Needs Assessment of Rural Emergency Medical Services

Xiao Qin, Zhaoxiang He, and Haifa Samra

Unintentional mortality rates attributed to disease, fertility, and motor vehicle crashes are higher in rural areas than in urban areas because of the more limited nature of emergency medical services (EMS), hospitals, and the highway network connecting them. For rural states with long travel distances that result from the sparsely distributed population, it is important to gain a reliable assessment of EMS demand and an unbiased evaluation of service performance within the current highway system. The goal of this research was to conduct a needs assessment for rural EMS and identify issues related to the delivery of quality services. The data set was from the National EMS Information System and consisted of 50,396 EMS responses in 2012 in South Dakota. Spatial analysis focused on the visual presentation and cluster analysis of service demand and performance on a county level. Temporal analysis was performed to magnify the service demand by month, day of week, and time of day. Descriptive statistics and two-tailed *t*-tests were applied to describe and compare the variables of interest. The findings not only offered a comprehensive view of EMS from geographic and temporal perspectives but also stressed key time- and distance-dependent factors, such as response time, en route time, on-scene time, and transporting time. The authors call for continued efforts to improve EMS data quality and recommend linkage between EMS data and crash outcomes to establish specific, data-driven, and performance-based measures.

Rural transportation networks connect local residents to employment, health care, social activities, and business opportunities. A functional and reliable rural transportation system is critical to rural economic growth, public health, traffic safety, and social welfare. Long travel distances in South Dakota, a prominent rural state, are not uncommon and result from the state's sparsely distributed population. The transportation of 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 disease, fertility, and motor vehicle crashes are higher in rural settings than in urban settings (*1*). According to NHTSA, "Delay in delivering emergency medical services is one of the factors contributing to the disproportionately high fatality rate for rural crash victims" (*2*).

Improved EMS will have direct impacts on 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 good quality services, it is necessary to obtain a realistic estimate of the medical demand as well as the capacity of the current transportation infrastructure that pertains to the services. The gaps between service providers and patients, as well as in the transportation network connecting the two groups, need to be identified and closed to support better EMS.

The goal of this research was to identify issues related to the delivery of quality EMS to rural residents and conduct a needs assessment from the perspective of a rural transportation system. The research was supported by two major objectives: (*a*) identify the service needs of rural communities and (*b*) evaluate the rural transportation system components that support swift and safe EMS.

LITERATURE REVIEW

EMS 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 vital expansions of emergency room care for the community (*3*). EMS transport patients to hospitals by ground or air and provide medical assistance both on the scene and en route. Because of the close association between EMS, transportation infrastructure, and the services provided for traffic accident injuries, EMS have long been considered one of the four cornerstones of a successful transportation safety management system (the so-called four Es): EMS, engineering, education, and enforcement (*4*).

The enhancement of EMS to reduce mortality is one of the 22 goals identified in AASHTO's Strategic Highway Safety Plan (*5*). Because motor vehicle traffic fatalities are consistently higher in rural areas than in urban areas, NCHRP Report 500 addresses strategies and methods to enhance EMS in rural areas (*6*). To guide effective interventions, it is important to understand the issues, gaps, and needs in service and provide an objective evaluation of the EMS activities in rural areas.

In recent years, substantial progress has been made in data collection and system information management, human factors and ergonomics, standards and protocols, and vehicle design and fleet management. The impact, however, is mostly felt in urban areas that are well supported by EMS. A wide disparity still exists in the delivery of EMS in rural areas. The factors that contribute to such disparities include geographic barriers; a lack of professional, paraprofessional, and financial resources; aging or inadequate equipment; an absence of specialized EMS care and local medical facilities; the sporadic nature of rural crashes; and a workforce that is predominately composed of volunteers (*3*).

X. Qin, Department of Civil and Environmental Engineering, University of Wisconsin, Milwaukee, NWQ 4414, Milwaukee, WI 53201-0784. Z. He, Department of Civil and Environmental Engineering, South Dakota State University, Brookings, SD 57007. H. Samra, Sanford Education Center, 1525 South Euclid, Sioux Falls, SD 57105. Corresponding author: X. Qin, qinx@uwm.edu.

Transportation Research Record: Journal of the Transportation Research Board, No. 2513, Transportation Research Board, Washington, D.C., 2015, pp. 30–39.
DOI: 10.3141/2513-04

Considered a major performance index, response time has been extensively used to evaluate EMS performance. Although patient outcomes depend on many other factors, such as the severity of the injuries and the existence of preexisting conditions, the time required for an EMS unit to arrive at the scene (the response time) and the time required for a patient to receive definitive care (the overall response time) play a significant role in the outcome. The Centers for Disease Control and Prevention report a 25% reduction in the mortality risk when trauma victims receive definitive care at a Level 1 trauma center (*7*). Crashes in rural areas usually occur far away from Level 1 trauma centers, and timely transportation to those centers depends on the availability of swift EMS. To date, the explicit relationship between clinically significant improvements in patient outcomes and reductions in EMS time to definitive care has not been fully established, but the general consensus is that a shorter time before definitive care is received is associated with improved outcomes in patients who need emergency care. Therefore, it is crucial to get critical patients to definitive care immediately [within 60 min (known as the "golden hour")] after the occurrence of the emergency.

However, this response time is not always achieved in rural areas. In 2004, NHTSA reported that the national average for the overall EMS response time (the time from notification to definitive care) for fatal crashes was 36 min in urban areas and 53 min in rural areas (*8*). Over 36% of fatal crashes that occurred in rural areas had response times that exceeded 60 min, and only 10% of fatal crashes in urban areas exceeded the 60-min limit. According to those statistics, the response time in rural areas approached the end of the golden hour. Seven years later, those statistics had not improved but had, on the contrary, slightly deteriorated. The 2011 reported national average for EMS response time for fatal crashes was 37.22 min in urban areas and 54.49 min in rural areas (*9*). Table 1 provides a comparison of the South Dakota and national statistics. South Dakota performed slightly better (3.13 min, or 9%, shorter) in urban areas. The interval between the time of the crash and the hospital arrival, or the 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 South Dakota was 1.5 min, or 23.7%, shorter than the national average, but the en route time to the crash scene was 2 min, or 16.1% longer than the national average.

