

# Application of GIS Tools to analyze changes in road network parameters: the case of Berkane province

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**Abstract.** Road network management is an aspect of infrastructure heritage preservation that requires special attention from the departments concerned, in order to accurately predict maintenance, reinforcement and planning interventions, which requires effective methods for visualizing and tracking the network. This research aims to integrate techniques of the Geographic Information System (GIS) for modeling, classifying and analyzing the evolution of two parameters: Traffic and pavement deterioration. In this context, a case study examining GIS spatial representation options visualized these two parameters on national, regional and provincial roads in the Berkane province in Morocco based on the results of traffic investigations and visual surveys of pavement deterioration between 2016 and 2022. This study will provide road network managers and decision-makers with the information they need to make the right decisions regarding future maintenance programs.

**Keywords:** GIS, road network, evolution, traffic, deterioration.

## 1 Introduction

In today's world of communication and exchange, the main role of a road network is to enable people's circulation easily and safely, thus contributing to the economic expansion of the country. Approaches to space planning, infrastructure enhancement and investment promotion are based on these networks, which make an effective contribution to the optimal distribution of the territory. Morocco has long deployed considerable efforts in developing its roads infrastructures, to continuously increase their numbers and strengthen them to meet the needs of social and economy interactions, while implementing an action plan focused on preserving the road network, adapting it to traffic growth and improving pavement condition[1].

The study of road networks is one aspect of scientific analysis that has garnered the interest of researchers from many fields [2], giving it great importance, especially the part concerning the conservation and development of road networks, which are among the largest promising projects and priority strategic approaches for government authorities considering the remarkable impact of these investments on the economy and population [3], hence the

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need to provide for a solid management process adapted to the nature of the network's challenges, such as GIS, which is a preferred tool for graphically modeling the various parameters of road networks. In the literature, there are several similar studies, [4] focused on developing a classification system that maps 11 network performance concepts (travel time reliability, flexibility, vulnerability, accessibility, connectivity, reliability, connectivity reliability, capacity reliability, flexibility, redundancy, robustness and resilience). [5] presented a spatial classification of the road network with travel speed to measure effectiveness. [6] employed PAVER 6 .5 .7 software, which is linked to GIS, and the Pavement Condition Index (PCI) value to prioritize repair and innovation for the entire road network. [7] examined the need to analyze road accidents within urban perimeters through GIS techniques.

## **2 Road network typology**

### **2.1 Study context**

This study is part of an ambitious project chaired by Morocco's Ministry of Public Works, Transport, Logistics and Water, aiming to globally adjust the classification of the current road network. This project is based on the identification of the structuring network linking the kingdom's main centers and on the classification of unclassified roads carried out by the Ministry under approved agreements with specific criteria. It also includes the modernization of the classified road network and is part of the national territory planning policies. The objectives of this revision are numerous: from a technical point of view, it is a question of harmonizing road functions with current and future road transport needs by classifying them according to their functionality, and from an institutional point of view, it involves creating coherence between the responsibilities of different entities of the road sector and the objectives of the decentralization policy.

### **2.2 Road network classification**

The 1990 Moroccan road network classification divides roads into three categories: national (NR), regional (RR) and provincial (PR), with a specific numbering for each type, national roads are identified by two-digit numbers from 1 to 20. Regional roads have three-digit numbers between 100 and 800, while provincial roads use four-digit numbers ranging from 1000 to 8000 [8]. To improve orientation mapping, an orientation rule has been introduced: odd-numbered roads run from North to South, while even-numbered roads run from West to East. In the case of shared sections between two roads, the lowest number rule applies: the road with the smaller number retains its route, while the one with the larger number is diverted. In this way, the sections overlapping two roads are assigned to the road with the lower number.

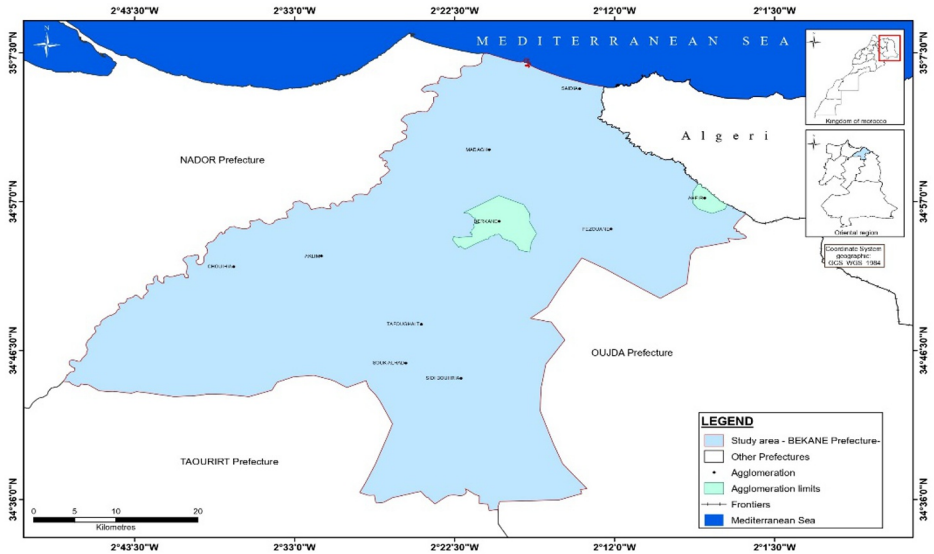
### **2.3 Classification of performance evaluation parameters**

