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Application of the IRAP Method Combined with GIS to Improve Road Safety on New Highway Projects in Algeria

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Abstract

This article aims to proactively predict high-risk accident areas in a new highway project in terms of its technical and geometric characteristics. The purpose of this study is to provide road project managers with better road safety assessment tools for the vehicle occupant category. The methodology used combines the International Road Assessment Program (IRAP) methodology and the Geographic Information System (GIS). The IRAP program enables the calculation and classification of risks for each 100-meter segment besides their categorization using a star rating; whereas, the GIS is used to map the risks and identify high-risk accident segments. This method was applied to a new highway project of 110 hectometres located in GHAZAOUET in Algeria. The results of the study revealed that this combined method is innovative in more than one way as it is an effective decision-making aid tool for road safety experts. It, therefore, makes it possible to target accident-prone sections in a faster way before carrying out on site road safety inspections. Technically speaking, this study shows that the existence of closely curved radii mixed at traffic speeds exceeding 80 km/h and the presence of road exits are the main factors affecting the safety of vehicle occupants. Speed control; thus, remains one among the cheapest measures to improve safety.

Keywords

road safety in Algeria, proactively predicting, geometric characteristic, International Road Assessment Program (IRAP), GIS

1 Introduction

The Algerian road network constantly records human and material losses caused by road accidents. Currently, road insecurity is becoming a major social threat and a heavy burden on the public treasury. As a result of the increasing number of road accidents, safety has become one of the main concerns in various areas.

The causes of road accidents in Algeria are largely attributed to the human behaviour with 90% of cases (Azzeddine and Ghiat, 2015). The interpretation given to this factor (human behavior) is generally reduced to the road user's sanction, i.e., the driver of the vehicle. The question to the problem of road accidents can arise early on from the birth of the project idea through its study and realization until its opening to the vehicles traffic.

According to the Highway Safety Manual (HSM) published by the American Association of Road and Transportation Officials (AASHTO), road infrastructures have an important impact on road users' safety (vehicles, motorcyclists, etc.). At present, numerous studies have been carried out on the influence of road infrastructure properties and technical parameters on road safety. Sipos (2014) conducted a study on the influence of horizontal and vertical curves on the number of traffic accidents concluding that both types of curves have a significant effect on the number of accidents. Pokorny et al. (2020) conducted a study on the effect of lane and shoulder widths on safety for Norwegian rural two-lane undivided roads. They found a non-monotonic link between the risk

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categories and the shoulder width to mean that increased risk was associated with the increase in the lane width categories. As technical parameters have an impact on road safety like the movement speed, a significant positive relationship is found between the individual speed of movement and the risk of personal injury (Brenac et al., 2015).

Internationally, road accident records are alarming in terms of the number of deaths and injuries recorded to become the eighth cause of death (World Health Organization, 2018). For this reason, high-income countries strive to implement effective solutions for road safety improvement, namely Swedish Zero Vision which aims to ensure that no one is killed or seriously disabled on the road (Lie and Tingvall, 2002). The sustainable safety approach implemented in the Netherlands aims at reducing road risks by relying on the infrastructures and vehicles up to the limits of human capacity (Wegman and Wouters, 2002). International programs were developed, such as EuroRAP, AusRAP, UsRAP, and iRAP, with the aim of classifying road sections according to their level of safety.

This work aims to provide an assessment and a decision support approach for highway planners and designers. The proposed approach consists of predicting high-risk segments before the road is opened to traffic relying mainly on the technical and geometric characteristics of the road infrastructure).

This paper is organized into five sections. Section 1 represents the introduction. Section 2 describes the evolution of road safety in Algeria. Section 3 describes the methodology used including the study area, the data collected and the risk assessment and application of the IRAP in Algeria. The results of the assessment and the identification of high-risk areas are presented in Section 4. The conclusion is described in Section 5.

2 Evolution of road insecurity in Algeria

The economic growth in North Africa particularly in Algeria and the persistent underinvestment in road safety in front of the rapid population growth, as well as urbanization, have all led to the deterioration of road conditions. It is reported that 85% of the Algerian trade volume (freight, passengers) is by land (Ould El Alem and Ould Cheikh, 2016).

The number of traffic accidents continues to increase. According to the National Center for Road Safety and Prevention of Algeria, 39,010 accidents were recorded in 2007 with 4,177 deaths and 61,139 injuries compared to 42,477 in 2013 with 4,540 deaths and 69,582 injuries (Azzeddine and Ghiat, 2015; Bougueroua and Carnis, 2018). Since 2014, there has been a relative decrease in the number of traffic accidents as shown in Table 1. 35,500 traffic accidents were recorded in 2014 compared to 18,949 accidents in 2020 (Centre National de Prévention et de Sécurité Routière, 2020).

Despite its national importance, the East-West Highway in Algeria, which extends over 1,216 km, crosses 24 provinces, and connects the main economic hubs, has not been spared from traffic accidents. Table 2 shows the evolution of the number of accidents, deaths, and injuries on the highway from the date of its commissioning until 2016 (Gendarmerie Nationale Algerienne, 2017).

It is, therefore, noted that the issue of road accidents is still present on our roads with a number of injuries and deaths which is increasing rapidly. So, what measures can be applied to eliminate road hazards from the first step of a project design?

