VOL. 17, NO. 20, OCTOBER 2022 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

GIS APPROACH FOR THE PAVEMENT SURFACE INDEX MODELING USING A ROAD SURVEY DATA

Mohammed Amine Mehdi[1], Toufik Cherradi[1], Azzeddine Bouyahyaoui[1], Imane Mehdi[1] Said El Karkouri[3] and Ahmed Qachar[4]
[1]Mohammadia School of Engineers, Civil Engineering and Construction Laboratory, Rabat, Morocco
[2]Mohammadia School of Engineers, Quality Safety and Maintenance Laboratory, Rabat, Morocco
[3]National Center for Road Studies and Research, Rabat, Morocco
[4]Moroccan Road Directorate, Ministry of Equipment, Transport, Logistics and Water, Rabat, Morocco
E-Mail : aminemehdi@research.emi.ac.ma

ABSTRACT

Variation in road conditions, increasing traffic loads and decreasing funds have presented a complex management challenge for the road maintenance and rehabilitation process. Consequently, there is a need to assess the pavement network condition, make decisions on maintenance strategies, set rehabilitation priorities and implement a maintenance management system. In this regard, Geographic Information System (GIS) is a powerful tool for managing and analyzing data referenced to a geographic location, especially in the field of road infrastructure where pavement section information stored in textual databases can be linked by location and attribute in geographic maps. This article proposes a macroscopic evaluation approach of the major pavement surface deteriorations using a GIS applied on a Moroccan national road section with 50 km length. Since its birth, and despite all the interventions carried out based on the visual inspection results analysis, this pavement underwent mainly the following deteriorations: potholes, pull-outs and cracks. In this regard, using a matrix deterioration combination developed by the Moroccan Center for Studies and Road Research, we proposed firstly a reduction of data relating to visual inspections conducted from 2008 to 2018, this step is essential to deduce the surface condition index (SUI) of this pavement, secondly to model them thematically by studying their temporal variation. This approach leads to facilitate the data reading, reduce the information, helps to take future decisions on the maintenance and propose a technical solution to maintain the level of the pavement surface index.

Keywords: GIS, flexible pavement, pavement surface index, road deterioration, road inspection.

INTRODUCTION

The road infrastructure maintenance requires a considerable amount of time and money. Many millions of dirhams are invested each year in road maintenance to ensure the mobility of people and goods. However, deteriorating road conditions, increasing traffic loads and decreasing funds have presented a complex management challenge for the maintenance and rehabilitation process [1]. Pavement management is considered a systematic approach to analyzing and reducing the cost of maintenance needs.

In fact, activities such as pavement condition assessment, maintenance, rehabilitation activities, and treatment prioritization are all pavement management components [2-3]. Knowledge of pavement distress data, such as cracking, pullouts, and potholes, can lead to cost-effective maintenance. Several methods can be applied to collect and measure the road pathology characteristics, including manual, automated, and semi-automated methods [4]. Selection and prioritization of maintenance actions, pavement condition prediction, and optimization of budget allocation are performed using performance and surface distress indices. The most common indices in this regard are the International Roughness Index (IRI) [5], Pavement Serviceability Index (PSI), Surface Index (SUI), Pavement Condition Index (PCI), Pavement Condition Index (PCR), Ride Comfort Index (RCI) and the (PCR), Driving Comfort Index (RCI), and Distress Manifestation Index [6]. To assess pavement surface distresses and determine index, it is necessary to measure and quantify the pathologies through field inspections [7].

These characteristics can be expressed in terms of the deterioration level. Most studies have focused only on the extent and severity resulting from the identification and the measurement of road pathologies distributions. In addition, issues such as the creation of index thematic models representing all surface distress in all or part of a pavement section, deterioration, maintenance problems and safety problems can be addressed. This paper is a preliminary attempt to propose a geographic information system (GIS) approach to represent the surface index by a spatial model (degree of deterioration) at the project level. In this regard, the results of inspections performed, textual data of deterioration matrix, topographic maps and the image processing approach will be used. The level of the Surface Index (SUI) will be performed.

Background

Many studies have been conducted on pavement management. The focus has been on performance indices or surface distresses. In most studies, pavement condition, which is based on the measurement of surface distresses has been evaluated by measuring only the severity and the extent [8-9-10]. The spatial distribution of deterioration levels and graphical representation was not considered. The expert system and HDM-4 software were used to prioritize the maintenance of urban roads [11]. The measurement of severity and extent parameters has been developed a simple ranking method for prioritizing maintenance using

VOL. 17, NO. 20, OCTOBER 2022 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

pavement distresses such as cracking, patching and roughness [12]. However, they only studied the severity and the extent of distress. The pavement deterioration process at two airports based on PCI and IRI measurements was performed [13]. A fuzzy multi-criteria decision system for prioritizing maintenance actions has been developed [14]. They studied the effect of surface distress severity on pavement performance. Several other studies have been conducted on pavement condition evaluation using performance indices or surface distresses. These studies only investigated the severity and the extent of distresses, without considering the distribution of cracks in conjunction with potholes and pull-outs.

The pavement surface distress was investigated in New Mexico based on spatial modeling using geographic information system (GIS) [15]. They presented a pavement condition assessment index called the overall distress rate (ODR) by measuring the severity and the extent. Despite the use of spatial analysis capabilities, they did not investigate the intensity of distress (cracking). However, this method can be developed at both the project and the network levels. Several manuals have been developed to assess pavement condition and measure the severity and the extent of cracking [16-17].

