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Towards Safer Primary School Environments: A Hybrid IRAP-SR4S Tool and Participatory Approach for Pedestrian Schoolchildren Safety – Insights from Algeria

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ABSTRACT

Schoolchildren face heightened vulnerability to traffic accidents due to inadequate infrastructure and poor pedestrian consideration in urban planning. This study investigates risk factors associated with school commuting routes and peri-school environments to inform strategies for mitigating student exposure to traffic-related dangers. Data was collected *via* a questionnaire administered to 1,074 children aged 9-11 years (50.9% boys, 49.1% girls) across twelve Algerian primary schools. The methodology combined road safety assessments using the Star Rating for Schools (SR4S) tool around school vicinities with a participatory approach, capturing children's firsthand commuting experiences. Findings show that over 75% of surveyed children walk to school, with 85% unaccompanied by adults. Spatial analysis reveals that gender-based behavioral differences emerged, with female students demonstrating greater caution during road crossings. Infrastructure evaluations identify critical deficiencies—including absent pedestrian facilities, inadequate signage, and sub-standard road conditions—as primary contributors to elevated risk levels. The SR4S assessment classified school zones into distinct safety categories, ranging from high-risk (1-star) to optimal safety (5-star). This hybrid approach allowed both risk classification near schools and geospatial mapping of danger zones along routes based on children's experiences, extending hazard analysis beyond school perimeters. The findings support planning safer, inclusive school environments and more resilient urban development.

Keywords: Schoolchildren, Road safety, Participatory approach, IRAP-SR4S, Data analysis, Algeria.

INTRODUCTION

Road traffic crashes constitute a significant economic, social, and public health problem, according to the World Health Organization (2024). The WHO further reports that these crashes cause approximately

1.3 million deaths each year, representing the leading cause of mortality among children and young adults aged from 5 to 29 years. Notably, around 93% of all road traffic deaths occur in low- and middle-income countries. Within the African region, the road traffic fatality rate is the highest, and even in high-income countries, individuals from lower socio-economic backgrounds face a greater likelihood of involvement in road traffic incidents (WHO, 2024).

In Algeria, road traffic incidents lead to substantial fatalities and significant socio-economic consequences, costing billions of dinars. Data from 2011 to 2024 (Figure 1) shows an initial rise in road accident victims, followed by a decline in accident frequency between 2014 and 2020, which correlates with the implementation of national road safety brigades (Oulha & Derras, 2023). In 2020, the country experienced a historical low mortality since 1975, with 18,949 accidents, 2,844 deaths, and 25,836 injuries. However, this positive trend reversed in 2021, with the National Road Safety Delegation (DNSR) reporting 22,000 accidents, 3,061 deaths, and 29,763 injuries. Notably, young individuals under 29 years were over-represented in the first seven months of 2021, accounting for 46.30% of fatalities (n = 914) and 58.16% of injuries (n = 11,386). Child fatalities were also significant (DNSR, 2021). While the COVID-19 pandemic and associated lockdowns in 2020-2021 temporarily reduced accident numbers, the upward trend resumed, with 22,980 accidents, 3,409 deaths, and 30,777 injuries in 2022 (National Gendarmerie, 2023), and further increased in 2023 to 24,751 accidents, 3,628 deaths, and 33,995 injuries. Preliminary 2024 data (DNSR, 2024) indicated a continuation of this concerning rise, with a 6.15% increase in injury-causing accidents (26,272), a 3.09% increase in fatalities (3,740), and 35,556 injured individuals.

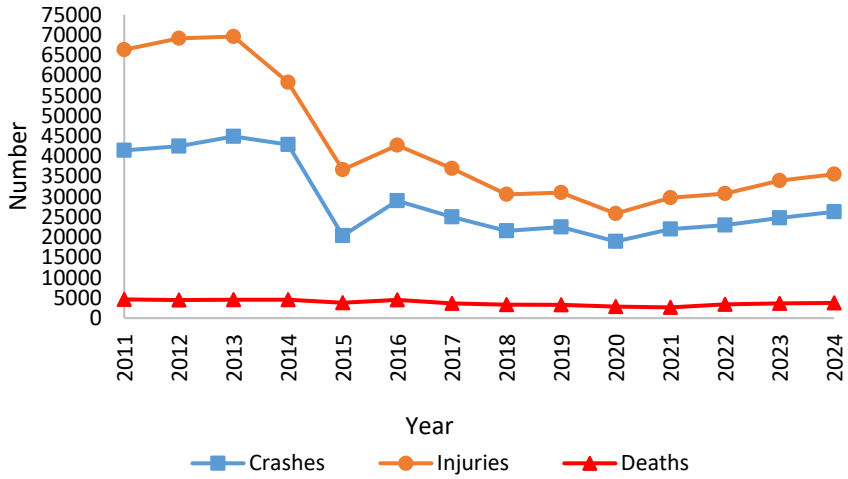

Figure 1. Number of road accidents, injuries, and deaths in Algeria (2011-2024), DNSR (2024)

Road traffic insecurity represents a persistent threat to Algerian children. They are exposed to a constant hazard in the vicinity of their school entrances. They enter and leave the school at the risk of being hit by passing vehicles. Data from the National Delegation of Road Safety (DNSR) reveals an increase in the number of fatalities among children under 14 years of age between 2020-2021 (371 deaths) and 2023-2024 (408 deaths), alongside a substantial number of injuries (4714 in 2023-2024) (DSNR, 2021; DSNR, 2024). These statistics underscore the importance of this issue and emphasize the imperative for sustained interventions aimed at enhancing road safety for children.

The lack of road safety audits and inspections in Algerian school zones exposes children to significant road hazards, hindering advocacy for essential governmental road safety improvements. The International Road Assessment Programme's (iRAP) Star Rating for Schools (SR4S) provides a global framework that has transformed school area road safety assessments. Implemented in 76 countries and evaluating 1940 schools to date, SR4S has demonstrably improved safety outcomes. This system offers a clear and objective methodology for evaluating the inherent safety levels of road design. Relying on evidence-based research, Star Rating for Schools focuses on identifying and documenting road features that contribute to the most common and severe crash types. A key advantage

of the iRAP approach is its capacity to assess road infrastructure safety even without readily available, complete, or easily collected crash data, a particularly relevant feature in many contexts like Algeria (Murozi et al., 2022).

Research in the Philippines by Gomintong and Regider (2022) demonstrated that tools, like SR4S, provide a systematic methodology for assessing pedestrian safety, identifying improvement opportunities, measuring impacts, and effectively communicating results to stakeholders for implementation. Malaysian studies (Hoong et al., 2021) revealed traffic speed as the predominant risk factor near schools, suggesting that institutions located on low-rated roads (1-2 stars) require urgent interventions, including pedestrian infrastructure, speed calming measures, and traffic enforcement. While higher-rated roads (3 stars and above) pose lower immediate risks, they still necessitate ongoing monitoring and improvement strategies to maintain long-term safety amid changing traffic conditions. Regidor et al. (2024) emphasized the necessity of extending programs, like iRAP-SR4S, to local road networks to enable comprehensive safety assessments, particularly around schools and along students' complete commuting routes. Furthermore, the authors raised a significant question regarding the scalability of implementing road safety surveys on a broader scale.

This research introduces an innovative methodology that integrates the iRAP-SR4S tool with child-centered participatory surveys, extending safety assessments beyond school perimeters to include hazardous points along commuting routes. Applied across twelve primary schools, this dual-method approach yields data on children's travel experiences while enhancing strategic road safety planning. The study consequently examines the critical question of:

- Can the daily experiences of children during their school commutes been leveraged to enhance their safety?

While existing data highlights children's particular vulnerability to traffic accidents, research specifically examining school-aged pedestrians remains scarce. Current iRAP studies have primarily focused on arterial roads and highways (Oulha & Derras, 2023; Derras et al., 2022; Tripodi et al., 2020), with only limited recent attention given to school routes (Murozi et al., 2022). These studies have seldom integrated participatory approaches with quantitative risk assessment in low- and middle-income settings. Moreover, in Algeria, such evaluations remain absent, despite the high rates of school-related road incidents. This study addresses these gaps by combining the iRAP-SR4S tool with school children engagement to produce locally grounded, evidence-based recommendations. In doing so, it builds on the methodological foundations of prior work, but extends their application to a context where such data-driven interventions are most urgently needed.

This identified global research gap forms the primary rationale for the present study, conducted in Algeria.

