Urban Sprawl and Delayed Ambulance Arrival in the U.S.

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Background: Minimizing emergency medical service (EMS) response time is a central objective of prehospital care, yet the potential influence of built environment features such as urban sprawl on EMS system performance is often not considered.

Purpose: This study measures the association between urban sprawl and EMS response time to test the hypothesis that features of sprawling development increase the probability of delayed ambulance arrival.

Methods: In 2008, EMS response times for 43,424 motor-vehicle crashes were obtained from the Fatal Analysis Reporting System, a national census of crashes involving ≥1 fatality. Sprawl at each crash location was measured using a continuous county-level index previously developed by Ewing et al. The association between sprawl and the probability of a delayed ambulance arrival (≥8 minutes) was then measured using generalized linear mixed modeling to account for correlation among crashes from the same county.

Results: Urban sprawl is significantly associated with increased EMS response time and a higher probability of delayed ambulance arrival (p=0.03). This probability increases quadratically as the severity of sprawl increases while controlling for nighttime crash occurrence, road conditions, and presence of construction. For example, in sprawling counties (e.g., Fayette County GA), the probability of a delayed ambulance arrival for daytime crashes in dry conditions without construction was 69% (95% CI=66%, 72%) compared with 31% (95% CI=28%, 35%) in counties with prominent smart-growth characteristics (e.g., Delaware County PA).

Conclusions: Urban sprawl is significantly associated with increased EMS response time and a higher probability of delayed ambulance arrival following motor-vehicle crashes in the U.S. The results of this study suggest that promotion of community design and development that follows smart-growth principles and regulates urban sprawl may improve EMS performance and reliability.

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Introduction

Urban sprawl is an increasingly prevalent development pattern in the U.S., typified by low-density construction, poor street connectivity, and single-use zoning that separates residential housing from civic and commercial districts.[1] These characteristics result in longer trip distances,[2] increased traffic congestion and trip time variability for commuters,[1,3] and higher rates of traffic and pedestrian fatalities.[4]

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Emergency medical service (EMS) response time is one of the key measurements for prehospital system performance, with rapid response being highly desirable in situations involving serious trauma or cardiac arrest.[5] Many of the features of sprawl that make personal automobile trips longer, more dangerous, and less time efficient also likely affect ambulance dispatch, potentially leading to delayed arrival. However, the relationship between urban sprawl and EMS response time has not been quantified.

Using national data, this study sought to measure the relationship between county-level urban sprawl and EMS response time in the U.S. It was hypothesized that sprawling counties would be associated with longer response time and increased probability of delayed ambulance arrival relative to counties exhibiting "smart growth" characteristics (i.e., less sprawl) such as higher-density residential development and connected street networks.[3] Confirmation of sprawl's association with

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Table 1. Distribution of EMS response time and motor-vehicle crash site characteristics[a,b]

		EMS response time (minutes)	
Crash site characteristic	All crashes	<8	≥8
n	43,424	22,688	20,736
Presence of construction near crash	1,146 (2.6%)	579 (2.6%)	567 (2.7%)
Crash occurred at night	22,146 (51.1%)	11,597 (51.2%)	10,549 (51.0%)
Wet road surface	7,229 (16.7%)	3,479 (15.4%)	3,750 (18.1%)
M (±SD) sprawl index	102.4±16.9	104.7±16.0	99.9±17.6

[a]Crash data including EMS response time obtained from 2000–2002 Fatal Analysis Reporting System (FARS)
[b]Except for sprawl index, data are reported in frequencies (columnwise percentages in parentheses).
EMS, Emergency and Medical Services

increased EMS response time would have important implications for EMS and emergency preparedness planning in metropolitan areas.

Methods

Data Sources

Emergency medical service response time data were obtained from the Fatal Analysis Reporting System (FARS), a nationwide motor-vehicle crash data collection program sponsored by the U.S. Department of Transportation[6,7] that provides a complete census of crashes in which at least one fatality occurs within 30 days of the crash. It includes extensive data regarding the circumstances of each crash, including location, road conditions, EMS notification time, and time of arrival by EMS at the scene. Many of the built environment measures used to develop the urban sprawl measure used in this analysis are based on 2000 census data. Therefore, FARS data from roughly the same time period (2000–2002) were used to calculate EMS response time following U.S. motor-vehicle crashes.

