Utilizing Safety and Speed Analysis to Establish Default Speed Limits on Gravel Roads

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ABSTRACT

The default speed limit of Wyoming gravel roads without a posted speed limit is covered under the same speed laws as the state highway system. The default statutory speed limit is 65 mph on all local gravel roads throughout the state. It has become a concern that excess speeds on gravel roads are unsafe, cause unnecessary road damage, and are irresponsible. This study was conducted to determine whether or not the speed limit should be altered. Speed and crash data were collected on gravel roads in eight counties throughout Wyoming. Traffic counters were placed on 83 roads in Wyoming counties to collect the necessary information to conduct the study. The 85th percentile speed was found to be 40 mph while the 85th percentile of the 85th percentile speed was 52 mph. Crash data was then collected from the CARE 9 database on the number of fatal, injury, and property damage only crashes on those road sections. This data was used to perform the risk analysis on the percent likelihood of having a crash event happen for every 5 mph of speed increased over 40 mph. It was found the observed number of crashes was 11.5 percent more when the running speed on a gravel road is increased from 50 mph than when it is 45 mph. The state of Wyoming's legislative transportation subcommittee has voted to reduce the default speed limit from 65 to 55 mph on gravel roads in Wyoming. The findings and methodology of this study will help states in setting a safer and more realistic speed limit within their jurisdictions.

KEYWORDS: default speed limits, crashes, safety, gravel roads

INTRODUCTION

Wyoming has over 21,000 miles of public collector and local roads, the majority of which are gravel. Because of the vast expanse of the state and the high number of miles maintained by Wyoming counties, it is very difficult to provide speed zones for every section of roadway. Instead, Wyoming defaults back to a statutory speed limit on those un-posted roads.

The current default statutory speed limit is 65 mph for all un-posted roads in Wyoming. Article 3 on Speed Regulations of the state code sets a limit of 65 mph "for all other roads." This includes state highways as well as local gravel roads. Because the only enforceable speed limit is so high, there is a need to re-evaluate this law to determine if action should be taken to change the statutory speed limit.

Many factors such as geometrics, functional classification, design speed, and the 85th percentile speed must be considered when determining the speed limit on paved roads. Gravel roads, however, use a much more general process for determining the speed limit. Wyoming's default speed limit is higher than 41 other states (USDOT 2001). Twenty- seven states have a default speed limit of 55 mph. Table 1 shows the default statutory speed limits for all states.

TABLE 1 States Statutory Speed Limits on Local Roads in 2001, USDOT (2001)

Speed Limit	States
35 mph	Alabama, Georgia, and Virginia
40 mph	Massachusetts and South Carolina
45 mph	Maine
50 mph	Delaware, Maryland, Nebraska, Rhode Island (45 mph at night), Vermont, and Washington
55 mph	California, Colorado, Connecticut, Florida, Hawaii, Idaho, Illinois, Indiana, Iowa (50 mph at night), Kansas, Kentucky, Louisiana, Michigan, Missouri, New Hampshire, New Jersey, New York, North Carolina, North Dakota, Ohio, Oklahoma, Oregon, Pennsylvania, South Dakota, Utah, West Virginia, Wisconsin
60 mph	Arkansas (50 mph for trucks) and Texas (55 mph at night)
65 mph	Alaska, Arizona, Minnesota, Mississippi (55 mph for trucks), Tennessee, and Wyoming
70 mph	Montana (65 mph at night)
75 mph	Nevada and New Mexico

Safety on gravel roads is a major concern for the State of Wyoming. It has become evident that a default statutory speed limit of 65 mph is too high for a number of reasons. This study will assess the current speeds being traveled on gravel roads in Wyoming and the crash severity associated with those speeds. It will also assess the risk involved with traveling at higher speeds as well as driver acceptability of those speed limits.

OBJECTIVES

The main objectives of this study are to: (1) evaluate the effect of observed vehicle operating speeds on crash frequency and severity on low-volume gravel roads; (2) compare the crash risk associated with increased travel speeds and; (3) provide a recommendation for revision to the statutory speed limit law on unpaved roads in Wyoming. The findings of this study will also help other states in setting more realistic speed limits.

LITERATURE REVIEW

Speed limits are the main form of traffic regulations in the United States. The most basic form of speed laws in all states affirm that drivers should operate a vehicle at a speed that is reasonable and prudent for the given conditions. This means that the driver is responsible for selecting speeds with regards to weather, traffic, and road surface, ITE (2009). According to the Institute of Transportation Engineers, statutory speed limits or blanket speed limits enact a maximum speed limit for roadways. Statutory speed limits are in effect unless a speed limit is posted.

Speed zones are determined by state and local governments and are instituted in certain areas though traffic engineering studies. Speed zones are always posted and are determined by taking into account prevailing vehicle speeds, roadway geometrics, traffic control characteristics, crash experience, and conditions not apparent to the driver. ITE also states that prevailing speeds are the primary determinate of speed limits, with spot speed studies being the primary factor in collecting this data. On gravel roads surface conditions have a large effect on the speed traveled by motorists. Motorists traveling at speeds of their choosing create a large speed range on gravel roads. ITE states that realistic speed limits are determined by a complimentary relationship between desired speed, operating speed, and the posted speed limit. A realistic statutory speed limit for gravel roads will be both safe, effective and respected by motorists, ITE (2009).

The design standards used for county roads in Wyoming are based on AASHTO's Policy on Geometric Design of Highways and Streets, according to a memo from the Wyoming Department of Transportation (WYDOT) (3). This memo discussed how the design speed affects design standards for county roads, and summarized AASHTO's design criteria for rural roads. The memo explains that posted speed limits are not the highest speeds that may be used by drivers. Instead, these limits are set to approximate the 85^{th} percentile speed. Design speed is a speed that is selected in order to determine the various geometric design features of a roadway, and should be the same or higher than the posted speed, Laird (2010). Some design features that are directly related to design speed include curvature, superelevation and sight distance, AASSHTO (2004). Other features, such as land and shoulder widths and clearances to walls and rails, are not directly related to design speed, but do affect vehicle speeds, Laird (2010). As a result, these features should be considered for higher design speeds.

