Analysis of Factors Influencing Walkability Among School Children in India

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Abstract: Ensuring school children's safety during their commute is essential for promoting healthy and active lifestyles. This study examines factors affecting walkability among school children in India, focusing on accidents during school travel. A questionnaire survey gathered 702 responses from states like Kerala, Karnataka, Maharashtra, and Delhi. Descriptive analysis and the Proportional Odds model identified key factors influencing walkability. The findings reveal important insights into students' road safety behavior and their understanding of traffic signs and signals. The data highlights critical issues, such as the absence of sidewalks, poorly marked crossings, and high-traffic areas near schools, which contribute to unsafe conditions. These results underscore the need for strategic interventions like traffic calming measures, school travel plans, and Road Safety Education (RSE) programs. Such initiatives can help build safer, more walkable environments for students, reducing accident risks and encouraging safer travel habits across all age groups.

Keywords: Safety, Walkability, Descriptive, Proportional Odds, Knowledge

1. INTRODUCTION

Walking to school is an important part of childhood, promoting physical health, independence, and social development. However, many children face significant safety risks during their commute due to poor infrastructure, heavy traffic, and inadequate pedestrian facilities. Walkability, the ease and safety of walking in an area directly impacts whether children can travel safely. Factors like the absence of sidewalks, unmarked crossings, and high-speed traffic heighten the risk of accidents, especially for younger children with limited traffic awareness. Understanding these risks is essential for designing safer school routes and reducing preventable injuries.To explore this issue, a survey was conducted across four Indian states namely Kerala, Karnataka, Maharashtra, and Delhi by collecting 702 responses. Descriptive analysis and the Proportional Odds Model were used to examine factors affecting walkability and accident occurrence. The data revealed key contributors to unsafe conditions, such as a lack of pedestrian infrastructure, high traffic volume, and poor road safety knowledge among students. Older children (15–18 years) faced higher accident rates due to increased independence, while younger children (10–14 years) were more vulnerable at crossings due to limited judgment of speed and distance.

The findings emphasize the need for targeted interventions to enhance safety and walkability for school children. Implementing traffic calming measures, creating safe school travel plans, and introducing Road Safety Education (RSE) programs are critical steps. Teaching students road safety rules, improving school zone infrastructure, and promoting community involvement can help build safer environments, reducing accidents and encouraging safer commuting habits.

These changes are vital for fostering a culture of safety and ensuring that every child can walk to school without fear of injury. Studies shows that in high-income countries, between 5% and 10% of children suffering road traffic injuries are pedestrians, while in low-income and middle-income countries, the proportion ranges from 30% to 40%. Traffic crashes are regarded as one of the world's most painful problems, and contribute to the main leading of injuries and fatalities in the 12- 18 age group. Children's behaviour in traffic is shaped by a combination of their knowledge, attitude, and risk perception. Their understanding of traffic rules and safety measures influences how they navigate roads, while their attitude determines their willingness to follow these rules. Additionally, their perception of risk plays a crucial role in decision-making, as children with a low awareness of potential dangers may engage in unsafe behaviours. Therefore, fostering traffic education, promoting positive attitudes, and enhancing risk awareness are essential in ensuring children's safety on the roads. Road safety among school-going children is a significant global concern, especially in urban environments. Walkability, which refers to how friendly an area is to walking, plays a crucial role in shaping children's commuting patterns and their overall safety. Various studies have explored the intersection between walkability, parental perceptions, and children's traffic safety behaviors. This literature review summarizes the current understanding of factors influencing children's road safety, emphasizing the role of walkability, parental perceptions, infrastructure, and educational interventions. Walkability significantly influences children's school commuting behavior, with parental perceptions playing a critical role. Cadima and Pinho (2024) highlighted that parents' fear of car traffic can deter children from walking to school, despite the benefits of active travel. Similarly, Hossen and Zaman (2022) found that children's mode choice, particularly walking, is largely influenced by parents' perceptions of traffic safety. Parents who perceive their neighborhoods as safe are more likely to allow their children to walk to school.Talan and Khalifa (2021) emphasized that traffic infrastructure, such as dedicated walking paths and safe pedestrian crossings, can alleviate parental concerns and promote walking as a viable mode of transportation. Rais et al. (2024) further underscored that inadequate infrastructure and dangerous driving behaviors are significant risk factors for school-aged pedestrian children.