Objectives

The main objective of this work is to investigate the potential of Geographic Information System (GIS) then to establish a flexible classification of pavement distress for maintenance priorities. The classification process includes the type and the level of distress through matrix. Three different pathologies are used to determine the SUI surface index, potholes, pull-outs and cracks. They are represented as 4 deterioration levels: A (good), B (average), C (poor) and D (very poor). The system used data collected during inspections on the study road.

The ArcGIS software is used on one hand for displaying, querying and analyzing the data and on the other one, to validate the model and the flat representation of the surface deteriorations under georeferenced topographic maps. Pavement distresses are assigned based on the calculated pavement condition index (SUI) values. This technique proved to be cost-effective and appropriate for sound decision making for different maintenance activities and programs. The study allowed the development of surface condition analyses that can provide maintenance scenarios for the entire road or for specific areas of its territory based on the results of the visual inspections performed. The potential of this procedure is demonstrated by its use to establish scenarios, which permit the development of maintenance programs for this road network. The data are represented in a Geographic Information System (GIS) and processed by Python scripts [19].

Moroccan Road Inspection

The Moroccan Road network management requires, on the one hand, a well-defined road maintenance strategy and, on the other hand, well adapted and properly organized services to carry out the works. These works are of two types: either periodic, multi-year maintenance works relating to structural maintenance, surface dressings, and horizontal signs, or regular maintenance works carried out each year and consisting of cleaning ditches and drainage works, pavement deflashing works, and vertical signs. Since short-term management for maintenance has always been a priority, the collection of detailed data on pavement conditions is extremely costly and time-consuming. Hence the need to schedule periodic inspections.

The road network inspection [1] is the major component of a road maintenance schedule. It provides essential information to determine their deterioration types, importance and location. The direct observation of the pavement and its environment is essential for the identification, quantification and research of the causes of deterioration. In Morocco, the visual survey consists in going through all the covered road networks, during a period going from 1 to 3 months, to note the deteriorations by section of about ten meters every 200 m [1]. The types of deteriorations noted are the following Potholes, Cracks and Pull-outs.

Potholes

Small, bowl-shaped depressions in the pavement surface that penetrate down to the base course. They generally have sharp edges and vertical sides near the top of the hole. Potholes are most likely to occur on roads with thin Hot Mix Asphalt surfaces (25 to 50 mm (1 to 2 inches)) and seldom occur on roads with 100 mm (4 inch) or deeper HMA surfaces [20]. Generally, potholes are the final result of fatigue cracking (Figure-1). As alligator cracking becomes severe, the interconnected cracks create small chunks of pavement, which can be dislodged as vehicles drive over them. The remaining hole after the pavement chunk is called a pothole (Figure-2).

Figure-1. Pothole.

ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

Figure-2. Fatigue cracking showing the beginning of a pothole.

Linear Cracks

Linear cracks are not associated with corner breaks or blow-ups that extend across the entire slab. Typically, these cracks divide an individual slab into two to four pieces. Often referred to as “panel cracking”. Roughness, allows moisture infiltration leading to erosion of base/sub-base support, cracks will eventually spall and disintegrate if not sealed.

Figure-3. Large panel cracks on highway.

Longitudinal Cracking

Longitudinal cracks are not associated with corner failures or bursts that extend throughout the slab (Figure-4). Typically, these cracks divide an individual slab into two to four pieces. They are often called "panel cracks" [4]. It allows moisture infiltration, roughness, and may indicate the possible development of crocodile cracks and structural failure. This pathology is related to several causes such as poor construction and joint location (Figure-5).

Figure-4. Longitudinal cracking from poor longitudinal joint construction.

Figure-5. Longitudinal cracking.

Pull-outs

Pull-outs are one of the pavement surface deterioration phenomena that can be observed in the singular points of the road network is characterized by aggregate stripping due to the passage of heavy vehicles. The extent of this deterioration depends on many parameters, including the geometry of the road, the type of axle, the nature and surface appearance of the materials in contact (tire tread and pavement) and the weather conditions. The most common removals are peeling and feathering. The feathering is pull-outs of the plaster layer gravels, due to a dosage defect gravels cleanliness or a compaction problem.

VOL. 17, NO. 20, OCTOBER 2022 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

Figure-6. Feathering.

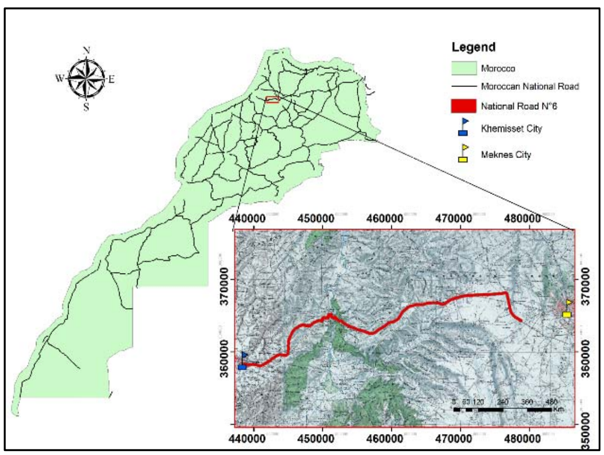

Figure-7. Peeling.

CASE STUDY

The 50 km length of the studied network was chosen according to its importance in terms of development in Morocco, it belongs to the Moroccan national road number 06, built with a flexible pavement structure [21], starting at kilometer point KP 0+081 and ending at KP 0+130 (Table-1), connects Meknes and Khemisset cities (Figure-8). This road link is permanently open (24/24). The traffic, estimated annually at 3639207 vehicle km/day. Given its important geographical location, the roadway must ensure the comfort and safety of traffic.

