Travel Behaviour and Society 2 (2015) 32–41

Contents lists available at ScienceDirect

Travel Behaviour and Society

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

Accounting for the short term substitution effects of walking and cycling in sustainable transportation

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ARTICLE INFO

Article history:
Received 9 November 2013
Received in revised form 11 July 2014
Accepted 13 July 2014
Available online 19 July 2014

ABSTRACT

The environmental benefits of bicycling and walking depend on the degree to which their use substitutes for car driving. Assuming that every walking and bicycling trip replaces a driving trip is likely to produce overestimates of the potential for such modes to reduce vehicle travel and city-scale greenhouse gas emissions. Measuring this "substitution effect" is not straightforward. There are many dimensions of the substitution effect, including trip type, substituting mode, extent, time horizon, and activity patterns. Previously used approaches to measure substitution include indirect inference and direct questioning. This study piloted an intercept survey using the direct questioning approach at five locations in two metropolitan areas. The rate at which utilitarian walking or cycling trips substituted for auto trips ranged between 25% and 86%. Logistic regression models demonstrate that disparate factors explain walking substitution and bicycling substitution behavior; age is significantly correlated with substitutive walking behavior while number of car trips per week and helmet use are each significant predictors of bicycle substitution. This research represents a valuable first step toward developing a method to estimate the substitution effect that is useful for practitioners. Better estimates of the substitution effect will in turn lead to better estimates of the environmental impacts of bicycling and walking.

Published by Elsevier Ltd. on behalf of Hong Kong Society for Transportation Studies.

Introduction

Proponents of walking and bicycling – active modes of transportation – commonly cite benefits to both personal health and the environment. While any level of walking or bicycling produces health benefits, the environmental benefits, such as reduced pollution and greenhouse gas emissions, depend in large part on the degree to which active travel (AT) substitutes for vehicular trips. The value of AT as a strategy for addressing environmental problems comes from its potential as an alternative to driving, the primary source of environmental problems stemming from the transportation sector. Thus, simply measuring the number of bicycling and walking trips or the share of trips by these modes is insufficient to estimate their potential environmental benefits. Accurately assessing potential AT benefits requires efforts to assess the degree and nature of substitution. Such an assessment will help cities evaluate the extent to which the promotion of AT mitigates greenhouse gas emissions (GHGs) and provides other environmental benefits.

The assumption that walking and bicycling substitutes for driving often does not apply. For instance, AT for recreational purposes, such as taking a stroll around the neighborhood, comprises trips taken for their own sake rather than as an alternative to auto trips. In other cases, AT might constitute additional utilitarian travel rather than replacing driving. One example is when a resident decides to walk to the grocery store, in part motivated by the desire to achieve some exercise on a nice day, but otherwise would have simply waited until his or her next driving trip to the store. This walk trip is an *extra* trip, rather than a replacement (or substitution) trip. Thus, it is inappropriate to assume a one-to-one match between AT trips made and driving trips not made, as this assumption could either over-estimate (if not every AT trip replaces a driving trip) or under-estimate (if AT trips sometimes replace more than one driving trip) actual substitution. In addition, the length of the AT trip could be shorter (or possibly longer) than the driving trip it replaces, in which case it is also inappropriate to assume a one-to-one match between miles by walking and bicycling and miles by car.

This research effort focuses on the ability of AT to substitute for utilitarian auto travel. While recreational driving is a popular past time (particularly in the United States (NSRE, 2002), such travel is predominantly associated with long-distance scenic drives and

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http://dx.doi.org/10.1016/j.tbs.2014.07.004
2214-367X/Published by Elsevier Ltd. on behalf of Hong Kong Society for Transportation Studies.

visiting national parks (Hallo and Manning, 2009). In contrast, the claimed significance of AT substitution is based on local or city-scale congestion and GHG-reduction potential. Identifying which AT trips substitute for utilitarian automobile trips and measuring how much driving is reduced as a result are critical steps to accurately assessing the city-scale environmental implications of walking and bicycling.

In this paper we first present a conceptual framework to understand substitution behavior in terms of its key dimensions: trip types, mode types, frequency of behaviors, time horizon, and activity patterns. Second, we review previous approaches to estimating and measuring the substitution effect in light of these dimensions. Third, we describe the methodology and results of a five-city pilot test of an intercept survey aimed to quantify trip-specific AT substitution. Finally, we present the results of the intercept survey, including two logistic regression models to estimate factors associated with auto substitution among walkers and bicyclists. Our approach employs direct questioning through intercept surveys as a basis for quantifying AT substitution for a specific trip. We discuss the applicability of intercept surveys and offer methodological recommendations for future study.

