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Improving Rural Emergency Medical Services (EMS) through Transportation System Enhancements

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Improving Rural Emergency Medical Services (EMS) through Transportation System Enhancements

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EXECUTIVE SUMMARY

Improved emergency medical services (EMS) will impact traffic safety and public health in rural communities. Better planned, designed, and operated roadway networks that connect hospitals with communities in need will enhance EMS performance. To provide safe, timely and quality services, it is necessary to obtain a realistic estimate of the medical demand and the capacity of current transportation infrastructure pertaining to the services. The gaps between service providers, patients, and transportation network connecting the two need to be identified and filled to support better EMS. The goal of this project was to identify issues with respect to the delivery of quality EMS to rural residents in South Dakota (SD) and to conduct a needs assessment from the rural transportation system perspective. Study objectives were:

1. Identify the service needs from the rural communities
2. Evaluate the rural transportation system components in support of swift and safe EMS
3. Identify the existing issues with the SD EMS providers or first responders related to roads and traffic controls

Study objectives were achieved through a combination of literature review, spatial and temporal analysis of SD EMS data, and EMS personnel surveys and focus groups. In addition to survey results, this report summarizes the SD EMS data from the geographic (e.g., counties in SD) and temporal (e.g., time of day, day of week, and month of year) perspectives and concentrates on several time- and distance-dependent variables such as response time, en-route time, on-scene time, and transporting time as well as the distance to and from the incident scene.

1. INTRODUCTION

Rural transportation networks connect local residents to employment, health care, social activities, and business opportunities. Functional and reliable rural transportation systems are critical to rural economic growth, public health, traffic safety, and social welfare. Long travel distances in South Dakota (SD), a prominent rural state, are not uncommon because of sparsely distributed population. Delivering people, goods, and services becomes more difficult as distances increase, especially for time-sensitive services such as emergency medical services (EMS). Unintentional mortality rates attributed to diseases, fertility, and motor vehicle crashes are higher in rural settings than urban settings (Blumenthal 2002). According to the National Highway Traffic Safety Administration (NHTSA), "Delay in delivering emergency medical services is one of the factors contributing to the disproportionately high fatality rate for rural crash victims" (NHTSA 1998). In addition, the safety of EMS is of serious concern, particularly when the crash fatality rate for EMS vehicles per mile traveled is estimated to be more than 10 times higher than that for heavy trucks (Levick 2008).

Ambulance vehicle crashes not only cause new casualties but also delay the golden rescue time for the patient. The same situation applies to the other time-dependent EMS which transport trauma, cardiac, and prenatal patients to nearby care centers. Driving under urgent and stressful circumstances is considerably different from driving under normal conditions, as it is more vulnerable to the potential risks in the current rural transportation system.

Improved EMS will have direct impacts on the traffic safety and public health in rural communities. EMS can be enhanced by a better planned, designed, and operated roadway network that connects hospitals with communities in need. To provide safe, timely, and quality services, it is necessary to obtain a realistic estimate of the medical demand as well as the capacity of current transportation infrastructure pertaining to the services. The gaps between service providers and patients, and transportation networks connecting the two need to be identified and closed to support better EMS.

1.1 Research Objectives

The goal of the project, which is the subject of this report, was to identify issues with respect to the delivery of quality EMS to rural residents and to conduct a needs assessment from the rural transportation system perspective. There were three major objectives in this research:

1. Identify the service needs from the rural communities
2. Evaluate the rural transportation system components in support of swift and safe EMS
3. Identify the existing issues with the SD EMS providers or first responders related to roads and traffic controls

The first two objectives were achieved through a combination of literature review and analysis of SD EMS data. The third objective was achieved through EMS personnel surveys and focus groups. Accordingly, this report is organized in three sections:

1. Literature review focused on relevant research and recent statistics and metrics related to EMS response and transport times in rural areas
2. Analysis of the SD EMS data
3. EMS personnel surveys and focus group interviews

1.2. Literature Review

Emergency medical services are defined as the personnel, vehicles, equipment, and facilities used to deliver medical services to those who need immediate care outside a hospital setting. Therefore, EMS are considered to be the vital expansion of emergency room care to the community (Rawlinson and Crews 2003). EMS transport patients to hospitals via ground or air, providing medical assistance both on the scene and en-route. Due to its close association with the transportation infrastructure and services provided to traffic accident injuries, EMS have long been considered one of the four cornerstones of a successful transportation safety management system, the so called "4Es": EMS, engineering, education, and enforcement (FHWA, HSIP).

Enhancing EMS to reduce mortality is one of the 22 goals identified in the American Association of State Highway and Transportation Officials (AASHTO) Strategic Highway Safety Plan (SHSP). Because motor vehicle traffic fatalities are consistently higher in rural areas than urban areas, the NCHRP 500 report, especially, addresses strategies and methods to enhance EMS in rural areas (NCHRP report 500). To guide effective interventions, it is important to understand issues, gaps, and needs in service and provide an objective evaluation of EMS activities in the rural areas.

In recent years, substantial progress has been made in the areas of data collection and system information management, human factors and ergonomics, standards and protocols, and vehicle design and fleet management. The impact, however, is most felt in urban areas that are well-supported by EMS. Wide disparity still exists in the delivery of EMS in rural areas. Several factors contribute to such disparities and include geographic barriers, lack of professional, paraprofessional, and financial resources, aging or inadequate equipment, absence of specialized EMS care and local medical facilities, sporadic nature of rural crashes, and workforce that are predominately composed of volunteers (Rawlinson and Crews 2003).

Response time has been extensively used as a major performance index to evaluate EMS performance. To date, an explicit relationship between clinically significant improvements in patient outcomes and reductions in EMS time to definitive care has not been fully established. The general consensus is that shorter time to definitive care is associated with improved outcomes in critically injured, stroke, and cardiac patients. Thus, it is crucial to get those patients to definitive care (often surgery) immediately and within 60 minutes (known as the golden hour) of the occurrence of the emergency. National statistics for 2011 showed that the average overall EMS response time (time from notification to definitive care) for fatal crashes was 36 minutes in urban areas and 53 minutes in rural areas (source, NHTSA, 2004[a]). Over 36% of fatal crashes in rural areas had response times greater than 60 minutes. Only 10% of fatal crashes in urban areas exceeded the 60 minute limit. According to those statistics, the response time in rural areas almost approaches the end of the "golden hour." Seven years later, those statistics have not improved but, on the contrary, have slightly deteriorated. In 2011, the national average for EMS response time for fatal crashes was 37.22 minutes in urban areas and 54.49 minutes in rural areas (NHTSA Traffic Safety Facts 2011). Table 1.1 provides a comparison of SD to national statistics. South Dakota performed slightly better (3.13 minutes or 9% shorter) in urban areas. SD time of crash to hospital arrival or overall response time for fatal crashes was shorter than the national average in urban areas but similar or slightly longer in rural areas. Specifically, the notification time in rural SD was 2 minutes, or 32.4% shorter than the national average, but the en-route time to crash scene was 2 minutes, or 16.1% longer than the national average.

Table 1.1 Average Emergency Medical Services (EMS) Response Times for Fatal Crashes

	Urban (minutes)		**Rural (minutes)**	
	SD[1]	**National Average[2]**	**SD[3]**	**National Average[4]**
Time of crash to EMS notification	5.00	3.47	4.71	6.17
EMS notification to EMS arrival at crash scene	6.40	7.19	14.49	12.39
EMS Arrival at Crash Scene to Hospital Arrival	26.18	27.39	40.07	38.65
Time of Crash to Hospital Arrival	34.09	37.22	54.57	54.49

1. Based on 15 fatal crashes
2. Based on 13,578 fatal crashes
3. Based on 86 fatal crashes
4. Based on 16,053 fatal crashes

*Source: NHTSA Traffic Safety Facts 2011

Although patient outcomes depend on many other factors such as severity of injury, preexisting conditions, etc., the time required for an EMS unit to arrive at the scene (response time) and the time required for a patient to receive definitive care (overall response time) play a significant role in patient outcome. The Centers for Disease Control and Prevention reports a 25% reduction in mortality risk when trauma victims receive definitive care at a level I trauma center (NAS-EMOS 2010). In South Dakota, there are no level I trauma centers, and crashes in rural areas usually occur far away from a level II or level I trauma center and timely transportation to those centers depends on the availability of swift EMS.

2. EMS DATA ANALYSIS

2.1 Data Sources

A subset of the National EMS Information System (NEMSIS) data bank, consisting of 50,396 SD EMS data responses covering the period between 1/1/2012 and 12/31/2012, was obtained from the Eastern South Dakota EMS Data office. The subset was analyzed to identify service needs and potential issues on SD roads and bridges in support of swift and safe EMS operations. The NEMSIS data had two components: the demographic dataset and the EMS data set. The demographic dataset provided information related to the EMS submitting agency. The EMS dataset consisted of critical information or events collected through the EMStat 5™ system (Figure 2.1). NEMSIS records are usually maintained by EMS officers and used to monitor and coordinate system resources.

