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Investigating Roadside Severity for Army Canal Highway in Baghdad City Using Risk Assessment Models

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Abstract

Roadside type is a crucial factor that affects road safety. This study aims to investigate the impact of 15 roadside types using the international Road Assessment Program (iRAP) model, which utilises the star rating system as a measure of road safety. The study, uniquely, focuses on using risk assessment models to evaluate the impact of roadside types on road safety in the case of a lack of crash data. The required geometric and traffic data were collected for two sections of the Army Canal highway in Baghdad city. The results showed that one roadside type (wire rope) improved safety performance, while others led to a reduction or limited effect on safety levels compared to the existing metal barriers in each section. It was observed that this option lowers the Star Rating Score (SRS) for section 1, driver side and passenger side, from 12.71 to 11.58 and from 12.62 to 11.42, respectively, corresponding to an 8.9% and 9.5% reduction in risk score, which was sufficient to shift the road section from Star Rating 2 to Star Rating 3. The study revealed similar results for section 2 with different SRS.

Keywords: International Road Assessment Program (iRAP), Road Safety, Roadside Severity, Safety Barrier Metal, Safety Barrier Wire Rope.

1. Introduction

It is a fact that road safety is a major factor in everyday life. [1]. One of the factors that affect road safety is road infrastructure. This includes the geometric and traffic road characteristics such as lane width, shoulder width, number of lanes, etc [2][3]. In this study, the focus is on the effect of roadside type on road safety.

There are many types of roadsides used on road networks [3]-[5]. For the purpose of this paper, fifteen of the most common roadside types were selected for analysis. These are: Cliff, Tree >= 10cm diameter, Sign, post or pole >=10cm diameter, Rigid structure/bridge or building, Unprotected safety barrier end, Large boulders >= 20cm high, Aggressive vertical face, Deep drainage ditch, Upwards slope rollover gradient, Downwards slope, Upwards slope - no rollover gradient, Semi-rigid structure or building, Safety barrier – metal, Safety barrier – concrete, and Safety barrier - wire rope.

One of the most common roadside types is Safety barrier - metal. In the event of run-off crashes, this roadside type plays a crucial role in protecting errant vehicles. It reduces the hazard resulting from collisions with infrangible roadside objects such as trees or utility poles [6], [7]. Although the main part of this roadside type, the horizontal steel barrier, is considered relatively safe, the vertical steel bars could represent an aggressive surface causing high risk in accidents [8].

Concrete barriers are another common type that could be employed as a roadside barrier on both driver and passenger sides permanently, or temporarily in road maintenance projects. This type of roadside barriers is considered one of the types that provide unaggressive surface. However, drivers still consider them as an infrangible roadside object because of their heavy weight [9] [10].

The cable barrier system is also a common barrier type that has gained in popularity and thus has been the focus of research in recent years due to its noticeably good performance demonstrated in containing or redirecting errant vehicles with less imposed impacts. Cable barriers have become an alternative to steel guardrails [11]-[13]. On the other hand, although cables are considered a flexible type of roadside barrier, there are controversial thoughts that this type could result in potential risk for drivers and passengers through the vertical posts used to anchor the cables [8].

Other types of roadside include trenches and ditches, utility poles, trees, or cliffs. A great portion of run-off-the-road fatalities occur in collisions with fixed objects at the roadside, including roadside hardware. Roadside hardware is meant to prevent fatal injuries caused by more dangerous collisions, for example, collisions involving utility poles, trees, steep slopes, or cliffs. Collisions with fixed objects account for about 20% of all reported crash deaths [14[15].

Previous research has shown that roadside type significantly affects the severity of run-off-road crashes. Roadside objects such as trees could increase the severity of run-off crashes, especially with the lack of sufficient distance [16]-[19].

It is suggested that the presence of guardrails on the shoulder decreases the injury level from run-off- road crashes [20]. The positive estimation of hit object indicates that the run-off-road crash severity outcomes are more likely to be serious with fatal injuries when the vehicles collide with roadside objects. The marginal effects show that the probabilities of serious and fatal injuries are found to increase by 0.068 and 0.018 units, respectively, if the vehicle collides with the roadside objects in run-off accidents. These situations could lead to serious injuries and fatalities. Therefore, it is important to keep sufficient distance from roadside objects as a recovery area to reduce the severity of run-off crashes [16]-[22].