Most county roads in Wyoming are classified as Local Rural or Rural Collector roads, Laird (2010). According to AASHTO, Rural Collector roads generally serve travel of intracounty importance and are composed of routes that have shorter travel distances than on arterial routes, ASSHTO (2004). Local Rural roads also serve travel over relatively short distances, but primarily provide access to land adjacent to the collector network, ASSHTO (2004). The minimum design speeds for Rural Collector roads and Local Rural roads are shown in Table 2

and Table 3, respectively. As shown in these tables, the design speed for rural roads is dependent upon the type of terrain and the Average Daily Traffic (ADT).

TABLE 2 Minimum Design Speeds for Rural Collectors *(4)*

	US Customary		
	Design Speed (mph) for Specified Design Volume (veh/day)		
Type of Terrain	0 to 400	400 to 2000	over 2000
Level	40	50	60
Rolling	30	40	50
Mountainous	20	30	40

TABLE 3 Minimum Design Speeds for Local Rural Roads *(4)*

	US Customary					
	Design Speed (mph) for Specified Design Volume (veh/day)					
Type of Terrain	under 50	50 to 250	250 to 400	400 to 1500	1500 to 2000	over 200
Level	30	30	40	50	50	50
Rolling	20	30	30	40	40	40
Mountainous	20	20	20	30	30	30

An extensive gravel road study was done by Kansas State University in March of 2009. That study focused on developing a system for determining the speed limit for a particular road section. They found that the speeds being traveled on gravel roads had less to do with the actual speed limit and were affected more by roadway geometrics, roadway characteristics, and drivers' perception of safety, Dissanayake (2009). The study also indicated that many state DOTs, such as Oregon and Minnesota, feel that because the conditions of gravel roads are always changing, it is not logical to place a speed zone on such a road. There are a few well accepted thoughts on speed limits. These considerations are as follows: (1) speed limits do not affect traffic speeds; (2) most drivers travel at prudent speeds and are able to recognize conditions that require more caution; (3) the more uniform the stream of traffic, the less chance there is for crashes; and (4) unreasonably low speed limits are difficult to enforce.

To the knowledge of the author, there are no studies that use the method described hereafter to determine crash probability at different running speed groups. Several studies have evaluated speed limits and developed methods on the determination of speed limits on paved roads. It was determined that because gravel roads have more variables with much smaller ADTs, that a separate method should be used.

DATA COLLECTION

In this study, Diamond Apollo automated traffic counters were used for data collection. Each set of traffic counters consists of a traffic counter device, two pneumatic tubes, and some additional

accessories. The two pneumatic tubes are placed across the road, eight feet apart from the other. Two ends of the tubes are fixed on the shoulder, while the other two ends are connected to the traffic counter device. When a vehicle passes over the tubes, air pulses are created by each axle. These air pulses are sensed by the counter and are recorded and analyzed to create volume, speed, and axle classification data. The information collected by the traffic counters was analyzed with the TRAXPro and Diamond Traffic programs to yield output data. Output data consists of speed values, including mean travel speed, 50^{th} percentile speed, and 85^{th} percentile speed. Other traffic information including total vehicle count, vehicle classification, and Average Daily Traffic (ADT) are also provided. The duration of data collection at each site was usually one to two weeks.

Table 4 summarizes the scope of the data collection by listing the number of roads and the number of vehicles counted in each county. A total of 83 test sections were analyzed, representing 8 counties in Wyoming. The Wyoming Technology Transfer Center provided traffic counters and equipment for all test sections. Wyoming Technology Transfer Center employees installed the traffic counters in Laramie, Carbon, and Johnson counties. The traffic counters for the other five counties were installed by their respective counties. The counties selected demonstrate a diverse sample of geography, demographics, and roadway maintenance programs. The roads were selected by county officials to be included in this study. Figure 1 highlights these test counties on a Wyoming state map and lists the number of roads analyzed in each test county.

TABLE 4 Summary of Test Sections

County	Number of Roads	Vehicles Counted
Carbon	10	20996
Converse	18	7542
Crook	26	5711
Johnson	10	11249
Laramie	11	16222
Lincoln	2	2612
Sweetwater	5	3630
Uinta	1	770

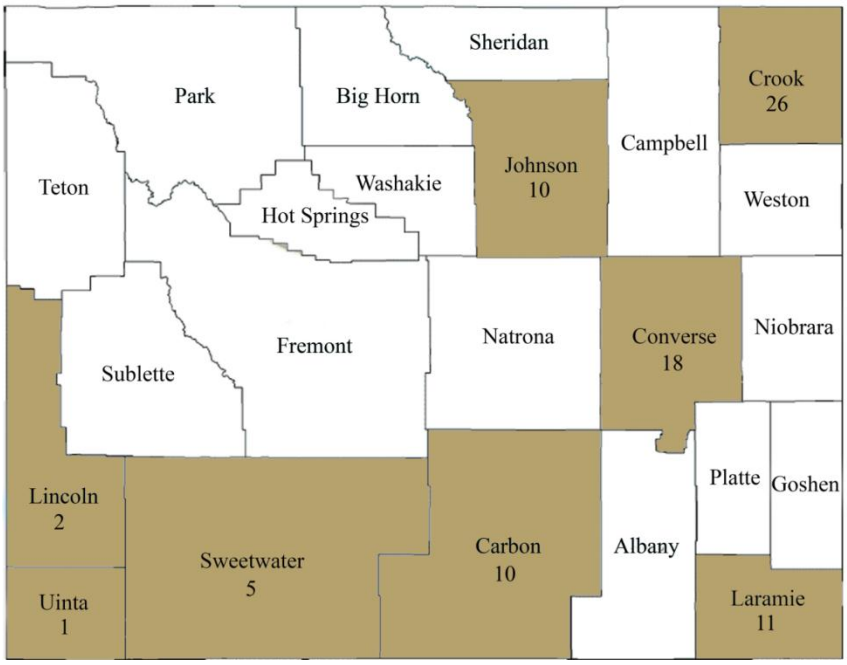

FIGURE 1 Map of Wyoming Test Sections

Crash data was also collected for every test section, in order to compare the crash risk associated with increased travel speeds. Crash data was collected using the CARE 9 database program. This data is comprised of all reported crashes from 1998 to 2007 and shows the number of Fatal, Injury, and Property Damage Only (PDO) crashes on each road section. Each reported crash is categorized by its highest severity. A crash that resulted in two fatalities and one injury, for example, would count as one fatal crash only. This data is presented in the Crash Risk Data section of Data Analysis.