This study pursues three principal objectives: (1) evaluating pedestrian safety conditions in school zones through SR4S methodology to assess existing road infrastructure risks for children under 12 years of age, (2) identifying targeted safety interventions based on current road conditions, and (3) implementing a participatory approach that incorporates children's experiential knowledge of their daily journeys to both inform road safety improvements and develop context-appropriate countermeasures for creating safer school environments.

The remainder of this paper is structured to systematically address the research objectives through six key sections. It begins with reviewing reviews the relevant literature and theoretical framework, establishing the foundation for the study. Then, it details the methodology, including the study area, data collection, and analytical techniques. The key findings, supported by data analysis, are presented thereafter, followed by discussing the implications of the results. Then, the paper acknowledges the limitations and suggests directions for future research, and concludes with a summary of the key takeaways.

MATERIALS AND METHODS

While previous studies that examined school site selection in pedestrian safety assessments most have either relied on convenience sampling or targeted sites with homogenous environmental conditions, limiting the scope for comparative analysis, few have systematically integrated spatial, infrastructural, and mobility-related parameters into their sampling framework—particularly in low- and middle-income settings where traffic exposure and transport options vary widely. This study addresses that gap by applying a clearly defined set of geographic and contextual criteria: (i) inclusion of schools from different administrative districts to ensure spatial representation;

(ii) selection of sites near major high-traffic corridors (RN91, RN91 Bypass, and CW18); (iii) representation of populations where walking is the dominant mode of travel (aim of the SR4S tool: pedestrian school children safety); and (iv) consideration of logistical accessibility for consistent field data collection.

Logistical accessibility was considered as a selection criterion to ensure the feasibility and consistency of field work. Specifically, schools were required to be physically accessible by vehicle or on foot, located in areas that did not pose undue safety risks to the research team, and open to granting the necessary administrative permissions for data collection. Furthermore, the timing of surveys was coordinated with school administrations to align with academic schedules, thereby avoiding disruptions during examination periods or holidays.

Data acquisition for this research spanned from January to March 2023. This temporal framework was established in consultation with school administrations (principals and teachers) to mitigate interference with the academic curriculum.

Study Group and Sample Size: Selection of Children Under 12 Years of Age

The study participants, selected for their capacity to observe their environment, were 4th- and 5th - grade students (aged 9-11 years). Data was collected *via* questionnaires administered to 1074 students within their respective classrooms, which ranged in size from 28 to 41 children. The sample included a balanced gender representation in both grades: 273 boys and 239 girls in the fifth grade, and 274 boys and 288 girls in the fourth grade.

Study Area

This study was conducted in the Daïra (district) of Oued El Abtal, located in the Wilaya of Mascara, Algeria (see Figure 2), through a field survey carried out in 12 primary schools. These schools are located in different areas of the district, distributed as follows, and geographically mapped using GIS (Figure 3):

- Zone 01: Oued El Abtal

Nine (9) schools were selected: Sgheir Belkacem, Bounab Mustapha, Boudlel El Hachemi, Boukhers El Habib, Boulenoir Mohamed, Mokhefi Tayeb, Belegraa Abd El Kader, Ameur Mustapha, and Hassi Mohamed.

- Zone 02: Ain Farah-Oued El Abtal-

Ain Ferrah commune is situated in the southeastern region of the Wilaya of Mascara, approximately 20 kilometers from the Daïra of Oued El Abtal center. In this area, two schools were selected: Arbi Tebessi -Ain Bouras -and El Amir Abd El Kader school.

- Zone 03: Sidi Abd El Djebbar-Oued El Abtal-

This zone is served by a single school, Ain Kouir Abd El Kader.

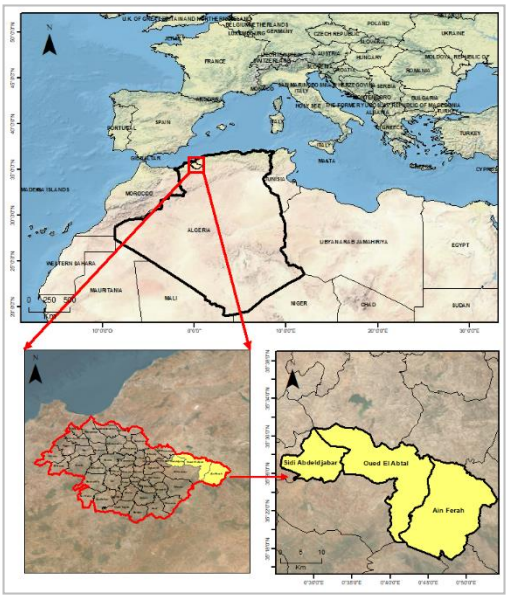

Figure 2. Wilaya of Mascara location and the study area (Oued El Abtal) (source: authors)

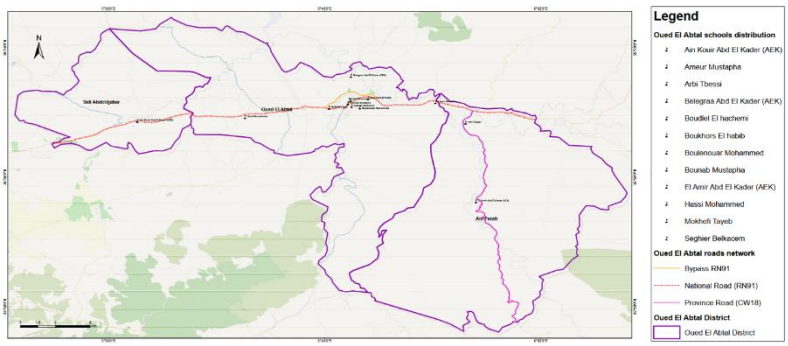

Figure 3. Spatial distribution of the twelve (12) sampled schools in Oued El Abtal district (source: authors)

METHODOLOGY

The research methodology is based on combining the Star Rating for Schools (SR4S) tool from the International Road Assessment Programme (iRAP) and a participatory approach that engages children within urban areas (Figure 4).

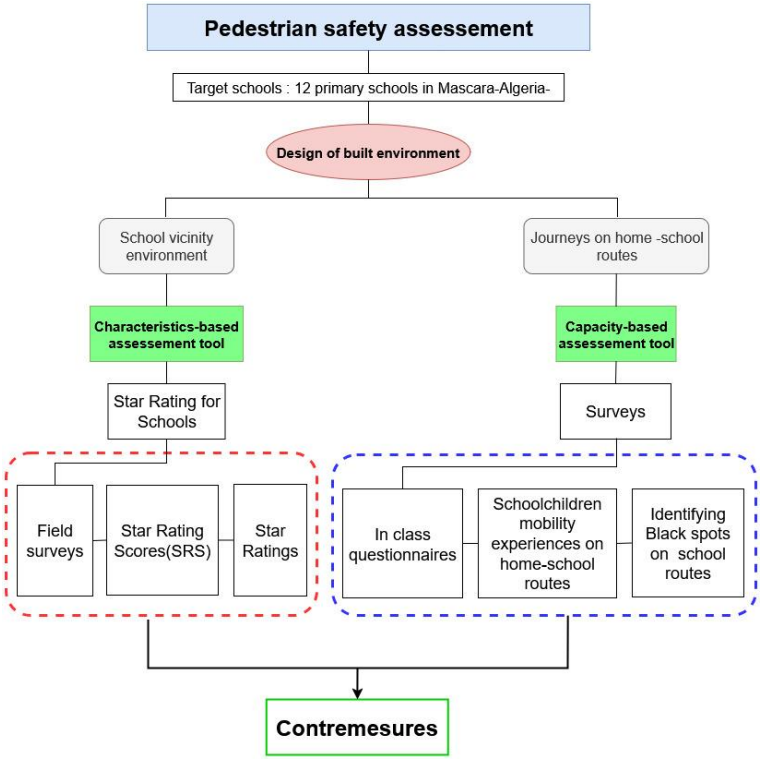

Figure 4. Methodological framework

IRAP-SR4S

The Star Rating for Schools (SR4S) tool has recently been developed by the International Road Assessment Program (iRAP) for the purpose of studying, measuring, and mitigating the risks to which pedestrians are exposed daily. The road risk assessment process, which focuses on a group of road users, is quite simple and is therefore easier to implement by school communities around the world (iRAP).

