

# Evaluation of Road Safety at School Zones Using the iRAP Star Ratings for Schools Tool: The Case Study of Arnavutkoy, Istanbul

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## ABSTRACT

Worldwide, road traffic injuries are a leading cause of death and disability among children aged 15 to 19 and rank as the second leading cause of death for those aged 10 to 14. In 2022, there were 1,232,957 crashes on Türkiye's road network, according to the Turkish Statistical Institute. Among all such crashes, 197,261 caused death or injury. The purpose of this study is to investigate and analyze road safety surrounding schools in Istanbul's Arnavutköy area. This study deploys the iRAP Star Rating for Schools (SR4S) methodology. A field survey of 10 schools in the Arnavutköy, Mustafa Kemal Paşa Neighborhood and a road safety inspection were conducted, determining the star rating for each school. Effective and evidence-based infrastructure interventions were proposed to reduce road risks and increase road safety around these schools. The results showed that road safety around schools should be improved. As the star rating results demonstrate, 6 schools fell below the star rating of 3 stars, and among them, 4 schools were even below 2 stars, indicating a higher risk for vulnerable road users. Implementing and sustaining a long-term strategy for street design that prioritizes children requires a collaborative effort from different organizations and stakeholders. The findings of this study can be utilized in other locations to assist authorities in improving and upgrading the road infrastructure for safer routes to schools.

*Keywords-road safety; sustainable mobility; vulnerable road users; school zones*

## I. INTRODUCTION AND LITERATURE REVIEW

Road traffic injuries remain a leading cause of death among children and the youth, particularly those aged 5-29 [1]. Statistics from the Turkish Statistical Institute indicate over 1.3 million traffic crashes in 2023, with an average of 6,548 deaths and 350,855 injuries, disproportionately affecting vulnerable road users, including children, who account for 39.9% of the total road accident deaths [19].

In this context, school zones require targeted road safety interventions. Children are among the most vulnerable pedestrians due to their physical and cognitive limitations, which hinder their ability to accurately judge traffic risks. Their heightened exposure in urban environments and near educational institutions necessitates enhanced protective measures.

This study aims to examine and evaluate the level of road safety in school zones within the Mustafa Kemal Paşa Neighborhood of Istanbul's Arnavutköy area, with a particular focus on protecting child pedestrians. Set against the broader

context of increasing urbanization and rising road traffic risks in growing areas, like Arnavutköy, the study uses the SR4S tool, developed by the International Road Assessment Program (iRAP). SR4S is an evidence-based, technology-driven methodology that assesses the safety of road environments around schools by assigning a safety rating from 1 to 5 stars, where 1 star represents the most dangerous conditions and 5 stars the safest. By applying this tool to ten school zones, the research provides critical insights into infrastructure-related safety gaps and potential interventions. The significance of this study lies in its potential to inform scalable, data-driven solutions that can be replicated in similar urban settings globally to safeguard vulnerable road users, particularly children.

### A. Road Safety Importance to Protect Vulnerable Road Users

According to the latest statistics by the Turkish Statistical Institute, in 2023, an average of 644 road traffic crashes occurred, resulting in death or injury, with 18 deaths and 961 injuries reported every day. Compared to the previous year (2022), the total road motor vehicle traffic increased by 8.5%,

the total crashes by 6.6%, the crashes involving death or injury by 19.2%, the crashes resulting in material loss by 4.2%, the number of people killed by 25.2%, and the number of people injured by 21.5%. Vulnerable road users accounted for 39.9% of the total road accident deaths, while children aged 0 to 17 accounted for 10.1% of all traffic crash deaths [19].

Children are particularly vulnerable for several reasons: their low cognitive ability to estimate vehicle speed and distance, their shorter height compromises visibility, and their increased probability of being unaccompanied near traffic [2]. Furthermore, most fatal pedestrian injuries in children take place within a short distance of their schools [3]. The vulnerability of child pedestrians is also reflected in global commitments, such as the first and the second United Nations Decade of Action for Road Safety 2011-2020 and 2021–2030 [4], and the Sustainable Development Goals 3 and 11 [5]. Sweden's Vision Zero strategy, launched in the late 1990s, encapsulates the Safe System and envisions a future with no fatalities or major injuries [6]. It acknowledges that speed is a crucial element in injury severity since the chance of pedestrian

fatalities increases considerably when speeds exceed 30 km/h [7].