Several studies have investigated the role of infrastructure in enhancing or compromising children's pedestrian safety. Rais et al. (2024) reported that inadequate infrastructure and insufficient signage contributed significantly to pedestrian accidents in urban Algerian settings. Similarly, Riaz et al. (2022) found that road design features such as one-way and two-way streets influence children's crossing behavior, with elevated crosswalks enhancing safety. Lee et al. (2020) developed a School Walkability Index using environmental audit tools and GIS to identify areas requiring improvements. Their findings suggest that supportive environments, including proper road connectivity and reduced vehicular traffic exposure, are critical for promoting children's active school travel. Piragauta (2024) highlighted the importance of community input in improving walkability and road safety infrastructure in Blantyre, Malawi, where high-speed traffic poses a danger to school-going children. Interactive educational programs have shown promise in improving children's traffic safety behaviors. Hammond et al. (2013) demonstrated that interactive video training significantly improves children's crossing behaviors between parked cars, enhancing traffic safety. Similarly, the Safe Kids/FedEx program in the Philippines (Fuente, 2015) combined pedestrian safety education with engineering improvements to create safer walking environments for children. Scott (2014) developed an online pedestrian safety training program in Central Florida, which improved children's risk-taking attitudes and perceptions of pedestrian behavior. Kendi and Johnston (2023) emphasized that community programs promoting independent mobility can contribute to broader strategies like Vision Zero, which aims to eliminate traffic fatalities and severe

injuries among children. While walkable environments are generally assumed to enhance safety, some studies have found conflicting evidence. Rothman et al. (2023) discovered that higher Walk Scores were associated with increased child pedestrian injuries near schools in Canadian cities. They suggested that the built environment's characteristics might contribute to higher injury rates despite the higher walkability scores. This finding highlights the importance of integrating collision risk assessments into school travel planning. The literature emphasizes the need for comprehensive approaches to improve road safety among school-going children. Swami et al. (2024) proposed stakeholder surveys, pedestrian corridor evaluations, and microscopic simulations to provide design-centric solutions that enhance walkability. Armstrong and Petch (2013) developed a hazard assessment framework to systematically evaluate traffic safety hazards along school routes.

Future research should focus on the intersection of infrastructure, education, and parental perceptions to develop integrated interventions. Combining physical improvements with targeted educational campaigns and community engagement can create safer environments for children's school commutes. The reviewed literature highlights that walkability, parental safety perceptions, infrastructure quality, and educational interventions are key determinants of children's road safety behaviors. Addressing these factors through comprehensive policies and targeted interventions can promote active commuting, reduce traffic congestion, and enhance children's physical activity and social interaction. Further research is needed to evaluate the long-term effectiveness of integrated road safety programs and their impact on children's commuting patterns.

2. METHOD

To assess walkability and safety for school children, a detailed questionnaire survey was conducted across multiple regions. The survey collected data on students' walking routes, perceptions of safety, road conditions, and accident history. The analysis was performed in two stages: Descriptive Analysis to summarize key patterns, and the Proportional Odds (PO) Model to evaluate factors influencing walkability and accident risk severity.

2.1 Descriptive Analysis

Descriptive analysis helps to summarize and visualize data, revealing patterns and differences across groups, such as variations in perception levels between genders. This initial exploration provides valuable insights into central tendencies and distributions.

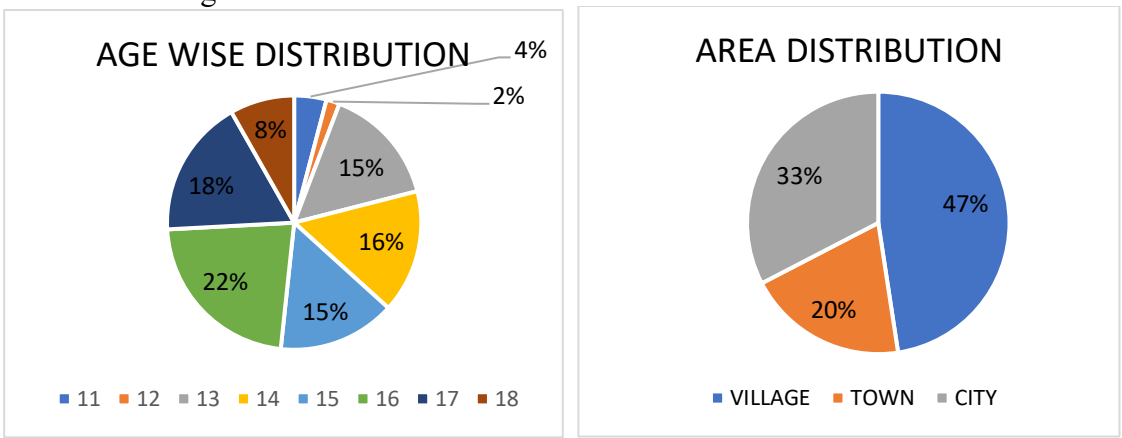

Figure 1 : (a)Age wise distribution (b)Area Distribution

Figure 1 depicts the (a)age wise distribution of selected category of school children. Mostly the students selected comes under the age of 18 years old. Figure 1 (b) represents the Majority of students were from village area followed by town and cities.