It is worth highlighting that the SR4S is the first road safety tool. It is evidence-based and helps assess, manage, and communicate the risks that children face as they move between home and school. To use this system, one ought to know road characteristics that may affect pedestrian safety. An evidence-based research approach should be applied in order to investigate the impact of these features on the safety of school children, and to calculate the star rating at some specific point locations. It should be noted that 1 star corresponds to the least safe place, while 5 stars stand for the safest place. Once the risk has been assessed, effective road treatment countermeasures and their impact on safety can then be simulated to identify cost-effective solutions (iRAP; SR4S).

Depending on the road user considered in the study (pedestrians), a Star Rating Score (SRS) is then calculated for each type of potential accident that the road user may encounter, using the following equation:

$$SRS = \sum \text{Accident type scores} \quad (1)$$

Accident type score = Probability x Severity x Traffic speed x Influence of external flows.

Each of the data collected, such as road attributes that affect the likelihood and severity of traffic accidents, school zone warning, intersection type, lane width, number of lanes, pedestrian crossing facilities, pedestrian crossing quality, pedestrian fencing, street lighting, speed management, vehicle parking, sidewalk provision, and median type, has an established risk factor. These risk factors are multiplied to obtain the star rating for each type of accident. In addition, various road

attributes associated with crash modification factors (CMFs) are described in detail in a methodological sheet that is part of the iRAP methodology sheets, as is explicitly described on the website:https://irap.org/fr/methodology/

The calculated star ratings, which depend on the type of road user, are summarized in Table 1.

Table 1. Star rating bands and colors (source: IRAP, 2025)

Star Rating	Star Rating Score				
	Vehicle occupants and motorcyclists	Bicyclists	Pedestrians		
			Total	Along	Crossing
5	0 to < 2.5	0 to < 5	0 to < 5	0 to < 0.2	0 to < 4.8
4	2.5 to < 5	5 to < 10	5 to < 15	0.2 to < 1	4.8 to < 14
3	5 to < 12.5	10 to < 30	15 to < 40	1 to < 7.5	14 to < 32.5
2	12.5 to < 22.5	30 to < 60	40 to < 90	7.5 to < 15	32.5 to < 75
1	22.5 +	60 +	90 +	15 +	75 +

The SR4S tool was selected for this study due to its specific design for the unique context of child pedestrian safety, offering significant advantages in proactive risk assessment, reproducibility, and applicability in data-scarce environments. Unlike reactive crash analysis tools that require reliable historical incident data—often unavailable in low- and middle-income countries—SR4S proactively evaluates road attributes to predict crash risk before incidents occur. Furthermore, while broader tools, like the iRAP methodology, assess various road users, SR4S is a specialized adaptation focused exclusively on school journeys, accounting for child-specific risk factors, such as pedestrian crossings, footpaths, and traffic speeds in school zones. Its standardized, evidence-based methodology ensures reproducibility and accessibility, providing clear, quantitative star ratings that enhance objectivity and replicability compared to qualitative approaches, like Road Safety Audits, which depend heavily on auditor expertise. This makes SR4S particularly suitable for contexts with limited crash data, aligning with the WHO and iRAP Safe System approach to protecting vulnerable road users.

Participatory Approach

Questionnaire. To pinpoint hazardous locations along school routes, a survey utilizing a standardized form was administered to 1,074 schoolchildren. The questionnaire explored students' gender, accompaniment status, travel mode, pedestrian crossing behavior, infrastructure assessment (signage quality, safety fencing, crosswalk availability), and parental safety instructions. The primary aim was to accurately identify black spots identified by schoolchildren during their daily commutes. Before distribution, the questionnaire received approval from teachers and school principals, who, as key intermediaries representing parents, played a vital role in the study's implementation.

Mind Maps. In the absence of official data on student risk zones in the study area, this research employed mental mapping as an alternative methodology. Through interactive discussions, children actively participated in identifying hazardous locations during their daily commutes, providing valuable experiential data to compensate for the lack of formal records. This participatory approach not only mapped perceived danger zones, but also revealed their underlying causes, offering unique insights into road safety from children's perspectives. The technique proved particularly effective in capturing young pedestrians' concerns and generating context-specific risk analysis unavailable through conventional data sources.

- Children were asked to draw and mark locations that they considered significant along their routes (such as roads, residential areas, educational institutions, hospitals, … etc.) and to name these locations accordingly.
- To ensure uniformity across the maps, a standardized legend was implemented. Participants were instructed to utilize two distinct colors: blue to represent their daily road and red to highlight the road dangers that they encounter(see Figure A1).

Given the participants' young age, all of whom were minors under 12 years, protective measures were implemented to secure participants' identities, with a strong emphasis on maintaining privacy throughout the study. Rigorous protocols ensured data anonymity and confidentiality at all stages. This approach fostered a secure environment for children to express themselves without fear of identification. The ongoing commitment to safeguarding personal data highlighted the critical ethical considerations in research involving vulnerable populations.

This structured approach enhances sample representativeness while providing a replicable operational framework for evidence-based interventions in other regions. By integrating a multi-dimensional accessibility assessment, the methodology balances scientific rigor with logistical feasibility, ensuring protocol standardization across diverse sites without compromising data quality or ethical requirements.

Data Processing

The research team employed IBM SPSS Statistics 27 for data entry and analysis, utilizing descriptive statistics, such as frequencies and cross-tabulations, to summarize findings. To explore potential associations between variables, chi-square tests of independence or Fisher's exact tests were conducted where appropriate. A standard significance level of $p < 0.05$ was adopted throughout the analysis to determine statistical significance, indicating a low probability that the observed relationships occurred by chance. These methodological approaches enabled a systematic examination of survey data to identify meaningful patterns and substantiate findings regarding the studied phenomena.

RESULTS AND ANALYSIS

Environment around Schools

Assessment of Roads around the Selected Schools with iRAP-SR4S

Following the assessment of all 12 schools, a risk-based ranking was established. Notably, Hassi Mohamed School, located in the Daira of Oued El Abtal, was classified as a high-risk zone (1-star rating), as shown in Figure 5.

To ensure consistency, all schools underwent standardized analysis, with surrounding roads systematically categorized by risk level and represented in a histogram (Figure 5). Finally, the spatial distribution of the 12 schools, classified by their SR4S ratings (from 1 star to 5 stars), is mapped in Figure A2.

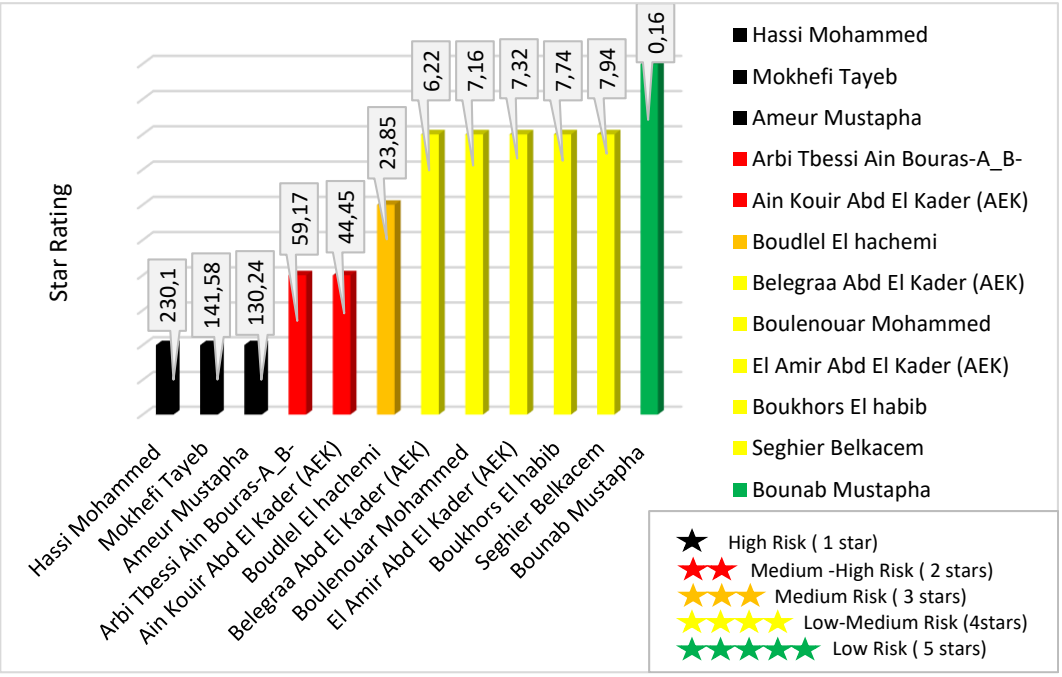

Figure 5. Star rating scores (SRS) and star ratings for each school

Table 2 provides a comparative analysis of the road safety risk factors to which students of the 12 primary schools in Oued El Abtal are exposed. This analysis enabled a precise evaluation of the specific risks

associated with each school, thereby revealing existing disparities in road safety.