Road managers are constantly seeking to identify indicative parameters in order to assess users satisfaction and roads performance comparing to the objectives set [2]. The performance of a road network was assessed by its length, the percentage of paved roads and their condition. These traditional indicators have been supplemented by spatial density (length per kilometer) and social density (length per inhabitant). New indicators are currently being explored to appreciate the social role of roads, in particular as a crucial means of accessing basic social services and improving living conditions. Among these indicators are

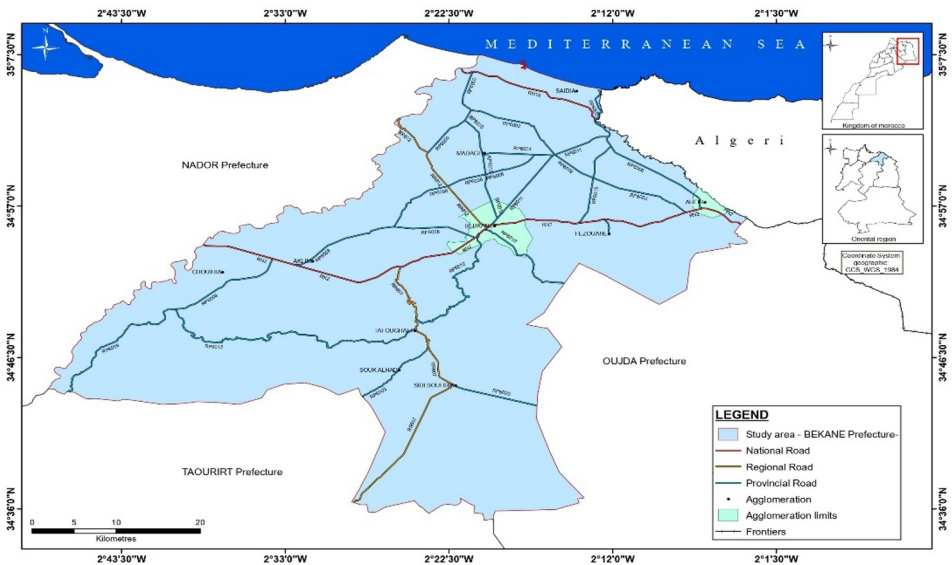
those relating to the size of the network, giving an idea of its composition and distribution, as well as the density in relation to population and surface area. The pavement surface indicator (SUI) is also crucial, as it provides information on the state of deterioration of the pavement surface, while the condition of the shoulders (IAC) and the condition of the structure (IST) are still used [9]. Finally, exploitation's indicators, which relate to traffic volumes and accidents, are all equally important.

## 2.4 Study area

The study is applied to the three types of roads forming the road network of the province of Berkane, located in the North-East of Morocco.



**Fig. 1.** Study area- the province of Berkane in the North-East of Morocco-



**Fig. 2.** Road network of the province of Berkane in North-East Morocco.






### 3 Methodology

GIS is the ideal tool for harmonizing and combining road network data for an appropriate asset management by providing a clear overview of traffic and pavement deterioration through modeling and classification, represented in the form of thematic maps, each map shows the graphic distribution of one of the two parameters whose evolution over time 2016-2022 will be described.

#### 3.1 Traffic mapping

The traffic is an essential data in pavements dimensioning and maintenance, that is present at every stage of road study, it enables a huge number of factors and indices to be calculated, such as the thickness of the pavement structure to be installed, deterioration coefficients, accidentology rates and others, therefore, it is necessary to have a good mastery of this parameter. GIS-based traffic mapping is a way of managing the road network that involves modeling traffic data by thematic maps showing the spatial distribution within the study area, for this purpose, we classify the traffic by converting the numbers of vehicles passed per day per road section into 4 traffic classes according to the following grid [10].

**Table 1.** Assignment of road traffic classes.

Traffic class	T0	T1	T2	T3	T4
Number of vehicles per day	Superior to 4500	Between 2000 and 4500	750 and 2000	200 and 750	50 and 200
Graphical representation					

#### 3.2 Mapping of pavement deterioration state

The state of pavement deterioration is a parameter assessed on the basis of visual observations of deterioration which are used to determine the surface condition indicator (SUI) and prioritize sections of the road network, updated every two years. Each kilometer of pavement is classified into 04 surfaces deterioration classes based on the decision matrix and total scores.

