Simulation Modelling Practice and Theory 21 (2012) 78–90

Contents lists available at SciVerse ScienceDirect

Simulation Modelling Practice and Theory

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

# A simulation framework for real-time fleet management in internal transport systems

Amel Jaoua *, Diane Riopel, Michel Gamache

*Group for Research in Decision Analysis (GERAD), Department of Mathematical and Industrial Engineering, Polytechnic School of Montreal, Québec, Canada*

ARTICLE INFO

*Article history:*
Received 19 June 2009
Received in revised form 19 October 2011
Accepted 25 October 2011
Available online 22 November 2011

*Keywords:*
Container terminal
Surface mine
Congestion
Simulation model
Fleet management

ABSTRACT

This paper presents a simulation framework incorporating traffic simulator with classical discrete event simulation model of internal transport systems. The objective behind this integration is to provide a simulation model in which traffic is captured in the internal haulage networks. For this purpose, the highly detailed microscopic traffic modelling approach is adopted. The developed simulator can reproduce the punctual trucks movement's in the haulage network between pickup and delivery stations. Furthermore the complex traffic behaviour of platoon formation and congestion propagation is accurately emulated. This traffic behaviour is widely uncounted and criticized in the outdoor and internal transport system such as in container terminals and in surface mines applications. Experiments are conducted in two typical surface mines transportation systems. Results demonstrate that when the dispatching and routing problem is solved based on such detailed simulation model; the real-time truck fleet management is enhanced and the inherent traffic in the internal transport system is controlled.



## 1. Introduction

The present work focuses on fleet management problems encountered in internal transportation systems. The main goal of fleet management is to maximize transporter (trucks, vehicle, etc.) efficiency by moving loads through the internal (i.e. within physical boundary) and shared haulage network as quickly as possible. This transportation between pickup and delivery stations is conducted under operational constraints. More precisely, this work addresses transportation activities taking place in the unpredictable, non-stationary, outdoor environment. Several applications in transportation belong to this class, including transportation of containers in transhipment terminals, transport of broken rock in surface mines or quarries, etc.

Over the last decades many works have addressed the problematic of fleet management in such transportation systems. At the beginning, algorithms were proposed to deal with fleet dispatching under deterministic conditions i.e. constant travel time, no upset occurrence, etc. More recently a special emphasis is made to find better dynamic solutions to real-time fleet dispatching as well as to fleet routing under non-stationary system state. As stated in Van der Meer [1] this real-time fleet management can enhance the overall system performances as it takes into account the highly stochastic environment in which such internal transportations systems evolve. To reach this desired efficient real-time fleet management in internal transport systems, authors such as, Grunow et al. [2], Vis [3], Murty et al. [4], Burt and Caccetta [5] and Krzyzanowska [6], pointed out the importance of tracking the inherent traffic behaviour in the internal and often congested haulage networks. They explain that the used analytical or the simulation models have to take into account the unpredictable and highly variable travel time induced by truck bunched together in platoons and congestion appearance in the shared closed network.

* Corresponding author.
*E-mail address:* amel.jaoua@polymtl.ca (A. Jaoua).

1569-190X/$ - see front matter © 2011 Elsevier B.V. All rights reserved.
doi:10.1016/j.simpat.2011.10.003

In this context, the purpose of this work is to provide a simulation framework incorporating traffic simulator with classical discrete event simulation model of internal transport systems. For this purpose, the microscopic traffic modelling paradigm is integrated with the classical object-oriented model formerly used to address the pickup and delivery problems arise in internal transport systems. The idea behind using a highly detailed microscopic approach to model the transportation comes from its successful use in the traffic engineering field, Barcelo et al. [7]. The herein provided model can capture the travel delays as well as congestion and platoon formation because the adopted microscopic approach uses equations designed to mimic punctual trucks movement and interactions through the haulage network. In this work, the conceptual model specification phase is conducted based on the Unified Modelling Language (UML) methodology. Its purpose is to show modifications needed on the classical models. In the classical models, trucks travelling in the haulage network between pickup/delivery stations used to be modelled as an activity processing with a specified time. This time is computed off-line and is based on stationary assumption. This classical modelling approach may be sufficient at an earlier design stage of the transportation system, but it is inadequate for real-time fleet management as it fails to reproduce the inherent complex behaviour of traffic flows.

