Simulation Modelling Practice and Theory 17 (2009) 597–611

Contents lists available at ScienceDirect

Simulation Modelling Practice and Theory

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

A multi-modal discrete-event simulation model for military deployment

Uğur Z. Yıldırım *, Barbaros Ç. Tansel, İhsan Sabuncuoğlu

Department of Industrial Engineering, Bilkent University, Bilkent 06800, Ankara, Turkey

ARTICLE INFO

Article history:
Received 23 February 2008
Received in revised form 5 June 2008
Accepted 27 September 2008
Available online 1 November 2008

Keywords:
Discrete-event simulation
Military deployment
Event graphs
Java
Geographical information system

ABSTRACT

This paper introduces a logistics and transportation simulation that can be used to provide insights into potential outcomes of proposed military deployment plans. More specifically, we model a large-scale real-world military deployment planning problem (DPP) that involves planning the movement of military units from their home bases to their final destinations using different transportation assets on a multi-modal transportation network. We apply, for the first time, the event graph methodology and listener event graph object framework to create a simulation model of the DPP. We use and extend Simkit, an open-source Java Application Programming Interface for creating discrete-event simulation (DES) models. We use a medium-resolution modeling approach, as opposed to either high-resolution or low-resolution modeling paradigms, to reduce lengths of simulation runs without compromising reality. To accurately incorporate real and detailed transportation network data into the simulation, we use GeoKIT, a licensed, state-of-the-art, Java-based geographical information system. While our DES model is not a panacea for all, it allows for testing the feasibility and sensitivity of deployment plans under stochastic conditions prior to committing members of the military into harm's way. The purpose of the paper is to acquaint the readers with the details of the DPP, the simulation model created, and the results of the analysis of a typical real-world case study.

1. Introduction

Regional and asymmetric threats and the increase in worldwide terrorist activity have made logistics and mobility increasingly important in our rapidly changing world. This paper focuses on logistics and transportation simulations or computer-based planning tools that are used to provide insight into the potential outcomes of proposed logistical courses of actions prior to and after committing members of the military into harm's way. Specifically, we deal with the Deployment Planning Problem (DPP), defined and thoroughly described first by Akgün and Tansel [1]. DPP involves positioning of many military units to carry out a mission. During peace-time, military units move from their home bases to their designated destinations using different transportation assets. This movement usually takes place on a multi-modal (land, rail, sea, air, and inland waterways) transportation network. During a crisis, where time is of essence, it has become critical to move soldiers and equipment with limited resources and on a short notice. The movement of the units must conform to a preplanned timetable called time-phased force deployment data (TPFDD). The TPFDD describes, among other things, the initial departure times of military units from their home bases, and their earliest and latest arrival times at their designated destinations. When many units need to deploy, the TPFDD is intended to coordinate their movement in order to efficiently use the existing transportation assets and network. It is also meant to prevent congestion at destinations and transfer points, where mode changes are necessary. Yet, creating TPFDD requires joint work of well-trained logistical and operational planners, and is

* Corresponding author. Tel.: +90 312 4112773; fax: +90 312 2664054.
E-mail addresses: uziya@bilkent.edu.tr (U.Z. Yıldırım), barbaros@bilkent.edu.tr (B.Ç. Tansel), sabun@bilkent.edu.tr (İ. Sabuncuoğlu).

1569-190X/$ - see front matter © 2008 Elsevier B.V. All rights reserved.
doi:10.1016/j.simpat.2008.09.016

very time consuming. Military deployment planners need a fast and accurate tool that takes into account the stochastic nature of events to analyze a military deployment plan.

A deployment plan may not always go as initially planned. Unexpected breakdown of transportation assets, road traffic accidents, and congestion at transfer points are some of the things that may disrupt a plan. A deployment involves simultaneous movement and utilization of many entities, resources and transportation assets. Thus, a stochastic model is more suitable for this truly hard and real-world problem that deals with expensive military hardware and irreplaceable human life.