3 Methodology

3.1 Study area

Algeria has launched several motorway projects linking major economic centers to the East-West Motorway in order to facilitate trade and increase its profitability. As a case study, the first 11 km long section of the penetrating highway connecting the port of GHAZAOUET in the

Table 1 Number of accidents, deaths and injuries in Algeria (2010–2021)

Years	Number of accidents	Deaths	Injuries
2010	31740	3541	51002
2011	42000	4531	64900
2012	42477	4447	69141
2013	44907	4540	69582
2014	35500	4055	50000
2015	20361	4610	36657
2016	28856	3992	42652
2017	25038	3639	36287
2018	23024	3310	23570
2019	22507	3275	31010
2020	18949	2844	25836

Source: Centre National de Prévention et de Sécurité Routière (2020)

Table 2 Evolution of the number of accidents on the East-West Highway

Years	Accidents	Deaths	Injuries
2011	1255	219	2468
2012	1474	204	2719
2013	1405	208	2719
2014	1345	227	2438
2015	1238	342	2196
2016	942	215	1705

Source: Gendarmerie Nationale Algerienne (2017) region of Tlemcen to the East-West Highway was chosen (Fig. 1) (Ingénieur Conseils Associés, 2015). The first section extends from the port of GHAZAOUET to a village named EL ASSA (GHAZAOUET PK0 to EL-ASSA PK11). The route of the first section is parallel to the main axis of the national road RN98 and vertically crosses several national roads, such as the RN7AA which connects GHAZAOUET to MAGHNIA via SOUHLIA, the RN35 which connects REMCHI to the East-West motorway, and the RN99 which connects GHAZAOUET to MAGHNIA via NÉDROME.

3.2 Data collection

The following data were collected and used as input characteristics to assess the project.

3.2.1 Traffic data

The annual average daily traffic (AADT) data were collected from the report of the Chinese Railway Construction Corporation company which was responsible for carrying out the project. The estimated daily traffic volume is 11,000 PSU. The AADT expresses the amount of risk exposure of road users (Tripodi et al., 2020).

3.2.2 Implementation of IRAP (International Road Assessment Program)

To date, road safety research has proposed many methods mainly based on the physical characteristics of the road to assess the safety performance of existing road infrastructures.

The use of these new programs, such as the IRAP for proactive road risk assessment on new road projects, in our view, is absent from current research, while these modern quality control tools for road safety must have a preventive influence on the occurrence of accident factors not only on existing roads but also on future ones (Baklanova et al., 2021).

The International Road Assessment Program (IRAP) is probably the best-known methodology (Tripodi et al., 2020). It was created to eliminate road accidents and their devastating social and economic burdens (McInerney and Smith, 2009). IRAP is based on estimated scores (SRS). The SRS module assigns safety levels to the road infrastructures based on their efficiency to prevent accidents and protect users involved in accidents (Lynam, 2012). Based on the calculated Road Protection Score (RPS), the road section is classified according to a Star Rating.

A crash modification factor (CMF)

According to American Association of State Highway and Transportation Officials (2010) and Choi et al. (2018), the collision modification coefficient (CMF) is defined as a coefficient reflecting the effects of changes in trafficelements, operating elements, and road design elements on the number of traffic accidents occurring in the analysis area.

For example, an intersection has 100 angular collisions and 500 rear collisions per year. If you apply a countermeasure that has a CMF of 0.80 for angle collisions, you can expect to see 80 angle collisions per year after the countermeasure is implemented (100 × 0.80 = 80) (iRAP, 2013).

Types of users

In general, the types of users involved in accidents that are included in the IRAP program are vehicle occupants, motorcyclists, bicyclists, and pedestrians.

Types of crashes

The types of accidents which IRAP relies on are exits from the road (driver's sides), loss of control, and accidents on the intersection involving vehicle occupants (iRAP, 2013).

Star rating score equation

The star rating score equation calculates for each 100 m (hectometre) segment the relative risk of death and serious injury to the road user. The equation is given as follows:

$$\text{SRS} = \sum \text{Crash Type Scores}, \quad (1)$$

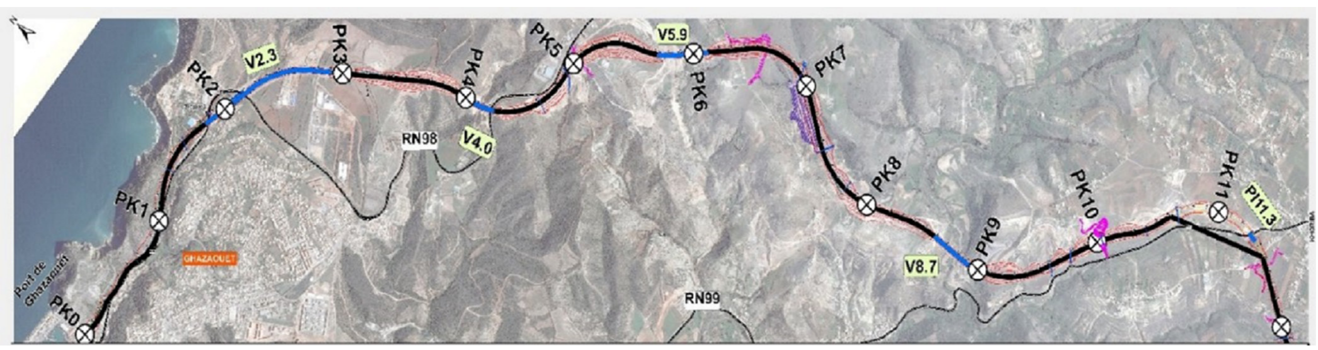

Fig. 1 Penetrating highway of GHAZAOUET (Ingénieur Conseils Associés, 2015)

such as:

- **SRS:** The relative risk of death and serious injury to the road user for every 100 m
- **Accident type score:** probability × severity × traffic speed × external traffic.

