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Time of day effects on railroad roadway worker injury risk

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ABSTRACT

Introduction: The purpose of this study is to examine how time of day affects injury risk of railroad maintenance of way employees and signalmen (roadway workers). Railroads reported 15,654 serious roadway worker injuries between 1997 and 2014. Roadway workers primarily work outdoors on or near railroad tracks and frequently encounter hazardous conditions. To avoid closing an active rail line during peak hours, railroads sometimes require roadway workers to work at night. Previous studies of roadway worker injury have not adequately accounted for exposure to time of day effects, nor have they investigated the human factors issues contributing to roadway worker injury. *Method:* The Federal Railroad Administration (FRA) database of injury reports provided data for circadian rhythm models of the odds of fatal and nonfatal injuries. The FRA database and fatal injury investigation reports also permitted an analysis of the circumstances and the human factors issues associated with injuries that occur at different times of day. *Results:* Odds of injury increased during nighttime work. The odds of nonfatal injury for both roadway worker crafts rose above 9:1 in the early morning hours. The relative odds of a fatal injury also increased significantly at night. A human factors analysis suggested that during all three shifts most nonfatal injuries involve workload, but workload was not identified as a factor in fatal injuries. *Conclusions:* Nighttime work is more hazardous for roadway workers than daytime work. Several factors related to fatigue and other conditions appear to increase the risk of injury during the outdoor, nighttime work required of roadway workers. *Practical application:* For practical reasons, nighttime roadway work is sometimes unavoidable. Therefore, new practices for nighttime work must be developed to adequately address fatigue and protect roadway workers from harm.

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1. Introduction

Risk of injury is associated with railroad work under a variety of circumstances. Maintenance of way (MOW) employees and signalmen are roadway workers who work outside on or near active tracks for substantial periods of time. MOW employees are responsible for building and maintaining railroad tracks and structures, while signalmen are responsible for building and maintaining signaling, switching, and communication equipment along the railroad. The most obvious hazard for roadway workers is being struck by a moving train. The primary forms of protection against moving trains for MOW employees and signalmen are posting a watchman to provide track warning; foul time, which keeps trains from operating in a work zone for a limited period of time; taking a track out of service; and individual train detection, which requires a lone worker to visually detect a train's approach and move to safety at least 15 s before the train's arrival at the worker's location. These protections are necessary because a freight train traveling at full speed has enough momentum that it may be impossible to stop the train in time to avoid an accident, even if the engineer sees a worker on the tracks.

While working on or alongside active train tracks may be the most salient hazard of railway work, it is not the only one. Railway work also often involves operating heavy machinery, working on surfaces with unstable footing, and working under adverse weather conditions. During a routine daytime shift, job tasks frequently involve exposure to these and other potential hazards; a seemingly minor error can lead to injury or death. Maintenance of way and signal maintenance can occur at all hours, and hazards that can be avoided during the daytime may be harder to see and avoid during nighttime work. Constant vigilance, adherence to safety protocols, and effective communication among work gang members are among the procedures and precautions that are necessary to prevent an accident. When serious accidents and incidents do occur, railroads must report them to the Federal Railroad Administration (FRA). Human factors are reportedly the most frequent cause of accidents among roadway workers. In an analysis of the FRA Accident/Incident Report Database, Guthy, Rosenhand, Bisch, and Nadler (2014) found that railroads attribute 48.1% and 54% of all casualties among MOW employees and signalmen, respectively, to human factors.[1]

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[1] The FRA Office of Safety makes available railroad safety data that railroads update monthly. See http://safetydata.fra.dot.gov/OfficeofSafety/default.aspx. Employee injury criteria that require reporting include medical treatment beyond first aid, one or more days away from work, or loss of consciousness. Attribution to human factors indicates that the railroad believes that the railroad employee may have been at least partly responsible for causing the accident/incident.

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Previous efforts to improve railway worker safety have focused on minimizing fatigue as a cause of error, because both signalmen and MOW employees respond to emergencies at night, and the late night is associated with a peak in operator error during the circadian low from approximately 02:00–05:59 (e.g., Gander et al., 2011; Horne & Reyner, 1995; Pruchnicki, Wu, & Belenky, 2011). The circadian time system, marked by a regular pattern of body temperature fluctuations that correlate with time of day, is frequently conjoined with the duration of time since waking, both of which contribute to fatigue effects on operator performance (Carrier & Monk, 2000). Gertler, DiFiori, and Raslear (2013) found that the amount of sleep, and the time of day when sleep occurs, account for 85% to 96% of fatigue exposure of train and engine workers, signalmen, maintenance of way workers, and dispatchers.

Hours of service regulations, intended to promote safety (Sussman & Coplen, 2000), apply to signalmen and require a specified number of hours off duty (Hours of Service of Railroad Employees, 2011). There is not an equivalent hours of service regulation for MOW employees. Hours of service regulations can constrain hazards associated with fatigue originating from continuous work duration (see Miller, 1976), but do not alleviate circadian effects (Gander et al., 2011) or prevent fatigue (Thomas, Raslear, & Kuehn, 1997). Beyond fatigue and circadian rhythms, nighttime work may be more dangerous for railway workers than daytime work because low light conditions reduce sight distances and make it harder to see environmental hazards (e.g., poor footing conditions). These considerations all predict an elevated risk of injury during nighttime work among MOW employees and signalmen.