Table 2. Road risk benchmarking for Oued El Abtal primary schools (12)

Star Ratings	High-medium risk (1 star and 2 stars)	Low risk (safe routes) (5 stars)
Schools	• Mokhefi Tayeb • Hassi Mohammed • Ameur Mustapha • Arbi Tbessi -Ain Bouras -A_B- • Ain Kouir Abd El Kader (AEK)	• Bounab Mustapha
Risk factors/safety indicators	• Missing signs and road markings • Unregulated parking • Insufficient or non-existent sidewalks • Lack of pedestrian crossings • Speeding • Unregulated commercial activity (sidewalk obstruction) • Poor road conditions	• Proper school-zone signage (signs/road markings) • 30 km/h speed limit signage • Adequate and continuous sidewalk width • Clear and visible pedestrian crossing markings • Road surfaces in good condition

School Commutes (Home-School) Survey Data Analysis Using SPSS

Participant Profile

The study sample demonstrated near-equal gender balance, with males representing 50.9% (n=547) and females 49.1% (n=527) of the 1,074 participants. This equitable distribution ensures robust comparative analysis of gender-specific perspectives and experiences, eliminating potential bias from sample imbalance while enhancing the reliability of findings regarding sex-based differences in school commute safety perceptions.

Schoolchildren's Mobility on the Home-School Commute. Children's school mobility is significantly shaped by various factors, notably gender. This variable influences travel modes, road crossing behaviors, and accompaniment patterns, underscoring disparities in students' commuting experiences and safety conditions, as detailed in Table 3.

Table 3. Children's school mobility on the home-to-school commute by gender (cross-tabulation)

	Male N(%)	Female N(%)	Total N(%)	Chi-square (P-value)	Fisher exact test (P-value)	Cramer's V-value
Schoolchildren accompaniment						
Friends	310(28.86%)	320(29.80%)	**630 (58.7%)**	**15,756[a] (0.000)**	**15,785 (0.000)**	**0.121**
Alone	172(16.01%)	115(10.70%)	**287(26.7%)**			
Adult	65(6.05%)	92(8.56%)	**157(14.6%)**			
Travel mode choices (Home-school routes)						
School Bus	101(9.40%)	96(8.93%)	**197(18.3%)**	**3.217[a] (0.370)**	**3,328 (0.351)**	**0.055**
Walking	404(37.60%)	404(37.60%)	**808(75.2%)**			
Car	40(3.72%)	25(2.32%)	**65(6.1%)**			
Urban transit	2(0.19%)	2(0.19%)	**4(0.4%)**			

Crossing behaviors						
Ensuring safety before crossing the street	397(36.96%)	400(37.24%)	**797(74.2%)**	**4,789[a] (0.094)**	**4,790 (0.094)**	**0.067**
Seeking help from an adult	82(7.63%)	83(7.72%)	**165(15.4%)**			
Making a quick crossing of the street	68(6.33%)	44(4.10%)	**112(10.4%)**			
Crossing locations						
At the pedestrian crossing	127(11.82%)	136(12.66%)	**263(24.5%)**	**1,164[a] (0.566)**	**1,165 (0.563)**	**0.033**
At any location	382(35.56%)	359(33.42%)	**741(69.0%)**			
At the police officer's location	32(2.97%)	38(3.53%)	**70(6.5%)**			

Schoolchildren accompaniment. Data analysis revealed that walking is the predominant mode of school travel for the surveyed student population, with nearly three-fifths (58.7%, N=630) preferring to walk with peers, while approximately a quarter (26.7%, N=287) walked unaccompanied, and a smaller proportion (14.6%, N=157) were supervised by adults. Statistical analysis confirmed a significant gender-accompaniment association (χ^2/Fisher's $p<0.001$), though with modest effect size (Cramer's V=0.121), indicating a weak, but meaningful, relationship between these variables in students' commuting practices.

School travel mode choice. Transportation modes among study participants were analyzed (Table 3). The majority of pupils (75.2%, n = 808) reported walking as their primary travel mode. The second most common mode was the school bus, used by 18.3% (n = 197) of the students. Parental car transportation accounted for the remaining 6.1% (n = 65), while public transit usage was minimal (0.4%, n = 4), contingent upon parental approval. A statistical analysis demonstrated no significant correlation between sex and mode of transportation (P=0.370/P=0.351 > 0.05), demonstrating that gender does not affect students' travel mode preferences.

Schoolchildren's behavior during school commutes. As shown in Table 3, the majority of pupils (74.2%, n = 797) demonstrated cautious behavior by waiting for a clear road before crossing. In contrast, 15.4% (n = 165) sought adult assistance, while a minority (10.4%, n = 112) crossed without observing traffic. A chi-squared test indicated no significant correlation between gender and crossing behavior (χ^2 = 3.217, P = 0.094 > 0.05), suggesting that gender did not affect students' road crossing habits.

Schoolchildren's road crossing locations. Crossing locations analysis (Table 3) showed that 69.0% of the students (n=741) crossed at unauthorized locations, while only 24.5% (n=263) used designated pedestrian crossings. A small minority (6.5%, n=70) crossed under police supervision. The statistical analysis revealed no significant correlation between gender and the selection of crossing location (P = 0.566 / P = 0.563 > 0.05).

The overall behavioral mobility patterns are summarized in the histogram presented in Figure 6.

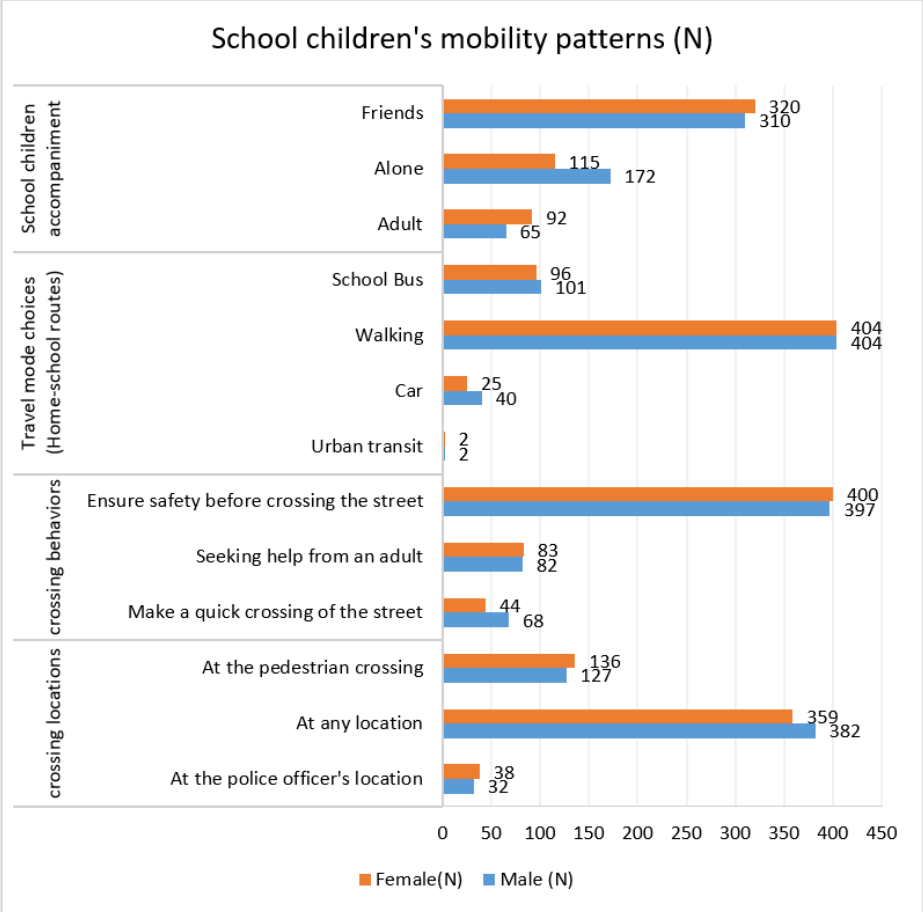

Figure 6. Schoolchildren's mobility patterns by gender

Assessing Road Safety in School Environments: Parental Guidance, Infrastructure, and Student Experiences

The survey assessed both the availability of pedestrian infrastructure near schools (including crosswalks, safety barriers, and crossing guards) and parental provision of road safety education during school commutes, as shown in Table 4.

