Transportation Research Part B 93 (2016) 631–647

Contents lists available at ScienceDirect

Transportation Research Part B

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

A comparison of three idling options in long-haul truck scheduling

Çağrı Koç[a,*], Tolga Bektaş[b], Ola Jabali[c], Gilbert Laporte[a]

[a] CIRRELT, Canada Research Chair in Distribution Management and HEC Montréal, Montréal, Canada
[b] Southampton Business School and CORMSIS, University of Southampton, Southampton, United Kingdom
[c] CIRRELT and HEC Montréal, Montréal, Canada

ARTICLE INFO

Article history:
Available online 16 September 2016

Keywords:
Truck driver scheduling problem
Idling
Long-haul transportation
Fuel consumption
CO_2 emissions
Hours of service regulations

ABSTRACT

This paper studies the Truck Driver Scheduling Problem with Idling Options (TDSP-IO), an extension of the long-haul truck driver scheduling problem with a more comprehensive objective function that accounts for driving cost, fuel cost, and idling cost. The best-known idling option is the widespread practice of keeping the vehicle engine running while the vehicle is not moving, which primarily stems from the drivers'desire to keep their vehicle at an adequate comfort level during breaks. Here, we explore two additional cleaner idling options: resting at an Electrified Parking Space (EPS) or using an Auxiliary Power Unit (APU) while idling. We also account for the initial investments associated with the equipment required for the use of these technologies. We formulate a mathematical model for the TDSP-IO under these three idling options, and we perform extensive computational experiments on realistic benchmark instances. The paper sheds light on the trade-offs between various performance indicators and offers several managerial and policy insights. Our analyses quantify the advantages of using EPSs and APUs, and show that they yield both economical and environmental benefits.

1. Introduction

In long-haul transportation, where travel distances can be considerable, drivers often have to be on the road for several consecutive days. As a natural consequence, truck driver fatigue ensues and emerges as a significant cause of serious accidents (McCartt et al., 2008). The United States (US) Hours of Service (HOS) regulations restrict the duration of driving and impose rest periods on commercial vehicles making long-haul trips (FMCSA, 2014). Similar rules exist in the European Union (EU), Canada and Australia (Goel and Vidal, 2014).

During rest periods at truck stops or while loading and unloading at customer locations, drivers tend to keep the engine of their vehicle running in order to maintain their comfort level, resulting from the use of air conditioners, heaters, televisions, refrigerators and lights (Argonne National Laboratory, 2015; Brodrick et al., 2002b). This practice is called *engine idling*. In the US, an idling heavy-duty vehicle consumes an average of three liters (≈ 0.8 US gallon) of fuel per hour, and a truck idles an average of 1800 hours per year (Argonne National Laboratory, 2015). Long-haul trucks idle between six and 16 hours per day (Grupp et al., 2004; Rahman et al., 2013). Engine idling is a major problem in long-haul transportation since it increases fuel consumption as well as emissions of NOx, PM, CO_2, CO, and hydrocarbons.

* Corresponding author.
E-mail addresses: Cagri.Koc@cirrelt.ca (Ç. Koç), T.Bektas@soton.ac.uk (T. Bektaş), Ola.Jabali@hec.ca (O. Jabali), Gilbert.Laporte@cirrelt.ca (G. Laporte).

http://dx.doi.org/10.1016/j.trb.2016.08.006
0191-2615/

On average, if an engine idles for more than 10 seconds, it consumes more fuel than does a restart (Brodrick et al., 2002a). An idling engine cannot function at an efficient operating temperature and results in incomplete fuel combustion, which leaves fuel residues in the exhaust (Rahman et al., 2013). Furthermore, engine idling accelerates wear and tear, and decreases the time interval between oil changes which not only increases fuel consumption, but also maintenance and repair costs. Over a year, engine idling is equivalent to 322,000 extra km (≈ 200,000 miles) of engine wear and adds operational costs of between $4,000 and $7,000 per truck (Rahman et al., 2013). The impact of engine idling on CO_2 emissions is also well documented (Brodrick et al., 2002a; Frey and Kuo, 2009; Khan et al., 2009). Some jurisdictions impose strict engine idling limits through fines. For example, in the states of California and New York, engine idling is limited to five minutes and the fines for violations range from $300 to $10,000, and from $375 to $22,500, respectively (ATRI, 2015). For further information on engine idling, the reader is referred to the report produced by the Argonne National Laboratory (2016).

