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Reducing intercity bus crashes through driver rescheduling

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ABSTRACT

Intercity bus crashes often involve driver fatigue, which itself is usually the result of sleep deprivation, long driving hours, a maladjusted circadian rhythm, or some combination of the above. And driver scheduling has long been suspected as the root cause affecting sleepiness and fatigue. As such, a fundamental question for intercity bus carriers is how to reduce crashes associated with driver schedules, while maintaining a nonstop service? This research seeks to develop a paradigm to minimize overall fleet crash risk by rescheduling. In this study, we first identified those driving schedules associated with the highest crash risks, and a rescheduling scheme is then proposed to reduce fleet crashes overall. A case-study approach was employed to identify driver scheduling associated with higher crash risk, and a mathematical program was then formulated to minimize fleet crash risk. Our results showed that several types of driver schedules would lead to higher crash risk; for example: (1) working in the afternoon or early hours in the morning for two consecutive days; and (2) commencing a driving shift in the mornings, the afternoon or the early hours of the morning after being off-duty for more than 24 h. To meet the challenge of maintaining a nonstop service while simultaneously minimizing the crash risk associated with these risk patterns, a mathematical program was developed, and it was found that rescheduling based on our algorithm could reduce the incidence of crashes by approximately 30 percent.

1. Introduction

Driver fatigue and sleepiness have been found to be closely correlated with crash risk; indeed, they are often cited as the major crash contributing factor for intercity bus drivers who are often required to drive long hours and do night-shift driving. More and more research has demonstrated that a driver's shift schedule (referred to as working pattern in the rest of this study) is associated with driver fatigue, and hence crash risk (e.g.Jovanis et al., 2012). The reasons why driver working pattern is associated with driver fatigue and sleepiness include sleep deprivation, long driving hours, and circadian rhythm (Pack et al., 1995; Feyer and Williamson, 1995; Williamson et al., 1996; Williamson et al., 2011). Hence, a well-designed driver schedule was found to be beneficial in lowering crash risk (e.g. Shinar, 2007; Crum et al., 2001; Crum and Morrow, 2002). A well-designed schedule will obviate the need for overlong working or irregular working patterns, and reduce the likelihood of driver fatigue and sleepiness.

Nevertheless, despite the obvious benefits, there have been limited studies into how to manage intercity bus drivers' crash risk through proper scheduling. Clearly, the greatest constraint on intercity bus carriers is their need to maintain a nonstop service 24 h a day, seven days a week. In other words, although there may be some time slots associated with a higher crash risk (e.g. 2 AM to 4 AM) the bus carriers have no choice but to assign drivers to run a service at these times in order to operate a 24/7 timetable. Moreover, as crash risk is determined not only by the driving environment but also by the time of day (or night), it is challenging to quantify crash risk for different working patterns.

1.1. Driver scheduling patterns and crash risk

Past research suggested that fatigue would lower drivers' overall level of attention, or disrupt matching of effort to task demand, and hence result in slower information processing and higher crash risk (e.g. Kahneman, 1973; Desmond and Matthews, 1997). Many factors related to driver scheduling have been argued to be associated with driver fatigue, including sleep deprivation, time-on-task/distance driven, and circadian rhythm (Shinar, 2007). The effects of sleep deprivation and time-on-task/distance driven on fatigue and fatigue-related crashes are straightforward and have been well-established to some extent (e.g. Rogé et al., 2003; Hulst et al., 2001). Studies on circadian rhythm indicate that most people experience a slight drop in their wakefulness from approximately 2 to 4PM and a significant drop from approximately 2 to 6 AM. In fact many drivers report they are more likely to

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experience fatigue during these hours than during other hours (Feyer and Williamson, 1995).Wylie et al., (1996), who used alertness tests and instrumented truck measures rather than crashes, found a strong correlation between fatigue and time of day, and little correlation between fatigue and driving hours. Williamson et al. (2011) found that the speeds of driver reaction time, divided attention, short-term memory, and vigilance vary according to the drivers' circadian rhythm. Pack et al. (1995) reported that for all age groups, peak crash involvement is in the two time periods of the circadian rhythm. In particular, older drivers have more difficulty in altering the cycle, and they are more prone to have single-vehicle crashes in early afternoons. In summary, circadian rhythm is likely to play an important role affecting driver fatigue and crash risk.