Categorization of risk scores

For the risk assessment for each hectometre, the score is linked to different intervals depending on the type of road user. Five risk intervals are considered for each category of road user in the IRAP program:

- Green = very low risk;
- Yellow = low risk;
- Dark orange = medium risk;
- Red = high risk;
- Black = very high risk.

3.3 Road risk assessment and application of the IRAP program in Algeria

The following points constitute the bases on which this method was applied:

- Although the motorway axis under study is located in a rural environment, it crosses several urban areas.
- Even if the section is considered a penetrating highway, the accesses in the vicinity of the urban area are "roundabout" type intersections as is the case of the access to the port of GHAZAOUET (PK 0.000) and the neighboring village (PK 0.00+400). This makes the highway look like a national highway in some segments.
- In addition, it is common to find motorcycles or pedestrians circulating on the existing motorway sections in Algeria.
- Outside urban areas, lighting is not provided and protection is provided by concrete, GBA, or DBA type that are often crossed by pedestrians.

In previous research (Hoque et al., 2012; Tripodi et al., 2020), the iRAP program was applied to existing road projects using the physical characteristics of roads in a reactive manner. Attributes are often visually recorded and possible security corrections become expensive and sometimes difficult to implement.

On the other hand, the present study brought the following originalities:

- The iRAP program was adapted in the study context to be applied on a road network in a proactive way. The risk assessment is carried out even before the project is realized, which allows the contracting authorities to make the necessary and less costly corrective measures aiming to improve road safety.
- The attributes were taken directly from the technical files intended for the realization of the future motorway project.
- The number of lanes was not included in the calculations because the type of accidents for which our assessment was made does not relate to frontal accidents. Thus, the fact that there is a separation of the roadway by a central platform, the risks relating to overtaking in both directions of traffic are considered to be zero (iRAP, 2013).

3.3.1 Road attributes

Attributes used in the proactive risk assessment methodology were identified from several information sources:

- Use of the final implementation file obtained from the Algerian highways department in Tlemcen region, (Ingénieur Conseils Associés, 2015) in paper and Covadis format. It contains several technical parts (geometric report of the alignment, longitudinal profile, Cross-section, and synoptic plans).
- Traffic speed was determined for each segment from both signalling and equipment plans.
- Attributes related to intersections, access points, and surface types were captured using the OpenStreetMap.

Thus, Table 3 gives the list of attributes included in the study.

3.3.2 Type of accident and type of users adopted

After an in-depth analysis of the highway segments by exploiting the execution folder, two types of crashes were considered only for the risk assessment:

1. The type of crash due to control loss
2. The type of crash due to Run-off road.

As long as the two traffic directions were separated by a median, the type of frontal accident was eliminated in the calculation.

With regard to the type of users, this study took into account only the case of vehicle occupants.

For each segment's risk calculation, three risk assessment possibilities are presented:

1. Risk assessment for roundabout intersections;
2. Risk assessment for straight segments;
3. Risk assessment for intersections of Run-off road.

Table 3 List of attributes considered for the proactive risk assessment methodology

N	Road attributes	Documents and methods used
1	Lane width (m)	execution folder paper format + Covadis format
2	Roadside severity - object	execution folder paper format + Covadis format
3	Roadside severity - side distance (m)	execution folder paper format + Covadis format
4	Grade %	execution folder paper format + Covadis format
5	Median width (m)	execution folder paper format + Covadis format
6	Median type	execution folder paper format + Covadis format
7	Curvature	execution folder paper format + Covadis format
8	Road surface conditions	CMF = 1 (new project)
9	External flow	traffic study
10	Traffic speed	signalling plans and equipment plans
11	Intersection type	OpenStreetMap
12	Area type	OpenStreetMap
13	Property access points	OpenStreetMap

3.3.3 Traffic speed

The crash modification factor associated with the different traffic speeds used in IRAP is developed by multiplying a probability factor (the link between the speed and the probability of an accident occurrence) and a gravity factor (the link between the speed and the gravity). In our study, three speeds were used, 40, 60, and 80 km/h associated with FMCs of 0.021, 0.05, and 0.15, respectively.

3.4 Use of geographic information systems

Numerous studies were conducted to explore black areas of road accidents using GIS (Anderson, 2007; Austin et al., 1997; Oulha et al., 2013; 2016; Sayed and Mhaske, 2013). In this study, GIS is primarily used to map hectometers with different levels of road risk on the highway using a proactive approach. The data processing was carried out on the ArcGis10.8 software. Using the collaborative Open Street Map (OSM) project, a geographical database was built containing different entities essential for road risk analysis on the new section of the GHAZOUET highway.

