Impact of Seasonality on Accident Frequency Rate at a German Car Manufacturer

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Abstract: Seasonality can have a significant impact on workplace safety in certain industries, making it crucial to investigate its potential influence on accident frequency rates (AFR). This paper aimed to investigate seasonality as a possible factor for reducing the AFR in a German automotive manufacturer. An analysis of variance (ANOVA) was employed to examine accidents that occurred at its four German production plants according to quarter, month, workday, and working hour. Our findings reveal no evidence of seasonality influencing the AFR. Overall, the research supports that the seasonality can be neglected and that there are others factors to improve the safety management systems.

Keywords: Safety, Accident Prevention, Accident frequency rate (AFR), Analysis of variance (ANOVA), Workplace Safety

1. Introduction

Workplace accidents cause both injuries to workers and production interruptions, which is a significant problem (Altunkaynak 2018; Fidancı 2015; Kifle et al. 2014). In order to prevent accidents in the long term, prevention strategies exist to protect workers, but the influencing factors that increase the risk of accidents need to be identified. It has been reported that there are temporal and seasonal influences on the frequency of accidents.

Identifying the factors that increase the risk of accidents is crucial to effective accident prevention. In this way, prevention measures can be tailored to these patterns, creating a healthy working environment in the long term (Martens 2022). In his work, Wigglesworth (2006) showed that workplace accidents occur more frequently on Mondays than on other days of the week. However, more data was needed for a more detailed analysis distinguishing between early, late and night shifts.

There are several studies on the influence of temporal and seasonal factors. In the study on metal production in Spain (Fuentes-Bargues et al. 2022), several factors were analysed and "time of day" was identified as a significant factor. It was also found that most accidents occur between 10:00 and 12:59. The influence of the day of the week was also investigated. However, it did not demonstrate significant results in this study, with only assembly work showing a slightly higher frequency.

Lundstrom et al. (2023) analysed accidents that required hospital treatment and found that most accidents at work unrelated to falls, slips or trips were hospitalised in July and August. According to Lundstrom et al., most accidents occur in January when these accidents are included in the analysis.

Although numerous studies in the transport, construction and healthcare sectors have investigated temporal and seasonal factors influencing accidents, no study exists for the German automotive industry. Therefore, this study aims to investigate whether similar temporal and seasonal patterns exist at a German car manufacturer as in other industries or whether such factors may not exist due to the high level of production or safety management automation. For this purpose, the period from 2012 to 2022 is examined, using quarters, months, weekdays, and hours as analysis intervals.

The article's main aim is to investigate whether there are temporal or seasonal aspects that influence occupational accidents at German car manufacturer.

2. Methodology

2.1 Data sources

In this paper, an accident is defined as follows: An accident is an event that is limited in time and has an external effect on the body, resulting in an injury and a negative impact on health or death. If two employees are injured in one accident, we count two accidents. If there is a longer-term (> one shift / 8 hours) impact on the body, it is not an accident but an illness. If the negative impact on health or death is caused by the body itself (e.g., heart attack, stroke, epileptic seizure), it is also not an accident. In this work only the accidents were analysed.

The accident data were collected using a tool to document accident data. The data were collected from at all four German plants and analysed. No distinction was made between the severity of the accidents, to avoid introduction of an additional variable in this preliminary analysis. The data period covered is from 2012 to 2022 inclusive. The analysis is based on accident data and working hours to ensure the validity and comparability of the data. The information is standardised based on hours worked. This results in the unit of measurement "accidents per 1000 hours worked", which is used as the basis for the analysis. This unit was first introduced by (Herbert William Heinrich, 1931).

Table 1: Number of Accidents per month and workday for the assembly technology.

	Monday	**Thuesday**	**Wednesday**	**Thursday**	**Friday**
January	16	15	16	14	17
February	18	18	14	22	18
March	25	20	20	19	17
April	12	24	11	30	16
Mai	8	12	7	10	7
June	19	17	24	13	15
July	21	18	28	24	18
August	13	13	9	6	4
September	18	8	19	17	15
October	20	14	23	18	27
November	19	23	18	20	21
December	17	12	20	14	16

2.2 Data analysis

The data were first checked for duplicates and completeness. The accident and hours worked data were then aggregated using the department abbreviations and converted to the unit "accidents per 1000 hours worked". These data were used for statistical analysis using ANOVA (analysis of variance) with a significance level of 0.05. ANOVA is a parametric statistical method used to identify significant differences between the means of more than two groups. The groups are quarters, months, days of the week or individual hours of the day. The dependent variables were checked for normal distribution to ensure that the assumptions for ANOVA were met.

In the first step, the data for the assembly department were analysed, and progressively more detailed evaluations were carried out. The assembly is a one of the technologies during the car manufacturing process. The assembly technology was chosen because the jobs change monthly, and the data is current. The significance level was first analysed quarterly using ANOVA and then refined on a monthly, weekday and daily hourly basis. These levels of analysis allowed a granular examination of the temporal dimension of accident frequency. The quarters were January to March, April to June, July to September and October to December. The days of the week were Monday, Tuesday, Wednesday, Thursday and Friday. The hours of the day were from 6:00 to 00:00, and the time for an hour was, for example, from 8:00 to 8:59. These analysis steps were then repeated for the three remaining locations to ensure the generalisability of the results.

