Research in Transportation Economics 47 (2014) 82–91

Contents lists available at ScienceDirect

Research in Transportation Economics

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

Land-use impacts in transport appraisal

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ARTICLE INFO

Article history:
Available online 4 November 2014

JEL classification:
H43
C25
D61
R41
R42

Keywords:
Cost-benefit analysis
Transport planning
Land-use planning

ABSTRACT

Standard cost-benefit analysis (CBA) does not take into account induced demand due to relocation triggered by infrastructure investments. Using an integrated transport and land-use model calibrated for the Stockholm region, we explore whether this has any significant impact on the CBA outcome, and in particular on the relative ranking of rail and road investments. Our results indicate that induced demand has a larger impact on the benefit of rail investments than on the benefit of road investments. The effect on the relative ranking is still limited for two reasons. First, the number of houses that are built over 20–30 years is limited in comparison to the size of the existing housing stock. Second, the location of most of the new houses is not affected by any single infrastructure investment, since the latter has a marginal effect on total accessibility in a city with a mature transport system. A second aim of this paper is to investigate the robustness of the relative CBA ranking of rail and road investments, with respect to the planning policy in the region 25 years ahead. While the results suggest that this ranking is surprisingly robust, there is a tendency that the net benefit of rail investments is more sensitive to the future planning policy than road investments. Our results also underscore that the future land-use planning in the region in general has a considerably stronger impact on accessibility and car use than individual road or rail investments have.

1. Introduction

Most studies analyzing uncertainty in cost-benefit analysis (CBA) outcomes focus on errors in transport model outputs (Beser Hugosson, 2005; Brundell-Freij, 2000; De Jong et al., 2007; Zhao & Kockelman, 2002). De Jong et al. (2007) find, however, that the uncertainty induced by modeling errors is small compared to uncertainty induced by future scenario assumptions. Hansson (2007) and Mackie and Preston (1998) discuss uncertainty induced by omitted effects, model errors, input assumptions and valuations. Börjesson, Eliasson, and Lundberg (2014) analyze robustness of CBA with respect to various input data and valuations. The main purpose of this paper is to explicitly study uncertainty of CBA outcomes due to uncertainty in future land-use. To the author's knowledge this is not done in previous research, although the importance of land-use impacts in appraisal were identified as a key challenge at the International Transport Forum (Worsley, 2011).

The transport and land-use systems are mutually dependent on each other in the transportation–land-use cycle (Kelly, 1994). This is, however, not taken into account in standard transport CBA. Swedish and British guidelines for infrastructure appraisal (Department for Transport, 2009; Swedish Transport Administration, 2012) discuss land-use effects only very briefly. When applying cost-benefit analysis, it is usually the ranking of many investments that are most relevant.[4] A central hypothesis tested in this paper is that the future land-use matters when rail and road investments are ranked. We analyze two different land-use effects in separate sub-studies.

In the first sub-study we explore to what extent the evaluated investments influence the future land-use and thereby the travel demand, as suggested by Goodwin and Noland (2003), Hills (1996), Litman (2007), Noland (2001) and SACTRA (1999). We denote this

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[4] CBA is usually not used to determine the infrastructure budget and there are globally uncertain parameters such as discount rate and traffic growth which substantially affect the absolute outcome of all investments. If these change then the cut-off rate for what is good value for money will also change, which essentially means that it is the ranking of investments that is relevant.

http://dx.doi.org/10.1016/j.retrec.2014.09.021

effect induced demand from land-use changes. Induced demand from short- and medium-term behavioral responses, such as trip frequency, route and mode choice and car ownership, is well established.[5] In the present study we take them into account in the transport model and in the CBA, but do not explicitly study the effect of them on the CBA.[6]

Smart Growth advocators argue that transit investments may help to form higher density, while new highway investments tend to lead to the opposite, i.e. more urban sprawl (Bernick & Cervero, 1997; Newman & Kenworthy, 1989). Litman (2007) and Noland (2001) hypothesize that households tend to locate further away from the city in response to highway capacity expansions, increasing the vehicle kilometers traveled over and above the increase due to the short-term responses. These studies suggest that induced demand from land-use changes could increase the net benefit for rail investments more than road investments, because negative externalities (congestion, emissions and accidents) arise from induced car use and the use of transit infrastructure is usually more dependent on a dense and structured land-use.