TABLE 1 Average EMS Response Times for Fatal Crashes (*10*)

Interval	Urban (min)		Rural (min)	
	South Dakota[a]	National Average[b]	South Dakota[c]	National Average[d]
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

[a]Based on 15 fatal crashes.
[b]Based on 13,578 fatal crashes.
[c]Based on 86 fatal crashes.
[d]Based on 16,053 fatal crashes.

EMS DATA ANALYSIS

Data Sources

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

Five individual time intervals, which constituted the entire EMS process, were analyzed in this study. These intervals were the response time, the en route time, the on-scene time, the transporting time, and the destination time. The sum of the response time, the en route time, the on-scene time, and the transporting time may be referred to as the "overall response time." The time intervals for the response, en route, transporting, and on-scene times (see Figure 1 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 the time the responding unit starts moving to the time the responding unit stops physical motion at the scene. The transporting time is defined as the time the responding unit begins physical motion from the scene to the time the patient arrives at the destination or definitive care.

Data Inclusion and Exclusion

Quality controls were performed on the odometer data, the time intervals, the distance, and the 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 times longer than 240 min, travel distances to the scene or return to the hospital distances greater than 400 mi, and odometer speeds greater than 120 mph. Values outside the above parameters were assumed to be erroneous and unrealistic. Out of state, air transportation, interfacility transfers, nonemergency transportation, and responses with missing data were also excluded. The inclusion criteria included only 911 dispatch–type or EMS-type requests.

Measures

The measures of demand included EMS calls or service volumes by population, population density, county, month, day of the week, and time of day. Demand was also examined in relation to the demographic characteristics of users, such as age, gender, and medical condition. To obtain a detailed description of each service component of the EMS process and that component's performance, the travel speed, distance, and duration that corresponded to the response time, the en route time, the on-scene time, the transporting time, and the

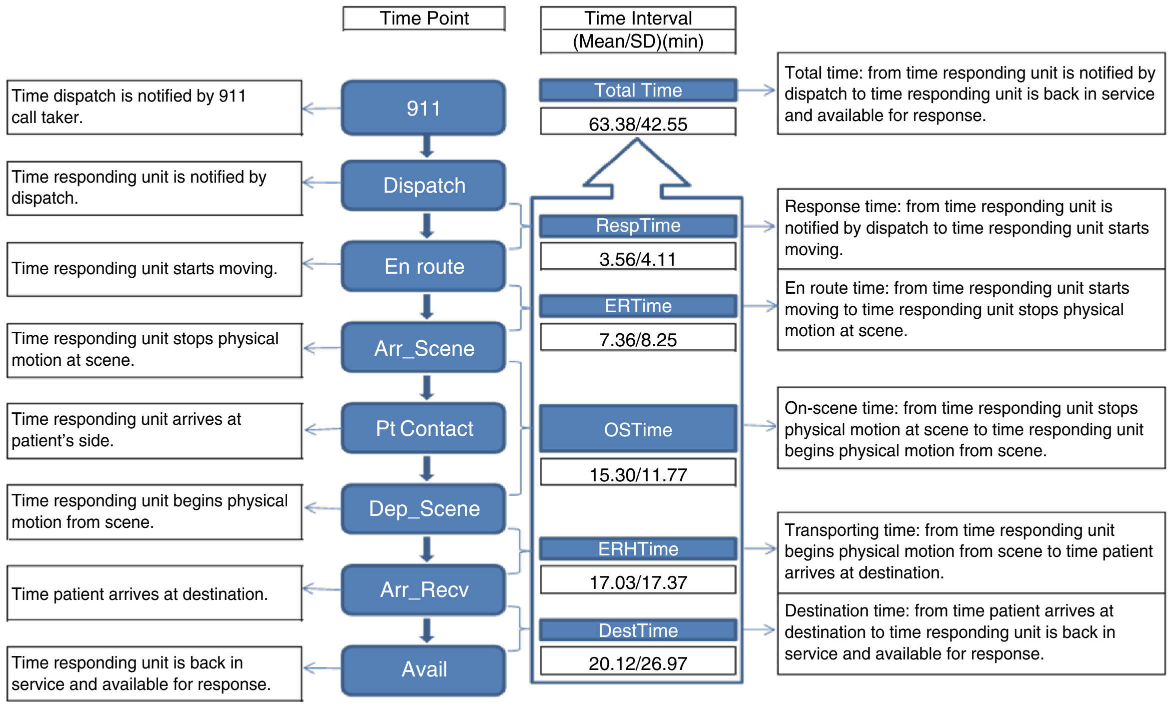


FIGURE 1 EMS flowchart (SD = standard deviation; Arr_Scene = arrival at scene; PtContact = patient contact; Dep_Scene = departure from scene; Arr_Recv = arrival at receiving agency; Avail = available) (*11*).

total time were analyzed. An investigation of the EMS performance by dispatch complaint was also made.

Analysis

Data were analyzed from both spatial and temporal perspectives. Spatial analysis was conducted through geographic information system–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, day of the week, and time of day. Descriptive statistics were used when continuous variables were presented as means and standard deviations (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 .05 ($p < .05$) was considered to be statistically significant. South Dakota operates three regional dispatch centers that divide the state into western, central, and eastern regions. These regions were maintained in the analysis to enable the results across the state to be compared. To establish the volume per capita, population information for each county in South Dakota was obtained from the U.S. Census Bureau website (*11*).

RESULTS AND DISCUSSION

In 2012, South Dakota had 50,396 EMS transports, of which 29,354 were in response to a 911 call only. The remaining cases were classified as interfacility, medical, mutual aid, and standby. Of the 911-type transports, 15,140 (51%) had valid and accurate travel time, travel speed, and distance data and, therefore, met the inclusion criteria for EMS performance analysis. Table 2 shows the data processing procedure that led to the final sample.

