



# Modeling accessibility of screening and treatment facilities for older adults using transportation networks



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## ABSTRACT

Increased lifespans and population growth have resulted in an older U.S. society that must reckon with the complex oral health needs that arise as adults age. Understanding accessibility to screening and treatment facilities for older adults is necessary in order to provide them with preventive and restorative services. This study uses an agent-based model to examine the accessibility of screening and treatment facilities via transportation networks for older adults living in the neighborhoods of northern Manhattan, New York City. Older adults are simulated as socioeconomically distinct agents who move along a GIS-based transportation network using transportation modes that mediate their access to screening and treatment facilities. This simulation model includes four types of mobile agents as a simplifying assumption: walk, by car, by bus, or by van (i.e., a form of transportation assistance for older adults). These mobile agents follow particular routes: older adults who travel by car, bus, and van follow street roads, whereas pedestrians follow walkways. The model enables the user to focus on one neighborhood at a time for analysis. The spatial dimension of an older adult's accessibility to screening and treatment facilities is simulated through the travel costs (indicated by travel time or distance) incurred in the GIS-based model environment, where lower travel costs to screening and treatment facilities imply better access. This model provides a framework for representing health-seeking behavior that is contextualized by a transportation network in a GIS environment.

## 1. Introduction

This study is motivated by the problem of access to community-based screening and treatment facilities for older adults who rely on different transportation modes. Senior centers that host health education and screening events are used to represent screening facilities in an agent-based model that includes a GIS-based road transportation network. In particular, *ElderSmile* is an oral and general health promotion program that offers educational outreach and preventive screening services at senior centers and other places where older adults gather in northern Manhattan, New York City (Marshall et al., 2013). Participants in the *ElderSmile* program receive referrals for treatment at dental clinics or primary care practices when indicated.

### 1.1. Challenges for an aging population in accessing prevention and treatment services

Increased lifespans and population growth have resulted in an aging U.S. society that must reckon with the complex health needs that arise

as adults age. Disparities in access to health care for groups with fewer versus more economic means and political representation have long been recognized as a problem with determinants at multiple levels. Perhaps not surprisingly, middle-aged and older racial/ethnic minority adults with disabilities have been found to lack sufficient access to health care (Miller, Kirk, Kaiser, & Glos, 2014). In one report, disparities in access to physician services diminished for African Americans but grew worse for Hispanics over time (Mahmoudi & Jensen, 2013).

The uneven distribution of health care facilities also contributes to inequities in spatial accessibility (Ngamini Ngui & Vanasse, 2012). Older adults who lack access to transportation services tend to experience reduced well-being relative to their peers with greater access to and more transportation options (Cvitkovich & Wister, 2001).

Oral health conditions are prevalent among older adults and cause pain and suffering that are usually preventable with early intervention. In a recent study, fully two-thirds (68%) of adults aged 65 years and older had periodontitis (Eke et al., 2015). Oral health disparities in the prevalence of periodontal disease are especially acute for racial/ethnic

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minority populations and those who live in poverty or subsist on low incomes versus white majority and wealthier populations (Eke et al., 2015). The aim of this study is to explore the accessibility of community-based health promotion and disease prevention services for racial/ethnic minority older adults, so as to improve the health and well-being of this population.

## 1.2. Study scope

To examine the accessibility of oral health screening and treatment facilities for older adults living in the neighborhoods of northern Manhattan, this study employs an agent-based model to simulate older adults as mobile agents who are distinguished by the type of transportation mode they utilize: by foot (walk), by car, by bus, or by van. For the study area and population, the car option represents not only privately owned cars, but also rental cars and taxi services, which incur a higher travel cost. The van option represents a transportation assistive service provided by certain social service and health care agencies.

Older adults who live with or close to friends and family members are assumed to have their transportation needs satisfied through social support mechanisms. The model reflects this situation using a simulated social network, which utilizes each agent's connectedness to assess the strength of her/his social support. The spatial dimension of an individual's screening and treatment center accessibility is simulated through the travel costs (indicated by travel time or distance) incurred in the GIS-based model environment, where lower travel costs to these community-based facilities imply better access. The non-spatial dimension of an individual's accessibility to preventive and treatment services is simulated through her/his health outcome, which varies by her/his socioeconomic resources and demographic characteristics. A higher health outcome means better access to preventive and treatment services. Hence, this model provides a framework for representing health-seeking behavior that is contextualized by the transportation network and a simulated social network in a GIS environment.