We consider two alternative idling options that can save money and reduce pollution: Electrified Parking Spaces (EPSs) and Auxiliary Power Units (APUs). An EPS enables the vehicle to be plugged into an electric power outlet and thus vehicles will not consume fuel while idling. An APU, which is fueled by diesel, provides sufficient power for functions required during idling but consumes significantly less fuel than engine idling.

The HOS regulations, engine idling and truck driver scheduling all bear on emissions in long-haul transportation. While the routing and scheduling aspects of long-haul trucking have already been extensively studied (e.g., Kok et al., 2010; Rancourt et al., 2013; Goel and Vidal, 2014), the interplay between vehicle scheduling and idling options, and the influence of these options on costs and emissions have not yet been investigated. Our purpose is to analyze these two interrelated components. Before we proceed with our study, we briefly review the relevant literature on long-haul truck scheduling.

1.1. Literature review on the truck driver scheduling problem

Several studies have focused on the Truck Driver Scheduling Problem (TDSP) under the HOS regulations. Archetti and Savelsbergh (2009) studied the problem of sequencing full truckload requests, each with a dispatch window at the origin. These authors proposed an algorithm that produces a feasible schedule in polynomial time if one exists. Goel (2012b) later developed a mixed integer linear programming formulation and a dynamic programming algorithm for a variant of the TDSP in which customers have multiple time windows, with the aim of minimizing total duration under the US and EU regulations. A similar problem was studied by Goel and Kok (2012) in which each customer location must be visited within one of several time windows. Provided the gaps between windows are at least 10 hours, the complexity of their proposed algorithm is similar to that of the single window case. Goel and Rousseau (2012) developed two heuristics and an exact algorithm for the TDSP under Canadian regulations, while Goel (2012a) proposed a mixed integer linear programming formulation and an iterative dynamic programming algorithm for the minimum route duration problem. Goel (2012c) presented a mixed integer programming formulation and valid inequalities for the problem arising from the Australian regulations, and Goel et al. (2012) later developed four heuristics and an exact method with dominance criteria for the same problem.

In addition, several researchers have also studied the combined vehicle routing and TDSP, which simultaneously determines routing and scheduling decisions under the HOS regulations. The first such study is due to Xu et al. (2003). Ceselli et al. (2009) later solved a rich problem containing some operational difficulties arising in real-world applications. Goel (2009) focused on several EU regulations, and Kok et al. (2010) integrated a basic break scheduling method within a dynamic programming framework under the EU regulations. Prescott-Gagnon et al. (2010) developed a large neighborhood search algorithm based on a column generation heuristic under the EU regulations, while Kok et al. (2011) proposed a sequential insertion heuristic for the vehicle routing and time-dependent travel times in the same context. Rancourt et al. (2013) later solved a long-haul truck routing and scheduling problem under the US regulations with a heterogeneous fleet of vehicles, by embedding several scheduling algorithms within a tabu search heuristic. Finally, Goel and Vidal (2014) developed a unified genetic algorithm for the EU, US, Canadian and Australian HOS regulations.

1.2. Scientific contributions and structure of the paper

Fuel consumption and CO_2 emissions have been extensively studied by researchers within the context of vehicle routing (see Bektaş and Laporte, 2011; Franceschetti et al., 2013; Koç et al., 2014; 2016). These studies focused on the routing aspect of the problem and on the use of speed optimization as a means of reducing CO_2 emissions. Here we assume that vehicle routes have already been designed and are given as inputs. We concentrate instead on the combined scheduling and idling components of the problem. In particular, we investigate how to optimally combine scheduling decisions with the choice of idling options in order to minimize operational and emissions costs. We note that in the TDSP papers surveyed, the trucks can idle at rest areas or at customer locations, and sometimes anywhere along their route. Here we take a more restrictive yet natural approach by disallowing the latter possibility, since it is reasonable to assume that drivers will prefer rest areas given the amenities that they provide.

In this paper, we make two main scientific contributions. Our first contribution is to introduce and model the Truck Driver Scheduling Problem with Idling Options (TDSP-IO) as a variant of the TDSP using a comprehensive mixed integer linear programming model that jointly determines the schedule of a fixed route and the idling options when the vehicle is not moving. The objective function minimizes the cost of fuel consumption emissions along with the costs of drivers and idling options. It can easily be extended to incorporate the cost of CO_2 emissions, which we actually do in some analyses.