By using the GIS, we were able to transfer recovered DWG files on the Covadis software to shape geographic data. The latter has allowed us to build a more complete geographical database that offers the possibility of analyzing road risk.

4 Results and discussions

After drawing the basic attributes from the technical documents for a new highway project, the data were analyzed using a combined methodology described in Section 3.

Tables 4, 5 and 6 present the risk assessment results for each type of accident mentioned in the methodology.

Table 4 shows the results of the calculation of risk by the IRAP method for a typical segment of control loss accident type. This type represents 104 segments, or 95.6% of the project segments studied.

Table 5 gives the results of the risk calculation by the IRAP method for a typical segment of the accident type with control loss and Run-off road accidents. This type represents 4 segments (3.6% of the total segments).

Table 6 provides the risk calculation results for intersections. The study area contains two roundabout intersections.

Table 7 summarizes the overall risk assessment results for the 110 segments (108 alignment segments and 2 intersections) with a star rating.

Table 4 Star rating score for occupants of vehicles for crash type loss-of-control: PK01-Segment 2

Type of risk factor	CMFs	Score
Road attribute (likelihood)		
Lane width	1	
Curvature	3.5	
Curve quality	1	
Delineation	1	
Center line rumble strips	1.25	
Road condition	1	
Grade	1	
Skid resistance / grip	1	
Product of road attribute (likelihood) risk factors		4.375
Road attribute (severity)		
Median type	80	
Product of road attribute (severity) risk factors		80
External flow influence		0.185
Median travers ability		1
Operating speed		0.021
Head-on (loss-of-control) star rating score		1.359

Table 5 Star rating score for occupants of vehicles for crash type Run-off road (passenger side)

PK	1	2		
Segment	10	1	2	3
Run-off road (passenger side)	2.625	5.775	5.775	5.775
Loss of control	2.775	6.105	6.105	6.105
Star rating score	5.4	11.88	11.88	11.88
Star rating	3	3	3	3

Table 6 Star rating score for intersection of roundabout type

Type of risk factor	Category	Risk factor
Speed management / traffic calming		
Intersection type	Roundabouts	15
Intersection quality	Good	1
Grade	2.2%	1
Street lighting	Present	1
Skid resistance / grip	Sealed - adequate	1.4
Sight distance	Adequate	1
Intersection channelization	Present	1
Speed management / traffic calming	Speed reduction devices	1
Road attribute (severity)		
Intersection type	Roundabouts	15
External flow influence	11 000	0.185
Operating speed	40 km/h	0.021
Intersection star rating score		1.224
Star rating		5

Table 7 Star rating result

Star rating	Number of segments	SRS
5	2	1.407
	3	1.359
	25	0
4	2	3.2375
	20	2.775
3	1	5.4
	35	6.105
	15	9.712
	3	11.88
2	None	–
1	None	–

The results of Table 7 show 58 segments (or 52.8% of the segments studietabled) with an assignment of 03 stars thus representing a potential accident risk. All these sections then require a reassessment in terms of road safety. Although we are still in the design phase, rectifications are still possible and less costly. The 52 segments (47.2% of the segments studied) with an assignment of 04 and 05 stars do not require security interventions because the risk is estimated to be low.

As a result, identifying high-risk sections in a preventive manner will enable the road project to eliminate safety errors at an early stage of the work before the road is opened to traffic.

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4.1 The influence of geometric and speed characteristics on safety

4.1.1 Case of tight curvature segments and high speed

Several studies showed that the rate and severity of accidents are proportional to the degree of curvature. Sipos (2014) demonstrated through accidental statistics and geo-computer analyzes that there was consistency between horizontal and vertical curves, and the number and severity of accidents. Gelnnon (1987); Johnston (1982) and Zegeer et al. (1991) concluded that tight curves of less than 500 m are associated with high accident rates. Aram (2010) and Mohammed (2013) demonstrated that accidents with injuries predominate over horizontal curves more than accidents with property damage only.

Table 8 shows that 15 from the 58 segments that are characterized by a tight curvature geometry (radius less than 500 m) and a speed of 80 km/h have a high risk level (3-star rating). These are the following segments: 6 and 7, 50 to 55 and 65 to 71.

Furthermore, for segments 8 and 9, the fact that the traffic speed was reduced to 60 km/h, the risk became low (rating by 4 stars) although the curvature remains tight (radius less than 500 m).

Where the speed is above 80 km/h and the curvature is tight, road safety experts should pay attention to the safety aspect (see Fig. 2).

4.1.2 Cases of moderate curvature and high-speed segments

42 segments are characterized by a high speed (80 km/h) and a moderate curvature (550 m, 650 m, and 820 m), where the estimated risk is high with an assignment of 03 stars. This is the case for segments 11 to 49, 57 and 58, and 74 to 110. In all cases where the speed is above 80 km/h, road safety experts must also pay attention to the safety aspect.