TABLE 2 Data Processing Procedure

				Percentage	
Step	Objective	Criteria	Data	Filtered	Remaining
1	Complete data set	na	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 mi	15,540	1.84	30.84
6	Filter invalid speed data	ERSpeed, ERHSpeed >120 mph	15,140	0.80	30.04

NOTE: na = not applicable; ER = en route to crash scene; ERH = en route from crash scene to hospital.

Service Demand

In 2012, the demand for EMS in response to 911 calls was equally distributed between males and females, and 47% of EMS users were over 60 years of age. The mean ± standard deviation age of an EMS user was 53 ± 25 years. The median age was 54, and the range was zero to 110. Sixty percent of EMS users were white, 24% were American Indian, and 16% were of other ethnicity (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 descending order, falls (13.54%), feeling sick (13.15%), chest pains (11.27%), breathing problems (10.34%), and traffic accidents (8.44%).

Figure 2 shows the 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 each had less than 1,000 emergency calls in 2012. When call volumes were examined per 1,000 persons, over 90% of the counties had emergency call volumes of less than 100 calls per 1,000 persons. Todd County remained the highest ranked, with more than 300 calls per 1,000 persons, followed by Mellette and Dewey Counties, each with more than 200 calls per 1,000 persons.

The 911 call locations were distributed spatially across the state with patterns and clustering. The recognition of spatial clusters of EMS demand helps to discover underlying factors associated with service needs that contribute to spatial disparities. The Getis *G**-statistic indicates locations surrounded by a cluster of high or low values, also known as "hot spots" or "cold spots" (*12*). A *z*-score measures the statistical significance compared with a random geographic distribution. A positive *z*-score indicates a 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, the Getis *G**-statistic was calculated to identify spatial clusters in South Dakota. In Figure 3, the high values of the Getis *G**-statistic represented by dark color show a clustering of counties with high 911 volumes per 1,000 persons in the south central region of South Dakota. The *z*-score above 1.96 indicates a 5% significance level. For the rest of the state, no obvious clusters were found.

Temporal analysis was performed to identify the pattern in EMS demand over time. Figure 4 shows the demand by month. The peak monthly demand, which was more than 1,300 calls, occurred during the summer months of June, July, and August as well as in December. The emergency call volume was lowest in February and April.

Saturday and Friday had the highest demand levels (10% higher than the other days of the week). Sunday was ranked as the lowest-demand day of the week. Figure 5 shows the EMS demand by day of the week.

The hourly emergency 911 call volume variations over a 24-h period are shown in Figure 6. The call volume steadily increases from 6 to 9 a.m., maintains a high level throughout the day, and then gradually decreases after 8 p.m. From 9 a.m. to 8 p.m., the emergency call volume is relatively stable and has a small standard deviation of 50 calls per hour (150 when all calls are included). The highest hourly demands can be seen between 11 and noon and between 4 and 6 p.m.; these peak hours see demands as high as 800 calls per hour (2,400 when all calls are included).

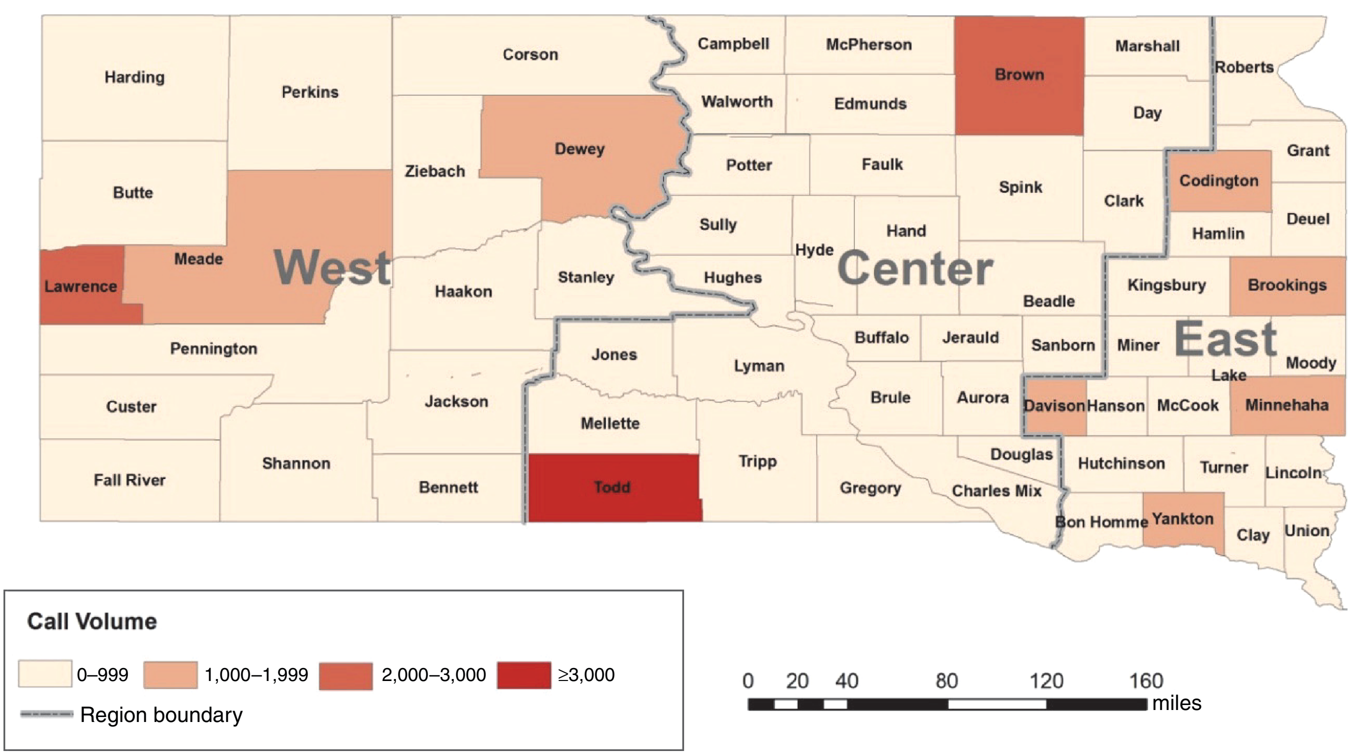


FIGURE 2 EMS demand by county in South Dakota.

