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# A COMPREHENSIVE PLS-SEM MODEL FOR THE MEDIATING ROLE OF DRIVER PERCEPTION ON ROAD LIGHTING CONDITIONS IN THE BURAIDAH REGION

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**ABSTRACT**

This study investigates the factors influencing road lighting quality and their relationship with driver satisfaction in the Buraidah region. Focusing on the dimensions of drivers' perception and road lighting conditions, the research utilized a questionnaire survey method involving 253 volunteer drivers of various ages. To analyze the links between latent variables, partial least squares structural equation modeling (PLS-SEM) was applied. Statistical analysis validated the survey's reliability, demonstrating an 87% stability coefficient and a Cronbach's Alpha of 0.76. The results revealed a statistically significant relationship ($p < 0.001$) between the adequacy of road lighting and driver satisfaction. While most respondents were satisfied due to lower luminaire glare and improved visibility, some expressed concerns regarding poor pavement visibility in certain areas and moderate feelings of safety while driving at night. The study highlights LED lighting as a superior alternative, offering up to 80% operational efficiency compared to the conventional high-pressure sodium lamps still utilized in parts of the city. Ultimately, this research provides empirical evidence detailing the factors affecting lighting conditions and satisfaction. Despite largely positive feedback, the findings emphasize the necessity for infrastructure improvements using cutting-edge technologies. Aligning lighting systems with global standards and user-centered design is essential for developing a cohesive street lighting strategy tailored to Buraidah's safety and environmental needs.

**Keywords:** road lighting, road signs construction, drivers' perception, Buraidah city, partial least squares structural equation modelling (PLSSEM), lighting distribution.

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## INTRODUCTION

Examining the existing lighting infrastructure and signage design, the study also aims to pinpoint areas that require improvement, especially in view of new technologies like LED lighting that provide improved visual performance and energy efficiency. In addition to supporting municipal planning initiatives, the findings are meant to help create a cohesive, evidence-based street lighting strategy that satisfies community expectations and technical standards. The purpose of this paper was to evaluate the feasibility of streetlights according to the outdoor lighting standard and scrutinize the Excitant Street light, road sign construction, and advantages in Buraidah city based on public opinion [1] [2]. Al-Qassim Region Municipality Electricity Division enlisted assistance as part of its ongoing endeavour to determine whether light-emitting diode (LED) street lamps were a viable solution for reducing energy consumption, maintenance costs, and refining the area of Buraidah's visual appeal [3] [4]. The driver's opinion and responses help the team to assess whether excitant light by streetlamps was a desirable possibility to decrease accidents due to road signs construction and lighting appearance [5].

Colour appearance, colour rendering, and anxiety glare are all indispensable subjective lighting factors because they impact the overall impression formed in the observer's eye-brain system [6]. New LED lighting solutions are persistently improving and can save a large amount of energy [7]. For various lighting and traffic conditions, increased efficiency, optimized luminaire design, and variable lighting control offer greater performance at a lower cost and increase the visual performance of street lighting [8]. While LED acceptance in the outdoor lighting sector is continuing, widespread adoption has yet to be recognized. It is well recognized that observers can describe the illumination of streets intended for clear road traffic management, which is characterized by comparable values of objective lighting considerations, such as luminance level, threshold increment, and surround ratio of road signs construction [9], [10].

The purpose of these Design Requirements is to establish minimum standards for the design of street lighting to support the City of Buraidah in the ultimate degree of development. These Design Standards shape typical procedures for the installation of new or advanced street lighting systems, such as Al-Qassim Region Municipality specified in Buraidah City to change the street lighting system entirely to LED lighting.

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For data collection in the research paper, questionnaires have long been the preferred method [11]. In cross-sectional research, decreased response rates over the last decade have increased the potential of the selection area.

## STUDY BACKGROUND

Road lights serve essential metropolitan and community needs, supporting downtown commerce and economic advancement and enhancing security, particularly within the more densely populated areas of town where people's activity is most prominent [12]. This light source must account for how both the cones and rods within the eye see. Light sources with shorter wavelengths, which generate a "cooler" light, are essential to deliver superior light vision [13], [14].

