Accessibility of Low-Income Populations to Safe Zones During Localized Evacuations

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Access to transportation is of utmost importance for an evacuation, especially to the disadvantaged population. This study presents a simple yet revealing and practical tool for measuring the level of accessibility to so-called safe zones. Usually accessibility is reported on the basis of time, cost, or distance and does not account for the many other variables that influence travel behavior. This research bypassed those limitations by using results from the Maryland Statewide Transportation Model to take advantage of the log-sum measure. Flood and storm surge estimates, shelter and hospital locations, demographics, and other data were collected from official sources. Two locations in the Metropolitan Washington Council of Governments region were analyzed: the city of Frederick, Maryland, and the Anacostia neighborhood of Washington, D.C. Results suggest a positive correlation between income and accessibility. However, the results also reveal that factors such as location and vehicle ownership could greatly affect accessibility.

"At any moment, the most vulnerable are those whose lives are the most constrained, such as the poor, who have the least access to coping resources," wrote Godschalk more than a decade ago (*1*). Evacuations are more common than many people realize. Even though many people along the Gulf and Atlantic Coasts of the United States evacuate almost every year when faced with approaching hurricanes, such events are unusual in and around Washington, D.C. Nevertheless, Hurricanes Agnes in 1972, Floyd in 1999, and Isabel in 2003 are recent hurricanes turned into tropical storms that caused significant damage to the region. Furthermore, during the months of June and July 2013, flash floods became common, causing damage and forcing people to leave their homes. Such recent events make it clear that research is needed to develop evacuation-oriented evaluation frameworks that could complement existing robust traffic simulation techniques. For example, Chakraborty et al. used a geographic information system (GIS) framework to determine the magnitude of evacuation assistance need of zones in the coastal area of Hillsborough County, Florida (*2*). They combined various geophysical patterns (i.e., flood estimates) and social vulnerability indicators (i.e., population demographics). Socioeconomic demographics, however, are not the only factors that influence the effectiveness of evacuation strategies (*3*). Murray-Tuite and Mahmassani modeled household evacuation behavior by incorporating people's desire to find relatives before leaving an area and then evacuate as a unit (*4*). Their model yields higher (and more realistic) evacuation times than traditional evacuation models, which assume that people move away from the danger immediately.

Of the many factors influencing evacuation behavior, accessibility is of utmost importance, especially to disadvantaged populations (e.g., individuals with low incomes or special needs). These populations have a transportation network different from the rest of the population, mainly because of their limited access to a full set of transport alternatives and resources, and such restrictions are exacerbated in the midst of a disaster. Having access to transportation alternatives, even partial access, provides individuals freedom from social, economic, and physical isolation (*5*). Therefore, transportation plays an important role, if not the most important role, in the process of preparing for and recovering from a disaster. It was evident in New Orleans, Louisiana, with Hurricane Katrina and in Haiti with its catastrophic 2010 earthquake.

In this study, disadvantaged individuals are defined as people who live below the poverty line (as set by the 2010 National Poverty Guidelines) or who require special assistance. According to the Federal Transit Administration, the six types of individuals who may require special assistance include individuals who cannot independently get to a pick up (evacuation) point, live independently and require transportation from their location, live in a group setting (e.g., group home, assisted living center) and require transportation directly from their location, live in acute-care or inpatient facilities, have disabilities, or have limited English proficiency (*6*).

The preliminary work for this research was performed as part of the Regional Public Transportation Capacity Study for the Washington, D.C., Metropolitan Region, petitioned by the Metropolitan Washington Council of Governments (MWCOG). This study builds on and adds to that work by using transportation models such as the Maryland Statewide Travel Model (MSTM), a state-of-the-practice model system developed to support policy analysis and decision making. Currently, metropolitan planning organizations and the Maryland State Highway Administration (SHA) use the MSTM.

An available planning tool is proposed for evaluating accessibility in emergency situations, and a simple, yet revealing and practical method is presented for measuring the level of accessibility to safe zones. For this study, safe zones are defined as locations that provide safe haven to evacuees or serve as transition points to such locations. Examples include pickup and meeting points, shelters, hospitals, high-altitude (flood-free) areas, and locations at least 5 mi from the affected area; however, this definition of safe zone can change depending on the magnitude, type, and location of the event. The tool allows visual analysis of accessibility though GIS systems by superimposing layers of information and identifying deficiencies. The tool provides practitioners, first responders, planners, and other decision makers with insight into the mobility capabilities of different communities to take the necessary steps to ensure the efficient and optimal distribution of resources. This tool is flexible in its application

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and easily transferable to any location for which the necessary data are available.

The rest of this paper is organized as follows. First, the method used to calculate network accessibility to recovery sites during evacuation is presented. Next, low-income households are defined, as well as the methods and data available to locate them in the study areas. Then, two case studies are presented: evacuations of the city of Frederick, Maryland, and the Anacostia neighborhood of Washington, D.C., both caused by localized floods. Finally, a detailed accessibility analysis is presented, followed by conclusions and suggestions for future investigations.

METHODOLOGY

Transport modeling measures (based on existing behavior) what people would do, whereas accessibility measures what people could do (*7*). Being able to measure accessibility enables comprehensive policy evaluation by taking into account all potential alternatives of transportation linked with demographic data. Usually, accessibility is reported as the number of people or percentage of a population that can access a destination in a specified threshold—usually related to time, distance, or cost or some combination of these factors. Apparicio et al. used different distance types (i.e., Cartesian and network) and aggregation methods (e.g., population weighted mean) to measure the geographical accessibility of residential areas (i.e., census tracts) to selected health care services (*8*).