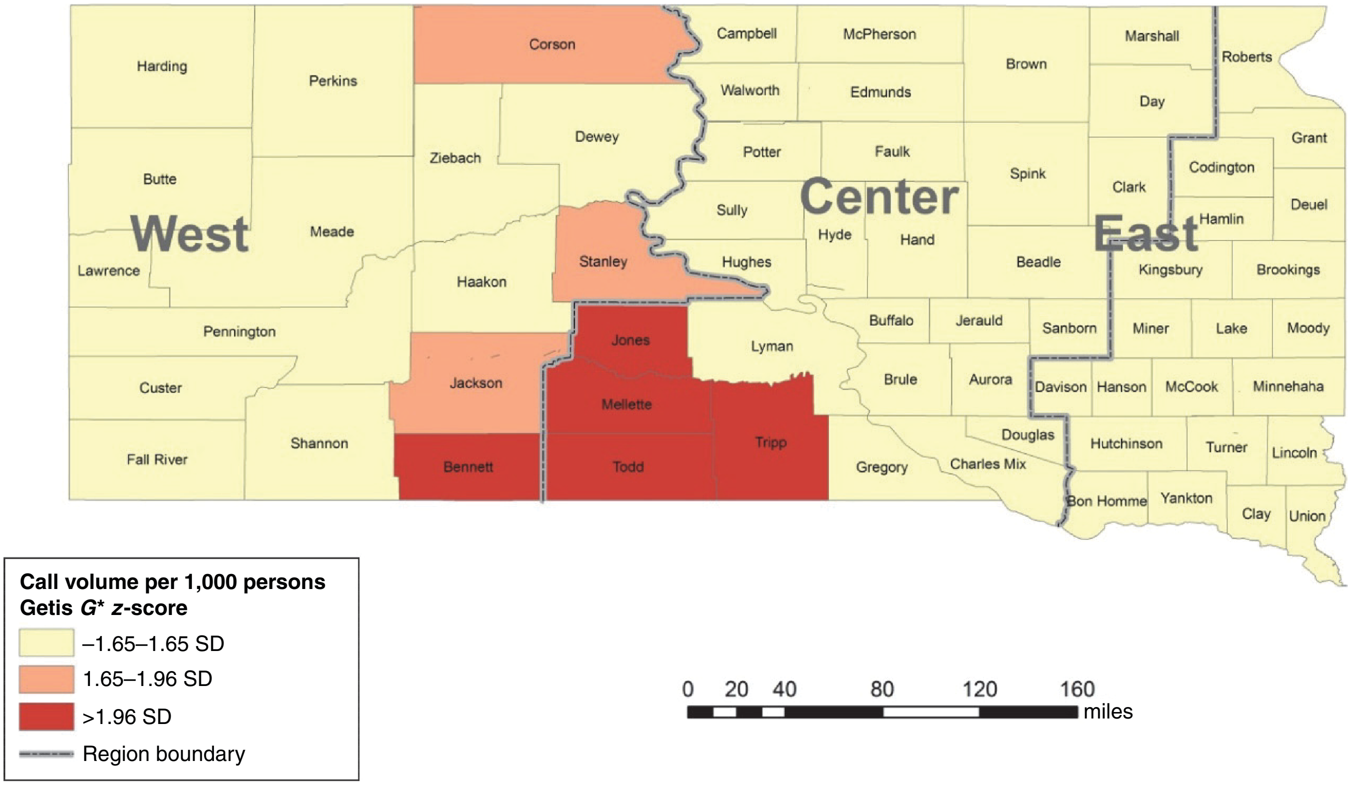


FIGURE 3 Getis *G** *z*-score for EMS demand per 1,000 persons by county.

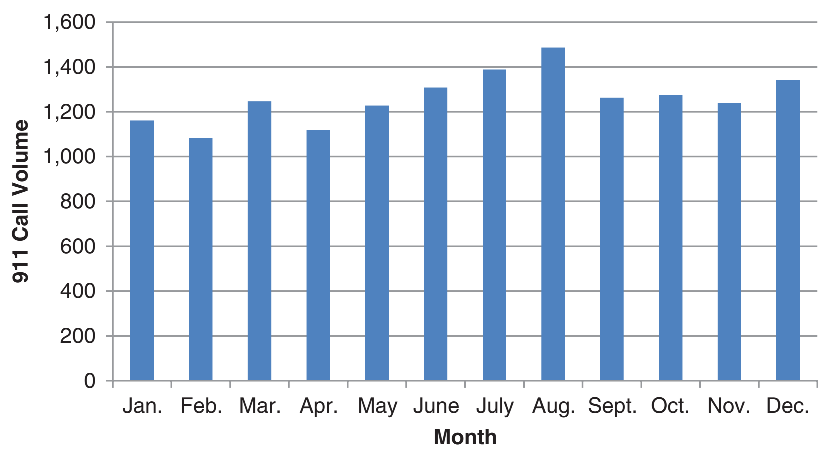


FIGURE 4 EMS demand by month (Jan. = January; Feb. = February; Mar. = March; Apr. = April; Aug. = August; Sept. = September; Oct. = October; Nov. = November; Dec. = December.)