B. iRAP SR4S Tool and its Application

The SR4S tool serves as a scientifically validated, evidence-based methodology developed by the iRAP to evaluate road safety for child pedestrians in school zones. It was designed to fill a critical gap in road safety evaluation by providing a practical tool that can identify dangerous environments and prioritize improvements [8]. The program's global reach, reliability, and applicability increased with worldwide assessments [9]. Using field data from school areas, SR4S assesses more than 40 road attributes, as shown in Figure 1, which are then analyzed using a model that computes a star rating for each location, ranging from 1-star (high risk) to 5-star (very safe) [10]. The tool assumes that children walking to and from school should never be exposed to speeds exceeding 30 km/h, especially where pedestrian and vehicle paths intersect [11]. A pedestrian struck by a vehicle traveling at 30 km/h has a 90% chance of survival, while the survival rate drops to less than 50% at 45 km/h [12].



Fig. 1. SR4S road attributes.

The SR4S tool adopts a standardized, evidence-based, and data-driven methodology that offers significant advantages over conventional assessment approaches, which frequently rely on consultant-led evaluations that may be cost-prohibitive and lack flexibility. Its capacity to model the projected impact of proposed interventions before implementation enhances strategic decision-making and facilitates more effective allocation of resources.

The successful application of the SR4S tool, which improves road safety around schools, has been demonstrated. In Armenia, targeted interventions, such as speed reductions, upgraded signage, and pedestrian-activated signals, increased school zone ratings from as low as 1.5 stars to over 5 stars [13]. In Nepal, authorities achieved similar results, with star ratings rising from 1.0 to over 4.0 after implementing high-visibility zebra crossings, speed-calming measures, and a 30 km/h speed limit [14]. In Colombia, the SR4S tool was used under Bogotá's Vision Zero initiative to assess risk and implement improvements, resulting in a 2-star safety increase for local students [15]. In Iran, multiple studies validated SR4S's effectiveness compared to traditional consultant assessments and documented star rating upgrades in several schools, including a jump from 1 to 4 stars [16, 17]. Similarly, in Bangkok, the tool highlighted ongoing high-risk areas with 1- and 2-star roads, emphasizing the need to meet the WHO's proposed 3-star minimum for school zones [18].

Despite the growing adoption of tools like SR4S, being applied in more than 74 countries, the literature on localized applications of school zone safety evaluation remains limited in Türkiye.

The Ministry of Interior, under the Turkish Road Traffic Law, has developed regulations to enhance road safety in school zones [20]. However, these mandates have often lacked uniform implementation. Despite this, Türkiye has made national and international commitments to improving school road safety. As part of its pledge to the Worldwide Initiative for Safe Schools (WISS), Türkiye aims to ensure that all schools become safe learning environments. This aligns with Vision 2050, which promotes sustainable mobility, safe roads, and livable public spaces. A lack of road safety physical infrastructure persists in many urban school zones. Furthermore, enforcement of speed limits in school areas remains inconsistent, often depending on local governance capacity.[16]

Road safety in school zones is a key topic in transportation. Wider shoulders and lanes, flashing beacons at speed limit signs, and fewer driveways reduce crash frequency [25]. The effectiveness of various traffic control devices (e.g., signs, flashing beacon) has been assessed. However, there is a lack of research proposing innovative operational and engineering countermeasures that could significantly improve safety in school zones [29].

The effects of reducing speed limits from 50 to 30 km/h in school zones were analyzed. The results showed that fatal and injury collisions decreased by 45.3%, and injuries to vulnerable road users by 55.3%. Additionally, for every 1 km/h reduction in mean speed, fatal and injury crashes were reduced by

approximately 4% [26]. Posted speed limits are usually 30 km/hour at most schools, but many drivers exceed these limits. Bolder interventions are needed to effectively reduce speeding around schools [28]. Other studies focused on special trends of road traffic crashes and found that road traffic injuries are higher in commercial areas compared to residential areas [30].

Infrastructure and traffic calming measures improve safety, though their effectiveness varies by region. Safety interventions are promising but need ongoing monitoring. There is still a shortage of long-term studies and tailored solutions for low- and middle-income countries [27].