Table-1. Studied section location.

Kilometer point	X	Y
Origin	439617,09960	358252,362678
Fin	478570,08923	364436,6971297

The studied section has been the object of several maintenance interventions carried out by the Directorate of Roads of Morocco under the Ministry of Equipment, Transport and Logistics. In spite of these operations, the pavement has experienced superficial deteriorations [22] which are mainly expressed by cracks, potholes and tears, which implies the mandate of the managers to improve the criteria of durability and safety which are increasingly difficult to satisfy on the one hand and on the other hand, to find methodical solutions to control the evolution of the pathologies it affects based on the knowledge of the behaviour of all the pavement components , as well as on the processing of the existing road databases. The road under study is subdivided into sections of 1km length based on the main function of each road in the road network. This classification was carried out using the Moroccan survey method (Figure-9). Four levels of deterioration structured the pavement surface condition: A (very good), B (average), C (bad) and D (very bad). This level separation is based on the level matrix assigned to each type of deterioration.

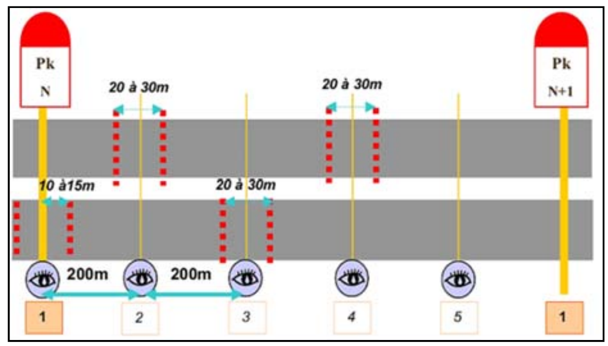

Figure-8. Road study location.

METHODOLOGY

The proposed method is based firstly on the analysis of the road inspection results carried out on this section from 2008 until 2018, the reduction of these data according to their deterioration state through the matrix developed by the national center of studies and road research [1]. This operation serves to facilitate the reading of the pavement surface index (SUI) on one side and to prepare needed input data to model using a GIS software on the other side.

Pavement Surface Index Evaluation (SUI)

The pavement condition assessment process begins with an inventory of the road network. In general, this assessment is based on a visual surface survey conducted by the Moroccan National Center for Road Studies and Research which allows to record data concerning deterioration such as cracks [22-24], pull-outs and potholes [23].

In this project, the inspection was carried out by recording certain parameters while walking on the evaluated road. The principle of the survey is based on the observation at regular intervals of 200 m of the existence or absence of each type of deterioration, indicating its severity (Figure-9).

 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

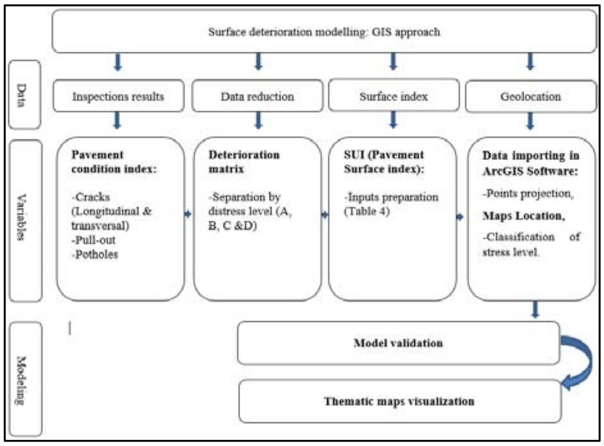

Figure-9. Visual Moroccan inspection method.

The integration of the observations is performed by adding the scores attributed to each kind of deteriorations (cracks, pull-outs and potholes) on each 1 km section. During the same surveys, the nature of the wearing course, the width of the pavement and shoulders, the traffic class, the nature and the date of the last intervention are also noted. For each km of pavement, the surface distress condition is classified into four classes for each distress according to the following decision grid, based on the cumulative scores over the km (Table-2).

The pavement surface condition index SUI for each km of paved road is determined according to the three classes of deterioration status, according to the following matrix represented in Table-3.

Table-2. Matrix of deterioration levels according to their types.

Deteriorations classes	Cracks	Potholes	Pull-out
A	0	0	0-1
B	1-2	1	2-3
C	3-10	2-4	4-5
D	11-20	5-10	6-10

Table-3. Surface deterioration matrix.

Potholes	Pull-out	Deteriorations			
		AB		C	D
A	A	A	B	C	D
	B	A	B	C	D
	C	B	C	C	D
	D	B	C	D	D
B	A	B	B	C	D
	B	B	C	C	D
	C	C	C	D	D
	D	C	D	D	D
C	A	B	C	C	D
	B	C	C	C	D
	C	C	D	D	D
	D	D	D	D	D
D	A	C	D	D	D
	B	D	D	D	D
	C	D	D	D	D
	D	D	D	D	D

GIS Approach

A spatial database was prepared, in particular the pavement surface index on the basis of the matrix presented in the Table-4. The transformation of the obtained qualitative variables into other quantitative values became essential for the import of the collected data stored in a spreadsheet on ArcGIS software (Table-5). Since the collected data concern pathologies located along the road, the georeferenced was realized using geographical locations using the relative positions along linear feature measured from a linear referencing system measured from a defined starting point. 50 linear reference points was recorded in all databases so that the information related to the surface index mapped and the data more easily analyzed. With this integration, ArcGIS improves data integration and access, improves accuracy, minimizes redundancy in the databases, and visualizes the four deterioration levels: A, B, C and D.