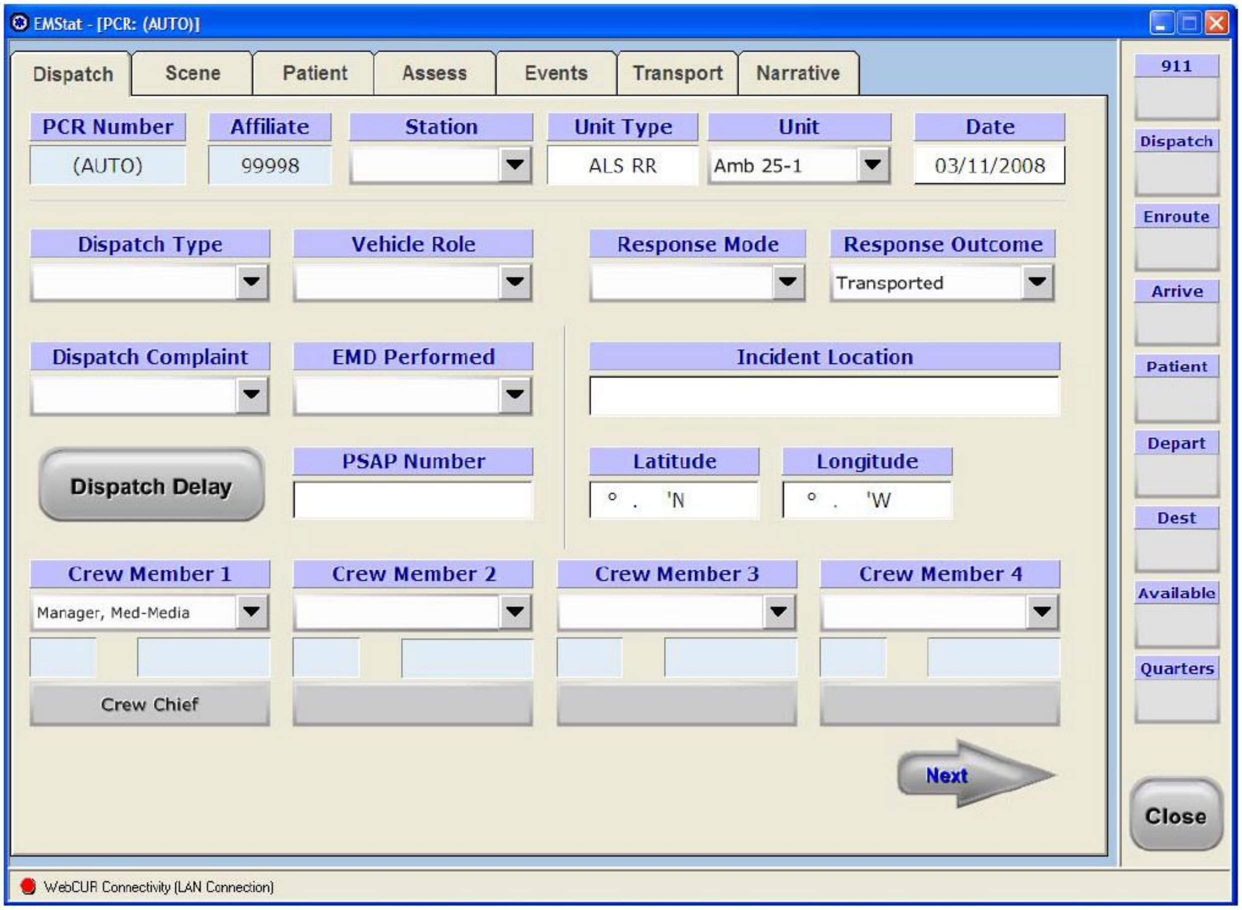


Figure 2.1 EMStat 5™ Interface

As illustrated in Figure 2.2, five individual time intervals, which constitute the entire EMS process, were analyzed in this study. This included response time (RespTime), en-route time (ERTime), on-scene time (OSTime), transporting time (ERHTime), and destination time (DestTime). The sum of response time, en-route time, on-scene time, and transporting time may be referred to as overall response time. The time interval for response, en-route, transporting, and on-scene (See Figure 2.2 for definitions) can be estimated between two consecutive time-stamped events. For example, the response time interval is defined as the time lapse between dispatch (the time the responding unit is notified by dispatch) and en-route (the time the responding unit starts moving). The en-route time is defined as when the responding unit starts moving to the time the responding unit stops physical motion at the scene. Transport time is defined as when the responding unit begins physical motion from the scene to when the patient arrives at the destination or definitive care.

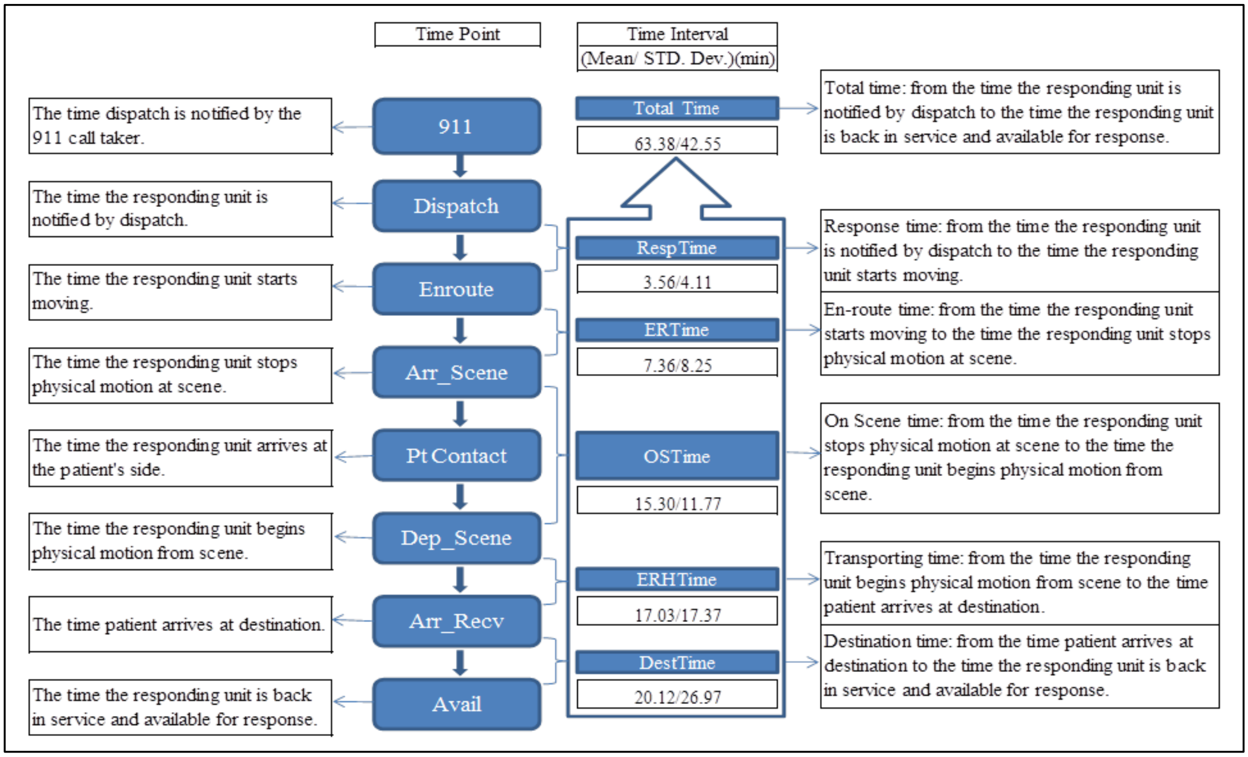


Figure 2.2 EMS Flowchart

*Source for the definition: SD Data Dictionary, SD Department of Public Safety & Med-Media, 2008, http://dps.sd.gov/emergency_services/emergency_medical_services/documents/SouthDakota-NEMSISDataDictionaryver1.1.pdf

2.2 Data Inclusion and Exclusion

Quality controls were performed on speedometer data, time intervals, distance, and speed. After consultation with EMS data specialists, it was determined that extremely high values should be excluded from the analysis. Therefore, the exclusion criteria included en-route or transporting time values greater than 240 minutes, travel distance to the scene or return to the hospital distance greater than 400 miles, and speedometer speed greater than 120 miles per hour. Values outside the above parameters were assumed to be erroneous and unrealistic. Out-of-state air transports, inter-facility transfers, non-emergency transports, responses with missing data were also excluded. Inclusion criteria included only 911 dispatch type or EMS service type requests.

2.3 Measures

Measures of demand included EMS calls or service volume by population, population density, county, month of the year, day of the week, and time(s) of the day. Demand was also examined in relation to demographic characteristics of users such as age, gender, and medical condition. In order to obtain detailed description of each service component of the EMS process and its performance, the travel speed, distance and duration corresponding to response time (RespTime), en-route time (ERTime), on-scene time (OSTime), transporting time (ERHTime), as well as total time were analyzed respectively. An investigation of the EMS performance by dispatch complaint was also made.

2.4 Analysis

Data were analyzed from both spatial and temporal perspectives. Spatial analysis was conducted through GIS-based maps to summarize the EMS demand and performance by county. Temporal analysis was performed to describe the EMS demand and performance patterns by month of year, day of week, and time of day. Descriptive statistics were used where continuous variables were presented as means and standard deviations (std. dev.) (unless otherwise stated), and categorical variables were presented as percentages. A two-tailed t test was conducted between variables and a p-value of less than 0.05 ($p<0.05$) was considered to be statistically significant. South Dakota operates three regional dispatch centers, which divide the state into western, central and eastern regions. These regions were maintained in the analysis in order to compare the results across the state. To establish the volume per capita, population information for each county in SD was obtained from the US Census Bureau website (United States Department of Commerce 2010).

2.5 Results

In 2012, SD had a total of 50,396 EMS transports, of which only 29,354 were in response to a 911 call only. The remaining cases were classified as inter-facility (9,487 transports), medical (4,830 transports), mutual aid (157 transports), and standby (265 transports). Of the 911 type transports, 15,140 (51%) had valid and accurate travel time and travel speed and distance, and therefore, met the inclusion criteria for EMS performance analysis. Table 2.1 shows the data processing procedure that led to the final sample.

Table 2.1 Data Processing Procedure

Step	Objective	Criteria	Data	Percentage (%)	
				Filtered	Remained
1	Complete dataset	N.A.	50,396	0	100
2	911 Response only	Dispatch Type = “911 response”	29,354	41.75	58.25
3	Filter missing or invalid odometer data	Mile_Scene, Mile_Dest, Mile_In = 0 or blank	17,972	22.59	35.66
4	Filter missing or invalid time intervals	ERTime, ERHTime, Total Time = 0, blank,or > 240 min	16,472	2.98	32.68
5	Filter missing or invalid distance data	ERDistance, ERHDistance, Distance_Back = “-”, 0, or >400 miles	15,540	1.84	30.84
6	Filter invalid speed data	ERSpeed, ERHSpeed >120 mph	15,140	0.80	30.04

2.5.1 Research Objective 1 (Service Demand)

In 2012, demand for EMS services in response to 911 calls was equally distributed between males and females with 47% of EMS users over 60 years of age. The mean ± std. age of an EMS user was 53±25 years. The median age was 54, and the range was 0-110. Sixty percent of EMS users were white, 24% American Indians, and 16% others (African American, Asian, Hispanic, etc.). Seventy-six percent of EMS dispatches resulted in a transport from the scene to a hospital. The top five complaints to dispatchers that resulted in an EMS response were in ascending order: fall victim (13.54%), feeling sick (13.15%), chest pain (11.27%), breathing problem (10.34%), and traffic accident (8.44%).