DATA ANALYSIS

Speed Data

In the State of Wyoming, the default statutory speed limit is 65 mph for all un-posted roads. The only enforceable speed limit is very high for unpaved roads; therefore re-evaluation of this statutory speed law is needed to determine if the statutory speed limit should be changed. Wyoming's default speed limit is higher than 41 other states *(1)*. Twenty- seven states use a default speed limit of 55 mph. Figure 2 summarizes the default statutory speed limits for all states.

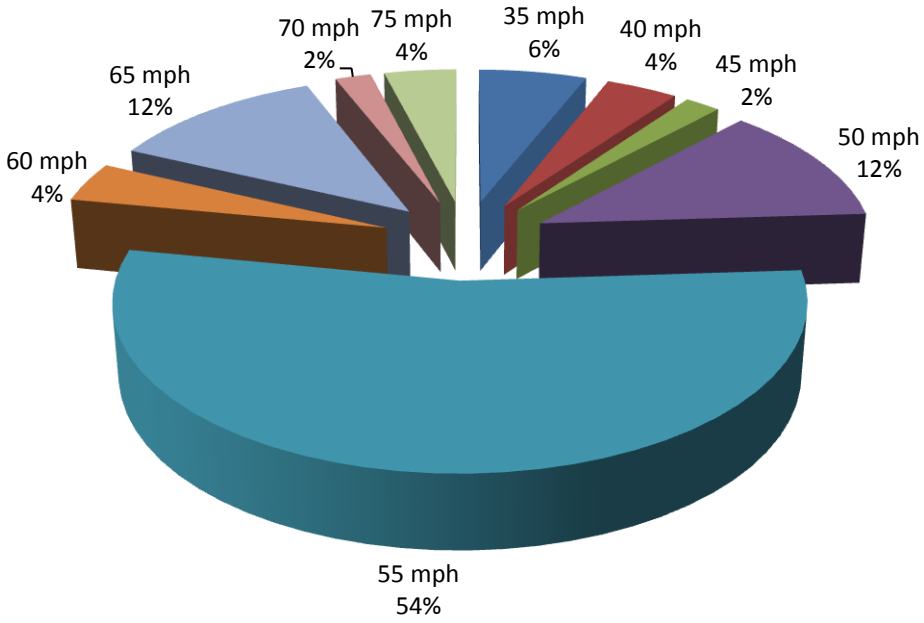

FIGURE 2 State Statutory Speed Limit Distribution on Unpaved Roads in 2001 *(1)*

The first objective of this study is to evaluate the effect of vehicle operating speeds on crash frequency and severity on low-volume gravel roads. The information collected by the traffic counters was analyzed with the TRAXPro and Diamond Traffic programs to yield output data. Output data consists of speed values, including mean travel speed, 50th percentile speed, and 85th percentile speed. Other traffic information including total vehicle count, vehicle classification distribution, and Average Daily Traffic (ADT) are also provided.

With the given vehicle classification distribution and ADT, the Average Daily Truck Traffic (ADTT) was then calculated for each road. Table 5 shows all collected speed data on the road sections tested. This table includes the Total Vehicle Count for the duration of data collection, the ADT, the ADTT, the 50th Percentile speed, the 85th Percentile speed, and the average speed for each test section. All 83 test sections are sorted by their respective Counties and named under the road column. Additionally, the 85th percentile speed and average speed were further analyzed by calculating (1) the average; (2) the 85th percentile; (3) the standard deviation; and (4) the median for all collected data. This information is included in the last four rows of Table 5.

TABLE 5 Collected Speed Data on Wyoming Unpaved Roads

County	Road	Total Vehicle Count	ADT	ADTT	50% Speed (mph)	85% Speed (mph)	Average Speed (mph)
Carbon	Baggs Dixon 702	170	46	17	31	40	30
Carbon	Brush Creek 203 A	1554	116	35	31	41	32
Carbon	Buck Creek 550 1	3879	197	20	25	42	27
Carbon	Dad / Wamsutter 701 North	6496	262	140	35	49	35
Carbon	Finley Hill 353	1654	86	19	24	30	24
Carbon	Four Mile 603	1538	194	95	38	53	40
Carbon	Hanna Leo 291	238	37	10	41	50	41
Carbon	Jack Creek 500 1	2841	201	37	31	41	32
Carbon	Poison Basin 700	1014	128	61	40	56	42
Carbon	Savery North 561N	1612	216	58	25	33	26
Converse	Esterbrook Road 5	1039	145	2	22.1	27.4	21.8
Converse	Glendo Road 6	408	57	0	22	28.4	21.3
Converse	Braae Road 7	569	79	0	24.6	30.7	24.5
Converse	Bedtick Road 8	580	92	1	19.9	24	19.8
Converse	Spring Canyon Road 11	419	67	1	25.7	37.7	27
Converse	Laprele Hall Road 12	187	30	7	12.7	19.4	13.7
Converse	Windy Ridge Road 14	420	59	2	30.4	36.8	30.1
Converse	Moss Agate Road 15	85	10	0	14.1	17.1	14
Converse	Old Fort Fetterman Road 16	575	79	2	29.6	35.9	28.4
Converse	Stevens Road 20	210	35	0	22	26.1	21.4
Converse	Coal Creek Road 22	929	134	6	26.3	36.4	26.2
Converse	Cold Springs Road 24	554	77	7	22.7	31.2	22
Converse	Cherokee Trail Road 30	636	103	2	21.7	29.9	22.2
Converse	Jenne Trail Road 34	298	49	7	10.7	15.1	11.7
Converse	Dull Center Road 38	385	63	4	29	37.5	28.5
Converse	Combs Road 42	89	15	0	17.5	21.7	17
Converse	Eberspecher Road 55	60	10	0	19.9	25.1	19
Converse	Bill Hall Road 63	99	16	1	16.2	20.2	16.2
Crook	Banks West	252	85	72	46.7	57.8	46.2
Crook	Birtha South	948	320	31	40.3	48.1	40.4
Crook	Cabin Creek South	309	109	89	44.4	55.5	43.9
Crook	Canyon Springs East	207	67	53	35.6	43.8	34.1
Crook	D Road	152	11	6	27.8	38.5	28.3
Crook	Garman Road	108	35	21	46.5	57.3	44.1
Crook	Grazing Ass Road	95	32	19	45.9	58	43.3
Crook	Grazing Ass Road South	208	19	14	23.9	33.9	24.4
Crook	H Kay North	64	22	3	28.5	33.7	28.5
Crook	Humphrey Road	143	36	5	28	35.1	28.3
Crook	Inyan Kara Creek North	161	55	1	23.1	29.6	23.5
Crook	Left Creek	50	17	9	31.9	41.6	32.1
Crook	McKean South	178	45	1	41.6	52.6	42.3
Crook	Miller Creek	202	69	40	39	47	38.7
Crook	Mule Creek Road	258	32	30	47	53.4	45.5
Crook	New Haven 2	680	209	106	48.9	60.6	48.6
Crook	New Haven North	120	40	17	51.9	67	51.5
Crook	Robison Road	532	179	1	26.5	31.1	26
Crook	Schlup Road	150	50	32	29.6	38.3	27.8