## II. METHODOLOGY

The Mustafa Kemal Paşa neighborhood was selected as the study area within Arnavutköy, given its status as the neighborhood with the highest density of schools (both public and private), with a total of ten schools. Site assessment of Arnavutköy Belediyesi includes 38 neighborhoods and is served by 90 schools.

To conduct an SR4S assessment, a ViDA account and a project within the SR4S platform were created. Before data collection, users are required to complete formal training on the SR4S methodology according to the SR4S Coding Manual [10].

The data is organized hierarchically in the following structure: Project → Schools → Surveys → Locations.

The first step is to create a project form that includes all schools to be assessed. Then, to access the Data tab and create a new Survey, linking it to the schools being assessed. After that, creating new locations takes place, and for each location, which is the entrance of each school, the following information is recorded:

- The GPS coordinates the location.
- At least three images from each location show the road environment, including road signage, marking, speed management measures, and road infrastructure (i.e., lanes, road condition, medians, safety measures)
- Field data collection and recording of the road attributes specified by the SR4S tool.

Road attribute data, as specified in the SR4S Coding Manual, included more than 40 variables collected at school entrances. Data were collected on weekdays when schools are open. These attributes include land use, area type, vehicle parking, sight distance, number of lanes, lane width, presence of rumble strips, road condition, road grip, grade, type of road median (if any), lines and signs, street lighting, school warning, crossing supervisor, sidewalks presence and width, road edge condition, pedestrian crossing facility presence and quality, vehicle daily flow, pedestrian presence, presence of driveways, presence and quality of intersections (if any), presence and quality of curves (if any), speed limit, operating speed, speed management, and percentages of motorcycles and heavy vehicles. Most of these attributes are recorded through site visits and field observations. For the vehicle flow, an approximate methodological count based on the iRAP data

collection methodology was carried out. A 15-min count was conducted at each location, the results were multiplied by 40, and the data were recorded to the nearest 100 integer. Only motorized vehicles were recorded, including cars, heavy vehicles, buses, and motorcycles. The operating speed, though, was recorded based on driving along the road under consideration, following the actual speed of existing traffic passing the school entrance. For the remaining attributes, the star rating for the school manual specifies in detail the options and the coding procedure for each attribute.

After that, each location was submitted to be reviewed by iRAP engineers (SR4S Quality Reviewer). Upon the approval of each location, a star rating and score were calculated automatically. Finally, the iRAP SR4S demonstrator was used to change road attributes to reach optimum solutions that could lead to an evidence-based improvement with a higher new calculated star rating.

### III. RESULTS AND DISCUSSION

The findings of this study were based on the in-depth field assessment of the 10 schools in the Mustafa Kemal Paşa neighborhood of Arnavutköy using the SR4S methodology. Overall, the star rating and score results are presented in Table I, while Table II depicts the Star Rating Band, and Table III displays pictures from each school entrance.

TABLE I. RESULTS OF STAR RATINGS AND SCORES

School Name	Star rating	Decimal star rating	Improved decimal star rating	SRS (before)	SRS (after)	Reduction in FSI
İBB Pireis ilkokulu	3	3.5	3.8	15.3	12.9	30%
Martyr Selçuk Gürdal Anatolian	1	1	1.3	276.6	150	45.7%
Cemal Reşit Rey İlkokulu	1	1	3.7	446.7	12.2	97.3%
Mehmet Akif Ersoy Ortaokulu	1	1.5	3.9	115.4	3.9	92%
Şht. Corporal Murat Şengöz Primary	3	3.9	5.4	9.5	1.6	83%
Anafartalar Middle School	3	3.7	3.9	12.9	10	22.5%
Rehberlik ve Araştırma Merkezi	2	2.8	3.1	28.6	21.7	24.1%
MAVİGÜN KOLEJİ	2	2.8	3.3	27.9	18.3	34.4%
Private İlkseç Diriliş	1	1.9	2.6	67.7	34	49.8%
Neşeli İzler Anaokulu	3	3	3.6	23.6	14.9	36.9%

A particularly critical issue in Arnavutköy Schools was non-compliance with the speed management measures. Despite the official 20 km/h or 30 km/h speed limits, actual operating speeds ranged between 50–60 km/h at several schools. This directly contradicts Safe System principles, which highlight that pedestrian survival drops significantly at speeds above 30 km/h [7, 12]. The SR4S attribute “Operating Speed” proved to be a major contributor to low safety scores across all schools.