Figure 2.3 shows EMS demand by county. The counties of Todd, Brown, and Lawrence had the highest demand, with over 2,000 emergency calls in each. Of these three counties, Todd had the highest call volume of more than 3,000 calls. The counties of Meade, Dewey, Codington, Brookings, Davison, Minnehaha, and Yankton had a volume of 1,000 to 1,999 calls each in 2012. The remaining counties had less than 1,000 emergency calls in 2012.

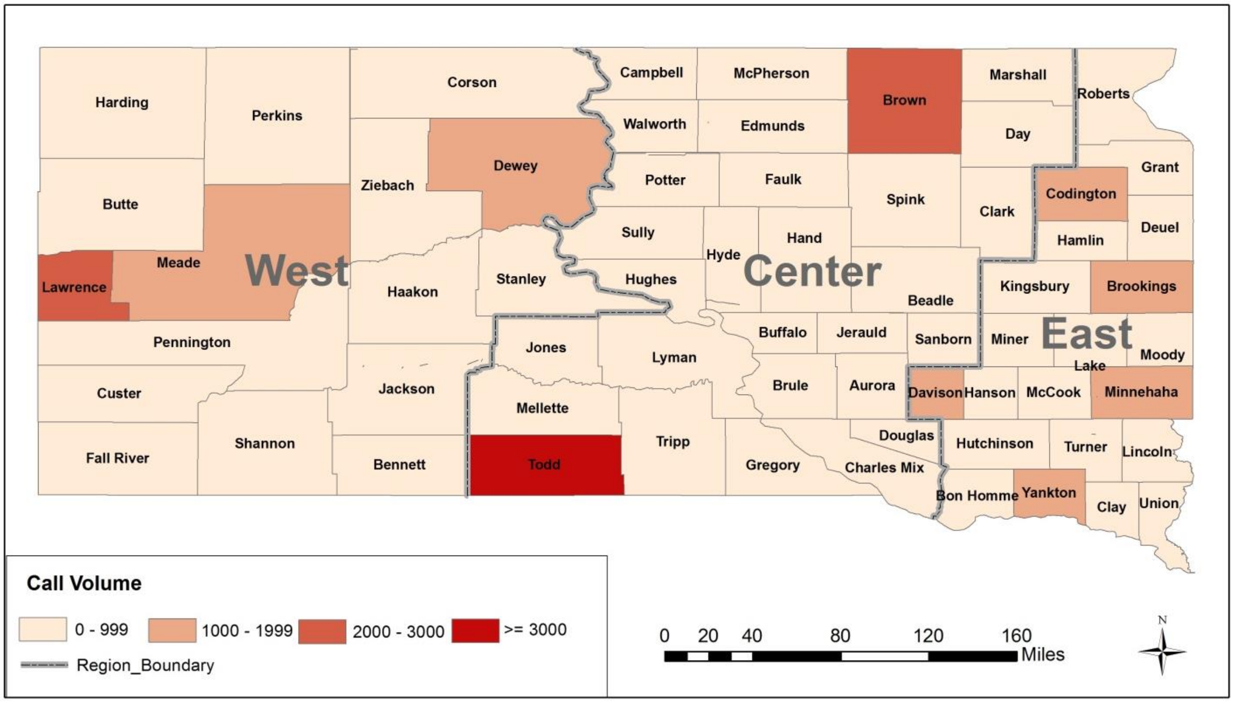


Figure 2.3 EMS Demand by County in SD in 2012

When call volumes were examined per capita (1,000 population), over 90% of the counties had emergency call volumes of less than 100 calls per 1,000 population. According to Figure 2.4, Todd County remained the highest ranked with more than 300 calls per 1,000 persons, followed by Mellette and Dewey counties with more than 200 calls per 1,000 persons.

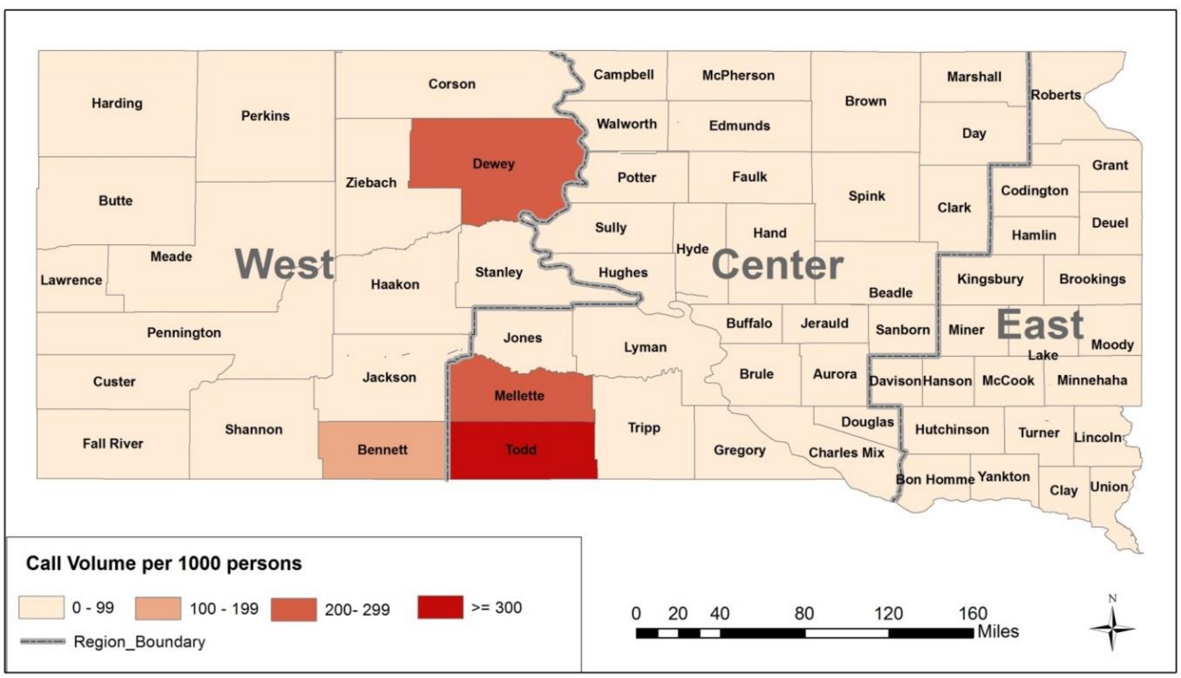


Figure 2.4 EMS Demand per 1,000 Persons by County in SD in 2012

The 911 calls appear to be spatially distributed across the state with some degree of spatial patterns and clustering. Recognizing spatial clusters of EMS demands helps to discover underlying factors associated with service needs that contribute to spatial disparities. Getis G* statistic indicates locations surrounded by a cluster of high or low values, a.k.a. “hot spots” or “cold spots” (Ord and Getis 1995). A z-score measures the statistical significance as compared to a random geographic distribution. A positive z score means the cluster of locations with high values and a negative z score means that locations with low values are close together. A local indicator of spatial autocorrelation (LISA), Getis G* was calculated to identify spatial clusters in SD.

In Figure 2.5, high values of Getis G* statistic represented by dark color show clear clustering of counties with high 911 volume per 1,000 persons in the south central region of SD. The z-score above 1.96 indicates a 5% significance level. For the rest of the state, no obvious clusters were found.

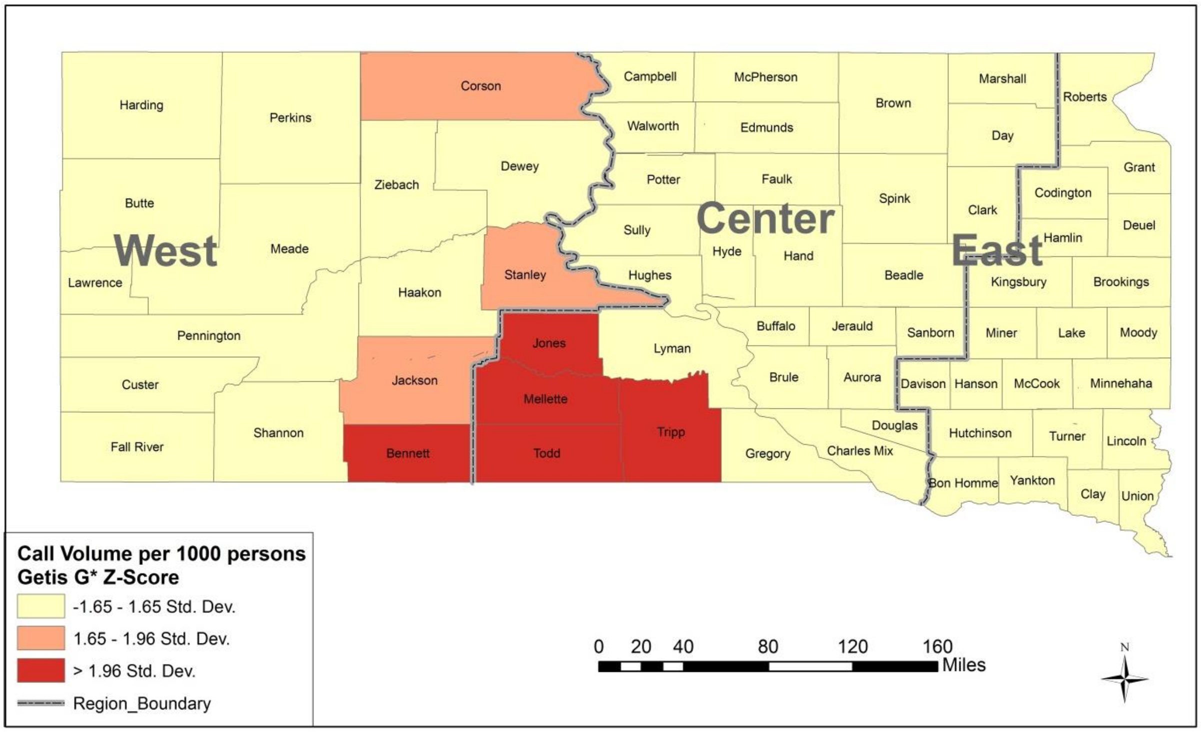


Figure 2.5 Getis G* for EMS Demand per 1,000 Persons by County in SD in 2012

Temporal analysis was performed to identify the pattern variation in EMS demand over time. Figure 2.6 shows demand by month of year. The peak monthly demand, which was more than 1,300, occurred during the summer months of June (6), July (7), and August (8) as well as the month of December (12). In comparison, the emergency call volume was the lowest for February and April.

