Alaska Department of Transportation & Public Facilities
Alaska University Transportation Center
Pacific Northwest Transportation Consortium

SAFETY EVALUATION OF STATEWIDE OFF-HIGHWAY VEHICLE USE IN ALASKA

CRASH REVIEW, ON- AND OFF-ROAD SYSTEM USE AND CONFLICT EVALUATION

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16. Abstract

The research presented here had four primary objectives. First, to document existing state of practice and policies in the State of Alaska regarding OHV use on roads and in public rights of way. Second, to characterize and identify the spatial distribution of OHV crashes and injuries using DMV crash records and the AKTR. Third, conduct a media discourse analysis using online media with OHV content to construct themes related to OHV issues. Lastly, develop a GIS framework for identifying locations of possible conflict and interest where OHV use is likely and to conduct in-field counts of frequency and use. Based on the analysis of state-, borough- and town-based policies on OHV use on roads, it is clear that there are significant variations in policies across the state. The results of the spatial analysis of crash and injury data indicate that, in general, the trauma registry is a more reliable and comprehensive source of OHV "conflicts" than the DMV crash records. Over 1300 articles were retrieve during the period of July 1, 2017 through June 30, 2018. From these articles, the four most prevalent content themes included injuries, fatalities, policy, and education. Of these 1300 articles, only 18 were from Alaska. Of those, 55% and 39% of those were on the subjects of fatalities and policies, respectively. Counts were then conducted at twelve locations selected from the GIS analysis. The counts showed a range of usage rates, some locations with no observations (Nome-Teller Highway) and others as high as 141 in a five day period (Hilltop Road). Additionally, rates of helmet use, passengers, and on-road use also varied widely. These results presented here further illustrate the unique transportation environment present in Alaska. It is important that we holistically consider the transportation needs of residents and how they may vary for those living in villages and towns than those in larger cities.

SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
^oC	Celsius	1.8C+32	Fahrenheit	^oF
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380. (Revised March 2003)

SAFETY EVALUATION OF STATEWIDE OFF-HIGHWAY VEHICLE USE IN ALASKA

Crash Review, On- and Off-road System Use, & Conflict Evaluation

FINAL PROJECT REPORT

by

Nathan Belz | University of Alaska Fairbanks

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LIST OF ABBREVIATIONS

AK	Alaska
AKDOT&PF	Alaska Department of Transportation and Public Facilities
AKTR	Alaska Trauma Registry
ASGDC	Alaska State Geographic Data Center
ATV	All-terrain vehicle
BAC	Blood alcohol content
DMV	Division of Motor Vehicles
DVR	Digital video recorder
NMT	Non-motorized transportation
OHV	Off-highway vehicle
SHSP	Strategic Highway Safety Plan
USDOT	United States Department of Transportation

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EXECUTIVE SUMMARY

Many households, particularly those in rural and isolated locations in Alaska, maintain some level of mobility through the use of more "non-traditional" forms of transportation such as off-highway vehicles (OHVs) and all-terrain vehicles (ATVs). The multi-purpose nature of these vehicles and their usefulness for other activities such as hunting, recreation, and daily chores make them even more appealing for rural residents. However, their use on roads and public facilities places them in close proximity to various other modes of travel with disparate capabilities and performance. Both anecdotal and documented safety issues prompted OHVs to be included as a "special users group" in the AKDOT&PF Strategic Highway Safety Plan and motivated the research presented herein. The objectives of this research were fourfold: (1) document existing state of practice and regulations of OHV use and travel in public rights-of-way; (2) better understand the spatial distribution of OHV safety issues by reviewing and analyzing injury data available through the Alaska Vital Statistics, Trauma Registry (AKTR) and crash data through the Alaska State Motor Vehicle Crash Database; (3) improve the extent of safety knowledge and vocabulary associated with OHVs by conducting a media discourse analysis to identify trends and issues in the United States; and (4) identify connectivity and potential extent of OHV routes using a GIS platform to inform a pilot counting study.

First, based on the analysis of state-, borough- and town policies on OHV use on roads in Alaska, it is clear that there are significant variations in policies across the state. In some locations there are provisions requiring the use of protective equipment, functional headlights and taillights, and sometimes restrictions on when and where OHVs can be used. In other locations, stipulations on OHV use are non-existent or unenforced (according to conversations with local public safety

officers). It is highly recommended that, where possible, these policies be aligned to achieve consistency.

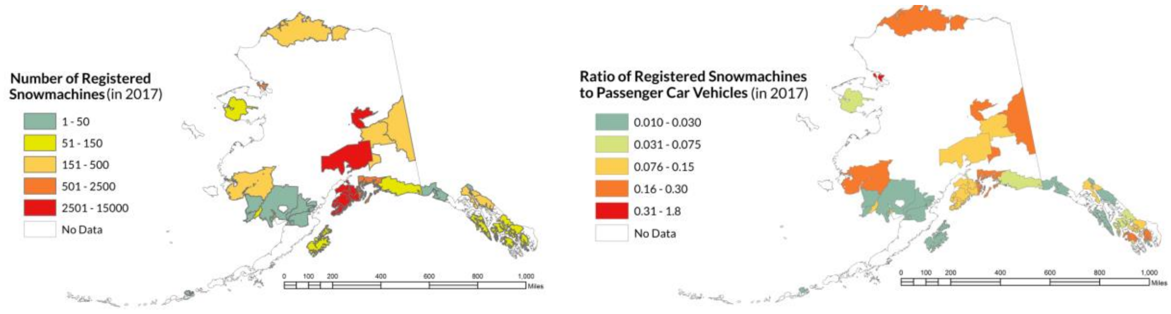
Second, the spatial analysis of crash and injury data indicates that, in general, the trauma registry is a more reliable and comprehensive source of OHV safety data, particularly in locations located off primary highway corridors. While the AKTR provides better spatial coverage, the Alaska Division of Motor Vehicle (DMV) records provide more robust data on the larger population centers. However, while DMV records provide more comprehensive information, there are more variables within the datasets useful for parsing out other relevant issues. If possible, agencies that manage safety data should consider formats that make cross-source comparisons easier.

Third, over 1300 online media articles were retrieved during the period of July 1, 2017, through June 30, 2018. In this review, the four most prevalent content themes included injuries, fatalities, policy, and education, and 55% and 39% of those were on the subjects of fatalities and policies, respectively. Article content indicated that events occurred at night and on the weekend more frequently than other times of the day or week. Snowmachine-related incidents were more prevalent in off-road events; ATV/OHV-related incidents were more prevalent in on-road events.

Lastly, counts were then conducted at twelve locations across the state in Fairbanks, Ester, Delta Junction, Tok, Two Rivers, Healy, Anchor Point, Palmer, Nome (two locations), and Bethel (two locations). These counts ranged from as low as zero, on the Nome-Teller Highway in Nome, and as high as 141 (over a five-day period), at the intersection of Hilltop Road and Parks Highway in Healy, AK. Additionally, rates of helmet use, the presence of passengers, and on-road use also varied widely; these differences are likely due to variations in local preference and practices, and to proximity to certain types of amenities such as gas stations and recreational areas (targets of desire). Based on these findings, it would be worthwhile to support efforts to develop a multiagency task force including both local and user group-specific representation to improve or revamp OHV policies and to develop future research directions.

1 INTRODUCTION

Alaska has the eighth highest vehicle ownership rate per capita (USDOT, 2015; U.S. Census Bureau, 2016), yet estimates suggest that about 10% of households where children are present and 10.3% of households in total do not have access to a vehicle (McDowell Group, 2017; NHTS, 2017). Many of these households, particularly those in rural and isolated locations in Alaska, maintain some level of mobility through the use of other more "non-traditional" forms of transportation such as off-highway vehicles (OHVs) and all-terrain vehicles (ATVs). Tracking this information as a contributor to the mobility of a community or village can be difficult. Though users are required to register snowmachines (the colloquial term for snowmobiles) on an annual basis, registering ATVs is not required by the State of Alaska Division of Motor Vehicles (DMV). ATVs with low-pressure tires may be registered as "snow vehicles," but again registration is not required. In 2017, there were approximately 45,000 registered snowmachines and 473,000 registered passenger vehicles in the state (Alaska Division of Motor Vehicles, 2017). When looking specifically at rural communities, the ratio of snowmachines to passenger vehicles increases dramatically (Figure 1.1). For example, the village of Kotzebue, population 3,245 (U.S. Census Bureau, 2016), had 604 snowmachines and only 372 passenger cars registered.



(a) (b)

Figure 1.1. Total number of registered snowmachines (a) and ratio of registered snowmachines to passenger car vehicles in Alaska (b) for 2017.

The multipurpose nature of these vehicles and their usefulness for other activities such as hunting, recreation, and daily chores make them even more appealing for rural residents. However, their use on roads and public facilities puts varying modes of travel with disparate capabilities and performance in close proximity to each other. These mixed-use environments often jeopardize user safety. This has direct implications for community safety. As an example, about a quarter of all traffic-related crashes in the village of Kotzebue (population 3,245) involved either snowmachines or ATVs; 21 crashes in the last 4 years alone involved speeding ATVs on local roadways (Native Village of Kotzebue, 2015). The problem remains that, for Alaska villages like Kotzebue, ATVs and snowmachines are often the only travel option, and they fulfill basic mobility needs for residents. The figures below note further evidence in other cases: a pedestrian fatality caused by a drunk ATV operator in Akiachak (Figure 1.2), ongoing discussions of road-related ATV policies in Bethel (Figure 1.3), and the death of an ATV operator on the Denali Highway (Figure 1.4). These all illustrate the need for further research and study into these travel modes and how they interact with existing transportation infrastructure and more conventional modes of transportation, particularly in Alaska.

Akiachak woman dies when struck by ATV

Author: Chris Klint   Updated: October 3, 2016   Published October 3, 2016

A 76-year-old pedestrian was killed in the Western Alaska village of Akiachak late Friday when she was struck by an all-terrain vehicle, Alaska State Troopers said.

Figure 1.2. News article of ATV-related death in Akiachak, AK (Klint, 2016).

Sudden crackdown on four-wheelers quiets Bethel streets and upsets residents

Author: Lisa Demer   Updated: October 10, 2016   Published October 10, 2016

BETHEL — In the space of just days, a crackdown targeting four-wheelers and snowmachines on the streets in the rural Southwest Alaska hub of Bethel changed life for many.

The Bethel City Council on Sept. 27 passed two enforcement measures. Streets grew quiet. In the first week, Bethel police wrote more than two dozen tickets carrying $50 fines for four-wheelers illegally on the streets.

Figure 1.3. News article of ATV-related policy disputes in Bethel, AK (Demer, 2016).

Anchorage man killed in ATV crash on Denali Highway

Author: Michelle Theriault Boots   Updated: August 27   Published August 27

An Anchorage man was killed in an ATV crash on the Denali Highway Saturday, the Alaska State Troopers said.

Song Her, 50, of Anchorage, was riding westbound on the highway at Mile 92 of the road when his ATV "left the roadway and rolled down an embankment," troopers wrote in an online dispatch.

Troopers were told the ATV driver appeared to be trying to avoid a vehicle, said troopers spokesperson Megan Peters.

Figure 1.4. News article of ATV operator death on the Denali Highway in Alaska (Boots, 2017).

Currently, we lack the proper knowledge to develop strategic, targeted engineering and policy decisions for nonconventional (ATV/snowmachine) or more traditional ways of travel (e.g., mushing/dogsledding). As we expand automobile-focused roadway infrastructure, we need to ensure that we are not hindering the mobility of those with limited travel options. The nature of OHV travel on mixed-use roads and facilities creates a travel environment where modes with disparate capabilities and performance are in close proximity. This has considerable implications for the safety of these environments. All-terrain vehicles alone account for approximately 100,000 injuries in the United States, while snowmachines contribute over 14,000 injuries and 200 deaths annually (Pierz, 2003).

In 2014, over 100,000 snowmachines were sold in the U.S. and Canada, with an average operator driving 1,620 miles per year (International Snowmobile Manufacturers Association, 2014). Nationwide, approximately 200 deaths and 14,000 injuries on snowmachines occur every year (Pierz, 2003). Nationally, about 700 people die each year as a result of ATV-related crashes. In addition, it is estimated that there are roughly 100,000 injuries, about 25% of which involved children under the age of 16 (Topping & Garland, 2012).

In a local context, Alaska contributed one of the top ten highest ATV rider death rates on public roads, with 28.6 deaths per 100 million people between the years 2007 and 2011 (Williams et al., 2014). Though usually more off-road in nature, travel by snowmachine (another form of OHV) is quite typical in winter months. Historically, Alaska has seen years where the number of injuries and fatalities on snowmachines was higher than that for motor vehicles (Landen et al., 1999).

Existing guidance in the Pacific Northwest and other select states was examined and evaluated to determine what might be transferable across the region and most appropriate for the State of Alaska. A framework was developed to address conflict and safety concerns of OHVs on and near state highways. This research addresses the need for both safety and travel demand data in rural areas of Alaska where the frequency of OHV users is largely unknown. These data serve to quantify the concerns and provide better understanding of safety issues when compared with traditional travel modeling and safety analysis.

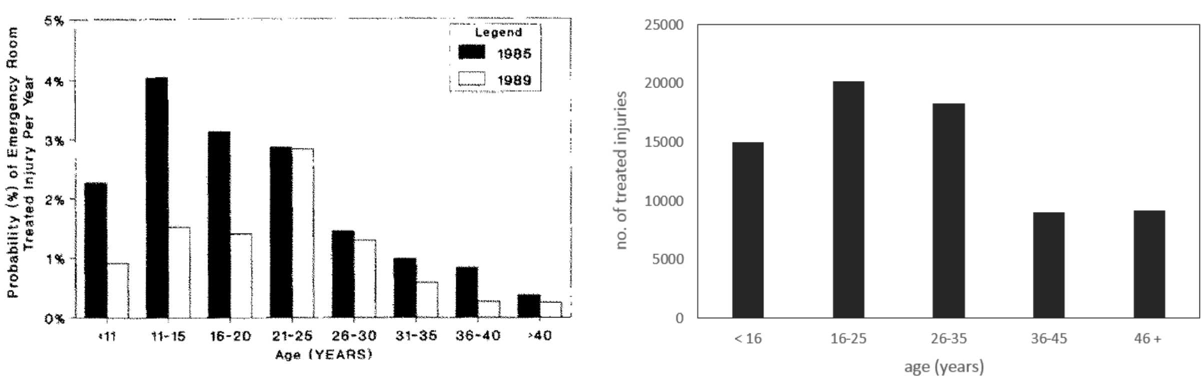
1.1 Background and Literature Review

1.1.1 General OHV/ATV Regulations

The U.S. Consumer Product Safety Commission (CPSC) began investigating the hazards associated with ATVs in 1984, after which a formal regulatory proceeding was initiated in 1985. The principal outcome of this proceeding was a legal settlement involving a series of consent decrees which stopped the sale of three-wheeled ATVs, called for the implementation of a nationwide rider training program, and the development of a voluntary standard to make ATVs safer. This decree was formalized in 1988 between the U.S. Department of Justice, representing the Commission, and ATV distributors (Rodgers, 1993). The need for this decree stemmed directly from the following complaints being made by the Department of Justice (U.S. District Court, 1987) stating that:

1. Although relatively safe to drive, ATVs are complex machines that require a high degree of skill for safe operation;
2. The industry failed to warn consumers about the potential risks and hazards associated with ATVs in an adequate manner; and
3. There was a relatively high risk of injury to ATV users, especially for those who are young and inexperienced.

After the CPSC’s actions (warning labels discouraging young operators, free training programs, and ceasing three-wheeled ATVs), risk of injury did decline, in general, except for operators in the 21–25 and 26–30 age groups (Figure 1.5). Why is this important? First, even after a federally initiated program to improve the safety of ATV use in the United States, the potential risk of injury for certain age groups was not reduced. Second, even though the initiative explicitly stated that consumers must be informed that ATVs are intended for adults and not recommended for children if the vehicle has an engine displacement size of 90cc or larger (the majority of all ATVs on the market currently are in this category), the potential risk for younger users (those under the age of 16) only declined by about 50% meaning that there are still a significant number of incidents in this age group. Third, it is highly contingent upon “the market” to provide sufficient product risk information as to not distort the consumer decision-making process, i.e., not using the ATV in a safe way if operators are uninformed, purchasing an ATV if one would not have done so with complete information, or purchasing the wrong (and possibly riskier) type of ATV (Rodgers, 1993). Lastly, successful safety outcomes are highly contingent upon continued enforcement of the policies and regulations put in place. For example, Rodgers (1999) indicates that about only 4% of consumers opted to take the vehicle training course, and 20% of ATV riders (an estimated 5.85 million in the United States) frequently operate their vehicles on paved roads.



(a) (b)

Figure 1.5. Nationwide ATV injuries shown by age group as (a) probability of injury in 1985 and 1989 (Rodgers, 1993); and (b) total number of emergency room treated injuries in 2010 (Garland, 2014).

1.1.2 OHV/ATV Safety Trends

Over half of all ATV-related fatalities occur on roadways, and nonfatal roadway crashes result in more serious injuries than those off the road. A number of jurisdictions have passed or have considered legislation allowing ATVs on public roadways, sometimes limiting them to unpaved roadways, arguing that they are safe for ATVs. Garland (2014) illustrates, however, that both paved and unpaved road surfaces are the only two topography types where the risk of fatality to an ATV operator is higher than that of injury (Figure 1.6) and that more fatal ATV crashes occur on roadways than off (Denning et al., 2016). This is consistent with other studies that show lack of helmet use and the use of alcohol by ATV operators are more prevalent on roadways than off-roadways (Denning & Jennissen, 2016). Although some trends show a general reduction in the overall number of ATV-related injuries in the United States, when looking specifically at the under-16 age group, there has been little in the way of injury reduction (less than 2%) since 2007 (Figure 1.7).

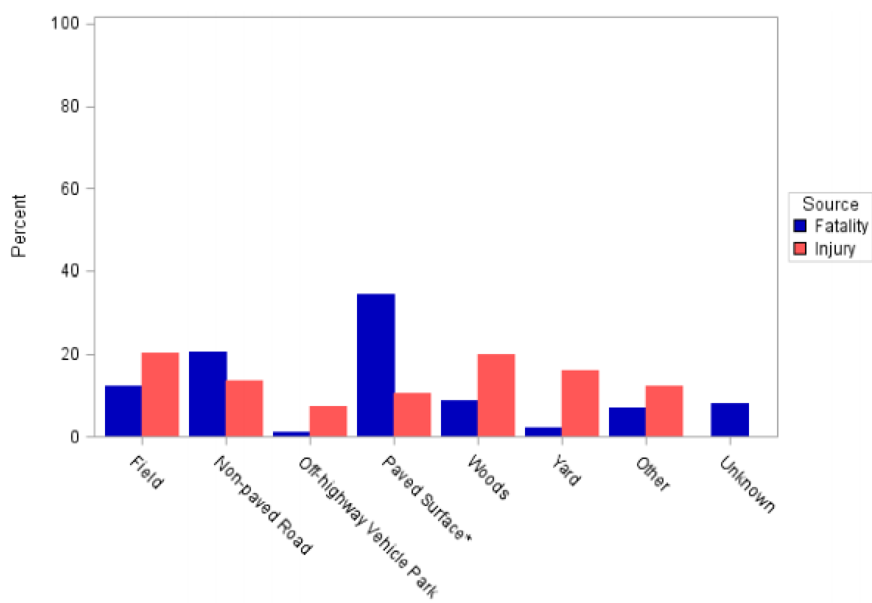


Figure 1.6. Percent of ATV fatalities and injuries by location.

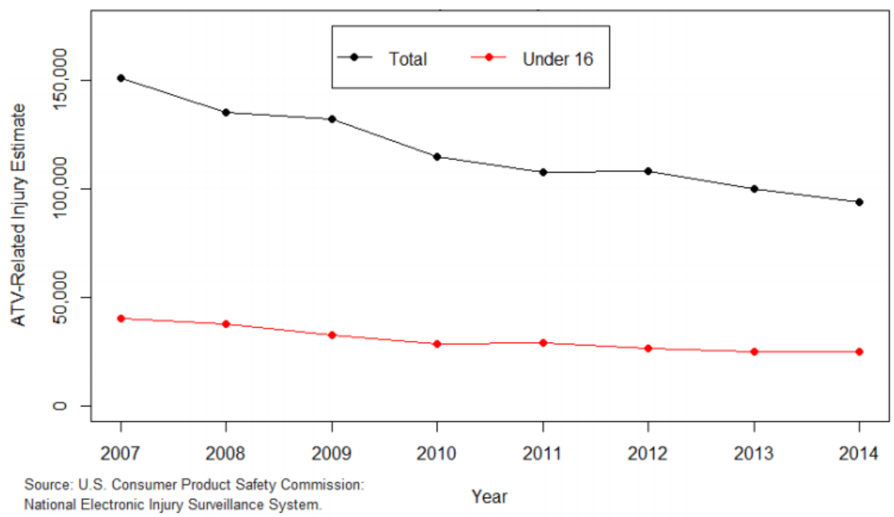


Figure 1.7. Yearly ATV-related injuries, 2007 – 2010 (Topping, 2015).

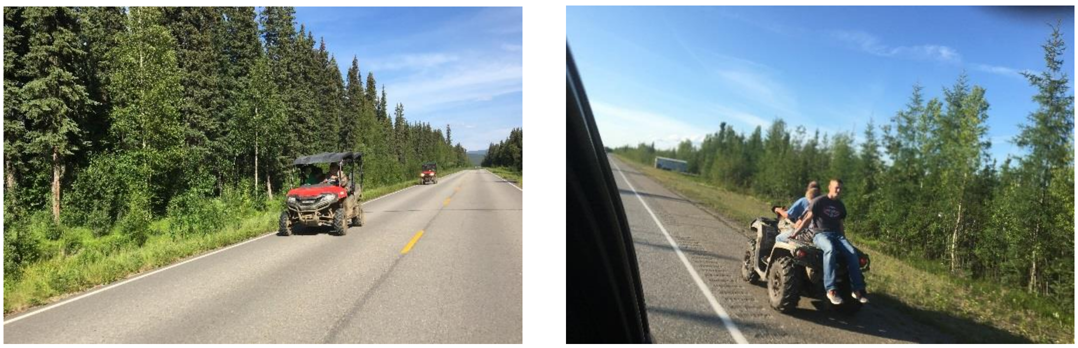
Conversely, a number of recent studies indicate that the injuries from ATVs are becoming both more serious and frequent (Phrampus et al., 2005), primarily due to an increase in engine power, more prevalent use by younger operators (under the age of 16), inconsistent enforcement of helmet laws, and inconsistent enforcement of use, e.g., on public roadways (Axelband et al., 2007; Rodgers, 1999; Bansal et al., 2008; Su et al., 2006; Williams et al., 2014). Although some studies indicate that certain states with laws regarding ATV use and safety have lower mortality and injury rates and that a stated preference survey shows support for stricter laws related to young drivers, driver certifications, number of passengers, and helmet use (Stolz et al., 2009), the previously mentioned studies (e.g., Rodgers, 1999, and Bansal et al., 2008) show by way of hospital records and surveys that policies and enforcement, though arguably fairly limited, have done little to actually improve overall ATV safety.

These trends are consistent with ATV injuries in Canada (Vanlaar et al., 2014; Waight & Bath, 2014), Ireland (Moroney et al., 2003), and Sweden (Gustafsson & Eriksson, 2013), which call for better planning and enforcement of these modal types as their use becomes more utilitarian in nature. In general, studies support laws/ordinances greatly restricting ATV riding on all types of public roadways. It is clear that new research and new approaches are needed to address the issue of ATV and OHV use on public roadways. Conversations about how to appropriately plan, design, and enforce laws related to ATV and OHV use are occurring in isolation. The work proposed in this research presents new data and perspectives on the issue of non-traditional vehicle use on Alaska's roads and highways to provide better planning, design, and enforcement guidance and improve the safety of the traveling public.