Table-4. Variable representation.

Pavement Surface Index classes	Reading in ArcGIS
A	1
B	2
C	3
D	4

ARPN Journal of Engineering and Applied Sciences

Table-5. Data input.

X	Y	SUI 2018	SUI 2016	SUI 2014	SUI 2012	SUI 2010	SUI2008
439617,099	358252,363	3	2	2	1	1	1
440601,846	358120,473	3	3	2	1	1	1
441533,506	358323,76	1	1	1	1	1	1
442394,995	358829,321	1	1	1	1	1	1
443205,305	359401,317	1	2	3	1	1	1
444153,653	359567,774	1	1	1	1	1	1
444972,172	359852,565	3	2	1	1	1	1
444979,532	360829,462	1	1	1	1	1	1
445157,017	361790	3	1	1	1	1	1
445578,25	362695,211	1	1	1	1	1	1
446305,751	363329,971	1	1	1	2	1	1
447182,413	363731,362	1	1	1	1	1	1
448150,194	363636,07	1	1	1	1	1	1
448996,36	364149,162	1	1	1	2	1	1
449918,491	364287,383	1	1	1	1	1	1
450551,542	364708,602	2	1	1	1	1	1
451155,046	365168,599	1	1	1	2	1	1
451704,736	364625,782	1	1	1	2	1	1
452234,065	364333,109	2	2	2	1	1	1
453070,917	363932,047	1	1	2	1	1	1
453954,791	363481,019	2	1	1	1	1	1
454887,925	363149,669	1	1	1	2	1	1
455848,908	362885,038	2	2	2	1	1	1
456787,042	362542,541	2	2	3	1	1	1
457734,114	362758,724	1	3	1	1	1	1
458567,522	363297,157	2	1	1	1	1	1
459389,03	363854,587	2	1	1	1	1	1
460314,759	364186,58	1	2	1	1	1	1
461110,112	364761,141	1	1	1	1	1	1
461653,469	365599,752	1	1	1	1	1	1
462449,789	366202,028	1	2	2	1	1	1
463401,15	366489,742	3	3	3	1	1	1
464393,688	366538,223	4	3	3	4	4	2
465362,275	366738,917	3	3	3	4	4	3
466360,119	366782,829	4	3	3	4	4	2
467318,862	366574,753	3	3	3	4	4	2
468194,151	366976,959	3	3	3	4	3	1
469104,299	367369,792	4	4	4	3	4	3
470066,743	367641,233	4	3	3	4	3	3
471052,668	367800,389	4	4	4	4	4	4
472051,503	367847,909	4	4	3	4	4	3
473050,33	367896,14	4	3	3	4	3	3
474049,07	367946,327	4	3	4	4	4	2
475047,883	367995,036	4	4	4	4	4	3
476043,184	368077,375	3	3	1	1	1	4
476807,769	367791,437	2	2	2	1	1	3
477023,336	366814,962	1	1	1	1	1	4
477237,209	365838,11	3	2	2	1	1	4
477737,319	364987,015	3	3	3	2	1	2
478570,089	364436,697	3	2	3	3	2	4

VOL. 17, NO. 20, OCTOBER 2022 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

RESEARCH METHODOLOGY

The modeling process follows several steps which are summarized in the figure below:

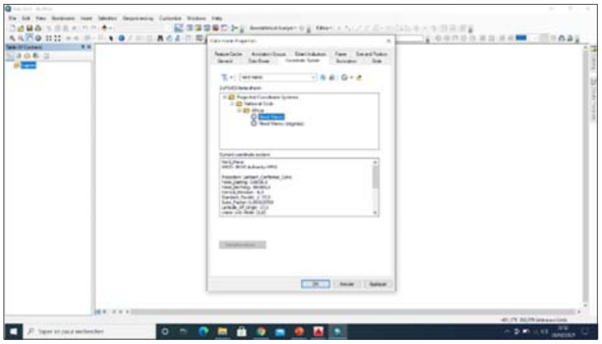

Figure-10. Proposed methodology.

To locate the work map (Figure-11), we join Meknes and Khemisset regions maps used to create an initial database for this road link. The Figure-12 represents the map of Meknes and Khemisset cities.

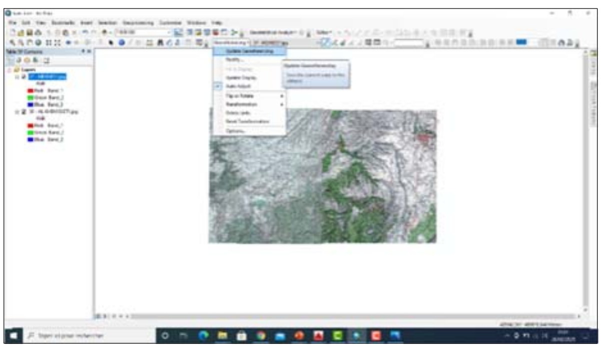

Figure-11. Map location.

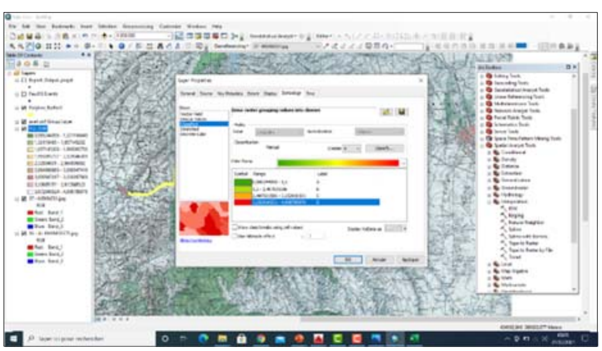

Figure-12. Topographic map of Meknes and Khemisset regions.