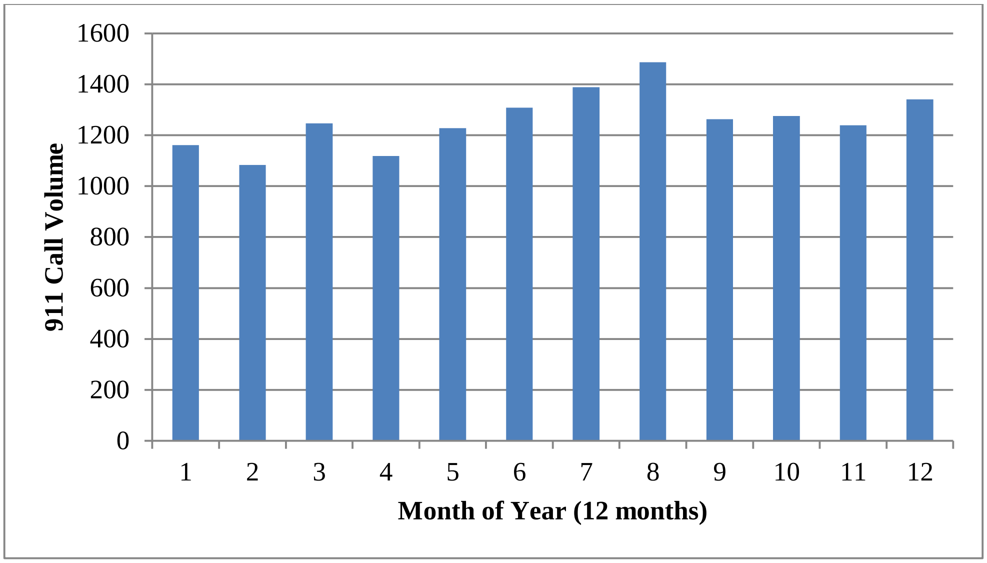


Figure 2.6 EMS Demand by Month of Year

Saturday and Friday had the highest demand (10% higher than the other days in a week). Sunday was ranked as the lowest day of the week. Figure 2.7 shows EMS demand per day of week (7 days).

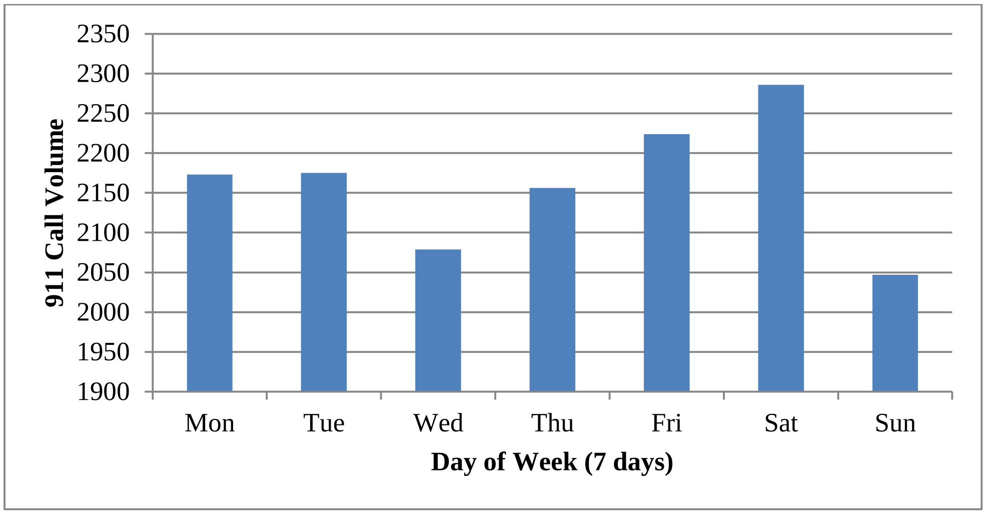


Figure 2.7 EMS Demand by Day of Week

The hourly emergency 911 call volume variations throughout a 24-hour period are shown in Figure 2.8. The call volume steadily increased after 6 am until 9 am, maintained a high level throughout the day, and then gradually decreased after 8 pm. From 9 am to 8 pm, the emergency call volume was relatively stable with a small standard deviation of 50 calls per hour (150 with all calls included). The highest hourly demands can be seen at 11am to 2 pm, 4 pm to 6 pm; these peak hours see demands as high as 800 calls per hour (2,400 with all calls included).

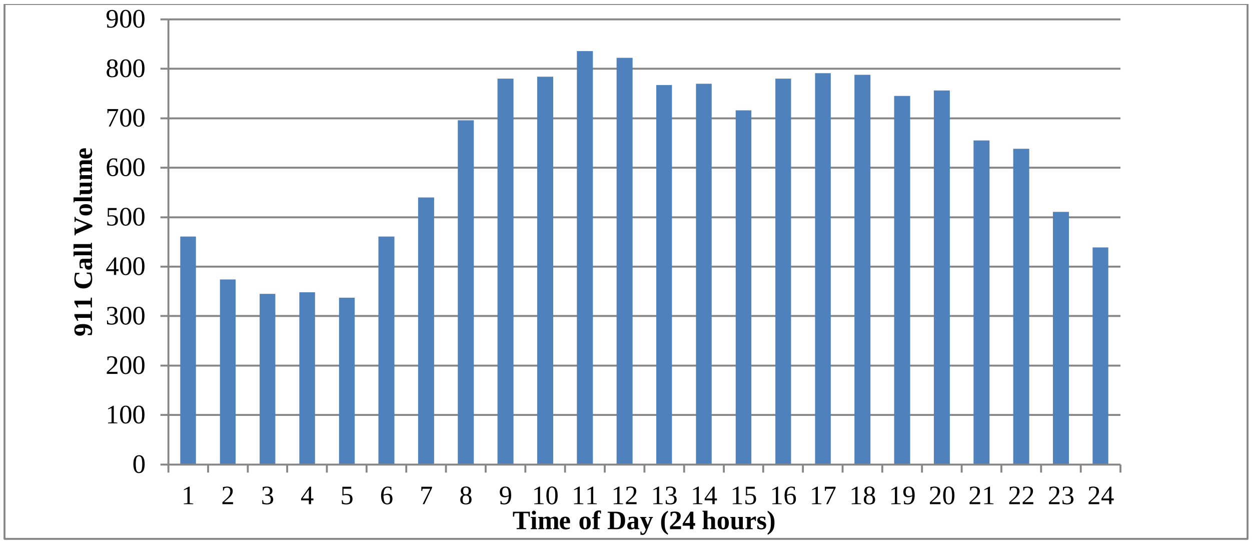


Figure 2.8 EMS Demand by Time of Day

2.5.2 Research Objective 2: Measures (System Performance)

2.5.2.1 Time and Distance

The following analysis was based on 15,140 emergency calls that had complete and valid information. Summary statistics of time duration, travel distance, and speed are presented in Table 2.2. The average RespTime, ERTime, OSTime, and ERHTime were 3.56 minutes, 7.36 minutes, 15.30 minutes, and 17.03 minutes, respectively, resulting in a 43.26 minutes (± 25.97 minutes) Overall Response Time and 63.38 minutes TotalTime (± 42.55 minutes). The median ERTime was merely 4 minutes and the median distance (ERDistance) between EMS station and incident scene was less than 2 miles. ERHTime was much greater than ERTime, so was the mean distance (ERHDistance) between incident scene and receiving agency. The large disparity between ERTime and ERHTime, and ERDistance and ERHDistance suggested excellent EMS coverage but also confirmed a low density of hospital facilities in rural SD. Travel speed was calculated from distance and time.

Table 2.2 Summary Statistics of Travel Duration, Distance, and Speed

Variable		Description	Mean	STD. Dev.	Median	Range [min, max]
Duration (mins)	**RespTime**	Duration from the time the responding unit is notified by dispatch to the time the responding unit starts moving.	3.56	4.11	3.00	[0, 131]
	ERTime	Duration from the time the responding unit starts moving to the time the responding unit stops physical motion at scene.	7.36	8.25	4.00	[1, 178]
	OSTime	Duration from the time the responding unit stops physical motion at scene to the time the responding unit begins physical motion from scene.	15.30	11.77	14.00	[0, 730]
	ERHTime	Duration from the time the responding unit begins physical motion from scene to the time patient arrives at destination.	17.03	17.37	11.00	[1, 207]
	Overall Response Time	Duration from the time the responding unit is notified by dispatch to the time patient arrives at destination.	43.26	25.97	37.00	[5, 737]
	Total Time	Duration from the time the responding unit is notified by dispatch to the time the responding unit is back in service and available for response.	63.38	42.55	53.00	[5, 1488]
Distance (miles)	**ERDistance**	Distance between EMS and the incident scene.	5.51	8.38	1.90	[0.02, 175]
	ERHDistance	Distance between incident scene and the receiving agency.	13.74	17.90	6.00	[0.01, 258]
Speed (mph)	**ERSpeed**	Average speed from the time the ambulance set out to the time the ambulance arrived at the scene.	35.34	20.61	30.00	[0.17, 120]
	ERHSpeed	Average speed from the time the ambulance departed from the scene to the time the ambulance arrived at the receiving agency.	37.01	19.88	36.00	[0.20, 120]

The bottom five counties in terms of the longest Overall Response Time (call volume >=10) are listed in Table 2.3 and the rest are in the Appendix. In Harding County, the Overall Response Time was almost 18 minutes longer than the state average, making it the worst among all 72 counties.