Table 8 High-risk segments and their technical and geometric characteristics

Segment (100 m)	Curvature		External flow influence			Traffic speed		Star rating
	Curvature (m)	CMF	AADT (PVU)	CMF: Run-off road	CMF: loss of control	Speed (km/h)	CMF	
6	240	3.5	11 000	-	0.185	80	0.15	3
7	215	3.5	11 000	-	0.185	80	0.15	3
10	> 900	1	11 000	0.5	0.185	80	0.15	3
11	650	2.2	11 000	0.5	0.185	80	0.15	3
12	650	2.2	11 000	0.5	0.185	80	0.15	3
13	650	2.2	11 000	0.5	0.185	80	0.15	3
14	650	2.2	11 000	-	0.185	80	0.15	3
15	650	2.2	11 000	-	0.185	80	0.15	3
37	820	2.2	11 000	-	0.185	80	0.15	3
38	820	2.2	11 000	-	0.185	80	0.15	3
39	820	2.2	11 000	-	0.185	80	0.15	3
44	550	2.2	11 000	-	0.185	80	0.15	3
45	550	2.2	11 000	-	0.185	80	0.15	3
46	550	2.2	11 000	-	0.185	80	0.15	3
47	550	2.2	11 000	-	0.185	80	0.15	3
48	550	2.2	11 000	-	0.185	80	0.15	3
49	550	2.2	11 000	-	0.185	80	0.15	3
50	445	3.5	11 000	-	0.185	80	0.15	3
51	445	3.5	11 000	-	0.185	80	0.15	3
52	445	3.5	11 000	-	0.185	80	0.15	3
53	445	3.5	11 000	-	0.185	80	0.15	3
54	445	3.5	11 000	-	0.185	80	0.15	3
55	445	3.5	11 000	-	0.185	80	0.15	3
56	650	2.2	11 000	-	0.185	80	0.15	3
57	650	2.2	11 000	-	0.185	80	0.15	3
58	650	2.2	11 000	-	0.185	80	0.15	3
65	440	3.5	11 000	-	0.185	80	0.15	3
66	440	3.5	11 000	-	0.185	80	0.15	3
67	440	3.5	11 000	-	0.185	80	0.15	3
68	440	3.5	11 000	-	0.185	80	0.15	3
69	440	3.5	11 000	-	0.185	80	0.15	3
70	440	3.5	11 000	-	0.185	80	0.15	3
71	440	3.5	11 000	-	0.185	80	0.15	3
74	650	2.2	11 000	-	0.185	80	0.15	3
75	650	2.2	11 000	-	0.185	80	0.15	3
76	650	2.2	11 000	-	0.185	80	0.15	3
77	650	2.2	11 000	-	0.185	80	0.15	3
78	650	2.2	11 000	-	0.185	80	0.15	3
79	650	2.2	11 000	-	0.185	80	0.15	3
80	650	2.2	11 000	-	0.185	80	0.15	3
81	650	2.2	11 000	-	0.185	80	0.15	3
84	780	2.2	11 000	-	0.185	80	0.15	3
85	780	2.2	11 000	-	0.185	80	0.15	3
86	780	2.2	11 000	-	0.185	80	0.15	3
91	650	2.2	11 000	-	0.185	80	0.15	3
92	650	2.2	11 000	-	0.185	80	0.15	3
93	650	2.2	11 000	-	0.185	80	0.15	3

Table 8 High-risk segments and their technical and geometric characteristics (continued)

Segment (100 m)	Curvature		External flow influence			Traffic speed		Star rating
	Curvature (m)	CMF	AADT (PVU)	CMF: Run-off road	CMF: loss of control	Speed (km/h)	CMF	
94	650	2.2	11 000	-	0.185	80	0.15	3
95	650	2.2	11 000	-	0.185	80	0.15	3
96	650	2.2	11 000	-	0.185	80	0.15	3
103	650	2.2	11 000	-	0.185	80	0.15	3
104	650	2.2	11 000	-	0.185	80	0.15	3
105	650	2.2	11 000	-	0.185	80	0.15	3
106	650	2.2	11 000	-	0.185	80	0.15	3
107	530	2.2	11 000	-	0.185	80	0.15	3
108	530	2.2	11 000	-	0.185	80	0.15	3
109	530	2.2	11 000	-	0.185	80	0.15	3
110	530	2.2	11 000	-	0.185	80	0.15	3

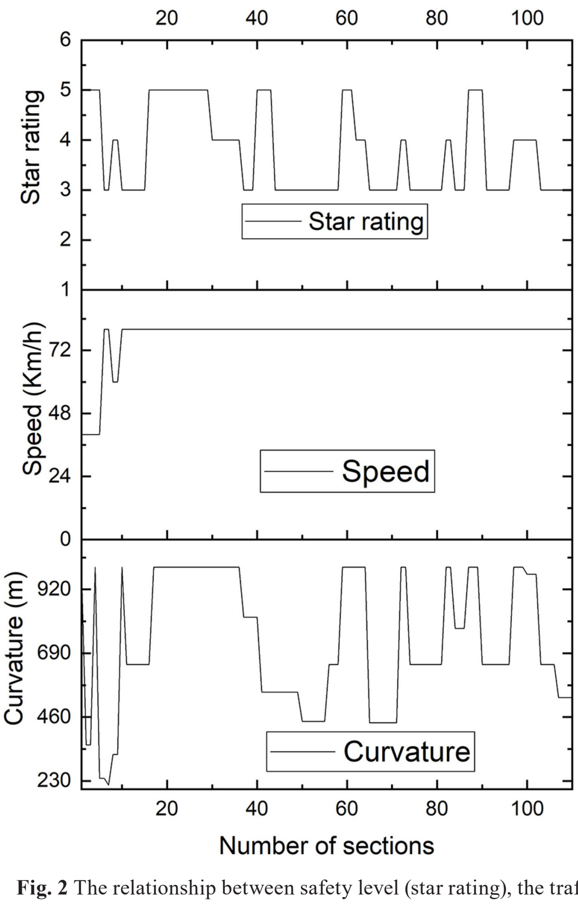

Fig. 2 The relationship between safety level (star rating), the traffic speed, and the curvature radius