Points Projection

The following figure represents the projection of the points in coordinates (X, Y). This is an essential step to represent the axis of the projected road. It is subdivided into two steps: importing the prepared road data base (Figure-13), and projection on the map (Figure-14).

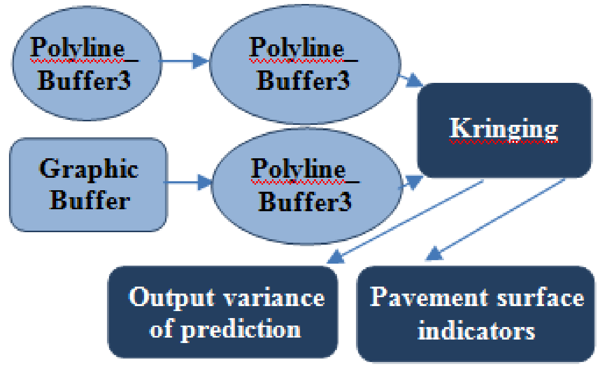

Figure-13. Data importing.

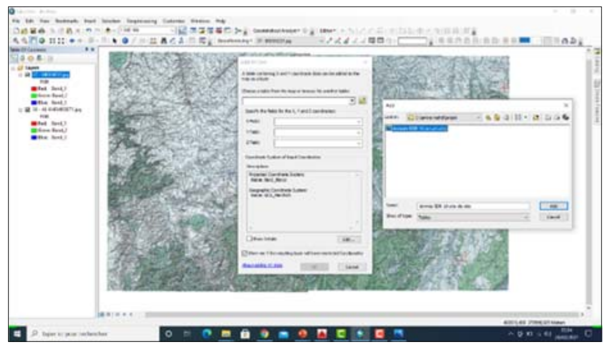

Figure-14. Road projection axis.

Deteriorations Levels Classification

On ArcGIS, the classification by deterioration level goes through several steps:

- Making buffer [7]: since the road is linear, we have proposed a buffer of 200 m to simplify the analysis, (Figure-15);
- Exporting data (Figure-16) and classify the deterioration levels by the choice of four colors (Figure-17).

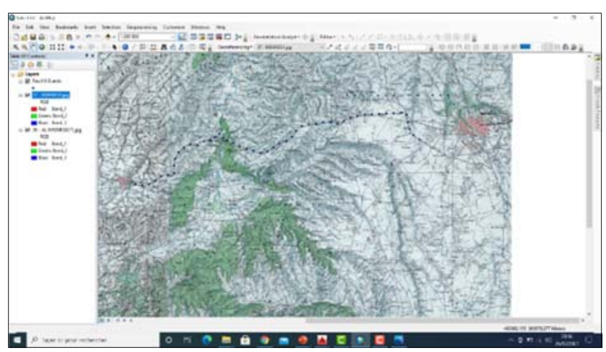

Figure-15. Making buffer.

ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

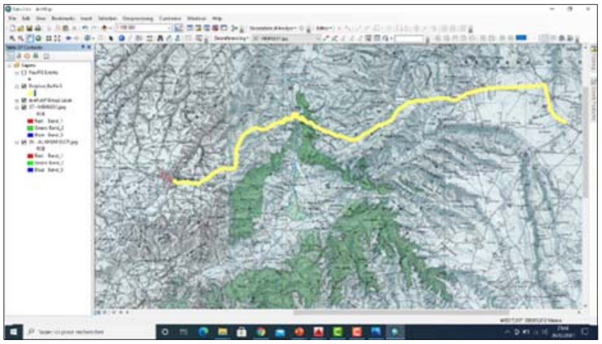

Figure-16. Data exporting.

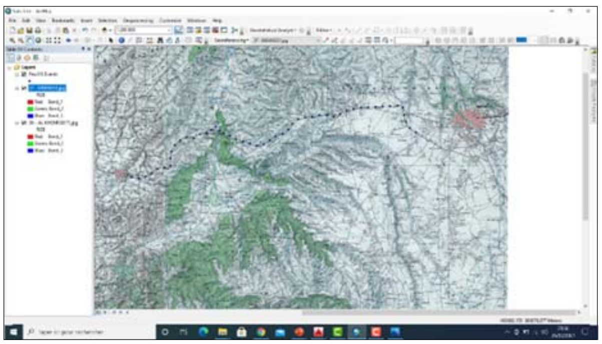

Figure-17. Classification by deterioration level.

GIS Model Validation

The proposed model verification is performed by kringing before compiling the model. In geostatistics, Kringing is the linear estimation method that guarantees the minimum variance. Kringing performs the spatial interpolation of a regionalized variable by calculating the mathematical expectation of a random variable, using the interpretation and modelling of the experimental variogram. It is the best non-bias linear estimator. It takes into account not only the distance between the data and the estimation point but also the distances between the two data. After the kringing check, the GIS model process is represented as follows:

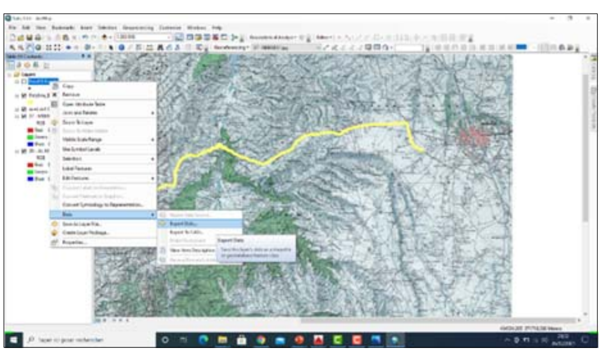

Figure-18. GIS Model process.