Table 2.3 Overall Response Time for Counties with Low Performance

County	Overall Response Time (min)			
	Mean	**STD. Dev.**	**Min**	**Max**
Harding	61.12	40.51	11.00	204.00
Deuel	48.40	37.88	12.00	290.00
Clark	47.08	26.88	12.00	168.00
Marshall	47.00	17.08	22.00	74.00
Lyman	46.81	28.76	9.00	149.00

State average ERTime and ERHTime were used as benchmarks to measure the response and transport times in each county. Figure 2.9 depicts a fairly mixed picture. Red color counties had longer ERTime and ERHTime than the state average. Light blue counties had shorter ERTime and ERHTime than the state average. Todd County, with the highest call volume and the highest calls per 1,000 persons, had a shorter than state average ERTime but longer than state average ERHTime. Mellette County exceeded the state average in both ERTime and ERHTime, and Bennett outperformed state average in both ERTime and ERHTime. Counties around the state that border with Nebraska, Iowa, and Minnesota performed better than counties inside SD or those bordered with North Dakota and Wyoming.

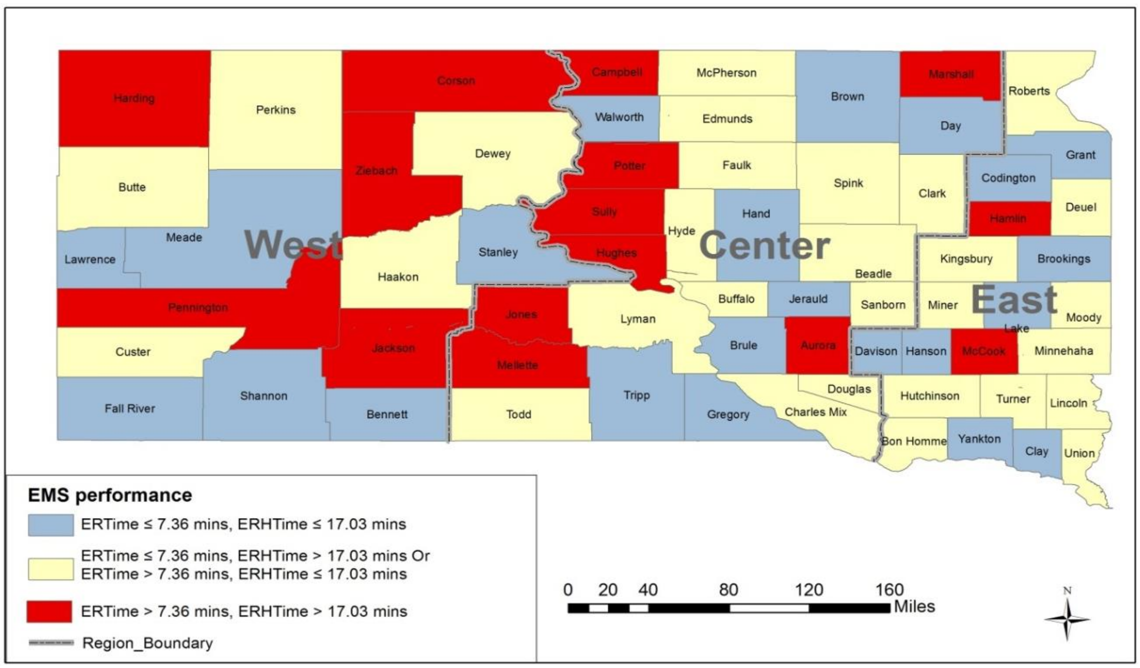


Figure 2.9 EMS Performance by County in SD in 2012

Since ERHTime was considerably longer than ERTime, a local spatial analysis was performed for ERHTime to identify the location of those areas with longer ERHTime. According to Getis G* in Figure 2.10, no obvious cluster for ERHTime was identified.

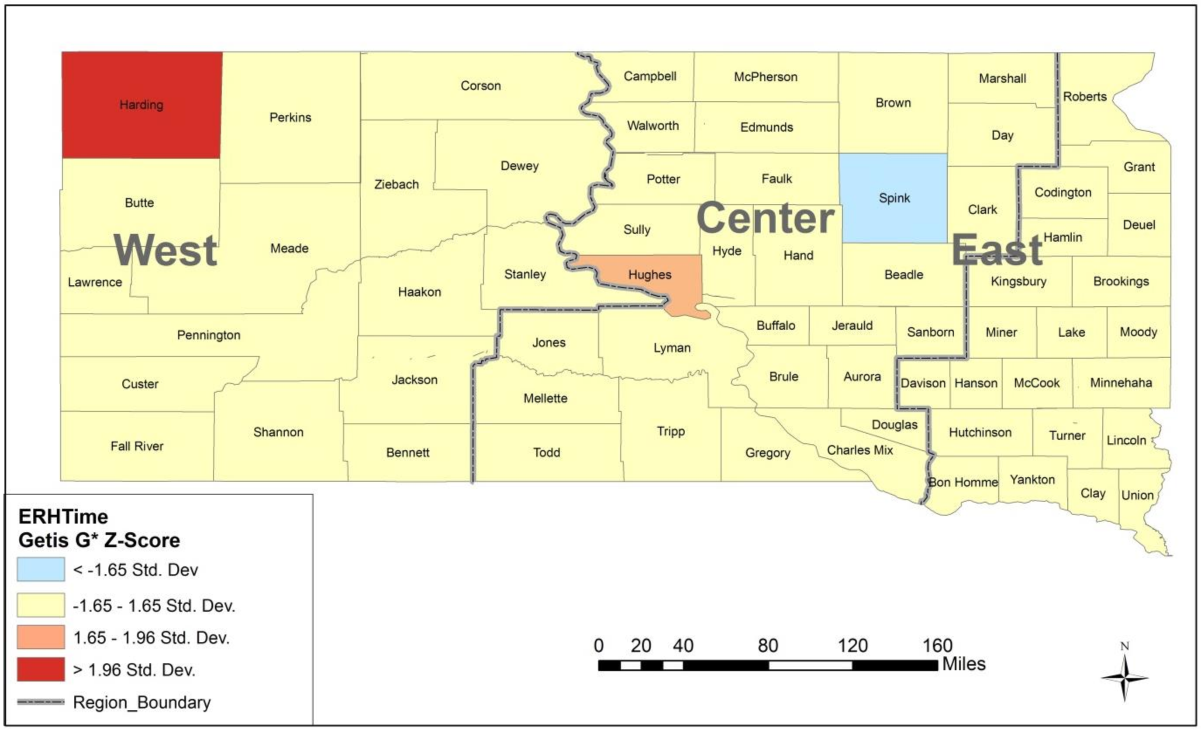
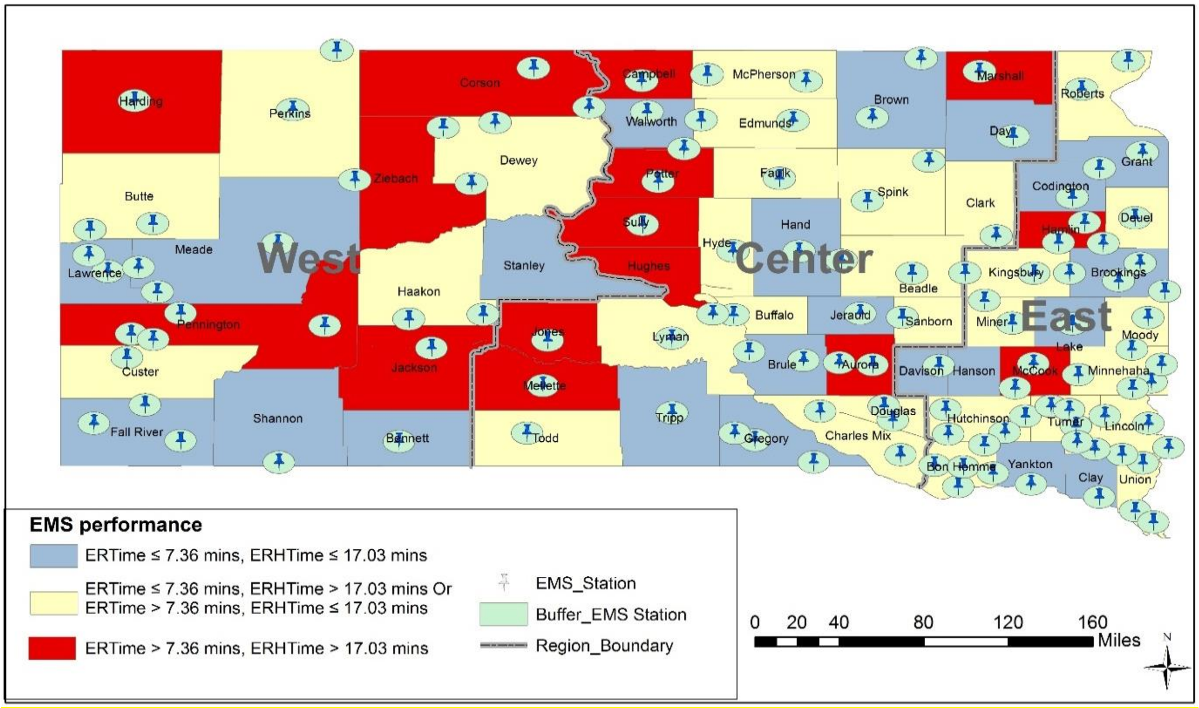