This research found to achieve the reported necessity to verify the existing street light condition at Buraidah city according to standard, which considered counting the mainstream of accidents in this manner [15] to recognize their contribution causes in the main objectives of the research.

As expressed in the introduction, the chief target was to establish the association between road lighting standards and road sign construction correlated to the accidents that happened. The idea shows consideration of lighting standard establishment for scientific work: a better lighting design concept according to the standard results in much higher driver visibility. Furthermore, an incredible chance to provide more realistic solutions to current issues of an accident at Buraidah city based on the control given by Al-Qassim Region Municipality by changing the entire existing road lights by LEDs technology. This paper stresses to discourse the problems that take place after fundamental ideas: driver concern; corporate street light management obligation; green technology and smart city according to the Al-Qassim Region Municipality expectation.

Street lighting considerations, such as colour appearance, colour interpretation and strain of glare visualization, are moreover extraordinarily problem since they influence the general impression made within the observer's eye-brain expression [16],[17]. It is well recognized that the light of street planning for drivers' visualization is well required for more comfort.

Previous studies affirmed the self-evident preference for warm white light from a driver's point of view concerning visual comfort, whereas the latter agrees with the discoveries presented by Hong and his co-authors [18], who declared that better visibility of green items corresponds to higher brightness and clear perception.

When planning the streetlight of an intended for mixed, traffic must select a good designer according to the colour of a streetlight. Nevertheless, there is no management regarding this issue. Both the International Dark-Sky Association (IDA) [19] and the American Medical Association (AMA) [20] have addressed this issue: the former due to the claimed negative influences of blue light on sky glow, nightscapes, and nighttime creatures, and the latter to decrease the negative effects of exposure to short-wavelength light on human wellbeing.

## RESEARCH DESIGN

In accordance with the goals of the study, the researcher explains the kind of research and methodology employed. To use PLS-SEM analysis, researchers make sure that the research objectives are pertinent. PLS-SEM is appropriate for exploratory research, particularly when the research goal is prediction and theory development. It is variance-based, accounting for total variance to estimate parameters.

This study primarily investigates how drivers' happiness in the Buraidah Region is related to the surrounding environment, perceived utility, perceived ease of use, and lighting conditions. Figure-1 represents the Partial Least Squares Structural Equation Modelling (PLS-SEM) path diagram based on the statistical data structure of this study.

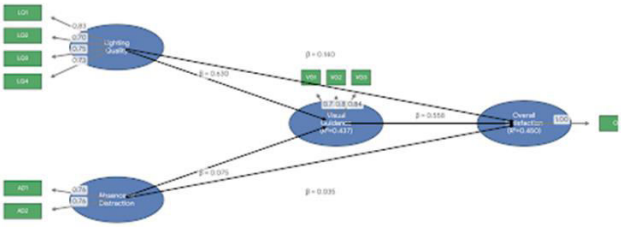


**Figure-1.** Partial Least Squares Structural Equation Modelling (PLS-SEM) path diagram.

Standard structural equation modeling conventions are followed in the detailed information in Figure-1, which represents the underlying structures (Lighting Quality, Absence of Distraction, Visual Guidance, and Overall Satisfaction) that cannot be directly measured with a single query.

## MATERIALS AND METHODS

Paper questionnaires have long been the favored method of gathering survey data in research [21]. The method used in this paper was appropriate for the research objectives about streetlights and the characteristics of the Buraidah luminaires inspection. In an exhibition to supply proof of the present street lighting environment on the association between corporate standards, intellectual performance and execution, we employed questionnaires to surveys and explore driver's respondents. However, the declining response rates were based on 15 closed-ended questions, with multiple-choice response possibilities, which we believed to be adequate as expert validation for the targeted research objectives. Furthermore, all the 15 questions in unambiguous and direct questions, which specify numerous choice questions, where the respondents were, advertised a set of answers from which they had the plausibility to select only one question out of the five multiple-choice.