4.1.3 Cases of segments with two or more types of accidents at high speeds

Segment No. 10 contains a road exit; it is characterized by a straight line with a traffic speed of 80 km/h. The probability of two types of accidents (control loss and road exit accidents) is a major factor in the increase of accident risks. This segment was classified as a high-risk segment with an assignment of 03 stars.

Similarly, all segments that do not contain road exits and have only one type of accident (control loss only) with moderate curvatures even if the speeds used are 80 kph, the level of risk remains low (rating of 04 stars). This is the case for sections 8 and 9; 33 to 37; 62 to 64; 72 to 78 and 97 to 102. As a result, experts should be aware of all road exits with speeds exceeding 80 kph.

4.1.4 Cases of tight curvature segments and low risk

Two segments are characterized by a tight curvature (less than 500 m) with a low speed of 40 km/h. These are the two segments at the level of the urban area close to the roundabouts. Although the curvature is tight, the calculated risk is too low with a rating of 05 stars.

Traffic speed is therefore a major factor in the risk equation. Controlling the speeds used once the road is put into circulation by speed control points or by automated radars is recommended in order to ensure safety with acceptable financial costs without making significant modifications to the road geometry which is often expensive.

Table 9 proactively provides overall guidance to road safety auditors on the relationship between traffic speeds, the curvature radius, the traffic flow, the types of accidents on the stretch, and the likely level of road safety.

Table 9 Proactive risk assessment

Speed (km/h)	Curvature (m)	Flow (PVU*)	Types of accident		Risk
			Loss of control	Run-off road	
≥ 80	sharp	< 18 000	✓		high risk
≥ 80	moderate	< 18 000	✓		high risk
≤ 40	sharp	< 18 000	✓		low risk
≥ 80	moderate / gently curving	< 18 000	✓	✓	high risk

* Private Vehicle Unit

4.2 Geomatics tools for decision support

Analysing a road project from a road safety perspective requires the use of several sources of information. In order to facilitate decision-making, geomatics tools such as GIS are becoming indispensable by the capabilities they offer to store, organize and display these diverse data in layers of information. For example, the location of high-risk accident segments is better visible than on a digitized map.

Fig. 3, thus, shows the motorway section which is the object of study and the set of surrounding spaces which it crosses (urban areas, secondary road network, buildings, forests, etc.). It is a translation from real space to a geolocated space.

The digitization of the space was elaborated using Open Street Map and ArcGis 10.8 software. The digitalization of the motorway axis was done by transforming the DWG files obtained from the plans in Covadis format to layers of information in the ".shp" format of the ArcMap.

Fig. 4 visually shows the curvature radii for each 100 m segment. According to the recommendations of (iRAP, 2013), the curvature radii were divided into four classes. Very sharp curvatures with radii less than 200 m are shown in red on the map (Fig. 4). The sharp curvatures (radii less than 500 m) are indicated by the orange color. Moderate curvatures (radii greater than 500 m and less than 900 m) are represented by the yellow color and finally straight or gently curving segments with a radius greater than 900 m are shown by the green color.

Fig. 5 shows the location of the road segments according to their accident risk level. Three levels of risk were identified in the study area:

1. Very low-risk segments (0 < SRS > 2.5): they are represented on the map by the green color with rating of 05 stars;
2. Low-risk segments (2.5 < SRS > 5): they are represented by the yellow color with a 04-star rating;
3. Medium risk segments (5 < SRS > 12.5): they are represented by the orange color and a rating of 03 stars. Inspection and audit work should give priority to these sections.

The calculations revealed that there were no high risk (segments with 20 red stars) and no very high risk (10 black stars).

