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Do employees' work schedules put them at-risk? The role of shift scheduling and holidays in predicting near miss and incident likelihood

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ABSTRACT

Introduction: Using crew scheduling and injury incident data from a Fortune 500 manufacturing company, this study analyzed the effect of consecutive shifts and shifts near holidays on near misses and incidents. *Methods:* Logistic regressions were conducted with consecutive workdays, days near holidays, and time of shift as predictors of incident and near miss outcomes. *Results:* The logistic regression analysis indicated that working consecutive day shifts increases the probability of an incident occurring, with the fourth consecutive shift resulting in the most risk. The consecutive shift pattern did not replicate to employees working the night shift. However, the first and second shifts when transferring to a night schedule appear to have a greater chance of incident. Shifts near holidays did not have a significantly higher risk than other shifts. *Practical application:* The current research suggests that organizations can use similar analytic techniques to determine if shift scheduling might be related to increased risk and allocate resources to mitigate hazards during those peak probability shifts.

1. Introduction

In 2019, there were 2.8 million workplace injuries and illnesses, with 888,220 lost-time injuries (Bureau of Labor Statistics [BLS], 2020a). Additionally, there were 5,333 fatalities in the private sector (Bureau of Labor Statistics [BLS], 2020b). Each injury or fatality brings costs to the employee and their families (Schulte, 2005). Weil (2001) found that workplace injury costs are highly underestimated when the social costs (e.g., work disability, earning losses) are omitted from the calculations. Reviews of the social costs resulting from injuries indicate negative relationships with earnings and household family activities (Boden, 2005). Workers who experienced serious injuries were more susceptible to psychological issues, substance abuse, and marital problems (Texas Workers' Compensation Research Center, 2005). These findings illustrate the impact that workplace safety incidents have on employees, their families, and organizations. As such, organizations across many industries, particularly those whose employees are exposed to hazardous conditions, are turning to data analytics to help identify and mitigate risk factors associated with incidents.

One specific risk factor associated with workplace incidents is fatigue and labor scheduling practices, as previous literature has shown that scheduling can have profound effects on the safety and well-being of employees (Dembe, Erickson, Delbos, & Banks, 2005; Lombardi, Folkard, Willetts, & Smith, 2010; Nakata, 2011; Olds & Clarke, 2010). In the present study, we investigated the impact of consecutive days worked, day or night shifts, and holiday scheduling on injuries and near misses (i.e., an unplanned event that did not result in injury, illness, or damage – but had the potential to do so; National Safety Council, 2013). Data from worker crews at a large Fortune 500 chemical manufacturer in the southeastern United States were analyzed. Crews were selected as the level of analysis to protect animosity of employee identities.

1.1. Employee work schedules

1.1.1. Work hours and scheduling

Physical and psychological demands of a job and the workplace are related to employee fatigue (Li, Jiang, Yao, & Li, 2013). Employees with less than 11 hours of rest a day have been shown to have higher levels of psychological distress (Tsuchiya, Takahashi, Miki, Kubo, & Izawa, 2017) and increased fatigue (Vedaa et al., 2016). Work schedules can sometimes restrict the amount of rest

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between shifts to under 11 hours and can be considered both physically and psychologically demanding. This can result in acute negative health outcomes, such as lack of sleep and fatigue (Vedaa et al., 2016). Other research suggests that daily rest periods under 13 hours do not allow employees to adequately recover from fatigue (Ikeda et al., 2017).

Because of their associations with employee health and fatigue, work hours and scheduling have been shown to have direct relationships with employee safety outcomes. Dembe et al. (2005) found that jobs with overtime schedules, shifts of 12 or more hours, or workweeks of 60 or more hours have significantly higher self-reports of injuries than jobs without these characteristics. Across various industries, including both the commercial driving and medical industries, increased work hours are predictive of adverse safety outcomes (Dembe et al., 2005; Soccolich et al., 2013). These findings are supported by Yamauchi et al. (2019), who found that near miss likelihood was significantly higher for employees working over 41 hours a week compared to those working 35–40 hours a week. Further, incident likelihood was significantly higher for employees working over 51 hours a week compared to those working 35–40 hours a week.