County-level sprawl was measured using index scores previously developed by Ewing et al.[3] This validated continuous index represents a composite of factors incorporating measures of residential density, segregation of land use, strength of metropolitan centers, and accessibility of the street network and has been widely used in the public health and urban planning literature.[1,2,4,8]

The sprawl index is available for most census-defined metropolitan counties (n=954); some exceptions are the District of Columbia and independent cities in Virginia. The SI also does not apply to rural areas. Available SI values are centered on a value of 100 and range from 55 (Jackson County, Topeka KS) to 352 (Manhattan–New York County, New York NY). Higher index values indicate counties with development more consistent with smart-growth principles.

Study Sample Characteristics

Data from 113,879 motor-vehicle crashes were obtained from the 2000–2002 FARS databases. Where possible, sprawl index values were assigned to each crash based on the county and state in which it occurred. Sprawl index values were available for 77,382 of these crashes (68%); most of the crashes without an index measure occurred in rural areas where the sprawl index does not apply. To focus on more typical metropolitan regions, crashes that occurred in counties with sprawl index values >200 (>97th percentile, n=1086) were excluded. These included the Queens, Bronx, Kings, and New York Counties in New York, and San Francisco County in California. Finally, crashes with incomplete or invalid EMS response time data were also excluded (n=32,872). The final sample included 43,424 motor-vehicle crashes occurring in 46 states and 797 counties.

Analysis

As a measure of EMS response time (dependent variable), the time from notification to ambulance arrival at the crash scene for each motor-vehicle crash in FARS was calculated. Use of mean response time as a quality metric for EMS is generally discouraged given its sensitivity to outliers.[9] Current guidelines by the National Association of EMS Physicians instead suggest the use of fractile response metrics that measure the percentage of EMS responses that meet established time criteria.[9] This approach is intended to reflect and emphasize the importance of EMS response time reliability in the context of medical emergencies.

Incorporating this perspective, the primary outcome measure (EMS response time) used in this study was analyzed as a dichotomized threshold value. Published response time criteria specific to motor-vehicle trauma are not currently available. Therefore, a "delayed" ambulance arrival was defined as ≥8 minutes based on the performance goal of 90% response within 8 minutes that is often used as a quality metric for ambulance dispatch systems.[10] Preliminary analysis demonstrated that ambulance arrival was delayed for approximately 48% of motor-vehicle crashes in the analytic sample (≥8 minutes=20,736, <8 minutes=22,688; Table 1).

The association between delayed ambulance arrival (≥8 minutes) and county-level sprawl was then measured using generalized linear mixed models within the PROC GLIMMIX procedure of SAS, version 9. This approach was chosen to account for the clustered nature of the data because traditional regression techniques would not adjust for correlation among EMS responses that occur within the same county.[11]

Odds of delayed EMS response were modeled as a function of the sprawl index while controlling for crash-level covariates determined to be significant predictors of response time in preliminary analyses. These included time of day, road surface conditions, and presence of construction at the crash site. Given that the relationship between sprawl and odds of delayed response was initially assessed as a quadratic function, the sprawl index was centered (about 100) when included in the model to avoid collinearity. Predicted probability of delayed EMS response at three sprawl index values chosen to approximate average, sprawling, and smart-growth counties was then calculated by subgroup (road surface condition, road construction status, and time of crash).

Table 2. Significant predictors of delayed ambulance arrival (≥8 minutes) following motor-vehicle crashes in the U.S.

Model covariate	OR estimate	95% CI	*p*-value
Presence of construction near crash	1.17	(1.03, 1.33)	0.0195
Wet road surface	1.23	(1.16, 1.30)	<0.0001
Crash occurred at night	1.06	(1.02, 1.11)	0.0042
Sprawl index[a]	Not applicable[b]		<0.0001
(Sprawl index)[a]	Not applicable[b]		0.0346

[a]County sprawl index centered around 100
[b]Relationship between probability of delayed ambulance response and county sprawl index modeled as a quadratic function

This project was approved by the University of Virginia IRB. All analyses were conducted in 2008.

Results

Urban sprawl was found to be significantly associated with increased EMS response time and a higher probability of delayed ambulance arrival (≥8 minutes) following motor-vehicle crashes in the U.S. ($p=0.03$, Table 2). This probability decreases quadratically (Figure 1) as the county sprawl index increases (signifying less sprawling development) while controlling for nighttime crash occurrence, wet road surface, and presence of construction. This decrease in the probability of a delayed ambulance arrival appears to stabilize in counties with prominent smart-growth characteristics (i.e., high sprawl index values); however, definitive conclusions are not possible because relatively few counties in the sample met these criteria.