The FRA Accident/Incident Report database documents the circumstances of each injury reported by railroads to the FRA. We analyzed this database to determine whether railroads report more injuries at night compared to the day than would be anticipated from the proportion of employees on duty at night and during the day (i.e., exposure to risk). This analysis consisted of the calculation of odds ratios as a measure of relative risk. We also determined whether daytime and nighttime injuries occur under the same circumstances.

2. Previous research

Research on occupational risk by time of day across a range of transportation domains and industries supports the hypothesis that nighttime work is more dangerous than daytime work. A review by Williamson and colleagues found a greater risk of accident at night in a variety of transportation modes, from automobile to aviation (2011). Horne and Reyner (1995) and Langlois, Smolensky, Hsi, and Weir (1985) found a higher risk of single-driver accidents for both cars and trucks during the night. Similarly, an elevated risk for nighttime work has been found in the manufacturing sector (Smith, Colligan, & Tasto, 1982; Smith, Folkard, & Poole, 1994). Workers on a night shift encounter the highest risk of accident around midnight, with an additional period of increased risk around 03:00 (Folkard, 1997; Folkard, Lombardi, & Spencer, 2006).

A higher rate of human error due to fatigue has been found in controlled experimental studies. Fatigue can reduce performance in a variety of ways that could result in injuries. It has been found to produce slower reaction times and lapses in a psychomotor vigilance task and an increase in lane drift during a simulated driving task (Baulk, Biggs, Reid, van den Heuvel, & Dawson, 2008). Fatigue has also been linked to reduced performance on divided attention tasks (Drummond & Brown, 2001). Sauer, Wastell, Hockey, and Earle (2003) found that nighttime performance in a complex process control task environment was associated with the deliberate use of corner cutting strategies focused on maintaining primary task performance at the expense of secondary task elements.

Although no studies have examined the effects of nighttime work on reaction time, vigilance, divided attention, and multi-tasking strategies of MOW employees and signalmen, research has investigated the prevalence and effects of fatigue in railroad employees. Fatigue, as assessed with the biomathematical Sleep, Activity, Fatigue and Task Effectiveness (SAFTE) model (Raslear, Hursh, & Van Dongen, 2011) predicts the probability of railroad accidents among on-call railroad engineers (Hursh, Raslear, Kaye, & Fanzone, 2008) and employees in other railroad crafts (Raslear, Gertler, & DiFiore, 2013). The SAFETE model provides input to the Fatigue Avoidance Scheduling Tool (FAST). Using this tool, Gertler et al. (2013) found that as a group, MOW employees and signalmen in the United States worked for nearly a thousand hours while very fatigued during the study year.

Some forms of protection for roadway workers who are working on or near active railroad tracks are entirely dependent upon vigilance. Fatigue could reduce the cognitive performance of MOW employees and signalmen increasing the likelihood of an accident resulting in a serious injury or fatality. Under circumstances where more than one worker is working on an active track, a watchman may be designated to warn other employees of an approaching train. Under circumstances where a roadway worker is working alone, the lone worker may be responsible for providing his or her own on-track safety. Reduced vigilance could cause either of these forms of protection to fail and increased reaction time would provide less time to move clear of the tracks after a train is detected. Impairment in divided attention could decrease the ability of a roadway worker to detect an approaching train, especially if attention is focused on the work at hand.

The primary objective of this study is to determine whether nighttime work is associated with higher odds or risk of serious injuries among MOW employees and signalmen than daytime work. We analyzed the distributions of injuries across times of day coupled with exposure rates to determine the effect of time of day on the odds of injury. We determined the times of day when MOW employees and signalmen experienced heightened odds of injury attributed to human factors.

The second objective is to analyze both fatal and nonfatal injuries. Investigations of roadway worker accidents that focus only on fatalities would limit the sample size that is available for analysis, which reduces the power of statistical tests and would create difficulty in generalizing from any temporal patterns that emerge. Accidents among MOW employees and signalmen that result in nonfatal injuries are several orders of magnitude more frequent than those that result in fatal injuries. By considering accidents resulting in both fatal and nonfatal injuries, we dramatically improve our ability to draw inferences from meaningful patterns.

The third objective of this study is to explore whether injuries among MOW employees and signalmen are associated with the same human factors causes, and whether they occur under the same circumstances at all times of day. Findings may suggest different approaches to improving safety for daytime and nighttime work.

3. Method

To compare daytime and nighttime accident risk, we examined all MOW employee and signalman injuries attributed to human factors that railroads reported to the FRA from January 2, 1997 to February 27, 2014. The year 1997 was selected as the start because this is when the Roadway Worker Protection Rule went into effect. Prior to 1997, roadway workers worked under a different set of safety regulations, so data prior to 1997 may not be directly comparable to those that are more recent. Data on MOW employee and signalmen injuries are available in the FRA Accident/Incident Report Database including the time of the accident, whether or not the injury was fatal, and the circumstances of the accident. We used work schedule data from Gertler and Viale (2006a, 2006b) to determine the exposure of roadway workers to potentially hazardous conditions at each time of day. Finally, we reviewed detailed FRA Fatality Investigation Reports to obtain additional information about the causes of fatal injuries that

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