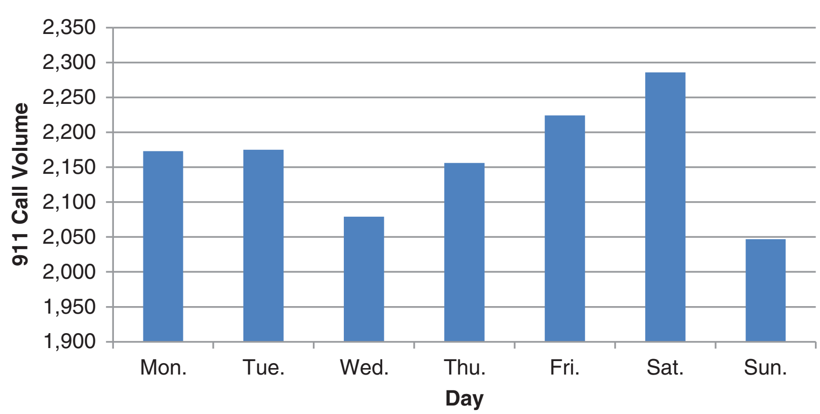


FIGURE 5 EMS demand by day of week (Mon. = Monday; Tue. = Tuesday; Wed. = Wednesday; Thu. = Thursday; Fri. = Friday; Sat. = Saturday; Sun. = Sunday.)

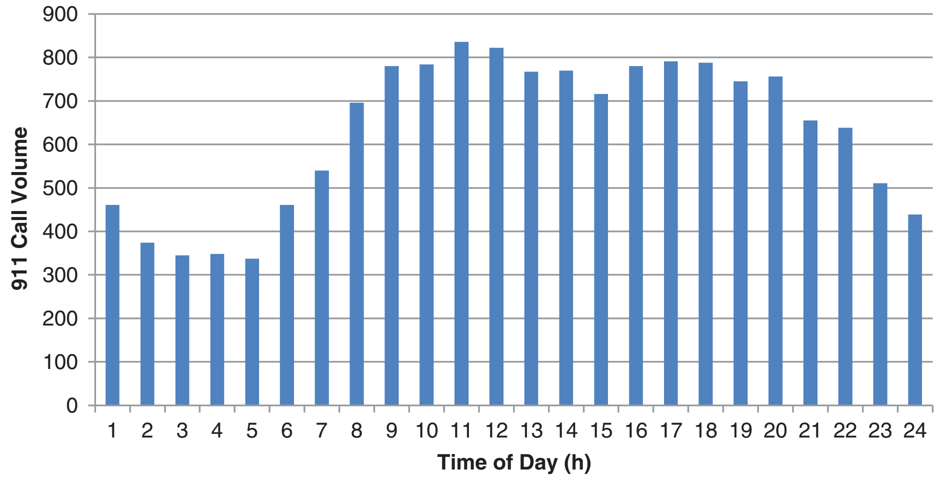


FIGURE 6 EMS demand by time of day.

System Performance

Time and Distance

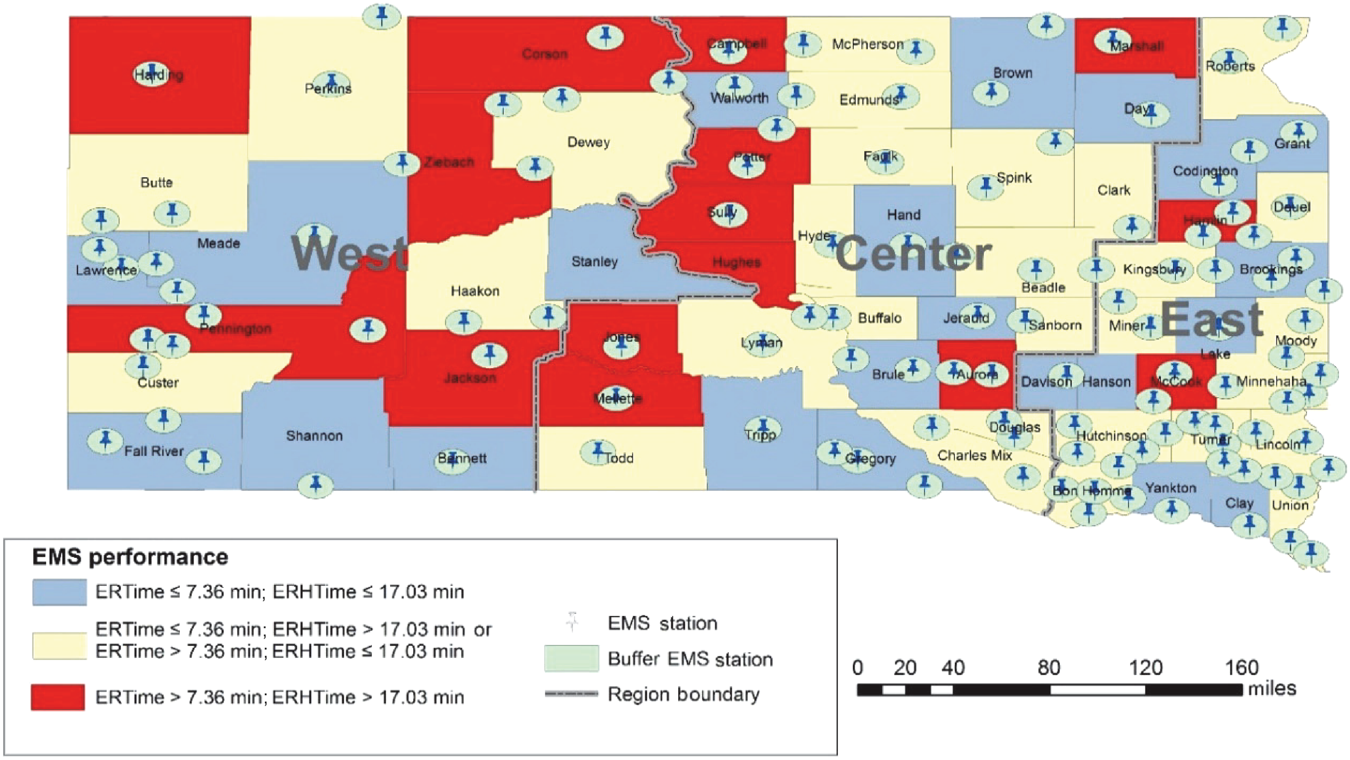
The following analysis was based on 15,140 emergency calls that had complete and valid information. Summary statistics of time duration, travel distance, and speed are presented in Table 3. The average response, en route, on-scene, and transporting times were 3.56, 7.36, 15.30, and 17.03 min, respectively, and resulted in a 43.26 min (±25.97 min) overall response time and a 63.38-min (±42.55-min) total time. The median en route time was merely 4 min, and the median distance (en route distance) between the EMS station and the incident scene was less than 2 mi. The transporting time was much greater than the en route time, so was the mean distance (transporting distance) between incident locations and receiving agencies. This large disparity suggested an excellent EMS coverage but a low density of hospital facilities in rural areas.