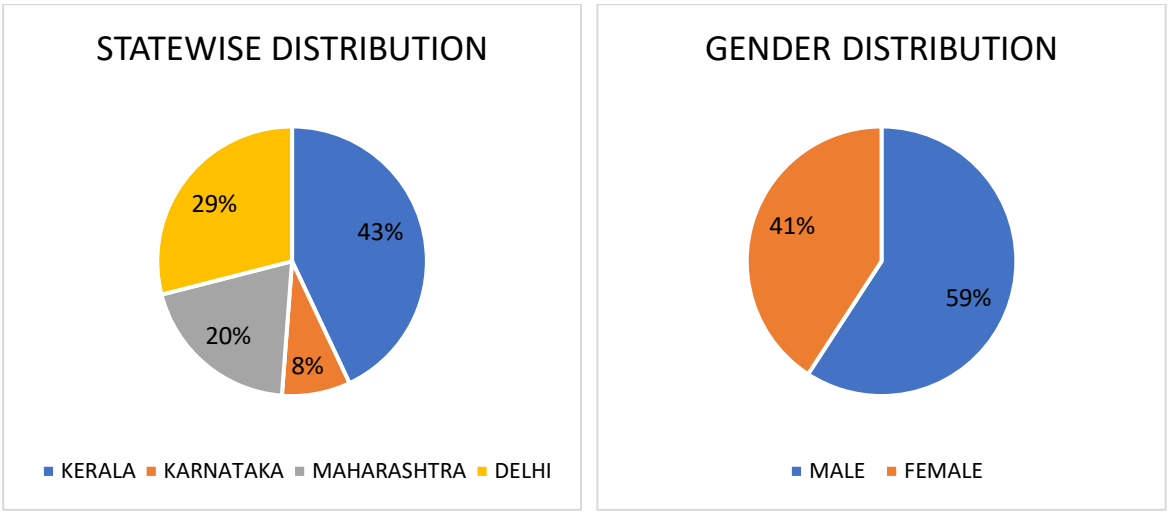

Figure 2 : (a) Statewise Distribution and (b) Gender Distribution

Figure 2 depicts the (a) statewise distribution and (b) gender distribution of the surveyed students. It shows that majority of the data contributed from the state of Kerala followed by Delhi then Maharashtra and Karnataka. Majority of the participants were males than females.

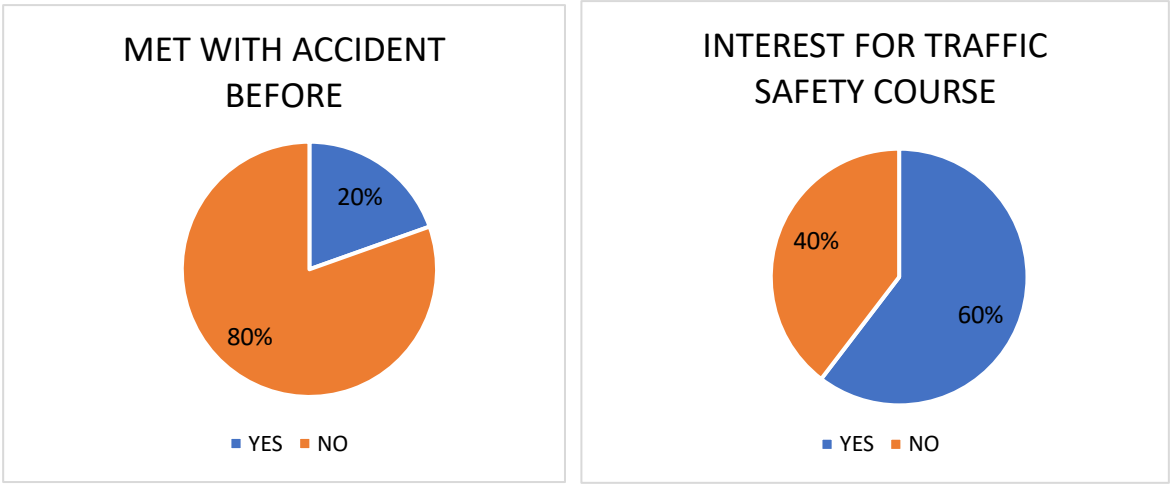

Figure 3 : (a) Met with accident before (b) Safety course interested students

The above figure 3 (a)depicts the details regarding the students who go to schools by walking and aha met with accidents and (b) those students who are interested to study traffic safety courses in their academics.