Table 4. Distribution of students' identified road safety guidance and facilities around schools

		Frequency	Percentage(%)	Total (%)
Do your parents provide you with road safety guidelines before leaving home?	**No**	0	0	0
	Yes	1074	100	100
Is there a protective fence (safety barrier)in front of your school?	**No**	1074	100	100
	Yes	0	0	0
Do students perceive the presence of a school crossing guard as a positive safety measure?	**No**	0	0	0
	Yes	1074	100	100
Is there an adequate pedestrian infrastructure, such as crosswalks, to ensure student safety in front of the school?	**No**	178	16.6	100
	Yes	896	83.4	

All participants (N=1074) reported receiving road safety instructions from their parents prior to going to

school. Conversely, the absence of safety barriers was a notable gap in student protection. The need for school crossing guards was acknowledged by all students participating in the study, especially during peak hours of school traffic. As for pedestrian crossings, 83.4% of the students reported their existence, while 16.6% (n=178) indicated their absence.

Identification of High-risk (Black Spots) Areas on School Routes

Analysis of perceived travel hazards (Table 5) reveals that students in Oued El Abtal primarily identified major roadways (RN91, CW 18, and RN91 bypass) as high-risk zones, with 70.2% (N=754) considering these primary corridors as accident-prone areas for various reasons (see Table 6). Less frequently cited were specific risks associated with areas near the school (4.5%), markets/town hall (2.4%), bus stops (1.3%), and bridge/river (1. 1%). Notably, 20.5% of the respondents reported no travel-related risks, suggesting potential under-estimation of road hazards, possibly due to limited exposure (short commutes) or adult supervision. (see Figure A3).

Table 5. Distribution of students' identified high-risk (black spots) areas

		Frequency	Percentage	Valid percentage	Cumulative percentage
Valid	National road RN91, departmental road N°18, and the RN91 bypass	754	70,2	70,2	70,2
	No response	220	20,5	20,5	90,7
	Curve towards the school	48	4,5	4,5	95,2
	Market – Town Hall	26	2,4	2,4	97,6
	Bus stop	14	1,3	1,3	98,9
	Bridge-River	12	1,1	1,1	100,0
	Total	**1074**	**100,0**	**100,0**	

Risk Criteria Defining Hazardous Areas

The analysis of Table 6 reveals that students' perceptions of road hazards are largely shaped by infrastructural and behavioral factors, with 11.7% (n=126) citing the lack of road signage and pedestrian crossings, 5.1% (n=55) highlighting inadequate or obstructed sidewalks, and 3.2% (n=34) reporting poor road conditions, such as narrow, slippery, or deteriorated surfaces. Risky behaviors by other road users, including speeding (29.5%, n=317), reckless driving (12.2%, n=131), and heavy traffic (16.2%, n=174), were also prominent concerns. Additional factors mentioned include insufficient traffic calming measures (1.1%, n=12), limited visibility (2.0%, n=21), and minor references to issues like the absence of school crossing guards (0.2%, n=2), roadside commercial activity (0.7%, n=8), and the general risk of accidents (2.1%, n=23). Interestingly, 15.9% (n=171) of the students reported perceiving no dangers, potentially attributable to a subjective sense of safety stemming from familiarity with their environment. (see Figure A5).

Table 6. Statistical distribution of risk indicators in student-identified black spots

		Frequency	Percentage	Valid percentage	Cumulative per centage
Valid	Lack/Insufficient signage	126	11,7	11,7	11,7
	Poor road conditions	34	3,2	3,2	14,9
	Lack of sidewalks/Sidewalk obstruction	55	5,1	5,1	20,0
	Reckless driving	131	12,2	12,2	32,2

	Lack of speed bumps	12	1,1	1,1	33,3
	Commercial activity	8	0,7	0,7	34,1
	Poor visibility	21	2,0	2,0	36,0
	Speeding	317	29,5	29,5	65,5
	No response	171	15,9	15,9	81,5
	Heavy traffic	174	16,2	16,2	97,7
	Absence of school crossing guards	2	0,2	0,2	97,9
	Accident risk	23	2,1	2,1	100,0
	Total	**1074**	**100,0**	**100,0**	

Assessment of Student Perspectives on Road Safety Enhancements in Oued El Abtal

To foster student engagement, an open-ended question solicited suggestions for improving road safety near the selected schools (response rate: 49.2%, n=528). As presented in Table 7, responses primarily advocated for improved road signage (38.6%, n=415), followed by requests for crossing guards (7.4%, n=80) and enhanced school transportation (1.2%, n=13). Additional suggestions included stricter traffic law enforcement (0.6%, n=6) and infrastructure maintenance (1.1%, n=12). (see Figure A6).

Table 7. Statistical distribution of student-suggested road safety measures

		Frequency	**Percentage**	**Valid percentage**	**Cumulative percentage**
Valid	Add a school bus	13	1,2	1,2	1,2
	Assign a school crossing guard	80	7,4	7,4	8,7
	Add signage	415	38,6	38,6	47,3
	Respect traffic rules	6	0,6	0,6	47,9
	Road/bridge rehabilitation	12	1,1	1,1	49,0
	Parental accompaniment	2	0,2	0,2	49,2
	No response	546	50,8	50,8	100,0
	Total	**1074**	**100,0**	**100,0**	

DISCUSSION

School Environment

Road Safety Assessment around Schools Using iRAP-SR4S

Figure 5 indicates that three (03) areas can be considered as high-risk locations (1 star). Two areas; i.e., Arbi Tbessi (A-B) and Ain Kouir Abd El Kader, have a 2-star rating, while another area; i.e., Boudlel El Hachemi, has a medium risk rating with 3 stars. Five (05) areas have a 4-star rating i.e., Belegraa Abd El Kader (AEK). Finally, the last one (01) place; namely, Bounab Mustapha have a 5-star rating.

It is worth indicating that the frequent accompaniment of Boudlel El Hachemi School pupils by parents is driven by significant safety concerns arising from hazardous environmental conditions, including proximity to the high-traffic RN91 national road and an unsecured river crossing. Despite this 3-star-rated school zones, its exhibit systemic safety deficiencies: inadequate pedestrian infrastructure (missing sidewalks, poor lighting), absent traffic calming measures, and heavy commercial encroachment forcing pedestrians onto roadways. The combination of high-volume traffic along RN91, sub-standard road maintenance, and unregulated parking creates particularly hazardous conditions that necessitate parental intervention for child safety.

The spatial distribution of these high-risk areas is further influenced by the location of studied schools along major transportation corridors, including National Road RN91, its bypass, and Wilaya Road (CW18) (Figure 3). Within this context, speeding—particularly on RN91—emerges as a critical aggravating factor (with 29.5%). This problem is perpetuated by the absence of traffic-calming measures, such as speed limit signs, road

markings, and safe pedestrian crossings near school zones. These areas experience high pedestrian traffic, especially during school arrival and dismissal times.

Winter conditions introduce an additional complexity, including rain, fog, and inadequate public lighting, severely impairing visibility for both drivers and pedestrians. The root cause of this issue can also be attributed to insufficient school infrastructure in certain localities, particularly newly developed urban areas. Despite ongoing rehousing initiatives, the lack of coordinated planning for educational facilities and supporting infrastructure (Ouedraogo & Bonnet, 2019) remains a persistent gap, leaving schoolchildren in these areas exposed to preventable dangers.

Assessment and Benchmarking of Road Safety Risks in the Vicinity of Primary Schools

The assessment contrasted high-risk (1 star and 2 stars) and safe (5 stars) schools, exemplified by Bounab Mustapha (Table 2). Despite its proximity to major arterial (RN91)—a factor typically associated with elevated risk—this school achieved high safety ratings due to the implementation of multiple protective measures. Key contributing factors included the installation of standardized traffic control devices (e.g., 30 km/h speed limit signage, road markings, speed bumps), the presence of traffic guards during peak school hours, clearly demarcated pedestrian crossings, and adequately dimensioned sidewalks complemented by well-maintained roadway conditions.

The star ratings range from 1 star to 5 stars is determined by the level of 'built-in' road safety. The safest roads (4 stars and 5 stars) incorporate safety features appropriate for prevailing traffic speeds, unlike the least safe roads (1 star and 2 stars). The latter necessitate immediate attention and the implementation of road safety interventions to achieve a minimum of 3 stars. Following iRAP's methodological guidelines on star rating bands, the 3-star rating is considered to represent 'a reasonable balance between providing a safe environment and setting a design standard that, while challenging, is also achievable and delivers a positive return on investment in most cases.' This target is particularly crucial for low- and middle-income countries, where financial resources allocated to infrastructure development remain limited (Regidor et al., 2024).