Finally, all German plants were analysed rather than restricted to a specific activity area. Analyses were again carried out using ANOVA and the above levels to identify consistent patterns and differences in accident frequency across all sites.

3. Results

When analysing assembly at the four different sites, no significance was found in the four categories (quarter, month, day of the week, hour of the day). The analysis is deepened by analysing the daily assembly hours at the Munich plant. The ANOVA table 2 and table 3 shows no significant differences between the five groups, as the F-value of the factor is 0.41 for table 2 and the p-value is 0.802. Same for the 3 table were the f-value is 0.57 and the p-value is 0.741. It is important to note that the data variation within the groups is greater than the variation between them (error). If the F-value is greater than 1, the differences between the groups are more significant than the random variation. Hence, the difference between the groups is more significant than the random variation in the data. This result could indicate a significant influence of the factor on the dependent variable, but this would need to be confirmed by calculating the p-value.

Table 2: ANOVA of the comparison of the weekdays in the assembly for 2021.

Source	DF	ADj SS	ADJ MS	F-Value	p-Value
Factor	4	0.001386	0.000346	0.41	0.802
Error	55	0.046605	0.000847		
total	59	0.047991			

Table 3: ANOVA of the comparison of the weekdays in the assembly for 2022.

Source	DF	ADj SS	ADJ MS	F-Value	p-Value
Factor	4	0.002075	0.000671	0.57	0.741
Error	55	0.058061	0.000978		
Total	59	0.059073			

This study's number of degrees of freedom is appropriate. The p-value of 0.802 indicates no significant difference between the groups.
In the second part of the analysis, the same analyses were carried out for all four German plants without restriction to a specific technology. Again, no significant differrences were found in any of the four categories analysed. Based on the data analysed, there is no significant influence on accidents at the plants of the German car manufacturer.

4. Discussion

It was investigated whether seasonal aspects influence the accident frequency rate (AFR) at a German car manufacturer. However, the analysis of the available data showed that there is currently no significant seasonal influence on the AFR.
In comparison, an analysis of data from the German Social Accident Insurance (DGUV 2023) shows that more accidents occur in the morning between 9 a.m. and 12 p.m. than at other times. In addition, the average number of accidents was higher on Mondays than other days. However, no significant difference was found between months or quarters.

Another study of the construction industry found that most accidents occurred between 10:00-11:00, 14:00-15:00 and 17:00-18:00. The causes varied and depended on different risk factors. For the first period (10:00-11:00), the accumulation of accidents was associated with a decrease in alertness just before midday. It was hypothesised that a different type of break management could help to reduce the risk of accidents during this time. For the second period (14:00-15:00), the influence of the weather was cited as a possible cause of an increased accident rate. Poor lighting and reflections at this time of day could contribute to further risks. In the last period (17:00-18:00), it was pointed out that employees' minds were already at the end of the working day, which could lead to a lack of awareness and an increase in accidents (Fuentes-Bargues et al. 2022; Jung et al. 2022).

Due to the methodology used in this study, no distinction was made between the severity of the accidents. Instead, all accidents reported for assembly and the four plants analysed were considered. Although a significant influence of seasonality could be demonstrated if other technologies were considered in isolation, only one technology was critical in this study. Nevertheless, it can be inferred from the results that

overall health and safety management is working well, as significant differences between plants would be observed if health and safety were poorer.

Another limitation of this study is the limited amount of data available. Due to the small number of accidents, the database could be more extensive. For 2021 for the technology assemble there were 1012 accidents in all 4 plants and in 2022 there were 1153. Looking at all accidents of all 4 plants in 2021 there were 3702 accidents and in 2022 were 5266. Nevertheless, by analysing the individual parameters, the ANOVA shows that the reason for this assessment is not only determined by the p-value but is also justified by other factors. In addition, the data were subjected to a standard distribution test, which was always satisfied, further increasing the significance of the data in the analysis.

In conclusion, the present study of the role of seasonal factors in accident frequency at a German car manufacturer produced insignificant results. However, the analysis of the DGUV data shows that accidents occur more frequently at certain times of the day and on certain days of the week. The study's results underline the importance of taking industry-specific risk factors into account when improving occupational safety to minimise potential risks in the future.

5. Conclusion

This study investigated whether seasonality plays a role in the frequency of accidents at the assembly technology and plants of a German car manufacturer. The results showed no significant effect of seasonality, indicating that the safety management systems are highly effective. Despite the challenges of comparing safety practices across industries, the safety management is exemplary, having maintained accident frequency rates below the German index for their field. The company's proactive commitment to creating safe and healthy working conditions for employees is evident and laudable. Overall, this study supports reputation of the German car manufacturer for prioritising safety and underscores the importance of effective safety management in preventing workplace accidents.

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