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Applications of TRANSIMS in transportation: A literature review

Kwang Sub Lee[a] *, Jin Ki Eom[a] , Dae-seop Moon[a]

[a]*Korea Rainroad Research Institute, 176 Railroad Museum Rd., Uiwang-si, 437-757, KOREA*

Abstract

TRANSIMS is an activity-based and an integrated system of travel forecasting and microscopic simulation models developed for regional transportation planning. It uses a new paradigm of modeling individual travelers on microscopic network, thus it differs from traditional 4-step travel demand forecasting models in its underlying concepts and structure. Although TRANSIMS was originally developed for regional travel demand forecasting, the use of TRANSIMS is not limited to them. A variety of case studies and researches using TRANSIMS was being conducted in various transportation fields. This paper introduces main functions and capabilities of TRANSIMS, reviews various applications of TRANSIMS and explores future opportunities of using TRANSIMS.

Keywords: TRANSIMS, Activity-based model, Application;

1. Introduction

TRANSIMS (TRansportation ANalysis SIMulation System) is an activity-based and an integrated system of travel forecasting and microscopic simulation models developed for regional transportation planning. It uses a new paradigm of modelling individual travellers on microscopic network, thus it differs from traditional 4-step travel demand forecasting models in its underlying concepts and structure. The differences include a consistent and continuous representation of time, a detailed representation of persons and households, time-dependent routing, and a person-based microsimulator. The microsimulator identifies each traveller and traces the movement of people as well as

* Corresponding author. Tel.: +82-31-460-5686; fax: +82-31-460-5359.
E-mail address: leeks33@krri.re.kr

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vehicles on a second-by-second basis. Even though there are a few concerns of using TRANSIMS due to the requirements of large data and learning the system, the use of TRANSIMS is not limited to the regional multimodal travel demand model and the air quality analysis tool. A variety of case studies and researches using TRANSIMS was being conducted in various transportation fields. This paper introduces main functions and capabilities of TRANSIMS, reviews various applications of TRANSIMS and explores future opportunities of using TRANSIMS.

2. Introduction to TRANSIMS

TRANSIMS was initially developed at Los Alamos National Laboratory as representing the next generation of transportation models. It is now being made available and furthermore developed as an open source project. TRANSIMS is based on four primary modules: population synthesizer, activity generator, route planner, and traffic microsimulator (Fig.1). The population synthesizer module generates the synthetic population from Census data. The activity generator module generates activities of the population from activity surveys. Route planner routes the trips based on the activities on a time-aware road and transit network. Microsimulator executes the plans for each trip on the road network and develops feedback in form of a link delay file. A typical feedback is applied to the equilibration process iterating between route planner and microsimulator.

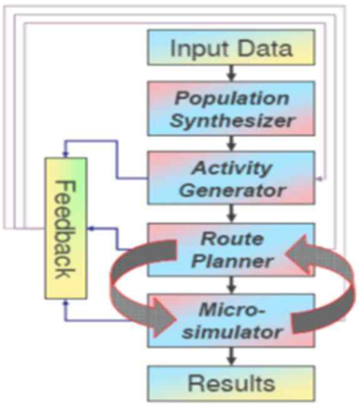

Fig. 1. Core components of TRANSIMS.

TRANSIMS simulates the travel behaviour of each synthetic individual throughout an entire 24 hour period based on representative activities derived from survey data. Based on highly detailed road and transit networks, individuals are traced for every second of the day while analysing their local interactions. Routes for travellers are determined by a routing module that considers time-dependent link delays throughout the 24-hour period. Microsimulation is used to determine link travel times, rather than volume delay functions. The major TRANSIMS results include detailed snapshot data, the location of each individual traveller, car, or transit vehicle, statistics on traffic volume, congestion, queues at intersections, time-dependent link delays for the entire road and transit network.

TRANSIMS models are significantly more complex than traditional transportation models. The software requires intensive data and computing resources. However, much of the detailed network is generated based on rules by default. TRANSIMS can accommodate large road and transit networks (i.e., more than 100,000 links) and large populations (i.e., more than 30 million travellers).

3. Application of TRANSIMS

One of the most popular application of using TRANSIMS is related to the emergency evacuation modelling (Ley and Park, 2009; Park, 2011; Pasupuleti et al., 2009). In any emergency evacuation plans, the planners have to predict how people react to catastrophic events. In this case, planners need to consider the major and minor transportation routes and public transportation modes, so that individuals are able to safely exit the affected site. In addition, the planners also have to identify routes for emergency vehicle entering and exiting the accident site, as well as transport the injured from the accident sites to hospitals. In particular, needs for modelling and transportation systems management during emergencies has received national attention since unfortunate events such as terrorist attacks of 9/11, Hurricane Katrina in New Orleans and Hurricane Rita in Houston. Although several research studies were making efforts to address emergency management, unfortunately there are few decision support systems for transportation system management during emergencies. In this respect, an activity-based and individual microsimulator model is a very useful tool for evacuation and emergency modelling.