As commissioned by the New Zealand Transport Agency, Abley developed a method to assess the accessibility of a neighborhood (*7*). The method yielded color-coded maps indicating the accessibility level of a given neighborhood based on a desired time, distance, or cost bound. In a 2011 report, Tomer et al. measured the effectiveness with which transportation networks in metropolitan areas connect workers with jobs (*9*). They measured how many people (grouped by skill set) were covered by transit and how many jobs they could reach in a reasonable time (usually 90 min). Yigitcanlar et al. measured accessibility to basic community services via public transportation as walking distance and travel time (*10*). Nicholls measured accessibility to recreation locations (i.e., parks) with a 0.5-mi threshold for coverage radius and walking distance (*11*). Other authors have used a distance-based gravity calculation approach, such as the sum of attraction measures (e.g., number of doctors or jobs) divided by a distance-based attribute (e.g., travel time or area) to measure accessibility between locations (see Kockelman, *12;* Thouez et al., *13*).

Although practical, these approaches do not simultaneously account for all available modes of transportation and the many other variables that influence their use, such as in-vehicle travel time, parking cost, walk time, toll cost, and transit fare. Kwan and Weber state the need to go beyond conventional spatial and temporal frameworks to measure accessibility (*14*). Geurs and Wee (*15*) and Litman (*16*) suggest that utility- and activity-based accessibility measures that are more advanced, yet easy to interpret, are needed to improve current practice in accessibility measurement. Therefore, this research attempts to fill such a void and bypass the stated limitations by taking advantage of the log-sum measure that results from transportation models.

Consumer Surplus

Consumer surplus (CS) is the utility a person receives from a choice situation. A researcher often is interested in measuring the change in CS associated with a particular policy (e.g., building a new subway line or applying a new parking policy) because it is important to measure the project benefits and compare them with the costs. Similarly, a change in the attributes of an alternative can have an impact on CS that is important to assess. The equation for CS is $\mathrm{CS}_n = (1/\alpha_n)\max_j(U_{n,j})$, where α_n is the marginal utility of income (defined as dU_n/dY_n, with U_n = utility of income n and Y_n = income of person n) and $U_{n,j}$ is the utility of alternative j for income n. Division by α_n translates utility to dollars, because $1/\alpha_n = dY_n/dU_n$. The researcher observes only the known part of $U_{n,j}$ ($V_{n,j}$) instead of $U_{n,j}$. Furthermore, the expected CS can be calculated as

$$E(\mathrm{CS}_n) = \frac{1}{\alpha_n} E\left[\max_j\left(V_{n,j} + \varepsilon_{n,j}\right)\forall j\right]$$

where $\varepsilon_{n,j}$ is the unknown part of the utility of alternative j for income n. If each $\varepsilon_{n,j}$ is an independent and identically distributed extreme value and the utility is linear in income (so that α_n is constant with respect to income), then

$$E(\mathrm{CS}_n) = \frac{1}{\alpha_n}\ln\left(\sum_{j=1}^{J} e^{V_{n,j}}\right) + C$$

where C is an unknown constant to account for the fact that the absolute level of utility cannot be measured. The argument in parentheses in the previous expression is the denominator of the logit choice probability. The expected CS in a logit model is simply the log of the denominator of the choice probability and can be estimated for any population that has the same representative utility; it often is called the log-sum term. Train presents more details on discrete choice models and their application (*17*).

Log-Sum Approach

Often used in transportation, logit models provide the basis for CS, which is measured by the log-sum. In practice, log-sums rarely are used in project assessments. Instead, the benefits of a project are measured as changes in cost and time to travelers. This study applies the CS concept to evaluate accessibility in the MWCOG region. The MSTM is used to compute CSs on the basis of a disaggregated log-sum accessibility measure. The log-sum provides a robust solution for measuring the full accessibility benefits from policies for land use and transport, taking advantage of the availability of discrete choice models of travel demand. The MSTM accounts for changes in generalized transportation costs and destination utility and works at multiple levels (regional, state, and urban). Key input data to the MSTM include population and employment by income group for each traffic zone as well as highway and transit networks (e.g., Washington Metropolitan Area Transit Authority, Maryland Transit Administration, MARC Train commuter rail, and all local transit systems in the Baltimore, Maryland–Washington, D.C., area).

Because of limitations in the data, this study uses income as the only discerning factor between populations that are disadvantaged and those that are not. The accessibility analysis was grouped by income; income data were available in 1999 dollars (Table 1). Furthermore, information about several transportation combinations was available to calculate utility. Such combinations include all transportation modes: drive alone, share ride or carpool, and walk or drive to transit (e.g., bus, express bus, metro, or commuter rail). The analysis was performed with all transportation modes available to the population of

TABLE 1 Income Groups, in 1999 dollars

Income Group	Income Range ($)	Median Income ($)
1 (lower quartile)	<20,000	10,720
2 (lower–middle quartile)	20,000 to 39,999	29,840
3 (middle quartile)	40,000 to 59,999	49,240
4 (upper–middle quartile)	60,000 to 99,999	76,350
5 (upper quartile)	>100,000	161,330

TABLE 2 2010 Poverty Guidelines for 48 Contiguous States and District of Columbia

Number of Persons in Family or Household	Poverty Guideline ($)	Number of Persons in Family or Household	Poverty Guideline ($)
1	10,830	5	25,790
2	14,570	6	29,530
3	18,310	7	33,270
4	22,050	8[a]	37,010

[a]For families with more than eight persons, add $3,740 to the poverty guideline for each additional person.
SOURCE: U.S. Department of Health and Human Services.

the selected zones. Ideally, the analysis also would separate by vehicle ownership, but such disaggregation was not available in the data and approximation from drive-alone or carpool data is ill-advised because of the high attraction of transit users in Washington, D.C., who own or have access to a vehicle.