The above studies relied mainly on crash data analysis. However, limited research has compared roadside types using risk assessment models in situations where crash data are unavailable.

The literature on crash data analysis has extensively investigated the impact of different roadside types on the occurrence and severity of casualty crashes on road networks. However, there is still a knowledge gap in developing a comparative methodology for available roadside types to assess road safety based on roadway attributes, even in the absence of reliable crash databases [2][23]. In many developing countries, including Iraq, crash data are often incomplete, underreported, inconsistently geo-referenced, or unavailable for specific road segments [23][24]. Therefore, to address the lack of historical crash data, the International Road Assessment Program (iRAP) is designed as a risk assessment model that evaluates road safety based on roadway attributes, even when reliable crash databases are unavailable [25][26].

Previous research shows that infrastructure features and observed crash outcomes can be used to assess roadside safety. For instance, prior studies have examined the impact of roadside features on the severity of run-off-road crashes and have reported the efficacy of cable barriers [11], [20]-[22]. These studies provide substantial evidence regarding the safety consequences of roadside hazards. However, they do not directly offer a consistent infrastructure-based comparison of a wide range of alternative roadside conditions using a common Star Rating framework. In order to fill this gap, the current study essentially modifies only the roadside type in ViDA while maintaining the primary geometric and traffic characteristics. Therefore, the novelty is in creating a comparative scenario-based application of iRAP for roadside alternatives on a multilane urban highway in Baghdad where dependable segment-level crashes occur rather than developing a new crash-risk model.

The method is not meant to replace locally calibrated crash prediction models, but rather to serve as an infrastructure screening and option-comparison technique. It is not assumed in this study that the default iRAP model, an internationally developed infrastructure-risk model, will accurately replicate the absolute crash risk of Iraqi roads. Rather, while maintaining the other observed road characteristics, it is used to estimate the relative change in infrastructure risk caused by alternative roadside scenarios. As a result, comparative changes in SRS and Star Rating for the study sections should be the main way to interpret the results. Only in cases where the geometry, traffic conditions, operating speeds, roadside configuration, and surrounding environment of other Iraqi roads are sufficiently similar to those examined in this study should generalizations be made.

2. Methodology

Although the roadside types in the segments considered in this study do not include all the investigated types, this research tries to develop a comprehensive methodology to investigate and compare the impact of the most common roadside types. While many studies have investigated the impact of roadside types on safety level, there is still a significant shortage in dealing with the comparison methodology of the available roadside types. This could help road safety engineers to choose safer options when considering road safety issues. The aim of this study is to evaluate the effect of changing roadside type on safety level. To reach this aim, the International Road Assessment Program (iRAP) model was employed as the risk assessment model, using the ViDA platform, to simulate the effect of different roadside types on road safety level. This could provide a model to evaluate the effect of changing roadside type on road safety for multilane highways in level terrain based on the change in safety level represented by the Star Rating system utilised in iRAP. As mentioned above, in the introduction, the iRAP is employed as the risk assessment model to evaluate road safety based on road attributes as historical crash databases are unavailable. Therefore, the use of the Star Rating Score SRS as the sole performance indicator is appropriate and consistent with the intended application of iRAP.

2.1 Data Collection

Two multilane dual carriageway sections were selected on the Army Canal Highway in Baghdad city (the first section from Al-Muthaffar Intersection to Al-Talibia Intersection (2200 m) and the second section from Al-Talibia Intersection to Al-Shaab Intersection (2800 m) as shown in Picture 1.

The data required for this research include the geometric elements and traffic characteristics of the selected sections. The geometric elements required for this study as input data may include the presence or absence of sealed shoulders, the combination of steep downhill grades and curves, offsets between the road and roadside hazards, travel lanes, medians, roadside barriers, sidewalks, and side slopes. The main geometric data for the selected sections are shown in Table 1.

