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Endogenous treatment of residential location choices in transport and land use models: Introducing the MetroScan framework

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ABSTRACT

Within a random utility maximisation modelling framework, the paper develops a residential location choice model as part of an integrated transport and land use modelling system, called MetroScan – a quick scanning tool to evaluate transport and land use initiatives, including benefit-cost analysis and economic impact analysis. We describe how the developed model is integrated, as an empirically calibrated module, into the behaviourally richer transport and land use modelling system of MetroScan for practical application. A full application of MetroScan modelling system to Sydney West Metro link recently proposed by the New South Wales government is presented as a case study. The results demonstrate how the residential location choice model works with other inter-connected models, such as work and non-work location choices, dwelling tenure and dwelling type, and vehicle fleet size choice embedded in the modelling system, in simulating the impact of transport and housing development on household choices of residential location.

1. Introduction

A recognition that transport and land use mutually influence each other has resulted in a growing interest in integrating transport and land use models for metropolitan planning. Since Lerman's (1976) pioneering work to link the long-term decision of residential location with shorter-term decisions of workplace, vehicle ownership, and commuting mode as a discrete choice model of the multinominal logit form, many attempts have been made to extend this modelling approach to examine the interactions between transport and land use. Examples range from Abraham and Hunt's (1997) model that captures the interactions between location choices (home and work) and mode choices through a nested logit model with variable nesting structures, to the UrbanSim framework that uses travel demand as an input into land use models that simulate the development of housing and labour markets (Waddell, 2000), to recent advancements of activity-based models in which the interdependencies between long-term and shorter-term decisions are captured through a series of discrete choice models that are linked together via an accessibility measure (Bowman and Ben-Akiva, 2001; Bradley and Bowman, 2006; Davidson et al., 2011).

Discrete choice models have created additional opportunities for modelling the interaction between transport and land use. Over the last two decades, a few modelling efforts have been made to integrate transport with land use through modelling the interdependence amongst the four sets of household choices: residential location, job location, vehicle ownership, and travel patterns (de Palma et al., 2007; Ben-Akiva & Bowman, 1998; Miller & Salvini, 2001; Salvini & Miller, 2005; Waddell, 2000). These choice models are typically operationalised within an overall framework of strategic travel models in which the interactions between transport and land use are captured through constraints and feedback using the accessibility or logsum concept in a nested logit structure (see Pagliara et al., 2010 for a review of various operational models). However, most operational activity-travel demand models have not yet taken advantage of these opportunities for modelling residential location choice. For example, the two major operational frameworks, namely DaySim (Bradley and Bowman, 2006) and CT-RAMP (Davidson et al., 2010) family of activity-based models, treat residential location as exogenous to other travel-related decisions. Specifically, the choice of residential location is synthesised as opposed to being modelled endogenously in the modelling system. Synthesising where people live may be sufficient for understanding how residential location influences short-term travel behaviour, but this offers no clues as to how day-to-day travel experiences and job mobility may factor into longer-term household decisions to change residential location. This limitation is also applied to stand-alone models whereby the choices of residential location are modelled either in isolation with or with little reference to short-term decisions (for example, see Guo and Bhat, 2001; Yates and Mackay, 2006).

Within a random utility maximisation modelling framework, the current study develops a residential location choice model as part of an