The end result of this approach is a measure of accessibility that can be mapped from one origin zone to all possible destinations in the MWCOG region. The measure represents accessibility benefited by population groups making the same trip; segmentation is based on income. Historical and estimated weather information are also used to locate vulnerable locations. The level of accessibility to safe zones (i.e., shelters, hospitals, and unaffected areas) and evacuation routes can be evaluated by applying the log-sum framework to the vulnerable location.

Maryland Statewide Travel Model

The MSTM relies on a four-step model to develop the parameters used for accessibility analysis. Some assumptions were made in the analysis, as applied by the MTSM: (*a*) only MWCOG statewide modeling zones (SMZs) were considered; (*b*) coefficients were calibrated for the work trip purpose; (*c*) accessibility was considered across the five income groups listed in Table 1; (*d*) 11 mode choices were available; and (*e*) utility was specified for a nested logit structure and predefined specifications and parameters. The four model steps are structured as follows.

1. Trip generation. For the 866 SMZs used as input to the MSTM, each zone contained the aggregated information necessary for estimating trip generation (e.g., numbers of households, workers, employers, and schools and whether the zone was a central business district).
2. Trip distribution. In the MSTM, trip distribution was based on a gravity model formulation that uses composite travel time function by purpose (a function of highway and transit time), as well as roadway tolls and value of time.
3. Mode choice. A nested logit choice model divides mode options into transit and auto. The transit mode consists of three nested alternatives: rail (light rail and Metrorail), commuter rail (Amtrak and MARC), and bus (all bus services). The auto mode is disaggregated into drive-alone and ridesharing alternatives. Information used in the utility function includes in-vehicle time, operating cost, waiting time, and parking cost.
4. Route choice. Travel demand forecasts from both MSTM statewide model components are assigned to a network through factors of the respective daily trip matrixes to derive peak and off-peak trip matrixes for network assignment.

The MSTM users' guide, available on request from the Maryland SHA, contains a complete explanation of the MSTM model.

LOW-INCOME MWCOG POPULATION

The first part of this study entails locating the areas with the highest percentages of low-income populations. For the purposes of this study, low-income households are defined as those with a total income of less than 1.5 times the 2010 National Poverty Guidelines for the respective household size. These guidelines are updated each year and issued in the *Federal Register* by the U.S. Department of Health and Human Services (Table 2).

The American Community Survey's 5-year estimates for 2006 through 2010 were used. The information is aggregated at the public use microdata area (PUMA) level. This data set has been a valid information source because of its wide-ranging sample size and the reputation of its collector, the U.S. Census Bureau. Figure 1 shows the PUMA locations that characterize the scope of this report. However, PUMAs vary in shape and size and therefore encompass different communities; household and individual weights provided by the American Community Survey were used to reduce sampling bias and error of over- and under-represented subpopulations.

Overall, nearly 10% of Maryland's households meet the low-income criteria. The highest percentages of low-income households are in PUMAs 00300 and 01005 (part of Frederick and Prince George's Counties, Maryland), with 1% and 0.8%, respectively; nearly 45% of all low-income households are located in Prince George's County, and 18% of the households in PUMA 01101 (College Park and Hyattsville, Maryland) are low-income. Approximately 19% of the Washington, D.C., households are low-income. The city's central and southeast regions (PUMAs 00105 and 00104, respectively) have the overall highest percentage of low-income households, with 6.8% and 4.3% low-income households, respectively; 30.8% of the households in the city's southeast region are low-income. The two subareas chosen for this analysis, Anacostia and Frederick, were selected for contrast because of their different concentrations of low-income populations, the variety of available transportation modes, and the difference in proximity to a metropolitan area, which help demonstrate the range of the log-sum approach (Table 3).

CASE STUDY: FLOOD EVACUATIONS

On average, hundreds of lives and billions of dollars are lost across the United States every year as a result of extreme weather events. According to the National Weather Service (*18*), floods and flash floods are the second-deadliest weather phenomenon in the United States, taking more lives than hurricanes and tornados combined (Figure 2). As defined by the National Weather Service, a flash flood