Furthermore, the absence of pedestrian channelization or fencing, poor visibility at crossings, and inadequate road markings were dominant factors influencing low star ratings. These observations reflect global concerns highlighted in the WHO and Cities4Children reports, which underestimate the need for vibrant crossings, clear signage, and sidewalk protection as non-negotiable for child pedestrian safety [1, 2].

Pedestrian fencing can be installed on the side of a road or within the median to restrict pedestrian access to the roadway, hence reducing conflict between motor vehicles and

The SR4S web application used data from 40 parameters for each school [32] to determine the star ratings and scores at the assigned location (i.e., school entrance).

Out of the ten schools evaluated, six obtained ratings below three stars, with four receiving ratings below two stars, suggesting unacceptable dangers to children and pedestrians and a non-compliance with WHO recommendations for school road safety. According to the SR4S score scale and the safe system principles, any school zone with a rating less than three stars requires immediate attention [31]. The most worrying result was at Cemal Reşit Rey Primary School, which received one star and a Star Rating Score (SRS) of 446.7, indicating extreme danger for pedestrians, well beyond the safe exposure threshold proposed by iRAP (i.e.,  $446.7 \gg 22.5$ ), as illustrated in Table I [10].

For the Martyr Selçuk Gürdal Anatolian site, the inspection showed that the curve quality was poor and that vehicles parking on the roadside limit the ability of drivers to detect pedestrians, especially young children; therefore, the proposed improvements were limited and the star rating scores could not be improved to 3 or more unless major re-design works are done.



pedestrians. Fencing is frequently utilized to lead people to a selected official crossing place while discouraging pedestrians from making risky crossing actions where sight is limited. Implementing this measure ensures an estimated potential causality reduction that ranges between 25% and 40% [20].

TABLE II. STAR RATING BAND

Star rating band	SRS	Notes
	22.5 +	The most dangerous road
	12.5 - < 22.5	
	5.0 - < 12.5	
	2.5 - < 5.0	
	< 2.5	The safest road

These findings follow the global patterns observed in countries with rapid urbanization but limited school zone traffic governance [13, 14, 16].

TABLE III. SCHOOL ENTRANCE LOCATION

School name and coordinates	Google earth view of school
İBB Pirireis ilkokulu 41°11'23.41"N, 28°43'26.51"E	
Martyr Selçuk Gürdal Anatolian 41°11'24.17"N 28°43'54.78"E	
Cemal Reşit Rey İlkokulu 41°11'0.27"N 28°44'3.15"E	
Mehmet Akif Ersoy Ortaokulu 41°11'6.83"N 28°44'5.39"E	
Şht. Corporal Murat Şengöz Primary 41°11'28.59"N 28°43'44.74"E	
Anafartalar Middle School 41°11'40.09"N 28°43'22.49"E	

Rehberlik ve Araştırma Merkezi 41°11'25.12"N 28°43'47.69"E	
Mavigun Koleji 41°11'10.88"N 28°43'50.82"E	
Private İlkseç Diriliş 41°11'30.19"N 28°43'52.70"E	
Neşeli İzler Anaokulu 41°10'57.20"N, 28°43'55.89"E	

The relatively better-performing schools, such as Anafartalar Middle School (3.7 stars) and Piri Reis Primary School (3.5 stars), offered better pedestrian crossing facilities, signage, functioning traffic lights, and more adequate speed management. However, even these schools lacked school crossing supervisors, a component significantly improving pedestrian compliance and reduces the risks of fatalities and serious injuries, as in Colombia's Bogotá case study, where supervisors and channelization led to an increased star rating and pedestrian road safety [15].

Another key insight was the urban context of risk, where schools located near improperly managed construction sites, commercial centers, or complex intersections (e.g., Cemal Reşit Rey School) scored lower due to increased risks as a result of deteriorated pedestrian walkways or increased traffic volumes. Therefore, an increased exposure risk for pedestrians to interact with vehicles was documented. This observation aligns with research studies indicating that land use patterns directly influence pedestrian exposure risk [9].

