Accident Analysis and Prevention 119 (2018) 104–113

Contents lists available at ScienceDirect

Accident Analysis and Prevention

journal homepage: www.elsevier.com/locate/aap

Do Silver Zones reduce auto-related elderly pedestrian collisions? Based on a case in Seoul, South Korea

Yunwon Choi[a], Heeyeun Yoon[b,c,*], Eunah Jung[c]

[a] Interdisciplinary Program in Landscape Architecture, Seoul National University, 1 Gwanak-ro, Gwanak-gu, Seoul 151-742, Republic of Korea
[b] Department of Landscape Architecture and Rural Systems Engineering, College of Agriculture and Life Sciences, Seoul National University, 1 Gwanak-ro, Gwanak-gu, Seoul 151-921, Republic of Korea
[c] Research Institute of Agriculture and Life Sciences, Seoul National University, 1 Gwanak-ro, Gwanak-gu, Seoul 151-921, Republic of Korea

ARTICLE INFO

Keywords:
Silver Zone
Pedestrian safety
Generalised linear model
Difference-in-difference
Bivariate Moran's I
Kernel density mapping

ABSTRACT

Inaugurated in 2007, in Seoul, South Korea, the Silver Zone is a designated pedestrian safety zone for the elderly that adopts speed limit measures such as traffic signage and road surface markings. In this study, we empirically investigate the effectiveness of the Silver Zone in two respects: first, whether the establishment of the Silver Zone has lowered the number of elderly pedestrian collisions, and second, whether Silver Zones are established in the appropriate areas, that is, those with the highest frequency of such collisions. From our quasi-experimental statistical analysis, Difference-in-Difference, we learn that the Silver Zone has no effects on reducing elderly pedestrian collisions. From our spatial statistical analyses—Kernel Density mapping and Bivariate Moran's I—we found a spatial mismatch between the frequency of senior pedestrian-vehicular collisions and the location of Silver Zones. For better performance of the Silver Zone system, we suggest additional types of physical measures to be integrated into the Silver Zone system. Municipal-level comprehensive master plan for Silver Zone system is also necessary, under which local governments should use periodic surveys to inventory and prioritise the locations of highest elderly pedestrian-vehicular collisions.

1. Introduction

As the world's population rapidly ages, with the ratio of the elderly[1] growing from the current 11% to 22% of the population by 2050 (United Nations, 2015), many societies have made efforts to create healthier and safer environments for senior citizens (Zhao, 2014; Li and Zhao, 2015). Improving neighbourhood walkability, as an integral part of daily life, is one strategy towards this goal (Hahm et al., 2017; Kim et al., 2014). Walking is both a means of exercise and transportation for the elderly. As they experience physical and cognitive losses, they forgo driving and taking public transit to avoid collisions, while maintaining physical activity (Piatkowski et al., 2015; Burbidge and Goulias, 2009).

Elderly pedestrian-vehicular collisions, however, are a serious problem (Rosenbloom et al., 2016; Cœugnet et al., 2017). While pedestrian deaths account for 22% of all vehicle-related casualties, approximately 40% of those involve the elderly[2] (International Transport Forum, 2014). This number has been increasing along with the aging population in many member countries of the Organization for Economic Cooperation and Development (OECD). Especially, increase of the traffic volume in high-density cities in the East Asia is a threat to elderly pedestrian safety (Zhao et al., 2014). South Korea is no exception. Currently, elderly pedestrian collisions account for 40% of all vehicle-related casualties (International Transport Forum, 2014; Whi, 2015).

In order to protect elderly pedestrians from collisions, the South Korean government established the Silver Zone system in 2007. The system mandates areas as safety zones where speed-limit measures, such as traffic signage and road surface markings, caution drivers about the presence of elderly pedestrians. The similar systems in other countries are Silver Zone[3] and Green Man Plus system[4] in Singapore and Safe Routes for Seniors program[5] in the U.S.A. (Fwa, 2016; Tan,

* Corresponding author at: Department of Landscape Architecture and Rural Systems Engineering, College of Agriculture and Life Sciences, Seoul National University, 1 Gwanak-ro, Gwanak-gu, Seoul 151-921, Republic of Korea.
E-mail addresses: yunwon.choi@snu.ac.kr (Y. Choi), hyyoon@snu.ac.kr (H. Yoon), jea0610@snu.ac.kr (E. Jung).

[1] Age group of 60+
[2] Age group of 65+
[3] Singapore's National project to enhance road safety for seniors, since 2014.
[4] Technology to help the elderly cross the road more comfortably without adversely affecting the traffic flow by giving more green light time.
[5] City-wide project to improve pedestrian infrastructure for seniors in the U.S.A.

https://doi.org/10.1016/j.aap.2018.07.005
Received 14 November 2017; Received in revised form 23 June 2018; Accepted 1 July 2018
0001-4575/

2008; Transportation Alternatives, 2009).

Since the inception and spreading implementation of the Silver Zone, however, questions have been raised about its effectiveness in reducing collisions. Although some analytical research has pointed to the ineffectiveness of these approaches (Park and Oh, 2011; Lee, 2012), and the media has speculated about possible reasons for its failures, the lack of relevant data has prevented a full assessment of its performance. The accumulated number of Silver Zones in Seoul reached 80 in early 2016, but it was not until 2010 that the database on the pedestrian collisions became available by the Korea Road Traffic Authority.

In this study, we empirically investigate the effectiveness of the Silver Zone in two respects: first, whether the establishment of Silver Zones has lowered the number of elderly pedestrian-vehicular collisions, and second, whether Silver Zones were established in the appropriate areas, that is, those with the highest frequency of such collisions. To better evaluate Silver Zone program, we not only focused on the effect of Silver Zone, but also the effect of ten other physical elements in the zone, which may have effects on the frequency of collisions. With the analytical results, we further explore ways to improve the performance of Silver Zones.