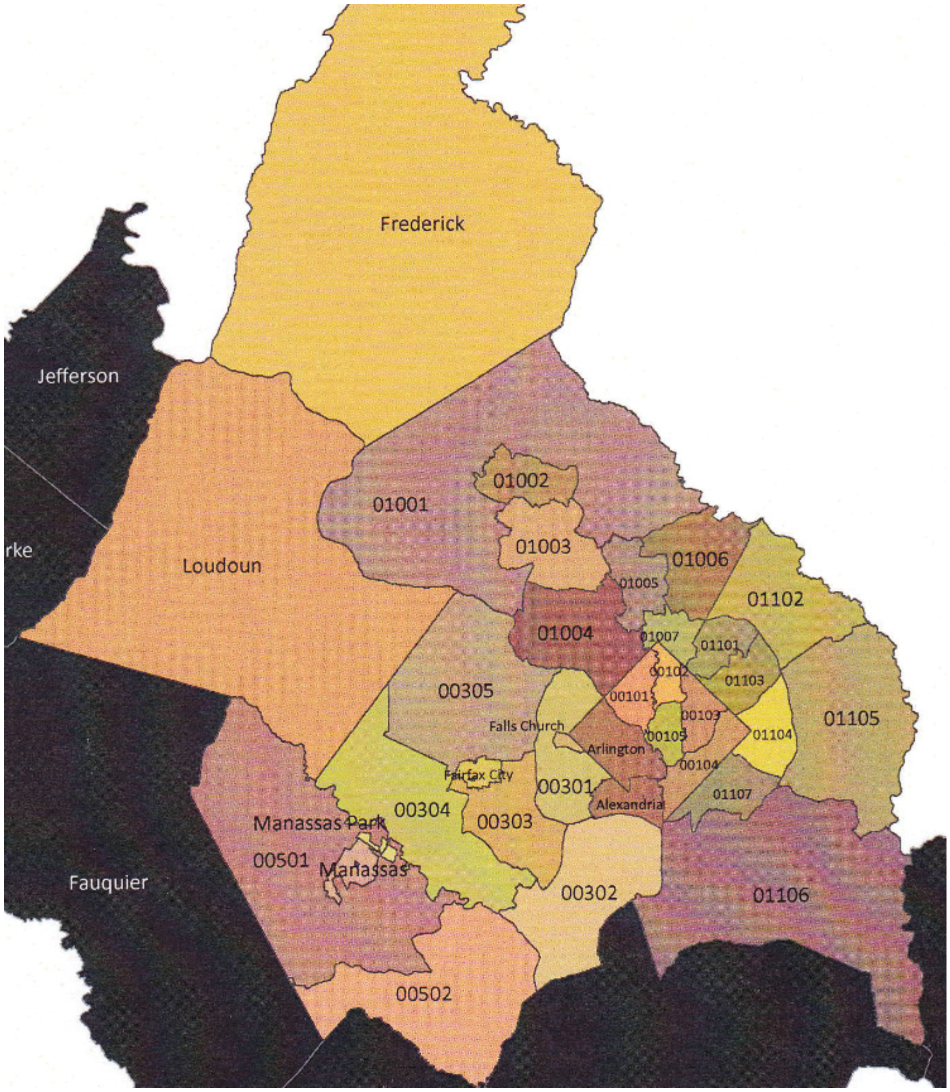


FIGURE 1 MWCOG map with PUMA locations for Washington, D.C., metropolitan area.

is a flood that develops in less than 6 h, but it also can form in a matter of minutes—therefore, the danger. Flash floods tend to occur in low-lying areas with poor drainage, and urban areas are particularly at risk. A significant percentage of the people who die in floods make the mistake of attempting to drive or walk through flooded areas and are swept away by rapid water. Causes of flash flooding include heavy rain, ice jams, and a dam or levee break.

In this study, two scenarios are studied: evacuations of Frederick and the Anacostia neighborhood of Washington, D.C., as a result of localized floods. The case studies were developed as realistically as possible with information from several official sources. Each scenario is based on storm surge and 100-year flood information extracted from the OSPREY map, developed by the Maryland Emergency Management Agency. The storm surge map shows potential flood heights resulting from assessments of pressure, size, forward speed, track, and wind data of historical, hypothetical, and predicted hurricanes. The calculations are applied to an area's shoreline, its physical features (e.g., bay and river configurations, water depths, bridges, and roads) are analyzed, and the worst-case scenario for the entire basin is presented. Storm surge has been developed for Category 1 through 4 hurricanes represented by the Saffir–Simpson scale. In contrast, the 100-year flood map shows hazard areas corresponding to floods that have a 1% chance of being equaled or exceeded annually.

The Maryland SHA provided shelter and hospital locations and evacuation routes; this information includes 170 locations approved to serve as shelters (schools, recreational centers, and fire stations) and 175 hospitals. Even though the totality of these locations is spread over Maryland, Virginia, and Washington, D.C., only 109 shelters and 36 hospitals are located in the MWCOG region and therefore are incorporated into the analysis. Finally, the evacuation routes used

TABLE 3 Case Studies for Accessibility Analysis

Location	PUMA	SMZ	Reference	Median HH Income ($)
Washington, D.C.	00104	1268	Anacostia	19,238
Frederick County	00300	956	Frederick City	42,529

NOTE: HH = household.