There is some evidence that working multiple days in a row exacerbates inadequate rest between shifts, contributing to further fatigue and injuries. Thompson (2019) investigated how fatigue accumulates across three consecutive 12-hour shifts in healthcare. Reaction time, attention, and muscle function all depreciated over those consecutive shifts. Rotating night-shift schedules, such as the Dupont schedule, during which workers alternate weeks between working consecutive night shifts consecutive day shifts, have been shown to conflict with employees' circadian rhythms, resulting in sleepiness and worse job performance (Akerstedt, 1990). Industrial employees with rotating shift schedules tend to get less sleep in the initial days of a series of consecutive shifts (Budnick, Lerman, Baker, Jones, & Czeisler, 1994). Variance in employee well-being created by shift scheduling could result in an increased chance of injury.

A meta-analysis by Folkard and Lombardi (2006) modeled the compounding effects that longer shifts, non-daytime shifts, and consecutive shifts have on incident risk. First, they examined these factors in isolation, finding that night shifts were riskier than afternoon shifts, which were riskier than day shifts. Similarly, 12-hours shifts were riskier than 10-hour shifts, which were riskier than 8-hour shifts. Incident risk also increased for each consecutive shift worked. When examining these factors in tandem, they found that the safest way for an employee to work a 48-hour week was to work six consecutive 8-hour day shifts. This option was 20% safer than working four consecutive 12-hour day shifts, 40% safer than working six consecutive 8-hour night shifts, and 50% safer than working four consecutive 12-hour night shifts. A similar pattern was observed when modeling a 60-hour workweek. Folkard and Lombardi (2006) summarized two general findings from their results. First, working more but shorter shifts is safer than fewer but longer shifts. Second, day shifts tend to be safer than night shifts. Based on the previous studies, we expect to find that the more consecutive shifts a crew has worked, the higher the chance of an incident or near miss.

Hypothesis 1. The more consecutive days a crew works, the higher their risk of experiencing (a) an incident or (b) a near miss.

1.1.2. Employee work around holidays

In the United States, the average manufacturing employee receives nine paid holiday days per year (Bureau of Labor Statistics, 2019). Employees also average eight paid vacation days within their first year on the job and 12 days after five years of job tenure. Some employees may wish to use their vacation days around the holiday to extend time off. For manufacturing organizations operating 365 days a year, days around holidays can result in personnel changes that deviate from normal scheduling. When employees work around the holidays, their tasks and workload may change due to these personnel changes. Those changes may result in increased stress. Nawijn, de Bloom, and Geurts (2013) reported that prior to holidays, increased workload demands predicted decreases in self-reported health and well-being leading up to a vacation. Syrek, Weigelt, Kühnel, and de Bloom (2018) found that employees with a larger amount of unfinished work prior to the holiday were more likely to return to work with lower levels of positive affect. Therefore, work schedules prior to and post-holiday can be stressful for employees.

Workplace stressors are related to occupational injuries. For example, Haruyama et al. (2014) provided evidence for associations between job demands, physical and psychological stress, and reported cuts and burns in kitchen staff. A study of dam construction workers found a positive relationship between job stress and occupational injuries (Hussen, Dagne, & Yenealem, 2020). Self-reported time pressure, increased workload, excessive work, and working multiple job roles were related to occupational injuries among firefighters (Kim, Ahn, Kim, Yoon, & Roh, 2016). Similar relationships have also been found in the manufacturing industry (Kim, Min, Min, & Park, 2009; Nakata et al., 2006).

Based on this research, it is hypothesized that crews will be more likely to experience an incident or near miss on shifts near a holiday.

Hypothesis 2. Crews will be more likely to experience an incident or near miss while working shifts two days prior and following a company holiday.

1.2. Exploratory variable

1.2.1. Day or night shift

Across many jobs and industries, non-standard shifts (i.e., those that deviate from the conventional nine-to-five workday) are associated with a higher risk of injuries and illnesses (Dembe et al., 2005). For example, laborers who work past midnight have been shown to have poorer mental health (Sato, Kuroda, & Owan, 2020). There is some evidence that employees who switch from a non-night shift to a night shift may have an increased chance of developing depressive or anxiety disorders (Beltagy, Pentti, Vahtera, & Kivimäki, 2018). The same study found that when employees switched from a night to day shift, there was an increased recovery rate from these disorders. Night shifts have also been associated with a greater risk of injury than day shifts (Smith, Folkard, & Poole, 1994). Other studies have found no association between working night shifts and injuries (Nielsen et al., 2019). For example, a recent review of over 13,000 occupational injuries found no differences between day and night shifts and occupational injuries. Due to mixed findings in the literature, no hypotheses were made regarding day or night shift risk differences prior to conducting the analyses.