An implementation of the proposed conceptual model is also carried out with SIMAN/ARENA® simulation language, which is widely used in industrial applications. The purpose of this phase is to elucidate simulation model coding issues allowing capturing the longitudinal truck interaction along the haulage road segments. This longitudinal interaction is important as it is the source of platoons' formation and the resulting congestion propagation in internal transport systems. Generally speaking, in internal transport system such as is surface mine haul road network as well as in the road network inside a container terminal, the movement of trucks is similar to vehicles in a one-lane scenario without overtaking. Thus, the travel time delay is dominated by this longitudinal interaction which induces platoons' formation and congestion.

Finally a proof of efficiency of the proposed framework is carried out through the use of the developed simulation model to solve the truck dispatching and routing problem in surface mine. For this purpose the simulation model is embedded as the kernel of a simulation-based control architecture. The role of this control architecture is to insure the real-time truck fleet management in the internal transport system. In literature many simulation-based control architecture were proposed [8]. The herein used architecture is inspired form the model-based predictive control and is developed by our research team [9]. Experiments are conducted on two realistic surface mines to assess the benefit of embedding the proposed highly detailed simulation model. In the first study, a common problem of route blockage in the traffic network is emulated. In the second experiment, the problem of heavy traffic congestion is considered.

This paper is organized as follows. Section 2 reviews some previous applications which have considered the issue of traffic and discusses the traffic modelling approach used. Without a loss of generalization for internal transport applications, this review is restricted to the transport of containers at transhipment terminals and material transportation in surface mines. Section 3 deals with the specification phase of the conceptual model we propose. Section 4, details some important implementation issues of the simulation model. Section 5 includes experiments and discusses results. Finally, Section 6 summarizes the findings and the main conclusions.

## 2. Literature review

Modelling traffic has been addressed since the 1950s mostly by the civil engineering community in highway and urban transportation. However as stated in Vis [3], Murty et al. [4], Burt and Caccetta [5] few researches have considered the traffic behaviour when studying fleet management problems encountered in internal transport systems. Basically fleet management in this class of internal systems is addressed by the operational research community and is solved as the common problem of Automated Guided Vehicle (AGV) dispatching in flexible manufacturing systems. But unlike the indoor nearly deterministic manufacturing environment, outdoor internal transportation activity is confronted to more complex stochastic non-stationary environment. This work considers this class of outdoor of internal transport system. Specifically the literature reviews address the two typical applications of container terminals and surface mines.

For container terminal operations this review concerns the papers dealing with container handling and storage operations in stack yards. Generally speaking, vessels bring inbound containers to be picked up by internal trucks and distributed to the respective stocks in the yard. Once discharged, vessels have to leave with on board outbound containers which also are delivered by internal trucks from the storage yard. For this purpose, trucks are moving through a terminal internal road network. Grunow et al. [2] explain that this path network is of much larger size and height complex structure than the simple and well structured one in a manufacturing system. In order to decrease the vessel turnaround time, which is the most important performance measure of container terminals, it is important to perform those pickup and delivery operations as quickly as possible. However, Murty et al. [4] state that this network is very often congested due to the large number of trucks operating simultaneously. This traffic congestion significantly increases the ship turnaround time. In order to solve pickup and delivery problem encountered in this context many dispatching algorithms were proposed. Vis and de Koster [10] give an extended review of those algorithms. However they criticize some simplistic assumptions behind them. They state that the highly stochastic and unpredictable container terminals environment must be taken into account in order to provide more efficient dispatching decisions. As an example of such assumptions in Bielli et al. [11], a travel time of a container internal truck is modelled as a static mean time of travel, based on the distance and the truck average speed. In Duinkerken et al. [12], authors put a uniform distribution between zero and 30% of the nominal travel time formulation, aiming to assimilate the complexity