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Generally, surveys may have both principal points and disadvantages. In any case, it ought to be taken into consideration that not all information collection using the survey strategy experiences these drawbacks. Thus, the prevalence of one drawback or another depends on various components and conditions. Furthermore, these conditions must be taken into account when choosing the right consideration. Moreover, careful attention must be paid to the response rate, in any case, it ought to be recalled that the response rate is not an issue in the circumstances in which the surveys are managed in collective circumstances. Extraordinary caution must be taken when amplifying the results of the overview to a larger sample, since, on the one hand, the responses to address may well be impacted by the answers provided to other questions.

**Participants**

Participants (Drivers) in this study were selected according to their age of 18 years old and above in Buraidah City, the total study population involved 384 people, as illustrated in Figure-2. The participants were asked to complete all mandatory questions in the questionnaires and to provide information about themselves, such as age, whether they use glasses, and the number of accidents, if any. A stacked bar chart representing the survey respondents' age group distribution is shown in Figure-2. There are five different age groups represented by the horizontal axis: 18-30, 31-40, 41-50, 51-60, and over 60. The vertical axis displays the percentage of respondents in each of these age groups, which ranges from 0% to 100%. To differentiate between age groups, each bar segment is color-coded as follows: blue from 18 to 30, red from 31 to 40, green from 41 to 50, and purple from 51 to 60 and over 60. According to the chart, most respondents are younger, with the 18-30 and 31-40 age groups accounting for 29 and 26 percent of all responses, respectively. This suggests that early- and mid-career participants are well represented. Five percent of respondents are over 60, while 23 percent of responses are from the 41-50 and 17 percent are from the 51-60 age groups.

According to the visualization, the study population is primarily made up of people under 40 years old, as it shows a largely youthful respondent base at Figure-2. The target professional or academic community's age distribution or the study's outreach methods may be reflected in this demographic distribution.

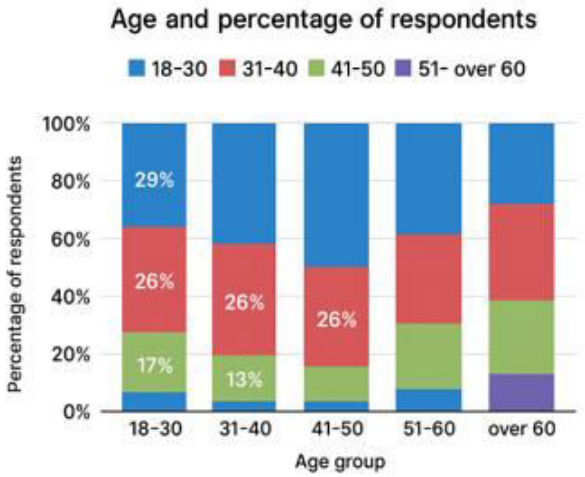



**Figure-2.** Ages and percentage of respondents.

**Settings**

TThe research team initially created the questionnaire in 2020 at Qassim University with funding provided by the Deanship of Scientific Research. The study's particular research goals and methodological framework served as a guide for its design to guarantee alignment with the desired results. The instrument was designed specifically to gather trustworthy and contextually relevant data in Buraidah City, the site of the field application. The Qassim region's capital, Buraidah City, Saudi Arabia, is regarded as one of the region's biggest and most vibrant cities. Serving as a significant center for the economy, society, and culture, it is home to a wide range of businesses, academic institutions, and community events. Given the city's importance and demographic diversity, it is the perfect place to carry out in-depth field research that captures the traits and patterns of the larger region [22].