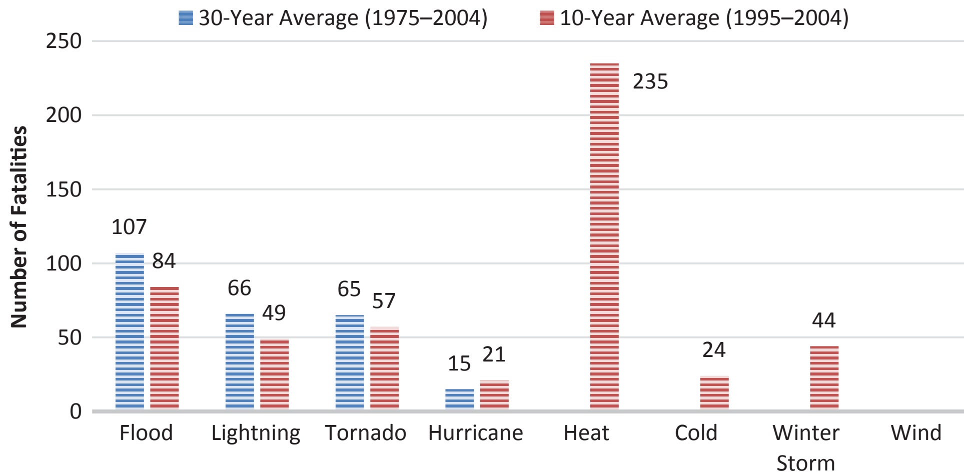
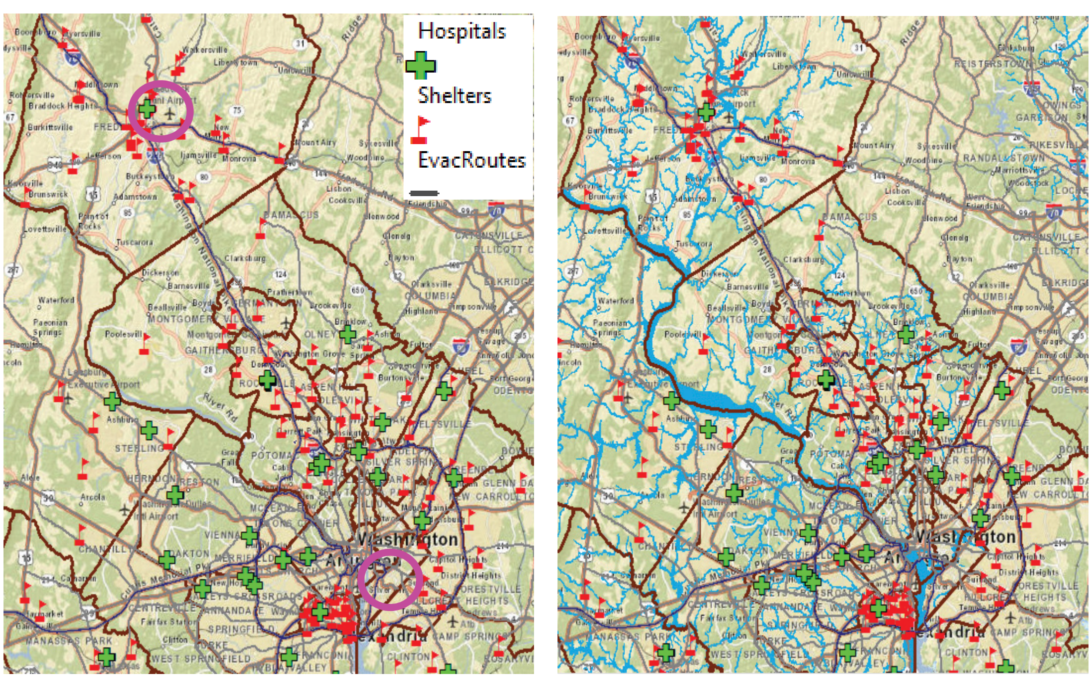


FIGURE 2 Average number of weather-related fatalities, by weather event, from 1975 to 2004 (*19*).

in this study are the ones served by the Federal Emergency Management Agency and the Maryland SHA to evacuate people from high-risk areas in events such as hurricanes; these routes were complemented with information on routes prone to flooding extracted from the OSPREY map (identified as routes that present recurrent and occasional flooding problems).

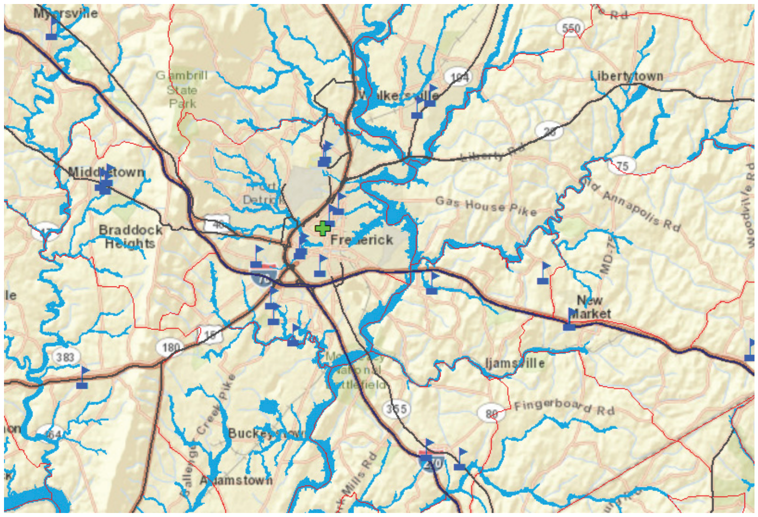
The MWCOG region is peculiar in that it consists of two states (Maryland and Virginia) and the District of Columbia, with the Potomac River and the Anacostia River (a branch of the Potomac) passing through or near all three locales. Communities close to these rivers tend to be at high risk during hurricane and flood events. Figure 3 compares the MWCOG region in its normal state and under the effect of extreme water events; some information for locations east of Washington, D.C., is missing because 100-year flood data were not available for all counties. Figure 3 also illustrates the locations of hospitals, shelters, and evacuation routes as provided by official agencies.