1.1.3 Motivations for OHV and ATV Use

It is clear that the use of OHVs and ATVs in Alaska is not negligible. Many indigenous people of Alaska (e.g., Alaska Natives), in addition to others, maintain a subsistence lifestyle in areas without roads or even access to roads or conventional towns. In these rural and remote areas, OHV forms of transportation are critical lifelines for subsistence practices. In addition, gas and fuel prices can be cost-prohibitive and as expensive as $7/gallon in some locations of the state. For these areas, non-motorized and non-conventional modes of transportation can be more economical for everyday travel (Demer, 2015). Recent estimates indicate that the average ATV/OHV fleet fuel economy is roughly 40 miles per gallon, with a range of 10 to 70 miles per gallon (Giacchino, 2012). Compare this estimate with the mid-year 2015 estimate of adjusted fuel economy for personal vehicles at only 24.8 miles per gallon (U.S. EPA, 2016).

The increase in facilities being created for vehicles, bicyclists, and pedestrians in rural areas on highways directly competes with space that would have otherwise been available for OHVs/ATVs. Anecdotally, the following observations have been made: (1) the number of OHVs/ATVs being operated on public roads has increased; (2) the number of OHVs/ATVs being operated on non-motorized facilities (e.g., bike paths and sidewalks) has increased; and (3) the rate of unauthorized operation of OHVs on private property (e.g., across driveways just beyond the limits of public rights-of-way) has increased (Figure 1.8). The first two observations have direct implications for road and highway safety.



(a) (b)

Figure 1.8. Examples of unauthorized and unlawful use of OHVs on (a) Chena Hot Springs Rd. in Fairbanks, AK and (b) the Parks Highway near Wasilla, AK

1.2 Research Need

Off-highway vehicle (OHV) modes of travel are not as regulated as conventional modes of travel, and laws pertaining to OHV use are difficult to enforce. There are no requirements for permits, operating licenses, or training of any kind. Nationally, an estimated 77% of injuries suffered while operating an ATV are attributed to drivers under the age of 35, and 21% are attributed to drivers under the age of 16 (Garland, 2014). Even though ATVs are not permitted on most roadways, 62% of ATV-related deaths in the nation between 1985 and 2009 resulted from on-road crashes. Since 1998, an ATV operator is three times more likely to be killed in an on-road incident than on off-road incident (Denning et al., 2012). A large number of ATV users (94%) ride with more than one person (Jennissen et al., 2012). One study noted that over the years of 1993 and 1994 in Alaska, the total number of injuries, deaths, and hospitalizations related to snowmachine use (both on- and off-road) was higher than for conventional on-road vehicles (Landen et al., 1999). As of 2003, snowmachines are responsible for approximately 200 deaths per year and 14,000 injuries per year (Pierz, 2003).

Use of ATVs and OHVs on public roadways is regarded a “significant safety issue” in the Alaska Strategic Highways Safety Plan (SHSP) (AKDOT&PF, 2013) with regard to fatalities and serious injuries on public roadways, and this safety issue motivated the research presented herein.

1.3 Objectives

This research addresses issues associated with the use of OHVs within public rights-of-way intended for what are to otherwise be considered “conventional” modes of travel (e.g., automobiles, pedestrians, and bicyclists). However, the issues are confounded by the fact that OHVs provide a certain level of mobility in some towns and villages, and in some cases, policies and laws dictate that their use is both appropriate and legal. That said, making sure that facilities are provided such that safe accommodation is ensured, limiting the improper use of public rights-of-way, and maintaining mobility are paramount. This study is intended to inform future guidelines for design, safety, education, and enforcement for OHV use in the State of Alaska. Four specific objectives were identified as integral pieces of this research effort.

First, this research seeks to document the existing state of practice for OHV use and travel in public rights-of-way, and includes a review of AKDOT&PF’s design guidelines and practices and review of national and international literature related to OHV/ATV safety and use. Understanding the motivations for use of and accommodations for OHVs is central to understanding some of the key questions surrounding the safety of OHV use on corridors that accommodate other traffic types.

Second, the research seeks to better understand the spatial distribution of OHV safety issues by reviewing and analyzing injury data available through the Alaska Trauma Registry and crash data through the Alaska DMV Crash Database. Where available, events recorded in these data will be mapped, characterized, and compared spatially. This comparison may help to identify deficiencies in injury/fatality reporting for crashes and injuries on OHVs. Non-reporting of crashes or reports that contain insufficient data are problematic, particularly those occurring in public rights-of-way. Data completeness is a critical piece to understanding the safety problem associated with OHV modes of transportation. The rate of OHV injuries and crashes has prompted AKDOT&PF to include OHV uses in a special users group in the SHSP, with targeted programs and objectives to reduce injuries and fatalities.

Third, this research will improve the extent of and vocabulary associated with OHV safety by conducting a media discourse analysis to identify trends and issues in the United States related to OHV/ATV use on public facilities. These data will supplement and validate traditional crash and injury data, help to develop a better definition of the safety and regulation issues, and contribute to gaining a better understanding of these issues in a national context. Ultimately, the outcome of this portion of the project is to develop language that better frames the issue of OHV safety on and near public facilities.

Lastly, this research will identify the connectivity and extent of OHV user facilities and/or routes using a GIS platform and will compare roadway system versus non-roadway system locations as well as formal and informal networks. The connectivity analysis will directly inform the execution of seasonal mode counts using motion-activated day/night cameras at strategic locations. This preliminary counting effort is anticipated to (1) provide a better understanding of how many OHVs are being used in certain locations beyond the anecdotal evidence currently available; and (2) inform and provide suggestions for where and how frequently future and broader OHV counts should be conducted.

2 OHV AND ATV POLICIES

Current regulation of snowmachines and ATVs/OHVs on highways and public rights-of-way in Alaska is done in accordance with Statute 13AAC 02.455 (Appendix B) and strictly prohibits the following when traveling within the right-of-way:

1. Use on multi-use trails, sidewalks or other areas located within a highway right-of-way that are intended for use by pedestrians;
2. Use in a controlled access highway right-of-way;
3. Use of roadways or shoulders within a highway right-of-way;
4. Use of the area dividing roadways of a divided highway;
5. Traveling at night in the opposite direction of traffic in the nearest lane of a roadway within a highway right-of-way.

Further, Statute 13AAC 02.455 explicitly states the following:

> A snowmobile or an off-highway vehicle may be driven on the roadway or shoulder of a highway only under the following circumstances:
>
> 1. when crossing a highway provided in (f) of this section, or when traversing a bridge or culvert on a highway, but then only by driving at the extreme right-hand edge of the bridge or culvert and only when the traverse can be completed with safety and without interfering with other traffic on the highway;
> 2. when use of the highway by other motor vehicles is impossible because of snow or ice accumulation or other natural conditions or when the highway is posted or otherwise designated as being open to travel by off-highway vehicles;
> 3. when highway driving is authorized by an authority having jurisdiction over the highway, but only in accordance with restrictions which may be imposed by that authority with regard to highway use; or

4. when driving on the right-of-way of a highway which is not a controlled-access highway, outside the roadway or shoulder, and no closer than three feet from the nearest edge of the roadway; night driving may be only on the right-hand side of the highway and in the same direction of the highway motor vehicle traffic in the nearest lanes of the roadway; no person may drive an off-highway vehicle within the area dividing the roadways of a divided highway, except to cross the highway as provided in (f) of this section.

(f) A snowmobile or an off-highway vehicle may make a direct crossing of a highway if:

1. the crossing is made approximately at a right angle to the highway and at a location where visibility along the highway in both directions is clear for a sufficient distance to assure safety, and the crossing can be completed safely and without interfering with other traffic on the highway; and
2. the vehicle is brought to a complete stop before crossing the shoulder or roadway, and the driver yields the right-of-way to all traffic on the highway.

(g) No snowmobile or other off-highway vehicle may cross or travel on a sidewalk, a location intended for pedestrian or other non-motorized traffic, an alley, or a vehicular way or area which is not open to snowmobile or off-highway vehicle operation, except as provided in (f) of this section. (Eff. 12/31/69, Reg. 31; am 7/23/70, Reg. 35; am 6/28/79, Reg. 70)

Of consideration is that state code applies to local roads and does not allow a particular community to pass ATV/OHV allowances that conflict with state code. However, the regulations and policies regarding the use of ATVs/OHVs and snowmachines vary widely across Alaska. Take for example the community of Bethel, which in 2006 passed an ordinance allowing the use of ATVs and snowmachines on local roadways (DeMarban, 2006). This action followed a similar ordinance in the community of Kotzebue, which limited use to operators older than the age of 14. In 2012, East Bethel modified the ordinance to require any operator born after July 1, 1987, to complete a safety training test and limited off-road vehicles to only Class I or Class II

ATVs (Hagen, 2012). Then in 2013, the Bethel City Council decided to replace local traffic code with state laws, thereby making the use of ATVs and other OHVs on roadways illegal. However, many residents state that this 2013 change did little in the way of limiting on-road use of ATVs/OHVs (Figure 1.3). Upon calling the City Council to take action, local police went from having issued seven citations related to ATVs and snowmachines on roadways over the course of nine months, to issuing 25 over the span of four days with an additional two citations for driving an ATV without a license (Demer, 2016). The newly proposed ordinance would allow ATVs to operate on roads but restrict them from passing other cars and limit speeds to 15mph and under.

In light of these events, we developed a comprehensive list of state, borough, and select town/village policies on OHV/ATV use. This list was compiled by searching public records and statutes or by contacting local municipalities directly by phone. These policies are summarized in Table 2.1 through Table 2.3. Records highlighted in yellow indicate municipalities that have policies specific to their political region. For boroughs and towns without a policy, there is specific mention in their local code that they default to state provisions.

Table 2.1. Summary of Alaska State Regulations on OHV/ATV Use

State	Policy	Allowed to cross state roads?	Allowed on state roads?	Allowed on city roads?	User Requirements	Vehicle Requirements	Speed Limit	Time Restrictions	Other Notes
Alaska	Yes	Yes	No*	No*	AS 28.39 and 13 AAC 02.430 through 13 AAC 02.455	13 AAC 04.400 through 13 AAC 04.420	N/A	N/A	All laws pertaining to snowmachines and ATVs at the state level are included in the Alaska State

Table 2.2. Summary of Alaska Borough Policies on OHV/ATV Use

Borough	Policy	Allowed to cross state roads?	Allowed on state roads?	Allowed on city roads?	User Requirements	Vehicle Requirements	Speed Limit	Time Restrictions	Other Notes
Aleutians East	No	Default to State Provisions							
Anchorage	Yes	Yes	No*	No*	Must wear helmet meeting Snell Foundation requirements with proof attached, must have license or licensed individual riding on same machine	Red light only 500'	N/A	Shall not operate from 10 PM to 7 AM	Operations on private property requires express consent of owner on paper. Can't operate within 500' of ice rink, skiing establishment, etc. Can't operate on lands not owned if destruction of soil or undergrowth is likely.
Bristol Bay	No	Default to State Provisions							
Denali Borough	No	Default to State Provisions							
Fairbanks North Star	No	Default to State Provisions							
Haines	Yes	Yes	No*	No*	16 years or older. Valid driver's license. Proof of insurance. Hand signals when turning.	Default to State Provisions	<25 mph on borough streets	Shall not operate from 9 PM to 9 AM at Tlingit Park or Seward parade grounds	
Juneau	Yes	No	No	No	N/A				
Kenai Peninsula	No	Default to State Provisions							
Ketchikan Gateway	No	Default to State Provisions							
Kodiak Island	No	Default to State Provisions							All road surfaces are gravel
Lake and Peninsula	No	Default to State Provisions							
Matanuska-Susitna	No	Default to State Provisions							
North Slope	No	Default to State Provisions							
Northwest Arctic	No	Default to State Provisions							
Petersburg	No	Default to State Provisions							Local provisions submitted for approval in October 2016
Sitka	No	Default to State Provisions							
Skagway	Yes	Yes	No*	Yes	**ATV**: if under 16 years old requires parent/guardin, if under 18 requires helmet, see city ordinances for designated and restricted steets of use. | **Snowmachines:** requires driver license, travel in single file on streets and alleys, may only tow passengers via a sled and skid, cannot operate on schoolgrounds or municipal streets designated by borough assembly	**ATV**: requires noise suppression muffler, liability insurance, trailers during daylight hours only	**ATV**: <15 mph, except on Yakutania Point and Pat Moore Bridges <5 mph **Snowmachine:** <20 mph in muncipality		Must travel single file along street or alley
Wrangell	Yes**	Yes	No*	Yes	Default to State Provisions	**Snowmobile:** Borough registration valid for 3 years. Forward light that reveals at least to 100'.	Default to State Provisions		ROW permitted for use changes based on decision of council, consult website and local authorities for currently approved areas
Yakutat	Yes	Yes	No*	Yes	Requires valid driver's license, approved safety helmets worn by operators and passengers, must be 16 or older, if under 16 valid license required.	Lights must be on at all times of operation,mufflers and tail pipes shall be sealed and operational	<15 mph	Unauthorized from 10 PM to 6 AM	

*** Special provision exists**

**** Policy on snowmachines only; ATVs categorized as snowmachines because of low-pressure tires**

Table 2.3. Summary of Select Alaska City and Town Policies on OHV/ATV Use

City	Census Area	Policy	Allowed to cross state roads?	Allowed on state roads?	Allowed on city roads?	User Requirements	Vehicle Requirements	Speed Limit	Time Restrictions	Other Notes
Unalaska	Aleutians West	No	Default to State Provisions							
Bethel	Bethel	Yes	Yes	No*	Yes	**ALL:** If under 18 requires a driver's license or be within 100' of 21 year old who is supervising and has a valid driver's license, minors must wear helmets and travel shortest reasonable distance along city roads | **ATV**: liability insurance, proof of insurance, valid driver's license, may not pass other moving vehicles or weave in traffic | **Snowmachine**: proof of registration displayed, liability insurance, proof of insurance, may not pass other moving vehicles or weave	**ATV**: must be under 1500 pounds	**Low-speed vehicle**: <25 mph | **ATV**: <15 mph city road, <5 mph parking lot or congested with pedestrians | **Snowmachines**: <15 mph on city road, <5 mph parking lot or congested with pedestrians	N/A	Definitions: ATV = 3 ormore low-pressure tires, Low-speed vehicle = motor vehicle with 4 wheels that reaches minimum speed of 20 mph, Snow machine = motorized vehicle under 1300 lbs propelled by a track system over snow/ice
Dillingham	Dillingham	Yes	Yes	No*	Yes	**OHV/ATV**: 14 or older and possess a valid driver's license, 18 or younger requires helmet, cannot be operated within business district (see extra), allowed on ROW of all roads as long as 3' or more from edge of shoulder, operation after dark requires same direction of roadway motor traffic **Snowmachines:** Show proficiency of knowledge of rules of the road, under 18 must wear helmet, after dark operation remanded to right side of a designated snowmobile route and in same direction as roadway traffic, cannot be operated within business district (see extra) and Main Street from Denny Way to intersection of Second Avenue West	**OHV/ATV**: Cannot be modified to make more noise than when manufactured | **Snowmboile**: headlight illuminated at all times, visibly display valid state snowmobile registration	<20 mph	**OTV/ATV**: prohibited to operate between 12 AM and 5 AM from Serpt 1st until June 1st	
Haines	Haines	Yes	Yes	No*	Yes	16 years or older, valid driver's license, proof of insurance, must display hand signals while making turns if machine not equipped with turn signals	Equipment originally installed shall be in good working order, lighted headlight and tailight at all times	<25 mph	No snow machine or ATV use within confines of Tlingit Park or the Fort Seward parade grounds bewtween 9 PM to 9 AM	
Homer	Kenai Peninsula	Yes	Yes	No*	No*	Default to State Provisions				Beach is open for atv use and travel
Hoonah	Hoonah-Angoon	Yes	Yes	No*	Yes	Must have driver's licence, be 16 years or older, vehicle must obtain permit, must wear protective head gear	Protective shield over all moving parts, reflectors on sides of cowling	N/A	Operation allowed bewtween 6 AM and 9 PM except fridays and saturdays where they may be operated until midnight	
Hooper Bay	Kusilvak	Yes	Yes	No*	Yes	Default to State Provisions				
Nome	Nome	Yes	Yes	No*	Yes	If under 16 must be under direct supervision of adult, valid drivers license, must drive on far right of roadway and on shoulder if available, must wear helmet		<20 mph	N/A	If an alternative route is available that will not violate regulations it must be taken; Local police implied they do not enforce on local roads.
Craig	Prince of Wales-Hyder	No	Default to State Provisions							
Delta Junction	Southeast Fairbanks	No	Default to State Provisions							State troopers said ATV/snowmachine use is predominant; enforcement is lax unless user is blatantly speeding
Valdez	Valdez-Cordova	Yes**	Yes	No*	Yes	Motor vehicle operator's license, hard protective head gear	Default to State Provisions	N/A	Operation allowed between 6 AM and 11 PM, except Friday and Saturday allowed until midnight	No policy on ATV; In or within 100' of ski area or within 100' of ice rinks
Wasilla	Matanuska-Susitna	Yes	Yes	No*	No*	Valid driver's license, carry proof of registration, liability insurance, carry proof of insurance, wear DOT approved crash helmets, 16 or older unless supervised by adult	Red light mounted on rear visible at 500',	10 mph or less on right of way, 5 mph in congested areas or parking lots	Operation allowed 8 AM to 10 PM within city limits	Allowed on right of way of all roads, not allowed within 20' of railroad track unless crossing
Fort Yukon	Yukon-Koyukuk	Yes**	Yes	No*	Yes	City permit & 14 or older	Default to State Provisions	<15 mph	N/A	Local police indicated that snowmachine regulations apply to ATVs

*** Special provision exists**
**** Policy on snowmachines only; ATVs categorized as snowmachines because of low-pressure tires**

As can be seen in the preceding tables, the variations in policies across the state are tremendous. In some locations, provisions require the use of protective equipment and functional headlights and taillights, or place restrictions on when and where OHVs can be used. In other locations, stipulations on OHV use are non-existent or unenforced (according to local public safety officers). However, it is important to note here for reference that the information provided in the tables was gathered in June 2017. As Alaska ordinances may change over time, it is recommended that a person with any questions or concerns regarding OHV/ATV or snowmachine use and laws checks with local authorities before operating in that area.

Though it seems that in some cases these policies are specific to a small geographic region and unique locale (e.g., no or limited operation in select parks or streets), several policies may warrant modification to provide better consistency at the borough and city levels (e.g., speed limits, vehicle restrictions, and hours of operation). A more robust sampling and comprehensive documentation of city/town policies could be completed to identify other possible variations in policies at the local level.

3 OHV FACILITIES AND NETWORK CONNECTIVITY

There are 355 incorporated places in Alaska (Figure 3.1) according to the U.S. Census Bureau (2016). Not all of these incorporated places are located on the contiguous road system. Anecdotally, Alaskans typically use the statistic that *"70% of Alaskans don't live on the connected road system."* Data available through the Alaska State Geographic Data Center (ASGDC) indicate that there are 31,692 miles of streets/roads and 23,205 miles of trails, with an additional 20,428 miles of RS2477[1] trails (Figure 3.2 and Figure 3.3a). Many of these trails reach places in the state that roads simply do not go. It is in these locations where one may expect higher rates of OHV use as a primary form of transportation. Figure 3.3b shows the ratio of trails to roads for each town/place in Alaska and indicates that there are large geographic regions which have more trail mileage than road mileage. Further still, there are a handful of locations where only trails are present, no roads. To be conservative, it is worth noting that although these datasets are the most current, they may not reflect *all* of the trails (or roads for that matter) that exist in the state, but represent our best guess and are the most comprehensive given the tools and data that we have. However, there are some places that are identified as having no trails and no roads but are known to have "boardwalks" as their primary transportation network within the village because they are situated on permafrost.

[1] RS2477 trails are rights-of-way designated for the construction of roads/trails over public lands but (officially) not reserved for public uses, though across much of the state these trails are substantiated and used frequently by OHV users.

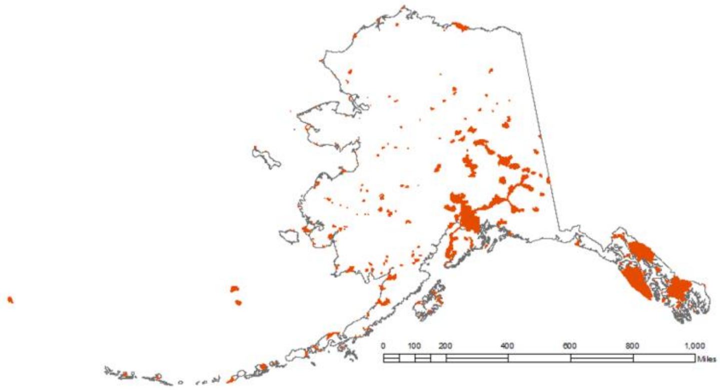


Figure 3.1. U.S. Census Bureau defined incorporated places in Alaska.

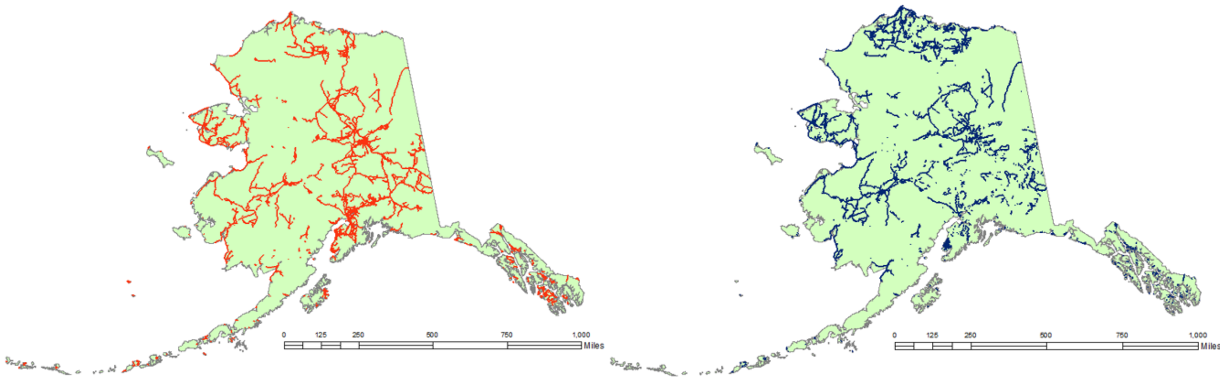


Figure 3.2. Statewide (a) street and (b) trails networks in Alaska.

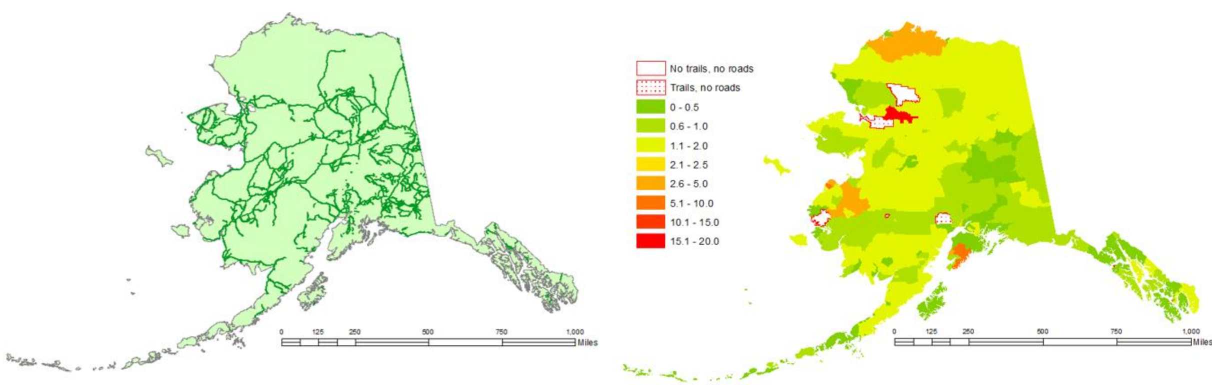


Figure 3.3. Statewide (a) RS2477 trails and (b) ratio of miles of trails to roads by zip code in Alaska.

Figure 3.4 shows examples of proximal (e.g., in the ditch or on the slope of the roadway), adjacent (e.g., on the dirt shoulder), and coincident (e.g., fully or partially on the road or non-motorized shared-use facility) trails. Not only do these uses have inherent safety issues (e.g., mixed-use), but also they can cause physical damage to the transportation infrastructure. Beyond that, informal crossings are often established at locations with poor sight distance (e.g., on horizontal curves or in ditches that intersect and cross side streets and driveways) or at critical points of conflict at or near the head of intersections. The former two are of particular concern with respect to safety, as they increase exposure rates for the more vulnerable party (see Figure 3.5 and Figure 3.6).