For the first question, we use generalised linear modelling: Zero Inflated Poisson (ZIP), Zero Inflated Negative Binomial (ZINB), Zero Truncated Poisson (ZTP) and Zero Truncated Negative Binomial (ZTNB) in Difference-in-Difference, one of the quasi-experimental specifications. To answer the second question, we use spatial statistical analyses, namely, the Kernel Density estimation and Bivariate Local Moran's I.

The present study is the first attempt to investigate the environmental components of the Silver Zones that explain the elderly pedestrian-vehicular collisions, and the spatial alignment of the zones and the collision locations. Our multi-pronged evaluation will provide a more comprehensive understanding of the performance of Silver Zones, and thereby be a useful reference for municipalities wanting to improve the current system.

The structure of this study is as follows. In the next section, we briefly review the literature on Silver Zones in South Korea, followed by a description of our analytical methods. After presenting our analytical design, we describe the results, including an overview of the actual effects of Silver Zones as well as the other environmental factors on pedestrian collisions, and the degree of spatial alignment between the designated Silver Zones and senior pedestrian-vehicular collision spots. The final section discusses the implications of our findings and future research direction.

2. Background

2.1. Pedestrian safety

Safety zones are purposed to protect pedestrians from vehicles, adopting a number of safety measures and techniques. School Zone and Silver Zone are some of those examples, made for protecting children and the elderly, respectively, and are established in areas where a large volume of such populations gather. School Zones are commonly located around schools and day-care facilities to help children's commuting safer. Silver Zone is relatively newer than the School Zone system, conceived in response to the increasing concern on the aging society. Japan is a pioneer of Silver Zone since 1986, and South Korea and Singapore have adopted the system recently (Ibrahim, 2003; Fwa, 2016; KoRoad, 2012).

Safety Zones adopt traffic calming measures and techniques, to limit the speed of vehicles. In most of the safety zones, cars are not allowed to drive faster than 20mph (30 km/h). To inform drivers about the condition, speed signs are installed in the entrance and the exit of the zone. Within the zones, speed humps, smaller corner radii, pavement treatment, and chicane are deployed to physically and visually deter drivers from speeding. Also, more frequent and brighter lighting and fences are installed to help pedestrians walk with caution. Occasionally, surveillance cameras are operated to warn the drivers and detect the violation (Lee et al., 2013).

2.2. Silver Zone

In South Korea, to address the increasing elderly pedestrian-vehicular collisions, the Ministry of Government Administration and Home Affairs (MOGAHA) established the legal framework for the Silver Zone system, with the passage of the Road Traffic Act in May 2007. Since then, as of September 2016, a total of 746 zones have been created in South Korea, of which 80 are located in Seoul (Ministry of Government Administration and Home Affairs, 2016; Kim, 2015).

The Silver Zone designation is initiated by the requests from the heads of public or private facilities for seniors, such as senior welfare centres, medical institutions, sports centres and parks. Where the request is granted, a safety zone is created with special treatment to vehicular roads within a 300- to 500-metre radius outward from the facility (Ministry of Public Administration and Security, 2012). The borough, the city government and the police department coordinate efforts to manage the Silver Zones thereafter.

In the Silver Zones, the speed is limited to below 30 km/h, and the zone-designation and speed-limit signage is installed. Road surface is marked with colouring in red-brown and lettering the phrase "Silver Zone". Occasionally, extra measures are added, such as fences, speed bumps, elevated crosswalks, reduced crosswalk slope, realignment to one-way traffic, widened pedestrian pathways, and speed and signal cameras (Ministry of Public Administration and Security, 2012).

However, previous studies, using Before-After evaluation methods, suggested that Silver Zones have no or only a slight effect in reducing collisions (Lee, 2012; Park and Oh, 2011). Lee (2012) analysed the effects of Silver Zone by types of senior care facility, shapes of Silver Zone boundary (rectangular, T, Y, L, and I shape), and the locations of Silver Zone (at the corner or along the straight road). In Lee (2012), Silver Zone was partially effective in reducing collisions at some locations. Park et al. (2010) found that Silver Zone is effective in reducing the severity of collision by 9.5% but showed only a slight effect, 1.6%, in reducing the number of collision. Anecdotal evidence points to the impracticality of the speed reduction measures the system currently adopts, and pressing the necessity of more vigorous enforcements such as speed and signal cameras, speed bumps and radar speed signs (Kim, 2017). Some editorials also argue that the lack of consideration on the previous collision records leads to failure in prioritizing Silver Zones in the collision-prone spots (Choi, 2015; Yoon, 2013; Lim, 2015; Lee, 2015). Silver Zones are established only when the requests are made, thus locations with high collision rates could have been left untreated if such request was not made (Busan Ilbo, 2016; Park, 2016).

2.3. Analytical methodology

2.3.1. Poisson, negative binomial, ZIP, ZINB, ZTP and ZTNB in difference-in-difference approach

The Difference-in-Difference (DID) approach is one of the quasi-experimental analyses frequently used to evaluate the impact of policy interventions, since it is useful for inferring near-causality in observational studies (Li et al., 2012; Chabé-Ferret, 2015; Dempsey and Plantinga, 2013; Wang and Shi, 2012; Pope and Pope, 2012). DID estimates the effects of interests by comparing the outcome from the treatment and control groups in two different time periods: usually before and after the treatment. While the treatment group is exposed to the intervention only in the after period, the control group does not receive treatment during either period or receives treatment during both periods. By deducting the difference in the outcomes between the two groups with and without the treatment, in the periods before and after the treatment, we can understand the remaining "difference-in-difference" as a pure impact of the treatment, controlling for all other factors that simultaneously affect both groups, in the before and after