**Questionnaire Statement to Subjective Evaluation**

The questionnaire circulated to different age groups after explaining the general idea and target of the questionnaire to assess two main parts: road lighting efficiency and associated road sign construction. Three sheets of paper made up the questionnaire. The first sheet's front side was devoted to the respondents' (age, whether they use glasses, number of accidents, if any, time of the accident, and main road or branch road). On the other hand, there were ten primary questions, each with an explanation that each question should be answered by ticking the blank circle that corresponded to the superior lighting installation and road signs construction. The three remaining questions were on the second sheet. The target population is the group of individual drivers of different ages (greater than 18 years) in Buraidah city-Qassim that intends to answer the questions in the questionnaire to conclude from their responses.

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## Ethical Approval

The Research Ethics Committee of the Deanship of Scientific Research, Qassim University, approved the Questionnaire on Wednesday, March 24, 2021. Because the study did not contain biomedical intervention, permission from the Committee on Health Research Ethics of the Deanship of Scientific Research was not required under Qassim University law. This research design is based on a cross-sectional method using data obtained from a questionnaire, which validated by experts and approved by the research ethical committee (20-06-15) at Qassim University.

## RESULTS AND DISCUSSION

This study aims to appraise the road lighting related to driver's feelings of reassurance when using the road alone at Buraidah City at night. The procedure was designed to evaluate the efficiency of the lighting criteria. The participants filled out the online questionnaire accessed through a Google Form. The data were gathered from the drivers' concerns. A total of 384 drivers participated in this study, and the features of road lighting efficiency, road signs construction and overall road lighting performance were analyzed using statistical analysis (SPSS), in which a predetermined number of observations were taken from a larger population. Table-1 displays the demographic data of the drivers who participated in the study, which conveys the statistical descriptive of the respondents. Pearson correlation shows a strong relationship between the overall appraisal of road lighting with the first part axis (adequacy of road lighting and its efficiency) and the second part axis (traffic road lights and signals (r= 0.66, 0.62; p<0.001) respectively.

**Table-1.** Data summary of preferred respondents.

| statement | Strongly agree | agree | Not sure | disagree | Strongly disagree | χ2 | p-value |
|---|---|---|---|---|---|---|---|
| The illumination brightness of the city roads is considered adequate | 68 | 194 | 66 | 38 | 18 | 182.33 | <0.001 |
| The level of lighting distribution in the roads is sufficient and regular | 71 | 156 | 90 | 50 | 17 | 105.90 | <0.001 |
| During bad weather (dust or rain) the lighting is clear and adequate | 53 | 86 | 83 | 96 | 36 | 40.70 | <0.001 |
| The currently available street lighting in your city is suitable for eyes and not cause glare | 81 | 164 | 62 | 59 | 18 | 180.21 | <0.001 |
| Advertisement mobile screens beside the road do not adversely affect visibility | 72 | 135 | 59 | 71 | 47 | 46.88 | <0.001 |
| Current street lighting design leads you to choose the right track | 84 | 185 | 60 | 35 | 20 | 165.97 | <0.001 |
| Traffic signs available on the streets of Buraidah direct you to the right track at night clearly | 74 | 170 | 74 | 50 | 17 | 126.02 | <0.001 |
| The current night lighting in the city of Buraidah enables you to see the pavement and the sides of the road | 68 | 174 | 72 | 53 | 17 | 134.00 | <0.001 |
| Lights from incoming cars in the opposite direction do not adversely affect visibility | 63 | 119 | 72 | 89 | 42 | 112.89 | <0.001 |
| Road lighting level is generally good in the city of Buraydah | 74 | 206 | 50 | 32 | 23 | 33.01 | <0.001 |

## Overall Data Reliability

The number of concerns were acknowledged after evaluating the surveyed responses to the questionnaire. The statistical expressions display the psychometrics quality through the high consistency of the questions [18]. Figure-3 displays the degree of two main sections interpreted as extremely reliable data, according to the importance of question contribution and accurate consistency of 76% and 24% (Cronbach's Alpha) as a Level of Light visualization and Pavement associated construction respectively. Principally, the identical outcomes in this paper would be achieved in various kinds of reliability coefficients, with ideals ranging between (0 - 100), it is the characteristic of a set of associated responses that relates to the sum of arbitrary faults from the estimation.