(a) (b) (c)

Figure 3.4. Examples of (a) proximal, (b) adjacent, and (c) coincident informal ATV/OHV trail systems.

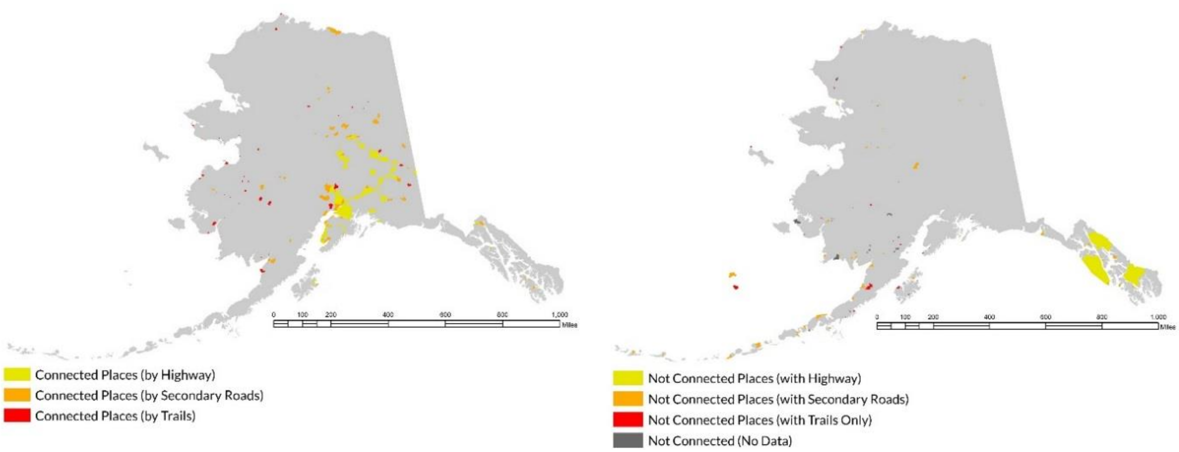
(a) (b)

Figure 3.5. Example of (a) ATV use on a highway in Copper Center, AK, and (b) OHV use adjacent to the highway and through an intersection in Fairbanks, AK.

(a) (b)

Figure 3.6. Examples of ATV use on roads in (a) McCarthy, AK, and (b) Nome, AK.

Of the 355 populated places (according to the U.S. Census Bureau) in Alaska, 227 places are connected to other places by various means. Only five places are connected by highways alone. The majority of places are connected via secondary roads and some by trail systems (Figure 3.7). Places connected by highways have a lower average percentage of Native Alaskans than places connected by roads—approximately 8% and 34%, respectively.



(a) (b)

Figure 3.7. Incorporated places in Alaska that are (a) connected by formal facilities (n = 227), i.e., highways and secondary roads, and (b) not connected on the contiguous road system (n = 128).

The total distance of recorded trails in Alaska is 23,205 miles. Of those, 22,350 miles of trail are one-half mile or more from roads and highways. Here, we consider this trail mileage to be supplemental to road and highway networks; they provide access for those using OHVs to a more varied set of points of interest. Only 855 miles of trails are within one-half mile of roads and highways. These trails are considered redundant and not considered to serve any other access function than to provide a presumably “legal” place for OHVs to operate. Figure 3.8 and Figure 3.9 show the spatial distribution of supplementary and redundant trail lengths over the state of Alaska. The interior and North Slope regions of the state have the most supplementary mileage; the interior region has the most redundant mileage as well.

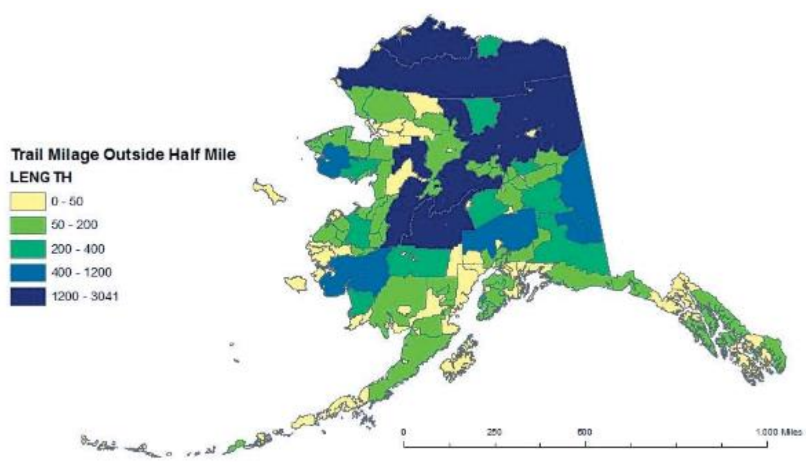


Figure 3.8. Trail mileage supplementary to road and highway networks in Alaska.

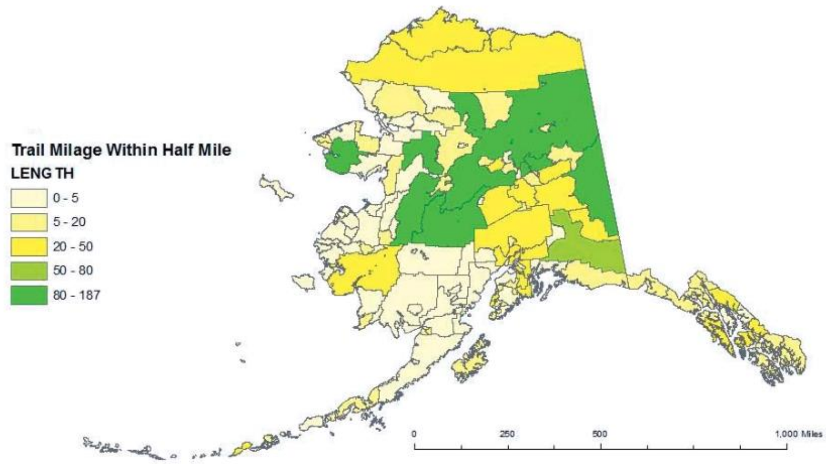


Figure 3.9. Trail mileage redundant with road and highway networks in Alaska.

4 OHV INJURY AND FATALITY DATA

Traditionally, limited data about OHV incidents are available through departments of public safety. Some OHV crashes do end up in the DMV crash records provided that the event was deemed to have occurred on a road or within the public right-of-way. In this report section, we present a summary of the Alaska Trauma Registry (AKTR) with the intent of providing more insight into these injury-related events.

The AKTR is a system used to track the most seriously injured persons in Alaska along with their treatment (if appropriate) received at an acute care facility. These data have been tracked for all 24 of Alaska's acute care hospitals since 1991. The primary purpose of the registry is to evaluate quality of care and to develop, execute, and evaluate injury prevention programs. In order to be included in the trauma registry, patients must be

1. admitted to an Alaska hospital;
2. held for observation;
3. transferred to another hospital or declared dead in the emergency department; and
4. obtained trauma information within 30 days of the injury.

Typical injuries may include trauma, poisoning, suffocation, and the effects of reduced temperature which may have occurred as the result of myriad events/causes. Trauma Registry data are confidential and protected under Alaska Statute 18.23.010-070. All trauma registry personnel and those requesting trauma registry data are required to sign a confidentiality statement. The trauma registry data used for this study were anonymized before being obtained and do not include patient, physician, hospital, clinic, or ambulance service identifiers.

4.1 Obtaining and Organizing Trauma Registry Data

Alaska Trauma Registry data were obtained by filing a request form via e-mail with the Department of Health and Social Services (see Belz & Chang, 2018, for more information). We analyzed only the five most recent and available years of the AKTR at the time of acquisition, which covers the period of 2009 through 2014. The AKTR is used as a supplement to DMV records because of the ability to compare on-road and off-road events and the prevalence of injuries in incorporated places without state roads or facilities, and because of lack of reporting and a lack of police presence in remote communities. These data were first sorted by injury cause to eliminate non-transportation mode causes. The remaining records were then consolidated into trauma events that occurred on/near roads, on paths/trails, and off road.

4.2 Trauma Registry Results by Category

The motor vehicle category shows the most traumas—about 2.5 times more traumas than ATVs. The ATV category shows a total of 1,352 traumas, 347 (25.6%) of which occurred on or near roads (based on previously defined categories). There were 983 snowmachine traumas with 172 (17.4%) of those categorized as on road. On-road injury and trauma counts and percentages are shown in Figure 4.1 and off-road counts and percentages are shown in Figure 4.2 In comparison with bike and pedestrian injuries, the total numbers for non-motorized and OHV injuries and traumas are similar. The AKTR records indicate that a higher percentage of injuries occur on roads, specifically for ATVs and snowmachines, than in wilderness areas or on trails.

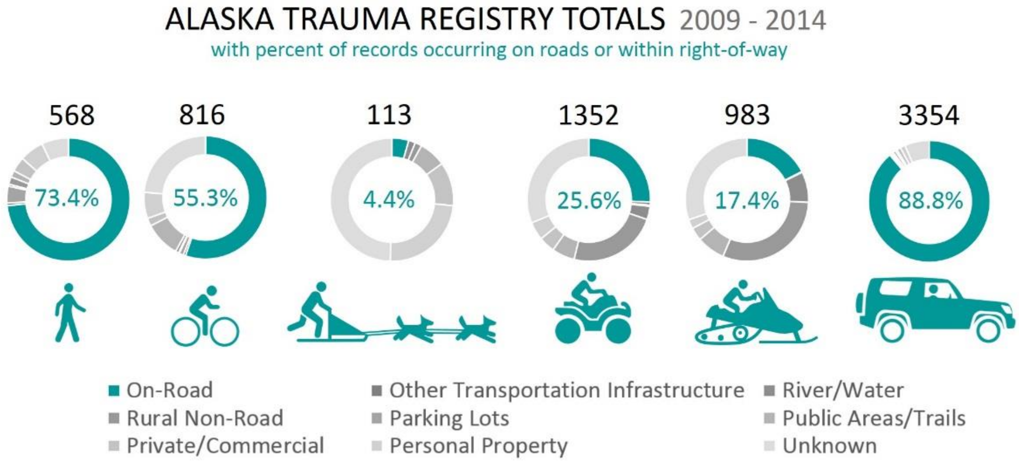


Figure 4.1. Number and percentage of modal traumas with percentage of on-road incidents.

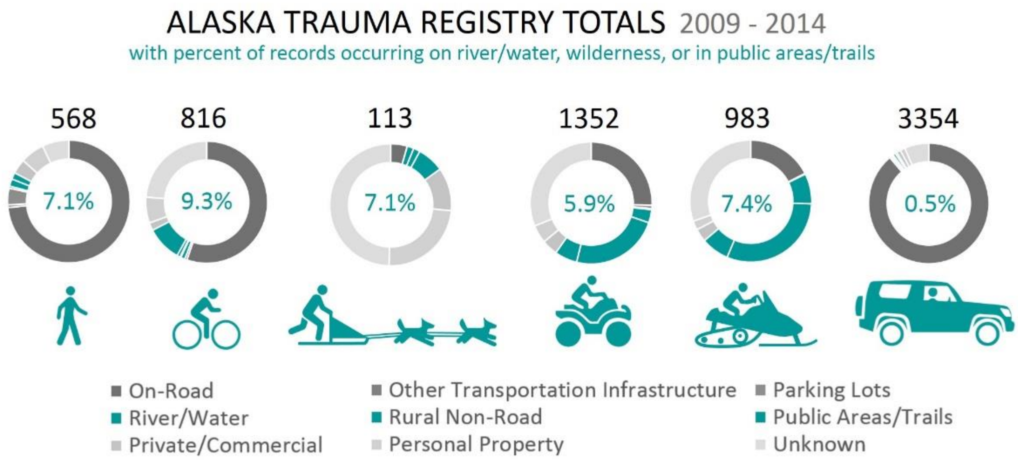
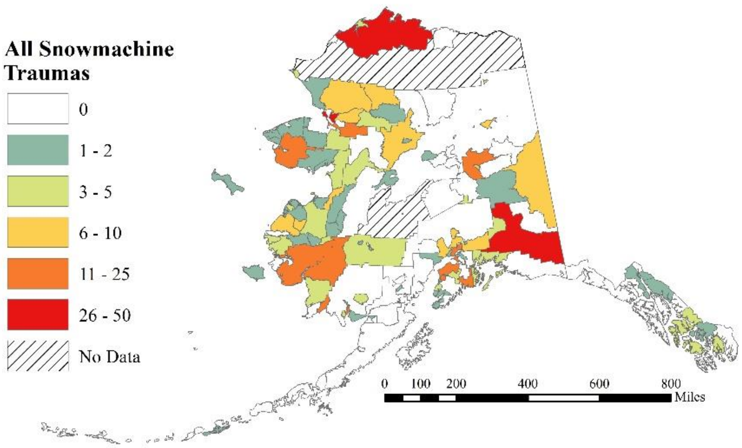
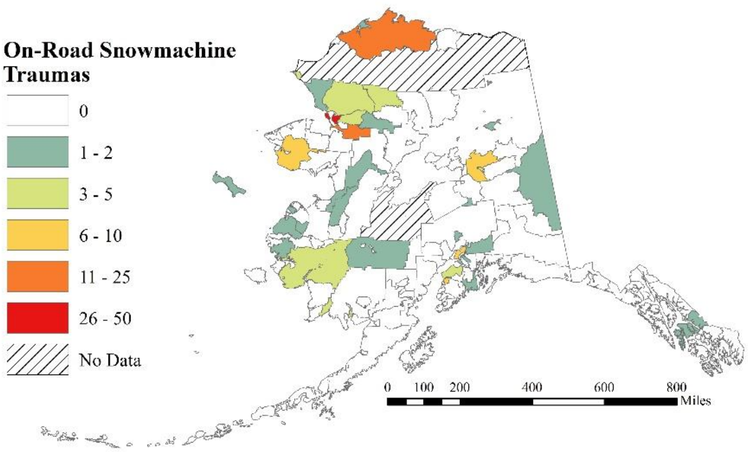


Figure 4.2. Number and percentage of modal traumas with percentage of public area and trail incidents.

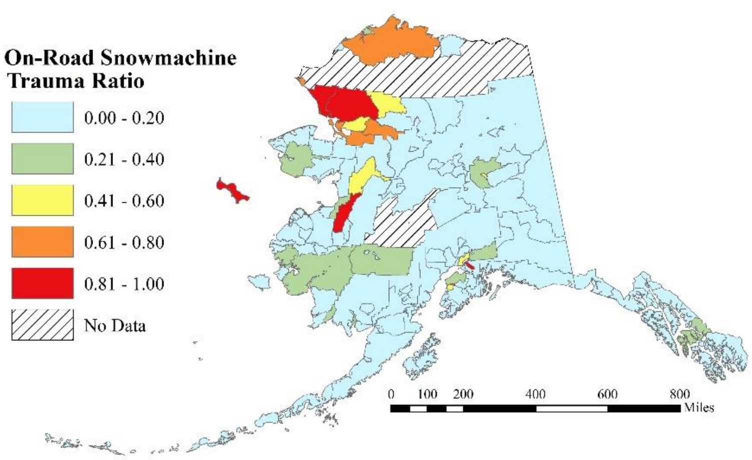
Figure 4.3 and Figure 4.4 show the spatial distribution of events in the AKTR for the period of 2009 through 2014 and are broken out for snowmachines and OHVs. A higher proportion of on-road snowmachine traumas is exhibited in the northwest and southcentral regions of the state, while the proportion of OHV traumas are fairly well distributed across the entire state.



(a)

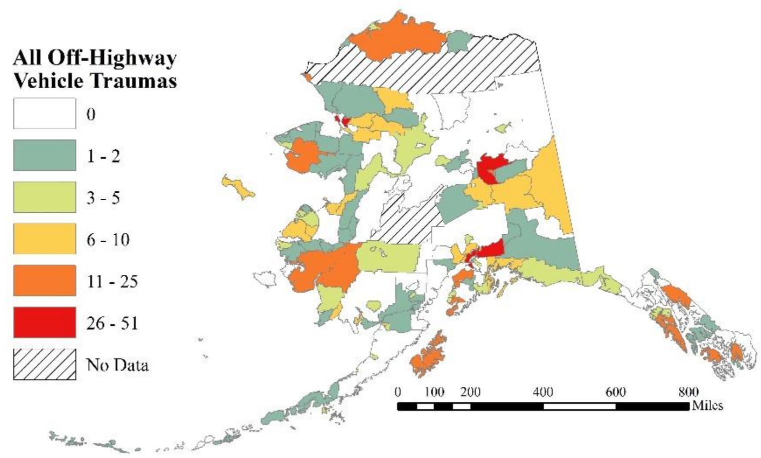


(b)

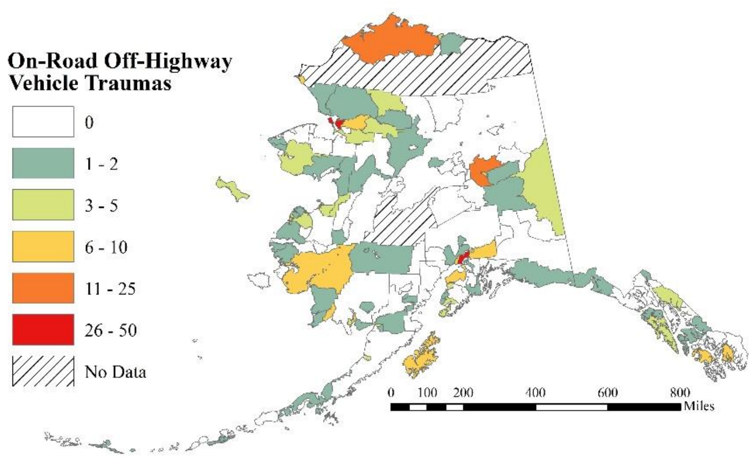


(c)

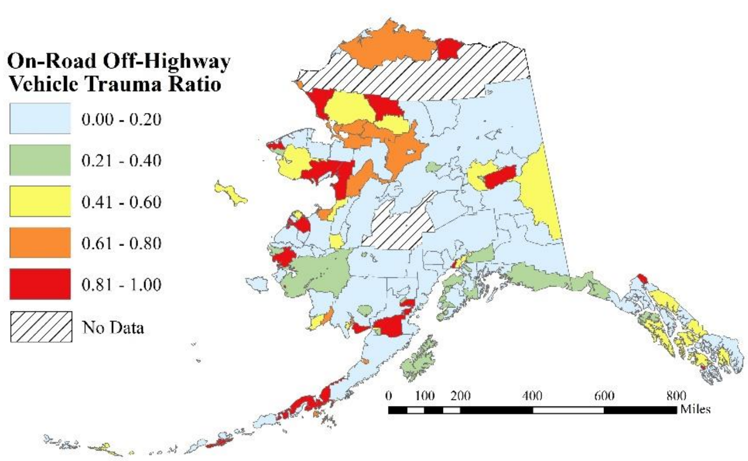
Figure 4.3. Snowmachine-related records in the Alaska Trauma Registry showing (a) all traumas, (b) on-road traumas only, and (c) ratio of on-road snowmachine traumas.



(a)



(b)



(c)

Figure 4.4. OHV-related records in the Alaska Trauma Registry showing (a) all traumas, (b) on-road traumas only, and (c) ratio of on-road OHV traumas.

4.3 Trauma Registry Results by Location

Table 4.1 indicates a significant difference (p = 0.012) in all ATV traumas between "connected" and "not- connected." There are more than twice as many ATV traumas on average in connected places than in not-connected places. Bicycle and pedestrian traumas are also shown for reference. There is a significant difference between categories of connected areas for all ATV traumas. Highway-connected places have about 3 times as many ATV traumas as secondary road-connected places (Table 4.2). There is a significant difference (p = 0.017) in the number of snowmachine traumas between highway and secondary road-connected places. There are roughly 4.5 times as many snowmachine-related traumas in highway-connected places. For not-connected places, the most traumas occur on highways as well, then secondary roads, then trails, and lastly not on roads at all (Table 4.3). For on-road traumas, significant differences are not observed for varying levels of connectivity or lack of connectedness (Table 4.4 through Table 4.6). However, for on-road ATV traumas, there is a marginally significant difference (p = 0.070) between places connected by highways and places connected by roads (Table 4.5).

Table 4.1. Comparative statistics for traumas by mode and by connectedness.

Transportation Mode & Trauma Location	Connected		Not-Connected		STAT	
	Mean	Std. Error	Mean	Std. Error	t-test	p-value
All ATV Traumas	7.23	1.492	3.12	0.568	2.576	0.012**
All Snowmachine Traumas	4.18	0.881	2.710	0.689	1.314	0.191
All Bicycle Traumas	8.47	5.060	1.140	0.395	1.445	0.154
All Pedestrian Traumas	6.54	4.560	1.290	0.395	1.147	0.256

** Indicates $p \leq 0.05$

Table 4.2. Comparative statistics for traumas by mode and level of connectivity.

Transportation Mode & Trauma Location	Connected						STAT	
	Highway		Secondary Roads		Trails			
	Mean	Std. Error	Mean	Std. Error	Mean	Std. Error	t-test	p-value
All ATV Traumas	10.56	2.468	2.96	0.654	No Data		2.978	0.005**
All Snowmachine Traumas	5.91	1.355	1.96	0.855			2.463	0.017**
All Bicycle Traumas	14.44	8.926	0.84	0.423			1.522	0.138
All Pedestrian Traumas	10.59	8.088	1.36	0.712			1.137	0.264

** Indicates p ≤ 0.05

Table 4.3. Comparative statistics for traumas by mode and level of non-connectivity.

Transportation Mode & Trauma Location	Not-Connected								STAT	
	Highway		Secondary Roads		Trails		None			
	Mean	Std. Error	Mean	Std. Error	Mean	Std. Error	Mean	Std. Error	F-test	p-value
All ATV Traumas	5.00	2.864	3.55	0.982	2.88	0.766	1.69	0.463	2.227	0.070*
All Snowmachine Traumas	0.80	0.374	3.48	1.260	2.47	0.986	1.63	0.446	0.818	0.516
All Bicycle Traumas	9.00	4.764	0.73	0.280	0.53	0.298	0.38	0.155	0.830	0.509
All Pedestrian Traumas	7.60	4.411	1.20	0.442	0.65	0.209	0.25	0.194	0.548	0.701

* Indicates 0.05 < p ≤ 0.1

Table 4.4. Comparative statistics for on-road traumas by mode and by connectedness.

Transportation Mode & Trauma Location	Connected		Not-Connected		STAT	
	Mean	Std. Error	Mean	Std. Error	t-test	p-value
On-Road ATV Traumas	2.28	0.580	1.67	0.394	0.875	0.383
On-Road Snowmachine Traumas	0.81	0.267	1.03	0.388	-0.464	0.643
On-Road Bicycle Traumas	5.81	3.794	0.83	0.322	1.306	0.197
On-Road Pedestrian Traumas	5.16	3.805	0.87	0.297	1.123	0.266

Table 4.5. Comparative statistics for on-road traumas by mode and level of connectivity.

Transportation Mode & Trauma Location	Connected						STAT	
	Highway		Secondary Roads		Trails		t-test	p-value
	Mean	Std. Error	Mean	Std. Error	Mean	Std. Error		
On-Road ATV Traumas	3.19	0.983	1.12	0.307	No Data		2.007	0.052*
On-Road Snowmachine Traumas	1.16	0.414	0.36	0.282			1.589	0.118
On-Road Bicycle Traumas	9.81	6.713	0.68	0.34			1.359	0.184
On-Road Pedestrian Traumas	8.41	6.756	1.00	0.523			1.093	0.283

* Indicates $0.05 < p \leq 0.1$

Table 4.6. Comparative statistics for on-road traumas by mode and level of non-connectivity.

