



Conditional value-at-risk (CVaR) methodology to optimal train configuration and routing of rail hazmat shipments

S. Davod Hosseini, Manish Verma*

DeGroote School of Business, McMaster University, Canada



ARTICLE INFO

Article history:

Received 19 April 2017

Revised 7 February 2018

Accepted 8 February 2018

Keywords:

Hazardous materials

Risk assessment

Railroad transportation

Conditional value-at-risk

Train configuration

Risk-averse routing

ABSTRACT

Hazardous materials (hazmat) incidents are rare though the consequences could be catastrophic. The low probability–high consequence nature of such events mandate that a risk-averse plan be implemented for routing hazmat shipments. We propose a conditional value-at-risk (CVaR) methodology for routing rail hazmat shipments, using the best train configuration, over a given railroad network using the pre-defined train services such that the transport risk as measured by CVaR is minimized. Freight train derailment records were analyzed to model the behavior of railroad accidents, and to estimate conditional probabilities. The proposed methodology was used to study several problem instances generated using the realistic network of a railroad operator, and to demonstrate that the proposed methodology is superior to other measures for risk-averse routing of hazmat shipments and versatile enough to yield routes based on risk preferences of the decision makers.

© 2018 Elsevier Ltd. All rights reserved.

1. Introduction

Hazardous materials (hazmat), such as crude oil and gasoline, are harmful to humans and the environment because of their toxic ingredients, but their transportation is integral to sustain our industrial lifestyle. In North America, a significant portion of the hazmat shipments are moved via the railroad network. For example, based on the latest commodity flow survey for 2012, railroad carried around 111 million tons of hazmat in the United States (U.S. Department of Transportation, 2015), whereas the number for Canada was 26 million tons (Searag et al., 2015). The quantity of hazmat traffic on railroad networks has been increasing steadily since 2009, in large part due to the need to move crude oil shipments from the Bakken shale formation region in the United States and Canada to the refineries along the southern and eastern coast of the continent, and the increased utilization of intermodal transportation to move chemicals (AAR, 2014; CAPP, 2014).

There are two groups of decision makers in hazmat transportation viz., hazmat carriers and regulatory agencies. The first group considers each hazmat shipment independently, and thus their objective is to seek the least risky path through the network in question between a given origin and destination. Erkut et al. (2007) and Bianco et al. (2013) review the pertinent papers for highway hazmat shipments. The second group, on the other hand, considers shipments between multiple origins and destinations, and thus strives to regulate hazmat risk for the entire network. To that end, several policies can be employed by the authorities such as restricting hazmat carriers from using certain road segments (Bianco et al., 2009; Dadkar et al., 2010; Erkut and Alp, 2007; Erkut and Gzara, 2008; Kara and Verter, 2004) and/or diverting hazmat carriers to

* Corresponding author.

E-mail addresses: hosses8@mcmaster.ca (S.D. Hosseini), mverma@mcmaster.ca (M. Verma).

less risky areas by assigning tolls to road segments (Bianco et al., 2016; Esfandeh et al., 2016; Marcotte et al., 2009; Wang et al., 2012).

Although railroad is one of the safest modes for transporting hazmat, in part because of a host of industry initiatives, the possibility of spectacular events resulting from multi-railcar incidents, however small, does exist (Verma and Verter, 2013; Vaezi and Verma, 2017). For example, the tragic event in Lac-Mégantic (Quebec), in July 2013, is a reminder of the possible catastrophe associated with railroad shipments. Though the last decade has witnessed the development of risk assessment methodologies that incorporate specific nature of railroad shipments, unfortunately, given the *low probability–high consequence* nature of rail hazmat incidents, their worth is rather limited. For instance, risk is most commonly defined as the product of the probability and the consequence of an undesirable event (also called *traditional risk*). This expected consequence approach, originally developed to evaluate risk from highway shipments and from fixed facilities, has been appropriately adapted to study rail hazmat shipments in Bubbico et al. (2004a, 2004b), Verma (2011), Bagheri et al. (2014), and Cheng et al. (2017). However, this traditional risk approach is risk-neutral, and thus not suitable for making risk-averse routing decisions.