## 2. Background

### 2.1. Accessibility to health services

The concept of accessibility relies upon an understanding of access, but the latter term is also hard to define and is often used interchangeably with accessible and available (Penchansky & Thomas, 1981). Access to health services varies across space because of both spatial/geographic factors such as the uneven distributions of screening and treatment facilities, and non-spatial/social factors such as the reality that population groups differ in terms of socioeconomic resources and demographic characteristics (Wang & Luo, 2005).

When spatial accessibility is calculated using geographic information systems (GIS), it is referred to as GIS-based accessibility. A benefit of GIS-based accessibility is that it may be used to map spatial patterns and analyze the spatial relationship between the demand arising from a given population and the supply of screening and treatment facilities (Mao & Nekorchuk, 2013; McGrail & Humphreys, 2009; Wang & Luo, 2005). As one example, Schuurman et al. (2006) created a road network to calculate travel time that better represents access to hospital-based services as compared to straight-line measurement.

Most research on accessibility examines the spatial aspect; fewer studies consider the non-spatial aspects (Neutens, 2015). Research on the measurement of accessibility often involves the computation of travel impedance (distance or time) between patient location and service points. This line of research employs the term “spatial accessibility” instead of “accessibility” to describe access to health services that considers only spatially-related factors (Guagliardo, 2004; Wang, 2012).

### 2.2. Multiple transportation modes

Intelligent transportation systems are key to “smart cities” initiatives that aim to provide more efficient services for various modes of transportation and enable diverse users to be better informed regarding transportation options (Ran & Boyce, 2012). Societal gaps exist in providing adequate transit for the growing population of older adults (Millar, 2005). More than one in five (21%) of Americans aged 65 years and older do not drive; more than half of non-drivers aged 65 years and older (comprising 3.6 million Americans) remain at home on any given day, partially due to the lack transportation options (Bailey, 2004). Therefore, it is essential to consider multiple transportation modes when analyzing the accessibility of screening and treatment facilities for older adults.

The majority of accessibility studies assume that people travel to health facilities using a single transportation mode, such as by car (Delamater, Messina, Shortridge, & Grady, 2012; Luo & Qi, 2009) or by foot (Loo & Lam, 2012). Fewer studies consider multi-modal travel choices that take into account public transportation options in addition to car and walking options to provide more realistic estimates of accessibility (Haynes, Lovett, & Sünnerberg, 2003; Mao & Nekorchuk, 2013). Qualitative research on accessibility has also considered different transportation modes, using data from focus groups to understand how older residents construct their transportation arrangements during different stages of the life course (Glasgow & Blakely, 2000).

The model implemented in this study allows for different choices of transportation modes using road networks and walkways that are available to older adults living in northern Manhattan, New York City. Although New York City is equipped with elevators and escalators in certain subway stations that make them more accessible to older adults, these amenities are only available for a limited number of stations on a few routes. In most situations, older adults still need to climb long staircases, which may be especially difficult for those with mobility limitations. In addition, real and perceived safety concerns surrounding the use of subways pose substantial barriers for certain older adults. Therefore, for disabled older adults or those who live far from a station, traveling by subways may not be the preferred choice if other travel options, such as buses or taxis, are available and affordable.

### 2.3. Social and transportation support

An analysis of U.S. population demographics conducted by the National Highway Transportation Safety Association found that older women who have smaller families with fewer children tend to have less social and transportation support than do older women with more extensive familial networks (Wallace & Franc, 1999). A conditional concern is the general lack of awareness about alternative transportation options such as van services, which are especially important for older adults with disabilities who rely on public transit services (Foster, Damiano, Momany, & Mcleran, 1996; Glasgow & Blakely, 2000).

Furthermore, many older adults subsist on limited incomes, with social security and retirement savings constituting the largest share (Peck, 2010). As a consequence, the cost of using public transit may present a barrier to many older adults. To improve access to care for underserved population groups, assistance services using vans may be provided by social service and health agencies as a way to reduce travel costs (Marshall et al., 2009).

### 2.4. Agent-based modeling approaches to accessibility

Because access to health services is influenced by both spatial and non-spatial factors, accessibility may be usefully modeled as a nonlinear complex system. Nonlinear systems, because of their structure, are often more conveniently analyzed using computer simulation models than by more traditional mathematical methods (O'Sullivan & Perry, 2013). Agent-based modeling is one of a class of computational models

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