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MODELING AND SIMULATION OF PORT-OF-ENTRY SYSTEMS

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ABSTRACT

This paper describes a suite of simulation models for Port-of-Entry (POE) systems, dubbed POESS (POE Simulation System). POESS was developed with the support of the U.S. Department of Homeland Security (DHS) for use primarily by the U.S. Customs and Border Protection (CBP) agency. POESS aims to assist CBP in POE design and operational decision making. A POESS simulation model of the Bridge of the Americas (BOTA) POE, located at El Paso, Texas, is described as an example.

1 INTRODUCTION

Fast and sustained secure flows of people and goods across U.S. Ports-of-Entry (POEs) are essential to the U.S. economy and its network of supply chains. In particular, excessive delays at POEs translate into a variety of economic burdens and environmental costs, including personal inconvenience to travelers in terms of time, increased supply chain lead times and their attendant cascading disruptive effects, and an elevated carbon footprint resulting in environmental and public health consequences.

The U.S. Customs and Border Protection (CBP) agency is the nation's largest law enforcement agency, responsible for securing U.S. borders while facilitating lawful travel and trade across its POEs. As such, CBP plays a key role in supporting the nation's physical and economic security. CBP needs to find efficient and cost effective solutions to the problem of managing traffic across POEs with fluctuating traffic levels. More specifically, CBP needs detailed and flexible simulation models serving as in-vitro labs that answer "what-if" questions that support POE optimized planning, such as decisions on POE reconfiguration, expansion, and response to disruptions. Accordingly, DHS funded a project to develop such a simulation platform and construct a suite of detailed and accurate simulation models of key POEs (DHS/CBP, 2016). This paper summarizes the salient features of the software tool created over the first two stages of this project (from 1/2016 to 6/2017). This tool has been dubbed *POESS* (*POE Simulation System*), and its initial users will be CBP analysts and possibly DHS-affiliated preparedness and response organizations.

2 POESS OVERVIEW

POESS is designed to serve as an in-vitro laboratory for experimentation and answering "what-if" questions related to effective and cost efficient traffic management across POEs. The simulation models provide decision support, primarily for strategic longer-term planning, such as capacity planning (e.g., expansion of existing POEs or creation of new ones before traffic growth overwhelms current POEs), and optimization (e.g., selecting the best configuration among a set of candidates). They can also support other DHS planning activities pertaining to hypothetical adverse scenarios, including (a) evacuation of a local population due to a natural or man-made disaster, such as inclement weather (e.g., impending hurricane or flooding), chemical accident, etc.; (b) loss of POE infrastructure (e.g., terrorist event resulting in POE partial or complete closure); and (c) traffic-disrupting events (e.g., an accident resulting in lane closures at a POE). POESS produces a set of performance metrics of interest to POE operations, to be described in the next section, computed from a single or multiple replications.

A POESS model consists of both immobile objects and mobile ones. The key immobile objects constitute the POE infrastructure: incoming and outgoing roads, incoming plazas, inspection booths, devanning

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docks and inspection equipment (X-ray and radiation facilities). The key mobile entities are vehicles that pass through the POE and handled by inspection personnel. The layout of a POE in a POESS simulation model is visualized by superimposing it on a geographical map of the POE facility and its vicinity. To facilitate experimentation, we developed a graphical user interface (GUI) with a dynamic editor that permits the user to pause a simulation and alter its parameters (including incoming traffic loads, inspection capacities, lane reconfiguration, and the introduction of physical traffic obstructions), and resume or restart runs. In a similar vein and to enhance model behavior, POESS takes advantage of traffic and statistics animation.

POESS is coded in Java over the AnyLogic simulation platform (Borschchev, 2013), which offers a rich set of graphical tools, including rendering in 2D and 3D views, a debugger, visual and textual model construction, animated simulation runs and dynamic statistics collection (charts and plots). AnyLogic affords an organic integration of multiple modeling paradigms, of which POESS makes use of discrete-event and agent-based simulation.

3 SIMULATION MODEL COMPONENTS

As an example, this section describes a POESS simulation model of the Bridge of the Americas (BOTA) POE, located at El Paso, Texas. Every POESS model consists of the following components.

(1) Input, Output and Trace Files. The simulation tool interacts with three set of external files, for reading simulation input parameters, writing output statistics, and dumping vehicle trace data for each vehicle passing through the POE system.

