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The cost-effectiveness of installing sidewalks to increase levels of transport-walking and health

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ABSTRACT

Objective. This study investigated the cost-effectiveness of installing sidewalks to increase levels of transport-walking.

Methods. Secondary analysis using logistic regression established the association of sidewalks with transport-walking using two transport-walking thresholds of 150 and 60 min/week using Western Australian data (n = 1394) from 1995 to 2000. Minimum, moderate and maximum interventions were defined, associated respectively with one sidewalk, at least one sidewalk and sidewalks on both sides of the street. Costs, average and incremental cost-effectiveness ratios were calculated for each intervention and expressed as 'the cost per person who walks for transport for more than 150 min/week (60 min/week) after the installation of new sidewalks'. A sensitivity analysis examined the robustness of the incremental cost-effectiveness ratios to varying model inputs. Costs are in 2012 Australian dollars.

Results. A positive relationship was found between the presence of sidewalks and transport-walking for both transport-walking thresholds of 150 and 60 min/week. The minimum intervention was found to be the most cost-effective at $2330/person and $674/person for the 150 and 60 min/week transport-walking thresholds respectively. Increasing the proportion of people transport-walking and increasing population density by 50% improved the cost-effectiveness of installing side-walks to $346/person.

Conclusions. To increase levels of transport-walking, retrofitting streets with one sidewalk is most cost-effective.

Introduction

Physical inactivity accounts for 6.6% of the total burden of disease and injury in Australia and is a major risk factor to ill health (Begg et al., 2007). Interventions focusing on individual and social environmental factors related to physical activity have only had modest effects on behavioral change (Giles-Corti et al., 2005). Thus, emphasis has been placed on modifying the built environment as a more sustainable means of increasing population levels of physical activity and health (Committee on Physical Activity, 2005; Ewing, 2005; Giles-Corti et al., 2005). This reflects an ecological approach to behavior changes and acknowledges multiple levels of influence (Sallis and Owen, 2002).

The most common form of physical activity among adults is walking, with three 10 minute bouts of brisk walking daily sufficient to protect health (Giles-Corti and Donovan, 2003; Owen et al., 2004; National Physical Activity Guidelines, 2005). People can engage in transport-walking (i.e., walking to work or the shops) and recreational-walking (i.e., for exercise or enjoyment), with different types of walking associated with different environmental attributes (Owen et al., 2004).

Commonly reported locations for walking are in the streets followed by public open spaces (Giles-Corti and Donovan, 2003). Easily accessible for all population groups, streets and street networks are a major contributor to neighborhood walkability and are relatively permanent in their design and serve a variety of uses besides walking (Van Dyck et al., 2013; Ehrenfeucht and Loukaitou-Sideris, 2010). Defined by high population density, mixed land use, and recreational and business destinations, highly walkable neighborhoods are also characterized by good street connectivity. Street connectivity improves access to routes for which sidewalks are integral in providing a sense of safety and convenience by separating pedestrians from motor vehicle traffic as conceptualized in the model proposed by Sugiyama et al. (2012). As a route attribute in this model, sidewalks are expected to influence transport-walking directly, and, by interacting with other factors including street connectivity, esthetics, and safety, additional sidewalks may also influence transport-walking indirectly (Humpel et al., 2002; Saelens et al., 2003; Duncan et al., 2005).

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Despite limited budgets, fragmented governance, and other barriers affecting the design, provision and maintenance of sidewalks, many infrastructure projects focus on sidewalk provision for which research and economic evaluations are requisite for an efficient use of resources and for having practical relevance to policy making (Rush et al., 2004; Ehrenfeucht and Loukaitou-Sideris, 2010; Evenson et al., 2011). While a number of studies have investigated the association between the built environment and walking, few studies have incorporated cost-effectiveness analyses (McCormack et al., 2004, 2012; Wendel-Vos et al., 2007; Saelensminde, 2004; Wang et al., 2004; Boarnet et al., 2008; Guo and Gandavarapu, 2010).

Using a societal perspective, the aim of this study was to assess the cost-effectiveness of installing sidewalks to increase transport-walking.

Methods

Survey data

This study uses data from the Study of Environmental and Individual Determinants of Physical Activity I and II (SEID I and II) (Giles-Corti and Donovan, 2002, 2003; Pikora et al., 2006). The SEID I cross-sectional survey collected data on demographics, individual attitudes, social characteristics and physical activity behaviors for 1803 randomly selected healthy workers and home-makers aged 18–59 years, living in metropolitan Perth, Western Australia between October 1995 and March 1996 (Giles-Corti and Donovan, 2003). In 2000, the SEID II survey collected data on the physical and environmental characteristics of 1987 km of street segments located within a 400-meter radial buffer around 1678 residences of participants previously surveyed in SEID I. Street segments are defined as the section of road between two consecutive intersections, and the 400-meter radial buffer represents the distance a person can walk in 5 minutes (Pikora et al., 2006). Data from SEID I were linked to SEID II providing complete analytical data for 1394 respondents. Full discussion of study methods for SEID I and II can be found elsewhere (Giles-Corti and Donovan, 2002, 2003).