For the traffic characteristics needed, the traffic datasets included: operating speed, average daily traffic, and heavy vehicle percentage. These data were collected in April 2025 for each weekday (the observation hours 7:00 - 15:00). The video recording method was used to collect the average daily traffic and heavy vehicles percentage for weekdays. In addition, the datasets included the average operating speed, which was calculated using video techniques depending on the distance traveled and time required between two fixed physical features such as utility posts or road markings (during free flow conditions) [27]. The operating speeds for sections 1 and 2 are 73 and 66 km/hr respectively.

Picture 1. Aerial photo of the sections' location

Table 1. Cross section elements of the considered road sections.

Cross section elements	Section 1	Section 2
Section length	2200 m	2800 m
Lane width	Wide (>= 3.25m)	Wide (>= 3.25m)
Number of lanes	4	4
Total width of the road (one direction)	15 m	15 m
Shoulder width	1.0 m	1.0 m
Median type	Depressed (categorized as physical median width > = 20.0 m in iRAP)	Depressed (categorized as physical median width > = 20.0 m in iRAP)
Median width	110 m	110 m
Sidewalk width	0	0

2.2 Risk assessment model

The International Road Assessment Program (iRAP) considers risk factors to assess road safety with regard to a star rating system where the one-star level represents the riskiest road sections and the five-star level represents the safest road sections. The international Road Assessment Program (iRAP) is a comprehensive road safety model, which accounts for many cost-effective factors that affect road safety. These star ratings are based on star rating scores (SRS), which are calculated by an appropriate model that considers the risk factors of road attributes, traffic volumes, and operating speeds. The outcome of this process is countermeasures (roadside types in this study) that can be used to improve road safety and reduce fatalities and serious injuries (FSI) numbers. These countermeasures can be used separately as a single countermeasure or as a combination of multiple countermeasures for a particular location [25].

By 2030, it is expected that fatalities resulting from road accidents could reach 2.4 million. The increasing cost of these crashes and their impact on societies and countries' economies raises the need for risk assessment models to evaluate road safety levels. Therefore, iRAP was established as one of the risk assessment models to consider road safety issues. High percentages of these crashes occur in low- and middle-income countries. It is estimated that around half of road fatalities include vehicle occupants [26].

The iRAP provides a comprehensive framework for assessing and rating road safety in an objective and innovative way, helping to guide efforts, and the iRAP website is a valuable source of information and resources relating to road safety assessment and evaluation. The model offers a wide range of tools, techniques and guidelines that can be used to assess and improve road safety. In addition, it includes a comprehensive database containing information about evaluated and proposed methods used to evaluate safety on existing roads and identify areas where safety improvements are required. Effective use of iRAP helps direct efforts and investments in improving infrastructure, designing roads, and implementing other measures to enhance user safety. Thus, the use of iRAP enhances road safety and reduces fatalities. In summary, the International Road Assessment Program (iRAP) is a valuable tool for developing a comprehensive and objective framework for road safety assessment and evaluation. The ViDA platform, which is the road safety analysis tool developed by iRAP, utilises the Star Rating system. This system includes risk assessment for road attributes and their impact on the likelihood of crashes. The Star Rating system divides road safety levels into five categories (SR1 to SR5). The highest Star Ratings, SR4 and SR5, represent the safest traffic and geometric characteristics for road safety; these may include wide lanes, good road condition, and protected roadsides, etc. In contrast, SR1 and SR2 are the levels that result from the least safe road attributes. Examples of these are: poor road condition, inadequate skid resistance, and dangerous roadsides [26]. The ViDA input data include the geometric and traffic characteristics of the considered roads. These may include features such as number of lanes, lane width, curvature, shoulder width and type, roadside types, speed, and traffic flow.

The collected geometric elements and the traffic characteristics were used as input data into the ViDA platform to calculate SRS and assess the Star Rating, which represents the safety level for the current situation for each section. Then, the current roadside type was virtually replaced by each of the fifteen types considered in this study to evaluate the change in the Star Rating affected by each roadside type according to the results achieved.