Using Australian data, Newman and Kenworthy (1988) find that increased average car speed increases fuel consumption per capita through land-use changes in the urban area. Rodier (2001; 2002; 2004) show that land-use changes induced by highway investments account for about 50% of the travel demand increase. Marshall and Grady (2005) find, on the contrary, that land-use impacts have only a small effect on travel demand in case of limited road capacity because congestion constrain the urban sprawl in any case. Condor and Lawton (2002) find that the need for new transport investments is overestimated if not taking land-use effects into account because strategic planning could be a substitute for investments. Cervero and Kockelman (1997) find that compact development in terms of high density, pedestrian oriented transport systems and land-use diversity in the San Francisco Bay Area reduces motorized travel significantly, which may indicate a reduced benefit from road investments. The varying conclusions from these studies may be caused by different land-use and congestion conditions. Preferences for high density may also vary between geographical areas due to self-selection (people with preferences for high density may to a larger extent live in dense cities). Different investments have also different functions in the transport system.

In the second sub-study we explore to what extent CBA outcomes depend on the future planning policy in the region, i.e. to what extent the future planning strive for high public transit accessibility and concentration of new housing, over a period of 25 years ahead. The future planning is genuinely uncertain because of the highly decentralized planning system. The County of Stockholm comprises 26 municipalities and each municipality decides about its own land-use. There is no long-term land-use plan for the region that the municipalities must comply with.

There are some prior studies quantifying the impact of uncertain future land-use. Pradhan and Kockelman (2002) find that outputs of the transport model is less variable than outputs of the land-use model, because the former seeks equilibrium. Ashley (1980) and Zhao and Kockelman (2002) find that uncertainty is likely to inflate over the model steps (i.e. location, trip frequency, destination, mode and route choice) except in the route choice, because larger transport demand leads to more congestion and thereby reduced demand. They also find that input variables accumulating over time, such as growth rates, induce larger uncertainty in the outcome than other input data. Other studies have found that uncertain socioeconomic forecasts are a significant source of uncertainty (Harvey & Deakin, 1996; Rodier & Johnston, 2002; Thompson, Baker, & Wade, 1997). In the present study, we do not consider uncertainty in population growth or demography. Since, however, the growth rate affects all investments in a similar way, their effect on the ranking are limited (Börjesson et al., 2014).

Table 1
Population density (inhabitants/km^2) in selected cities in Europe.

City	Population density Inh./km^2	Source
Stockholm	3597	Statistics Sweden (2013)
London	5632	National Statistics, UK (2010a)
Manchester	4002	National Statistics, UK (2010b)
Munich	4282	Statistisches Bundesamt Deutschland (2000)
Oslo	3192	Statistisk sentralbyrå (2012)

We apply a large-scale integrated land-use and traffic model estimated and calibrated for the Stockholm region and evaluate six rail and road investments in the Stockholm region. Some of them are more peripheral and others more central, affecting accessibility in large parts of the region.

The impact of induced demand in the first sub-study is estimated by simulating two land-use patterns over the period 2006–2030, one in which the investment (for which the CBA is made) is assumed to have been introduced in 2006 and one in which it has not. The impact of induced land-use changes on the CBA outcome is then calculated by using different land-use patterns in the traffic forecast model in the build and no-build scenario. The second sub-study investigates the impact of future land-use on the cost-benefit analyses. Three cost-benefit analyses for each investment is made, assuming different planning policies over the years[7] 2006–2030: one where the planning strives for high density and high public transit accessibility, one where the planning is oriented towards low density and low accessibility to public transit, and one in between, following current planning trend in terms of density and public transit accessibility of new housing. Three land-use patterns for 2030, corresponding to each policy, are simulated in the land-use model.

In Section 2 we describe the transport system and the land-use in the Stockholm region and Section 3 describes the models in use. Section 4 describes the method including experimental setup, the scenario assumptions and description of investments. Section 5 contains the results, and Section 6 discusses the results. Section 7 concludes.

2. The stockholm region

2.1. Land-use and transport systems

Regions face different degrees of freedom when developing the future land-use. In a built up dense region with strong restrictions, few realistic alternative development paths may be open (in such regions a land-use model would just fill in empty spaces in the landscape) while several different paths may be open in other

[5] Næss, Nicolaisen, and Strand (2012) show that they have significant effect on the CBA outcomes.

[6] Our transport model was able to reasonably well predict the responses in terms of frequency, mode, destination and route choice, when the congestion charges were introduced (Eliasson, Börjesson, Brundell Freij, Engelson, & Van Amelsfort, 2013), which suggests that the more short term travel behavioral responses are sufficiently taken into account in our analysis.

[7] 25 years is the normal forecasting period, beyond that assumptions input factors become very uncertain. The effects on land-uses changes may be proportionally larger with longer forecasting periods.