Transportation Mode & Trauma Location	Not-Connected								STAT	
	Highway		Secondary Roads		Trails		None		F-test	p-value
	Mean	Std. Error	Mean	Std. Error	Mean	Std. Error	Mean	Std. Error		
On-Road ATV Traumas	2.20	1.158	1.98	0.710	1.59	0.522	0.81	0.332	0.481	0.750
On-Road Snowmachine Traumas	0.00	0.000	1.28	0.692	1.14	0.697	0.31	0.176	0.584	0.675
On-Road Bicycle Traumas	7.20	4.055	0.50	0.203	0.35	0.191	0.19	0.101	0.724	0.577
On-Road Pedestrian Traumas	5.60	3.415	0.78	0.319	0.35	0.170	0.19	0.136	0.508	0.730

4.4 DMV Crash Records for Off-Highway Vehicles

The DMV crash records for the period 2009 through 2013 (the most current and complete 5-year set of data available at the time of acquisition) were acquired through AKDOT&PF (see Appendix C for signed user agreements). Events involving OHVs were identified using the "vehicle configuration" and "vehicle type categories," as this data category changed from the

2012 to the 2013 datasets. If either the primary or secondary vehicles listed in the event record included OHVs in the 2009 through 2012 data or “open body” in the 2013 data, these were reserved for further analysis. Figure 4.5 shows the total number of records present in the DMV data for 2009 through 2013. For reference, the figure also shows the total number of on-road specific injury events cataloged in the AKTR from 2009 through 2014. In general, it is clear that the two sets of data track each other. However, the data indicate that there are consistently more than twice the number of records in the AKTR than there are in the DMV. Figure 4.6 shows the spatial distribution of those events. To prepare this information, latitudes and longitudes associated with the records were used to match the event to a GIS shapefile representing zip code. This approach would allow a more direct comparison to the AKTR, where only town name and zip code of the event were provided. Figure 4.7 shows the AKTR records again for reference. Again, Figure 4.6 and Figure 4.7 show the spatial and numerical disparities between the DMV records and the AKTR records. These data are used to generate direct comparison between observations by zip code.

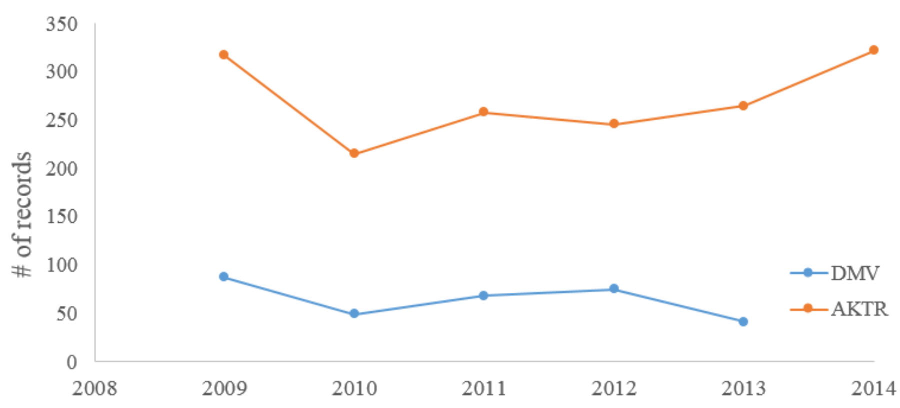


Figure 4.5. Total number of OHV-related crash and injury records in the DMV and AKTR databases for 2009 through 2014.

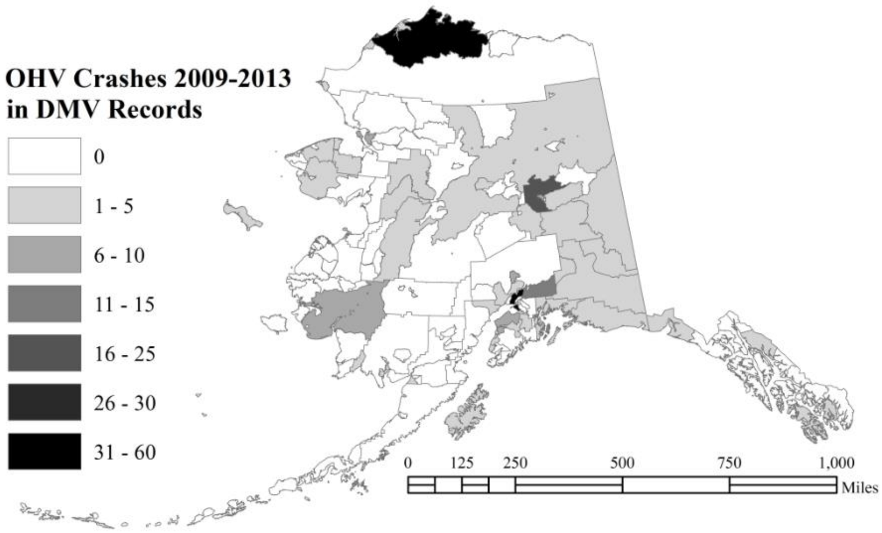


Figure 4.6. Spatial distribution of statewide OHV crashs in the DMV records, 2009 through 2013.

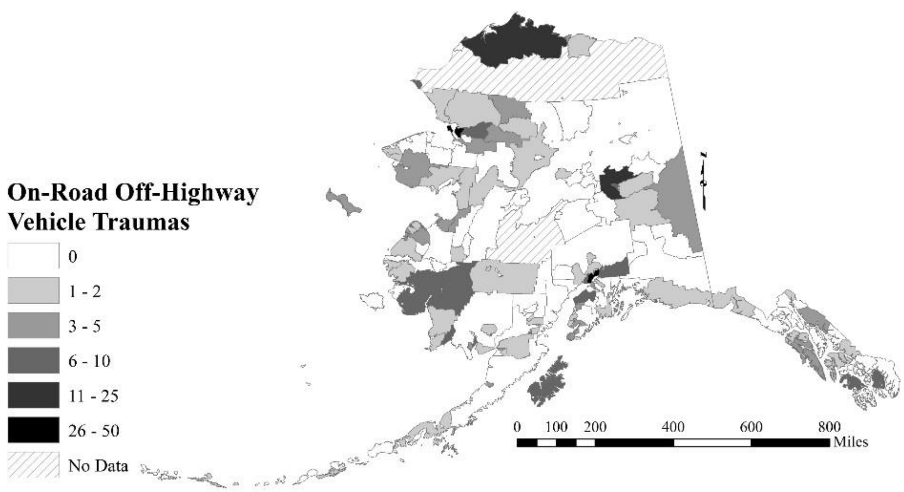


Figure 4.7. Spatial distribution of statewide on-road related OHV injuries/traumas in the AKTR records, 2009 through 2014.

Figure 4.8 shows the ratio of DMV to AKTR events by zip codes collapsed to place name. Events occurring in 2014 for the AKTR were ignored so the datasets would be comparable. There were only 12 cases (i.e., towns) where non-zero values appeared in the DMV records and zero values in the AKTR where the ratio could not be computed. These only totaled 25 out of the 272 total events in the DMV records. Areas in blueish-green, green, and yellow indicate places where more events were observed in the AKTR. Areas in orange and red are where more events were observed in the DMV. Areas in blueish green and red are highly problematic, as they indicate severe and significant discrepancies between the two datasets.

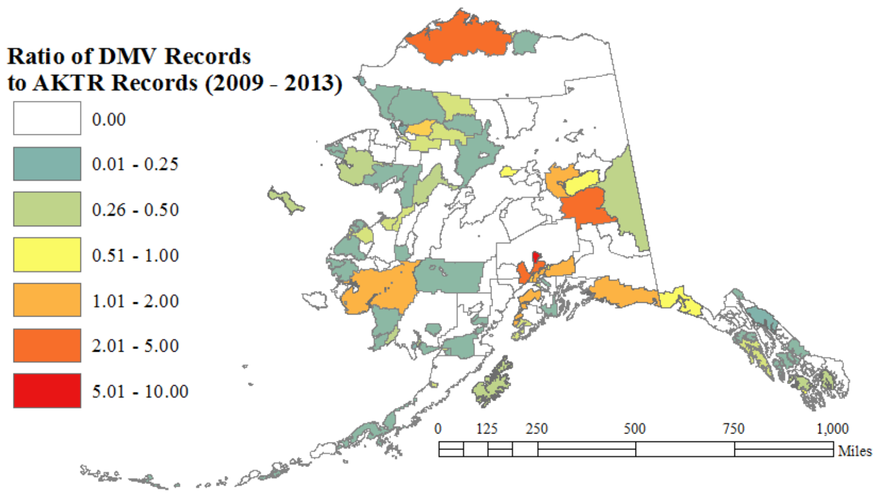


Figure 4.8. Ratio of on-road-related OHV events in the DMV to AKTR records for 2009 through 2013.

5 MEDIA DISCOURSE ANALYSIS

In order to gain a better understanding of the types of concerns, safety trends, and conversations surrounding OHV use, national online media was tracked and compiled for a period of 1 year beginning July 1, 2017, through June 30, 2018, using Google Alerts. Tracking was accomplished by identifying any article or online post that met the inclusion criteria of [ATV *OR* OHV *OR* Snowmobile *AND* road *OR* roadway *OR* “off-road vehicle” *OR* “all-terrain vehicle”] and then was analyzed and filtered to separate articles that reference cases or incidences that were on road from those that were off road. This period of analysis yielded 1,327 articles in total, 812 of which dealt with on-road OHV use. Table 5.1 summarizes the specific number of each article theme.

A common method for quantitative content analysis of media content is word counts (Riffe et al., 2005), which can be used to identify and extract themes from text. Crawley (2007) and Murphy (2001) analyzed keyword frequencies and applied factor analysis to the co-occurrence of words in articles on particular topics. From this factor analysis, themes (or frames) can be conceptualized as words that factor together. Keywords are identified as words that are used unambiguously, yet occur frequently in the set of text and substantively represent the issue of interest. Word analyses can also be achieved by developing content analysis dictionaries (Riffe et al., 2005), where words that are related or share a common theme are grouped, also referred to as “semantic fields” (Sonnet et al., 2006).

Extracting keywords from the one-year set of media (July 1, 2017, through June 30, 2018), we noted seven distinct topic areas within each of the themes: location and spatial relation, policies and laws, user characteristics, temporal relation, vehicle types, protective equipment (or lack thereof), and crash/accident descriptors. These categories reinforce the idea that policies, laws and the characteristics of the vehicle operator are at the forefront of OHV safety issues. Table 5.1

presents a summary of the number of articles by theme, the percent that involved an on-road incident or issue, and the number of articles from Alaska, specifically.

Table 5.1. OHV media discourse summary.

Theme	**Total**	**On-Road (N, %)**	**Alaska**
Injuries	409	232, 56.7	1
Fatalities	467	250, 53.5	10
Policy	360	297, 82.5	7
Education	91	33, 36.3	0
Total	1327	812, 61.2	18

One interesting finding that is clearly shown in Table 5.1 is the predomincance of on-road issues (reflected in percentages) for injuries, fatalities, and policies. However, most articles dealing with education are focused primarily on trails. Policy-related arcticles almost exclusively—roughly 83% of the articles—dealt with on-road issues. No articles dealt with education for Alaska specifically. Further breakdown is shown in Appendix C, where the most frequently occurring words in each of the identified thematic categories for injury- and fatality-related articles are given. Words indicating the event happened on the weekend and nighttime occurred more frequently than other times of the week and day. Snowmachine-related incidents were more prevalent in off-road-related events, while ATV/OHV-related incidents were more prevalent in on-road-related events. Words indicating that the operator was male (e.g., his, him, he, etc.) were, in total, more prevalent in off-road events.

6 OHV COUNTS

6.1 Site Selection

Multiple sources of mapping data were used to generate the network analysis and trails maps. Several types of data were assembled from a variety of sources including federal and local data (e.g., Department of Natural Resources trails and Department of Transportation road centerlines). These data were used to identify key locations where (1) trails and roads intersect; (2) a trail follows the road in an adjacent and proximal manner; or (3) a trail terminates and the road would be the only likely corridor to be used by OHVs. Some of these data are discussed previously in Chapter 3 and highlighted again here for reference.

The primary sources of data used to identify locations of interest were (1) DNR polylines that represent RS2477 trails (right-of-way for the construction of highways over public lands, not reserved for public uses); (2) DNR polylines that represent other general trail networks presumably open for public use; (3) AKDOT&PF road centerlines; and (4) ESRI street centerlines. The AKDOT&PF and ESRI datasets were used in conjunction to ensure complete road networks were represented. Figure 6.1 and Figure 6.2 show how the data overlay each other for a select location in Petersville, AK. Here, you can see several key locations where the road network provides shorter connectivity between trail ends and a location where OHV use could be observed.

(a) (b)

Figure 6.1. DNR (a) RS2477 trails (purple) and easement (gray) and (b) general trails data (red) in Petersville, AK.

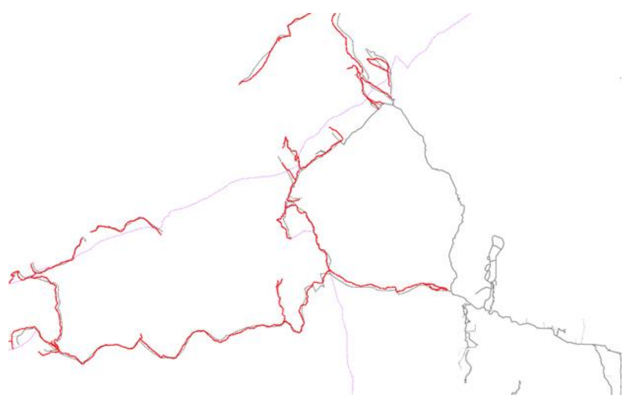


Figure 6.2. DNR RS2477 trails (purple) and easement data (gray), trails data (red), and AKDOT&PF and ESRI road centerline data (dark gray) in Petersville, AK.

Figure 6.3 shows the statewide network of roads and trails. Although this information is the most robust, complete, and up-to-date information available at this time, it may not represent all available road and trail networks in the state. However, when considered holistically, the data in their current form are sufficient for purposes of this research project and provide a good indication of current points of conflict for OHVs, automobiles, and non-motorized forms of transportation.

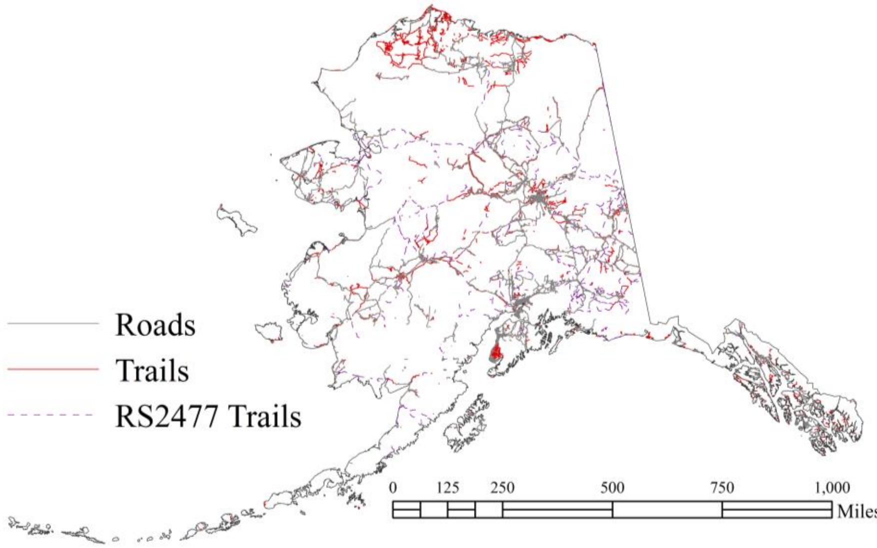


Figure 6.3. Statewide road, trail, and RS2477 trail networks.

Based on visual inspection of road and trail networks in towns with areas of concern (e.g., Delta Junction), six locations were chosen for the primary phase of data collection. Figure 6.4 through Figure 6.13 show the trail and road network in the final set of general locations, with potential areas for count locations identified with cyan-colored circles. Figure 6.14 shows an example—Google Street View of Nistler Road in Delta Junction—used to corroborate site identification in Figure 6.4 through Figure 6.13. From these, the following final set of locations was selected based on timeline and budget:

Phase 1: Healy, Two Rivers, Tok, Fairbanks, Delta Junction, and Ester

Phase 2: Nome, Palmer, Anchor Point, and Bethel

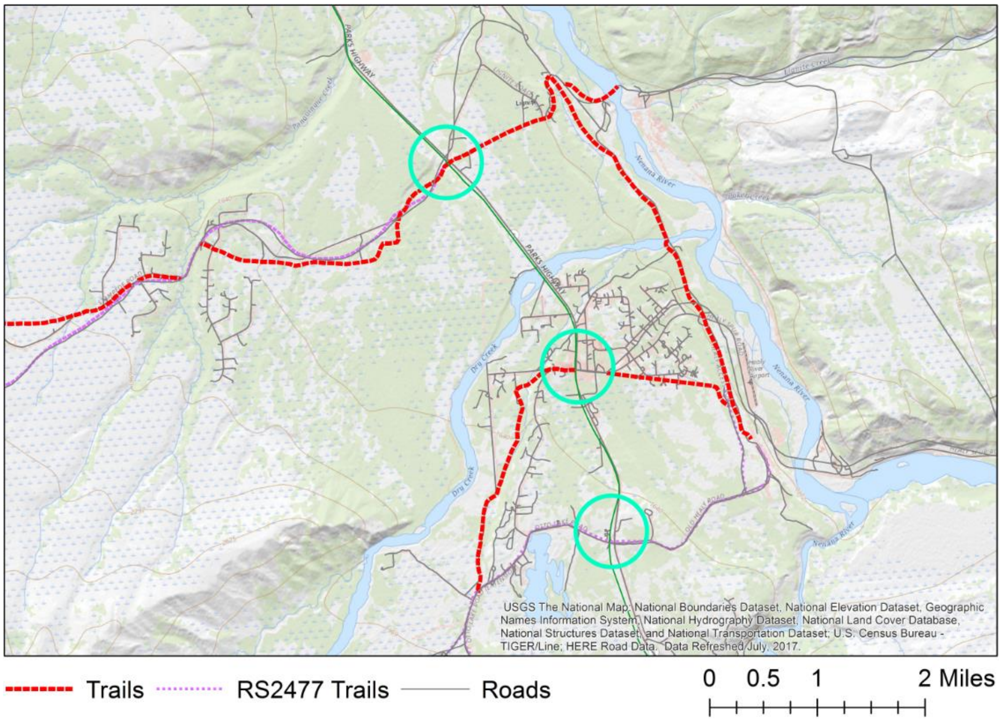


Figure 6.4. Count locations for consideration in Healy, AK.

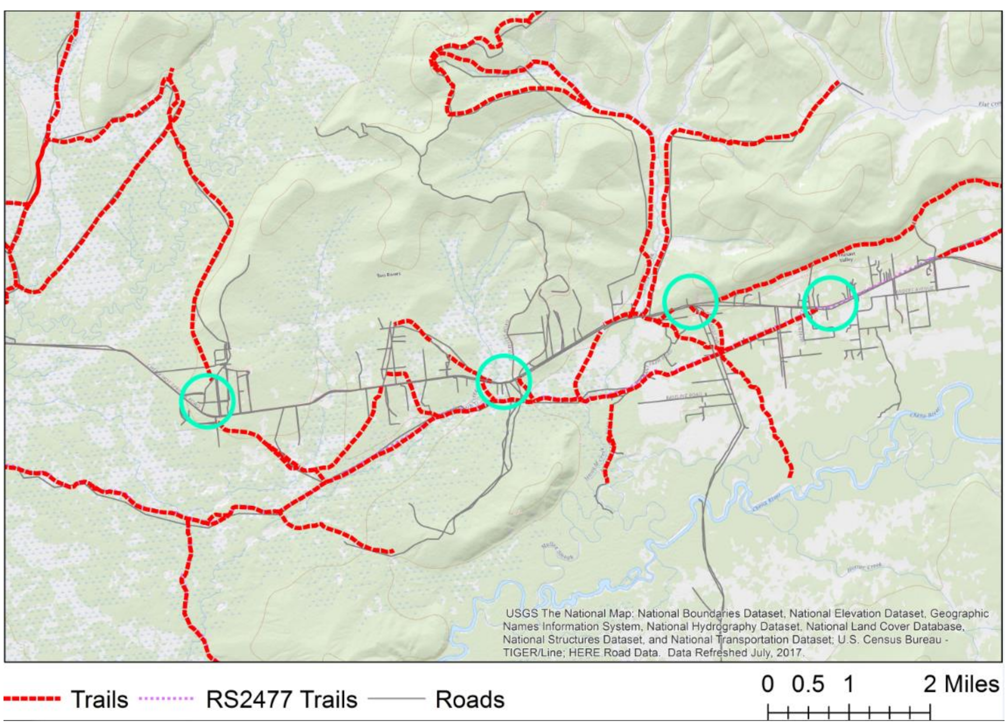


Figure 6.5. Count locations for consideration in Two Rivers, AK.

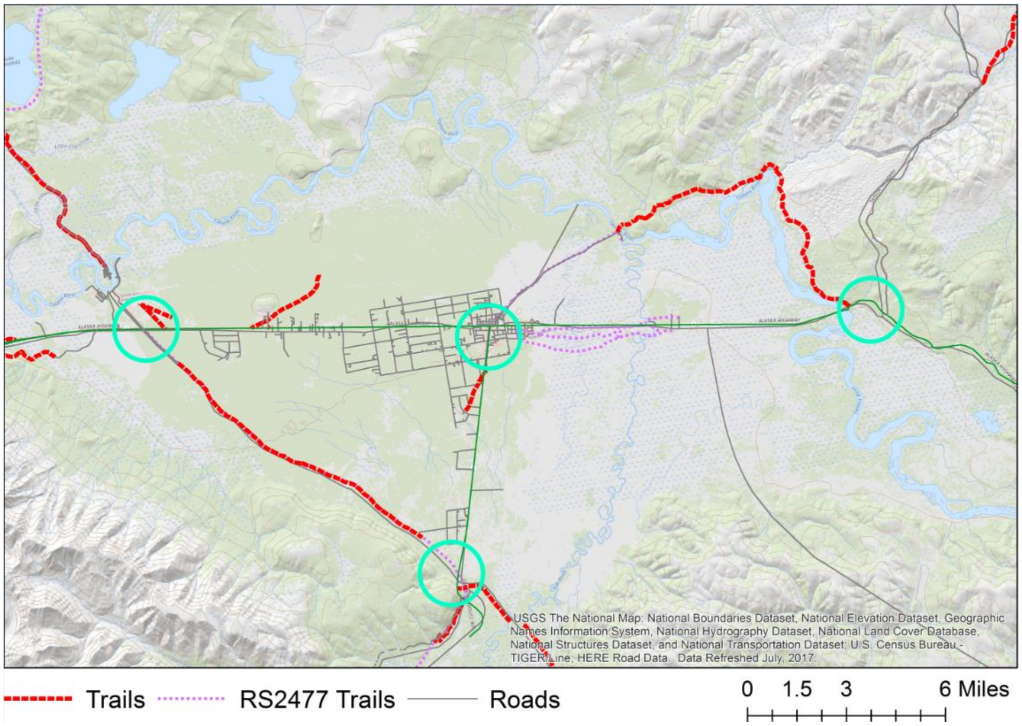


Figure 6.6. Count locations for consideration in Tok, AK.