In addition, existing models and simulations are of varying resolutions. Most of the time, higher-resolution models provide input to the lower-resolution models. This makes it necessary to run several models in succession for analysis. But such a set-up takes a long time. Almost all of the deployment models require a specific hardware system to run on. Yet, military usually employs different hardware systems, and thus it would be useful to have models or simulations which can run on multiple platforms. A detailed and accurate representation of the transportation network and infrastructure is necessary for realistic analysis. Thus, there is a need for a geographical information system to be used with deployment models or simulations. Currently existing models or simulations either do not have this capability or have a limited representation of geographical information. Furthermore, not all transportation modes are modeled in all deployment models or simulations, which makes it necessary to run at least two models in succession for a large deployment scenario. This again increases set-up and run times. Thus, it is desirable to have a multi-modal simulation model.

For these reasons, we have decided to develop a multi-modal, platform-independent, discrete-event simulation model of military deployment with accurate transportation network and infrastructure data and a medium-resolution allowing planners to develop and analyze plans in a relatively short time.

2. Background

There exist deployment planning models and simulations with varying levels of detail and purpose. For a more comprehensive survey of military planning systems and a review of strategic mobility models supporting the defense transportation system, the interested reader is referred to Boukhtouta et al. [2] and McKinzie and Barnes [3]. It is possible to classify military deployment models and simulations into two groups depending on their level of resolution and the purpose of use. First group includes relatively low-resolution models and simulations that may be used to model deployment of military units between theaters of operation (e.g., from Turkey to Afghanistan) or inside a theater of operation (e.g., inside Turkey). Deployments between different theaters of operation using only air and sea transportation assets are referred to as *strategic deployment*. The most frequently used modeling tools (software) for modeling strategic deployments are NATO's *ADAMS* (*Allied Deployment and Movement System*) and U.S. Military's *JFAST* (*The Joint Flow and Analysis System for Transportation*). A technical guide for ADAMS is provided by Heal and Garnett [4] and general information for JFAST is available at http://www.jfast.org. An example of simulations modeling deployment inside a theater of operation is *ELIST* (*The Enhanced Logistics Intra-Theater Support Tool*) [5]. The second group includes higher-resolution models and simulations that may also be used to provide input to the models in the first group. Examples of these models and simulations are *TLoaDS* (*The Tactical Logistics Distribution System*) [6] and *PORTSIM* (*The Port Simulation*) [7]. Other important examples of such models are TRANSCAP [8], SIMULOGS [9], and Simulation

Table 1
Mobility planning, logistics and transportation models and simulations commonly used by military planners.

Simulations/models	Multi-modal (yes/no)	Air (A), rail (R), sea (S), land (L)	Platform independence (yes/no)	GIS-support	Discrete-event simulation (yes/no)	Comments
ADAMS [4]	Yes	A, S	No	Limited	No	A NATO model for strategic deployment
JFAST	Yes	A, S	Yes	Limited	No	A classified, joint US model for strategic deployment
ELIST [5]	Yes	A, R, S, L	Yes	Limited	Yes	For intra-theater support planning
TLoaDS [6]	Yes	A, R, S, L	No	Limited	Yes	Built using EXTEND™ and SDI Industry Pro
PORTSIM [7]	Yes	R, S, L	No	Limited	No	Simulates seaport operations and determines throughput at the port
TRANSCAP [8]	Yes	L, R	Partially	No	Yes	Models deployment from US Army installations
SIMULOGS [9]	No	L	Partially	Limited	Yes	Runs on Sun Unix Workstation and PCs with Windows NT
Simulation of transportation logistics [10]	Yes	A, S	No	No	Yes	Based on ARENA, uses VBA and Excel
The simulation model proposed in this paper	Yes	A, R, S, L	Yes	Yes	Yes	Written in Java and uses GeoKIT for GIS-support