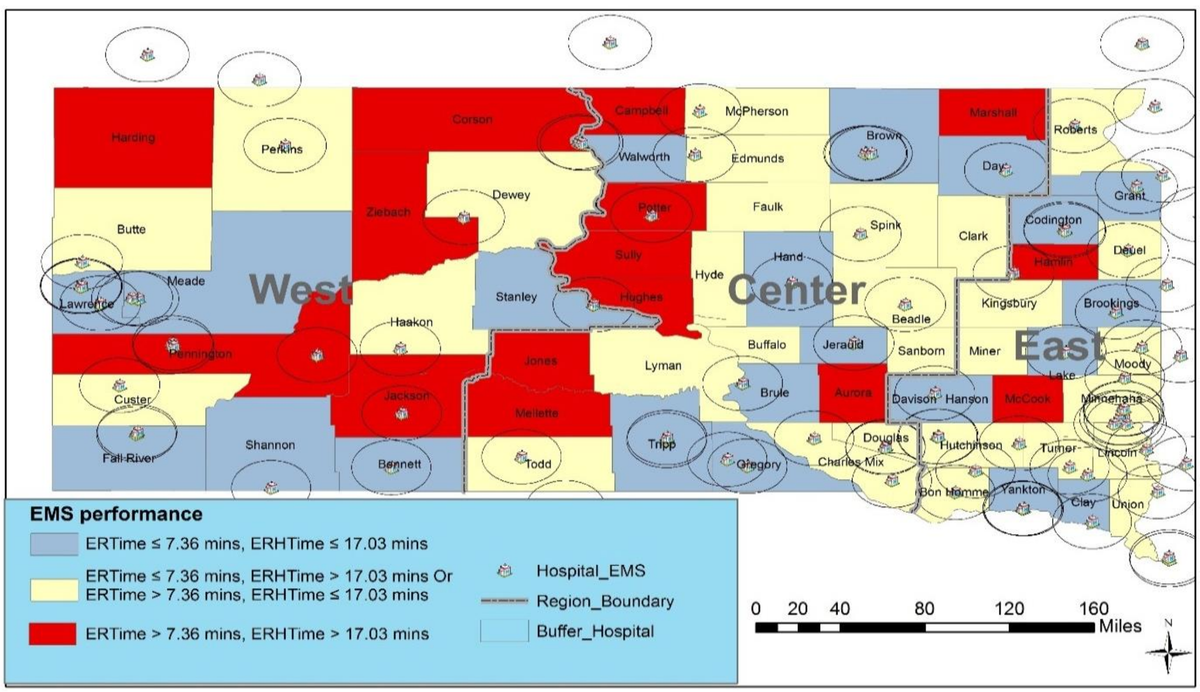
Figure 2.10 Getis G* for ERHTime by County in SD in 2012

With limited information regarding service performance, all the EMS stations and hospitals associated with emergency calls were retrieved in an attempt to explain their roles in affecting EMS performance. In total, 125 EMS stations and 114 hospitals responded to the 15,140 emergencies, including 19 hospitals in Iowa, Minnesota, North Dakota, and Nebraska. Figure 2.11 shows the EMS performance overlaid with EMS stations and hospitals. Buffer distance was created for each EMS station and hospital, with the average ERDistance of 5.51 miles for EMS and the average ERHDistance of 13.74 miles for hospital.

In general, counties with more EMS stations and hospital coverage performed better than counties with fewer stations and hospitals. In rural areas, the number of EMS call volumes remained low due to low population density. The travel distance between an incident location and an EMS station or a hospital was the most dominating factor that affected EMS performance under normal weather conditions. Journey time was highly predictable given the travel distance in rural areas because of less congestion. The sufficiency of highway connectivity is uncertain, and therefore, needs to be reviewed. A well-connected highway network should provide equal opportunities for accessing EMS, and should avoid, minimize, or mitigate disproportionately adverse effects on rural communities. The status quo of ERHTime and ERTime reveals sparsely covered central regions by EMS and hospitals. The counties in this region may be considered for future EMS enhancements.



(a) EMS Station



(b) Hospital

Figure 2.11 EMS Performance with EMS Stations and Hospitals

2.5.2.2 Determination of Destination

The choice of destination directly affects travel distance. In 50% of the cases, destination determination was made according to EMS protocols. In 21% of the cases, the receiving hospital was chosen by the patient or the family, and in 4%, the choice of hospital was made by the physician. Only in 2% of the cases was the victim transported to a specialty resource center.

2.5.2.3 Urban vs. Rural

In the following analysis, urban areas were separated from rural areas based on the US census 2010 classification. In SD, 17 cities have a population of 5,000 or greater and were considered urban (2010 US Census Data). Table 2.4 shows that large disparities exist in every performance measure between urban and rural. In rural areas, both ERTime and ERHTime were almost double those in urban areas (8.87 minutes vs. 4.60 minutes for ERTime and 19.95 minutes vs. 11.51 minutes for ERHTime). Correspondingly, ERDistance and ERHDistance were twice as long in rural areas than urban areas (7.29 miles vs. 2.26 miles for ERDistance and 16.96 miles vs. 7.65 miles for ERHDistance). As expected, ERSpeed and ERHSpeed in rural areas were markedly higher than those in urban areas (39.36 mph vs. 28.04 mph for ERSpeed and 43.03 mph vs. 26.26 mph for ERHDistance).

Table 2.4 EMS Performance Between Urban and Rural

Variable		Area	Mean	STD. Dev.	Min	Max
Time (min)	**ERTime**	Urban	4.60	4.49	1.00	96.00
		Rural	8.87	9.39	1.00	178.00
	ERHTime	Urban	11.51	15.38	1.00	140.00
		Rural	19.95	17.25	1.00	207.00
Distance (mile)	**ERDistance**	Urban	2.26	3.37	0.04	86.20
		Rural	7.29	9.68	0.02	175.00
	ERHDistance	Urban	7.65	15.85	0.05	116.00
		Rural	16.96	17.50	0.01	258.00
Speed (mph)	**ERSpeed**	Urban	28.04	15.11	1.20	120.00
		Rural	39.36	22.07	0.17	120.00
	ERHSpeed	Urban	26.26	16.12	0.60	120.00
		Rural	43.03	19.24	0.20	120.00

2.5.2.4 Caller Compliant and EMS response

To gain further insight on the impacts associated with an emergency caller's complaint to dispatch, the data with dispatch information (11,444) were analyzed. The top seven complaints to dispatchers in ascending order were: fall victim (13.54%), sick problem (13.15%), chest pain (11.27%), breathing problem (10.34%), traffic accident (8.44%), abdominal (5.99%), and traumatic injury (5.10%). However, not all the top seven complaints were time sensitive. Hence, six time-sensitive complaints such as breathing problems, traffic accident, traumatic injury, stoke/CVA, ingestion/poisoning, and cardiac arrest were selected from the 911 calls and an analysis on ERTime, OSTime, ERHTime, and Overall Response Time was performed (see Table 2.5). Incidents of strokes, breathing problems, and cardiac arrests had the shortest ERTime (5.26 minutes, 6.13 minutes, and 6.67 minutes) and cardiac arrests and traffic accidents required fairly long OSTime (18.90 minutes and 17.66 minutes). The ERHTime for cardiac arrest (13.79 minutes) and ingestion/poisoning (14.42 minutes) were the shortest. Also, cardiac arrest had the shortest

Overall Response Time (41.80 minutes) while traffic accidents had the longest (44.61 minutes). The fact that cardiac arrest incidents performed well on ERTime, ERHTime, and Overall Response Time confirms that a cardiac arrest is the one of the most urgent emergencies.

Table 2.5 Time Intervals by Different Dispatch Complaints

		Breathing Problem (10.34%)	Traffic Accident (8.44%)	Traumatic Injury (5.10%)	Stroke/ CVA (2.5%)	Ingestion/ Poisoning (1.57%)	Cardiac Arrest (0.87%)
ERTime (min)	**Mean**	6.13	8.4	8.35	5.26	7.33	6.67
	STD Dev.	6.71	7.86	8.37	4.61	7.89	5.99
OSTime (min)	**Mean**	15.49	17.66	15.77	14.58	13.42	18.9
	STD Dev.	22.48	10.71	12.42	6.55	6.57	13.96
ERHTime (min)	**Mean**	17.68	18.25	19.19	18	14.42	13.79
	STD Dev.	16.02	17.30	18.58	17.51	14.24	13.07
Overall Response Time (min)	**Mean**	43.49	44.61	43.99	44.91	42.62	41.80
	STD Dev.	27.16	26.64	26.21	27.84	22.22	18.67

2.5.2.5 Ambulance Speed and use of Lights & Sirens

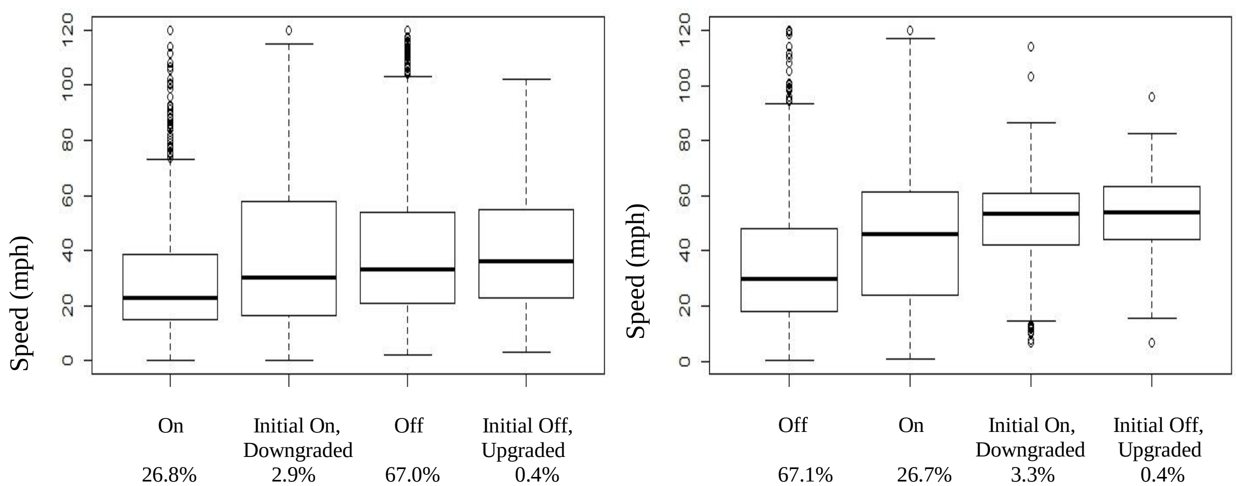
Transporting speed (ERHSpeed) was significantly higher than responding speed (ERSpeed) (p-value = <0.001). EMS speed was analyzed further using dispatch times. The data were separated into daytime (6 am to 6 pm) and nighttime (6 pm to 6 am). A t-test was conducted on ERSpeed and ERHSpeed using the daytime and nighttime categories (see Table 2.6). There was no significant difference for ERSpeed between daytime and nighttime. However, ERHSpeed in the nighttime was significantly lower than in the daytime, and ERHSpeed was significantly higher than ERSpeed in both the daytime and nighttime (p=<0.0001).