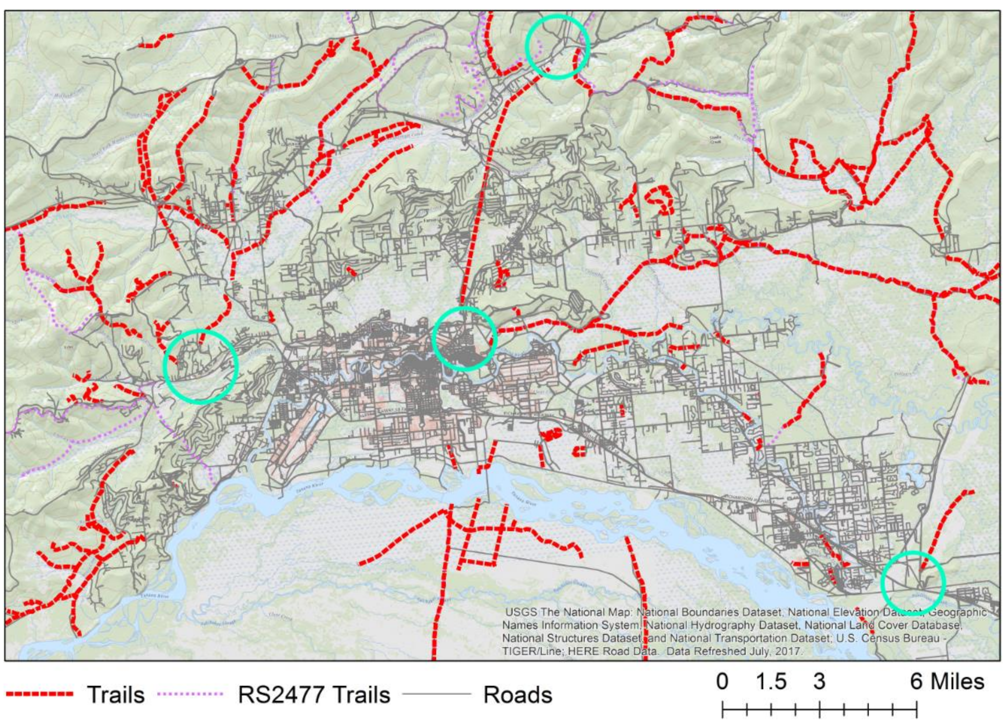


Figure 6.7. Count locations for consideration in Fairbanks, AK.

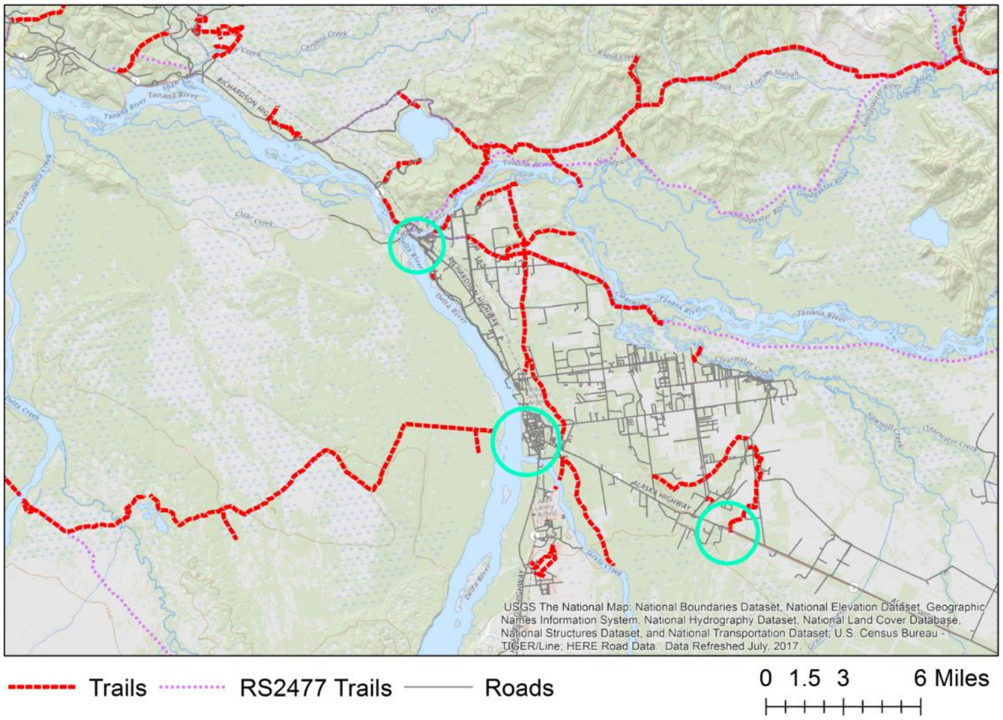


Figure 6.8. Count locations for consideration in Delta Junction, AK.

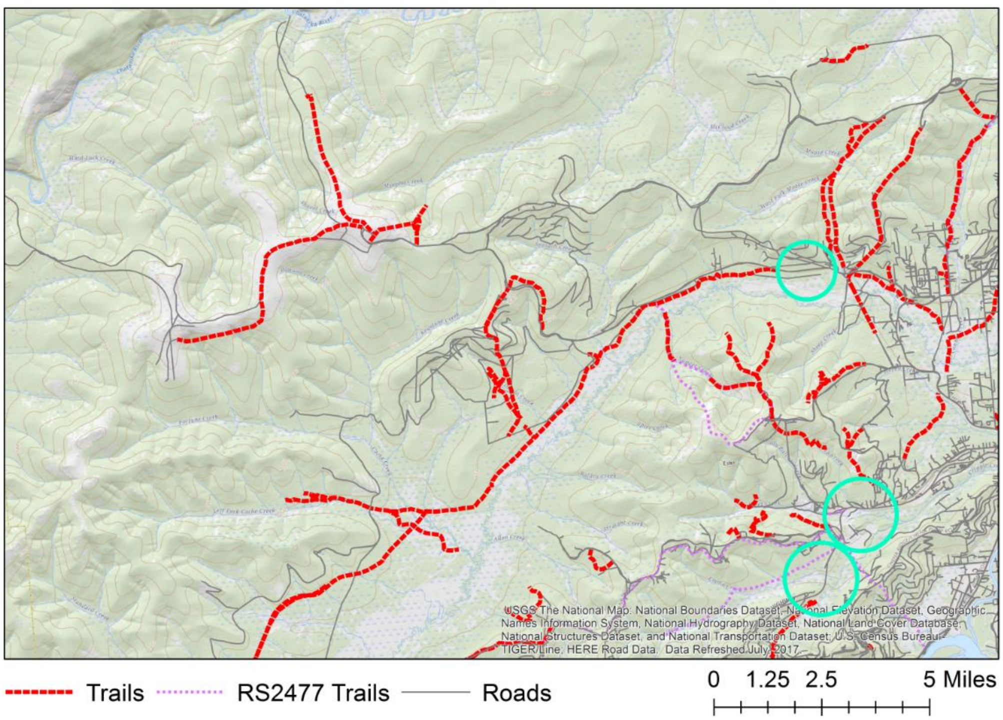


Figure 6.9. Count locations for consideration in Ester, AK.

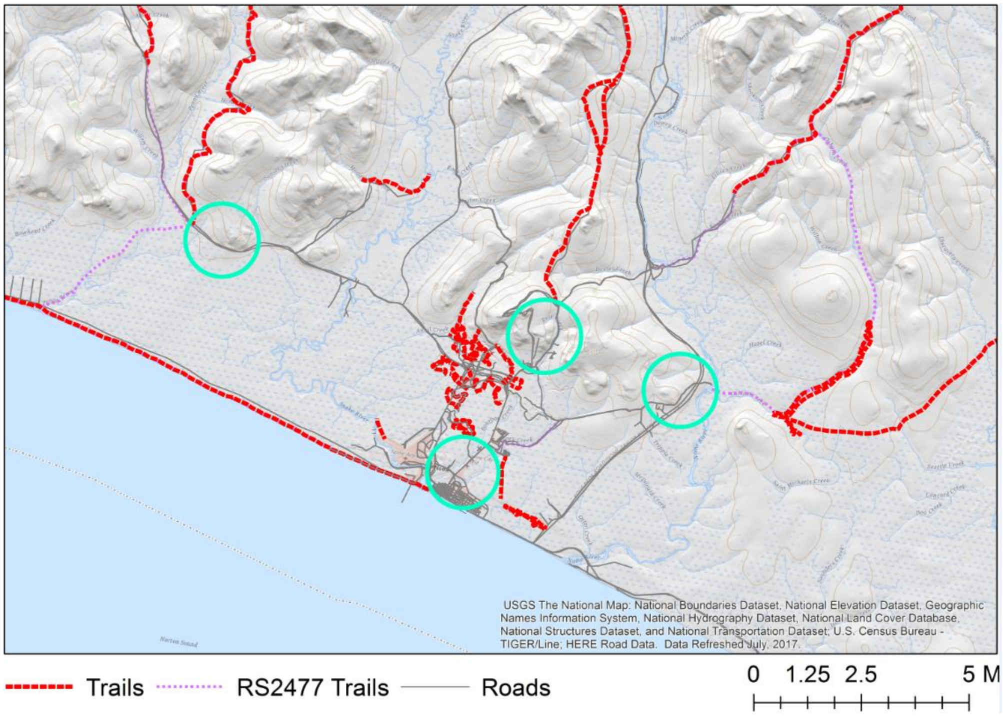


Figure 6.10. Count locations for consideration in Nome, AK.

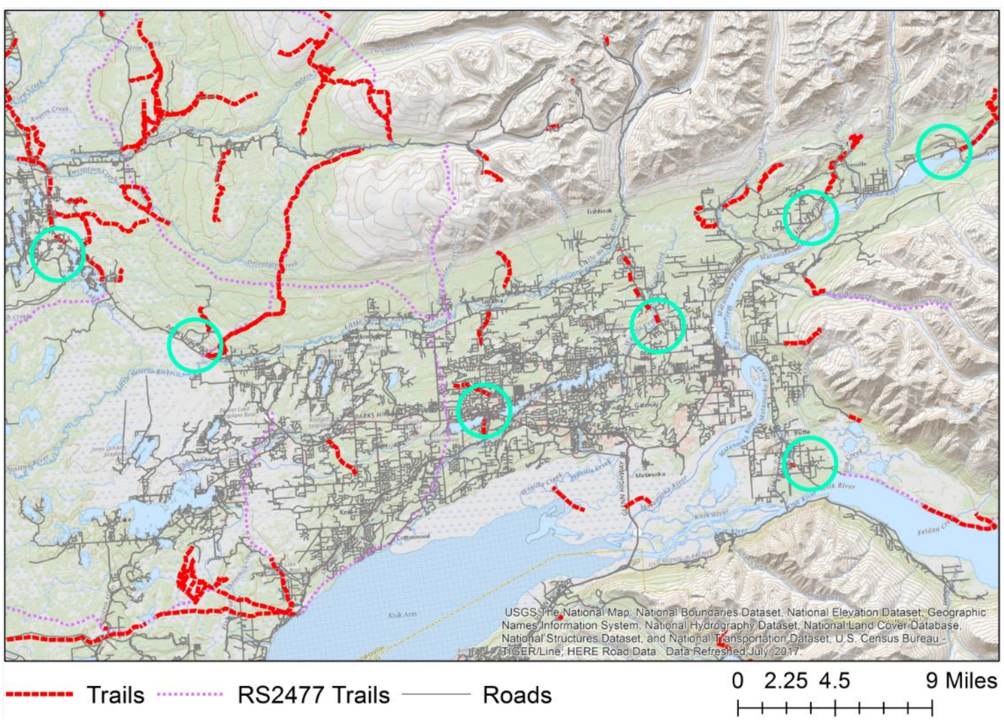


Figure 6.11. Count locations for consideration in Wasilla, AK.

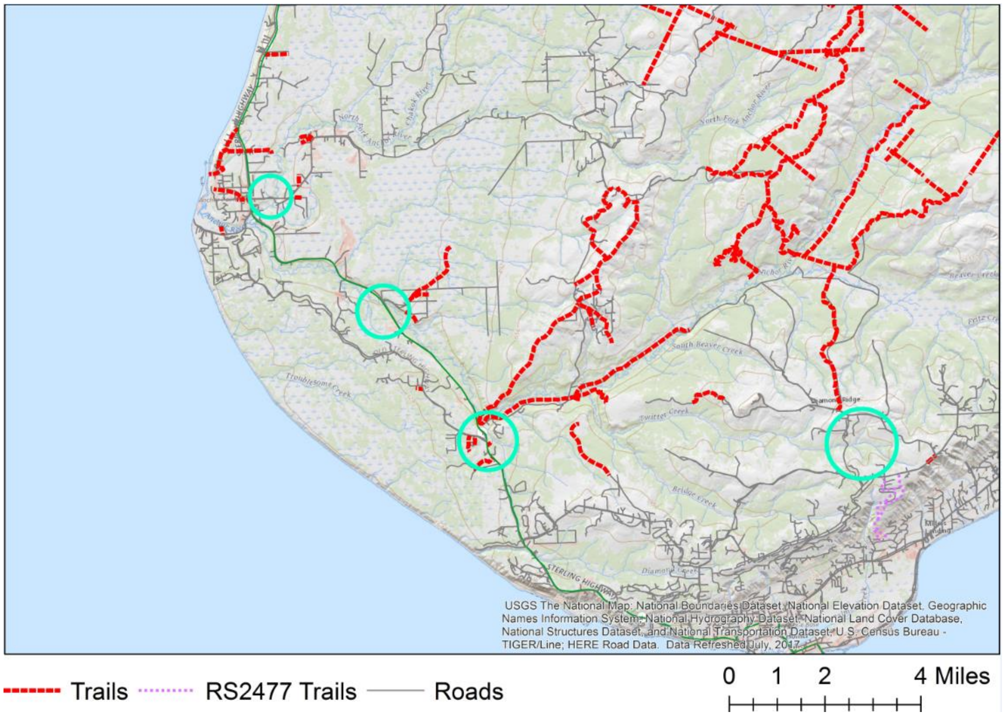


Figure 6.12. Count locations for consideration in Anchor Point, AK.

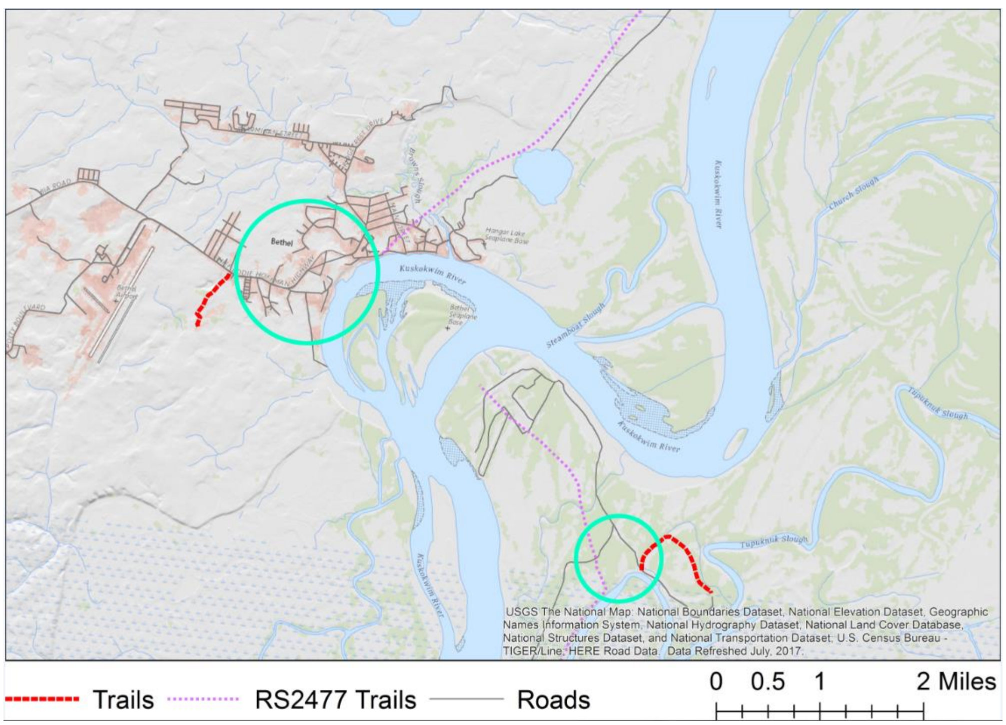


Figure 6.13. Count locations for consideration in Bethel, AK.

Figure 6.14. Google street view of intersection showing worn areas from OHV use at Nistler Road and North Clearwater Avenue in Delta Junction, AK, a potential site for counting.

6.2 Data Collection

Data collection for OHV use was executed during the summers of 2018 and 2019. The period of May 23, 2018, through May 30, 2018, was used to refine the data collection method and camera setup process. These data were used to provide information for the Fairbanks Metropolitan Area Transportation System annual bicycle and pedestrian count. During the refinement period, 10 OHVs were observed over a 3-day period using the bike path along the Parks Highway near Sheep Creek Extension (see Figure 6.15). These data were also used to refine the MATLAB coding used to extract still images of movement captured in the video frame. The final code used for video processing can be found in Appendix D.

(a) (b) (c)

Figure 6.15. Preliminary video-based OHV counting along Parks Highway near Sheep Creek Extension in Fairbanks, AK.

A motion-activated day-night camera was used, powered by two 12V batteries stored in a waterproof housing. A digital video recorder (DVR), which stored the video files, was placed in the waterproof housing. Existing infrastructure (e.g., light poles and power poles) or trees with unobstructed views to the point of interest were used to mount the cameras. The camera was affixed to a metal bar, and pipe strapping was used to affix the camera to the mounting device. Two example mounting setups are shown in Figure 6.16 and Figure 6.17 for the Healy and Fairbanks locations, respectively. The DVR allowed areas within the video frame that were not of interest to be masked out, which significantly reduced the number of purely events and consequently the amount of video that had to be processed. A total of 624 hours were observed at all the locations.

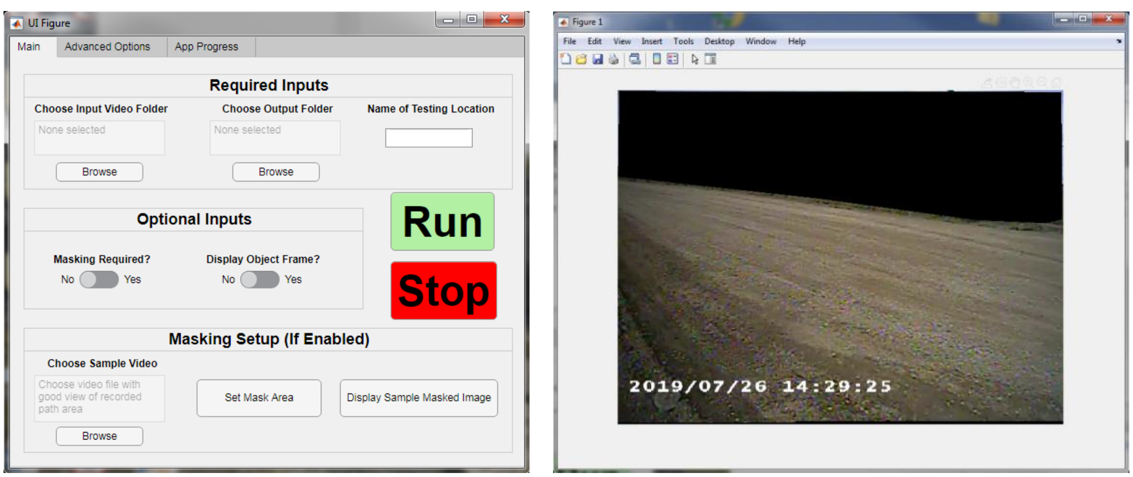
(a) (b) (c)

Figure 6.16. Camera mounting in Healy, AK, showing (a) location near Hilltop Road, (b) waterproof box locked to power pole, and (c) video camera mounted to pole with pipe straps.

(a) (b) (c)

Figure 6.17. Camera mounting example in Fairbanks, AK, showing (a) location along Farmers Loop Road looking west, (b) location along Farmers Loop Road looking east, and (c) location proximal to a "No Motor Vehicles" sign.

After the video collection for a particular location was completed, the video files were fed into a MATLAB video processing code (see Figure 6.18a) developed by the research team to extract still images of motion events and allow for secondary masking of areas in the video that triggered erroneous data capture (e.g., moving clouds or tree branches), as shown in Figure 6.18b. It was essential to process the events manually to produce modal counts of each vehicle event (e.g., bicycle, pedestrian, automobile, OHV, etc.) as well as the number of occupants on the vehicle and the presence (or non-presence) of a helmet. Figure 6.19 through Figure 6.24 show example images from select count locations. It is important to note, particularly in Figure 6.20, that even though the images show use in a “gore-like” area, the trail network connects and continues onto the roadway beyond the frame of the video. Locating the camera in some locations was problematic, as there were no fixed objects to accommodate the camera setup. In these cases, a proximal location was chosen.



(a) (b)

Figure 6.18. (a) Main screen of MATLAB code and (b) masking module.

(a) (b) (c)

Figure 6.19. Farmers Loop Road location in Fairbanks, AK, showing (a) an ATV, (b) a side-by-side, and (c) three ATVs using the space between a bike path and roadway.

(a) (b) (c)

Figure 6.20. Parks Highway location in Ester, AK, showing (a) an ATV using the shoulder, (b) an ATV and a dirt bike in the gore area, and (c) an ATV operator with no helmet.

(a) (b) (c)

Figure 6.21. Hilltop Road location in Healy, AK, showing (a) an ATV using the shoulder, (b) two side-by-sides using the shoulder, and (c) an ATV using the roadway.

(a) (b) (c)

Figure 6.22. Nistler Road location in Delta Junction, AK, showing (a) several ATVs and side-by-sides on the side and in the roadway, (b) a side-by-side using the shoulder, and (c) multiple ATVs using the informal side path.

(a) (b) (c)

Figure 6.23. Alaska Highway location in Tok, AK, showing (a) a side-by-side in the buffer between bike path and roadway, (b) an ATV partially on the bike path, and (c) an ATV in the buffer between a bike path and roadway.

(a) (b)

Figure 6.24. Chena Hot Springs Road location in Two Rivers, AK, showing (a) a dirtbike using the gravel shoulder and (b) a side-by-side using the gravel shoulder in the wrong direction of travel.

6.3 Results

In total, 422 OHVs were captured on video. Of these, 228 (54%) were observed using either the road or a facility meant (and signed) specifically for non-motorized use. The highest rate of use was observed at the Healy, AK, location. Although there are a number of ATV tour companies based in Healy, much of the OHV traffic was observed traveling to/from local attractors (e.g., Three Bears Convenience, Totem Inn, and 49th State Brewery). Many were also observed continuing across the Parks Highway and down Healy Spur Road. Regardless of whether an OHV is being used for a tour, the nature of the OHV use does not preclude an operator from being subject to the same laws regarding use on state roads and highways. The lowest rate of use was observed at the Two Rivers, AK, location. Only one day was counted at the Tok, AK, location due to a battery malfunction that melted the wire providing power to the camera and DVR.

Figure 6.25 shows a summary of each count location during Phase 1 (2018 season), with the icons depicting (from left to right) the total number of OHVs observed, total number of occurrences with one or more passengers, percentage of riders wearing helmets, and percentage of occurrences where the OHV was riding either directly on the road or on a non-motorized facility. The dates over which data were collected are listed under the location in italic font. Table 6.1 summarizes both Phase 1 and Phase 2 of the study.

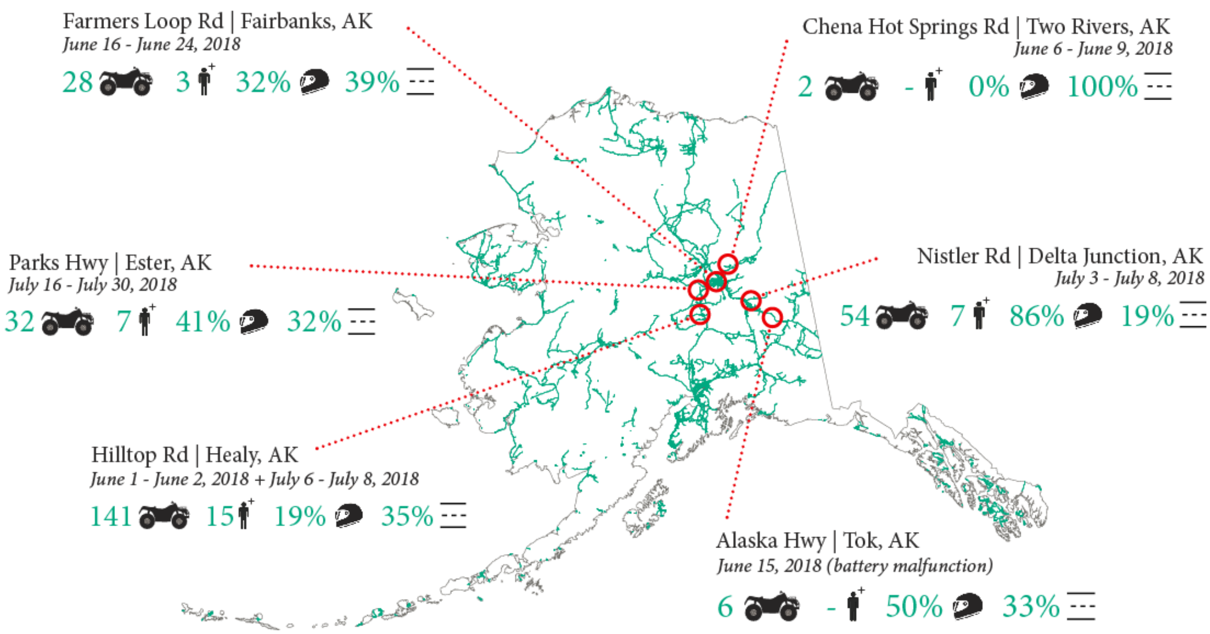


Figure 6.25. OHV count summaries by location during Phase 1.