2.3 ViDA Implementation and Calibration

The measurement and categorization of the input variables introduce an additional degree of uncertainty. While traffic and geometric characteristics were gathered for the chosen sections, operating speeds were calculated from video observations. Modest adjustments to these inputs could have an impact on the computed SRS. Therefore, a sensitivity analysis for the two sections and roadside combinations is included to overcome this problem. The primary conclusion, the relative benefit of the wire rope scenario and the extremely high risk associated with cliff conditions, is tested for stability across the two sections and both driver and passenger sides by looking at the distribution of SRS values produced by the fifteen roadside scenarios. This analysis is interpreted as a robustness assessment of the scenario results rather than as a formal probabilistic uncertainty distribution because the underlying ViDA algorithm is proprietary and the current dataset lacks a local calibration sample.

The study lacked a crash database to independently estimate local risk functions, and no Iraq-specific calibration coefficients were available for the current analysis. As a result, there was no local statistical calibration when using the iRAP default model. This limitation is specifically acknowledged because the relationship between infrastructure characteristics and observed crash outcomes in Iraq may be influenced by variations in traffic conditions. Therefore, it is not appropriate to interpret the results as proof that the absolute SRS values are precisely calibrated to Iraqi conditions. Future Iraqi calibrations should compare observed and modeled data using a representative database that links crash frequency and severity to road attributes, traffic exposure, operating speed, roadside hazards, and barrier characteristics. Until such calibration is available, the present results are most defensible as a relative comparison methodology for roadside attributes within the selected highway.

3. Results and Discussion

3.1 Outcomes of the Star Rating Scores

For section 1, the current roadside type (driver–side) setup has a metal safety barrier, with a Star Rating Score (SRS) of 12.71. The results showed that replacing it with a wire rope barrier could be the best option, which lowers the SRS to 11.58, showing a clear improvement in road safety level from Star Rating 2 to Star Rating 3. The reason behind this could be that the wire rope barrier is designed to be very flexible, so it can absorb the impact of crashes and safely guide errant vehicles back onto the road. This helps make crashes less severe and reduces the chances of serious injuries. On the other hand, the results showed that the cliffs are the worst roadside type, causing the SRS to jump sharply to 76.11, meaning safety becomes much worse (Star Rating 1). A cliff doesn't offer any protection or absorb impact energy, which makes it extremely dangerous. Vehicles could fall off uncontrollably, greatly increasing the risk of serious injuries or deaths. The other roadside types were applied using the iRAP model to reflect their effect on road safety, as may be seen in Fig. 1. The analysis showed that only one roadside type (wire ropes) improves the safety level (SR2 to SR3). The roadside types: Tree >= 10cm diameter, Sign, post or pole >= 10 cm diameter, Rigid structure/bridge or building, Unprotected safety barrier end, Large boulders >= 20cm high, Aggressive vertical face, and Deep drainage ditch could lower the safety level (SR2 to SR1) if one of them was implemented on the considered road section.

The results also showed that the roadside types, Safety barrier – concrete, Upwards slope rollover gradient, Downwards slope, Upwards slope - no rollover gradient, and Semi-rigid structure or building have no effect on the Star Rating, as they revealed the same Star Rating as the current roadside type (Safety barrier – metal). However, the Safety barrier – metal remains the safest option among this set of roadside types, to keep the Star Rating at the second level (SR2) with the lowest SRS of 12.71.