1.3. Overview

To evaluate the hypotheses described above, we conducted analyses of incident data collected at a chemical manufacturing plant over a three-year period in conjunction with human resources data regarding specific days and shifts those employees worked and holiday schedules. Analyzing organizational data has several advantages over analyzing self-reported survey data. Survey measures have limitations in the accuracy of self-reported information. Kessler et al. (2003) found that employees can overestimate their hours worked and underreport their work absen-

teeism compared to payroll records. Underreported and undercounted injuries often result in injury estimates much greater than reported data (Leigh et al., 2004, 2014). Across industries, unreported accidents occur at a greater rate than reported accidents (Probst & Estrada, 2010). Using self-report measures can potentially lead to misinformed analytic applications because of errors and inaccuracies in the data.

The objective of the present research is to examine three years of scheduling data to create prediction models for incident and near-miss outcomes. Logistic regression models were created to assess the impact of consecutive days worked and holiday scheduling on injuries and near misses. The hypotheses evaluated were: H1: *The more consecutive days a crew works, the higher their risk of experiencing (a) an incident or (b) a near miss.* H2: *Crews will be more likely to experience an incident or near miss while working shifts two days prior and following a company holiday.* We also explored the relationship between the type of shift (day or night) and injuries and near misses.

2. Materials and methods

2.1. Participants and setting

Data for the study were made available by a chemical manufacturer in the Southeastern United States that specializes in the production of various advanced materials, chemicals, and fibers. The scope of this study was limited to the division that manufactures advanced fiber materials. At the time of the study, the division contained approximately 350 operations employees. Within the division, there were five departments, with each department containing four crews. Employees did not alternate across crews. These crews follow a 12-hour shift DuPont schedule where they work a series of three or four days or nights in a row, followed by one to seven days off. Work tasks within the departments included (a) collecting samples of chemical materials, (b) switching out equipment configuration, (c) emptying excess chemical material from the system, and (d) transporting raw material with forklifts.

2.2. Measurement

Using R software, work scheduling variables were created based on the chemical company's crew schedule calendars for 2016–2018, totaling 2,144 observations. Safety outcome data were retrieved from the company's safety data tracking system and filtered to only include the participating departments' incident and near miss data. These outcomes were then linked to the specific crew that was impacted. All data were aggregated to the crew level across all five departments because multiple crews worked the same schedule across the different departments. Additionally, information on individual employees involved in incidents or near misses was excluded to protect the identity of those individuals. Therefore, each observation included a crew number, the crew's current shift in their work schedule, and the number of incidents and near misses for that crew.

2.2.1. Consecutive work days

A variable, ranging from one to four, was calculated based on the crews' shift calendar to indicate how many consecutive days a crew had worked prior to and including the current shift.

2.2.2. Near holiday

A binary variable was coded based on the crews' shift calendar to indicate whether a shift occurred two days before or after a company holiday. Company holidays include the following U.S. holidays: New Year's Day, Good Friday, Memorial Day, Independence Day, Labor Day, Thanksgiving Day, and Christmas Day. Additional holiday leave was also granted the day following Independence Day, Thanksgiving Day, and proceeding Christmas Day.

2.2.3. Time of shift

A binary variable was created based on the crews' shift calendar to indicate whether a shift occurred during the day or the night.

2.2.4. Incidents and near misses

Two binary safety outcome variables were created to indicate whether an incident or near miss occurred during a given shift. The chemical manufacturer classifies an event as an incident when it results in employee injuries (both recordable incidents and first aid events that were reported), fatality, property damage, or unintended chemical release. Events are classified as near misses when hazardous energy (e.g., electrical, gravitational, hydraulic, pneumatic, mechanical) is released or modified, and an incident resulting in personal harm nearly occurs. Binary variables for each of these were deemed more appropriate than continuous counts due to the low base rate of these events (i.e., there were only four days in which two near misses occurred and three days in which two incidents occurred).