Table 6.1. OHV count summaries by location during Phase 1 and Phase 2.

Road/Location	Period	Count	Count w/ Passengers	Helmet Use Rate (%)	On-Road Rate (%)
Phase 1 (2018 season)					
Hilltop Road, Healy, AK	6/1/2018 – 6/2/2018, 7/6/2018 – 7/8/2018	141	15	19	35
Chena Hot Springs Road, Two Rivers, AK	6/6/2018 – 6/9/2018	2	-	0	100
Alaska Highway, Tok, AK	6/15/2018[1]	6	-	50	33
Farmers Loop Road, Fairbanks, AK	6/16/2018 – 6/24/2018	28	3	32	39
Nistler Road, Delta Junction, AK	7/3/2018 – 7/8/2018	54	7	86	19
Parks Highway, Ester, AK	7/16/2018 – 7/30/2018	32	7	41	32
Phase 2 (2019 season)					
Nome-Council Highway, Nome, AK	7/26/2019 – 7/27/2019	55	18	34	100
Nome-Teller Highway, Nome, AK	7/26/2019 – 7/27/2019	0	-	-	-
Fishhook Road, Palmer, AK	8/11/2019 – 8/13/2019	9	4	67	0
Sterling Highway, Anchor Point, AK	8/16/2019 – 8/17/2019	0	-	-	-
Chief Eddie Hoffman Highway, Bethel, AK	9/19/2019 – 9/21/2019	84[2]	23	6	100
Ridgecrest Road, Bethel, AK	9/19/2019 – 9/21/2019	11	5	10	36

Notes: [1]battery malfunction; [2]accidental masking of traveled way resulted in undercounting

Based on this data collection effort, it is clear that OHV use near roads is not negligible. Further, the use of OHV modes on roads and non-motorized facilities was as high as 100% (in the case where the "informal" OHV facility coincided with the gravel shoulder of the road). However, this was only two cases at the Two Rivers location. That said, there were several instances at the other observed locations where on-road usage rates were also 100%. On average, on-road and public facility use for the twelve observed count locations was over 50% of total users, but is biased by the Nome-Teller Highway and the Chief Eddie Hoffman counts.

7 DISCUSSION AND CONCLUSIONS

The research presented here had four primary objectives. The first objective was to document Alaska's existing state of practice and policies regarding OHV use on roads and in public rights-of-way. The second objective was to characterize and identify the spatial distribution of OHV crashes and injuries using Alaska DMV crash records and the AKTR. The third objective was to conduct a media discourse analysis using online media with OHV content to construct themes related to OHV issues. The fourth objective was to develop a GIS framework for identifying locations of possible conflict and interest where OHV use is likely and to conduct in-field counts of frequency and use.

Based on the analysis of state-, borough-, and town-based policies on OHV use on roads, it is clear that there are significant variations in policies across the state. Some locations have provisions that require the use of protective equipment, functional headlights, and taillights, or have restrictions on when and where OHVs can be used. In other locations, stipulations on OHV use are non-existent or unenforced (according to local public safety officers). Though it seems that in some cases these policies are specific to a small geographic region and unique locale (e.g., no or limited operation in select parks or streets), several may warrant modification to provide better consistency at the borough and city levels (e.g., speed limits, vehicle restrictions, and hours of operation). It is highly recommended that, where possible, these policies are aligned to achieve consistency. Though policy alignment is not expected to be the sole solution to the problem, it will certainly facilitate rectification of problems that arise when residents relocate and move to new towns or when those enforcing the regulations move to new jurisdictions. Two limitations are worth noting. (1) The information provided in the tables was gathered in June 2017. As Alaska ordinances may change over time, it is recommended that one checks with local authorities about questions or concerns regarding OHV/ATV or snowmachine use and laws before operating in that area. (2) Only a select set of town-level policies were gathered and reviewed. Therefore, the town-level summaries do not provide a complete picture of variations that may exist across the state. A more robust sampling and comprehensive documentation of city/town policies could be completed to identify other possible variations in policies at the local level.

The results of the spatial analysis of crash and injury data indicate that, in general, the Alaska Trauma Registry is a more reliable and comprehensive source of OHV "conflicts" than the Alaska DMV crash records. However, this applies primarily to locations that are located off primary highway corridors. There were 12 cases (i.e., towns) where non-zero values were found in the DMV records and zero values were found in the AKTR, but these cases only accounted for 25 out of the 272 total events in the DMV records. While the AKTR provides better spatial coverage, the DMV records provide more robust data in the larger population centers and more comprehensive information and more variables within the datasets from which to parse out other relevant issues. If possible, agencies that manage datasets like the AKTR should consider formats (e.g., improving the 12-209 classification scheme with consideration of outlying and rural areas) that make cross-source comparisons easier.

For the media discourse analysis, over 1300 articles were retrieved during the period July 1, 2017, through June 30, 2018. From these articles, the four most prevalent content themes included injuries, fatalities, policy, and education. Of these 1300 articles, only 18 were from Alaska. Of those, 55% and 39% were on the subjects of fatalities and policies, respectively. None of the articles discussed education. Nationwide, article content indicated that events happened on the weekend and during nighttime more frequently than at other times of the week and day. Snowmobile-related incidents were more prevalent in off-road-related events, while ATVs/OHVs were more prevalent in on-road-related events. Words indicating that the operator was male (e.g., his, him, he, etc.) were in total more prevalent in off-road events. Several articles indicated that issues exist related to helmet use and injury of passengers, likely on vehicles not intended for more than one or two persons at a time.

The GIS framework for selecting count locations proved useful. Data regarding OHV transportation modes in Alaska were collected and analyzed to gain a better understanding of usage rates. This is a first step in providing a set of data that can be used to normalize other safety-related information specific to OHV use, i.e., DMV crash records and the AKTR. However, a few limitations of the network analysis and site selection methodology must be considered. First, the use of several sources of data has the potential to impart error, as mismatch between layers is likely because of varying scales of the source documents, the intended use of the mapping layers (i.e., easements may have been platted but never developed as actual trails), and cartographic generalization that results when road/trail features are generalized and complex detail is removed. Second, many of these features have not been validated directly in the field, ideally using GPS equipment. Thus, what may appear in an old air photograph used to develop a map layer of trails, may not in reality be traversable, an example being powerline rights-of way. Lastly, the analysis presented here is subjective even though the spatial data were entirely objective. Locations were chosen based on the spatial data, anecdotal evidence, and a priori knowledge of the research team, field visits, and local knowledge. This limitation is considered to have little to no adverse effect on the outcomes and needs of this project. But future work should seek to either (1) develop methods to avoid the use of subjective selection of locations; or preferably (2) develop a robust and static set of sites of interest so that counts can be conducted on a routine basis.

Counts were conducted at twelve locations in Alaska selected from the GIS analysis. These included sites in Fairbanks, Ester, Delta Junction, Tok, Two Rivers, Healy, Anchor Point, Palmer, Nome (two locations), and Bethel (two locations). These counts showed a range of usage rates, some locations with no observations (Nome-Teller Highway) and others as high as 141 in a 5-day period (Hilltop Road). Additionally, rates of helmet use, passenger number, and on-road use also varied widely. This variation is likely due to differences in local preference and practices and proximity to certain types of amenities such as gas stations and recreational areas. Accounting for these types of amenities in the GIS framework could prove beneficial for future count location selections.

The following are two notes worth mentioning regarding select counts:

1. Camera masking was enabled for the counts in Bethel, which obscured any capture of vehicles using the travel lane. Fortunately, a manual count was collected simultaneously and indicates that road use rate was nearly twice as high as that captured by the counters.
2. A count of automobiles conducted for the Nome-Teller Highway indicates that ATVs comprise approximately 7.5% of the traffic stream.

In addition to the GIS-based location selection, this analysis determined that (based on available spatial data at the time of analysis) highways and primary roads connect 184 of the census-defined populated places in Alaska and represent 52% of all populated places. Trails alone connect 72 places (21% of all populated places), and 97 places (27% of all populated places) are not connected by any formal network. On average 67% of the population in isolated places is

Native Alaskan. This percentage increases to roughly 88% when road and highway networks are not present.

Highway-connected places have a significantly higher risk of having ATV and snowmachine traumas than road-connected places (considering both on-road and off-road trauma events). This indicates that part of the issue could be the amount of traffic in connected areas, the frequency of use of ATVs rather than automobiles in non-connected areas leading to fewer mixed-use scenarios, or simply the presence of highways being inherent to higher populated areas and thus higher exposure rates overall. The data indicate that connected and urban locations have significantly more safety issues related to ATVs and OHVs on roadways, information that is supported directly by the OHV counts which show very high rates of OHVs on roads and on non-motorized paths. These usage rates can be tied directly to safety risk and safety outcomes. Considering that enforcement and regulation efforts to date have been largely unsuccessful, approaches could come in the form of alternative networks (e.g., separate facilities) or consideration and implementation of new design practices that can deter poor behavior and/or relocate use to safer areas. Complementary to this, it would be worthwhile to support efforts to develop a multiagency task force with local and user group-specific representation to improve or revamp OHV policies in the State of Alaska.

The results presented here further illustrate the unique transportation environment present in Alaska. It is important that we holistically consider the transportation needs of residents and how those needs vary for those living in villages and towns and those living in larger cities. By integrating data in a GIS framework, some spatial trends are apparent, but future work should seek to integrate the datasets presented here.

Future research should also attempt to define the network structure of trail-connected and trail-only places as well as the extent to which rivers and frozen tundra, particularly during winter months, contribute to these informal networks. Additionally, projects geared toward obtaining more robust counts of ATV and snowmachine use will help to normalize the trauma and DMV crash inventories. It is recommended that OHV injury and fatality rates be compared more explicitly with rates for motorcyclists, which have similar vehicle characteristics but are lawful for use on roads and highways. The results show that the Alaska Trauma Registry tends to be a better source of safety data in rural areas, which have a less defined or rigorous process for reporting incidents and have less police enforcement. Future research could address improvements to rural "self-reporting" methods by making forms easier (current methods require that a form be printed off and mailed in, only in English) through the use of electronic or GIS-based submissions that support Alaska Native languages. Lastly, the mechanical characteristics and capacity of OHVs is evolving quickly, with vehicles becoming heavier with larger engines, and having more throttle response and higher ground clearance. Follow-on research may be able to identify correlations between these advancing vehicle characteristics if driver trends, licensing, and enforcement seem to be providing little in the way of safety improvement.

This research contributes to the larger effort of promoting safe use and travel on roads in the Pacific Northwest. The project efforts presented are based on and were developed in accordance with the Alaska Strategic Highway Safety Plan in efforts toward zero deaths for special users, specifically operators of ATVs and snowmachines. Further, the Federal Highway Administration through the Office of Federal Lands Highway and the Tribal Transportation Program has expressed interest in and provided formal support for matters related to this project, which aligns with their efforts to conduct research on Alaska Winter Trails Safety (AWTS). This study seeks to develop and document opportunities to reduce serious and fatal incidents involving snowmachines that occur on winter trails in Alaska. The scope of the AWTS work may serve as follow-on research, supplementing the work being proposed in this study as it contributes to the spatial extent of safety issues related to non-traditional vehicles by considering formal and informal trail systems that are connected to public facilities.

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APPENDIX A: TRAUMA REGISTRY DATA REQUEST

THE STATE of ALASKA

GOVERNOR BILL WALKER

Department of Health and Social Services

DIVISION OF PUBLIC HEALTH
Emergency Programs

3601 C Street, Suite 424
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ALASKA TRAUMA REGISTRY
RELEASE OF INFORMATION POLICY

INTRODUCTION

The purpose of the Release of Information Policy is to establish guidelines for the release of data from the Alaska Trauma Registry to individuals or organizations requesting information pursuant to the provisions of 7 AAC 26.745 TRAUMA REGISTRY which provides in part: (b) The Trauma System Review Committee shall keep Trauma Registry Data confidential in accordance with AS 18.23.030 except that (3) reports on trauma registry data, not including patient identifiers, physician identifiers, or hospital identifiers, may be provided to epidemiologists, health planners, medical researchers, or other interested persons to study causes, severity, demographics and outcomes of injuries, or for other purposes of studying the epidemiology of injuries or emergency medical services and trauma system issues.

In sharing trauma registry information it is the intent of the Trauma System Review Committee that

1. patient, facility, health care provider, and service confidentiality be protected
2. legitimate and responsible use of trauma registry data for the purposes of promoting public health research, public health education, injury prevention, and peer review be insured, and
3. trauma registry data is represented accurately and without prejudice to an individual or institution.

PROCEDURE

Information requests will be put into one of two categories and considered as outlined below.

1. As established by the Trauma System Review Committee, participating trauma registry hospitals and ambulance services may request reports or information under 7 AAC 26.745. Customized reports or information will be provided to individuals or institutions requesting information pertaining to themselves to include privileged and nonprivileged data and information; privileged data or information is defined as any data or information identifying an individual patient, physician, hospital, or prehospital care provider, and acquired in the performance of activities of the Alaska Trauma Registry program.
2. A recognized and known legitimate individual or organization requesting nonprivileged data or information from the trauma registry for the purpose of promoting public health research or public health education will be provided the requested information by the Trauma Registry Database Manager. The Trauma Registry Database Manager may require that the requestor submit his/her request in writing and provide proof of requester legitimacy. Nonprivileged data or information is defined as any data or information that does not identify an individual patient, physician, hospital, or prehospital care provider, and data or information that constitutes a limited data set under 45 C.F.R. 164.514(e).

Release of information may be contingent upon signature of the following agreement:

ALASKA TRAUMA REGISTRY DATA UTILIZATION AGREEMENT

The Trauma Program of the Alaska Department of Health and Social Services, Division of Public Health, places the following conditions on the acceptance and utilization of data from the Alaska Trauma Registry:

1. Ownership of the data will remain with the Alaska Department of Health and Social Services, Division of Public Health, Section of Emergency Programs/Trauma Program (ADHSS/DPH/EP/TP).

2. Applicant will have access to the "raw" data that has been sent for research and analysis. No other person will have access to the data unless for technical support and with ADHSS/DPH/EP/TP approval. Upon completion of the proposed research project in the application, the "raw" data will be deleted, and transmittal copies destroyed.

3. Access to the data file will be protected by a security system that requires the user to provide at least one password.

4. Release of nonaggregate data to any other individual or agency without the express permission of the ADHSS/DPH/EP/TP is prohibited. If given permission, recipient will ensure that the individual or agency agrees to the same restrictions and conditions that apply to the recipient with respect to the data.

5. The recipient will commit to protecting the identity of trauma registry patients, ambulance services, and hospitals. (Although we do not give names, in some communities, the dates, age, sex, race and place of injury occurrence are sufficient to identify an individual or service.) No use will be made of the identity of a person, service or hospital discovered inadvertently.

6. The recipient will comply with all statutes and regulations related to the protection of patient-identifiable information, including HIPAA privacy and security regulations. An agency using the data will ensure minimum use and provide for personal sanctions against an individual who violates the regulations regarding disclosure.

7. The recipient shall immediately report to ADHSS/DPH/EP/TP any use or disclosure of the data not provided for by its data utilization agreement of which it becomes aware.

8. Data will not be linked to any data set with individually identifiable records.

9. The recipient will submit to the ADHSS/DPH/EP/TP a signed Alaska Trauma Registry confidentiality statement.

10. The data may only be used for studies of a public health nature.

11. The recipient will allow the ADHSS/DPH/EP/TP and the Trauma System Review Committee prepublication review of conclusions based upon data from the trauma registry. (This is to insure correct interpretation of the contents of the database.) If disagreement exists, the recipient will allow the Trauma System Review Committee the opportunity to include their comment within the published document. Acknowledgement is to be given to the ADHSS/DPH/EP/TP as the source of data in any publications, articles or studies that are prepared or published.

12. The recipient will not identify the data or contact the individuals represented in the data.

STUDY PROPOSAL

The study proposal will include objectives, methods, study population of interest, and specific elements needed from the trauma registry. The requestor must inform the Trauma Registry Database Manager of any changes to the study design or changes in the estimation of time for project completion.

DUTIES OF THE TRAUMA SYSTEM REVIEW COMMITTEE

The Trauma System Review Committee will be available to make final determinations on requests for information from the trauma registry. An information request review by the Trauma Registry Database Manager may be accomplished by circulation of the proposal to committee members.

DUTIES OF THE TRAUMA REGISTY DATABASE MANAGER

The Trauma Registry Database Manger will:

1. Prepare requested reports to participating hospitals or ambulance service
2. Answer legitimate requests for non-privileged data by recognized individuals
3. Reject inappropriate requests
4. Work with requestors and Trauma System Review Committee members on requests
5. Report all information requests, as requested by the Trauma System Review Committee, during regularly scheduled meetings by presenting short summaries of information provided.

CONFIDENTIALITY

Any and all release of information pursuant to this policy shall be expressly subject to the provisions of AS 18.23.030 (a), which provides that such information shall be held in confidence and is not subject to subpoena or discovery. Such released information shall be used solely for research/investigation purposes, and shall have any patient, provider and facility identifying information redacted. Those persons or institutions who receive any information pursuant to this policy shall be required to sign and return a confidentiality agreement that forbids re-disclosure of released information, except for the described purposes of study or research pursuant to the provisions of 7 AAC 26.745.

RESEARCH APPLICATION
(To be filled out by applicant)

Upon approval by the Trauma Registry Database Manager, and/or the Trauma Program Manager, and/or Trauma System Review Committee; the Trauma Registry has up to 30 business-days (excluding weekends and holidays), to complete a data request. Depending upon the complexity of the data request, more complex requests could lengthen this time period. This time period has the potential to be expedited for less complex data requests.

Please complete the following for data release.

Name NATHAN BELZ, Ph.D.

Agency UNIVERSITY OF ALASKA FAIRBANKS

Address 245 DUCKERING, 306 TANANA DRIVE

FAIRBANKS, AK 99775-5900

City FAIRBANKS State AK ZIP 99775-5900

Phone Number 907-474-5765

Fax Number 907-474-7067

Email npbelz@alaska.edu

Project Title: MIXED USE SAFETY ON RURAL FACILITIES IN THE PACIFIC NORTHWEST

Expected time of completion 12/31/2016

Person receiving data transfer NATHAN BELZ

I have read and agree to the above conditions for the use of data from the Alaska Trauma Registry of the ADHSS/DPH/EP/TP.

Signature [signature] Date 07.26.2016

(Print Name) NATHAN BELZ

PLEASE ATTACH A COPY OF THE STUDY PROPOSAL

1. Objective
2. Methods
3. Population of interest
4. Years of interest
5. Data elements of interest

(1) **OBJECTIVE**: This research will address the issues associated with providing safe accommodation, limiting the improper use of public rights-of-way, and maintaining mobility, and provide future guidelines for design, education, and enforcement for mixed-use rural facilities. Four specific objectives have been identified as integral pieces of this research effort. First, this research seeks to determine the characteristics of NTV and NMT crashes in five rural area types: edge, traditional/main street, gateway, resource dependent (agriculture and mining), and tribal/village/isolated. Second, this research will document the state-of-practice related to the motivation for use, extent and magnitude of safety-related issues, and deficiencies in fatality/injury reporting methods for NTVs and NMT on mixed-use facilities. Third, and directly tied to the first objective, this research will critique and identify deficiencies in injury/fatality reporting for crashes involving NTVs and NMT on rural mixed-use facilities. Lastly, and more generally, this research will improve the definition of "mixed-use facility" in a rural context by more robustly identifying the types of non-traditional and non-motorized forms of travel and considering the spaces and areas where specific conflicts occur both between and within these forms of travel.

(2) **METHODS:** Use SPSS software to determine frequencies of specific injuries or vulnerable populations. Calculate injury rates and trends using population data from the Alaska Department of Labor and Workforce Development. Serious and fatal crash data analysis to be accompanied by a comprehensive literature review and a regional travel survey.

(3) **POPULATION OF INTEREST:** Injuries due to crashes (motor vehicle, snow machine, ATV, boating, airplane). No single population of particular interest, though rural areas are most concern. All areas in the state needed for comparison.

(4) **YEARS OF INTEREST:** requesting data from the new ATR data system to include 2005 through the most recent available

(5) **Data ELEMENTS OF INTEREST:** All demography, injury event, emergency/admission, and injury data elements. Discharge information not needed.

THE STATE of ALASKA

GOVERNOR BILL WALKER

Department of Health and Social Services

DIVISION OF PUBLIC HEALTH
Emergency Programs

[illegible]
Anchorage, Alaska [illegible]
Main: [illegible]
Fax: [illegible]

ALASKA TRAUMA REGISTRY CONFIDENTIALITY STATEMENT

I understand and agree that in the performance of my role on a steering or review committee or board or group; or as an employee of Southern Region Emergency Medical Services Council, Inc.; or as an employee of ADHSS/DPH/EP/TP; or as an employee of a participating hospital or prehospital service; or as a trauma registry manager, trauma registrar, or data entry clerk; or as a professional services contractor for the Department of Health and Social Services; or as a recipient of trauma registry data, I must maintain and safeguard the confidentiality of privileged Alaska Trauma Registry data and information. I understand that privileged data and information is defined as:

> "Data and information generated and/or acquired by the Alaska Trauma Registry Program which identifies an individual patient, practitioner, or facility; written or recorded records of any trauma registry steering or review committee sessions, data collection staff meeting, or any regularly constituted committee of the Alaska Trauma Registry Program; data and information generated and/or acquired in the administration of the Alaska Trauma Registry Program; any personal knowledge of any representative or employee of the Alaska Trauma Registry Program who can identify an individual patient, practitioner, or facility."

Further, I understand that violation of the Alaska Trauma System Confidentiality Policy may result in legal action.

In order that we may exchange data from time to time which otherwise may be considered of a confidential nature, the undersigned agrees to abide by the following statement:

> "Any data or information identifying an individual patient, physician, hospital, or prehospital care provider, and acquired by either party in the performance of activities of the Alaska Trauma Registry project shall be held in strict confidence and shall not be disclosed to any person or legal entity without the prior written consent of the other party."