ERSpeed and ERHSpeed were also evaluated in relation to the incident location (incident occurred in a city different than the city of the dispatch center or the receiving hospital and incident occurred in the same city of the dispatch center or the receiving hospital). The dispatch speed to an incident that occurred in a different city was substantially higher (i.e., 50.16 mph vs. 37.87 mph) than the situation where both EMS station and incident were located in the same city. Similarly, the transporting speed for the case where incident and hospital were in different cities was considerably higher (i.e., 46.06 mph vs. 33.14 mph) than the same city situation. This large disparity in traveling speed between same city and different cities may be caused by the availability and use of high-speed roadway facilities between cities.

Table 2.6 ERSpeed and ERHSpeed Between Daytime and Nighttime

	ERSpeed (mph)		ERHSpeed (mph)	
	Daytime	**Nighttime**	**Daytime**	**Nighttime**
Mean	35.23	35.47	37.37	36.44
STD. Dev.	20.69	20.52	20.17	19.45
t Stat	-0.70		2.86	
P(T<=t) one-tail	0.24		0.00	

Statistical analysis was performed to examine the effect of lights & sirens on travel speed of EMS responders. Four different situations for the use of lights & sirens and the travel speed were examined: 1) lights & sirens are on; 2) lights & sirens are off; 3) initial lights & sirens are on, then downgraded; 4) initial lights & sirens are off, then upgraded. Figure 2.12 illustrates the travel speed by responding mode and transporting mode using two box plots. The data show that the majority of the EMS lights & sirens were off (67%) in both responding mode and transporting mode, suggesting that most incidents were not sufficiently critical to necessitate the use of the emergency lights & sirens. Figure 2.12a depicts the travel speed to an incident scene with different variations of lights & sirens. The small value of standard deviation for the speed with lights & sirens on suggests that the speed varies little with the use of lights & sirens. Interestingly, the results show that the mean speed with lights & sirens on was ranked lowest of any other combination. Figure 2.12b shows the travel speed to the hospital with different variations of lights & sirens. The transport speed with lights & sirens on appears to be much higher than transport speed with lights & sirens off. Another finding was that when the lights & sirens were upgraded from off to on, the speed moved from the lowest to the highest.



(a) (b)

Figure 2.12 Travel Speed by Responding and Transporting Mode

3. SURVEY FINDINGS

3.1 Objective 3-Purpose

A survey questionnaire was administered to a sample of 29 EMS personnel covering four counties in eastern SD to identify existing issues with the SD EMS providers or first responders related to roads and traffic controls from their perspective. Survey questions were designed to learn about what type of road and driver issues exist and the frequency with which issues were encountered by providers. The questionnaire items targeted two areas: driver's factors and road factors. Driver's factors addressed issues related to driver's behavior and how they affect safety and response time. Road factors were divided into sub-categories: situational factors and year-round or everyday road factors.

3.2 Methodology

A survey was developed by the primary investigators, and draft copies were distributed to five EMS directors who served as an advisory panel. The panel provided feedback on content validity of the initial items using two delphi rounds. Once the delphi rounds were completed and reviewer comments were incorporated in the final draft, the survey was administered to a convenience sample of 29 EMS providers representing the east region of the state. Institutional Review Board approval at South Dakota State University and informed consent were obtained. Participants were asked to rate each of the 42 survey items on a scale of 1-5 (1: never, 2: rarely, 3: sometimes, 4: very often, and 5: always).

3.3 Summary of Results

Results indicated that delays occur sometimes when responding to an emergency but more often during transports. This may, in part, explain the shorter ERTime that the EMS data analysis revealed. When asked to rate the quality of roads and bridges in SD, 21% of respondents indicated that SD highways were in excellent condition, 79% thought that SD highways were in good condition, 14% thought that SD bridges and intersections were in poor condition, and 86% thought that bridges and intersections were in good condition. Figure 3.1 provides survey results on the use of safety restraints among ambulance occupants while driving and while providing patient care in the back.

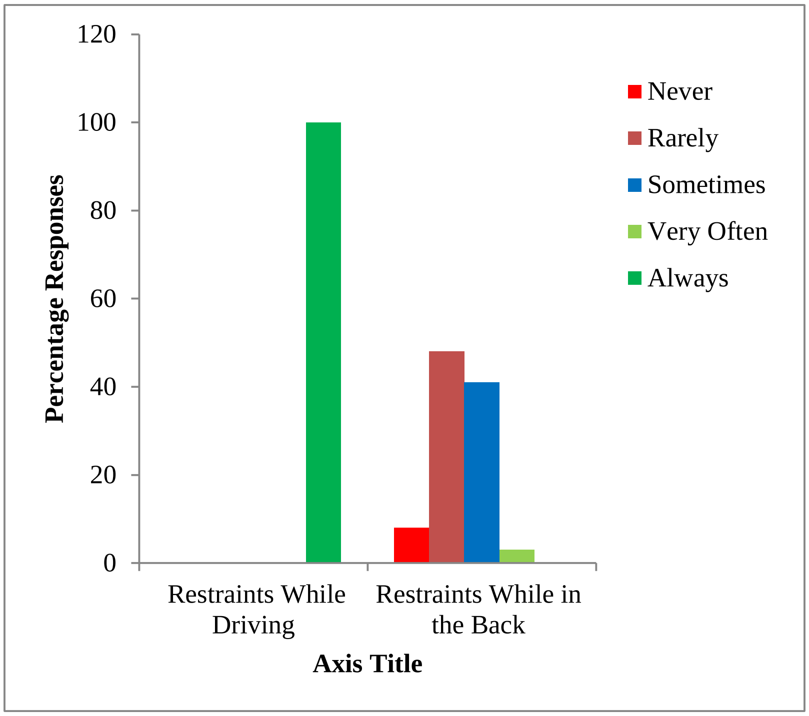


Figure 3.1 Use of Safety Restraints by the Ambulance Occupants

Table 3.1 EMS Survey Responses

Issue	**% of participants who responded with always of very often**
Driver Factors	
Use of flashing lights and sirens in accordance to standards set by the state when responding to a 911 call	100%
Use of lights and sirens based on reports from crewmembers regarding the medical condition of the patient when transporting a patient to definitive care	100%
Encounter distractions while driving. This includes in-vehicle devices, cell phones, computer screens, traffic radios, road maps, etc.	38%
Received training on how to manage new and uncertain situations while driving an ambulance	68%
Slow down or stop to check for other drivers, pedestrians, or trains before proceeding through traffic lights, intersections or train crossings	86%
Driving faster when familiar with road conditions	72%
Other Drivers and motorists fail to respond appropriately to a moving ambulance with lights and sirens	32%
Feel less likely to be involved in an accident compared to the average driver*	72%*
Cross unmarked or poorly marked lanes that pose safety risks to a moving vehicle	20%
Slow down due to icy condition and snow	69%
Encounter poorly lit roads without retro-reflective pavement which affect the safety of a moving EMS vehicle, particularly at night	13%
Encounter blocked roads that require a detour or parking the ambulance faraway while responding to a call	21%
Drive narrow lanes that pose safety risk for a moving ambulance	38%

*This may indicate overconfidence and perception bias which yields underestimation of risk on behalf of the driver (Svenson 1981)

3.4 Qualitative Data

When participants were asked on a scale of 1-5 (1 very poor, 2 poor, 3 good, 4 very good, and 5 excellent) to rate their perception on the safety of highways, bridges, and intersections in SD, the following ratings were received:

- 79% rated highways as good, 14% as excellent, and 7% as poor
- 86% rated bridges as good and 14% as poor
- 86% rated intersections as good and 7% as poor

When asked to explain their rating, participants provided a list of concerns, which they believe have a great impact on safety and contribute to delays in transport and response time. The list included the following:

- Among respondents, 85% indicated that bridges are rough and cause excessive patient jolting and discomfort.
- Other drivers, pedestrians, cars, flaggers, and construction zones were identified by 85% of participants as major safety hazards for a moving ambulance, especially within city limits. This in part may explain higher ERSpeed at night.

- Blind intersections, unmarked intersections, and blind spots were reported to be a major hazard
- All respondents reported that failure of other drivers to pull over and causing a crash is a major safety concerns.

3.5 Factors Leading to Delays

Respondents reported the following as the most common reasons for delays when responding to a 911 call:

- Availability of personnel
- Access to homes and wrong addresses
- Wrong mapping and directions
- Overload of the system
- Road markings
- Construction
- Drivers and pedestrians failing to pull to the side and respond appropriately to lights and sirens
- System overwhelmed by calls and no ambulance available
- Long turns
- Distance to the call and driver's error
- Weather and road conditions
- EMT communication

Respondents reported the following as the most common reasons for delays when transporting a patient to definitive care:

- Drivers and pedestrians failing to pull to the side and respond appropriately to lights and sirens
- Long transports
- Patient indecisive where to go
- Weather and road conditions

4. FOCUS GROUP FINDINGS

Two focus group discussions were held with 8-10 members in each group. The purpose of the group discussions was to learn about the concerns and needs of EMS providers and to identify existing issues with EMS system providers related to roads and traffic controls. Discussions were held in a private and comfortable location. Each session lasted for 1 to 1 1/2 hours. IRB approval and written consent were obtained. All discussions were audio-taped and labeled with a code but without any identifiers. Conversations from each of the groups were transcribed verbatim. Coded information were organized into categories and summarized in alignment with criteria for focus group reporting. The following themes were noted:

- Participants frequently mentioned concerns about uneducated drivers and poor driver behavior when encountered by a moving ambulance with lights and sirens. Participants verbalized concerns about EMS causing an accident because of others not understanding the rules. Some of the recurring phrases included:
  "Drivers are impatient, uneducated and sometimes ignore EMS"
  "Drivers are distracted with phones, texting, loud music, etc. and oftentimes do not see or hear an approaching ambulance"
  "Wish the city will designate police to follow and observe"
  "It comes down to education and law enforcement"
- Participants frequently mentioned concerns about cell phones making dispatch harder because the E911 system is not fully developed in SD
- Participants voiced concerns about the lack of signs to alert EMS personnel about road closures.
- Participants voiced concerns about plows keeping snow on curbs and outside lanes which creates an issue for ambulances.
- Participants mentioned the need for a unified EMS system with good communication
- Participants voiced concerns about rough roads (especially bridges) and dips, which cause delays in transports in certain situations. Sample statements include:
  "Dips and road engineering are done for water drainage and not traffic"
  "Road traffic speed cannot be achieved and cost ambulances lots of maintenance"
  "Bridges are rough and cause patient discomfort"
  "Ambulance cannot slow down on every bridge"
  "Does not help with broken hips, the impact is felt a lot in the back of the truck"
  "Railroad tracks are fixed but get rough in a year or so"
- Participants mentioned the need to improve gravel roads.
  "Gravel roads are bad, cannot control the ambulance at greater than 10 miles/hour on gravel roads"

5. CONCLUSIONS AND RECOMMENDATIONS

The goal of this project was to conduct a needs assessment for rural EMS in South Dakota and to identify issues with respect to delivering quality EMS to rural residents. There were three major objectives in this research: 1) identify the EMS service needs from the rural communities; 2) evaluate the efficacy of rural SD EMS service in support of swift and safe EMS operations; and 3) identify existing issues with the SD EMS providers or first responders related to roads and traffic controls.