Since the percentage of student commuters undergone accident is only 20 % it is not a small percentage. Finding the reason and taking necessary steps to reduce the accident rate further is very important. For the same purpose the traffic awareness classes should be provided to the public and school children. From the figure (b) itself it is known that 60% of the students are willing to study more about traffic safety courses in their academic curriculum. Policy makers and educationalists can consider these results for future modifications for academic curriculums.

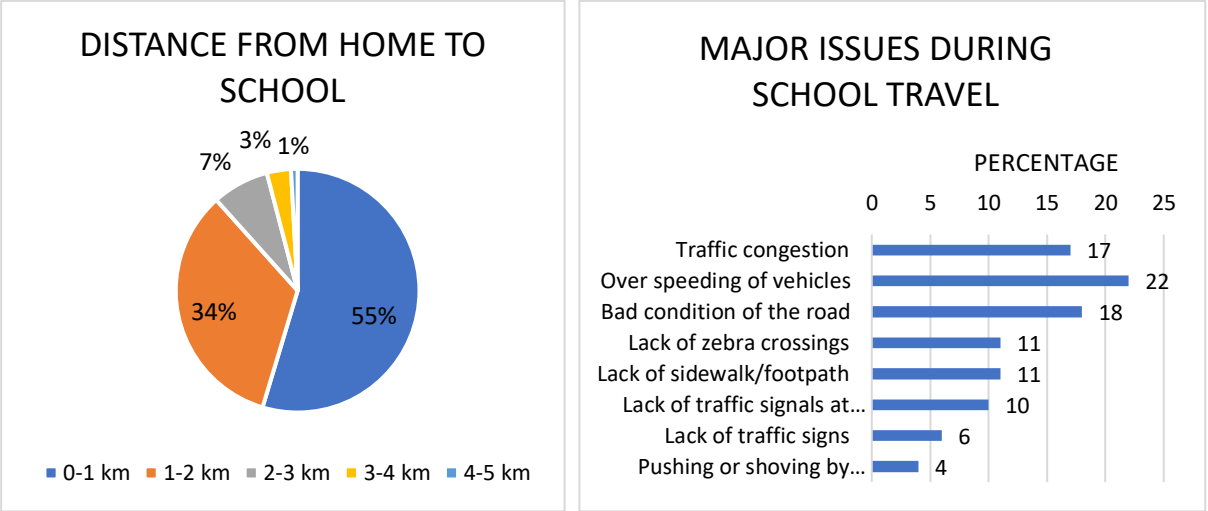

Figure 4 (a) Distance from home to school (b) Major issues during school travel

The above figure 4(a) depicts that about 55% of students who travel by walk take more than 4 km everyday and (b) depicts the major issues the students are facing during their commute to school from home every day. The most weired issue the walking students facing are over speeding of vehicles followed by bad condition of road, traffic congestion and lack of facilities like footpath, zebra crossings, signals etc.