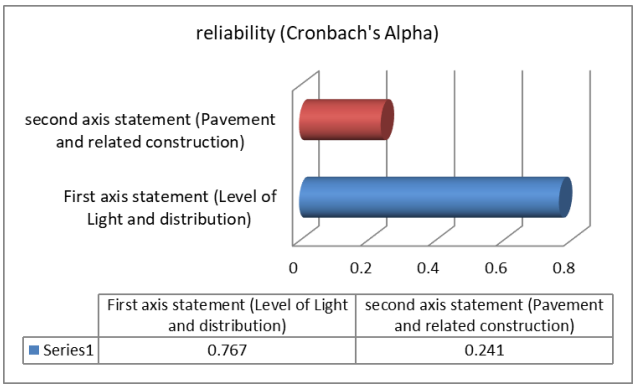



**Figure-3.** Overall data reliability.

Figure-4 provides a thorough evaluation of drivers' satisfaction with important elements of the night-time driving conditions on Buraidah roads. The evaluation is composed of three main parts: Overall Assessment of Buraidah Road Lighting Suitability: This measure gauges how drivers feel about the sufficiency and efficiency of the road lighting system. Based on the results, 76.3% of respondents said they were satisfied, indicating that most people thought the lighting was suitable for driving safely at night. A significant minority, however, who might have encountered problems like inadequate illumination or uneven light distribution, was highlighted by the 23.7 percent who expressed dissatisfaction. Road traffic signal and pavement condition assessment in relation to night vision: This component assesses how well pavement markings and traffic signals facilitate visibility and navigation at night. Most respondents were satisfied, as evidenced by the noteworthy 77.4% satisfaction rate.

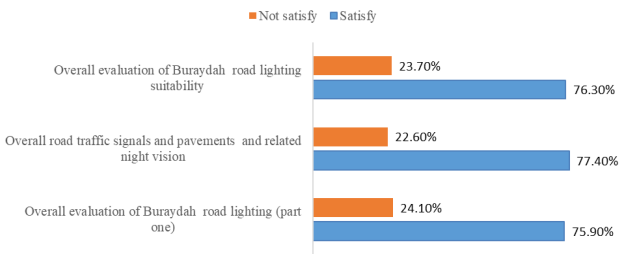



**Figure-4.** Overall driver evaluation (satisfaction).

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Moreover, the questions in the questionnaire were directed to determine the significance of clear light visualization and relaxation influence the human eyes in which are currently operating at a social responsibility level at Buraidah region. Table-2 shows a predicted overall streetlight corresponding to the audience response (p-value < 0.05); there were no significant consistencies between the responses obtained from this question when compared to the interview with the Al-Qassim Region Municipality.

**Table-2.** Overall Street light corresponding to the audience response.

| Statement | Satisfy | Not satisfy | $\chi 2$ | p-value |
|---|---|---|---|---|
| Overall evaluation of Buraydah road lighting (part one) | 75.9 % | 24.1% | 114.238 | < 0.001 |
| Overall road traffic signals and pavements and related night vision | 77.4 % | 22.6 % | 96.221 | < 0.001 |
| Overall evaluation of Buraydah road lighting suitability (one and two) | 76.3 % | 23.7 % | 214.649 | < 0.001 |

In order to demonstrate the light quality scenario and visual guidance at Buraidah City, Figure-5 then shows the median based on the drivers' responses using a Partial Least Squares Structural Equation Modeling (PLS-SEM) approach. Each question's median is arranged in ascending order, with more detailed data than the overall satisfaction average. The figure indicates that overall satisfaction with the light visualization in the Buraidah region is in the direction of agreement to strongly agree.