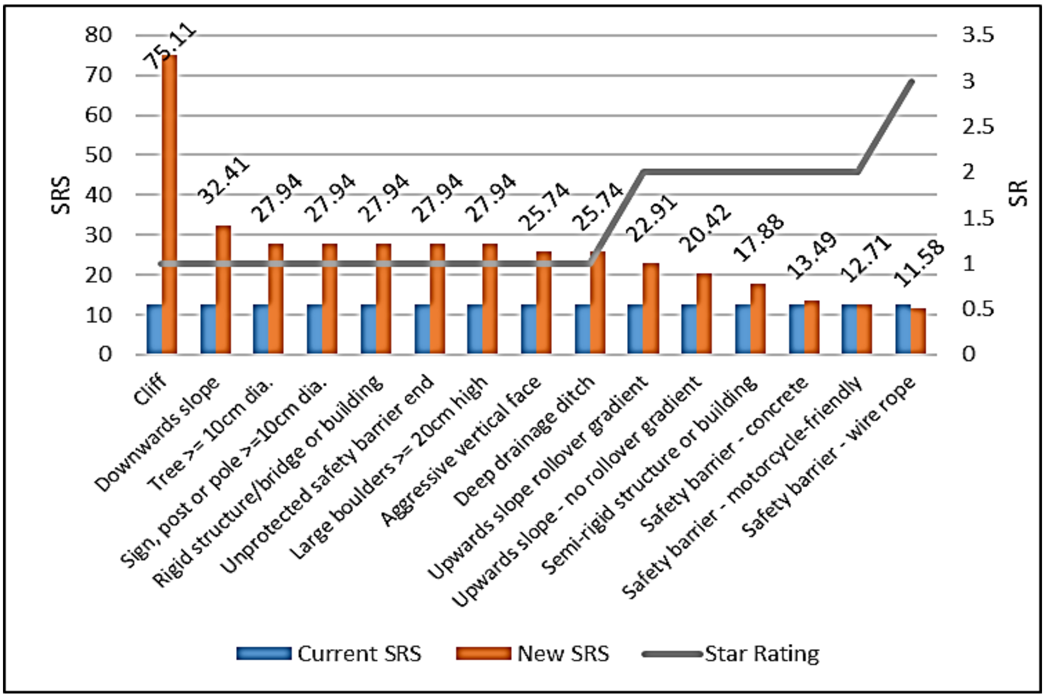

Figure 1. Star Rating Scores for roadside types (section1 – driver side).

The recorded values of the Star Rating Score on the passenger side were generally consistent with those on the driver side. This consistency could be attributed to two main factors: the symmetrical design of the current safety barrier and the uniformity of the road specifications across both sides. As a result, similar outcomes were observed under most conditions with regard to the Star Rating bands. However, an exception was noted in all roadside severity types, where a measurable difference emerged: Star Rating Scores on the driver side are higher than those on the passenger side, as shown in Figs. 1 and 2. This difference suggests that roadside severity exerts a more pronounced effect on the driver side, potentially due to the higher speeds on the left lane and vehicle dynamics.

The analysis of the collected data for both selected road sections showed significant similarity in the road specifications, especially the presence of the metal roadside barriers in both segments. This led to a noticeable similarity in the resulting SRS values. However, a slight difference was noted due to a change in the road condition in section 2, causing the Star Rating Scores to shift to higher values, lowering the road safety performance, as may be seen in Figs. 3 and 4. This minor variation confirms that even small differences in road characteristics can affect the results. Additionally, it can be concluded that the road condition had a more pronounced impact on the second segment compared to the first, highlighting the importance of the road condition as a key factor in evaluating road characteristics and analyzing the results.Although there is a difference in the operating speed values between the two considered sections, this has no effect on the safety level as the Star Rating is similar for both sections for all roadside types. The reason behind this could be that the operating speed values on both sections are below the speed limit for the selected road. Regarding the effect of traffic volume on road safety, the literature indicated a positive correlation between average daily traffic and crash frequency [25]. However, this research indicated that the difference in the average daily traffic between the two selected sections has no significant effect on the roadside severity type, as similar outcomes were observed under most roadside types.

3.2 Sensitivity and Robustness Analysis

A sensitivity analysis was conducted to evaluate the influence of roadside type on the Star Rating Score (SRS) while maintaining all other roadway characteristics unchanged. The analysis was performed by replacing the existing roadside barrier (metal safety barrier) with each of the fifteen roadside types available in the iRAP model. Since all geometric characteristics, operating speed, traffic volume, lane width, shoulder width, and median configuration remained constant, the observed variation in SRS can be attributed solely to the roadside severity category.