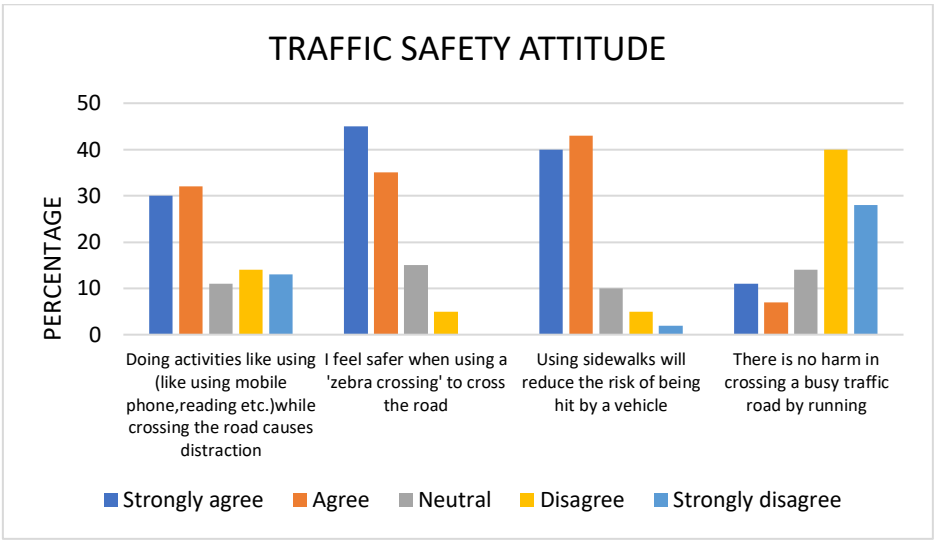

Figure 5 Traffic safety attitude

Figure 5 shows the traffic safety attitude of students who choose their mode as walk for school. The graph indicates that majority of the student commuters feel safer with the presents of facilities like footpath, zebra crossings etc. Running and crossing the roads are safe as per the students concept. But this should be corrected by giving correct awareness classes regarding traffic safety.

The graph in figure 6 illustrates the relationship between gender and average risk perception scores, highlighting a clear difference in perception levels between males and females. Males exhibit a higher average risk perception score, approximately around 4.75, compared to females, whose average score is closer to 4.45. This suggests that, on average, males perceive risks as

more significant or severe than females do. The difference in scores could stem from various factors, such as individual psychological traits, societal expectations, or gender-specific experiences that influence how risks are evaluated. For instance, research often shows that men may feel more vulnerable to certain external threats, while women might assess risks through a different lens, potentially prioritizing different aspects of danger. Understanding these variations is crucial for designing targeted interventions, communication strategies, or safety policies that account for gender differences in risk perception.

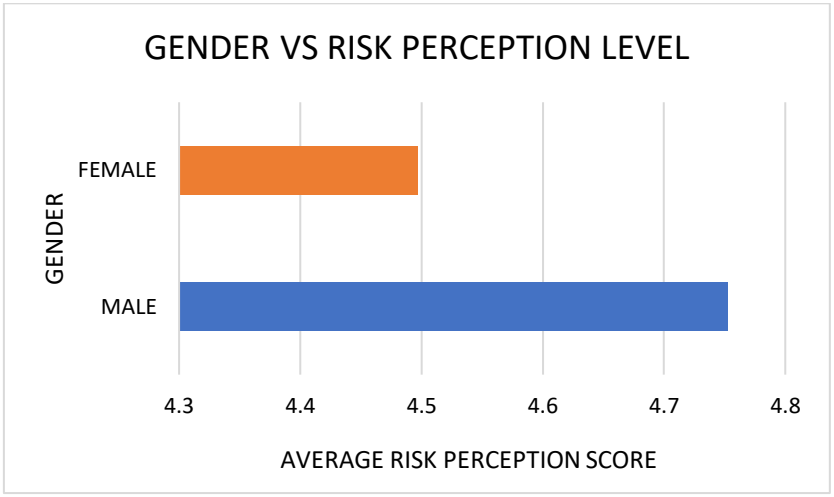

Figure 6: Gender vs Risk perception Level

This insight can help policymakers, businesses, and researchers better address the unique needs of diverse populations, ensuring that risk-related decisions and messaging are both inclusive and effective.