2.3. Analytic approach

To examine the effect of the number of consecutive days on incidents and near misses, we used a binary logistic regression model. The odds ratios associated with the consecutive days worked were examined in predicting the probability of an incident or near miss. The specific probabilities that an incident or near miss would occur for each level of consecutive days worked variable were also obtained. A chi-square analysis was used to examine the possible effect of holidays on incident and near miss occurrence by tabulating the type of shift with the binary incident and near miss variables separately. These binary variables were tabulated against whether a day was within two days of a holiday. The same methodology was applied to test associations between day versus night shift and the probability of an incident or near miss occurring. Lastly, to examine the combined effect of consecutive days worked and proximity to holiday, a binary logistic regression model was created in which these three variables were entered as covariates, and incident and near miss occurrence were entered as the dependent variable, separately.

3. Results

The means, standard deviations, and correlations among the variables used in the study are presented in Table 1. The mean value for the incident binary variable, which indicates whether or not there was an incident on a day, was 0.02 (SD = 0.16), indicating that 2% of the days in our dataset had an incident occurring. Similarly, 5% of the days had a near miss occurrence, and 8% of the days were considered to be near a holiday. The mean values for consecutive day and night shift variables indicate that, on average, the crews in the dataset worked 1.12 consecutive days and 1.13 consecutive nights, indicating that it was not common to work multiple back-to-back shifts.

The first hypothesis suggested that as the number of consecutive days worked increased, there would be a higher probability of (a) an incident and (b) a near miss occurring. To test this, a binary logistic regression analysis was performed. The number of consecutive days was entered as the predictor, and the binary incident and near miss variables were entered as the dependent variables in

Table 1
Descriptive statistics and correlations between the variables examined in the study.

	Incident Binary	Near Miss Binary	Near Holiday	Consecutive Days	Consecutive Nights
Incident Binary	–				
Near miss Binary	−0.02	–			
Near Holiday	0.03	0.04	–		
Consecutive Days	0.08***	0.03	−0.04	–	
Consecutive Nights	−0.05*	−0.05*	−0.04	−0.71***	–
Mean	0.02	0.05	0.08	1.12	1.13
SD	0.16	0.21	0.27	1.22	1.34

* p <.05.
*** p <.001.

separate analyses. Table 2 summarizes the results of the logistic regression analyses. Only one of the analyses resulted in a significant finding. Specifically, for employees working consecutive day shifts, the probability of an incident occurring significantly increased with a higher number of consecutive days worked, such that an increase of one day resulted in a 41.4% increase in the odds of an incident (95%CI = 2.7−94.7%). As further evidence, the correlation between consecutive days and incident variables was significant and positive (see Table 1), indicating that the probability of an incident significantly increased with each consecutive day shift. However, the relationship between consecutive days worked and near misses was not significant. Overall, Hypothesis 1 was partially supported. Table 3 summarizes the probabilities of incident or near miss occurring associated with each additional consecutive day employees worked. For example, if a crew was working their fourth consecutive day shift, they faced a 5.84% probability of an incident and a 4.93% probability of a near miss occurring during their shift.

The second hypothesis, which suggested that there would be a higher occurrence of incidents and near misses in days close to holidays, was tested using a Chi-square test of independence in which we tabulated the binary holiday variable with the binary incident variable indicating whether an incident or near miss had occurred during that shift. The relationship between these variables and incidents was not significant, $X^2(1, N = 2144) = 2.17$, $p = .141$. Similarly, we observed non-significant results in predicting near misses, $X^2(1, N = 2144) = 2.64$, $p = .104$.

In an exploratory analysis, we examined whether night shifts would have a higher likelihood of an incident occurring compared to day shifts. This was tested using a Chi-square test of independence in which we tabulated the shift variable (day vs night) with the binary incident variable indicating whether an incident had occurred during that shift. We found that the relationship between these variables was significant, $X^2(1, N = 2144) = 8.53$, $p < .01$. However, the direction of the effect was the opposite of previous findings from the literature, whereby day shifts had a higher likelihood of an incident than night shifts. The same pattern of results was observed for near misses, suggesting that day shifts may have a higher likelihood of those events, $X^2(1, N = 2144) = 4.67$, $p < .05$.

