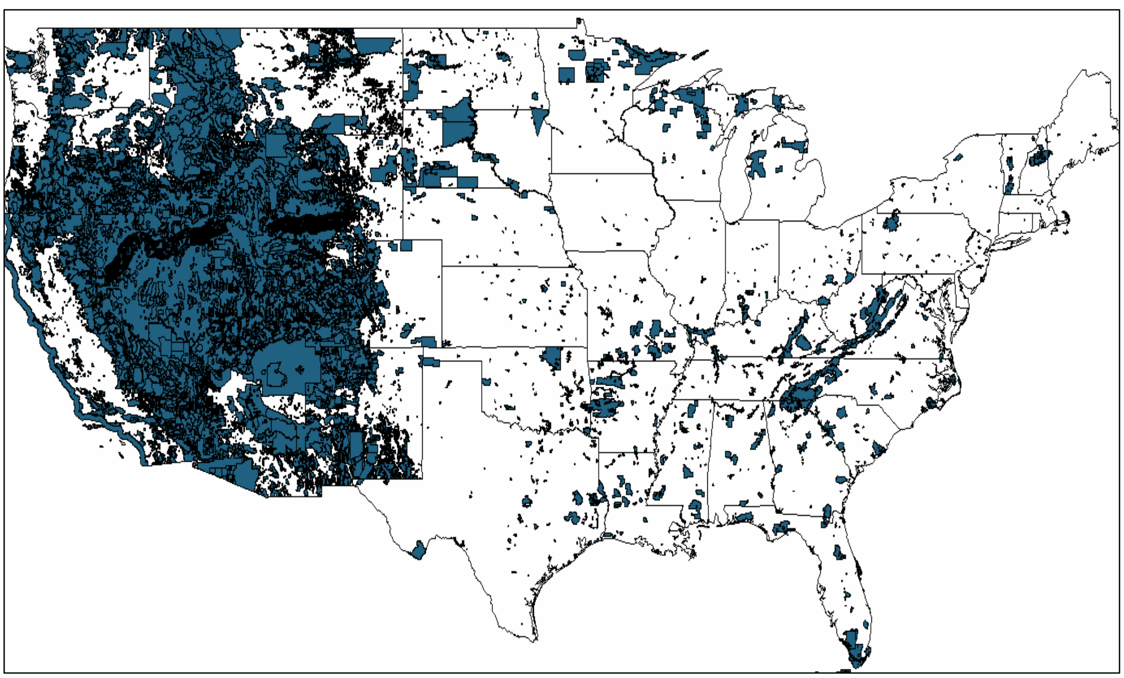

Figure 3: Federal lands in the contiguous U.S.

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.

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[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.

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[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.

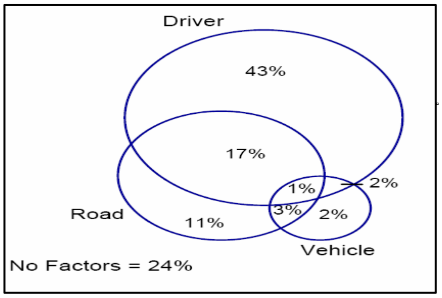

Figure 4: WA Crash Factors & Weights, McCormack & Legg (1999)

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.

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[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.