RESULTS AND DISCUSSION

The geographical maps related to the studied road surface indicator between the year 2008 and 2018 are represented in the following figures:

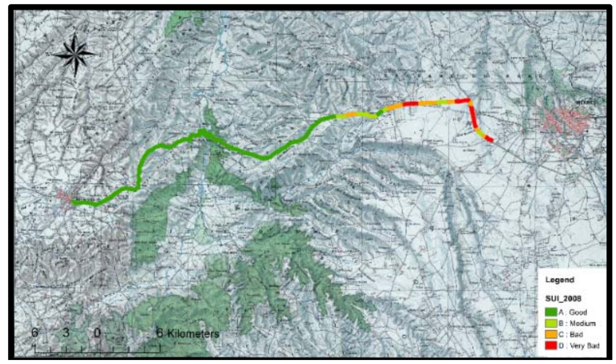

Figure-19. Pavement Surface Index map of the National Road number 06 from KP 0+080 to KP 0+130 in 2008.

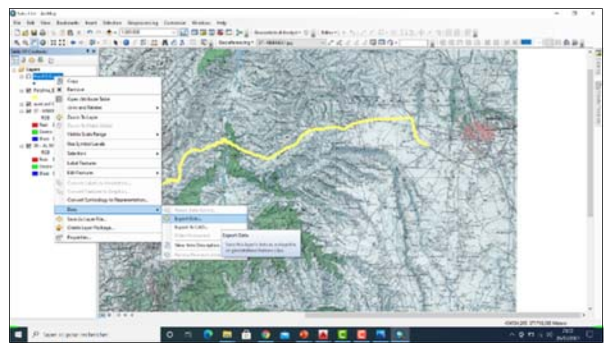

Figure-20. Pavement Surface Index map of the National Road number 06 from KP 0+080 to KP 0+130 in 2010.

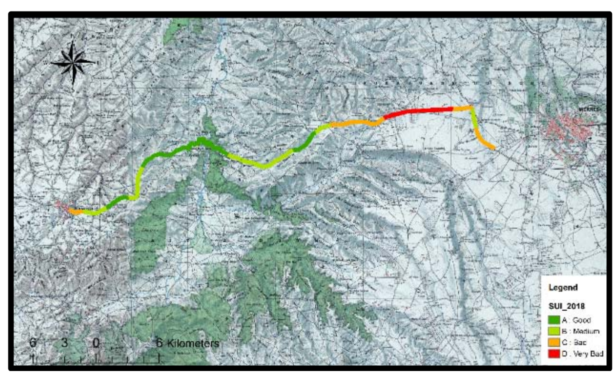

Figure-21. Pavement Surface Index map of the National Road number 06 from KP 0+080 to KP 0+130 in 2012.

VOL. 17, NO. 20, OCTOBER 2022 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

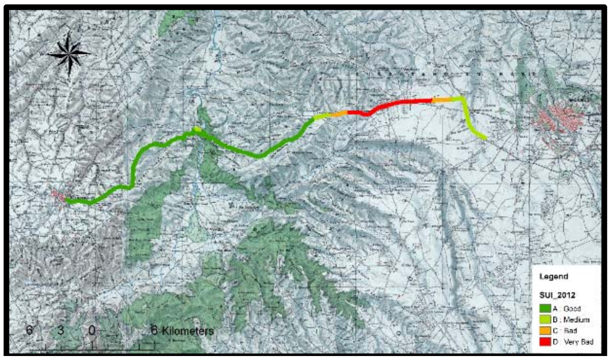

Figure-22. Pavement Surface Index map of the National Road number 06 from KP 0+080 to KP 0+130 in 2014.

Figure-23. Pavement Surface Index map of the National Road number 06 from KP 0+080 to KP 0+130 in 2016.

Figure-24. Pavement Surface Index map of the National Road number 06 from KP 0+080 to KP 0+130 in 2018.

The Pavement surface index levels have the same trend in the last few kilometers towards Meknes city, this tells us about the strong correlation between the intensity of cracks, potholes and tears on this location. As represented in the map of SUI 2008, the section is divided into subsets in advanced state of fatigue of level C (bad condition), did not allow to enhance the maintenance work done, including tears, cracks of level C and D disturbing the stability of surface condition index between the point kilometer 113 and 130. The traffic has increased significantly from 4521 AADT to 5999 AADT calculated in 2012, and to 6883 AADT in 2014. This increasing variability has undoubtedly influenced the predefined safety and sustainability calculations, noting the decrease in the surface index on this route. Another important issue is the cost to users. Indeed, the progressive deterioration of pavements can contribute significantly to increased costs. This is particularly important when the network experiences heavy traffic for long periods of the day.

In such a situation, user costs such as travel time and vehicle operating costs, as well as accident exposure, can significantly influence the maintenance decision process. Although maintenance policy tends to consider more frequent actions when the administration aims to reduce user costs, these actions often include pavement preservation techniques (light roadwork) and are increasingly common. The Figures 23 and 24 show an example of the weighted progression of the SUI surface index between 2016 and 2018. Just after the application of the maintenance action (moderate structural rehabilitation) during 2012, the pavement condition comes good (distress level B) and then started to deteriorate. The results show that this road will reach a poor to very poor surface index (C+D) on a percentage of 34% of its length about 17 km from kilometer 113 to 130. The percentage distribution of the degradation levels represented in Figure-25, shows a remarkable progression of the surface condition level from the year 2008 to 2018. The percentage decrease of the degradation level (A+B) and the evolution of the one of (C+D).