The state average en route and transporting times were used as benchmarks to measure the en route and transporting times in each county. Figure 7 depicts a fairly mixed picture. Red color counties had longer en route and transporting times than the state averages. Light blue counties had shorter en route and transporting times than the state averages.

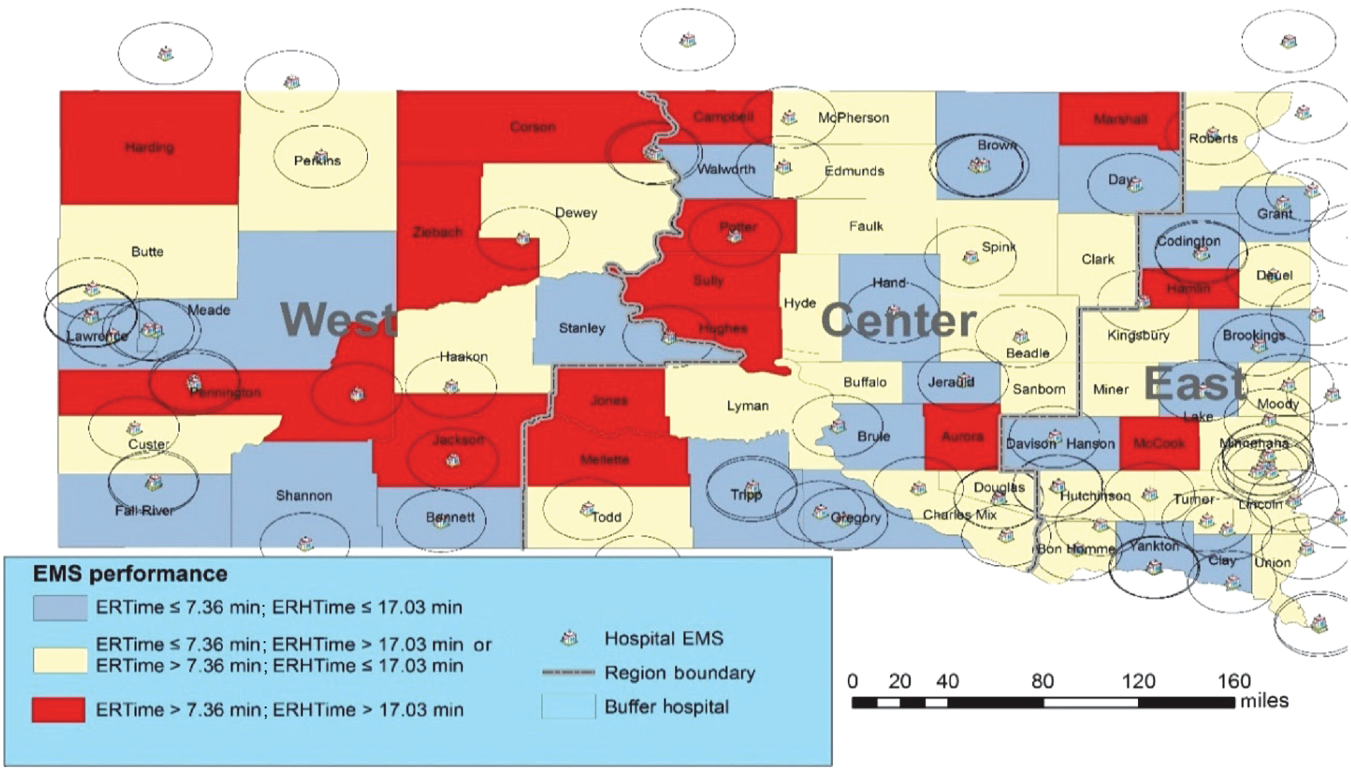
TABLE 3 Summary Statistics of Travel Duration, Distance, and Speed

Variable	Description	Mean	SD	Median	Range
Duration (min)					
RespTime	Duration from time responding unit is notified by dispatch to time responding unit starts moving	3.56	4.11	3.00	[0, 131]
ERTime	Duration from time responding unit starts moving to time responding unit stops physical motion at scene	7.36	8.25	4.00	[1, 178]
OSTime	Duration from time responding unit stops physical motion at scene to time responding unit begins physical motion from scene	15.30	11.77	14.00	[0, 730]
ERHTime	Duration from time responding unit begins physical motion from scene to time patient arrives at destination	17.03	17.37	11.00	[1, 207]
Overall response time	Duration from time responding unit is notified by dispatch to time patient arrives at destination	43.26	25.97	37.00	[5, 737]
Total Time	Duration from time responding unit is notified by dispatch to time responding unit is back in service and available for response	63.38	42.55	53.00	[5, 1,488]
Distance (mi)					
ERDistance	Distance between EMS and crash scene	5.51	8.38	1.90	[0.02, 175]
ERHDistance	Distance between crash scene and receiving agency	13.74	17.90	6.00	[0.01, 258]
Speed (mph)					
ERSpeed	Average speed from time ambulance set out to time ambulance arrived at scene	35.34	20.61	30.00	[0.17, 120]
ERHSpeed	Average speed from time ambulance departed from scene to time ambulance arrived at receiving agency	37.01	19.88	36.00	[0.20, 120]

NOTE: SD = standard deviation.



(a)



(b)

FIGURE 7 EMS performance with (*a*) EMS stations and (*b*) EMS hospitals.