Table 4 shows the raw numbers of day and night shifts with incidents and near misses, grouped by consecutive day/night shifts. The first night shift session has the second highest probability of an incident occurring and the highest near miss occurring among consecutive night shifts. To further explore this pattern of findings and complement the analysis in Hypothesis 1, we also tested whether the probability of an incident or near miss occurring significantly increased or decreased with each additional night shift by running logistic regression analyses, which yielded non-significant results. However, as seen in Table 1, the correlations between consecutive nights and both incident and near miss variables were significantly negative, indicating that the risk for an incident or near miss decreased with each consecutive night shift. More research is needed to explore this nuanced relationship between consecutive day and night shifts and the probability of an incident or near miss occurring.

Table 3
Predicted probabilities of an incident or near miss occurring in each consecutive day/night.

	Incident	Near Miss
Day 1	2.14%	6.09%
Day 2	3.01%	5.68%
Day 3	4.20%	5.29%
Day 4	5.84%	4.93%
Night 1	1.39%	4.69%
Night 2	1.47%	3.76%
Night 3	1.56%	3.00%
Night 4	1.65%	2.39%

4. Discussion

The current study examined the effect of scheduling on safety outcomes, specifically on the likelihood of an incident or near miss occurring in each shift. The predictors examined were the number of consecutive days worked by employees, whether the shift was shortly before or after a holiday, and in an exploratory manner, whether it was a day shift or a night shift. The results indicate that the probability of an incident significantly increased as employees worked consecutive day shifts. With night shifts, a reverse pattern was observed such that the first and second nights seemed to have a higher risk of incident or near miss compared to shifts occurring after the second consecutive night. There were more incidents and near misses occurring on day shifts compared to night shifts. Finally, the proximity of shift work to an upcoming holiday break was not associated with increases in incidents or near misses. The null finding for incidents and near misses around holidays

Table 2
Logistic regressions predicting incident and near miss occurrence.

IV/DV	B	Wald X^2	p	Odds Ratio (OR)	OR 95% CI
Consecutive Day Shifts/Incidents	0.35	4.51	0.034	1.41	1.03–1.95
Consecutive Day Shifts/Near Misses	−0.08	0.33	0.569	0.93	0.72–1.20
Consecutive Night Shifts/Incidents	0.06	0.06	0.811	1.06	0.66–1.71
Consecutive Night Shifts/Near Misses	−0.23	1.96	0.162	0.79	0.57–1.10

Note. Each line in the table represents a separate logistic regression analysis.

Table 4
Raw Numbers of 1st, 2nd, 3rd, and 4th Day & Night Shifts with an Incident or Near Miss.

	Day Shift		Night Shift	
	Incident	Near Miss	Incident	Near Miss
1st	5/322 (1.6%)	22/322 (6.8%)	6/317 (1.9%)	15/317 (4.7%)
2nd	14/311 (4.5%)	16/311 (5.1%)	4/311 (1.3%)	13/311 (4.2%)
3rd	9/299 (3%)	12/299 (4%)	1/301 (0%)	6/301 (2%)
4th	9/140 (6.4%)	10/140 (7.1%)	5/143(3.5%)	5/143 (3.5%)

Note. The numerator indicates the number of shifts with a reported incident/near miss. The denominator indicates the total shifts in the dataset.

may be due to other variables that are affected by the holiday, such as planned decreases in production requirements, fewer employees working, and some employees taking extended vacation days.

One potential explanation for the difference between consecutive days worked versus consecutive nights worked concerns the possible effect of circadian rhythms. The crews involved in this study worked alternating weeks of day and night shifts. After working their consecutive days on the day shift for one week, the crew was shifted to the night shift. Therefore, the entire crew experienced the shift from day to night. It is possible that the dramatic shift in sleep schedule creates the most fatigue the first night shift after having worked the day shift for a week, as it may take some time for the employees' circadian rhythms to adjust (Violanti et al., 2012). Employees may be less attentive at work on their first night shift (Budnick et al., 1994), leading to an increase in incidents. Note that for night shifts, this would contradict our first hypothesis, which suggested that each consecutive shift may increase the probability of an incident occurring. The crews in our dataset were rotating shifts every week, meaning that the first night shift was always their first shift after working day shifts.