The authors believed that the determination and identification of cracking intensity, which can be expressed as a spatial distribution of the pavement surface index (SUI), can play a central role in the pavement management system. The existence of a relationship between a set of cracks, potholes, and pull-outs and the quantification of their distribution are studied by spatial measurements can reduce the maintenance cost of the pavement, while prioritizing maintenance activities can be affected by the determination of the level of the surface index. For example, the thematic maps made represent a significant geolocalization of the pavement surface condition in the studied section, due to the weakening, poor monitoring and deterioration evolution of this pavement structure. In this regard, local rehabilitation actions must be taken into consideration from Kilometer 117 to 130 kilometers given the repeated tenacity since 2008 until 2018 despite the maintenance actions performed.

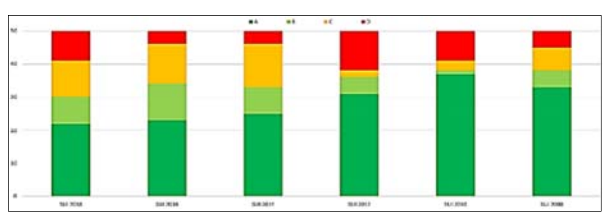

Figure-25. Repartition of stress level.

CONCLUSION

The following conclusions can be drawn from this work:

- The spatial nature of inspection data makes GIS a logical choice on which to base pavement management systems.
- GIS has proven to be an effective tool for spatially integrating, managing, storing, displaying, mapping, querying, and analyzing roadway data.
- This model should be considered a decision-making tool, not a decision-maker in itself. These systems are not intended to replace the expertise and judgment of engineers, but rather to assist in making cost-effective decisions.
- Many elements can be included as inputs, such as road surveys to complement structural condition information such as pavement smoothness and deflection.
- Many variables influence the choice of the right treatment.
- In this work, 50 sections were selected from the National Road number 06 and all these sections are in distress due to different causes like weathering, ageing, traffic load, and also poor maintenance.
- Future developments including other elements of a road maintenance management system should be considered. The completion of the entire road database with all types of recorded investigations, i.e., all distresses, construction, maintenance, and road upkeep.

In this project, it was demonstrated that one of the main advantages of an integrated pavement management system is its flexibility to visualize data in thematic maps. To visualize macroscopically the level of the pavement surface condition, this tool will allow the managers to facilitate the data reading, and compare them avoiding any conflicts, so it will serve as a helping tool to the agencies in the process of allocating funds and justifying their budget requests, for the pavement's maintenance and reconstruction.

This objective is achieved through implementing the graphical capabilities of GIS to manage the data to generate customized thematic maps. As a perspective of the present work, a predictive analysis of future scenarios presenting the evolution of this pavement surface condition will be proposed to predict the future thematic map. The study will be able to identify the geolocation of the surface index evolution associated with the different levels of deterioration and their quantities. This would allow to assign a concentration to these types of indexes on this section. Thus, the pavement weaknesses on the road network can be identified then can be improved, rehabilitated and localized. Perform various practical applications and query probabilities. This could help to obtain useful trends and results through the process of building queries for pavements, in addition to other databases.

- Expand the application of integrated GIS to provide an up-to-date, accurate, and complete pavement condition database to assign maintenance priorities and compare current and future pavement conditions.
- The spatio-temporal changes of the pavement surface index (SUI) lead us to carry out tendencies and forecasts of its evolution in the time.
- Apply SUI criteria to establish maintenance priorities, maintenance costs and pavement management programs.
- Adaptation of traffic management options by municipalities to relieve traffic pressure on the road network and reduce the effect of traffic on development
- Adaptation of comprehensive maintenance programs based on road data analysis developed integrated system, which would direct maintenance activities to sections with high deterioration rates rather than randomly selecting streets for maintenance.

DECLARATIONS

Author Contributions

Conceptualization, M. A.-M., T. C. and A. B; methodology M. A.-M., T. C. and A. B.; software, M. A. M. and T. C validation, M. A.-M., T. C., A. B and I. M; formal analysis, M. A.-M.,T. C, A. B., and S. E., Investigation M. A.-M., T. C, S. E and A. Q, resources, M. A.-M., S. E and A. Q.; data curation M. A.-M., S. E. and A. Q.; writing-original draft preparation M. A.-M., T. C, A. B and I. M., writing-review and editing, M. A.-M., T. C., A. B. and S. E., visualization M. A.-M., T. C. and A. B; supervision, T. C. and A. B; project administration T. C., S. E. and A. Q.; funding acquisition M. A.-M., T. C. and A. B.

Data Availability Statement

Data available on request due to restrictions privacy or ethical: The data presented in this study are available on request from the corresponding author. The data are not publicly available due to: [Confidentiality, sensitivity of the results obtained according to the Moroccan Center for Road Study and Research].

Funding

Funding information is not available.

ACKNOWLEDGEMENTS

The authors would like to thank: the Moroccan Center for Road Studies and Research for its collaboration. This research did not receive any specific funding from public, commercial, or non-profit funding agencies.

Conflicts of Interest

The authors declare no conflict of interest.

