International Journal of Researches on Civil Engineering with Artificial Intelligence

www.ceai.reapress.com

Int. J. Res. Civ. Eng. AI. Vol. 2, No. 1 (2025) 9–16.

Paper Type: Original Article

Prioritizing Urban Road Pavement Improvement Using the Analytic Hierarchy Process (AHP) Method (Case Study: Rasht City)

Reza Abedinpour[1,*], Habibeh Karimi[2]

[1] Department of Civil Engineering, Construction Management, Faculty of Engineering and Technology, Ayandegan University, Tonekabon, Mazandaran, Iran; rezaabedinpoor7@jmail.com.

[2] Department of Research Center, Shiroud Municipality, Mazandaran, Iran; sekarimimail@gmail.com.

Citation:

Received: 12 August 2024 *Revised: 08 October 2024* *Accepted: 19 November 2024*	Abedinpour, R., & Karimi, H. (2025). Prioritizing urban road pavement improvement using the analytic hierarchy process (AHP) method (Case study: Rasht city). *International Journal of Researches on Civil Engineering with Artificial Intelligence*, *2*(1), 9-16.

Abstract

Today, road pavement maintenance and improvement are considered costly. Generally, road pavement repair and maintenance projects are implemented at a very high cost, and over time, due to a lack of attention, pavement damage spreads, imposing additional costs on the employer. So it is clear that prioritizing road maintenance projects and carrying them out at the right time helps improve the condition of road pavements and makes the investments more economical. The purpose of this project is to develop a software model for prioritizing road pavement improvement projects using the Analytical Hierarchy Process. The selected criteria are traffic, vehicle axle load, road width, current Pavement Condition Index (PCI), and drainage quality. The options are Golsar Boulevard, Deylaman Boulevard, Isfahan Boulevard, and Tohid Boulevard in Rasht. After entering the criteria, improvement prioritization for pavement projects was conducted in Expert Choice. The results showed that Tohid Boulevard was the first priority, and Isfahan Boulevard was the last. MATLAB software was used to determine the priority of improvement based on the type of repair option. As the input data is entered into MATLAB, the results show the repair options' priorities.

Keywords: Urban road improvement, Analytic hierarchy process, Project management, Prioritization.

1 | Introduction

Urban pavement maintenance and improvement management is an operational necessity in many Iranian metropolises for optimal resource allocation [1]. Rasht exhibits pavement behavior different from that of dry

Corresponding Author: rezaabedinpoor7@jmail.com

https://doi.org/10.48314/ijrceai.v2i1.31

cities due to high rainfall, clay soils, and drainage problems. Pavement Condition Index (PCI) and surface deterioration indicators such as cracks, potholes, and ripples are basic criteria in pavement evaluation [2]. Analytic Hierarchy Process (AHP) provides the ability to combine technical, economic, and social criteria to weight and prioritize projects. Domestic research has shown that incorporating network criteria (the role of the road in urban access) improves decision-making [3].

Integrating AHP with a Geographic Information System (GIS) enables the production of spatial priority maps and the visual display of results, which are essential in urban studies [4]. Case studies in northern cities of the country show that scour and groundwater infiltration issues shorten the lifespan of pavement designs [5]. The direct costs of repairs and the costs of traffic (delays and social costs) are usually given significant weight in the models [6].In Iranian studies, the use of fuzzy AHP to cover expert uncertainties is increasing [7]. Involving local stakeholders and collecting accurate field data (traffic, layer types, repair history) increases the accuracy of prioritization models [8].

In Rasht, the lack of studies integrating AHP and hydrogeological data is evident. An empirical study of Rasht pavement performance shows that areas with poor drainage are more prone to erosion and potholes [9]. Incorporating safety, network availability, and Life Cycle Cost (LCC) criteria into the prioritization model provides more sustainable results. Sensitivity analysis in AHP studies helps clarify the effect of changing the weights of criteria on project rankings. Studies that have compared AHP with other multi-criteria methods (such as TOPSIS or VIKOR) show that each method has its own strengths.

In the urban area, phased prioritization (short-, medium-, and long-term) and continuous budget allocation are recommended. Local data for Rasht should include groundwater levels, bedrock, and seasonal rainfall patterns to weight actual technical criteria. Conclusions: Previous studies suggest that AHP models combined with GIS produce the best operational output for urban managers. The present study can fill a gap in Rasht regional studies and provide localized decision-making criteria. By applying AHP, conducting sensitivity analysis, and using GIS mapping, the prioritization of pavement improvement in Rasht will be feasible, practical, and transparent [10].