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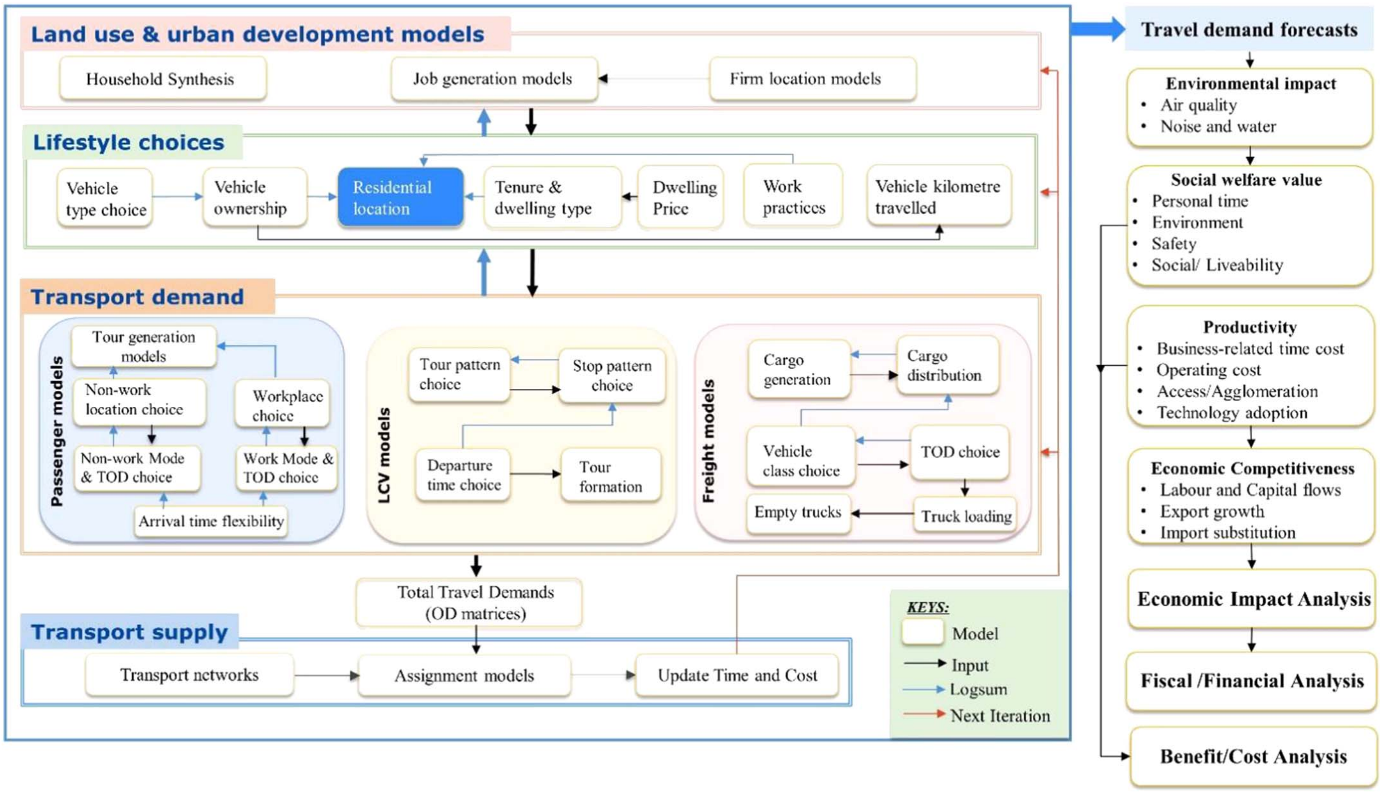

Fig. 1. Overall framework of MetroScan demand and supply models. (For interpretation of the references to color in this figure, the reader is referred to the web version of this article.)

integrated transport and land use modelling system, called MetroScan – a quick scanning tool to evaluate transport and land use initiatives, including benefit-cost analysis and economic impact analysis. Fig. 1 shows the overall structure of the MetroScan modelling system, comprising land use models, travel demand and supply models, as well as economic appraisal and impact models. On the demand side, MetroScan explicitly models travel demand arising from moving people (passenger module), moving goods (freight module), and providing services (light commercial vehicle or LCV module). These demand models interact with each other through network assignment models (i.e., transport supply module) in which the competition for network capacity among passenger vehicles (car and bus), trucks and LCVs is captured. This is important for investigating the impact of transport policies which target one sector but have indirect effect on another sector; for example, a congestion charge for cars will impact directly on passenger travel demand but will also create extra road capacity for freight movements. On the land use side, MetroScan accounts for not only individual and household choices of location (work and non-work places, residential location), but also business location and co-location choices. The firm location choice models provide the spatial distribution of jobs by industry as an input into the workplace choice model. MetroScan takes demand forecasts and feeds them seamlessly into benefit-cost and economic impact analyses to provide travel-related benefits, environmental benefits, productivity (i.e., wider economic) benefits, and jobs growth associated with transport investments and policies.

We focus in this paper on the residential location choice (RLC), highlighted in dark blue in Fig. 1. Residential location is a major household decision that determines not only the accessibility of each household member to their daily activities, but also the household's budget for other consumption such as vehicle and dwelling ownership. MetroScan structures the residential location choice model above the workplace location choice in a nested logit framework in light of empirical evidence which suggests that 80% of households choose residential location first and then household workers choose their workplaces conditioned on residential location (Waddell et al., 2007). In addition, the household choice of residential location conditions the choices of tenure and dwelling type, household fleet size, places for non-work activities, and work practices (e.g., telecommute vs. compressed work week). Short-term decisions of travel mode and time of day travelled also influences residential location choice, but only indirectly via the medium-term decisions of vehicle ownership, work and non-work location choices.

Modelling residential location choice within an integrated model of transport and land use is potentially the best way to investigate the interactions of residential location with other key decisions such as workplace, residential dwelling tenure and dwelling type, vehicle ownership and daily travel patterns. However, this approach requires that models describing these key decisions be estimated first to obtain the logsums (or inclusive values or expected maximum utility) for use in modelling residential location choice. All modules of MetroScan have been estimated and some detailed models can be found in previous papers (Ho and Hensher, 2014, 2016). This paper sets out the residential location choice model for Sydney residents and the empirical evidence, complete with all of the interconnected elements. A full implementation of MetroScan on a sample of synthesis households is conducted in a case study that assesses the impact of a recently announced Sydney West Metro on residential relocation. These households are synthesised in such a way that they are representative of the population in terms of household size, household structure, number of household workers, occupation and work industry, age, income and other demographics (Ellison and Hensher, 2016).

2. The empirical setting

This section describes the main survey and supplementary data from various sources that are used in developing the RLC model. The primary data used for estimating this model is revealed preference data drawn from a larger survey undertaken in 2013 to develop a number of