Home-School Commute

The National Center for Safe Routes to School and iRAP define school zones as the roadways immediately surrounding an educational institution, typically extending one to two blocks (SRTS Guide, 2025). However, a thorough analysis of school safety, encompassing both the school's immediate environment and students' complete commute routes, requires a participatory approach. This methodology is crucial for understanding the multi-faceted nature of school journeys that extend beyond the conventional school zone perimeter.

Participatory Approach

According to the Global Plan for the Decade of Action for Road Safety 2021–2030, young people are critical to shaping future transport systems, as they are both the most affected by road traffic fatalities—the leading cause of death among those aged from 5 to 29—and the generation that will bear the long-term impact of present-day mobility decisions (Global Plan for Road Safety, 2024). Their meaningful engagement can foster a new cohort of safety advocates with innovative perspectives on mobility. Estiara Ellizer et al. (2023) emphasized the importance of incorporating youth needs and experiences into policymaking, while Oulha et al. (2016) demonstrated the value of participatory approaches in identifying hazardous zones on Algerian roads. The present study applies this participatory model to schoolchildren, recognizing their potential to contribute to safer school environments through their daily experiences. Supporting this view, a study by Varma (2021) found that when children were empowered to co-design their school streets; they proposed inclusive, safe, and accessible solutions that improved urban livability for all.

Drawing on insights from prior research, this study engaged schoolchildren within the Oued El Abtal region as key participants in order to reconnect them with their environment. Through narrative-based methods, participants described their daily experiences and identified hazardous areas along their school routes (80% of the sample). These qualitative accounts were validated *via* field surveys, enabling systematic analysis and spatial representation of the data. Employing a frequency-based mapping approach within a GIS framework (ArcGIS software), the findings were visualized to highlight 'black spots' reported by children,

spatially contextualizing their perceived safety concerns (see Figure A4).

Children's Behavioral Patterns on School Routes and Recommended Countermeasures

Pedestrian behavior constitutes a significant risk factor for severe traffic injuries and fatalities, primarily through improper crossings, traffic signal violations, and inattentiveness, with studies documenting prevalent dangerous practices including roadway waiting, signal disregard, undesignated-zone crossings, and distraction (Poó et al., 2018; Mohammed, 2021). In the context of this study's locations, children, due to a lack of control, exhibit unpredictable behavior, whether alone or in groups, with divided attention affecting their crossing safety. Furthermore, children tend to over-estimate their abilities and, in their pursuit of independence, often resist adult supervision near traffic.

The analysis revealed critical behavioral patterns that directly inform road safety policy. Explicitly connecting these observations to proposed countermeasures demonstrates how each intervention constitutes a targeted response to a specific, data-supported issue, as summarized in Table 8.

Table 8. Observed behavioral patterns, inferred risks, and proposed countermeasures

Observed Behavioral Pattern (Finding)	**Interpretation & Inferred Risk**	**Evidence-based Countermeasure**
69.0% (n=741) of the students crossed at unauthorized locations.	Indicates a severe mismatch between infrastructure (crosswalks) and pedestrian desire lines. Children opt for the shortest path, perceiving designated crossings as inconvenient, which forces them to cross unpredictably and increases conflict risk.	**(1) Install protective infrastructure** at identified desire lines: **marked or raised pedestrian crossings** and **pedestrian refuges, speed bumps near the school's entrance**. **(2) Enforce parking restrictions** near corners to improve sightlines.
10.4% (n=112) crossed without observing traffic.	Demonstrates risk-taking behavior and a potential developmental underestimation of danger, likely exacerbated by distraction or peer influence in groups.	**(3) Conduct targeted awareness campaigns** focused on risk perception and "stop, look, listen" procedures. **(4) Foster driver compliance** with lower speed limits **(5)** to increase reaction time.
Observed Behavioral Pattern (Finding)	**Interpretation & Inferred Risk**	**Evidence-based Countermeasure**
58.7% (n=630) walk with peers; 26.7% (n=287) walk unaccompanied.	A high proportion of children without adult supervision are exposed to risks. Group dynamics can lead to imitative risk-taking behavior (e.g., following a child who darts into the road).	**(6) Establish designated school crossing guards** at high-risk intersections to provide supervised crossing. **Implement "Walking School Bus" programs** (Godillon & Cloutier, 2018) to structure group travel under supervision, a model Algeria should consider given the prevalence of unaccompanied child pedestrians.
75.2% (n=808) reported walking as their primary mode.	Highlights the critical importance of a safe pedestrian environment around schools. The sheer volume of child pedestrians necessitates a "Safe System" approach that prioritizes their protection.	**(7) Ensure pedestrian infrastructure continuity** via accessible, unobstructed sidewalks. **(8) Prioritize roadway maintenance** to prevent tripping hazards and ensure clear paths. **(9) Implement prominent 30 km/h speed limits** to reduce impact forces. This not only protects them from road traffic but also promotes the walking mode of travel as a safe and viable option.
15.4% (n=165) sought adult assistance while crossing.	While positive, this indicates a dependency that may not always be available. It also points to a perceived lack of safe and autonomous crossing options.	The countermeasures listed above (crosswalks, crossing guards, traffic calming) will empower children to cross safely independently, reducing this dependency. **(10) Integrate risk perception training into school curriculum.**

The countermeasures proposed in Table 8 are not isolated solutions but are intended to work synergistically. For example, a new marked crosswalk (1) is more effective when combined with a lower speed limit (5), better enforcement (2, 4), and awareness campaigns (3). A coordinated effort combining

preventive education with practical engineering and enforcement safeguards is essential for achieving a holistic and sustainable reduction in child road accidents.

Travel Mode Influence on Road Accidents

As highlighted by Godillon and Cloutier (2018), parents are responsible for determining their children's mode of travel to school, a decision often shaped by their financial situation. According to the World Health Organization, socio-economic status significantly influences children's exposure to traffic-related risks during daily commutes (Peden & WHO, 2008). Studies showed that children from households with access to a vehicle are less likely to walk or cycle (Lewis & Terres, 2010), and in developed countries, those transported by car face lower accident risks compared to pedestrian or cycling peers (Roberts et al. 1995; Sonkin et al., 2017). Conversely, children commuting with siblings or friends are more vulnerable to road hazards. In Algeria, this pattern persists, with car ownership largely limited to wealthier families, while approximately 75.2% of the surveyed students walk to school, providing firsthand accounts of daily road dangers encountered during their regular commutes.

Walking to School: A Benefit for Children, A Challenge for Safety

Data indicates that 75.2% (N=808) of participants, equally distributed by gender (37.6%, N=404 each), primarily walk to school, an activity beneficial for child health and autonomy that should be encouraged, aligning with public health initiatives in developed nations. However, this prevalence occurs within a context of significant risk. These findings directly align with the observation by Siddique (2025) who stated that pedestrian comfort and safety are compromised by street fatalities, narrow roads, disorganized on-street parking, and inadequate infrastructure. This is particularly critical for children, for whom road environments, designed for adults and vehicles, are often ill-suited to their cognitive and physical limitations, including reduced visibility and difficulty judging speed and distance. The absence of adult supervision for a significant number of children further heightens these risks.

Based on Siddique's (2025) argument, a concentrated effort is needed to prioritize people over cars, a principle that is especially urgent in school zones. The participatory approach's value lies in leveraging children's experiential knowledge gained from navigating these challenges to enhance their safety and provides a foundational step for this re-prioritization. In this spirit, Siddique (2025) identifies that the assessment of current walkability and pedestrian infrastructure as a crucial first step.

This assessment is not merely about safety; it is also about highlighting the substantial benefits of walking as a primary mode of transportation. By evaluating these conditions, policymakers and stakeholders can better understand the need for and establish priorities for increasing walkability. The long-term goal is to utilize this data-driven understanding to balance pedestrian circulation of schoolchildren with vehicular traffic in urban settings, ultimately creating accident-free zones and ensuring sustainable safety in Algeria. This process is essential for promoting a healthier, more sustainable, and human-centric urban environment, where the benefits of walking can be reaped without compromising the safety of its most vulnerable users.