Park (2011) noted that TRANSIMS is a useful tool for complex and detailed simulations of the highly dynamic effects of evacuation, and TRANSIMS allows emergency responders to evaluate regional emergency response plans with regards to their feasibility. TRANSIMS is capable of simulating individual travellers, their routes, and their transportation mode and calculates traffic patterns on the basis of the microscopic interactions between individual vehicles on the detailed street network. Ley (2012) and Park (2011) conducted the project of modelling and simulation of an emergency evacuation scenario for the Chicago metropolitan area. The project was to investigate the effects of a no-notice event on the multi-modal regional transportation system and to deal with the dynamic effect on the transportation system. For this purpose, TRANSIMS were modified using “turn prohibition table” and “lane use table” in TRANSIMS. Traffic in TRANSIMS was rerouted to resolve congestion, redirect traffic, or allow access by emergency vehicles. First, trips originating in the evacuation zone after the event were moved forward in time and were assigned a new departure time (Fig. 2). Then, a special distribution (evacuation response curve) of trip origination time was applied. In order to prevent trips to enter the affected area, evacuation trips from the area were directed out of the area into a specific direction. Turn prohibitions in TRANSIMS were used to assure proper re-routing and to keep travellers from entering the area (Fig. 3). Lane restrictions in TRANSIMS were used to restrict two-way traffic on the roads. They also developed a decision support tool using TRANSIMS for evacuation planning and emergency response plans. They analysed the effectiveness of emergency response strategies and simulated the impact of destination, mode, and route choice decisions, including emergency evacuation traffic, escape routes and routes for incoming emergency responders.

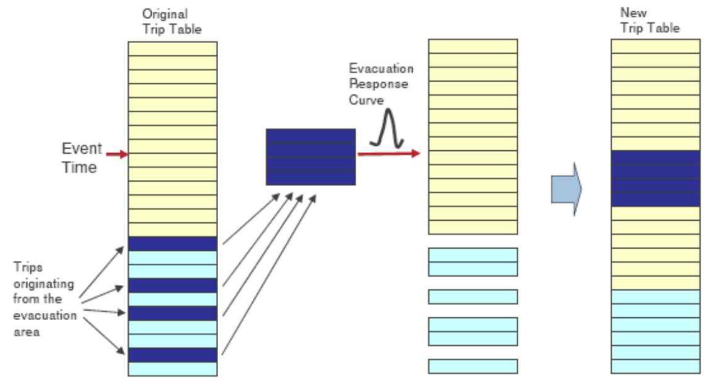

Fig. 2. Evacuation trips in TRANSIMS (Ley and Park, 2009).

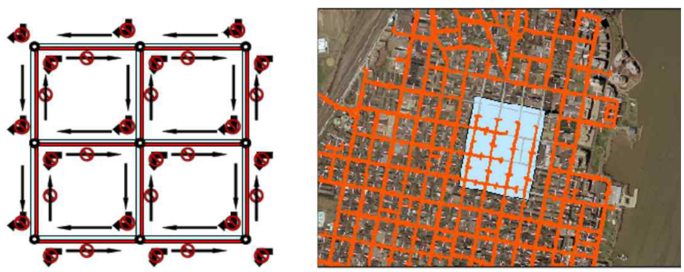

Fig. 3. Turn prohibition in TRANSIMS (Ley and Park, 2009).

The research team of the University at Buffalo conducted researches on the development, extension and calibration of a large-scale microsimulation of TRANSIMS (Sadek, 2012). In particular, the team assessed the level to which the TRANSIMS can be used for the online management of transportation system during emergencies. For this purpose, they developed models to quantify the impact of inclement weather (i.e., snow storms) on freeway traffic speeds at both macroscopic and microscopic levels, captured the impact of inclement weather on driver behaviour, and simulated emergency scenarios using TRANSIMS in the Buffalo-Niagara area. The research team concluded that TRANSIMS model can simulate freeway traffic under the inclement weather when model parameters are appropriately adjusted. However, they concluded that a small cell size is needed to achieve required speed resolution. For the future research, they have a plan to develop additional functionality needed to take full advantage of TRANSIMS in emergency transportation system management in order to allow TRANSIMS to receive real-time traffic information from loop detectors, video cameras and probe vehicles.