2 | Substrate

The road surface subgrade is the final compacted layer of existing or improved natural or excavated earth. This bed is prepared according to specific specifications and conditions, and the first layer of road pavement is placed on it. The pavement subgrade, which is ultimately considered the foundation of the road pavement, bears all the loads imposed by the pavement body and the vehicles on it. Existing asphalt cannot be used to improve asphalt roads. The asphalt layers must be removed, and the lower road surface prepared like the upper surface, or the pavement must be recycled using recycling methods.

3 | Type and Extent of Damage

Potholes: Potholes that occur due to local weakness of the subgrade or asphalt layer, or lack of bitumen, and separation of stone grains from bitumen (*Fig .1).*

Fig. 1. Pits.

Asphalt settlement: Asphalt settles due to insufficient compaction of the road infrastructure and the traffic that is carried out on its surface (*Fig. 2).*

Fig. 2. Meetings.

Roadside breakage: The edges of the asphalt may break due to the thinness of the asphalt or the lack of strength of the shoulders, and finally, water penetration into the substructure and its reduced resistance (*Fig. 3).*

Fig. 3. Roadside fracture.

4 | Asphalt Cracks

Longitudinal and transverse cracks: These cracks occur parallel and perpendicular to the road axis. Their occurrence may be due to the presence of poor-quality, fine-grained soils in the road embankment (such as clay soils that absorb water and swell with moisture, then contract after drying) and to shaking or contraction of the substructure during severe winter cold (*Fig. 4).*

Fig. 4. Longitudinal and transverse cracks.

Shrinkage cracks: These cracks are caused by a lack of bitumen in the asphalt mixture, the brittleness of the bitumen used, significant temperature differences during asphalt laying across different seasons, or the drying and aging of the asphalt, which can make it brittle (*Fig. 5*).

Fig. 5. Shrinkage cracks.

Cracks resulting from the asphalt layer sliding on the underlying layer: This problem may arise from a lack of adhesion between the hot asphalt layer and the substructure. Due to dirt and moisture on the substructure, the asphalt layer lacks sufficient adhesion to the underlying layer, and this occurs under the horizontal pressure from wheel movement (*Fig. 6)*.

Fig. 6. Cracks resulting from the sliding of the asphalt layer on the underlying layer.

Mosaic or lizard skin cracks: In most cases, these cracks occur due to insufficient subgrade strength, low asphalt diameter, or the end of the asphalt's lifespan. It should be noted that if cracks are not repaired promptly, water will seep beneath the asphalt, weakening the road's resistance. Due to wheel pressure, the asphalt will crumble, making the road dangerous. Therefore, immediate repair will prevent further damage to the asphalt surface (*Fig. 7)*.

Fig. 7. Mosaic cracks or lizard skin.

Waves in asphalt: The presence of too much bitumen in the asphalt mixture, failure to observe the correct grading, or the presence of too much moisture in the asphalt mixture causes waves to appear on the asphalt surface (*Fig. 8*).

Fig. 8. Wave in asphalt.

5 | Traffic

Traffic is one of the most critical parameters in pavement design. It is essential to determine the following parameters in traffic studies:

I. Traffic volume.

II. Type of vehicles, axle type, and their weight.

III. Annual growth rate of vehicle types.

Traffic volume is the total number of vehicles that pass through a specific section of road in a given time.
Traffic volume is the total number of vehicles that pass through a specific section of road in a given time. If statistics are lacking for the desired road, the consulting engineer will survey within at least 7 days when specific social and environmental conditions do not affect the traffic axis, and will include the results in the design.

It is imperative to count the number of different vehicle types, broken down by type, number of axles, and weight. The growth rate of vehicles in the plan period is determined separately for different traffic groups — such as light and heavy vehicles, or freight and passenger vehicles —based on traffic growth in previous periods, taking into account the effects of future developments and the amount of traffic attracted from neighboring areas.

6 | Equivalent Axis

The equivalent load factor is an essential coefficient in pavement design that shows the effect of traffic loads on pavement failure. In Regulation 234, traffic effects are considered in pavement design using the equivalent axis method. The ratio of damage caused by the desired axis to the damage caused by the standard Ard axis can be expressed by the equivalent load factor.

So that the total traffic passing through the road during the design period is replaced by a certain number of standard axles with a particular specification and weight (design base axle), and the effect of the equivalent number of EAL base axles is included in the design.

Usually, a single axle weighing 2.8 (80 KN) is considered the reference axle. To convert different axle types, such as single, tandem, or tridem, to the reference axle, the equivalent axle load factor (EALF) obtained from theoretical or experimental methods should be used. In the empirical method, equivalence is established by comparing the damage caused by the desired axle with that caused by the reference axle, which is usually a 2.8-ton axle.