[signature] — 07.26.2016

(SIGNATURE) — (DATE)

NATHAN BELZ

(PRINT NAME)

ASST. PROFESSOR

(TITLE)

ALASKA TRAUMA REGISTRY: INJURY SURVEILLANCE DATA ELEMENTS 1991 – 2012 (UPDATED 12/15/2010)			
DEMOGRAPHY	**VARIABLE LABE**	**DECSRIPTION**	ELEMENTS OF INTEREST PLEASE MARK WITH AN X
AGE	AGE		X
SEX	SEX	MALE OR FEMALE	X
RACE	ETHNICITY	WHITE,BLACK,HISPANIC,AMERICAN INDIAN,ASIAN,PACIFIC ISLAND, ALASKA NATIVE, UNK	X
CITY OF RESIDENCE	HOMECITY		X
REGION OF RESIDENCE	RESREGION		X
INJURY EVENT	**VARIABLE LABE**	**DECSRIPTION**	
MONTH OF INJURY	INJMO		X
YEAR OF INJURY	YEAR		X
PLEACE OF INJURY OCCURRENCE	PLACESPEC	ECODE CATEGORY	X
PLACE OF INJURY OCCURRENCE	INJPLACE	FREE TEXT	X
CITY OF INJURY OCCURRENCE	SCENECITY		X
REGION OF INJURY OCCURRENCE	INJREGION		X
ETIOLOGY CODE	ECODE	ICD9 ECODE	X
CAUSE OF INJURY	INJCAUSE		X
INJURY DESCRIPTION	INJDESC		X
INJURY DESCRIPTION CONTINUED	INJDESC2		X
WORK-RELATEDNESS OF INJURY	WORKRELATE		X
INDUSTRY	INDNARR		X
OCCUPATION	OCCNARR		X
SAFETY EQUIPMENT USE (1ST)	PROTECTION		X
SUSPECTED ALCOHOL USE	ALCOHOLDOC	TESTED POSITIVE OR NOTED IN MEDICAL RECORDS	X
SUSPECTED DRUG USE	DRUGDOC	TESTED POSITIVE OR NOTED IN MEDICAL RECORDS	X
EMERGENCY/ADMISSION	**VARIABLE LABE**	**DECSRIPTION**	
BLOOD ALCOHOL CONCENTRATION	EDALCOHOL	TEST RESULT IF PERFORMED	X
DRUG SCREEN	EDDRUGS	TEST RESULT IF PERFORMED	X
TOTAL NUMBER OF INTENSIVE CARE D	ICUDAYS		
INJURIES	**VARIABLE LABE**	**DECSRIPTION**	
PRIMARY DIAGNOSIS	DIAGNOSIS		
DIAGNOSIS CODE 1-10	NCODE1 - NCODE1	ICD9 NCODE	
TRAUMATIC BRAIN INJURY	TBI	TBI = B	
SPINAL CORD INJURY	SPINE	SPNIE = S	
ABBREVIATED INJURY SCORE	AIS_MAX	AIS OF THE MOST SERIOUSLY INJURED BODY REGION SCORES = 1-6, NA, INSUFFICENT DATA	X
ABBREVIATED INJURY SCORE	AIS_TEXT	AIS DESCRIPTION	X
INJURY SEVERITY SCORE	ISS	SCORES = 1-75, NA, INSUFFICENT DATA	X
DISCHARGE	**VARIABLE LABE**	**DECSRIPTION**	
HOSPITAL DISCHARGE DISPOSITION	FINALDISCH		
GENERAL CONDITION ON DISCHARGE	GENCONDDC		
DISABILITY	DISABILITY	THE JUDGEMENT MADE UPON DISCHARGE	
FATALITY	FATAL		
NUMBER OF HOSPITAL DAYS	HOSPDAYS		
NUMBER OF HOSPITAL DAYS	HOSPDAYS2	2ND FACILITY IF TRANSFERRED	
NUMBER OF HOSPITAL DAYS	HOSPDAYS3	3RD FACILITY IF TRANSFERRED	
HOSPITAL CHARGES	HOSPCHARGE	ZERO OR BLANK = NOT COLLECTED AT THE PARTICULAR FACILITY	
HOSPITAL CHARGES	HOSPCHARG2	2ND FACILITY IF TRANSFERRED	
HOSPITAL CHARGES	HOSPCHARG3	3RD FACILITY IF TRANSFERRED	
HOSPITAL PAYMENT SOURCE 1- 4	PAYER1 - PAYER4	ALL AT THE FIRST FACILITY	
HOSPITAL PAYMENT SOURCE	PAYER2ADM	2ND FACILITY IF TRANSFERRED	

MEMORANDUM

State of Alaska

Department of Transportation and Public Facilities
Office of the Commissioner

TO: Dave Eberle, P.E., Acting Regional Director, Central
Tony Johansen, P.E., Regional Director, Northern
Captain Robert Doll, Regional Director, S.E.
Michael Downing, P.E., Director, D&ES, HQ

DATE: May 8, 2000

FILE NO:

TELEPHONE NO: 465-3905
FAX NUMBER: 586-8365
TEXT TELEPHONE: 465-5245

FROM: Boyd Brownfield, P.E.
Deputy Commissioner

SUBJECT: Snow Machine & Off-Highway Vehicle Use of Rights of Way

Snow machine and off-highway vehicle (OHV) use within the department's rights of way is to be managed in accordance with 13AAC 02.455 (attached). The cited regulation gives direction as to the legal use of snow machines and OHVs in highway rights of way. Specifically, except for traversing bridges or culverts as authorized under 13 AAC 02.455(a)(1), traveling within the right of way (but off the roadway and shoulder) as authorized under 13 AAC 02.455(a)(4), and crossings authorized under 13 AAC 02.455(f), the regulation **prohibits:**

- Snow machine or OHV use on multi-use trails, sidewalks or other areas located within a highway right of way that are intended for use by pedestrians;
- Snow machine or OHV use in a controlled access highway right of way;
- Snow machine or OHV use of roadways or shoulders within a highway right of way;
- Snow machine or OHV use of the area dividing roadways of a divided highway;
- Snow machines or OHVs traveling at night in the opposite direction of the traffic in the nearest lane of a roadway within a highway right of way.

As guidance, the department will not prepare and maintain, or allow others to prepare and maintain, a dedicated snow machine or OHV pathway within the highway right of way.

The Department is currently conducting a Winter Transportation Study to examine the issue of OHV use of the rights of way. This study involves substantial public involvement and discussion of these issues. No changes are contemplated to the regulations or department policy until the Winter Transportation Study, policy review and possible adjustments to the regulations are made.

13 AAC 02.455

OPERATION ON HIGHWAYS AND OTHER LOCATIONS.

(a) A snowmobile or an off-highway vehicle may be driven on a roadway or shoulder of a highway only under the following circumstances:

(1) when crossing a highway as provided in (f) of this section, or when traversing a bridge or culvert on a highway, but then only by driving at the extreme right-hand edge of the bridge or culvert and only when the traverse can be completed with safety and without interfering with other traffic on the highway;

(2) when use of the highway by other motor vehicles is impossible because of snow or ice accumulation or other natural conditions or when the highway is posted or otherwise designated as being open to travel by off-highway vehicles;

(3) when highway driving is authorized by an authority having jurisdiction over the highway, but only in accordance with restrictions which may be imposed by that authority with regard to highway use; or

(4) when driven on the right-of-way of a highway which is not a controlled-access highway, outside the roadway or shoulder, and no closer than three feet from the nearest edge of the roadway; night driving may be only on the right-hand side of the highway and in the same direction as the highway motor vehicle traffic in the nearest lane of the roadway; no person may drive an off-highway vehicle within the area dividing the roadways of a divided highway, except to cross the highway as provided in (f) of this section.

(b) Repealed 6/28/79.

(c) Repealed 6/28/79.

(d) Repealed 6/28/79.

(e) Repealed 6/28/79.

(f) A snowmobile or an off-highway vehicle may make a direct crossing of a highway if

(1) the crossing is made approximately at a right angle to the highway and at a location where visibility along the highway in both directions is clear for a sufficient distance to assure safety, and the crossing can be completed safely and without interfering with other traffic on the highway; and

(2) the vehicle is brought to a complete stop before crossing the shoulder or roadway, and the driver yields the right-of-way to all traffic on the highway.

(g) No snowmobile or other off-highway vehicle may cross or travel on a sidewalk, a location intended for pedestrian or other nonmotorized traffic, an alley, or a vehicular way or area which is not open to snowmobile or off-highway vehicle operation, except as provided in (f) of this section.

History -

Eff. 12/31/69, Register 31; am 7/23/70, Register 35; am 6/28/79, Register 70
Authority -

AS 28.05.011

APPENDIX C: MEDIA DISCOURSE ANALYSIS RESULTS

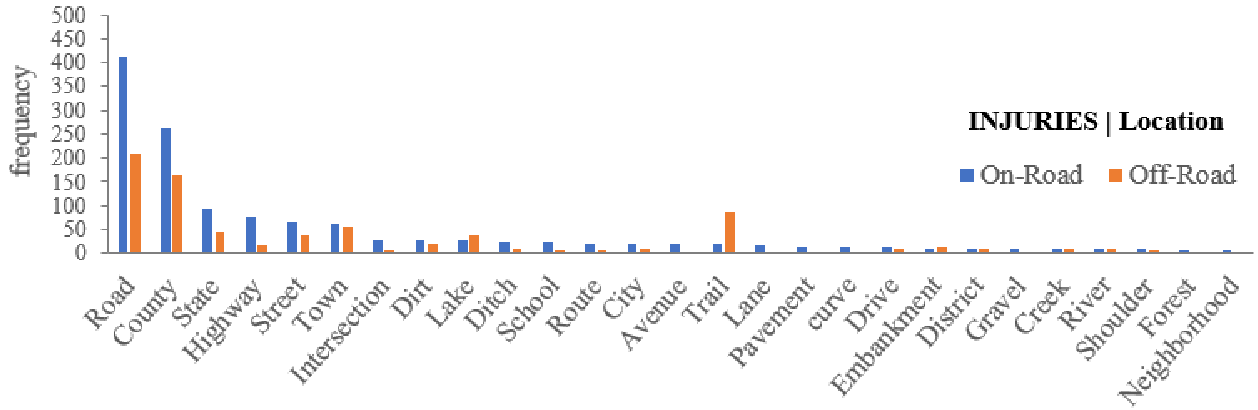

Figure A.1. OHV injury-related media content word frequencies related to location

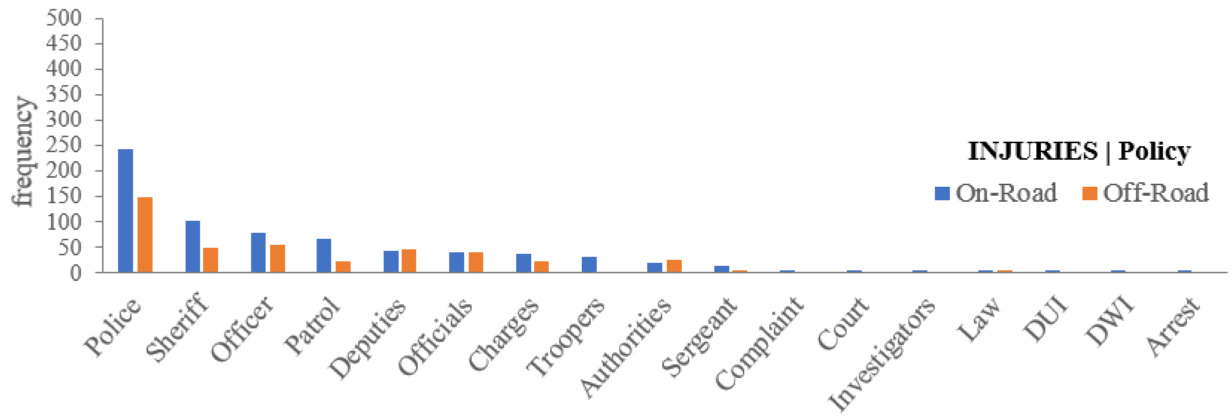

Figure A.2. OHV injury-related media content word frequencies related to policy

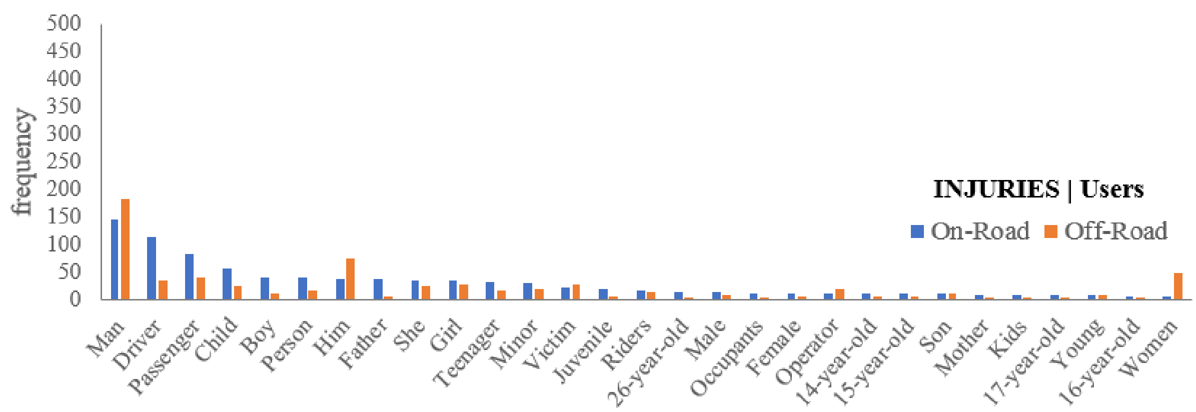

Figure A.3. OHV injury-related media content word frequencies related to users

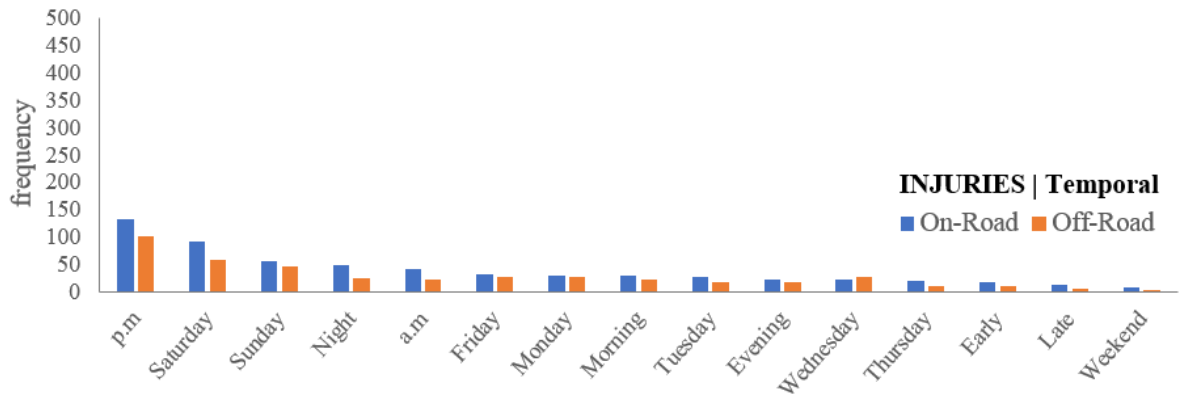

Figure A.4. OHV injury-related media content word frequencies related to temporal condition

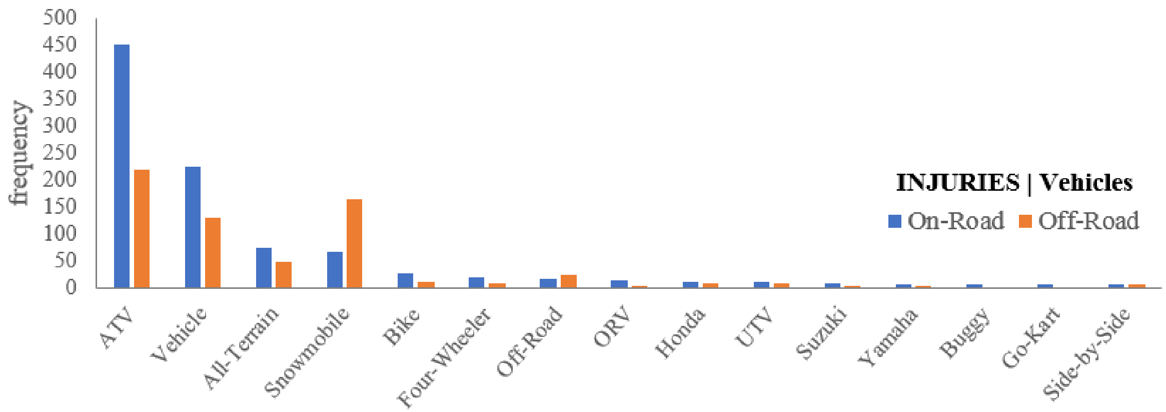

Figure A.5. OHV injury-related media content word frequencies related to vehicle type

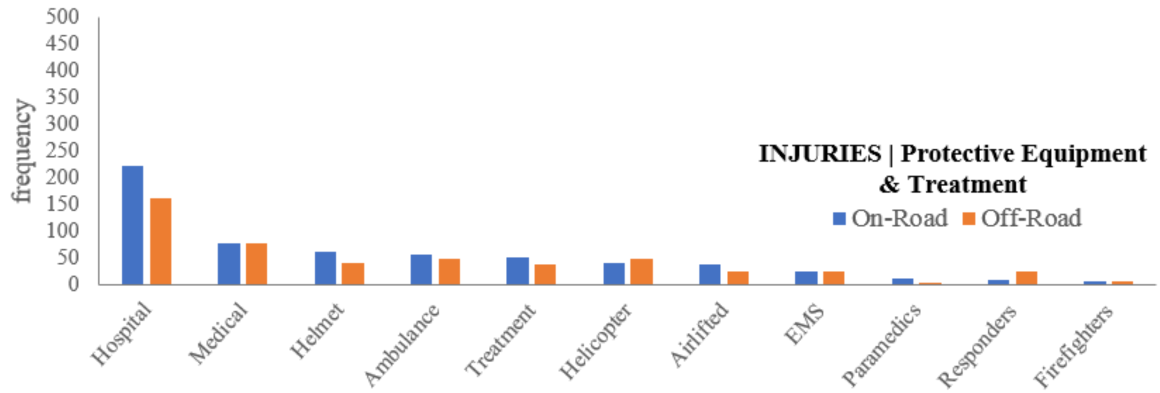

Figure A.6. OHV injury-related media content word frequencies related to protective equipment

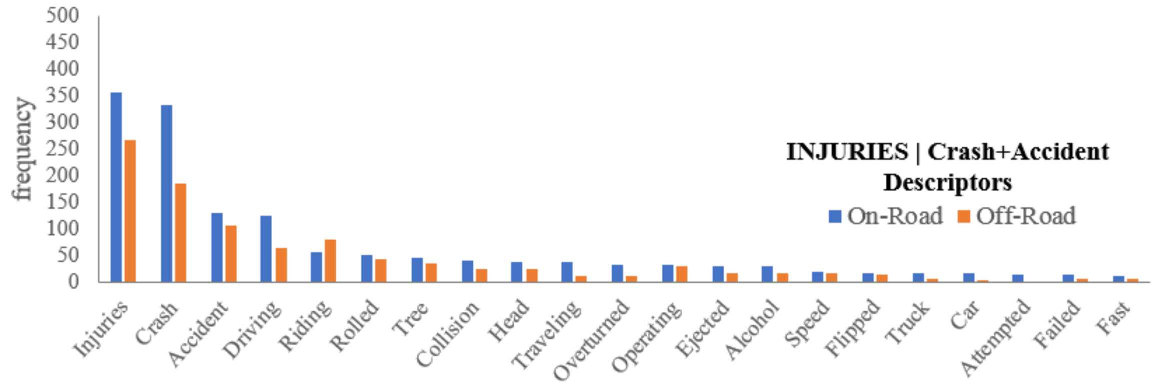

Figure A.7. OHV injury-related media content word frequencies related to general descriptors of the harmful event

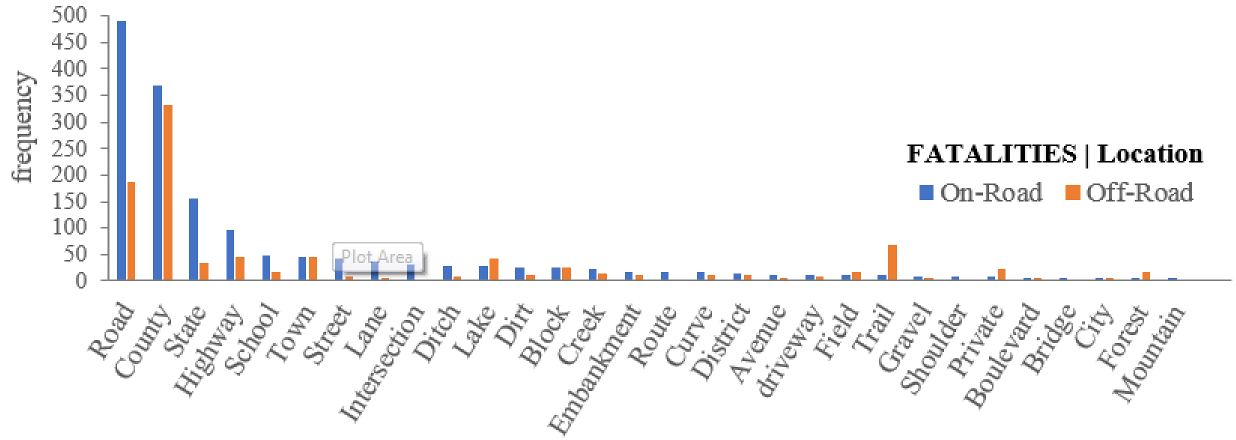

Figure A.8. OHV fatality-related media content word frequencies related to location

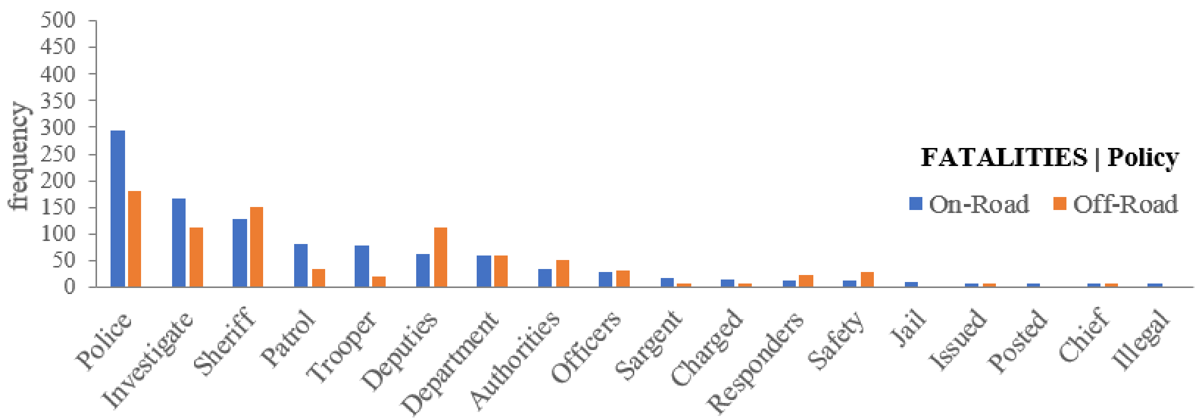

Figure A.9. OHV fatality-related media content word frequencies related to policy

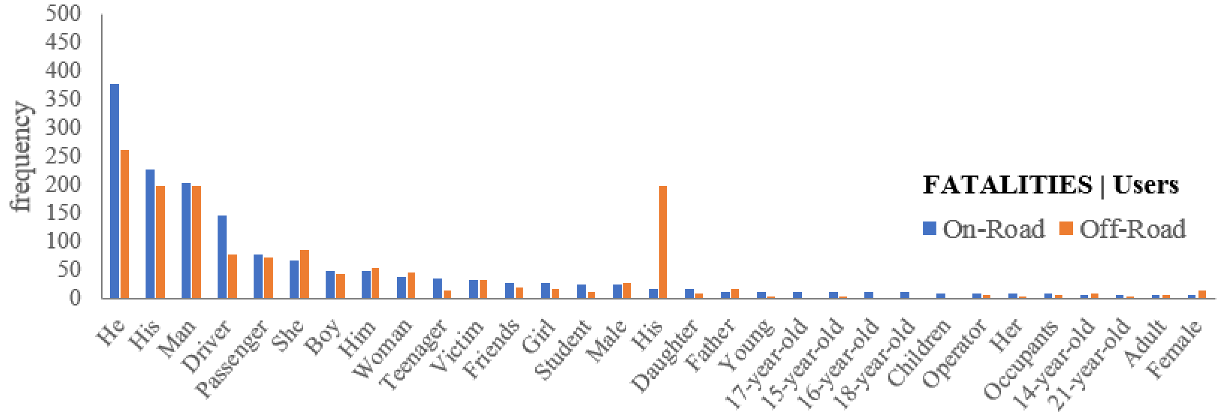

Figure A.10. OHV fatality-related media content word frequencies related to users