TABLE 5, Continued

County	Road	Total Vehicle Count	ADT	ADTT	50% Speed (mph)	85% Speed (mph)	Average Speed (mph)
Crook	Sndc Iynkra Road	135	46	35	40.6	46.4	39.5
Crook	Snooks Road	45	15	4	38	44.3	37
Crook	Tower Road	75	27	8	28.6	45	31
Crook	Wagner North	330	80	10	30.7	40.9	31.4
Crook	Wagner South	173	58	3	22	29.3	22.2
Crook	Wind Creek South	64	21	0	25.9	30.6	25.7
Crook	Wine Creek North	72	24	2	31.4	39.6	30.5
Johnson	Crazy woman 14 1	1268	160	48	36	46	36
Johnson	Crazy woman 14 2	152	19	5	16	20	17
Johnson	French Creek 91 2	385	64	9	36	43	35
Johnson	Hazelton 3 1	156	20	6	36	43	36
Johnson	Hazelton 3 2	43	5	2	29	38	30
Johnson	Kumor 40 1	1604	210	85	27	33	27
Johnson	Shell Creek 85 1	410	59	12	31	38	31
Johnson	Shell Creek 85 3	1720	248	97	24	33	24
Johnson	Stockyard North 8	2929	193	52	31	39	32
Johnson	Stockyard South 8	2582	170	42	30	38	31
Laramie	Arcola 207-1 West	851	125	49	36	46	36
Laramie	Crystal lake 210-1	1320	169	42	35	42	34
Laramie	Durham 136-1 North	841	105	37	38	46	38
Laramie	Durham 136-1 South	1903	237	61	38	47	37
Laramie	Gilchrist 109-1 North	415	54	24	23	28	23
Laramie	Gilchrist 109-1 South	2752	353	73	40	46	40
Laramie	Harriman 102-1	1073	137	17	44	52	44
Laramie	Hillsdale North 143-2	2365	290	123	43	53	43
Laramie	Old Burns 2127	160	18	10	26	34	26
Laramie	Telephone 120-1 Middle	3568	254	45	37	43	36
Laramie	Telephone 120-1 North	974	69	15	24	28	24
Lincoln	Fontelle North 316	2373	341	51	50.5	60.6	51
Lincoln	Exxon Mobile Road	239	45	13	37.3	50.5	38.3
Sweetwater	County Road 33	99	13	0	42.6	50.1	40.8
Sweetwater	County Road 34	123	15	5	32.5	56.7	37.7
Sweetwater	County Road 36	104	14	0	32.8	38	31.8
Sweetwater	Forest Service Road 8	3068	339	10	29.8	37.9	30
Sweetwater	Road Parallel to U.S. 30	236	33	6	39.8	48.7	39.4
Uinta	County Road 2	770	94	19	32.2	42.8	30.7
				Average	**31**	**40**	**31**
				85th Percentile	**41**	**52**	**41**
				Standard Deviation	**9.1**	**11.1**	**8.9**
				Median	**31**	**40**	**31**

The 85th percentile of the distribution of observed speeds is the most frequently used measure of operating speeds *(4)*. Therefore, the 85th Percentile speed was used to acquire a representative summary of the observed speeds. The 85th Percentile speeds for each road were distributed and grouped together in 5 mile per hour ranges. Figure 3 is a histogram that summarizes the distribution of the 85th Percentile speeds observed for all test sections. Figure 3 shows that 15

roads have an 85th Percentile speed that falls into the 35-39.9 mph range, more than any other range. Additionally, the 85th Percentile speeds replicate a normal distribution around the 35-39.9 mph range.