Naghawi (2010) developed a transit-based evacuation model to integrate both auto-based and the transit-based aspects and evaluated evacuation plans of New Orleans using TRANSIMS. The study evaluated a range of varying conditions, including two alternative evacuation transit routing scenarios and four alternative network loading and demand generation scenarios. The results of all scenarios were compared using relevant measures of effectiveness (MOEs) such as total evacuation time and average travel time. The results of this research demonstrated the applicability of large scale multimodal traffic simulations for evacuation processes.

It is often difficult to quantify the potential safety benefits of transportation alternatives. Samba and Park (2010) investigated safety treatments for the presence of heavy trucks in both uncongested and congested traffic. The safety treatments include peak hour travel restrictions, speed limiters, and lane restrictions. For this purpose, they developed a safety evaluation module for the TRANSIMS microsimulator to assess the applicability and benefits of the three heavy truck safety treatments for Hampton Roads, Virginia in U.S.A. They found that the left lane restriction was the most statistically significant and beneficial treatment strategy. This research showed that the TRANSIMS safety evaluation module could be a useful tool in measuring the safety of a transportation network and in comparing the benefits of candidate safety treatments.

Lee and Hobeika (2007) analysed a dynamic high-occupancy toll (HOT) lane using TRANSIMS, simultaneously considering user heterogeneity to estimate the travellers' response to tolls. They utilized individual value of time (VOT) function in route choice of a HOT lane value pricing system. The dynamic toll rates are varied by level of service in the HOT lane. A critical factor in modelling value pricing is the determination of individual VOT. Because TRANSIMS microsimulator is the only simulation tool that maintains the identity of the traveller throughout the simulation and is capable of accessing the database of each individual (e.g., income, age, trip purpose, etc.), the authors utilized heterogeneous VOT for each traveller. The use of nonlinear, individual VOTs relaxed the conventional assumption of constant VOT or randomly distributed VOT over the population. The research analysed 15-minutes toll rates that very dynamically with the congestion level in the HOT lanes, and demonstrated the feasibility of the proposed simulation methodology using TRANSIMS.

Lee et al. (2010) further developed a departure time choice model in response to value pricing using TRANSIMS. The proposed method was a post-processing of route choice and represents a sequential decision-making process of travelers who want to depart early or late based on congestion, individual attributes, and activity characteristics. The paper presented the results of a departure time choice model and its impacts on a HOT lane system using Portland, USA as a case study.

Kerenyi (2010) studied impacts of industrial land uses using TRANSIMS in order to investigate routing of traffic especially to the city of Moreno Valley's existing industrial area. The study was related to potential re-zoning of 4,700 acres of vacant land from a mix of uses to high-cube warehousing. In the study, the PlanTrips module in TRANSIMS was utilized for the time constraints from the original trip file and the trip duration from the plan file to update the trip start and end times in the new trip file.

4. Conclusion

TRANSIMS is a state-of-the-art transportation simulation model developed by USDOT (United States Department of Transportation). It is an activity-based large regional models and microscopic simulation of passenger and transit vehicles, based on the new paradigm of modelling individual travellers and their multi-modal transportation based on synthetic populations and their activities. TRANSIMS open source allows for the integration with dispersion models, infrastructure databases, and communication. In addition, TRACC (Transportation Research and Analysis Computing

Centre) is providing training courses on TRANSIMS in order to build a strong community of expertise. Traditional travel demand forecasting models that are based on aggregated zone lack in analysing impacts of individual movements. TRANSIMS is capable of analysing both future travel demand behaviour and modelling individual travellers on microscopic network. As shown in this study, TRANSIMS has been utilized in various fields related to transportation, in particular for the catastrophic events and evaluation of emergency responding strategies, because TRANSIMS allows the user to model diverse situation under emergency conditions. Although TRANSIMS was originally developed for the regional travel demand forecasting, many of its modelling and simulation features may be utilized in further analyses in the future, because TRANSIMS has unique abilities to microscopically model multiple modes of transportation. TRANSIMS allows the users to simulate the traffic as well as pedestrian patterns. Therefore, it can also be well-suited for transit and walking related modelling. For example, a modeller might be able to use activity locations where synthetic households live, and each activity location is attached to a corresponding parking location and/or transit stop via walk-network process links. Thus, it is possible to model pedestrian movements and accessibility of public transit passengers to the transit stop and to analyse optimal walking distance between homes and transit stops. In addition, TRANSIMS can be integrated with high performance visualization tool. An advanced interactive visualizer, TransVis, provides various capabilities, including compatibility with any current shape file, interactivity with snapshot data spatially and temporally, movie production tool, and creative paradigms for visualizing complex data concepts such as congestion.

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