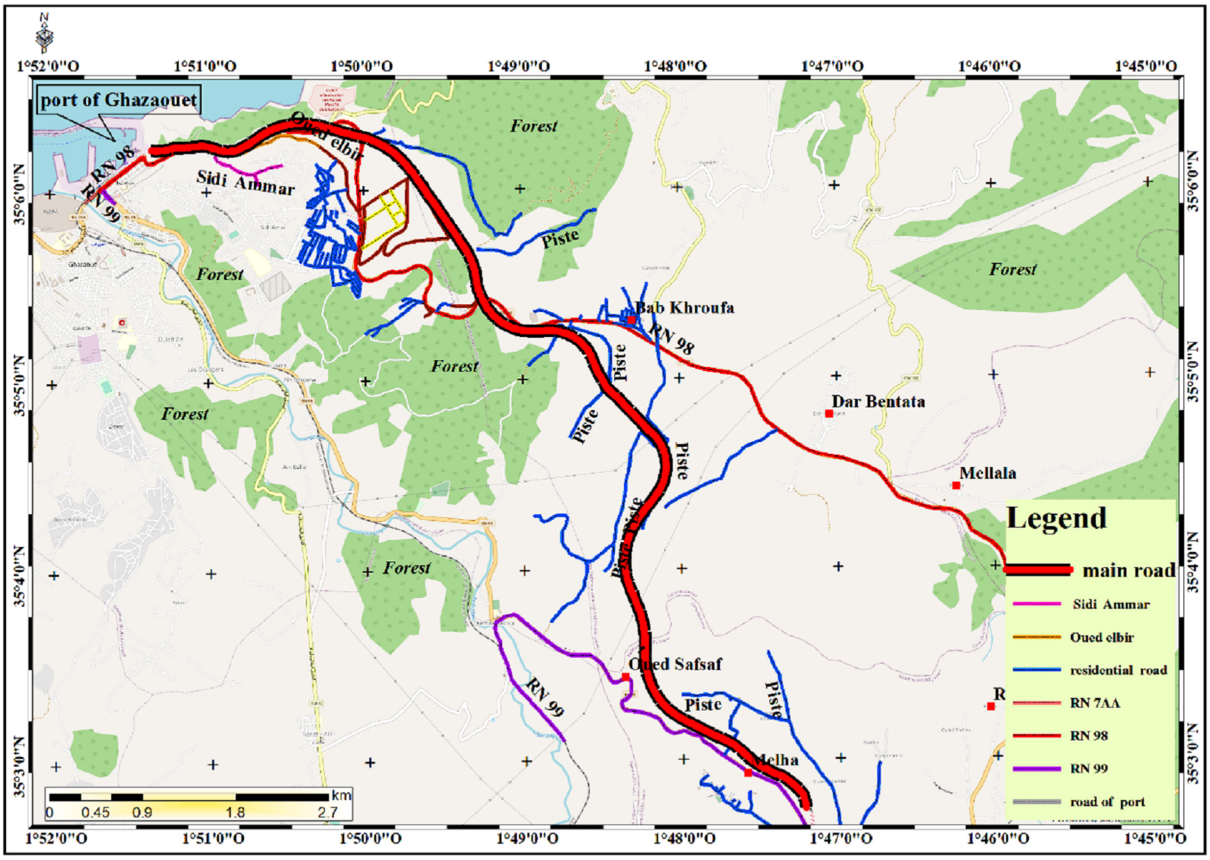

Fig. 3 Digitalization of the penetrating highway of GHAZAOUET

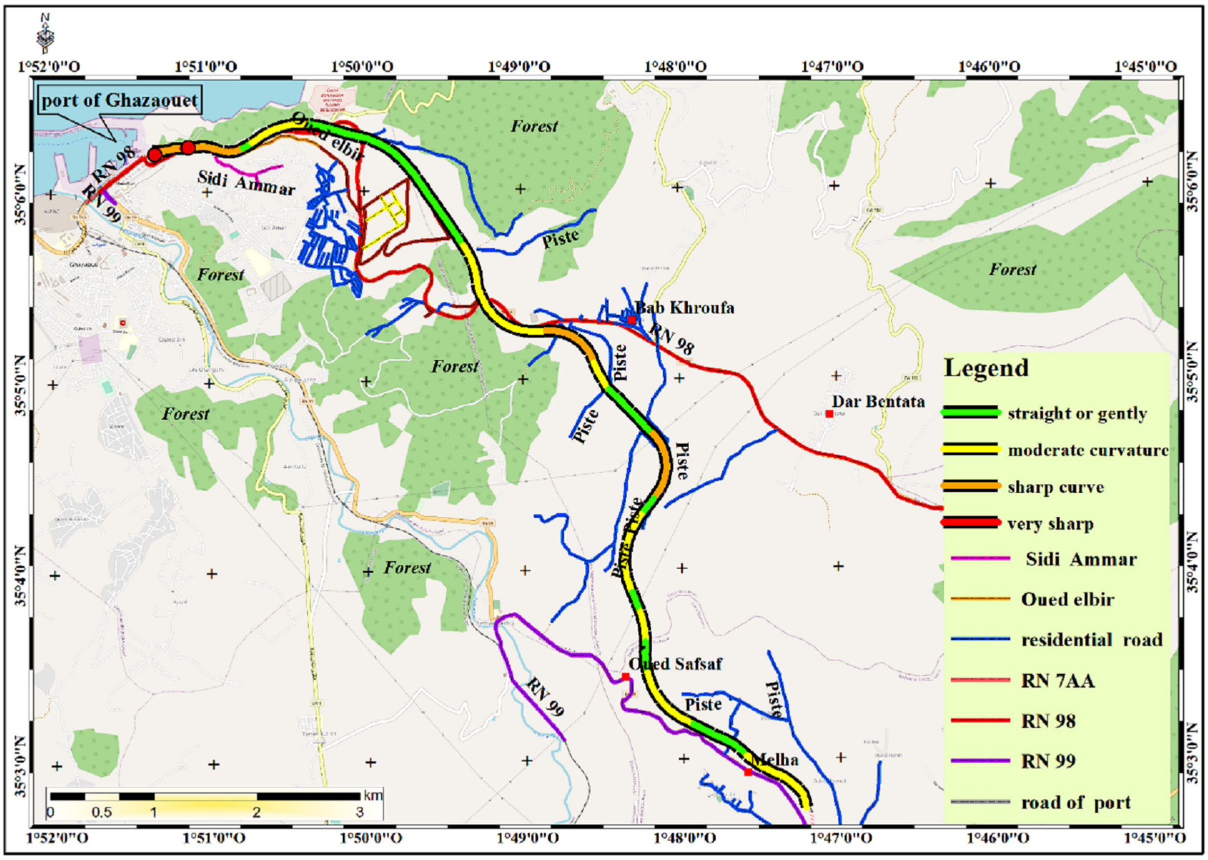

Fig. 4 The variation of the degree of curvature on the penetrating highway of GHAZAOUET