There was not a significant increase in near miss probability with each consecutive day worked during either day or night shifts. Since near misses are considered leading indicators of incidents (Occupational Safety and Health Administration, 2019), we would expect to see a similar increase in the probability of near misses with more consecutive day shifts. One possible explanation is that while reporting an incident is mandatory, reporting a near miss is optional. It may be possible for the near miss metrics to be influenced by idiosyncratic reporting behaviors, which likely vary across employees and situations, introducing a larger amount of error variance in near miss measures.

4.1. Practical Applications

When the potential for an incident is identified, an organization should direct resources (e.g., additional staffing) and safety initiatives to address that risk (e.g., increased observations/audits). Based on the results of the present study, adjustments in staffing, increases in break time, and additional safety initiatives (e.g., observations, audits, coaching) on the fourth consecutive day shifts and first night shifts after transitioning from day to night may be considered to mitigate the risk. If logistically possible, risk might be reduced by modifying shift schedules such that consecutive 12-hour shifts are limited to three consecutive days. In addition, given the finding that the first night shift appeared to have increased risk, crews may stay on day/night shifts for a longer amount of time instead of alternating every week.

4.2. Recommendations for future research

The current study examined the effect of consecutive workdays across day and night shifts on incidents and near misses with limited data containing relatively low base rates of both incidents and near misses. Regardless, we were able to tentatively identify increased incident and near miss probability after a number of consecutive days worked. Future research should use larger datasets to replicate and extend our findings to provide organizations with more specific guidelines regarding work scheduling.

Another area needing more extensive data analysis is the difference in the probability of an injury between night shifts and day shifts, as the findings in this area are mixed (Folkard & Lombardi, 2006; Fransen et al., 2006; Nielsen et al., 2019). While our analyses found that, on average, night shifts had a smaller number of incidents compared to day shifts, we were not able to control for the number of employees at work during those times. This may explain the difference in frequency of incidents (i.e., fewer workers equals fewer opportunities for injury). In addition, while the current study identified an increased risk on the first night shift worked after consecutive day shifts, this finding may only be a trend because of the low base rate of incidents in our data. However, this finding supports previous research showing that rotating shift schedules are associated with a greater risk of injury (Bagheri Hosseinabadi et al., 2019; Dembe et al., 2005; Wong, McLeod, & Demers, 2011). Finally, the organization providing the data for the current study utilized a DuPont work schedule, thus making it impossible to compare this schedule to other work schedule arrangements (Folkard & Lombardi, 2006). Future research could compare different work schedules in terms of safety outcomes such as incidents and near misses.

4.3. Limitations

This study has several limitations. First, data only included crews working in an advanced fibers manufacturing division within a chemical manufacturing company. Findings must be replicated in other settings and industries to support their generalizability. Second, data on day/night and consecutive shift scheduling were created using crew scheduling. This was later combined with a separate dataset indicating dates of incidents for employees within the crews. Consequently, when an incident occurred on a given date and time, we associated it with the crew assigned to work that day based on their day/night shift schedule. This meant we could not control for certain employee-level variables in our analyses, such as employee experience or tenure. In addition, while unlikely, there is a possibility that the employee might have worked a modified schedule for that week different from their crew. The third limitation involves the number of employees working in each shift. The number of labor hours directly influences the number of hours employees are exposed to hazards and risks. It is also plausible that when there is more activity on the shop floor (i.e., more employees working in the area), there will be a higher likelihood of an incident or near miss. Because the dataset did not include this information, we could not control the number of employees in each shift for our analyses.

5. Summary

Results from the current study provide evidence that an employee's work schedule is predictive of the probability of a safety incident. Logistic regression analysis indicated that working

consecutive day shifts increases the probability of an incident occurring, with the fourth consecutive shift resulting in the highest probability. The consecutive shift pattern did not replicate to the night shift. However, after transferring to a night schedule, the first and second shifts appear to have a greater chance of incident than later night shifts. The current research suggests that industrial organizations can use similar analytic techniques to determine if shift scheduling might be related to increased risk and allocate resources to mitigate hazards during peak probability shifts.

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