Despite Türkiye's regulatory framework under the Turkish Road Traffic Law and commitments under the WISS, local

implementation remains inconsistent. Many school zones in Arnavutköy lacked official markings or even defined school zone perimeters. This disconnect between policy and practice is similar to other countries' contexts, such as Iran, where local authorities had to improve the current situation and utilized SR4S to reduce school zone risks, since SR4S assessments were more reliable than other methods previously applied [16].

Several main infrastructure upgrades can improve road safety at school zones, as the iRAP SR4S demonstrator showed; these mainly include:

#### A. Clear Marking and Signage of School Zones

School zones are regions near schools and other educational establishments, where there is a large concentration of schoolchildren and young pedestrians. School zones frequently include more speed restrictions and traffic calming. They are likely to have suitable road signs (sometimes with flashing beacons for visibility) and markings to warn motorists of the presence of vulnerable road users. Parking restrictions may also exist in school zones. They are often used in and around schools to ensure that vehicles travel in predictable patterns and at low speeds. A school zone crossing supervisor must be present to help children as they cross highways on their way to and from school. The presence of a marked and signed school zone improves road safety around schools and results in a 10-25% reduction of the risk of death and serious injury [21].

#### B. Safe Pedestrian Crossings

Standard well-maintained zebra markings alert road users and drivers. They signal vehicles to halt and yield to pedestrians. Safe pedestrian crossings should be according to the Manual on Uniform Traffic Control Devices (MUTCD).

#### C. Speed Management

Speed calming measures are required in all areas where people are likely to approach moving cars, particularly at an intersection without signals and crossings. As a vehicle's speed increases, the driver's field of vision narrows, making it difficult to detect children or react to unexpected situations, such as a youngster rushing into the street [24]. Children have a limited awareness of speed, and their cognitive skills are still developing. It can be difficult to reduce speed since some drivers and riders love speeding or believe that it saves time. They may underestimate the dangers of driving or riding too quickly and be indifferent about the possible repercussions, feeling that their driving ability is such that speeding is acceptable. This is consistent with examples from similar contexts, such as in Nepal, where schools that were previously rated one star due to the lack of pedestrian crossings, poorly maintained sidewalks, and excessive operating speeds [14]. Following evidence-based infrastructure upgrades, such as speed management and improved pedestrian crossings, their ratings jumped higher than 3 stars, illustrating the potential effectiveness of targeted, cost-effective interventions.

Traffic speed must be limited to levels that are appropriate for the road environment to provide forgiving roadways. To design a safe road system and decrease deaths and serious injuries, the human body's tolerance to impact forces should be

utilized as a guideline. The impact speeds for various vehicle crash types that increase the probability of mortality are [22]:

- 70 km/h head-on collision
- 50 km/h side impact
- 30 km/h side contact with objects
- 30 km/h collision with pedestrians, bikers, and motorcycles

Setting a speed limit in isolation is ineffective as a speed management tool. It must be supplemented by:

- Design of road infrastructure that is consistent with the desired travel pace, such that the road is self-explanatory, and a driver or rider may more instinctively manage their speed based on the look and feel of the road.
- Traffic calming techniques, such as raised tables or chicanes, may be used to ensure compliance.
- Effective speed enforcement.

Finally, the SR4S (before) and (after) demonstrator simulation capability highlighted potential improvements. For example, when Cemal Reşit Rey School applied just three low-cost measures, lowering speed limits through enforcement, installing rumble strips, and appointing crossing supervisors, the iRAP SR4S model predicted a 97.3% reduction in fatal or serious injury risk. This strongly supports prior literature showing that incremental infrastructure upgrades can yield exponential safety gains [13, 14].

Other proposed treatment scenarios for Cemal Reşit Rey School could include narrowing the corner radius at the intersection to reduce the turning vehicles' speed, in addition to minimizing the pedestrian crossing distances. Another effective measure for this location is to widen the central median and provide a pedestrian refuge island. In addition, the pavement color and texture (e.g., using colored and pattern-stamped asphalt) can be altered to alert drivers while entering the school zone. Finally, properly designed speed humps should be provided, which are clearly marked and supplemented by adequate warning signs indicating the presence of speed and the allowable speed of 20 km/h. All these measures will improve the deteriorated road safety situation around this school.

It is very important, though, not to estimate the benefits and gains of upgrading road safety around schools based on increased school star rating (at least to three stars), as emphasized by WHO. This is due to the fact that the risk of death or serious injury is approximately halved for each incremental improvement in star rating [23].