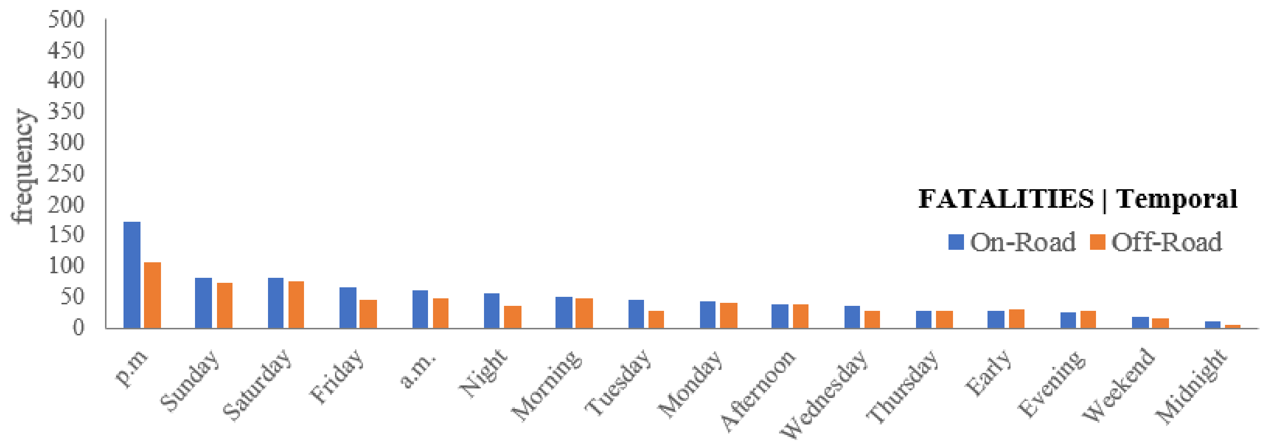

Figure A.11. OHV fatality-related media content word frequencies related to temporal condition

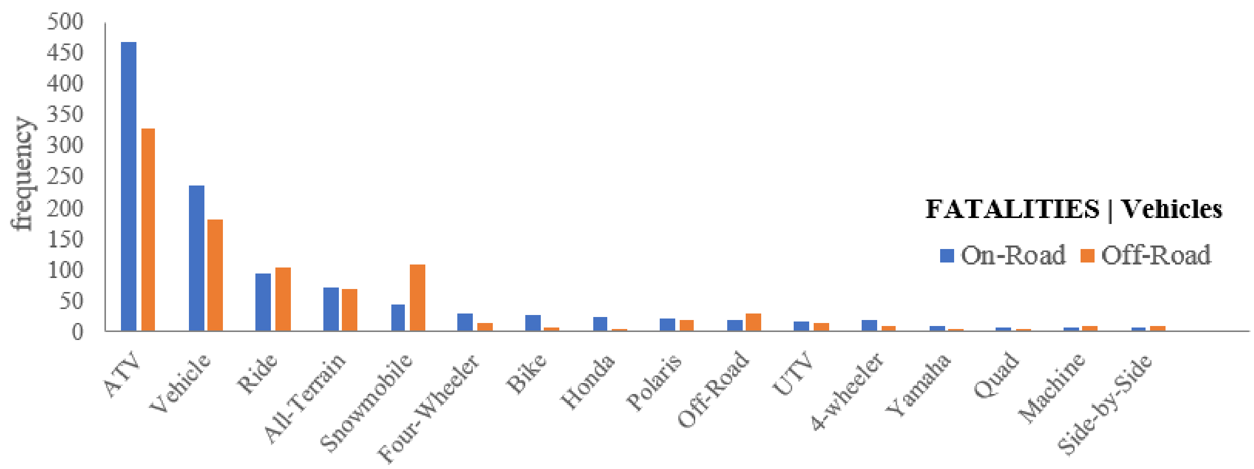

Figure A.12. OHV fatality-related media content word frequencies related to vehicle type

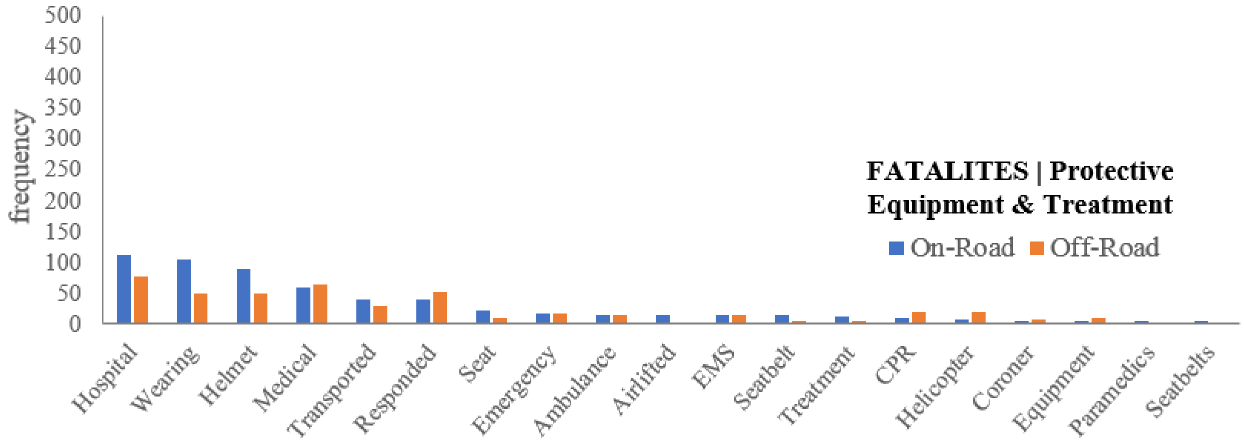

Figure A.13. OHV fatality-related media content word frequencies related to protective equipment

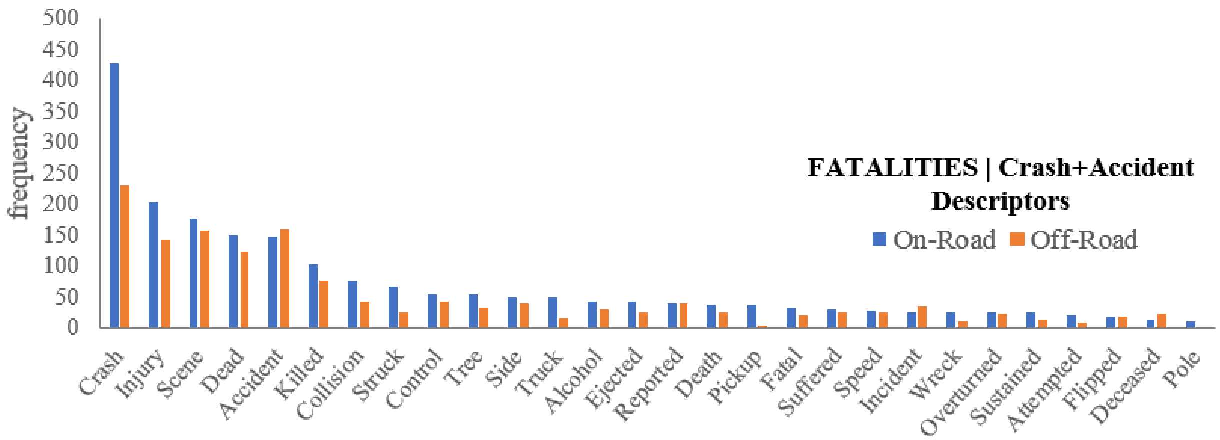

Figure A.14. OHV fatality-related media content word frequencies related to general descriptors of the harmful event

APPENDIX D: MOTION-BASED MULTI-OBJECT TRACKING (MATLAB)

```
%% Motion-Based Multiple-Object Tracking
%%
% Detection of moving objects and motion-based tracking are important
% components of many computer vision applications, including activity
% recognition, traffic monitoring, and automotive safety.  The problem of
% motion-based object tracking can be divided into two parts:
%
% # Detecting moving objects in each frame
% # Associating the detections corresponding to the same object over time
%
% The detection of moving objects uses a background subtraction algorithm
% based on Gaussian mixture models. Morphological operations are applied to
% the resulting foreground mask to eliminate noise. Finally, blob analysis
% detects groups of connected pixels, which are likely to correspond to
% moving objects.
%
% The association of detections to the same object is based solely on
% motion. The motion of each track is estimated by a Kalman filter. The
% filter is used to predict the track's location in each frame, and
% determine the likelihood of each detection being assigned to each
% track.
%
% Track maintenance becomes an important aspect of this example. In any
% given frame, some detections may be assigned to tracks, while other
% detections and tracks may remain unassigned. The assigned tracks are
% updated using the corresponding detections. The unassigned tracks are
% marked invisible. An unassigned detection begins a new track.
%
% Each track keeps count of the number of consecutive frames, where it
% remained unassigned. If the count exceeds a specified threshold, the
% example assumes that the object left the field of view and it deletes the
% track.
%
% For more information please see
%
<matlab:helpview(fullfile(docroot,'toolbox','vision','vision.map'),'multipleO
bjectTracking') Multiple Object Tracking>.
%
% This example is a function with the main body at the top and helper
% routines in the form of
%
<matlab:helpview(fullfile(docroot,'toolbox','matlab','matlab_prog','matlab_pr
og.map'),'nested_functions') nested functions>
% below.

function MotionBasedMultiObjectTracking()

% Create System objects used for reading video, detecting moving objects,
% and displaying the results.

% *********************************************************************
% User Input:
% Must add input folder to Matlab folder manually
```

```
% Assign desired folder name in MATLAB document folder to folderInputName
% variable
% Assign desired file name prefix to location variable, followed by a
% period
% *******************************************************************

folderInputName = 'Videos2';
location = 'Ester.';
addpath(folderInputName);
videos = dir(folderInputName);
count = 0;
n=2199;
oldFrame = [];
[minX, minY, maxX, maxY] = maskingArea();


for k = 3:length(videos)    %loops through (number of videos in folder) times
    vidName = videos(k).name
    obj = setupSystemObjects();

    tracks = initializeTracks(); % Create an empty array of tracks.

    nextId = 1; % ID of the next track

    % Detect moving objects, and track them across video frames.
    while ~isDone(obj.reader)
        frame = readFrame();
        [centroids, bboxes, mask] = detectObjects(frame);
        c=centroids;
        predictNewLocationsOfTracks();
        [assignments, unassignedTracks, unassignedDetections] = ...
        detectionToTrackAssignment();
        updateAssignedTracks();
        updateUnassignedTracks();
        deleteLostTracks();
        createNewTracks();
        displayTrackingResults();
    end
end
%% Create Masking Area
% Creates a limit to what parts of the frame will be used to be
% recorded for motion
    function [minX, minY, maxX, maxY] = maskingArea()

        % ***************************************************************
        % If desired masking area is in upper half of frame, assign new
        % value to minY:
        minY = 0;

        % If desired masking area is in lower half of frame, assign new
        % value to maxY:
        maxY = 480;

        % If desired masking area is in right half of frame, assign new
        % value to minX:
```

```
        minX = 0;

        % If desired masking area is in left half of frame, assign new
        % value to maxX:
        maxX = 710;

    end
%% Create System Objects
% Create System objects used for reading the video frames, detecting
% foreground objects, and displaying results.

    function obj = setupSystemObjects()
        % Initialize Video I/O
        % Create objects for reading a video from a file, drawing the tracked
        % objects in each frame, and playing the video.

        % Create a video file reader.
        obj.reader = vision.VideoFileReader(vidName);
        %obj.videoPlayer=vision.VideoPlayer;

        % creates videoplayer so video can be watched live with object
        % detection
        % obj.videoPlayer = vision.VideoPlayer('Position', [200, 400, 700,
400]);

        % Create System objects for foreground detection and blob analysis

        % The foreground detector is used to segment moving objects from
        % the background. It outputs a binary mask, where the pixel value
        % of 1 corresponds to the foreground and the value of 0 corresponds
        % to the background.

        obj.detector = vision.ForegroundDetector('NumGaussians', 5, ...
            'NumTrainingFrames', 30, 'MinimumBackgroundRatio', 0.7);

        % Connected groups of foreground pixels are likely to correspond to
moving
        % objects.  The blob analysis System object is used to find such
groups
        % (called 'blobs' or 'connected components'), and compute their
        % characteristics, such as area, centroid, and the bounding box.


        % ****************************************************************
        % Adjust MinimumBlobArea for program to recognize different sized
        % objects
        % ****************************************************************'

        obj.blobAnalyser = vision.BlobAnalysis('BoundingBoxOutputPort', true,
...
            'AreaOutputPort', true, 'CentroidOutputPort', true, ...
            'MinimumBlobArea', 1800);
    end
```

```
%% Initialize Tracks
% The |initializeTracks| function creates an array of tracks, where each
% track is a structure representing a moving object in the video. The
% purpose of the structure is to maintain the state of a tracked object.
% The state consists of information used for detection to track assignment,
% track termination, and display.
%
% The structure contains the following fields:
%
% * |id| :                  the integer ID of the track
% * |bbox| :                the current bounding box of the object; used
%                           for display
% * |kalmanFilter| :        a Kalman filter object used for motion-based
%                           tracking
% * |age| :                 the number of frames since the track was first
%                           detected
% * |totalVisibleCount| :   the total number of frames in which the track
%                           was detected (visible)
% * |consecutiveInvisibleCount| : the number of consecutive frames for
%                                 which the track was not detected
(invisible).
%
% Noisy detections tend to result in short-lived tracks. For this reason,
% the example only displays an object after it was tracked for some number
% of frames. This happens when |totalVisibleCount| exceeds a specified
% threshold.
%
% When no detections are associated with a track for several consecutive
% frames, the example assumes that the object has left the field of view
% and deletes the track. This happens when |consecutiveInvisibleCount|
% exceeds a specified threshold. A track may also get deleted as noise if
% it was tracked for a short time, and marked invisible for most of the
% frames.

    function tracks = initializeTracks()
        % create an empty array of tracks
        tracks = struct(...
            'id', {}, ...
            'bbox', {}, ...
            'kalmanFilter', {}, ...
            'age', {}, ...
            'totalVisibleCount', {}, ...
            'consecutiveInvisibleCount', {});
    end

%% Read a Video Frame
% Read the next video frame from the video file.
    function frame = readFrame()
        frame = obj.reader.step();
    end
%% Detect Objects
% The |detectObjects| function returns the centroids and the bounding boxes
% of the detected objects. It also returns the binary mask, which has the
% same size as the input frame. Pixels with a value of 1 correspond to the
% foreground, and pixels with a value of 0 correspond to the background.
%
```

```matlab
% The function performs motion segmentation using the foreground detector.
% It then performs morphological operations on the resulting binary mask to
% remove noisy pixels and to fill the holes in the remaining blobs.

    function [centroids, bboxes, mask] = detectObjects(frame)
        % Detect foreground.
        mask = obj.detector.step(frame);

        % Apply morphological operations to remove noise and fill in holes.
        mask = imopen(mask, strel('rectangle', [3,3]));
        mask = imclose(mask, strel('rectangle', [15, 15]));
        mask = imfill(mask, 'holes');
        % Perform blob analysis to find connected components.
        [~, centroids, bboxes] = obj.blobAnalyser.step(mask);
    end

%% Predict New Locations of Existing Tracks
% Use the Kalman filter to predict the centroid of each track in the
% current frame, and update its bounding box accordingly.
    function predictNewLocationsOfTracks()
        for i = 1:length(tracks)
            bbox = tracks(i).bbox;

            % Predict the current location of the track.
            predictedCentroid = predict(tracks(i).kalmanFilter);

            % Shift the bounding box so that its center is at
            % the predicted location.
            predictedCentroid = int32(predictedCentroid) - bbox(3:4) / 2;
            tracks(i).bbox = [predictedCentroid, bbox(3:4)];
        end
    end

%% Assign Detections to Tracks
% Assigning object detections in the current frame to existing tracks is
% done by minimizing cost. The cost is defined as the negative
% log-likelihood of a detection corresponding to a track.
%
% The algorithm involves two steps:
%
% Step 1: Compute the cost of assigning every detection to each track using
% the |distance| method of the |vision.KalmanFilter| System object(TM). The
% cost takes into account the Euclidean distance between the predicted
% centroid of the track and the centroid of the detection. It also includes
% the confidence of the prediction, which is maintained by the Kalman
% filter. The results are stored in an MxN matrix, where M is the number of
% tracks, and N is the number of detections.
%
% Step 2: Solve the assignment problem represented by the cost matrix using
% the |assignDetectionsToTracks| function. The function takes the cost
% matrix and the cost of not assigning any detections to a track.
%
% The value for the cost of not assigning a detection to a track depends on
% the range of values returned by the |distance| method of the
% |vision.KalmanFilter|. This value must be tuned experimentally. Setting
% it too low increases the likelihood of creating a new track, and may
```

```matlab
% result in track fragmentation. Setting it too high may result in a single
% track corresponding to a series of separate moving objects.
%
% The |assignDetectionsToTracks| function uses the Munkres' version of the
% Hungarian algorithm to compute an assignment which minimizes the total
% cost. It returns an M x 2 matrix containing the corresponding indices of
% assigned tracks and detections in its two columns. It also returns the
% indices of tracks and detections that remained unassigned.

    function [assignments, unassignedTracks, unassignedDetections] = ...
            detectionToTrackAssignment()

        nTracks = length(tracks);
        nDetections = size(centroids, 1);

        % Compute the cost of assigning each detection to each track.
        cost = zeros(nTracks, nDetections);
        for i = 1:nTracks
            cost(i, :) = distance(tracks(i).kalmanFilter, centroids);
        end

        % Solve the assignment problem.
        % ****************************************************************
        % costOfNonAssignment must be manually tuned
        % ****************************************************************
        costOfNonAssignment = 100;
        [assignments, unassignedTracks, unassignedDetections] = ...
            assignDetectionsToTracks(cost, costOfNonAssignment);
    end

%% Update Assigned Tracks
% The |updateAssignedTracks| function updates each assigned track with the
% corresponding detection. It calls the |correct| method of
% |vision.KalmanFilter| to correct the location estimate. Next, it stores
% the new bounding box, and increases the age of the track and the total
% visible count by 1. Finally, the function sets the invisible count to 0.

    function updateAssignedTracks()
        numAssignedTracks = size(assignments, 1);
        for i = 1:numAssignedTracks
            trackIdx = assignments(i, 1);
            detectionIdx = assignments(i, 2);
            centroid = centroids(detectionIdx, :);
            bbox = bboxes(detectionIdx, :);

            % Correct the estimate of the object's location
            % using the new detection.
            correct(tracks(trackIdx).kalmanFilter, centroid);

            % Replace predicted bounding box with detected
            % bounding box.
            tracks(trackIdx).bbox = bbox;

            % Update track's age.
            tracks(trackIdx).age = tracks(trackIdx).age + 1;
```

```
            % Update visibility.
            tracks(trackIdx).totalVisibleCount = ...
                tracks(trackIdx).totalVisibleCount + 1;
            tracks(trackIdx).consecutiveInvisibleCount = 0;
        end
    end

%% Update Unassigned Tracks
% Mark each unassigned track as invisible, and increase its age by 1.

    function updateUnassignedTracks()
        for i = 1:length(unassignedTracks)
            ind = unassignedTracks(i);
            tracks(ind).age = tracks(ind).age + 1;
            tracks(ind).consecutiveInvisibleCount = ...
                tracks(ind).consecutiveInvisibleCount + 1;
        end
    end

%% Delete Lost Tracks
% The |deleteLostTracks| function deletes tracks that have been invisible
% for too many consecutive frames. It also deletes recently created tracks
% that have been invisible for too many frames overall.

    function deleteLostTracks()
        if isempty(tracks)
            return;
        end

        invisibleForTooLong = 20;
        ageThreshold = 8;

        % Compute the fraction of the track's age for which it was visible.
        ages = [tracks(:).age];
        totalVisibleCounts = [tracks(:).totalVisibleCount];
        visibility = totalVisibleCounts ./ ages;

        % Find the indices of 'lost' tracks.
        lostInds = (ages < ageThreshold & visibility < 0.6) | ...
            [tracks(:).consecutiveInvisibleCount] >= invisibleForTooLong;

        % Delete lost tracks.
        tracks = tracks(~lostInds);
    end

%% Create New Tracks
% Create new tracks from unassigned detections. Assume that any unassigned
% detection is a start of a new track. In practice, you can use other cues
% to eliminate noisy detections, such as size, location, or appearance.

    function createNewTracks()
        centroids = centroids(unassignedDetections, :);
        bboxes = bboxes(unassignedDetections, :);
```

```
        for i = 1:size(centroids, 1)

            centroid = centroids(i,:);
            bbox = bboxes(i, :);

            % Create a Kalman filter object.
            kalmanFilter = configureKalmanFilter('ConstantVelocity', ...
                centroid, [200, 50], [100, 25], 100);

            % Create a new track.
            newTrack = struct(...
                'id', nextId, ...
                'bbox', bbox, ...
                'kalmanFilter', kalmanFilter, ...
                'age', 1, ...
                'totalVisibleCount', 1, ...
                'consecutiveInvisibleCount', 0);

            % Add it to the array of tracks.
            tracks(end + 1) = newTrack;

            % Increment the next id.
            nextId = nextId + 1;
        end
    end

%% Display Tracking Results
% The |displayTrackingResults| function draws a bounding box and label ID
% for each track on the video frame and the foreground mask. It then
% displays the frame and the mask in their respective video players.

    function displayTrackingResults()
        % Convert the frame and the mask to uint8 RGB.
        frame = im2uint8(frame);
        mask = uint8(repmat(mask, [1, 1, 3])) .* 255;

        % Enter desired output image filetype
        % ****************************************************************
        b = '.png';

        % Adjusts number of frames that must be changed for image to be
        % displayed
        % ****************************************************************
        minVisibleCount = 10;

        if ~isempty(tracks)
            % Noisy detections tend to result in short-lived tracks.
            % Only display tracks that have been visible for more than
            % a minimum number of frames.
            reliableTrackInds = ...
                [tracks(:).totalVisibleCount] > minVisibleCount;
            reliableTracks = tracks(reliableTrackInds);
```

```
    % Display the objects. If an object has not been detected
    % in this frame, display its predicted bounding box.
    if ~isempty(reliableTracks)
        % Get bounding boxes.
        bboxes = cat(1, reliableTracks.bbox);
        % Get ids.
        ids = int32([reliableTracks(:).id]);

        % Create labels for objects indicating the ones for
        % which we display the predicted rather than the actual
        % location.
        labels = cellstr(int2str(ids'));

        predictedTrackInds = ...
            [reliableTracks(:).consecutiveInvisibleCount] > 0;
        isPredicted = cell(size(labels));
        isPredicted(predictedTrackInds) = {' predicted'};
        labels = strcat(labels, isPredicted);

        % Draw the objects on the frame.
        % Uncomment this for yellow rectangle to appear around
        % object
        % ********************************************************
        % frame = insertObjectAnnotation(frame, 'rectangle', ...
        %   bboxes, labels);
    end
end

nDetections = size(c, 1);

if nDetections >= 1
    oldFrame = frame;
    if (count >= minVisibleCount)
        for i = 1:length(reliableTracks)
            % bbox parameters: [x y width height] where x,y is the
            % upper  left corner
            maskingBox = reliableTracks(i).bbox;
            whos
            xMinBox = double(maskingBox(1));
            yMinBox = double(maskingBox(2));
            boxWidth = double(maskingBox(3));
            boxHeight = double(maskingBox(4));

            %=====================================================
            % comment if statement if masking is not desired
            %if (xMinBox < maxX && (xMinBox + boxWidth) > minX &&...
              %     yMinBox < maxY && (yMinBox + boxHeight) > minY)

               for z = 1:length(reliableTracks)
               reliableTracks(z)
               end

               a = num2str(n);
               name = strcat(location,a,b);
               imwrite(frame,name);
```

```
                       n = n+1;
                       count=0;
                       break;
                    %end
               end
            else
                % counts the number of frames containing motion before a
                % frame is saved to file
                count = count+1;
            end

    % If motion is detected but does not reach minVisibleCount, the last
    % frame containing the motion is saved
    %{
        elseif count >= 1 && maskingBox(1)<maxX && maskingBox(2)>minX &&
maskingBox(3)<maxY && maskingBox(4)>minY
            a = num2str(n);
            name = strcat(location,a,b);
            imwrite(oldFrame,name);
            n = n+1;
            count = 0;
    %}
        else
            count = 0;
        end

        %obj.videoPlayer.step(frame);
    end
%% Summary
% The tracking in this example was solely based on motion with the
% assumption that all objects move in a straight line with constant speed.
end
```