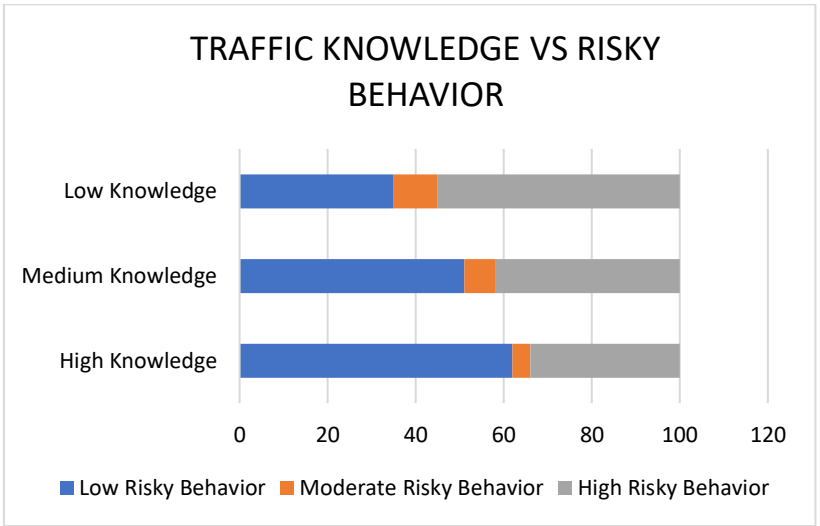

Figure 7 : Traffic Knowledge vs Risky Behaviour

The graph in figure 7, illustrates the relationship between traffic knowledge and risky behavior, showing a clear trend where higher knowledge is associated with safer behavior. Individuals with low traffic knowledge exhibit the highest proportion of high-risk behavior, as represented by the large gray section of the bar. This suggests that people with limited knowledge about traffic rules or safety measures are more likely to engage in dangerous behaviors on the road. A smaller portion of this group engages in low-risk behavior, while a modest fraction falls into

the moderate-risk category. In contrast, individuals with medium traffic knowledge show a shift toward safer behavior: the proportion of low-risk behavior increases, while high-risk behavior decreases compared to the low-knowledge group. However, high-risk behavior is still prevalent, highlighting that moderate knowledge may not be enough to fully deter risky actions. In the high-knowledge group, the distribution changes dramatically, with low-risk behavior dominating the bar, while high-risk behavior becomes the smallest proportion. This indicates that people with greater traffic knowledge are far more likely to adopt safe practices and avoid hazardous behaviors. The minimal presence of moderate-risk behavior in the high-knowledge group further reinforces the protective effect of knowledge. These findings emphasize the critical role of traffic education and awareness programs in promoting safer roads. Targeted interventions aimed at low-knowledge individuals could be especially impactful, helping them understand potential consequences and encouraging behavioral change. Overall, the graph suggests that improving traffic knowledge may be a key strategy for reducing risky behaviors and enhancing road safety.

The graph in figure 8, depicts the relationship between students' age and their risky behavior scores, revealing a general upward trend in risky behavior as age increases. At age 11, the risky behavior score starts relatively low, around 1.9, but rises to approximately 2.3 at age 12. Interestingly, the score dips slightly at age 13, suggesting a temporary decline in risky actions. However, the score fluctuates between ages 13 and 15, with small peaks and drops, indicating variability in behavior during early adolescence. After age 15, there is a more consistent upward trajectory, with scores climbing steadily through ages 16, 17, and reaching the highest point around 2.9 at age of 18.

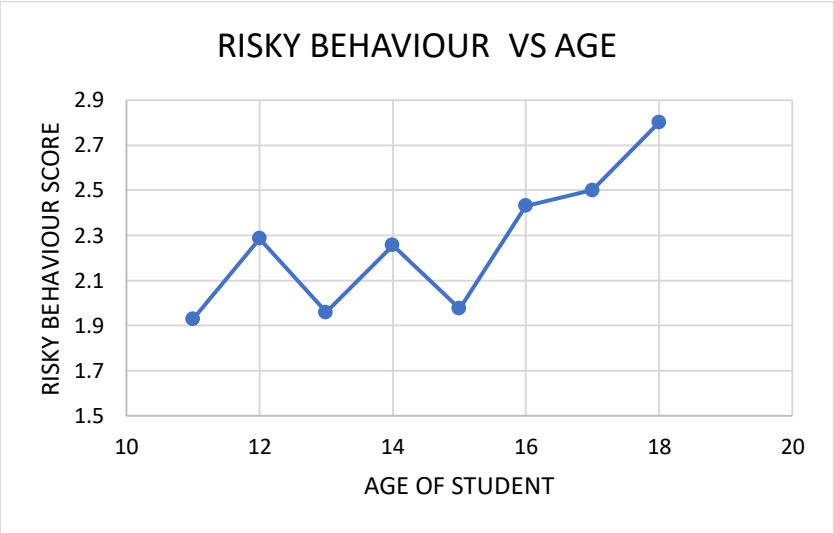

Figure 8 : Risky behavior vs age

This pattern suggests that as students grow older, they tend to engage in riskier behaviors, which aligns with developmental research indicating increased risk-taking during late adolescence due to evolving cognitive, emotional, and social factors. The rising trend may reflect growing independence, peer influence, and heightened sensation-seeking tendencies. Understanding this progression is essential for designing age-appropriate interventions and educational programs to promote safer decision-making as students mature.