Todd County, with the highest call volume and the highest calls per 1,000 persons, had an en route time shorter than the state average but a transporting time longer than the state average. Mellette County exceeded the state average for both times, and Bennett County outperformed the state average for both times. Counties around the state borders with Nebraska, Iowa, and Minnesota performed better than the counties inside South Dakota or bordering North Dakota and Wyoming.

With limited information about service performance, all the EMS stations and hospitals associated with emergency calls were retrieved in an attempt to explain the roles of these stations and hospitals in 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 7 shows the EMS performance overlaid with EMS stations and hospitals. A buffer distance was created for each EMS station and hospital with the average en route distance of 5.51 mi for EMS and the average transporting distance of 13.74 mi for hospitals.

In general, counties with more EMS station and hospital coverage performed better than counties with fewer stations and hospitals. In rural areas, the EMS call volume remained low as a result of low population density. The travel distance between an incident location and an EMS station or hospital was the most dominant factor that affected EMS performance under normal weather conditions. Journey times were highly predictable from the travel distance in rural areas because of the lower levels of congestion in these areas. The sufficiency of highway connectivity was uncertain and, therefore, needs to be reviewed. A well-connected highway network should provide equal opportunities to access EMS and should avoid, minimize, or mitigate disproportionally adverse effects on rural communities. The status quo of transporting time and en route time revealed a central region sparsely covered by EMS and hospitals. The counties in this region may be considered for future EMS enhancements.

Determination of Destination

The choice of destination directly affects travel distance. In 50% of the cases, the determination of destination 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% of the cases, the choice of hospital was made by the physician. Only in 2% of the cases was the victim transported to a specialty resource center.

Urban Versus Rural

In the following analysis, urban areas were separated from rural areas on the basis of the U.S. census 2010 classification. In South Dakota, 17 cities had a population of 5,000 or greater and were considered urban (*11*). Table 4 shows that large disparities exist between urban and rural areas in every performance measure. In rural areas, both the en route and transporting times were almost double those in urban areas (8.87 versus 4.60 min for the en route time and 19.95 versus 11.51 min for the transporting time). Correspondingly, the en route and transporting distances were twice as long in rural areas as in urban areas (7.29 versus 2.26 mi for the en route distance and 16.96 versus 7.65 mi for the transporting distance). As expected, the en route and transporting speeds in rural areas were markedly higher than those in urban areas (39.36 versus 28.04 mph for the en route speed and 43.03 versus 26.26 mph for the transporting distance).

TABLE 4 EMS Performance in Urban and Rural Areas

Variable	Area	Mean	SD	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 (mi)					
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

NOTE: Min. = minimum; max. = maximum.

Professional Versus Volunteer

A lack of professional emergency medical technicians and paramedics can be a major factor affecting service performance in rural areas. In South Dakota, less than 20% of the EMS stations are staffed with professional personnel. A comparison was performed on the time-dependent variables between professional stations and volunteer stations, and the results showed that the response and en route times were significantly shorter at stations staffed with professional emergency medical technicians (2.76 versus 4.53 min for the response time and 6.17 versus 8.81 min for the en route time).

Caller Complaint and EMS Response

To gain further insight into the impacts associated with an emergency caller's complaint to dispatch, the 11,444 data records with dispatch information were analyzed. The top seven complaints to dispatchers, in descending order, were falls (13.54%), feeling sick (13.15%), chest pain (11.27%), breathing problems (10.34%), traffic accidents (8.44%), abdominal pain (5.99%), and traumatic injury (5.10%). However, not all of the top seven complaints were time sensitive. Therefore, six time-sensitive complaints—breathing problems, traffic accidents, traumatic injuries, stroke or cerebral vascular accident, ingestion or poisoning, and cardiac arrest—were selected from the 911 calls, and an analysis on a variety of time scales was performed. Incidents of strokes, breathing problems, and cardiac arrests had the shortest en route times (5.26, 6.13, and 6.67 min), and cardiac arrests and traffic accidents required fairly long on-scene times (18.90 and 17.66 min). The transporting times for cardiac arrest (13.79 min) and ingestion or poisoning (14.42 min) were the shortest. Also, cardiac arrest incidents had the shortest overall response time (41.80 min), and traffic accidents had the longest (44.61 min). Cardiac arrest incidents performed well for en route, transporting, and overall response times; this finding confirms that a cardiac arrest is the one of the most urgent emergencies.

Ambulance Speed

The transporting speed was significantly higher than the en route speed (p-value < .001). Dispatch times were used to further analyze the EMS speed. The data were separated into daytime (6 a.m. to 6 p.m.) and nighttime (6 p.m. to 6 a.m.). A t-test was conducted on the en route and transporting speeds and used the daytime and nighttime categories. There was no significant difference for the en route speed between the daytime and the nighttime. However, the transporting speed in the nighttime was significantly lower than that in the daytime, and the transporting speed was significantly higher than the en route speed both in the daytime and in the nighttime ($p < .0001$).

The en route and transporting speeds were also evaluated in relation to the incident location (whether the incident occurred in a city different than the city of the dispatch center or the receiving hospital and whether the incident occurred in the same city as 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 versus 37.87 mph) than when both the EMS station and the incident were located in the same city. Similarly, the transporting speed when the incident and the hospital were in different cities was considerably higher (i.e., 46.06 versus 33.14 mph) than for the same-city situation. This large disparity in traveling speed between the same city and different cities may be caused by the availability and use of high-speed roadway facilities between cities.

CONCLUSIONS AND RECOMMENDATIONS

According to NHTSA crash facts, the 2011 national average EMS response time for fatal crashes was 37.22 min in urban areas in contrast to 54.49 min in rural areas. The time in South Dakota was 3.13 min (or 9%) shorter than the national average in urban areas and was approximately the same in rural areas, in spite of differences in a few specific phases [e.g., the notification time was 2 min (or 32.4%) shorter than the national average; the en route time to the crash scene was 2 min (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 and attempts to address the critical factors that affect the provision of satisfactory EMS.