(2) POE Infrastructure Modeling. A POE infrastructure model is superimposed on a geographical map of the POE under study and its vicinity. The BOTA POE contains two separate inspection areas as shown in Figure 1: a so called *Privately-Owned Vehicle* (*POV*) POE primarily for passenger vehicles, and a so-called *Commercially-Owned Vehicle* (*COV*) POE exclusively for commercial vehicles.

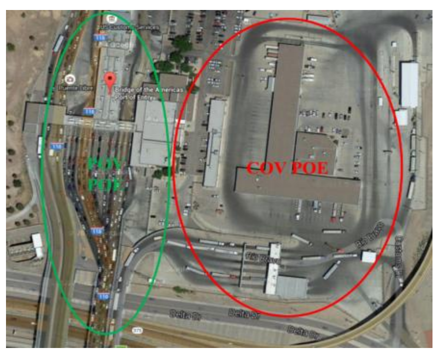

Figure 1: BOTA POE's POV inspection area (green) and COV inspection area (red)

(3) Inspection Booth Service Modeling. Each booth renders inspection service to an inbound lane. A booth is modeled as one or two servers depending on lane configuration and position. A random delay models the duration of inspection activity from a prescribed probability distribution, to be fitted to available data. Servers are assumed to be statistically independent of each other, but their delay distributions will vary according to the types of inbound lanes that the server renders service to.

(4) Traffic Modeling. Each vehicle is modeled as an agent with its behaviors captured by agent-based modeling techniques. Typical behaviors of vehicles include accelerating, decelerating, switching lanes, etc. While the driving behaviors of POVs and COVs are similar, they have different parameters to account for their physical size and speed. Inter-arrival times are drawn from exponential distributions.

(5) Disruption Modeling. Disruptions are events that adversely impact traffic evolution and hence system throughput. Disruptions in POESS model are user-specified obstructions, which represent a blocked area (unavailable for vehicle passage) in the inbound plaza and inbound roads. Its impact is to cause inbound vehicles to attempt to bypass this area, thereby increasing congestion.

(6) Model Statistics. POESS collects and computes operational and financial performance metrics, including (a) total number of inbound vehicles; (b) number of vehicles in the secondary inspection zone; (c) crossing time (total time that the vehicle spends in the POE from the moment it was generated until it was cleared by a booth server); (d) location-based waiting time (total time that the vehicle spends in the POE from the moment it arrived at a prescribed point until it arrived at an inspection booth); (e) speed-based waiting time (total time that the vehicle spends in the POE from the moment its speed drops below a specified speed threshold until it arrived at an inspection booth); (f) server utilization at primary inspection booths; and (g) opportunity cost of travelers' speed-based waiting times (monetary value of a speed-based waiting time of travelers in the POE, computed over a time interval; see Robinson (2007) and Frankel (2003) for conversion of waiting times into a monetary cost to travelers). Note that a reduction in the carbon level would be achieved by shortening vehicle waiting times in POEs.

4 VALIDATION

To validate our POE BOTA model, we obtained real-life (empirical) traffic data provided by the CBP-OFO (Office of Field Operations), and RFID-derived crossing time data provided by the Texas Transportation Institute (TTI). The CBP-OFO data contains POV vehicles' crossing time stamps, booth schedules, and estimated average waiting times per lane type over specific periods. The TTI data contains the COV arrival traffic stream (only for trucks equipped with RFID), and the corresponding time stamps between specific locations where RFID readers are installed. The simulation models were validated by comparing the empirical statistics to their simulation-generated counterparts. More specifically, two statistics were used as validation metrics: (1) the daily averages of speed-based waiting times computed by the POESS BOTA simulation model were compared to their CBP-OFO counterparts; and (2) the daily averages of location-based waiting times computed by the POESS BOTA simulation model were compared to their TTI counterparts. The created POESS model used a set of daily POE configurations (schedule of booth opening by type over time), and POE operational parameters (e.g., hourly arrival rates over a day, and service rates), extracted from the aforementioned data sets. The model was run for 3 days without a warm-up period. For the preliminary data obtained, we were able to achieve the validation goal of no more than 10% relative deviation of the simulation-generated statistics from their empirical counterparts.

REFERENCES

Borschchev, A. (2013) *The Big Book of Simulation Modeling*, AnyLogic North America.

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Frankel, E.H. (2003) "Revised Departmental Guidance, Valuation of Travel Time in Economic Analysis", *U.S. Department of Transportation Memorandum*.

Robinson, L.A. (2007) "Valuing Travelers' Time for Border Crossings and Related Activities", *U.S. Department of Homeland Security, U.S. Customs and Border Protection Report*.

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