The analysis of traffic knowledge, risky behavior, and age patterns among students highlights crucial insights for enhancing school children's traffic safety. The findings suggest that higher traffic knowledge is associated with lower risky behaviors, emphasizing the importance of

traffic education in promoting safer decision-making. However, as children grow older, their risky behaviors tend to increase, likely influenced by peer pressure, growing independence, and a desire for exploration. This highlights the need for age-specific safety interventions that address the unique psychological and social factors influencing adolescents' behavior. Tailored traffic safety programs, starting from a young age and evolving with developmental stages, can reinforce safe practices and help students make informed decisions. Schools, parents, and policymakers must collaborate to implement comprehensive education, practical training, and consistent reinforcement of traffic rules. By fostering awareness, responsibility, and critical thinking, we can empower school children to navigate traffic environments safely, reducing the risk of accidents and building a generation of conscientious road users.

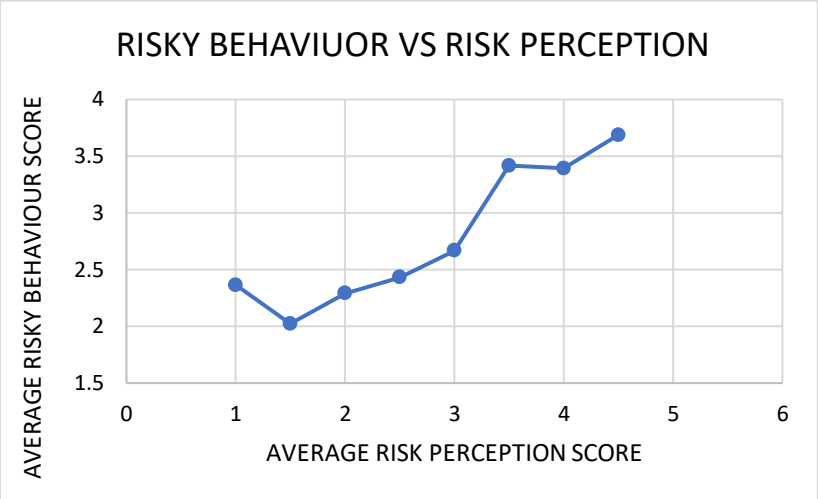

Figure 9: Risky Behaviour vs Risk Perception

The graph in the figure 9 shows the relationship between average risky behavior scores and average risk perception scores. At lower levels of risk perception, risky behavior scores are relatively low but show slight fluctuations. As risk perception increases, risky behavior also tends to rise, with a more pronounced increase after an average risk perception score of around 3. This suggests that individuals with higher risk perception may still engage in risky behaviors, potentially indicating a complex relationship where increased awareness of risk doesn't necessarily lead to reduced risky actions. The trend highlights that perception and behavior may not always align, possibly influenced by other factors like personality, peer influence, or risk-reward evaluations.

2.2 Proportional Odds (PO) Model Analysis

The Proportional Odds Model was applied to quantify how different factors affect walkability and accident risk severity. The model helped determine which variables increased or decreased the probability of walking safely to school without accidents.

The survey gathered insights into school travel safety among students, highlighting key factors like accidents, distance, area type, safety awareness, and observed road facilities. About 16% of students reported experiencing accidents on their way to school, while 49.9% had not, and others fell in between. The ages ranged from 9 to 18, with the majority being between 13 and 17 years old. Most students lived within 1–2 km of their school (28.8% within 0–1 km and 23.4% within 1–2 km), though some traveled over 10 km. Students came from various area types: 31.9% from towns, 19.7% from cities, and 14.2% from villages. Traffic safety

information primarily came from parents, teachers, social media, television, and newspapers, often in combination. Around 14% of students were afraid of traffic, while 51.9% were not. Regarding road facilities, students observed features like speed humps (6.6%), footpaths (5.7%), zebra crossings (4%), and traffic police presence (0.9%). However, some noted the absence of footpaths (25.9%) or zebra crossings (29.6%). Travel issues included factors like heavy traffic, lack of proper crossings, and inadequate safety measures. Overall, the data highlights both the challenges and the existing safety infrastructure around school routes, emphasizing the need for enhanced safety measures and awareness campaigns.

