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Baseline Synthesis and Microsimulation of Life-stage Transitions within an Agent-based Integrated Urban Model

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Abstract

This paper presents baseline synthesis and microsimulation of life-stage transitions within an agent-based integrated Transport Land Use and Energy (iTLE) modeling system. The baseline synthesis involves generation of synthetic population and vehicle ownership level synthesis. Synthetic population in generated in two stages: (1) generation of synthetic population at the dissemination area (DA) level, controlling for household- and individual-level attributes; and (2) allocation of the synthetic population at the micro-spatial unit of parcel using a logit-link model. Vehicle ownership synthesis involves a multinomial logit model to determine the vehicle ownership level for the base year. The life-stages of the synthetic population are simulated longitudinally at a yearly simulation time-step within the iTLE framework. The simulated life-stages include: aging, birth, death, in-migration, out-migration, and household formation. The iTLE is coded in the C# DotNET programming platform. A 100% synthetic population is generated for Halifax, Canada. The baseline synthesis and life-stage simulation results are satisfactory. For instance, population synthesis results suggest that around 62.81% of the DAs show an error percentage range of -5% to +5%.

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Keywords: Population synthesis, Vehicle ownership synthesis, Life-stage transitions, Agent-based modeling, Integrated urban model

1. Introduction

The development of integrated urban models has evolved from the initial aggregate-level models such as MEPLAN[1], and TRANUS[2], to the recent agent-based microsimulation models such as ILUTE[3], PUMA[4], and

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UrbanSIM[5], among others. Agent-based integrated urban models simulate essential decision processes (i.e. location choices, travel activities) at the disaggregate-level of the population (i.e. individuals, households) as well as at the micro-spatial resolution to predict the evolution of urban form and transportation system over time and space. To operate at the disaggregate spatial-level, considering individuals and households as the agents, agent-based urban models require micro-level information of the population for an entire region, which is not readily available. Hence, one of the major challenges in agent-based urban modeling is to generate synthetic population with associated household- and individual-level attributes at a micro-spatial resolution.

Integrated urban models simulate individual agents' decisions over a long multi-year time frame. During this period, individuals' demographic career evolves, such as a single person become married, have children, get divorced, and finally decease. A change in the demographic status influences individuals' decisions at different life-domains. For example, birth of a child influences residential location choices[6], as well as vehicle transactions[7]. Moreover, decision of where to live influences how many vehicles to own[8], and vice-versa. Therefore, it is imperative that integrated urban models accommodate the interactions among the life-stage transitions and multi-domain decisions over the life-course of the agents. To address such multi-way interactions, agents' life-course and associated changes need to evolve within the simulation environment of the integrated models. A large body of literature exists on the population demographic microsimulation[9,10]; however, integrated transport models have not sufficiently addressed baseline synthesis and life-stage transition processes. Although ILUTE[11], PUMA[4], and CEMUS[12] have demographic updating component, a comprehensive framework for the synthesis of population and vehicle ownership, and microsimulation of life-stage transitions have not occurred to any significant extent.

This paper offers a comprehensive baseline synthesis including population and vehicle ownership level synthesis, and microsimulation of life-stage transitions of the individuals and households. The baseline synthesis and life-stage transitions are implemented within an agent-based integrated Transport Land Use and Energy (iTLE) modeling platform, which is currently under development in Halifax, Canada. The iTLE adopts the concept of life-course perspective in developing the micro-modeling structures and computational procedures to simulate agents' decisions longitudinally at each simulation time-step along their life-course. The synthetic population for iTLE is generated at the most micro-spatial unit of parcel controlling for household- and individual-level characteristics. The baseline vehicle ownership level synthesis is performed by utilizing a multinomial logit model. Since the iTLE is a life-oriented urban model that addresses the multi-way interactions among the decisions and life-stages over the life-course of the population, one of the core components of the iTLE is the population life-stage transition module. This module simulates a number of demographic and life-cycle events, such as aging, death, birth, out-migration, in-migration, household formation, in- and out-of labor force, and job transition.

2. Conceptual Framework of iTLE

The integrated Transport Land Use and Energy (iTLE) model follows the theoretical framework of life-course perspectives[13]. Life-course perspectives focus on how transitions along the life-time and interactions among decisions taken at different domains along the life-time shape individuals' choices and behavior[13,14]. The iTLE maintains the theoretical underpinning of the life-course perspective in developing the micro-behavioral models and subsequent computational framework for the simulation. The iTLE is an agent-based microsimulation modeling platform for urban systems, which assumes individuals and households as the agents. It simulates agents' decisions longitudinally at each simulation time-step. An agent can enter the population through birth or in-migration and exit through death or out-migration. The simulation starts with a sample of baseline population, and the relationships among the agents in the population are maintained throughout the simulation period. The conceptual framework of iTLE is presented in Figure 1. To represent the behavior of the agents within each module, a number of micro-behavioral models are developed accommodating the life-trajectory dynamics. A brief description of the processes within iTLE are given below:

- Baseline synthesis involves population synthesis, and vehicle ownership level synthesis. Population synthesis for the iTLE is a two-stage process: (1) generation of synthetic population at the zonal-level, and (2) allocation of the synthetic population at the micro-spatial unit of parcel. Vehicle ownership level synthesis is performed through a