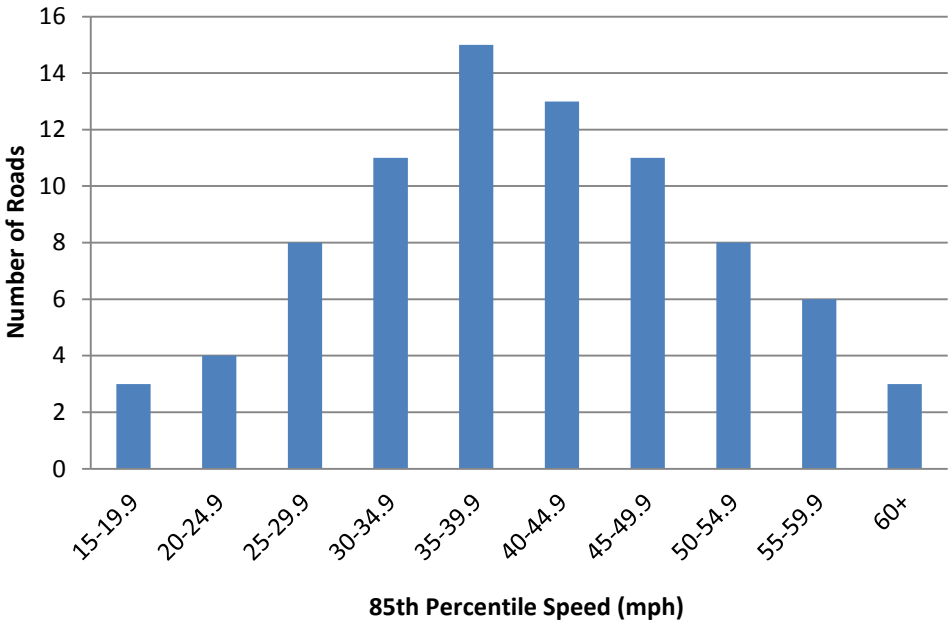

FIGURE 3 85th Percentile Speed Distribution

A similar histogram was created for the distribution of average speeds for all test sections. Figure 4 shows that 17 roads have an average speed that falls into the 30-34.9 mph range. Additionally, this figure shows that a vast majority of the tested roads have an average speed between 20 and 45 mph. In fact, only 5 roads had average speeds above 45 mph, as shown in Figure 4.

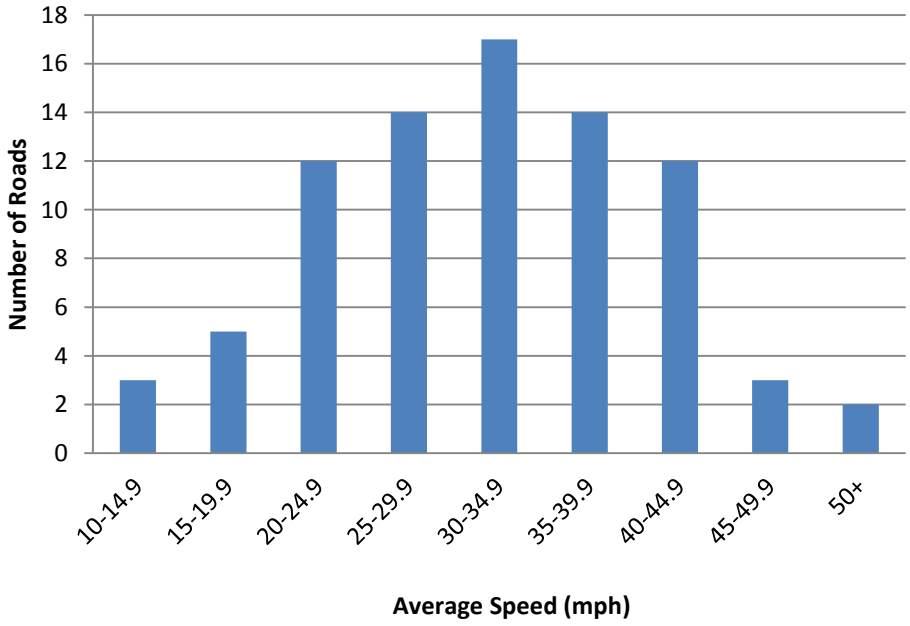

FIGURE 4 Average Speed Distribution

Traffic Volume Data

In addition to the speed data, the traffic counters also collected traffic information such as the total vehicle count and vehicle classification. AASHTO classifies very low volume roads as those having an ADT less than 400 vehicles/day. ADT is very important in determining certain parts of the roadway design features, such as design speed. Roadway geometric design depends on design speed for certain attributes such as stopping sight distance. Figure 5 shows the distribution of test sections by ADT. As shown in the figure, over half of the roads tested had an ADT less than 100 vehicles/day. Similarly, the average ADT for all roads is 98 vehicles/day.

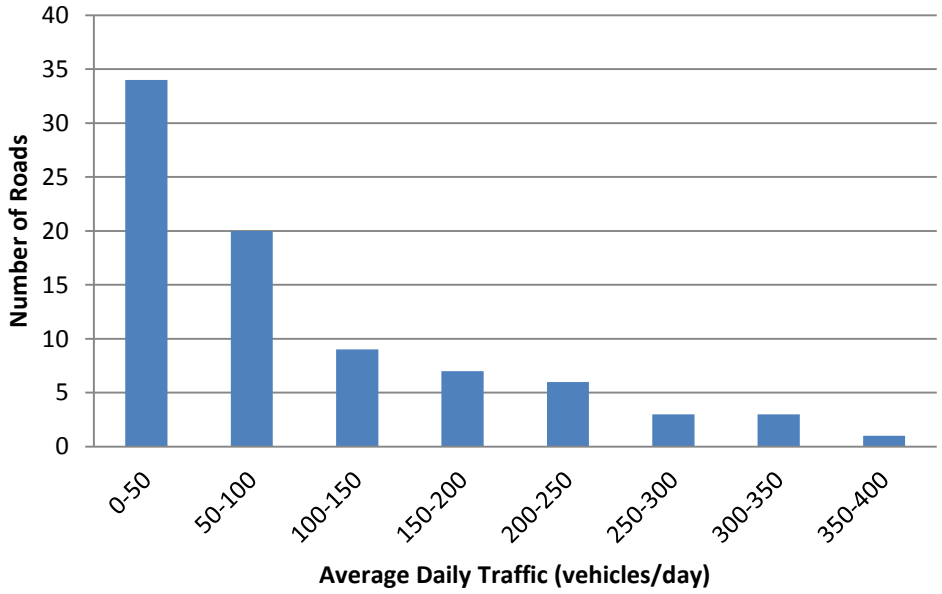

FIGURE 5 Distribution of Test Sections by ADT

Truck Traffic

In Wyoming, there is a relatively high percentage of trucks travelling on rural unpaved roads. Many of these trucks are commercially operated and are used for delivering supplies and equipment for heavy industry. These truck drivers routinely drive on the same roads every day, many of which are low-volume rural roads. As a result, truck drivers tend to drive faster than other local traffic. This phenomenon is illustrated in Figure 6, which is a scatter graph showing the relationship between the ADTT and the observed 85th Percentile Speed. The trend line shown in the figure illustrates that roads with higher truck traffic typically have higher 85th Percentile Speeds.