Combined Methodology: iRAP and Participatory Approach

This research employs a novel mixed-method approach, integrating site-level and route-level assessments to comprehensively evaluate pedestrian safety for school-aged children. The site-level analysis utilizes the SR4S tool, augmented by field surveys, to objectively assess infrastructure deficiencies in the immediate vicinity of schools, identifying high-risk zones. Conversely, the route-level analysis employs a capability-focused assessment, using classroom questionnaires and students' mobility experiences to capture their safety perceptions and travel challenges, uncovering hazardous areas often missed by traditional audits. This combined methodology provides a holistic understanding of the issues by triangulating objective infrastructure data with the subjective experiences of vulnerable users, thus enabling the effective targeting of countermeasures that address both physical infrastructure design and behavioral considerations specific to young pedestrians.

Risk Factors Influencing Schoolchildren's Safety

At the route level, school mobility analysis reveals that transportation modes, road-crossing behaviors, and accompaniment patterns significantly influence children's exposure to risk during their commutes.

However, a site-level perspective is equally essential, as localized environmental features—such as traffic calming measures, road conditions, and the presence of parking zones—further affect safety. Field assessments conducted at the twelve surveyed schools revealed critical infrastructure shortcomings: eleven lacked central medians or hatched areas, increasing the risk of head-on collisions; six were connected by deteriorated roads; and five had no school zone signage to alert drivers. None of the schools had protective barriers or crossing guards to assist students, leaving unaccompanied children particularly vulnerable. These findings expose a fundamental disconnect between road infrastructure and the specific safety needs of children. Current urban planning practices assume children can adapt to environments designed for adult users, overlooking their cognitive limitations and developmental vulnerabilities. As a result, children face elevated risks due to inadequate infrastructure, such as missing sidewalks, pedestrian crossings, proper lighting, and age-appropriate signage, forcing them to walk on roadways, cross at unprotected intersections, and traverse poorly lit areas, all of which heighten the danger of traffic-related accidents.

STUDY LIMITATIONS AND FUTURE ORIENTATIONS

While this study advances understanding of key risk factors for schoolchildren's pedestrian on school, several limitations should be acknowledged. These constraints, along with promising avenues for future investigation, are outlined below:

- The IRAP-SR4S methodology assessment assigned a five-star rating to five educational institutions located in Oued El Abtal. However, this evaluation does not preclude the persistence of significant road safety infrastructure needs, particularly regarding the implementation of basic road markings, speed limit signs, and other safety devices. These methodological limitations inherent to the IRAP tool underscore the necessity for further investigation and methodology refinement to ensure the robustness and accuracy of final ratings.
- Achieving a comprehensive representation of the studied school population necessitates the inclusion of primary schools not initially sampled, through combined SR4S surveys and a participatory approach. This crucial methodological extension will strengthen both the generalizability and validity of the study's findings.
- For the effective implementation of a school-aged pedestrian safety assessment project at a meaningful territorial scale, encompassing both local and national levels, institutional stakeholder engagement, particularly with road safety authorities and territorial assemblies (municipal and wilaya), emerges as an essential methodological step. Such collaboration should promote the standardization of student safety evaluation procedures and facilitate the concrete implementation of identified improvements.
- This study aims to assess the impact of interventions on star ratings and star rating scores of targeted schools in Oued El Abtal through subsequent evaluation. To further enhance this analysis, future research could pursue comparative studies of pre- and post-intervention data within these same schools.

The integration of a post-intervention evaluation framework is essential for assessing the long-term sustainability and impact of the study's findings, thereby significantly enhancing its practical relevance. While the current research focused on baseline risk assessment, the methodological framework is designed to support longitudinal follow-up once safety measures are implemented. Such evaluation could involve repeating the same field surveys and risk scoring protocols (Star Rating Scores /Star Rating) to quantify changes in pedestrian safety, complemented by observational and community feedback data. This would allow for direct comparison between pre- and post-intervention scenarios, thereby assessing the effectiveness of specific measures and informing evidence-based policy adjustments. We consider this an important direction for future research to consolidate the study’s applied impact.

CONCLUSIONS

Recognizing road traffic accidents as a major global issue, with Algeria facing a considerable yearly occurrence, this study utilized the SR4S tool and a participatory methodology to evaluate pedestrian safety for 1074 children (aged 9-11) across twelve Algerian primary schools. The findings indicated significant variations in risk, with school zones categorized as follows: three high-risk (1-star), two moderate-risk (2-star), one medium-risk (3-star), five low-medium-risk

(4-star), and one high-safety (5-star) zone. High-risk areas were characterized by critical infrastructure deficits, including insufficient crossings, inadequate signage, and flawed urban planning in proximity to major roadways (RN91, RN91 bypass, and CW18), alongside behavioral factors such as a high percentage (75%) of unaccompanied child pedestrians and increased vulnerability among boys when crossing roads. Spatial analysis, incorporating child-participatory mapping and validated by field surveys, extended beyond school perimeters is essential to identify black spots on school routes.

While these findings are context-specific to the studied region, the methodological framework and underlying mechanisms identified hold broader relevance. The observed determinants and patterns are not unique to the local setting but reflect structural and behavioral dynamics likely present in comparable contexts. Thus, although absolute values may vary across regions, the insights generated provide a transferable basis for guiding interventions in similar socio-demographic and infrastructural environments. Furthermore, the application of these standardized tools and protocols enhances the potential for replication and cross-regional comparison, thereby supporting a cautious, but meaningful, generalization of the findings beyond the studied area.

Addressing these complex issues necessitates a multidimensional strategy that integrates interventions targeting both individual behaviors and the built environment. Prioritizing urban design modifications tailored to children's pedestrian needs and implementing robust public awareness campaigns are crucial. Therefore, a collaborative, evidence-based approach that actively integrates students' perspectives into decision-making is a societal imperative for enhancing the safety of school-aged pedestrians in public spaces, ultimately fostering safer and more inclusive urban environments that support their independent and secure mobility.

Declaration Regarding Generative AI and AI-assisted Technologies

During the preparation of this work, the author used DeepL Gemini and Deepseek in order to improve the readability and language of the manuscript. After using this tool/service, the author reviewed and edited the content as needed and takes full responsibility for the content of the published article.

Statement of Informed Consent

Informed consent was obtained from all individual participants included in the study.

Conflict of Interests

No potential or actual conflict of interests was reported by the authors.

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APPENDIX

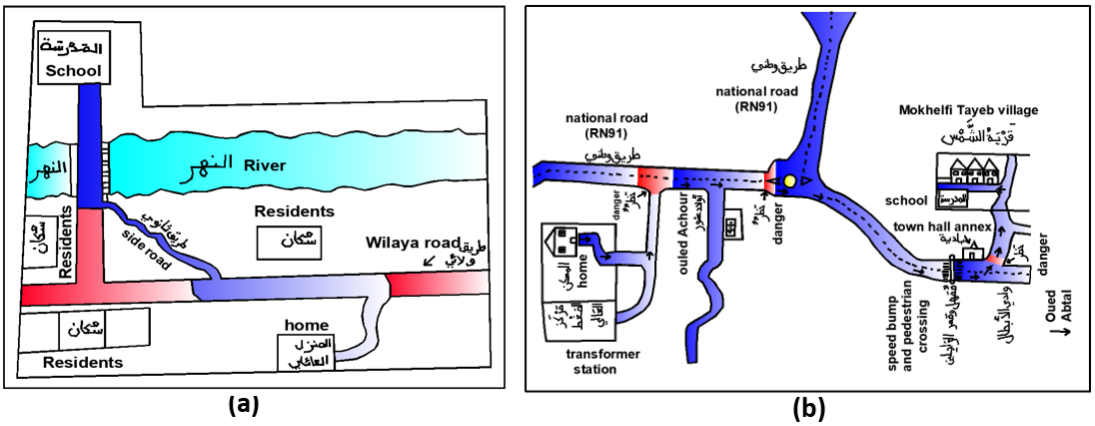

Figure A1. Mind maps drawn by students (source: authors)