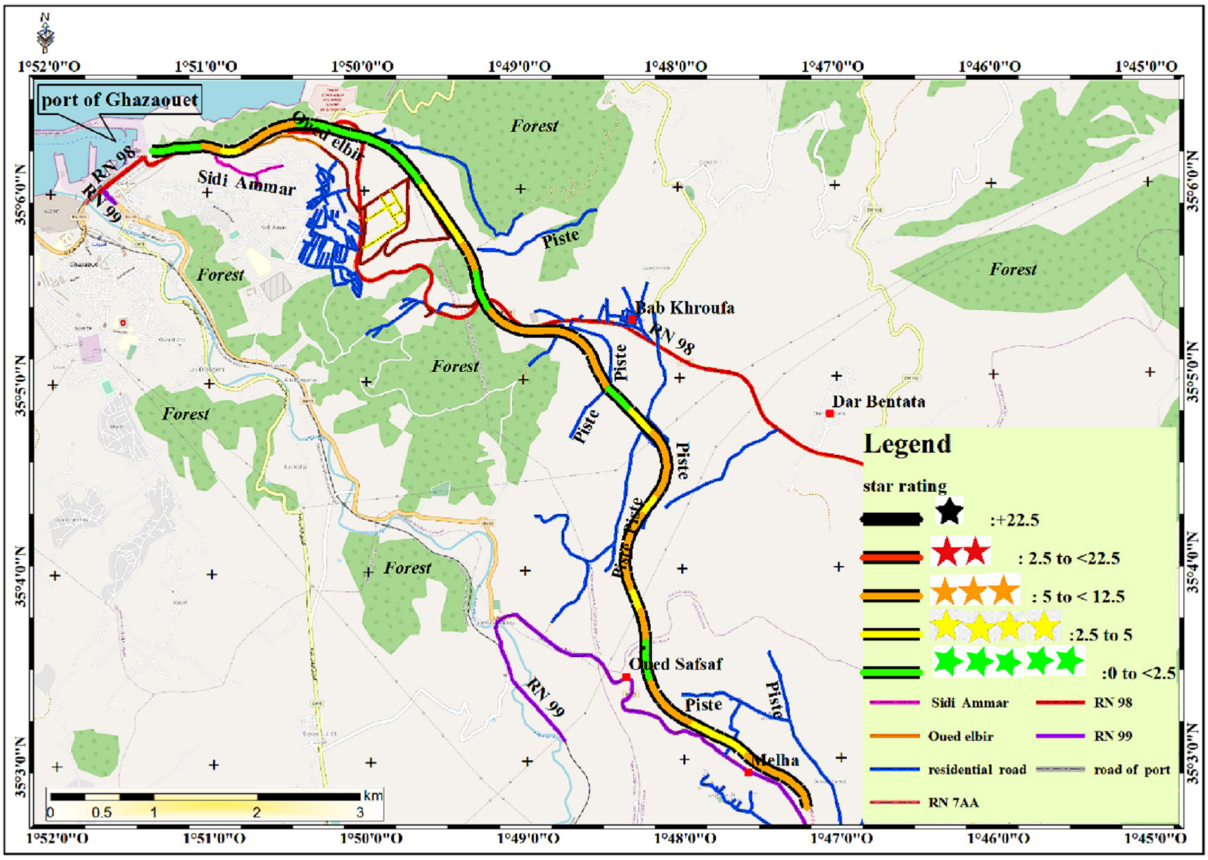

Fig. 5 Star rating of road risk on the Algerian motorway: case study of GHAZAOUET section

As a result, the integration of GIS into the IRAP methodology led to the following positive outcomes:

- The translation of the real space of the project to a geo-localized space via GIS makes it possible to better assimilate the road project as a whole and not in an isolated manner.
- The star rating introduced by IRAP was highlighted through maps produced by GIS. It thus facilitates the inspection work of road safety experts.
- These maps; then, become an easy-to-use decision-support tool for road safety audit teams to quickly identify segments that require road safety improvement.

5 Conclusions and recommendations

To conclude, this approach can be easily applied to future projects in the planning phase since it allows all kinds of risks affected by the infrastructure to be identified and then treated to avoid costly reconstructions.

The results of the study showed that the road infrastructure has a significant impact on the user's safety. The technical characteristics drawn from the final phase of the project study can be effectively used as a source of information for predicting high-risk areas of an accident in a new road project.

In our case, among the attributes on which the motorway section has been assessed: the curvature and traffic speed are the main characteristics affecting road safety.

Thus, following the problems defined we recommend the control of the speeds used once the road is put into circulation by speed control points at least by automated radars.

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