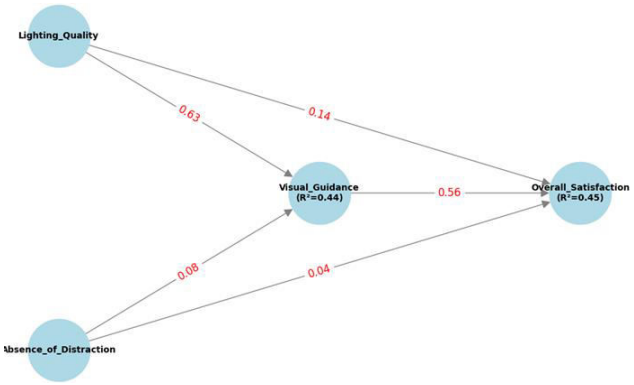



**Figure-5.** PLS-SEM Analysis of Driver Perception.

Figure-6 displays a lower-triangular correlation matrix heatmap that displays the pairwise correlations between 10 distinct lighting perception measures. The numerical values inside each cell represent the correlation coefficients between the intersecting variables. A corresponding color scale on the right ranges from dark blue (-1.00, indicating a perfect negative correlation) to dark red (1.00, indicating a perfect positive correlation). The matrix indicates that all evaluated lighting perception metrics exhibit positive correlations with one another, with coefficient values ranging from a minimum of 0.08 to a maximum of 0.61.

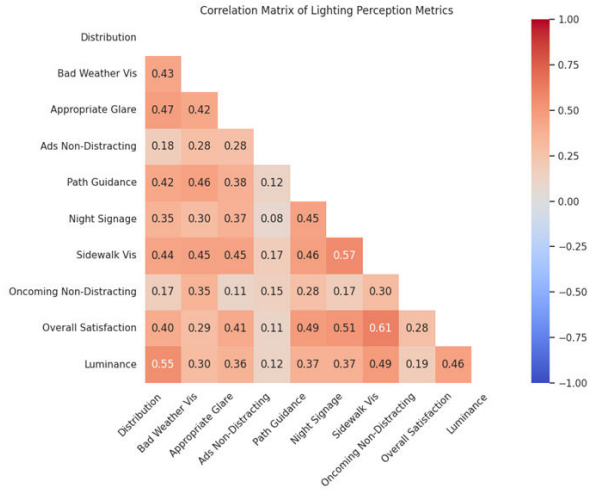



**Figure-6.** Correlation matrix for lighting perception.

Sidewalk Vis (visibility) and Overall Satisfaction have the strongest positive link, with a correlation coefficient of 0.61. This suggests that enhanced sidewalk visibility is the most potent individual driver of overall satisfaction among all the variables that were assessed. Other exceptionally high relationships are Luminance and Distribution (0.55) and Sidewalk Visibility and Night Signage (0.57). Furthermore, there is a reasonably strong association between Overall Satisfaction and Path Guidance (0.49) and Night Signage (0.51). The weakest correlations the measure Ads Non-Distracting, on the other hand, exhibits the smallest associations with the other factors. Particularly low correlation values are seen with Night Signage (0.08), Overall Satisfaction (0.11), and Luminance and Path Guidance (0.12).

This implies that the perception of obtrusive advertisements is not significantly influenced by the other lighting quality criteria. This implies that how annoying advertisements are considered to be glaring is not much influenced by the other illumination quality measures. Figure-1's comprehensive data follows accepted structural equation modeling guidelines. This stands for the underlying constructs (Lighting Quality, Absence of Distraction, Visual Guidance, and Overall Satisfaction) that are difficult to quantify with a single inquiry.

Figure-7a & 7b present two pie charts detailing the frequency and timing of self-reported traffic accidents. The left pie chart illustrates the distribution of accident involvement among the surveyed individuals. The data reveals the following breakdown.