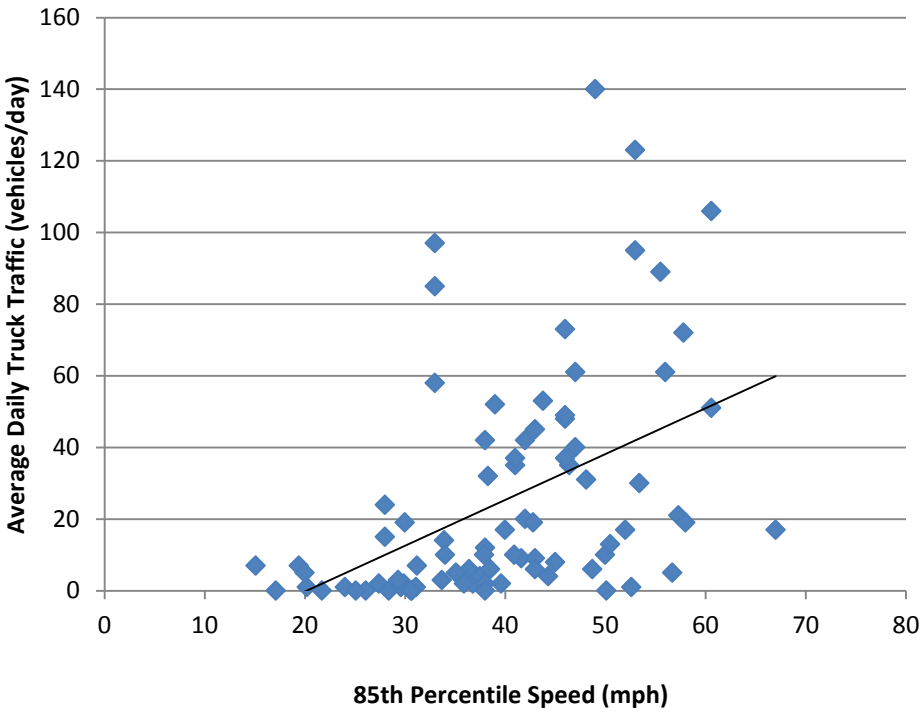

FIGURE 6 ADTT vs. 85th Percentile Speed

Crash Risk Data

Crash data are comprised of all reported crashes from 1998 to 2007 and shows the number of Fatal, Injury, and Property Damage Only (PDO) crashes on each road section. Each reported crash is categorized by its highest severity. A crash that resulted in two fatalities and one injury, for example, would count as one fatal crash only. This data is summarized in Table 6 below. The Fatal + Injury column sums the Fatal and Injury crashes, and the Total column sums the Fatal, Injury, and PDO crashes. The Equivalent Property Damage Only (EPDO) section is a system of rating all of the crash incidents with the same severity. It is a way to compare fatalities with property damage crashes, by weighting the injury and the fatality crashes. The fatalities are counted as 9.5 property damage crashes and the injuries are counted as 3.5 property damage crashes.

$$EPDO = 9.5 \times Fatal + 3.5 \times Injury + PDO \quad (1)$$

TABLE 6 Crash Data by Road

		Crash Data (1998-2007)					
County	**Road**	**Fatal**	**Injury**	**PDO**	**EPDO**	**Fatal + Injury**	**Total**
Carbon	Baggs Dixon 702	0	0	3	3	0	3
Carbon	Brush Creek 203 A	0	0	3	3	0	3
Carbon	Buck Creek 550 1	0	0	1	1	0	1
Carbon	Dad / Wamsutter 701 North	1	9	9	50	10	19
Carbon	Finley Hill 353	0	1	2	5.5	1	3
Carbon	Four Mile 603	0	0	6	6	0	6
Carbon	Hanna Leo 291	2	8	20	67	10	30
Carbon	Jack Creek 500 1	0	5	8	25.5	5	13
Carbon	Poison Basin 700	0	6	2	23	6	8
Carbon	Savery North 561N	0	3	3	13.5	3	6
Converse	Esterbrook Road 5	0	15	18	70.5	15	33
Converse	Glendo Road 6	0	1	2	5.5	1	3
Converse	Braae Road 7	0	4	4	18	4	8
Converse	Bedtick Road 8	0	0	3	3	0	3
Converse	Spring Canyon Road 11	0	3	4	14.5	3	7
Converse	Laprele Hall Road 12	0	0	0	0	0	0
Converse	Windy Ridge Road 14	1	1	1	14	2	3
Converse	Moss Agate Road 15	0	0	0	0	0	0
Converse	Old Fort Fetterman Road 16	0	4	3	17	4	7
Converse	Stevens Road 20	0	0	1	1	0	1
Converse	Coal Creek Road 22	0	1	1	4.5	1	2
Converse	Cold Springs Road 24	0	2	3	10	2	5
Converse	Cherokee Trail Road 30	0	0	1	1	0	1
Converse	Jenne Trail Road 34	0	2	6	13	2	8
Converse	Dull Center Road 38	0	0	1	1	0	1
Converse	Combs Road 42	0	0	0	0	0	0
Converse	Eberspecher Road 55	0	0	0	0	0	0
Converse	Bill Hall Road 63	0	0	1	1	0	1
Crook	Banks West	0	0	1	1	0	1
Crook	Birtha South	0	6	7	28	6	13
Crook	Cabin Creek South	0	2	1	8	2	3
Crook	Canyon Springs East	0	0	0	0	0	0
Crook	D Road	0	3	9	19.5	3	12
Crook	Garman Road	0	0	0	0	0	0
Crook	Grazing Ass Road	0	0	0	0	0	0
Crook	Grazing Ass Road South	0	0	0	0	0	0
Crook	H Kay North	0	3	2	12.5	3	5
Crook	Humphrey Road	0	0	0	0	0	0
Crook	Inyan Kara Creek North	0	1	3	6.5	1	4
Crook	Left Creek	0	0	0	0	0	0
Crook	McKean South	0	0	1	1	0	1
Crook	Miller Creek	0	0	0	0	0	0
Crook	Mule Creek Road	0	0	1	1	0	1
Crook	New Haven 2	0	13	16	61.5	13	29
Crook	New Haven North	0	13	16	61.5	13	29
Crook	Robison Road	0	0	0	0	0	0
Crook	Schlup Road	0	0	0	0	0	0
Crook	Sndc Iynkra Road	0	0	0	0	0	0