Although much research has associated increased crash odds (or relative risk) with total hours spent driving, particularly when exceeding five to six hours of driving (e.g. Jovanis et al., 2012; Soccolich et al., 2013; Sparrowa et al., 2016), some studies have highlighted driver scheduling patterns and multi-day driving patterns as also correlated with higher crash risk (e.g. Kaneko and Jovanis, 1992; Jovanis et al., 2012). Kaneko and Jovanis (1992) and Jovanis et al. (2012) used data logs from less-than-truckload carrier operations to estimate the probability of a crash after a certain amount of time spent driving. Driver logs for 7 days before each crash were used and compared with a random sample (two drivers) of drivers who did not crash and were selected from the same company, terminal, and month. Certain multi-day driving patterns were reported to have a higher crash risk, especially for those returning from extended periods off duty (Jovanis et al., 2012). Not surprisingly, research also showed that breaks from a particular driving task, defined as a period within a driving trip when the driver was off duty or took a nap, are beneficial in lowering crash risk (Akerstedt and Gillberg, 1990; Bonnefond et al., 2004; Jovanis et al., 2012; Soccolich et al., 2013; Chen and Xie, 2014; Torregroza-Vargas et al., 2014; Sparrowa et al., 2016). Taken as a whole, ad hoc driver scheduling patterns, referred to as driving patterns in the rest of this study, are likely to be associated with the onset of fatigue while driving, and hence of a higher crash risk.

1.2. Bus driver scheduling and traffic safety management

Current practice regarding bus driver scheduling and safety management focuses mostly on meeting hour-of-service regulations, national and local labor union rules, the balance of work load among drivers, number of days off work, and operational costs (Torrance et al., 2009), but little thought is given to the impact of multi-day driving patterns on overall crash risk. To meet these requirements while minimizing associated operating costs, most research on driver scheduling was conducted in the operations research field (e.g. Wren and Rousseau, 1995; Banihashemi et al., 2000; de Matta and Peters, 2009; Torrance et al., 2009). Although driver and vehicle scheduling are related, vehicle and driver scheduling problems were dealt with separately in the past due to their complexity. With increased computing power, current research is now able to account for both of them at the same time (Fischetti and Matteo, 2001).

For bus driver scheduling, the objective is to minimize the total costs associated with drivers while considering contractual constraints. The total costs associated with drivers generally include a driver's salary, compensation package, and overhead costs (Torrance et al., 2009). The contractual constraints are specified by bus carriers, including, but not limited to, national and local labor rules; total time worked per day, total time worked per week/month, and/or number of days off per week/month, etc. (Wren and Rousseau, 1995; Yaoyuenyong and Nanthavani, 2005; Al-Yakoob and Sherali, 2007).

Although bus driver scheduling should be based on minimizing both operational costs and crash risks, most research focuses on minimizing operational costs under existing contractual constraints. However, from a traffic safety management perspective, minimizing crash risks should be considered part of the objective functions rather than part of the contractual constraints, as those constraints generally do not promise minimum crash risk (e.g. Jovanis et al., 2012). More research is needed to account for the effects of driver scheduling on crash risk.

1.3. Research objectives

This study seeks to first identify bus driver scheduling patterns that are associated with higher crash risk, and to use the information identified to minimize a fleet's overall crash risk through rescheduling. The idea of minimizing a fleet's overall crash risk by rescheduling is illustrated in Fig. 1. In Fig. 1, the number in each node indicates a given driver's working pattern for a given day. A working pattern may be composed of multiple shifts in a day. As an example, suppose an intercity bus driver only needs to drive one round trip per day. Driver A's working pattern on the first day is "Pattern 1" (say he leaves at 8 A M,

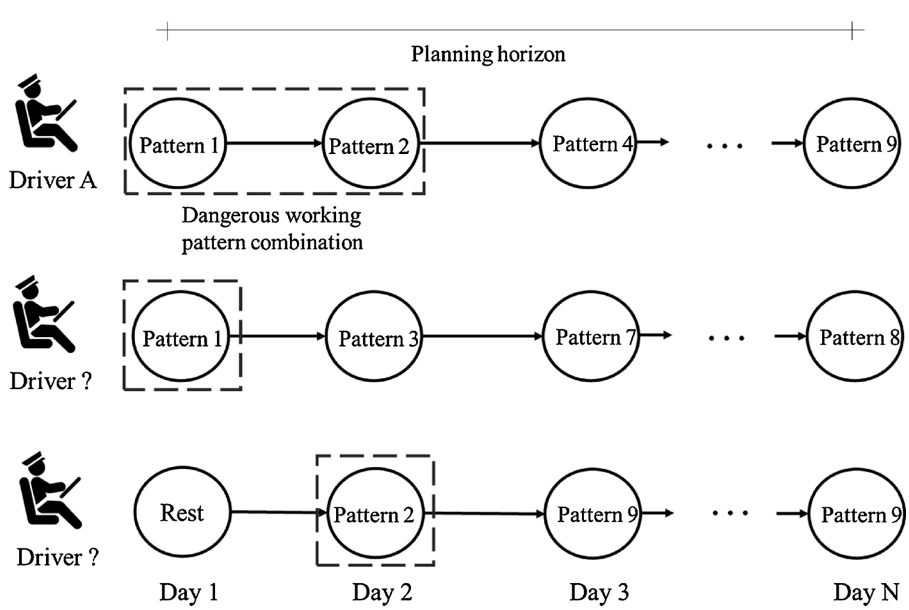

Fig. 1. Illustration of rescheduling.