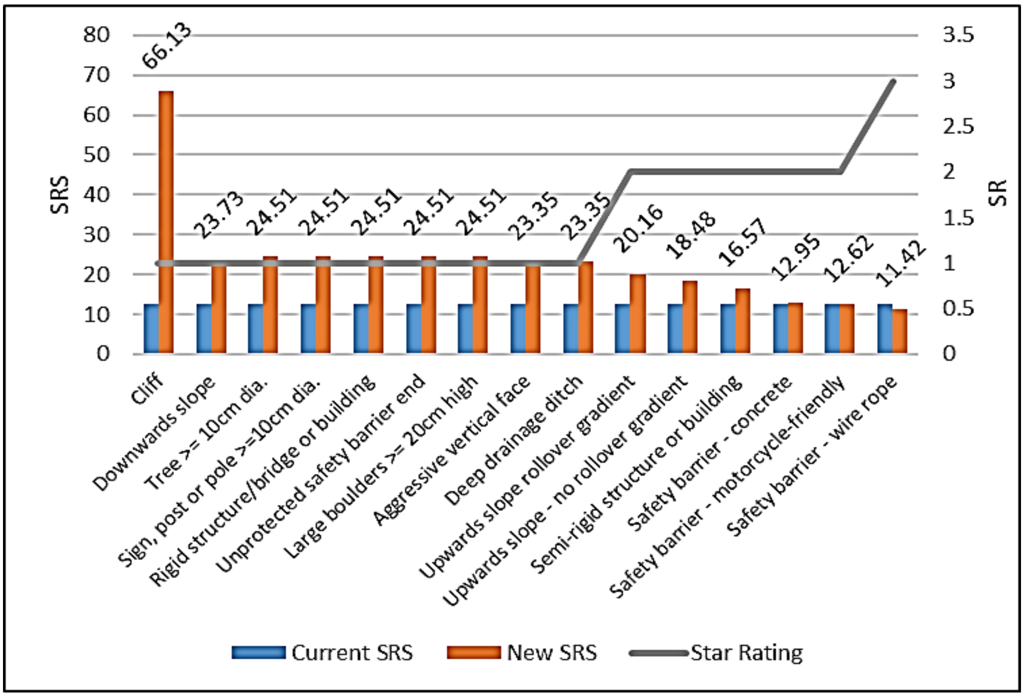

Figure 2. Star Rating Scores for roadside types (section1 – passenger side).

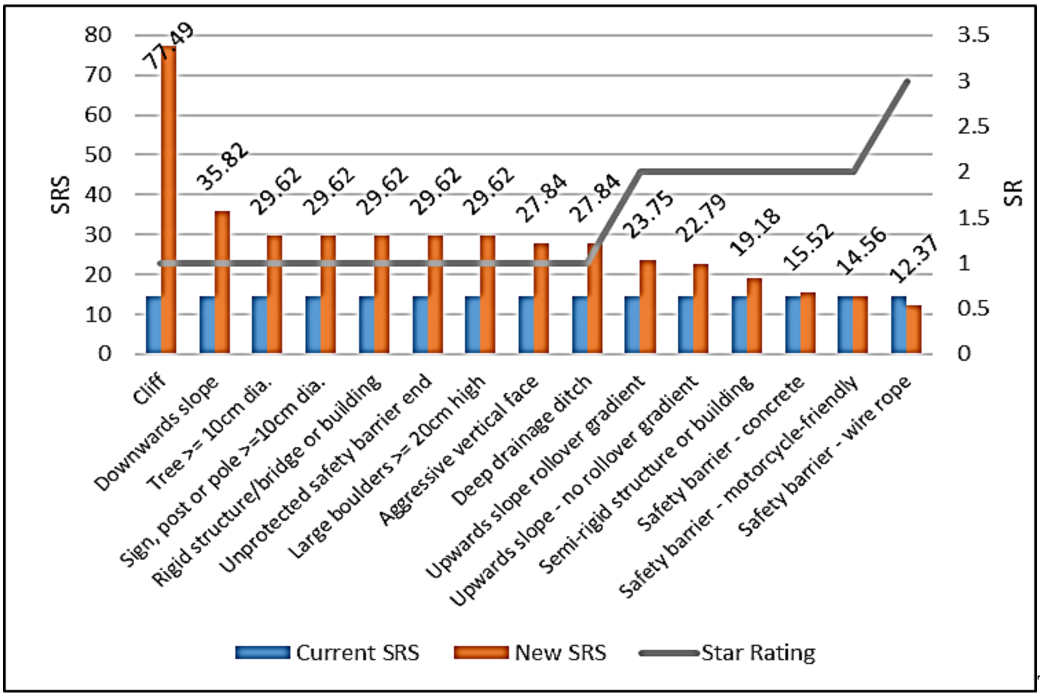

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Figure 3. Star Rating Scores for roadside types (section2 – driver side).