REFERENCES

[1] M. A. Mehdi, T. Cherradi, M. Qachar, A. Chigr. 2021. Analysis of structural and surface deteriorations of a flexible pavement, based on inspection results using the MCA method. Materials Today Proceedings, 45(8): 7538-7546. https://doi.org/10.1016/j.matpr.2021.02.358

[2] Shah Y. U., *et al*. 2013. A critical review of prioritization models for pavement maintenance management decisions. In: 2th international conference on Emerging Trends in Engineering &Technology, 12-13 April, College of Engineering, Teerthanker Mahaveer University.

[3] Fakhri M. and Shahni Dezfoulian R. 2019. Pavement structural evaluation based on roughness and surface distress survey using neural network model. Construction and Building Materials, 204, 768-780. 0. Doi: 10. 1016/j.conbuildmat.2019.01.142

[4] Haas C., *et al.* 1984. Application of image analysis technology to automation of pavement condition surveys. In: Proceedings of the International Transport Congress, 23-27 September, Montreal.

[5] L. Janani, V. Sunitha and Samson Mathew. 2020. Influence of surface distresses on smartphone-based pavement roughness evaluation. International Journal of Pavement Engineering. 22(13), https://doi.org/10.1080/10298436.2020.1714045

[6] Ningyuan L., Kazmierowski T. and Koo A. 2011. Key pavement performance indexs and predictions models applied in a Canadian PMS. In: 8th International Conference on Managing Pavement Assets, 15–19 November, Santiago, Chile. https://doi.org/10.1080/10298436.2019.1628961

[7] M. A. Mehdi, T. Cherradi, S. El Karkouri and Ahmed Qachar. 2021. Applying Geographic Information Systems (GIS) for surface condition indexs modelling of a flexible pavement. E3S Web of Conferences 298, 04001. https://doi:10.1051/e3sconf/202129804001

[8] Paterson W. D. 1994. Proposal of universal cracking index for pavements (with discussion and closure). Transportation Research Record, 145, 69–75.

[9] MTO (Ministry of Transportation of Ontario), 1989. Manual for condition rating of flexible pavements, distress manifestation. Downsview, ON: R&D Branch. No: SP-024. https://doi.org/10.1177%2F0361198196152900111

[10] MTO (Ministry of Transportation of Ontario), 2016. Manual for condition rating of flexible pavements, distress manifestation. Downsview, ON: Materials and Engineering Office. No: SP-024.

[11] Shah Y. U., Jain S. S., and Parida M. 2014. Evaluation of prioritization methods for effective pavement maintenance of urban roads. International Journal of Pavement Engineering, 15(3): 238-250. doi:10.1080/10298436.2012.657798

[12] Suma N. H., Chakraborty N. and Veeraragavan A. 1998. Simplified methodology for prioritization of pavement maintenance based on pavement condition index. In: 4th international conference on Managing Pavements, 17–21 May, South Africa https://doi.org/10.1080/10298436.2019.1628961

[13] Carvalho A. F. C. and Picado Santos L. G. 2017. Maintenance of airport pavements: the use of visual inspection and IRI in the definition of deterioration trends. International Journal of Pavement Engineering. doi:10.1080/10298436.2017.1309189

[14] Sandra A. K., *et al*. 2007. Prioritization of pavement Stretches using fuzzy MCDM approach- A case study. Soft Computing in Industrial Applications. doi: 10.1007/978-3-540-70706-6_25.

[15] Zhang S., Lippitt C. D. and Bogus S. M. 2017. Pavement surface condition estimation based on geospatial modeling. Annals of GIS, 23, 167–181. doi:10.1080/19475683.2017.1325404

[16] FHWA (Federal Highway Administration), 2006-2009. Pavement distress identification manual, NPS Road Inventory Program, Cycle 4.

[17] BCMoTI (British Columbia Ministry of Transportation and Infrastructure), 2016. Pavement surface condition Rating manual, Construction Maintenance Branch. 5th ed. Canada. https://doi.org/10.1080/10298436.2019.1628961

[18] Hanayn Li, Jack Cebe, Sara Khoeini, 2018, A Semi-Automated Method to Generate GIS-Based Sidewalk Networks for Asset Management and Pedestrian Accessibility Assessment. Journal of the Transportation Research Board https://doi.org/10.1177/0361198118757981

ARPN Journal of Engineering and Applied Sciences

[19] Surajo Abubakar WadaInt. 2016. Bituminous Pavement Failures. Journal of Engineering Research and Applications ISSN: 2248-9622, 6(2): 94-100.

[20] 1970. National Research Council National Academy of Sciences, National Academy of Engineering Standard, Standard Nomenclture and Definitions for Pavement Components and Deficiencies, Nomenclature and Definitions for Pavement and Dficiencies, HRB, USA, JUN.

[21] Lucky Sephumelele, Nkomoa, Sumaiya Amod Desaia, Khoboso Elizabeth Seutloalib, Kabir Yunus Peerbhaya, Timothy Dubec. 2019. Assessing the surface material quality of unpaved rural roads to understand susceptibility to surface deterioration. A case study of four rural areas in KwaZulu-Natal, South Africa. 112: 3-11. https://doi.org/10.1016/j.pce.2019.04.005

[22] Harral Clell, Faiz Asif. 1988. Road deterioration in developing countries: causes and remedies (English). A World Bank policy study Washington, D.C.: World Bank Group.

[23] 1987. John Hopkins Univ. Pr., Road Deterioration and maintenance effects: models for planning and management.

[24] D. Gary. 2004. Pavement Management Applications Using Geographic Information Systems. Transportation Research Board. http://www.national-academies.org/trb/bookstore

[25] J. Neelam and P. K. Nanda. 2003. Geographical Information System for Pavement Management Systems. Map Asia Conference, India.