Figure 4 illustrates the affected zones in more detail. Figure 4*a* shows how the high water levels cover part of downtown Frederick and its municipal airport, roughly 0.75 mi^2. The effects of the 100-year flood also are noticeable in Figure 4*b,* where the flood covers around 0.6 mi^2 along the shore of the Anacostia River and floods central Washington, D.C. Finally, Figure 4*c* highlights the roads prone to flooding (dots mark locations and data available on the OSPREY map). Given their history, these roads are expected to become unreliable or chokepoints in a major flood.

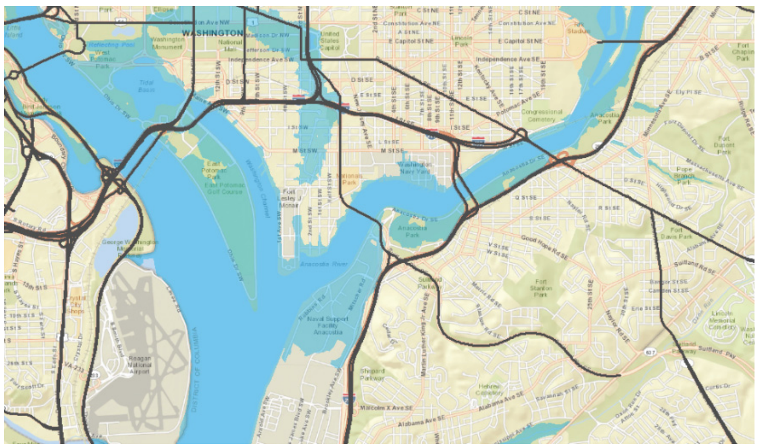


(a) (b)

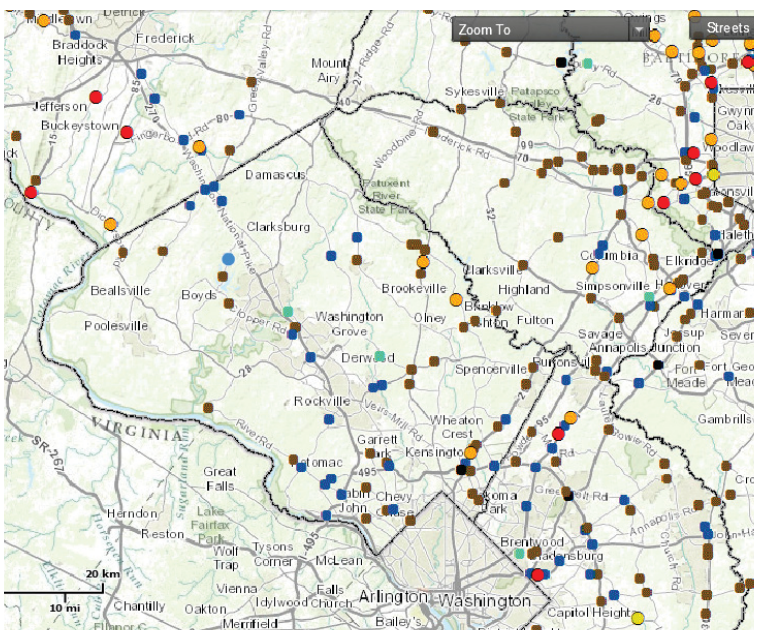
FIGURE 3 Comparison of MWCOG region (*a*) in its normal state (subareas for analysis circled in purple) and (*b*) as affected by storm surge and 100-year flood (shown as light blue).



(a)



(b)



(c)

FIGURE 4 Detail of extreme water events: (*a*) hurricane storm surge effect on Frederick, (*b*) 100-year flood effect on Anacostia, and (*c*) area roads prone to flooding.

ACCESSIBILITY ANALYSIS

The proposed method allows for a sketch-level assessment of the accessibility of targeted communities to safe zones by income group. Major findings of the analysis conducted for Frederick and Anacostia (marked with white stars on Figures 5 and 6, respectively) follow:

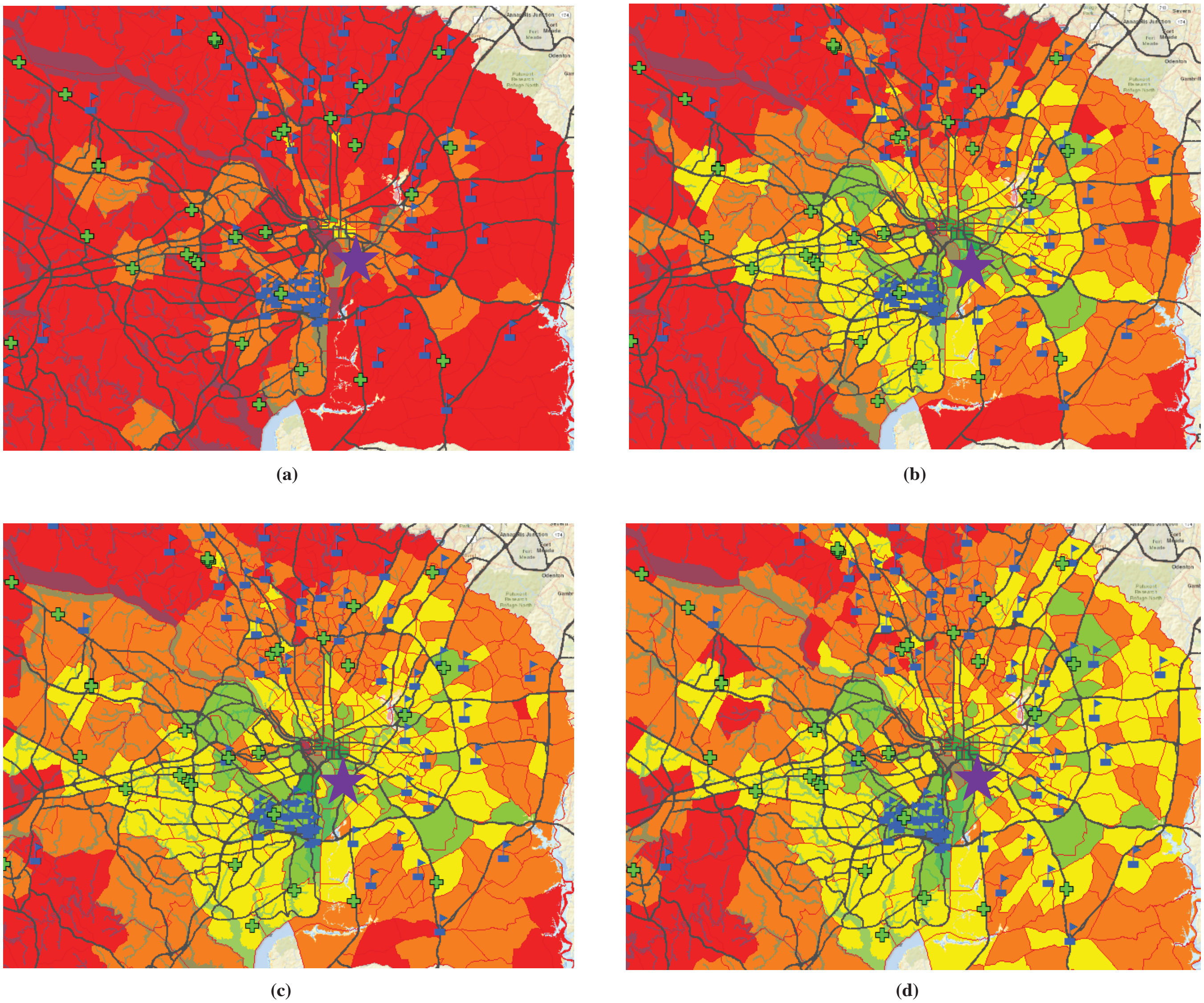
- Visual results suggest that income and accessibility are positively correlated. In Frederick and Anacostia, the accessibility to safe zones clearly is not equal across income groups.
- Income (or an overall lack of resources) may not be the sole limitation on accessibility. Location, lack of access to a vehicle, dependence on transit services, and longer travel times, among other

(a) (b)

(c) (d)

Accessibility Levels: = high; = medium–high; = medium; = medium–low; = low.

FIGURE 5 Accessibility to safe zones of Frederick population (SMZ 956) for Income Groups (*a*) 1, (*b*) 2, (*c*) 3, and (*d*) 5.



Accessibility Levels: = high; = medium–high; = medium; = medium–low; = low.

FIGURE 6 Accessibility to safe zones of Anacostia population (SMZ 1268) for Income Groups (*a*) 1, (*b*) 2, (*c*) 3, and (*d*) 5.

factors, also lead to inequality in accessibility. This finding is clear when income groups are compared for each location: Frederick residents can reach more locations than Anacostia residents can.

- According to the American Community Survey 5-year estimates for 2006 through 2010, only 23% of households in Frederick County do not own a vehicle, whereas in southeast Washington, D.C., almost 70% of households do not own a vehicle. The southeast Washington, D.C. residents do have access to a more developed transit network (i.e., Metrorail), which may affect vehicle ownership decisions.
- The availability of safe zones is correlated with how far the population can travel.
  - Frederick's low-income population has a moderate amount of shelters available in the case of a flood, and options increase as income increases. However, the county lacks hospitals (only one, in the city center), which puts residents at high risk if a flood occurs. Many hospitals do not become accessible until Income Group 3.
  - Anacostia's low-income population has limited access to shelters and hospitals. However, accessibility improves starting at Income Group 2; many alternatives become available to the population in the event of an evacuation.
- Potential floods on major roads could diminish accessibility in the MWCOG region.
  - Roads connecting Frederick to hospitals located southward (closer to Washington, D.C., and Leesburg, Virginia) and Anacostia to shelters located northward are prone to flooding (Figure 4*c*), increasing the probability of casualties to disadvantaged individuals.
  - Road and rail transit could be affected by excessive surface water, with services to different locations partially or completely interrupted.
- The spatial distribution of shelters does not adequately cover the MWCOG region. A large cluster of shelters is located south of Washington, D.C., thus making them more accessible to the low-income population of Washington, D.C. (the highest percentage of low-income households are located in the southern regions of Washington, D.C.). Nonetheless, the lack of shelters westward and, to a lesser degree, eastward from Washington, D.C., is striking.

Populations outside the Capital Beltway in both directions may be at the highest risk because of the lack of shelters, with few to no alternatives offered.