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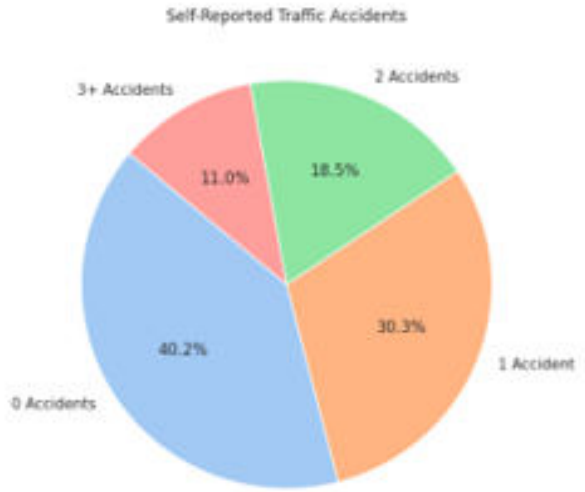




**Figure-7a.** Self-supported traffic accidents.

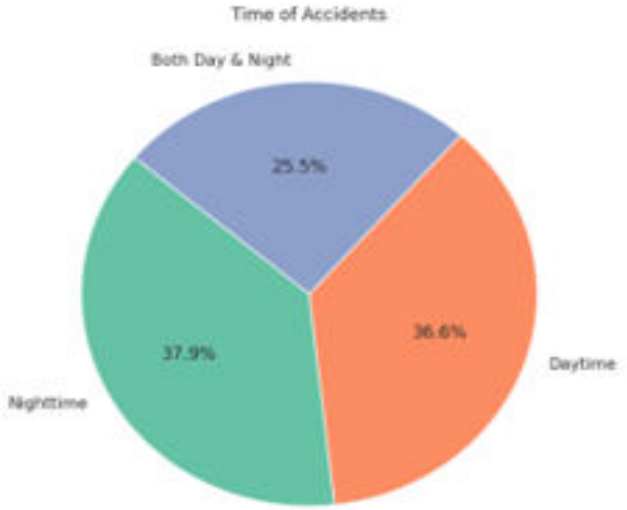



**Figure-7b.** Time of accidents.

40.2% of the sample, the greatest percentage, said they had no accidents. 30.3% of people with a history of accidents reported one, which is the most common occurrence. Only 18.5% of respondents claimed to have been in two collisions. Finally, 11.0% of the sample reported having been involved in three or more collisions. These figures collectively indicate that the majority of respondents (59.8%) have experienced at least one auto accident. Accident Time: The incidents are categorized by time of day in the pie chart on the right. The distribution looks like this: Nighttime accidents comprise the largest group, accounting for 37.9% of reported incidents. 36.6% of all events occur during the day.

## CONCLUSIONS

In conclusion, the Buraidah region's drivers' assessment of nighttime driving conditions focuses on three main areas: the suitability of road lighting, the efficiency of traffic signals and pavement visibility, and a general assessment of lighting conditions. Using a structured questionnaire, the study was able to collect and statistically validate driver responses. A stability coefficient of 253 percent, which indicates strong test-retest reliability, and a Cronbach's Alpha of 0.76, which indicates acceptable internal consistency, validated the instrument's reliability. According to the results, most respondents were happy with the lighting infrastructure as it stands right now. In particular, 75 percent of participants expressed satisfaction with the general lighting conditions in the first section of the evaluation, 77 percent expressed satisfaction with the visibility of traffic signals and pavement markings at night, and 75 percent expressed satisfaction with the overall lighting suitability. These findings imply that lighting is adequate. The data do, however, also point out areas that require improvement. In all three categories, about 25% of respondents expressed dissatisfaction, citing moderate perceptions of safety when driving at night and limited pavement visibility in some areas. These issues highlight the necessity of focused improvements, especially in areas where lighting may fall short of ideal levels. The ARM-ED has suggested the implementation of advanced brightness technologies in response to these findings in order to rectify current issues. The study highlights the increasing popularity of LED lighting, which has been shown to have up to 80% higher operational efficiency than the conventional high-pressure sodium lamps that are still in use in some areas of the Buraidah district. To sum up, the study supports the main goal of assessing and approving a single street lighting system for the Buraidah area. The findings are confirmed by direct driver feedback obtained through an online survey.

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