The risk-neutral behaviour of the traditional risk (TR) model and consequent failure to capture the public posture against hazmat transportation motivated the development of the perceived risk (PR) model for highway shipments, where risk-aversion was modeled using a perception factor (Abkowitz et al., 1992). However, the difficulties associated with both comprehending and quantifying the value of perception factor inspired Erkut and Ingolfsson (2000) to analyze three catastrophic avoidance models for highway shipments –i.e., maximum risk (MM); mean-variance (MV); and, disutility (DU). More recently, there have been efforts to generate dissimilar routes based on the risk preferences of the decision maker. To that end, Kang et al. (2014a, 2014b) proposed a value-at-risk (VaR) model for highway shipments, while Hosseini and Verma (2017) proposed a VaR-based assessment framework for routing rail hazmat shipments. Within hazmat transportation setting, VaR has a simple interpretation, viz., how many people are exposed to hazmat risk given a certain confidence level? Despite the interpretational ease, VaR has not found widespread acceptance because it is not a coherent measure of risk (Artzner et al., 1999; Dowd and Blake, 2006), and might lead to inaccurate perception of risk (Einhorn, 2008; Nocera, 2009) because it ignores the tail of the distribution, i.e., overlooks catastrophic events. The indicated shortcomings of VaR motivated the development of a more sophisticated measure, i.e. conditional value-at-risk (CVaR) which is capable of quantifying population exposure that may be encountered in the unfavorable tail of the distribution to avoid extreme events. Toumazis et al. (2013) were the first to adapt the CVaR notion to simultaneously generate flexible and risk averse route for highway hazmat shipments, and the notion was further developed in Toumazis and Kwon (2013), Faghih-Roohi et al. (2015), and Toumazis and Kwon (2016).

It is important that, given the possibility of hazmat release from multiple railcars, consequences are much more catastrophic within a railroad setting than for highway shipments. Hence, the proposed work makes a first attempt to develop a CVaR-based risk assessment methodology for rail hazmat shipments that incorporates the characteristics of railroad accidents, and then utilizes it to prepare rail hazmat routing plans for different confidence levels wherein risk-averse phenomenon is sustained. It is important that the proposed methodology incorporates physical infrastructure of railroad transportation system that entails using a limited number of pre-defined train services to move shipments that may involve transfer operations at intermediate yards, and determining the optimal train configuration. Thus, the proposed methodology is more complex than routing a single hazmat truck between a given origin-destination pair in an unconstrained highway network. In addition, we have also attempted to provide a succinct and clear definition of CVaR for hazmat shipments, which we felt was not done satisfactorily in the published peer-reviewed works. Finally, we use the proposed CVaR methodology to study and analyze several problem instances generated using the realistic infrastructure of a railroad operator, and to gain insights. Through numerical experiments we demonstrate that the proposed methodology is superior to other measures for risk-averse routing of hazmat shipments and versatile enough to yield routes based on risk preferences of the decision makers.

The rest of the paper is organized as follows. Section 2 contains an outline of the railroad transportation system and a brief discussion of the value-at-risk model, and a detailed discussion about the proposed conditional value-at-risk methodology. Section 3 contains the discussion about the railroad network and the parameters used to generate problem instances, which are then solved and analyzed to gain insights. Finally, conclusions and directions of future research are presented in Section 4.

2. Proposed CVaR methodology

In an effort to facilitate the discussion of the proposed CVaR methodology in Section 2.3, we introduce the two building blocks in the following subsections. Appropriate sets and notations pertinent to railroad transportation system are introduced in Section 2.1, followed by an outline of the concept of value-at-risk in Section 2.2.

2.1. Railroad transportation system

A rail transportation system can be represented via a network, whose nodes represent yards (or stations) and arcs represent tracks (or service legs) on which trains carry freight (or passengers). A sequence of service legs and intermediate yards constitute a route available to railcars for their journey (Verma et al., 2011), which is completed using the finite number

Download English Version:

<https://daneshyari.com/en/article/7539094>

Download Persian Version:

<https://daneshyari.com/article/7539094>

[Daneshyari.com](https://daneshyari.com)