TABLE 6, Continued

		Crash Data (1998-2007)					
County	**Road**	**Fatal**	**Injury**	**PDO**	**EPDO**	**Fatal + Injury**	**Total**
Crook	Snooks Road	0	0	0	0	0	0
Crook	Tower Road	0	0	0	0	0	0
Crook	Wagner North	0	1	4	7.5	1	5
Crook	Wagner South	0	1	4	7.5	1	5
Crook	Wind Creek South	0	0	1	1	0	1
Crook	Wine Creek North	0	0	1	1	0	1
Johnson	Crazy woman 14 1	0	1	4	7.5	1	5
Johnson	Crazy woman 14 2	0	1	4	7.5	1	5
Johnson	French Creek 91 2	0	3	22	32.5	3	25
Johnson	Hazelton 3 1	0	1	5	8.5	1	6
Johnson	Hazelton 3 2	0	1	5	8.5	1	6
Johnson	Kumor 40 1	0	3	1	11.5	3	4
Johnson	Shell Creek 85 1	0	1	5	8.5	1	6
Johnson	Shell Creek 85 3	0	1	5	8.5	1	6
Johnson	Stockyard North 8	0	3	6	16.5	3	9
Johnson	Stockyard South 8	0	3	6	16.5	3	9
Laramie	Arcola 207-1 West	0	5	7	24.5	5	12
Laramie	Crystal lake 210-1	0	19	11	77.5	19	30
Laramie	Durham 136-1 North	0	2	1	8	2	3
Laramie	Durham 136-1 South	0	2	1	8	2	3
Laramie	Gilchrist 109-1 North	1	10	10	54.5	11	21
Laramie	Gilchrist 109-1 South	1	10	10	54.5	11	21
Laramie	Harriman 102-1	0	6	9	30	6	15
Laramie	Hillsdale North 143-2	2	1	2	24.5	3	5
Laramie	Old Burns 2127	0	0	1	1	0	1
Laramie	Telephone 120-1 Middle	1	8	14	51.5	9	23
Laramie	Telephone 120-1 North	1	8	14	51.5	9	23
Lincoln	Fontelle North 316	0	1	5	8.5	1	6
Lincoln	Exxon Mobile Road	0	0	0	0	0	0
Sweetwater	County Road 33	0	11	10	48.5	11	21
Sweetwater	County Road 34	0	1	2	5.5	1	3
Sweetwater	County Road 36	0	2	2	9	2	4
Sweetwater	Forest Service Road 8	0	0	0	0	0	0
Sweetwater	Road Parallel to U.S. 30	0	0	0	0	0	0
Uinta	County Road 2	0	0	0	0	0	0
	Total	**10**	**212**	**335**	**1172**	**222**	**557**

There were 10 fatality crashes on the gravel roads in this study during the crash data collection period. By comparing the crash data, such as the EPDO or total crashes, against the 85th percentile speeds being traveled on those roads, correlations between the speeds and risk of an accident associated with increasing the speed were obtained. The fatality plus injury was also figured so as to eliminate the PDO accidents because these two are much more severe. Figure 7 shows the risk increase as a percentage as the speed is increased from the baseline of 40 mph. Forty mph was chosen as the base for the average and the median of the 85th percentile speeds. Additionally, this base speed was chosen in order to evaluate the crash risk for low- and high-speed. The design criteria, such as curvature and sight distances, for low-speed and high-speed

design differs distinctly. Because of these distinct differences, the upper limit for low-speed design is 45 mph and the lower limit for high-speed design is 50 mph *(3)*. Most gravel county roads are considered as low speed design with an upper speed design of 45 mph.

For the techniques used in this study the sections had to be split into running speed groups. Those running speeds are as shown in Table 7. Table 7 also shows the number of sections in each group as well as the average ADT in that group. There is a slightly larger number of vehicles using the road sections that have higher running speeds. This could have a small effect on the results shown below but as can be seen in the table ADT does not increase with running speed. This shows that ADT is most likely not having an effect on the crash analysis.

TABLE 7 Running Speed Group Data

Running Speed Group	Number of Sections	Average ADT
0-40	42	78
40-45	13	103
45-50	12	158
50-55	8	99
55+	9	110

Risk increase was calculated by finding the average crashes below a certain speed and the average below another increased speed. The difference in those averages is then divided by the average crashes below the lower speed to find the percent increase risk from one speed to the other. The risk involved with driving at 40 mph is not zero, but it was decided to use this speed as the basis for the risk analysis because it was the mean 85th percentile speed. There was no risk analysis preformed on speeds higher than 55 mph because such speeds would not apply to low speed designs.

Table 8 shows the added risk associated with increasing the travel speed for each five mile per hour increment over 40 mph. It is evident that for all methods of evaluating crash severity, the risk increased at a very similar rate as the speed is increased. Both Table 8 and Figure 7 show the greatest increase in risk occurs when the 85th percentile travel speed is increased from 40 mph to 45 mph. The risk of having an accident continues to increase with speed as it rises to 55mph.