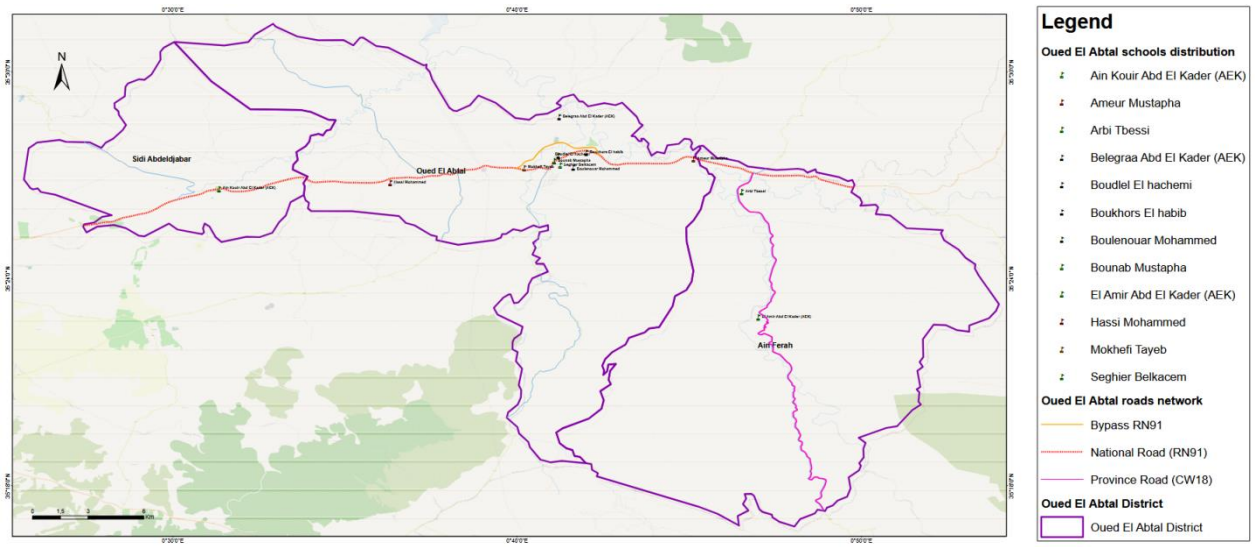

Figure A2. Spatial distribution of road star ratings in the vicinity of the 12 schools of Oued El Abtal (source: authors)

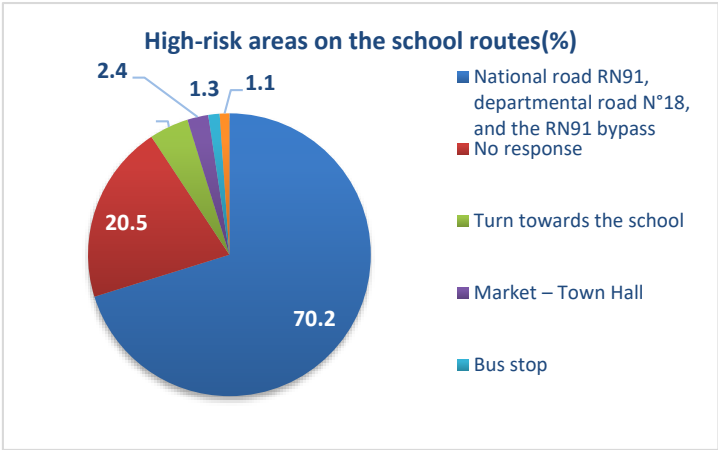

Figure A3. Distribution of child-reported black spots on home-school routes

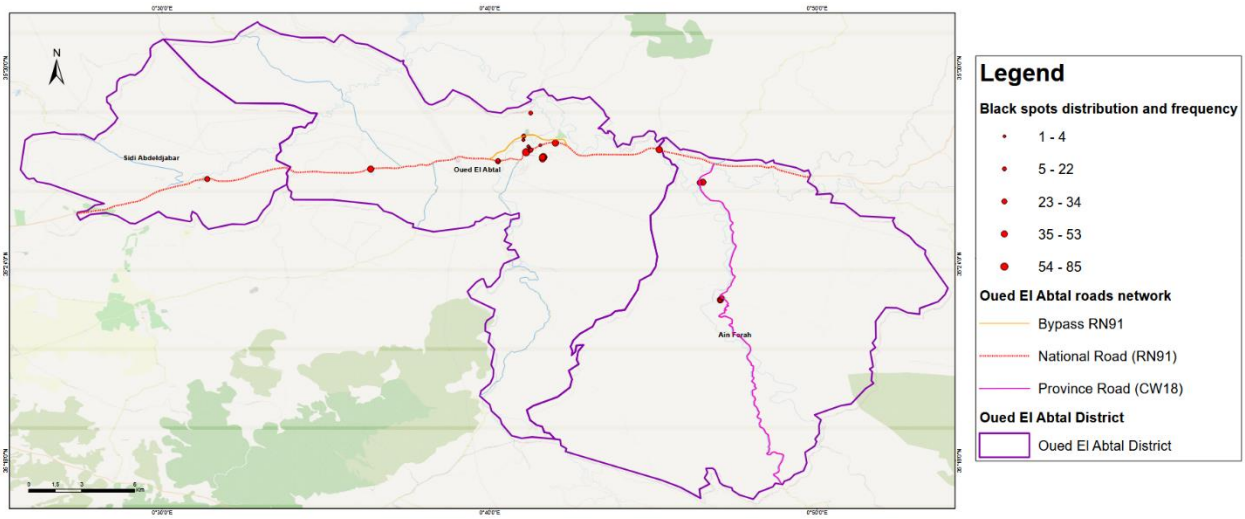

Figure A4. Frequency-based distribution of identified blackspots along school routes (source: authors)

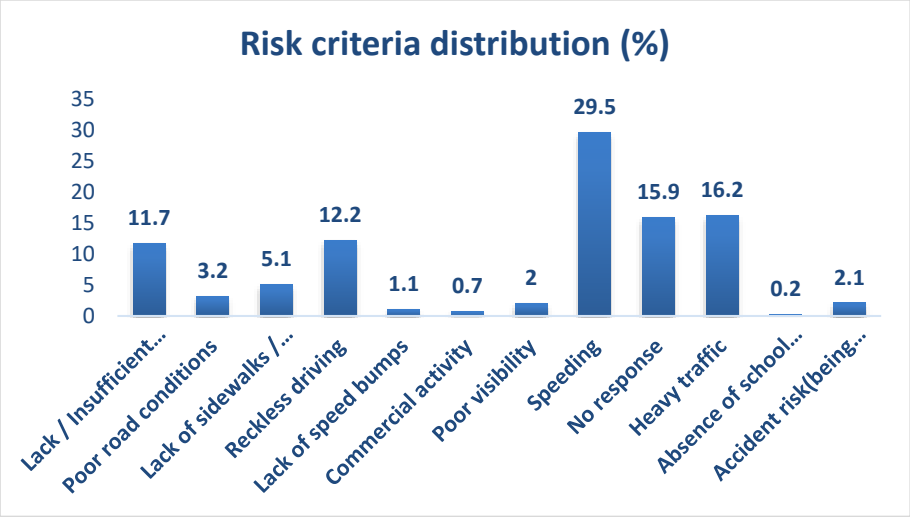

Figure A5. Risk criteria distribution identified by students

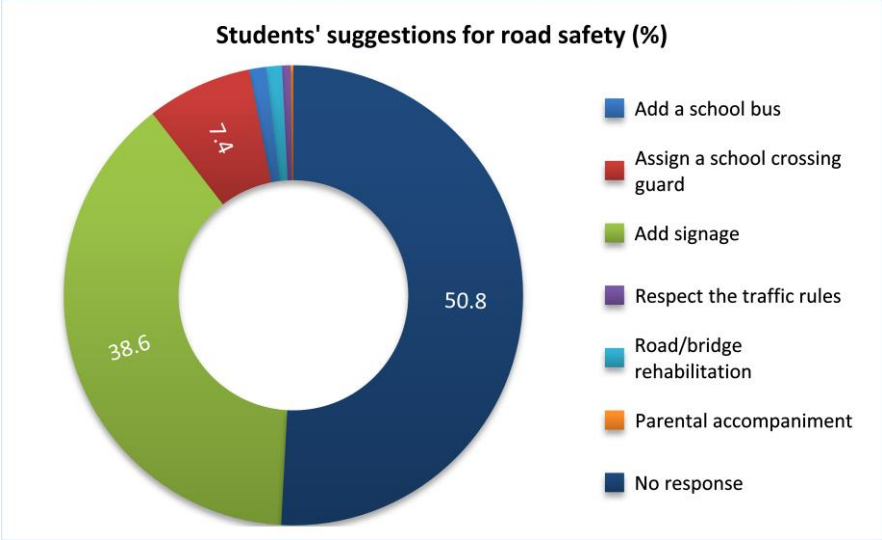

Figure A6. Distribution of student suggestions regarding road safety

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