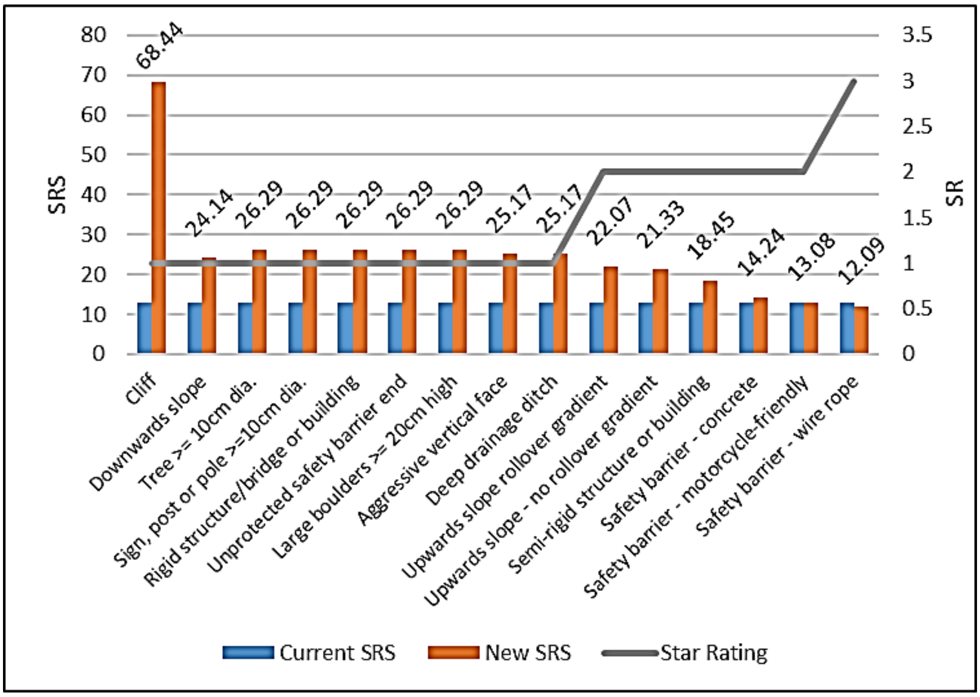

Figure 4. Star Rating Scores for roadside types (section2 – passenger side).

The percentage change in SRS relative to the existing metal barrier was calculated using:

Sensitivity (%) = [(SRSi – SRSbase) / SRSbase] ×100

where

SRSi = Star Rating Score after replacing the roadside type,

SRSbase = Star Rating Score of the existing metal safety barrier.

For Section 1 (driver side), the existing metal barrier produced an SRS of 12.71, while replacing it with a wire rope barrier reduced the SRS to 11.58, representing an 8.9% improvement in safety. This reduction was sufficient to improve the Star Rating from SR2 to SR3, demonstrating that the model is highly sensitive to replacing the roadside barrier with a more forgiving system. Conversely, replacing the roadside with a cliff increased the SRS to 76.11, corresponding to approximately a 499% increase in risk relative to the baseline, indicating extremely high sensitivity to hazardous roadside conditions.

The remaining roadside types produced varying degrees of sensitivity. Trees, rigid structures, aggressive vertical faces, deep drainage ditches, large boulders, signposts, and unprotected barrier ends all caused noticeable increases in SRS and reduced the Star Rating from SR2 to SR1. In contrast, concrete barriers, upward and downward slopes, and semi-rigid structures produced little or no change in SRS, indicating relatively low sensitivity compared with the existing metal barrier.

The passenger-side analysis demonstrated a similar pattern, although the SRS values were consistently slightly lower than those on the driver side. This suggests that the iRAP model responds consistently to changes in roadside severity on both sides of the carriageway while still reflecting differences in traffic operation and vehicle trajectories.