## IV. CONCLUSIONS AND RECOMMENDATIONS

This study confirms that road environments around schools in Arnavutköy are, in many cases, unsafe for children. The iRAP Star Rating for Schools (SR4S) assessment of ten school zones revealed that 40% of the schools were rated at just one star, with six schools falling below the internationally proposed three-star safety threshold. These low ratings indicate a high level of risk for vulnerable road users, particularly children,

and highlight the urgent need for evidence-based and context-sensitive interventions.

Most schools lacked essential infrastructure like elevated crossings, speed bumps, and proper signage, all of which are standard in Safe System school zones. Despite the imposed limits of 20 km/h or 30 km/h, operational speeds often exceeded 50 km/h, which drastically increases child pedestrian fatality and serious injury risks. Furthermore, the absence of school crossing supervisors was noted, even though it is one of the most effective and low-cost interventions for ensuring road safety at schools. Another issue of concern was the proximity of many schools to high-traffic roads, commercial areas, and construction sites, which increased the exposure risk, especially where sidewalks were narrow or blocked.

Despite legislative mandates in Türkiye, the practical implementation of school zone design standards is inconsistent and not systematic, and there is a need to adopt new technologies or applications such as SR4S. The SR4S tool proved to be effective in identifying risk, prioritizing interventions, and simulating upgrades, supported by findings from studies in other countries, such as Armenia, Nepal, Iran, and Colombia. These global case studies showed that SR4S can contribute to improving road safety levels, enabling data-driven road safety advocacy, while being adaptable and suitable for middle- and low-income countries. Showcasing substantial gains in safety metrics, these examples highlight SR4S as a cost-effective solution for school zones in both high- and low-resource contexts.

The findings are significant not only to Istanbul but also to national school safety recommendations, urban mobility planning, and international SR4S best practices. It adds to the global discussion around safer school zones while emphasizing the necessity for specialized studies in this domain.

Drawing on the findings of this study and aligned with international best practices, several key recommendations emerge. Infrastructure upgrades are required to improve the star rating and the road safety around schools. Installing evidence-based SR4S demonstrator-proved options at all 1- and 2-star schools improves SRS to at least 3 stars in almost all cases. Improving road markings and signs to meet the minimum standards of Uniform Traffic Control Devices (MUTCD) plays a key role in enhancing the road safety conditions around schools, as star ratings increased with adequate marking and signage conditions. This also shows the importance of these elements for drivers and their ability to read the road and drive safely.

The existing road safety measures should also be properly maintained to ensure their effectiveness for the intended purpose. Additionally, it is important that authorities develop and mark official school zones around each school as a special safety zone and enforce operational speed limits through mobile enforcement units to maintain speeds below 30 km/h. Schools should appoint school Crossing Supervisors who are well-trained, especially at high-risk schools that are below 3 stars.

It is equally important to conduct several road safety awareness campaigns for students, parents, and bus drivers to

promote road safety and ensure long-lasting behavior change. Municipal planners and school administrators in Türkiye are also encouraged to use SR4S to enhance road safety around schools and meet national road safety targets. Local capacity can be built through training based on iRAP's certification programs.

This research contributes a case study to the global body of literature on school zone safety by applying the SR4S model in a Turkish urban context. The findings underline the effectiveness of systematic innovative road safety tools and the immense potential for improving child safety with targeted evidence-based interventions.

#### A. Research Limitations and Future Recommendations

This research was subject to several limitations. That is, access to localized crash data from Arnavutköy limits the ability to correlate the star rating results with actual crash data. In addition, the assessment relied solely on visual field observations and SR4S-coded attributes. These constraints, while not diminishing the relevance of the findings, highlight the need for broader data availability and cross-agency collaboration in future research.

Future research should focus on integrating crash data from police or municipal sources to establish empirical links between star ratings around schools and injury or fatality patterns. Moreover, studies assessing the effectiveness of implemented improvements over time would strengthen evidence on the sustainability of SR4S-led interventions. Expanding the study across multiple districts or cities would also provide comparative insights and help shape school road safety policy frameworks.

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#### DATA AVAILABILITY STATEMENT

The data that support the findings of this study are openly available in the Zenodo repository at <http://doi.org/10.5281/zenodo.16935832>.

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