Conceptual framework

AT substitution for vehicular travel takes many forms and plays out in complex ways. This section seeks to provide a clear conceptual framework for the various dimensions of substitution and describes their relation to broader aspects of travel. Typical "four-step" travel demand modeling suggests that travelers decide to make a trip and select a destination prior to choosing a mode. But, individuals who regularly walk or bicycle often reverse these steps. Their desire to walk or bicycle may lead them to make a trip in the first place, or they may consider a different set of destinations than if they were to drive—not only closer destinations but also those for which walking and bicycling are safer, more comfortable, and more attractive—all qualities that are not accounted for in traditional destination choice models.

Furthermore, mode choice may lead to differences in choosing a single destination, but also in forming "trip chains" of stops at multiple destinations. Changes in mode, destination, and frequency may impact the type and frequency of activities one engages in, which in turn can lead to changes in VMT. An individual might cycle to the local market, then the pharmacy, and then coffee shop instead of driving to the large grocery store containing all those services in one destination. The same individual might then forego an auto trip to the gym, deciding he has gotten enough daily exercise through utilitarian cycling. In other words, mode substitution might go hand-in-hand with destination and even activity substitution.

Substituting a specific trip may be one component in a behavior change process that in turn leads to longer term substitution behaviors, possibly culminating in a decision to give up auto use entirely. An individual might choose to live in an AT-friendly neighborhood, forego auto-ownership, and rely entirely on walking and bicycling. In this case, daily AT use that does not qualify as trip-specific substitution could still be considered long-term, or lifestyle, substitution. These examples illustrate the inherent complexity in this issue. We identify five important dimensions of substitution behavior.

Trip type (or trip purpose)

Previous studies tend to focus on the ability of specific modes to substitute each other for certain trip types – such as commute trips, non-work trips, and recreational trips – though few have quantified the degree of substitution. Several studies focus on non-work travel (Handy and Yantis, 1997; Handy and Clifton, 2001; Krizek et al., 2009a). It is likely that different types of trips (e.g., work versus non-work, commutes to work versus travel to meetings) have different potentials for substitution.

Substituting mode

Many travel modes could potentially substitute for driving. The potential to substitute depends on the modes available to a particular individual for a particular trip; available modes are a function of both individual characteristics (e.g., auto ownership, bicycling ability) and the trip characteristics (e.g., distance to destination, presence of bike lanes along the route). Walking is a possible substitute for the shortest trips, bicycling for middle-range trips, and transit for longer-range trips, though the viable distances for each mode will vary, and many trips will have two or more possible substitutes. Note that substitution for other pairs of modes could also occur. (e.g., transit trips substituting for bicycling trips, or vice versa.)

Extent

Another consideration is the extent of substitution in terms of both trip frequency and trip length. A commuter cycling to work daily is likely to have a greater impact on a city's transportation system than someone bicycling to the corner store once per month. Both the frequency and the distance of the trip made can differ from the trip replaced. Destination substitution may go hand-in-hand with mode substitution; that is, a mile of bicycling (and an accompanying substitution for a nearer destination) may replace a much longer automobile trip, thereby increasing the extent of the substitution effect to greater than a 1:1 relationship. However, a single automobile trip could be replaced by more than one AT trip (as was found by Handy and Clifton (2001)), in which case the substitution effect is less than 1:1.

Time horizon

The most elusive dimension of substitution relates to the time horizon over which the effect takes place. Two disparate examples illustrate this point. Consider an individual who drives for most trips but decides to cycle to work on a pleasant spring day; his "default setting" is driving, and any AT could be considered substitution. At the other extreme is an individual who chooses to live in a location close to her work so that she does not need to own a car; she walks, cycles, or uses transit for almost all trips, having made this a lifestyle decision. In the latter example, it is difficult to assign a specific substitution rate; *all* trips are substituting for driving in some sense, though over the long-term rather than as a result of a daily substitution decision.

Activity patterns

Mode substitution can lead to other changes in an individual's activity patterns, which might lead to secondary changes in travel behavior. For instance, walking or bicycling instead of driving to work might provide enough exercise that it leads to a reduction in driving trips to the gym, thereby extending the reduction in driving beyond the initial substituted trip. Alternately, using telecommunications to carry out an activity rather than driving to a destination. In this case, saving time that could hypothetically be spent on an activity that necessitates an automobile trip that would not have otherwise occurred (Krizek et al., 2009a).