Analysis of sidewalk data and transport-walking

Logistic regression analysis was used to examine the relationship between sidewalks and transport-walking. Two dichotomous outcome variables were examined: the first, for participants achieving recommended levels of physical activity of 150 minutes or more of walking (i.e., five or more occasions of 30 minutes per week) (Giles-Corti and Donovan, 2003); the second, examined participants achieving 60 minutes per week or more of walking in recognition that many people in Perth, Western Australia meet physical activity requirements by combining a range of physical activities (Giles-Corti and Donovan, 2003; Bauman et al., 2003; Christian et al., 2011). For both thresholds we used minutes spent on transport-walking per week to define the dichotomous outcome variables. Increasing transport-walking, which is a form of active-transport, leads to improved health and reduced health care costs, mode shifts from using vehicles to walking resulting in improved air-quality, and improved community and social connectedness (Giles-Corti et al., 2010).

Let j represent the sidewalk condition. Three binary variables were defined respectively for each sidewalk condition: $j = 0$ for streets with no sidewalks; $j = 1$ for a sidewalk on one side of the street; and $j = 2$, when there are sidewalks on both sides of a participant's street.

The proportion of people transport-walking, p_j was calculated using the predicted value from the estimated logit regression after adjustment for demographic and built environment factors associated with transport-walking and according to each sidewalk condition, j. The adjustments were made using the median predicted value of each logit model respectively (Hosmer et al., 2013). Logistic regression analysis was conducted using SPSS (Version 15) and results are shown in Table 2.

The three sidewalk interventions

Three sidewalk interventions were proposed to evaluate the increase in transport-walking due to the installation of sidewalks.

Let k denote each intervention. The 'minimum' intervention, $k = 1$, involved building a new sidewalk along street-segments without sidewalks. The 'moderate' intervention, $k = 2$, involved building new sidewalks on the opposing side of the street for street-segments with a single pre-existing sidewalk, and building a new sidewalk along street-segments without sidewalks. The 'maximum' intervention, $k = 3$, involved building new sidewalks so that every street-segment contained sidewalks on both sides. The baseline scenario, or *status quo*, is defined by the existing sidewalk network.

The effectiveness of installing sidewalks

Let i represent each of the 1394 participants. w_i, is defined as the number of people who walk above the transport-walking threshold for each of the 1394 400-meter radial buffer zones and was calculated by the equation in Fig. 1. For each of the 400-meter radial buffer zones, the proportion of street segments f_{ij} corresponding to participant 'i' and sidewalk condition 'j' was multiplied with their corresponding estimated sidewalk effects $\hat{p}_j$ and summed together.

To calculate exposure to the sidewalk intervention, the resulting summation was multiplied by population density, N. N was estimated by converting the 400-meter radial buffer into a total measure of square kilometers and multiplying this figure by an estimate of the population density per square kilometer of residential area. Residential area was estimated using Geographical Information System (GIS) estimates using Western Australia Mesh Block Digital Boundaries in ESRI Shapefile Format from Australian Bureau of Statistics (ABS) and ESRI ArcGIS 10.0 software using population estimates from the ABS.

The effectiveness of the kth sidewalk intervention, $\overline{w}_k$, was found by averaging the number of people w_i who walked for transport for more than either 150 min/week or 60 min/week due to the addition of new sidewalks across the 1394 participants respectively.

The cost of installing sidewalks

A town planner was consulted to provide the cost per linear meter for installing concrete sidewalks, their expected lifetime and the cost of replacement (P. McEvoy, personal communication, January 2010). Costs associated with installing sidewalks for each intervention were calculated using estimates of the proportion of missing sidewalks derived from the SEID II data.

The cost of installing sidewalks was quoted at $70 (AUD 2010)/square meter for a concrete sidewalk with a width of 1.8 meters. This figure was indexed to 2012 values using the ABS Producer Price Index for Roads and Bridges which includes pricing information on concrete. The resulting value in AUD 2012 values was $137.30/linear meter. The average lifespan of a sidewalk was quoted as 15 years and the cost of replacement every 15 years was $205.95/linear meter which was 50% higher than the initial installation cost due to additional costs of removing and disposing of old sidewalks. The cost of installing sidewalks was initially defined for a period of 15 years.

The Equivalent Annual Cost (EAC) of installing sidewalks for 15 years using a discount rate of 5% was calculated to be $13.22/linear meter. This annuitized cost was multiplied by the aggregate length of newly installed sidewalks derived from the estimates for each 400-metre radial buffer zone. The corresponding costs for each intervention were averaged across all 1394 participants, and are shown in Table 3.

Average and incremental cost-effectiveness ratios

Average cost-effectiveness ratios (ACERs) were calculated by dividing the cost of each intervention by the effectiveness of each intervention.

The incremental cost-effectiveness ratios (ICERs) were calculated by dividing the difference in costs between interventions by the difference in effectiveness between interventions i.e. between the *status quo* and the minimum intervention; the moderate and minimum interventions; and the maximum and moderate interventions respectively.

ACERs and ICERs were calculated for each transport-walking threshold of 150 and 60 min/week respectively and are also shown in Table 3.

Sensitivity analysis

A sensitivity analysis was conducted to assess the robustness of the results to varying model inputs. This included altering the proportion of people transport-walking via the transport-walking thresholds of 150 and 60 min/week and decreasing population density by 50%, increasing the project lifetime to 30 years on the basis that concrete used for sidewalks lasts between 20 and 40 years (Rajani, 2002), and altering the discount rates to reflect those most commonly used in economic evaluations which better reflect the intervention costs and benefits across long time horizons (Smith and Gravelle, 2001; Johnston and Hope, 2012). Rates of 0%, 3% and 7% were included.

The original scenario utilized a discount rate of 5%, a project lifetime of 15 years, with population density estimated as 827 people, and was examined