To further quantify the relationship between sprawl and EMS response time, the predicted probability of a delayed EMS response was calculated for three specific sprawl index values while accounting for other significant predictors (Table 3). These index values were chosen to approximate counties with average, sprawling, and smart-growth development patterns. Overall, the probability of a delayed EMS response was higher in sprawling counties compared with compact counties. For example, the probability of a delayed EMS response for daytime crashes in dry conditions without construction was 69% (95% CI=66%, 72%) in Fayette County GA (sprawl index=75; sprawling) compared with 31% (95% CI=28%, 35%) in Delaware County PA (sprawl index=125; smart growth).

Discussion

This study demonstrates an association between urban sprawl and increased EMS response time as well as a higher probability of delayed ambulance arrival following motor-vehicle crashes in the U.S. The probability of a delayed ambulance arrival is nearly twice as high in counties with prominent features of sprawl, such as low-density construction, limited street connectivity, and segregation of residential development from civic and commercial districts compared with counties exhibiting smart-growth characteristics.[3]

The public health effects of urban sprawl on health issues such as pediatric obesity[8] and traffic injury risk[1,2,4] are well documented and frequently discussed, yet the potential impact of unregulated sprawling development on the performance, efficiency, and cost of EMS is often ignored. Efforts to integrate population density[12] and emergency event location[13,14] into predictive models to guide EMS resource allocation are ongoing. However, the results of this analysis suggest that integration of more comprehensive land-use metrics, such as measures of urban sprawl, into EMS dispatch algorithms may improve resource utilization and potentially response reliability.

Confirmation of sprawl's association with increased EMS response time supports previous calls for increased consideration of land use and its potential impact on emergency care. In his January 2007 *Annals of Emergency Medicine* commentary,[15] William Millard points out that medical infrastructure frequently lags behind residential development in sprawling suburban and ex-urban areas, placing these communities distant from major trauma and tertiary care centers. Lower home prices in sprawling ex-urban areas have also attracted lower-income populations, including the elderly, who are at higher risk for emergent medical

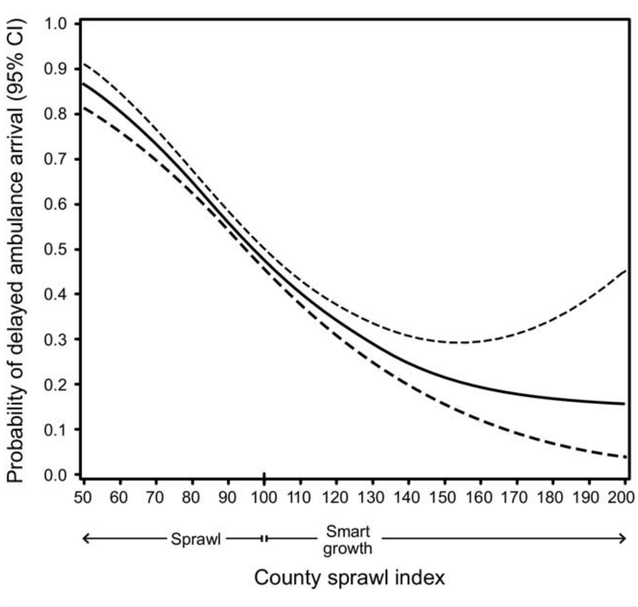

Figure 1. Model-estimated probability of delayed ambulance arrival (≥8 minutes) by county sprawl index[a,b,c]
[a]Relationship between probability of delayed ambulance arrival and county-level sprawl index modeled as a quadratic function ($p=0.0346$)
[b]Probability calculated for a crash that occurred on a dry road during the day with no construction present
[c]Dashed lines indicate the 95% CI around the model-predicted probabilities

Table 3. Model-predicted probability of delayed ambulance arrival (≥8 minutes) for select U.S. counties[a]