Comparison between Sections 1 and 2 showed that the ranking of roadside types remained unchanged despite minor differences in road condition, operating speed, and traffic characteristics. The wire rope barrier consistently produced the lowest SRS, whereas cliffs consistently generated the highest SRS. This consistency indicates that the model is robust and that roadside type is one of the dominant factors affecting the calculated safety performance for the investigated highway sections.

Overall, the sensitivity analysis confirms that the iRAP Star Rating Score is highly responsive to roadside severity classification. Among the evaluated alternatives, the wire rope barrier provides the greatest improvement in safety performance, whereas rigid roadside hazards such as cliffs produce the largest deterioration in safety. These findings demonstrate that roadside treatment selection has a significant influence on predicted road safety and should be considered a priority during highway design and rehabilitation.

3.3 Comparison with Previous Research

The results are generally in line with global evidence that flexible cable-type barriers can effectively contain and lessen the effects of errant-vehicle impacts [11]-[13]. The current analysis also supports research that indicates the severity of run-off-road crashes can be increased by roadside objects and insufficient recovery space [16]-[22]. The comparison in this study, however, is based on a common infrastructure-risk model rather than actual crash records, which sets it apart from the majority of these studies. This distinction is crucial: while crash-based studies estimate relationships from actual crashes, the iRAP results show how the infrastructure attributes are scored by the model. When trustworthy crash data becomes available, the two complementary methods should be used in tandem.

3.4 Cost and Implementation Considerations

Local Iraqi unit prices and agency records for barrier length, installation requirements, post and foundation requirements, routine inspection frequency, crash repair rates, replacement rates, and traffic-management costs should be used in a future cost-effectiveness analysis for the Army Canal Highway. The decrease in SRS, estimated FSI, or monetized crash risk could then be used to represent the safety benefit, making it possible to compute the cost per unit of safety improvement. No numerical cost-effectiveness ranking is asserted in this study. Subject to engineering viability, maintenance capability, local standards, and future economic evaluation, the wire-rope barrier is only suggested as the best-performing option in the iRAP safety scenarios tested.

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

Author Contribution Statement

Atheer Al-nuaimi and Samer Alsadik proposed the research problem.

Atheer Al-nuaimi was responsible for collecting and analyzing the data, as well as utilisation of the iRAP model to develop the proposed methodology.

Atheer Al-nuaimi and Harry Evdorides were responsible for finalizing the results, proofreading, evaluating the findings, and finalising the manuscript.

4. Conclusions and Recommendations

The aim of this study was to evaluate the effect of changing roadside type on infrastructure-based road safety using the iRAP Star Rating framework. For the two Army Canal Highway sections examined, the wire-rope barrier produced the lowest SRS among the fifteen tested roadside scenarios. In Section 1, the SRS decreased from 12.71 to 11.58 on the driver side and from 12.62 to 11.42 on the passenger side, while the corresponding Section 2 reductions were from 14.56 to 12.37 and from 13.08 to 12.09, respectively. These changes correspond to reductions of 8.89%, 9.51%, 15.04%, and 7.57% for the four section-side scenarios. These findings show that the iRAP Star Rating has improved on both sections. However, rather than reflecting actual decreases in crash frequency or injury severity, the findings reflect modeled changes in infrastructure risk.

Although there is a difference in the operating speed values between the two considered sections, this has no effect on the safety level as the Star Rating is similar for both sections for all roadside types. This could be attributed to the fact that the operating speed values on both sections are below the speed limit for the selected road. The motorcyclist-friendly barrier showed a similar SRS value (12.71) to the current metal barrier, indicating a limited effect on safety improvement. This type could also be recommended for future studies, especially in areas with high percentages of motorcycles.

The wire-rope barrier consistently produced the lowest SRS, while the majority of alternative roadside types produced higher SRS values than the current metal barrier based on the four section-side scenarios. Therefore, if their structural design, installation, maintenance, containment performance, and compatibility with local road standards are confirmed, wire-rope barriers may be taken into consideration for roads that have features similar to the Army Canal Highway sections under investigation. The study does not prove that wire rope is always better than concrete or metal barriers in every situation in Iraq. One significant obstacle is the lack of trustworthy segment-level crash data and Iraq-specific calibration. Longer road samples, local calibration, crash records, and cost-effectiveness analysis should all be included in future research on iRAP assessment.

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