TABLE 8 Risk Increase by Increasing Speed Limit

	EPDO	Fatal + Injury	Total
40 to 45 mph	13.3%	12.2%	15.3%
45 to 50 mph	20.8%	22.6%	18.6%
50 to 55 mph	31.0%	30.3%	26.8%

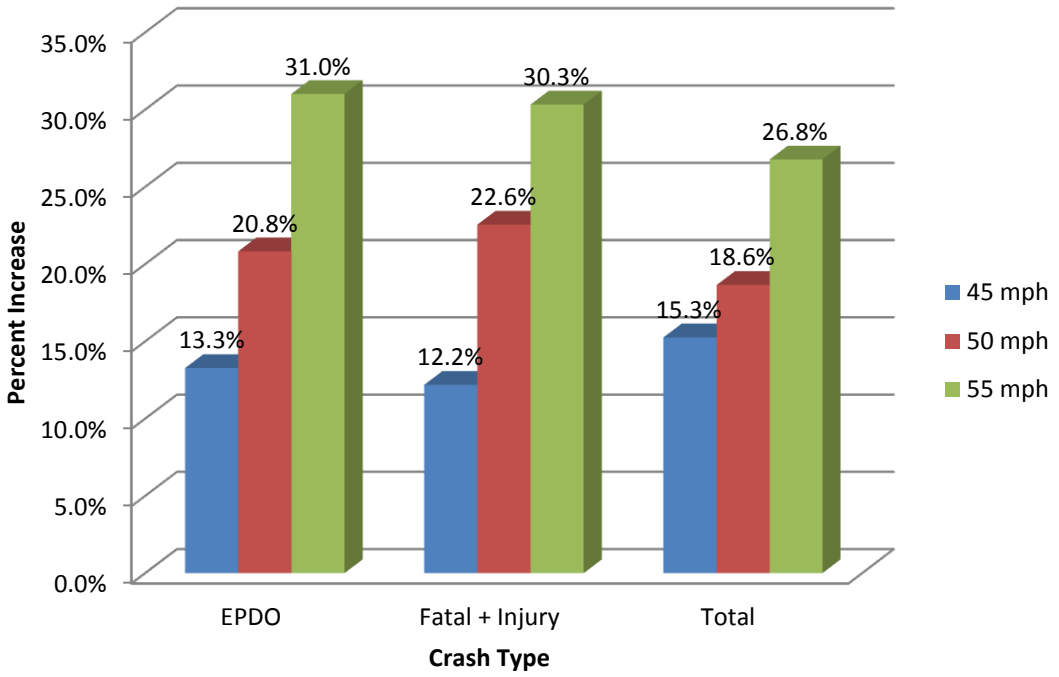

FIGURE 7 Risk Increase by Running Speed Group

CONCLUSIONS

States similar to Wyoming in terms of geography and layout, such as North Dakota, South Dakota, Kansas, and Idaho, all have statutory speed limits set at 55 mph. Nebraska, a state also having many similarities to Wyoming sets its statutory speed limit at 50 mph. Wyoming's default speed limit is set higher than 82% of all other states. It is clear from the analysis described in this paper in 8 Wyoming counties on 83 gravel roads that there is an increasing risk associated with roads with higher running speeds. While 40 mph is not a justifiable default speed limit from the aspect of being obeyed and respected, it is shown to be the mean 85th percentile speed and was therefore used as the base line for risk analysis. The average speed distribution showed a normal distribution centered on the 30 to 35 mph speed. Motorists on the gravel roads studied traveled on average 31 mph. This is shown both in the 50th percentile speeds and the average speeds.

The number of crashes observed with an increase of running speed of 5 mph increases every time the running speed increases. A running speed group traveling at 55mph is roughly 30% more likely to incur a crash than that of a running speed group traveling 40 mph. Depending on the justifiable risk, one could argue that 55 mph would be a viable solution, while others would argue that 40 mph is the safest and therefore should be used. It must be remembered that 40 mph is not necessarily the safest; it is simply the base line and there is a risk associated with traveling at that speed.

When using the method of total crashes to evaluate risk, the increase quite clearly has the least spread of any method. This is most certainly because PDO crashes occur more frequently at lower speeds. This is why the EPDO is calculated and relied upon more heavily in this study.

The risk analysis shows the risk of having a crash when traveling at 45 mph is 13.3 percent higher than traveling at 40 mph. Given that the highest design speed for all of the roads studied is 45 mph, it realistic to assume that some of those roads were designed for lower speeds. This is indicated by the lower average travel speeds on the gravel roads. Drivers employ speeds in which they feel safe. The average 85^{th} percentile speed shows that driver perception of the roadways is to not travel faster than 40 mph.

Some of the Wyoming counties initially wanted to establish a speed limit that would allow for the least amount of gravel being pushed off the road on corners and therefore lower the maintenance costs on those roads. It was decided to leave that information out of this study because maintenance costs should be secondary to safety in determining a speed limit on any roadway. Safety is paramount as well as geometrics and driver acceptability.

RECOMMENDATIONS

Many groups including the Wyoming Association of County Commissioners, the Wyoming DOT, the Wyoming Technology Transfer Center, and the Wyoming Legislative Committee on Transportation, have reviewed the information provided in this paper and have decided the level of risk which is acceptable. Understanding that every gravel road is not the same in the state of Wyoming, and that a default speed limit is going to blanket every road, this group decided that some risk would have to be taken to accommodate roads designed for higher speeds. With a speed limit of 45 mph, driver respect would not be an issue on Wyoming gravel roads while still maintaining an acceptable level of safety. The risk increase of setting the speed limit 5 mph higher to 45 mph is roughly 10 percent. This maintains a compromise between driver acceptability and safety.

The groups listed above recommended a default speed limit of 45 mph to the State of Wyoming Legislature. After many readings in committee and several rounds of voting, the default speed limit was changed to 55 mph and was passed. This was done primarily for legal issues relating to the fact that motorists can still experience a crash at speeds lower that 45 mph and it releases the state from liability. It was also decided that if a posted speed other than 55 mph was desired that it would have to meet a certain set of criterion and guidelines developed by the University of Wyoming Technology Transfer Center. This set of criteria has been approved by the Wyoming Association of County Commissioners and has become law.

It is recommended that other states with higher speed limits on gravel roads should conduct studies similar to the study described in this paper. Such studies would help other states in evaluating the risk associated with setting high speed limits on gravel roads.

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