According to NHTSA (2011) crash facts, 2011 national average EMS response time for fatal crashes is 37.22 minutes in urban areas in contrast with 54.49 minutes in rural areas. SD is 3.13 min (or 9%) shorter than the national average in urban areas and is approximately the same in rural areas in spite of differences in a few specific phases, e.g., the notification time in SD is 2 minutes (or 32.4%) shorter than the national average, the en-route time to crash scene is 2 minutes (or 16.1%) longer than the national average. Although the EMS response time for fatal crashes is one of the most critical performance measures, this research targets a broader EMS 911 response with the attempt to address critical factors affecting the provision of satisfactory EMS services.

This study started with 50,396 EMS responses that occurred between 1/1/2012 and 12/31/2012 in SD, of which 15,140 were 911 calls, meaning emergency services. The result shows the 911 calls are highly skewed with 30% of the counties making 60% of the calls. Todd County has the highest 911 call volume and the most 911 calls per population of 1,000, almost nine calls per day. Geographically, several counties with high service demand per 1,000 persons were clustered in the south central region of the state.

The temporal service demand was subsequently analyzed. More than 1,300 911 calls were made throughout the summer months of June (6), July (7), and August (8) as well as December (12). Fridays and Saturdays appear to have the highest demand. On average, the calls made in each of these two days were 10% higher than any other day of the week. During the daytime from 9 am to 8 pm, the emergency call volume was relatively stable with a standard deviation of 50 calls per hour. The highest hourly demands happened between 11 am and 12 pm as well as 4 pm and 6 pm.

The overall response time for EMS 911 calls in SD is 43.26 min ± 25.97 min. The overall response time is the summation of RespTime, ERTime, OSTime, and ERHTime. The average ERTime is 7.36 minutes because of an average ERDistance of 5.51 miles. ERHTime, however, is more than twice as high as ERTime because of an average 13.74 mile ERHDistance. Using local spatial analysis methods, no obvious cluster for ERHTime was identified. Based on the state average ERTime and ERHTime, the EMS performance of each county has been evaluated. The underperformers with longer ERTime or longer ERHTime, or both, are usually the areas that are short of EMS stations and hospitals. A further comparison between urban and rural areas in SD shows ERHDistance in rural is 16.96 miles, in contrast with 7.65 miles in urban and ERHTime is 19.95 minutes in rural in contrast to 11.51 minutes in urban.

Other noticeable differences include light conditions, location, and the use of light and sirens. Light conditions may be a factor in travel speed back to the hospital (ERHSpeed). Statistically, nighttime ERHSpeed is significantly higher than daytime ERHSpeed. If an incident occurs in a city different than where the receiving facility is located, the dispatch and transport speeds to those receiving hospitals are almost 13 mph higher than those within the same city. Ambulances may use lights and sirens to warn other traffic and gain valuable time by speeding when conditions are urgent. The majority (67%) of EMS lights and sirens are off both in responding and transporting modes. When they are on, the data show minor speed increases. Interestingly, the average speed with lights and sirens on is lower than any other combination of responding and transportation modes.

A survey was conducted to 29 EMS personnel covering four counties in eastern SD to identify existing issues with the SD EMS providers or first responders related to roads and traffic controls. The survey was also supplemented by two focus group discussions with 8-10 members in each group. Among the responses, one outstanding issue is motorists' lack of compliance to emergency vehicles. All respondents considered the failure of other drivers to pull over as a major safety concern.

Traffic delay does not seem to be a significant issue, as 50% indicated that delays occur sometimes during transports.

It is encouraging that all respondents rated SD highway conditions as either good or excellent. Based on their perception of road safety, 83% rated either good or excellent. Among the issues that may potentially threaten the travel safety and create delays, 85% of respondents mentioned that bridges are rough and cause excessive patient jolting and discomfort; 69% mentioned icy roads and 38% mentioned narrow lanes. One-fifth of respondents cited blocked roads and construction (e.g., lack of signs to alert EMS personnel about road closures) and unmarked or poorly marked lanes or blind intersections.

This project summarizes the SD EMS data from the geographic (e.g., counties in SD) and temporal (e.g., time of day, day of week, and month of year) perspectives and concentrates on several time- and distance-dependent variables such as response time, en-route time, on-scene time, and transporting time as well as the distance to and from the incident scene. It is noteworthy that the average distance between the EMS station and incident scene is only 5.51 miles and the median distance is less than 2 miles. On the other hand, the average distance between the incident scene and receiving agency is 13.74 miles and the median distance is 6 miles. The comparison suggests excellent EMS coverage but also confirms a relatively low density of receiving hospitals. Considering SD is a predominant rural state and many EMS tasks rely on volunteer community members, the network of first responders, paramedic personnel, or volunteers appear to be well connected.

Overall, the respondents rated SD highways as excellent and perceived road safety performance as good. Nevertheless, bridges, icy roads, narrow lanes, and poorly marked or blind intersections were often cited as top risk factors to travel safety and delay. Although the survey conducted in this research is informative, it does not help to identify issues with specific routes, bridges, and intersections. Given the rich location information of EMS data, it is recommended to thoroughly investigate the cases with undesirable performance to address location-specific problems as well as identify appropriate solutions.

Moreover, it is unclear how the EMS response and transport times affect the outcome of an incident. Taking traffic accidents as an example, what will be the consequence if the service is delayed? Crash data have abundant information related to the time, location, highway, traffic, and environmental factors contributing to a crash. More importantly, crash data have the consequence of a collision in terms of injury severity, e.g., fatal, severe injury, minor, or possible injuries. Therefore, it is recommended to link EMS data with crash data in order to predict service delivery more accurately and establish more specific, data-driven, and performance-based measures.

For a rural state like SD, the approximate annual EMS call volume of 50,000 may be expected. But the daily call volume, divided by the number of counties, is low, which presents a challenge for researchers to identify any clear patterns and trends. Such a small sample can be further deteriorated by missing or poor data. In our study, 29,354 are 911 or emergency calls but only 15,140 (51%) responses have valid information for performance analysis. Hence, for the sake of ongoing endeavor to enhance EMS services for rural areas, it is strongly recommended to improve EMS data quality in future data collection.

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APPENDIX

Overall Response Time by County

County	Population	911 Call Volume	Overall Response Time (min)			
			Mean	STD. Dev.	Min	Max
Aurora	2710	2	41.5	43.13	11	72
Beadle	17398	2	16	5.66	12	20
Bon Homme	7070	141	43.18	25.64	12	165
Brookings	31965	98	41.45	23.26	15	181
Brown	36531	1009	43.15	26.34	8	311
Brule	5255	162	45.94	25.64	5	141
Buffalo	1912	44	41.73	22.29	11	109
Butte	10110	361	43.11	24.88	13	184
Campbell	1466	26	43.46	19.21	8	81
Charles Mix	9129	4	52	41.00	17	111
Clark	3691	169	47.08	26.88	12	168
Clay	13864	333	42.41	23.19	10	173
Codington	27227	1211	43.67	25.01	6	236
Corson	4050	99	41.32	20.65	14	110
Custer	8216	252	42.86	27.11	8	246
Deuel	4364	72	48.4	37.88	12	290
Dewey	5301	978	43.39	25.91	9	406
Douglas	3002	64	44.86	27.68	16	169
Edmunds	4071	57	42.84	21.58	14	113
Fall River	7094	425	42.63	25.50	11	210
Faulk	2364	2	35.5	13.44	26	45
Grant	7356	170	43.21	23.65	14	137
Gregory	4271	49	39.12	20.48	12	134
Haakon	1937	11	38.82	13.62	22	58
Hamlin	5903	102	45.01	21.99	13	140
Hand	3431	2	19	8.49	13	25
Harding	1255	26	61.12	40.51	11	204
Hughes	17022	1	55	-	55	55
Hutchinson	7343	36	38.86	31.82	16	199
Hyde	1420	44	42.09	16.16	18	79
Jackson	3031	23	44.87	21.18	22	89
Jerauld	2071	8	43.75	19.28	20	67
Jones	1006	36	37.19	17.70	12	81
Kingsbury	5148	73	42.37	21.63	16	107

Lake	11200	1	20	-	20	20
Lawrence	24097	1476	43.35	25.10	7	224
Lincoln	44828	504	43.5	24.37	11	221
Lyman	3755	131	46.81	28.76	9	149
Marshall	4656	10	47	17.08	22	74
McCook	5618	25	40.16	19.23	20	85
McPherson	2459	23	39	19.04	10	79
Meade	25434	709	42.26	24.94	8	246
Mellette	2048	258	44.66	49.11	5	737
Miner	2389	4	29	10.68	18	42
Minnehaha	169468	662	44.09	27.06	10	398
Moody	6486	169	40.35	20.26	12	138
Pennington	100948	209	43.57	25.97	12	163
Perkins	2982	176	43.43	27.93	9	271
Potter	2329	4	53	29.87	30	96
Roberts	10149	521	42.47	24.44	12	228
Sanborn	2355	33	42.79	22.73	12	106
Spink	6415	114	42.01	18.56	11	93
Sully	1373	31	37.58	15.75	12	82
Todd	9612	1964	42.76	24.79	7	320
Tripp	5644	3	43.67	3.06	41	47
Turner	8347	367	43.13	23.40	11	204
Union	14399	216	45.11	32.54	10	386
Walworth	5438	307	41.21	23.22	12	198
Yankton	22438	899	43.94	27.32	9	380
Ziebach	2801	165	46.48	29.72	14	220
Total	765652	15140	43.26	25.97	5	737

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