The model's goodness-of-fit tests indicate an excellent fit, with Pearson Chi-Square ($\chi^2 = 1.107$, df = 579, p = 1.000) and Deviance Chi-Square ($\chi^2 = 2.164$, df = 579, p = 1.000) both showing non-significant p-values, meaning the observed and predicted values align almost perfectly. The pseudo R-square values are extremely high, with Cox & Snell $R^2 = 0.898$, Nagelkerke $R^2 = 0.997$, and McFadden $R^2 = 0.988$, suggesting the model explains nearly all the variation in the outcome. While this indicates a strong fit, such near-perfect results might suggest overfitting, complete separation, or data issues like multicollinearity or class imbalance. It's worth reviewing the data and model structure to ensure the results are truly reliable and not a sign of an overly complex model capturing noise rather than general patterns.
The results suggests that the model accounts for a substantial proportion of the variance in the dependent variable. However, such a perfect fit may indicate overfitting, where the model captures not only the underlying pattern but also the noise in the data, potentially compromising its generalizability to new datasets. Overfitting can occur when the model is excessively complex relative to the size of the dataset, leading to an overestimation of its predictive capabilities. Therefore, while the current model demonstrates an excellent fit to the existing data, caution is warranted, and it is advisable to validate the model with new data to ensure its robustness and generalizability.

3. RESULT

The analysis of the age distribution among school-going children commuting by walking indicates that the 13-15 years age group represents the largest portion of the sample population. This group, primarily consisting of students from classes 9th and 10th, exhibits greater independence in their daily commutes. The gradual decline in participation among older age groups suggests that younger students are more prevalent in walking-based commutes, possibly due to proximity to schools or parental restrictions on other modes of transport. This pattern highlights the importance of addressing pedestrian safety concerns within this critical age bracket.

The evaluation of risk perception by gender reveals significant differences in how male and female students assess traffic-related dangers. The descriptive analysis shows that female students consistently reported higher risk perception scores compared to their male counterparts. On average, female students scored approximately 5-10% higher in risk perception, indicating a more cautious approach towards traffic situations. This finding suggests that female students may have a more heightened awareness of road hazards, potentially due to social influences or personal experiences.

The assessment of traffic knowledge among participants indicates a moderate level of understanding of basic traffic rules and signs. Most students correctly identified common signs such as Stop Sign and Traffic Light Signals, which are frequently encountered in daily

commutes. However, a significant percentage struggled to recognize Pedestrian Crossing and Speed Hump signs, reflecting gaps in knowledge related to pedestrian-specific infrastructure. The cross-tabulation analysis further demonstrated that students with higher traffic knowledge scores exhibited fewer risky behaviors, supporting the hypothesis that enhancing knowledge can lead to safer pedestrian practices. This observation underscores the importance of targeted educational interventions to improve knowledge of lesser-known traffic signs.

The analysis of observed and self-reported risky behaviors highlights the substantial influence of social modeling on children's actions. Students who frequently observed adults crossing roads without using zebra crossings or violating traffic rules were more likely to replicate such behaviors. This finding aligns with the concept of subjective norms, where the behavior of significant others influences individual actions. Additionally, the data indicates that students living further away from school reported more risky behaviors, possibly due to increased exposure to traffic hazards along longer routes. These insights emphasize the need to involve parents and community members in road safety education initiatives.

4. DISCUSSIONS

Ensuring the safety of school children who walk to school is a multifaceted challenge that requires addressing infrastructure, education, and policy. Studies have shown that the built environment significantly influences children's active commuting behaviors. Features such as well-maintained sidewalks, traffic calming measures, and clear separation between pedestrians and vehicular traffic enhance safety and encourage walking. Implementing programs like the Walking School Bus, where groups of children walk to school under adult supervision, has demonstrated potential in teaching road safety skills and improving pedestrian behaviors. Educational initiatives, such as the Child Pedestrian Safety Curriculum, are essential in instilling safe walking habits from an early age. However, parental concerns about traffic dangers often hinder children's participation in walking to school. Addressing these concerns through community engagement and infrastructure improvements is crucial. Future research should focus on evaluating the effectiveness of various traffic calming strategies, exploring the impact of technological advancements like connected vehicle data on pedestrian safety, and developing comprehensive policies that prioritize safe walking environments for children.

5. CONCLUSION

The findings from this study provide valuable insights into the road safety behaviors of school-going children who commute by walking. The results indicate that traffic safety knowledge plays a critical role in mitigating risky behaviors among children. However, knowledge alone is insufficient to guarantee safe practices, as external influences such as observed behaviors from adults and peers significantly impact children's actions.

The gender-based analysis suggests that female students exhibit better risk perception, indicating that tailored interventions for male students could further enhance overall safety outcomes. The observed association between distance to school and self-reported risky behaviors highlights the need for localized safety education programs that address the specific challenges faced by students commuting from greater distances.

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