CONCLUSIONS

The approach proposed in this study, which is based on the log-sum measure for accessibility, accounts for many factors that influence a population's accessibility level (e.g., transit frequency, waiting time, number of transfers, transfer time, parking cost) other than those used in more traditional measuring approaches (i.e., travel time, travel cost, trip distance). Furthermore, the log-sum approach uses coefficients from the transportation model, which captures behavioral responses to changes in trip attributes, making it possible to capture trips in the study area regardless of travel time.

Visual results suggest a positive correlation between accessibility and income group; however, this correlation also can be affected by the attributes of the location. Logistics problems also were found in shelter locations, thus leaving some areas without options nearby. Low-income populations need careful attention, and a great deal of resources should be dedicated to enhancing their mobility in the event of an evacuation.

This study is a first iteration in the development of a comprehensive, practical assessment tool that evaluates the accessibility of the disadvantaged to safe zones. The main goal is to highlight, in a simple, presentable manner, those areas that lack such accessibility to safe zones and could potentially hinder the evacuation processes. Future iterations could address the present limitations, which include incomplete information about disadvantaged populations, the need for more accurate weather data, and the lack of noncommuter trips. In addition, statistical analysis is needed to increase the reliability of results, and future research should identify other factors that impede evacuation mobility and incorporate temporal constraints (e.g., departure time) into the accessibility analysis.

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REFERENCES

1. Godschalk, D.R. Urban Hazard Mitigation: Creating Resilient Cities. *Natural Hazards Review,* Vol. 4, No. 3, 2003, pp. 136–143.
2. Chakraborty, J., G. Tobin, and B. Montz. Population Evacuation: Assessing Spatial Variability in Geophysical Risk and Social Vulnerability to Natural Hazards. *Natural Hazards Review,* Vol. 6, No. 1, 2005, pp. 23–33.
3. Dash, N., and H. Gladwin. Evacuation Decision Making and Behavioral Responses: Individual and Household. *Natural Hazards Review,* Vol. 8, No. 3, 2007, pp. 69–77.
4. Murray-Tuite, P., and H. Mahmassani. Model of Household Trip-Chain Sequencing in Emergency Evacuation. In *Transportation Research Record: Journal of the Transportation Research Board, No. 1831,* Transportation Research Board of the National Academies, Washington, D.C., 2003, pp. 21–29.
5. Sohail, M. Sustaining Livelihoods by Improving Urban Public Transport. *Proc., ICE—Engineering Sustainability,* Vol. 158, No. 1, 2005, pp. 9–15.
6. *Disaster Response and Recovery Resource for Transit Agencies.* Federal Transit Administration, U.S. Department of Transportation, 2006.
7. Abley, S. Measuring Accessibility and Providing Transport Choice. Presented at National Conference of the Australian Institute of Traffic Planning and Management (AITPM), Brisbane, Queensland, Australia, 2010.
8. Apparicio, P., M. Abdelmajid, M. Riva, and R. Shearmur. Comparing Alternative Approaches to Measuring the Geographical Accessibility of Urban Health Services: Distance Types and Aggregation-Error Issues. *International Journal of Health Geographics,* Vol. 7, No. 7, 2008.
9. Tomer, A., E. Kneebone, P. Puentes, and A. Berube. *Missed Opportunity: Transit and Jobs in Metropolitan America.* Brookings Institution, Washington, D.C., 2011.
10. Yigitcanlar, T., N. Sipe, R. Evans, and M. Pitot. A GIS-Based Land Use and Public Transport Accessibility Indexing Model. *Australian Planner,* Vol. 44, No. 3, 2007, pp. 30–37.
11. Nicholls, S. Measuring the Accessibility and Equity of Public Parks: A Case Study Using GIS. *Managing Leisure,* Vol. 6, No. 4, 2001, pp. 201–219.
12. Kockelman, K.M. Travel Behavior as Function of Accessibility, Land Use Mixing, and Land Use Balance: Evidence from San Francisco Bay Area. In *Transportation Research Record 1607,* TRB, National Research Council, Washington, D.C., 1997, pp. 116–125.
13. Thouez, J., P. Bodson, and A. Joseph. Some Methods for Measuring the Geographic Accessibility of Medical Services in Rural Regions. *Medical Care,* Vol. 26, No. 1, 1988, pp. 34–44.
14. Kwan, M., and J. Weber. Individual Accessibility Revisited: Implications for Geographical Analysis in the Twenty-First Century. *Geographical Analysis,* Vol. 35, No. 4, 2003, pp. 341–353.
15. Geurs, K., and B. Wee. Accessibility Evaluation of Land-Use and Transport Strategies: Review and Research Direction. *Journal of Transport Geography,* Vol. 12, 2004, pp. 127–140.
16. Litman, T. Measuring Transportation: Traffic, Mobility and Accessibility. *ITE Journal,* Vol. 10, 2003, pp. 28–32.
17. Train, K. *Discrete Choice Methods with Simulation.* Cambridge University Press, Cambridge, United Kingdom, 2003.
18. *Floods and Flash Floods: Introduction.* Weather Forecast Office, National Weather Service, Des Moines, Iowa, 2012. http://www.crh.noaa.gov/dmx/?n=preparefloodintro. Accessed July 24, 2013.
19. *Floods Cost Lives and Billions of Dollars in Property Damage Each Year Around the United States.* National Oceanic and Atmospheric Administration, U.S. Department of Commerce, Silver Spring, Md., March 29, 2006. http://www.noaanews.noaa.gov/stories2006/s2601.htm. Accessed July 23, 2013.

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