**Table 2.** Pavement classification matrix using total score per kilometer.

Potholes	cracks	Pull-Out	Class
0	0	0_1	A
1	1_2	2_3	B
2_4	3_10	4_5	C
5_10	11_20	6_10	D

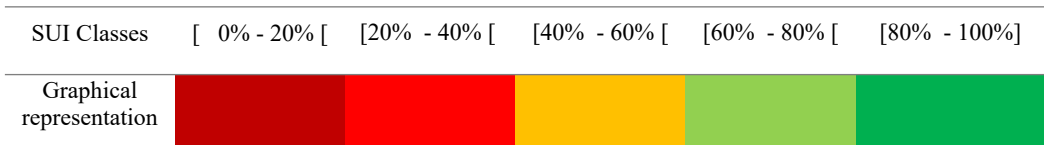
**Table 3.** Matrix of SUI class per km.

Pothols	A	B	C	D
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<b>Pull - Out</b>		A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
	A	A	A	B	B	B	B	C	C	B	C	C	D	C	D	D	D
<b>Cracks</b>	B	B	B	C	C	B	C	C	D	C	C	D	D	D	D	D	D
	C	C	C	C	D	C	C	D	D	C	C	D	D	D	D	D	D
	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D

The overall condition of the road network is evaluated based on the percentage of the li near road whose SUI is a Class A or Class B, so-called % (A+B). The ratings provided are as follows: A (Excellent), B (Passable), C (Bad) and D (Very bad).

**Table 4.** SUI index class distribution.



## 4 Results and discussion

The application of GIS to generate thematic maps showing the spatial and temporal distribution of the two parameters leads to the following outcomes:

### 4.1 Traffic evolution

- National roads: Traffic remained constant at class T0 on the NR02, from KP 494+480 to KP 538+800, and on the NR16, from KP 0+000 to KP 16+000, with the exception of traffic between 2020 and 2021, where it was reduced to T1 before returning to T0.
- Regional roads: On RR607, from KP 0+000 to 43+000, the traffic decreased by T1 between 2016 and 2019, reaching T2. On RR612, from KP 0+000 to 30+040, traffic has also decreased by T0 between 2016 and 2019, reaching T1.
- Provincial roads: Some provincial roads maintained the same level of traffic, such as the PR6000 and PR6010 in T0, while PR6015 remained in T4 and PR6020 in T2. By contrast, other provincial roads experienced minor variations in traffic class.

### 4.2 Evolution of the state of pavement deterioration

- National roads: the NR02 from KP485+000 to KP543+000 saw a steady increase between 2016 and 2022, rising from 93.10% in 2016 to 97.87% in 2022. However, the evolution of the SUI index on the NR16 is more contrasted. After a slight drop between 2016 and 2018, the index fell sharply in 2020 (50%). However, it then rebounded in 2022, reaching 55.56%.
- Regional roads: RR607 from KP 0+000 to KP37+000 and RR612 from KP12+000 to KP29+000 saw a significant improvement in the condition of their surfaces between 2016 and 2022. In 2016, RR607 had a SUI of 62.90%, while RR612 had a SUI of 37.50%, indicating surfaces in poor condition. In 2022, the SUI for both roads reached 100.00%, indicating surfaces in very good condition following major renovation work.
- Provincial roads: Analysis of SUI evolution reveals deteriorating trend in surface condition between 2016 and 2022. In 2016, the average SUI of PR was 62.37%,

indicating an overall average condition. However, in 2022, the average SUI has dropped to 51.59%, suggesting a significant deterioration, especially on PR6000 and PR6006.

## 5 Conclusions and prospects

This study proposed a method for modeling the evolution of road parameters from 2016 to 2022 in the Berkane province of Northeastern Morocco. The application of the road network mapping method has resulted in the classification and development visualization of national roads, regional roads and provincial roads according to their traffic classes and pavement conditions. In this respect, it is still essential to plan similar cartographic modeling for other pavement management parameters such as accidentality rate and fatality density per road section, in order to anticipate maintenance modalities to preserve the province's road assets.

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### Author contribution

All authors (Youssef Aouni, Souad EL Moudni El Alami & Abdennaby Toumi) reviewed and approved the final manuscript, with Youssef Aouni contributing to study design, methodology, and the draft manuscript, Souad EL Moudni El Alami and Abdennaby Toumi providing supervision and reviewing and interpreting the data.

### Ethics approval and consent to participate

Not applicable.

### Consent for publication

All the authors have agreed to publish this article.

### Competing interests

The authors declare that they have no competing interests.

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