Therefore, this study started with 50,396 EMS responses that occurred in 2012 in South Dakota, of which 15,140 were 911 or emergency services calls. The results show that the 911 calls were highly skewed: 30% of the counties made 60% of the calls. Todd County had the highest 911 call volume and the highest number of 911 calls per population of 1,000: almost nine calls a 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 calls were made to 911 throughout the summer months of June, July, and August, as well as in December. Fridays and Saturdays appeared to have the highest demand. On average, the calls made on each of those two days were 10% higher than on any other day of the week. During the daytime, from 9 a.m. to 8 p.m., the emergency call volume was relatively stable and had a standard deviation of 50 calls per hour. The highest hourly demands happened between 11 a.m. and noon and between 4 and 6 p.m.

The overall response time for EMS 911 calls is 43.26 ± 25.97 min. The overall response time is the summation of the response, en route, on-scene, and transporting times. The average en route time is 7.36 min because of an average en route distance of 5.51 mi. The transporting time, however, is more than twice as high as the en route time because of an average 13.74-mi transporting distance. No obvious cluster for transporting time was identified with the local spatial analysis method. On the basis of the state average en route and transporting times, the EMS performance of each county was evaluated. The underperformers, with longer en route times or longer transporting times or both, were usually the areas that were short of EMS stations and hospitals. A further comparison between urban and rural areas showed that the transporting distance in rural areas was 16.96 mi as opposed to 7.65 mi in urban areas, and the transporting time was 19.95 min in rural areas as opposed to 11.51 min in urban areas. Shorter response and en route times were found at stations staffed with professional emergency medical technicians than at stations staffed with volunteers.

Other noticeable differences included light conditions and location. The light condition might be a factor in travel speeds back to the hospitals (the transporting speed). The nighttime transporting speed was statistically significantly lower than the daytime transporting speed. If an incident occurred in a different city from the receiving facility, the dispatch and transport speeds to the receiving hospital in a different city were almost 13 mph higher than those within the same city.

This research summarizes the South Dakota EMS data from the geographic and temporal perspectives and concentrates on several time- and distance-dependent variables, such as the response, en route, on-scene, and transporting times as well as the distance to and from the incident scene. The average distance between the EMS station and the incident scene is only 5.51 mi, and the median distance is less than 2 mi. The average distance between the incident scene and the receiving agency is 13.74 mi, and the median distance is 6 mi. The comparison suggests an excellent EMS coverage but confirms a relatively low density of receiving hospitals. When one considers that South Dakota is a predominantly rural state and many EMS tasks rely on volunteer community members, the network of first responders, paramedic personnel, and volunteers appears to be well connected.

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

For a rural state like South Dakota, 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 in identifying any clear patterns and trends. Such a small sample can be further deteriorated by missing or poor data. In this study, 29,354 of the calls were 911 or emergency calls, but only 15,140 (51%) of the responses had valid information for performance analysis. Therefore, for the sake of ongoing endeavors to enhance EMS in rural areas, it is strongly recommended to improve EMS data quality in future data collection.

ACKNOWLEDGMENTS

This work was sponsored by the Mountain Plain Consortium at North Dakota State University. The authors thank the South Dakota Emergency Medical Services for providing the EMS data. The authors also thank Marty Link, Robert Keys, and Ghazan Khan for their assistance in reviewing this report.

REFERENCES

1. Blumenthal, S.J. The Effects of Socioeconomic Status on Health in Rural and Urban America. *Journal of the American Medical Association,* Vol. 287, No. 1, 2002, pp. 107–108.
2. *Promoting Safe Passage into the 21st Century: Strategic Plan, 1998.* NHTSA, U.S. Department of Transportation, 1998.
3. Rawlinson, C., and P. Crews. *Access to Quality Health Services in Rural Areas—Emergency Medical Services: A Literature Review.* Health Science Center, Texas A&M University System, Austin, 2003.
4. *Highway Safety Improvement Plan.* FHWA, U.S. Department of Transportation. http://safety.fhwa.dot.gov/hsip/resources/fhwasa1102/flyr3_in.cfm. Accessed Nov. 5, 2013.
5. AASHTO. Implementation of the AASHTO Strategic Highway Safety Plan. http://safety.transportation.org/guides.aspx. Accessed November 6, 2013.
6. Torbic, D.J., J. Chew, M. Light, H. Kirkwood, J.D. Miller, D. Miller, R. Pfefer, T.R. Neuman, K.L. Slack, and K.H. Hardy. *NCHRP Report 500: Guidance for Implementation of the AASHTO Strategic Safety Plan, Volume 15: A Guide for Enhancing Rural Emergency Medical Services.* Transportation Research Board of the National Academies, Washington, D.C., 2005.
7. Centers for Disease Control and Prevention. Motor Vehicle Safety: Injury and Violence Prevention. http://www.cdc.gov/motorvehiclesafety/index.html. Accessed Oct. 30, 2013.
8. *Traffic Safety Facts 2004: A Compilation of Motor Vehicle Crash Data from the Fatality Analysis Reporting System and the General Estimates System.* NHTSA, U.S. Department of Transportation. http://www-nrd.nhtsa.dot.gov/Pubs/TSF2004.PDF. Accessed Nov. 6, 2013.
9. *Traffic Safety Facts 2011: A Compilation of Motor Vehicle Crash Data from the Fatality Analysis Reporting System and the General Estimates System.* NHTSA, U.S. Department of Transportation. http://www-nrd.nhtsa.dot.gov/Pubs/811754AR.PDF. Accessed Nov. 6, 2013.
10. *South Dakota Data Dictionary.* South Dakota Department of Public Safety, Pierre, 2008. http://dps.sd.gov/emergency_services/emergency_medical_services/documents/SouthDakota-NEMSISDataDictionaryver1.1.pdf.
11. U.S. Census Bureau. 2010 Population Finder. http://www.census.gov/popfinder/. Accessed Nov. 3, 2013.
12. Ord, J.K., and A. Getis. Local Spatial Autocorrelation Statistics: Distributional Issues and an Application. *Geographical Analysis,* Vol. 27, 1995, pp. 286–306.

The Standing Committee on Transportation Safety Management peer-reviewed this paper.