Road surface condition	Construction present	Time of day	Fayette County GA: sprawling (sprawl index=75)	San Benito County CA: average (sprawl index=100)	Delaware County PA: smart growth (sprawl index=125)
Dry	No	Day	0.69 (0.66, 0.72)	0.48 (0.46, 0.50)	0.31 (0.28, 0.35)
Dry	No	Night	0.70 (0.68, 0.73)	0.49 (0.47, 0.51)	0.33 (0.29, 0.36)
Dry	Yes	Day	0.72 (0.68, 0.76)	0.52 (0.48, 0.55)	0.35 (0.30, 0.40)
Dry	Yes	Night	0.74 (0.70, 0.77)	0.53 (0.49, 0.57)	0.36 (0.31, 0.41)
Wet	No	Day	0.73 (0.71, 0.76)	0.53 (0.50, 0.55)	0.36 (0.32, 0.40)
Wet	No	Night	0.75 (0.72, 0.77)	0.54 (0.52, 0.57)	0.37 (0.33, 0.42)
Wet	Yes	Day	0.76 (0.73, 0.80)	0.57 (0.53, 0.61)	0.39 (0.34, 0.45)
Wet	Yes	Night	0.77 (0.74, 0.81)	0.58 (0.54, 0.62)	0.41 (0.36, 0.46)

[a]Counties chosen based on their sprawl index value to represent sprawling, average, and smart-growth areas (i.e., mean sprawl index value±1 SD)

issues and EMS utilization.[16] As a result, demand for EMS service is often increased per capita in the same sprawling areas where it is more difficult and expensive to provide. Recent declines in housing prices and clustering of foreclosures in sprawling suburban areas[17] threaten to further delay investment in healthcare facilities for outlying metropolitan areas, potentially intensifying stress on suburban emergency response systems.

Strengths and Limitations

The primary strengths of this study are its use of national EMS data, a continuous multicomponent measure of urban sprawl,[3] and the incorporation of multilevel analysis techniques to adjust for correlation between EMS runs occurring within the same county.[11] Previous studies investigating the impact of sprawl on EMS response in ex-urban areas have been limited by their use of broad development categories (urban, rural, ex-urban) to analyze variability in the built environment.[18,19] The current study uses a comprehensive specific measure of urban sprawl[3] that incorporates multiple land-use metrics and is widely used in both urban planning and public health.[1,2,4,8]

At the same time, this analysis is based solely on EMS response following motor-vehicle crashes; national EMS response time data for other health emergencies are currently unavailable. While the American Ambulance Association recommends the response interval of less than 8 minutes used in this study for all emergency call types including trauma,[10] the medical necessity of this response interval for serious injury remains debatable.[5] This limits interpretation of sprawl's potential impact on patient outcome due to delayed ambulance arrival from the current analysis. Availability of comprehensive national EMS data inclusive of emergent conditions with well-defined response-time criteria would allow quantification of potential negative health outcomes due to sprawl-related inefficiencies in prehospital care delivery. For example, hypoxic emergencies, such as cardiac or respiratory arrest, require initiation of treatment within 4–6 minutes to prevent permanent disability or death.[9] Building the capacity to directly measure the impact of urban sprawl and other built environment features on EMS performance and subsequent patient outcomes will be critical to successful land-use reform, particularly in rapidly expanding metropolitan areas.

Motor-vehicle crash databases, such as the FARS data set used in this analysis, also do not include information necessary to measure system-level variability in call processing time from notification to actual ambulance dispatch. In many communities, emergency calls are initially picked up by police and then routed to EMS, potentially introducing response delays that are independent of ambulance travel time. There is no obvious indication that these unmeasured delays systematically biased the results of the current analysis. However, development of EMS data systems that allow specific segments of the EMS response interval to be distinguished and measured will be very valuable.

Finally, the use of a county-level sprawl measure also limited the current analysis of EMS response to a regional geographic scale. It is likely that neighborhood-level design factors (e.g., "loop and lollipop" subdivisions prioritizing cul-de-sacs[1] versus more traditional grid neighborhoods) exert substantial effects on EMS response time, particularly in the context of hypoxic emergencies, where even short delays may have important implications for patient outcomes. The public health benefits of increased street network connectivity, including emergency response, are becoming increasingly well recognized. Certain states, including Virginia,[20] are beginning to mandate reductions in cul-de-sacs and limited-access neighborhoods through transportation and land-use legislation.[21] Future research will be needed to guide these efforts and measure their impacts on EMS response reliability.

Conclusion

Urban sprawl is significantly associated with increased EMS response time and higher probability of delayed ambulance arrival following motor-vehicle crashes in the U.S. The results of this study suggest that promotion of community design and development that follows smart-growth principles and regulates urban sprawl may improve EMS performance and reliability.

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