The equivalent axle load factor depends on pavement type, pavement failure model, structural capacity, layer thickness, and the ultimate serviceability index. The coefficients for the pavement structural number and ultimate serviceability index presented in this regulation are based on tests conducted by the AASHTO Institute. These coefficients are presented in the tables below. The design engineer should, based on previous experience, initially assume the structural number for the pavement, extract the equivalent load coefficients from the relevant tables, and perform pavement calculations. Then, if the initial and final assumed structural numbers differ, repeat the calculations.

7 | Axle Load of Passing Vehicles

According to the results, the pressure or weight force exerted by each vehicle axle on the road surface is called the axle load. Each vehicle has a specific weight limit. Failure to comply with it will not only reduce braking power and vehicle control and steering capabilities, but also shorten vehicle life, wear out tires, and increase fuel consumption. Still, it will also cause damage to road pavements. The latter is significant to us in this study.

8 | Present Serviceability Index (PSI)

An index of pavement performance is defined as the ability of a pavement to provide service to the traffic using it. This serviceability is expressed as the current service index (PSI).

This indicator is determined by measuring roughness and deterioration (cracking, staining, and rutting) at a specific point in the pavement's design and operational life. Roughness is the most essential factor in estimating pavement serviceability. PSI values range from 0 to 5, with zero indicating a deteriorated pavement and five indicating a new or excellent condition pavement.

Table 1. Results of PSI calculations for each street.

Boulevard Tohid	Boulevard Esfahan	Boulevard Deylaman	Boulevard Golsar	
10	1	20	30	The number of cracks in the skin of a lizard in square meters.
3	2	10	11	Staining and Repair Table In Square Meters P
2	1	0	1	Groove and dimple amount in centimeters RD
1	1	1	1	SV roughness level
2.75	3.06	3.12	2.74	PSI index

9 | Road Drainage

The verbal criteria of poor, average, good, and excellent are used to assess drainage quality. According to the table, the drainage quality for Golsar and Tohid Boulevards is "poor", for Deylaman Boulevard it is "good", and for Isfahan Boulevard it is "excellent" (*Fig. 9).*

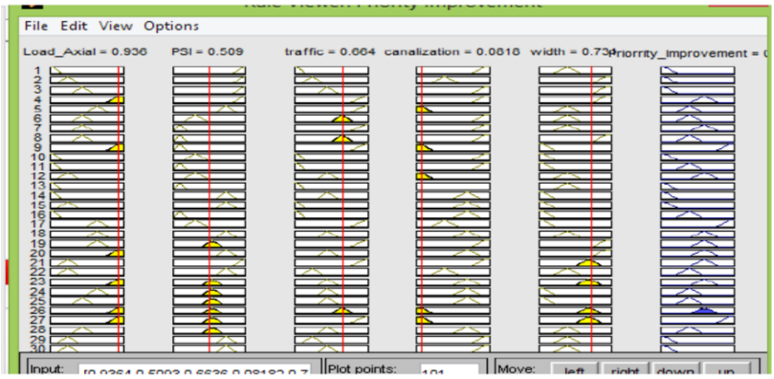

Fig. 9. Fuzzy software output for Golsar Boulevard.

10 | Conclusion

In this study, a model has been presented that, to optimally and comprehensively manage the pavement of the mentioned roads, uses essential parameters, including through traffic, vehicle axle load, PSI index, road width in use, and drainage, as the basis for decision-making and prioritization. Then, a multi-criteria decision-making model of fuzzy analytic hierarchy process was used to understand the importance of criteria and prioritize factors for improving and paving urban roads (Rasht city). And with the help of Expert Choice software, the verifiable options for project components have been analyzed with criteria in a pairwise comparison matrix. The result has been analyzed in a new pairwise comparison matrix with the main goal of prioritizing project improvements based on their importance. Then the output results have been obtained according to the priority of project implementation.

Also, in this thesis, fuzzy logic of MATLAB software has been used to prioritize and determine the type of pavement operations. In this method, the verbal parameters related to the criteria have been fuzzified, and, as a result, the limits of the fuzzy triangular membership functions have been determined and entered into MATLAB. The presented model can be used independently in projects. So that the information obtained after the expert review and completion of the standardization of the criteria and their conversion into verbal expression, using the software's fuzzy logic, and the entry of data related to the project, the type of paving operation for the desired project can be extracted.

The existence of factors and criteria that cannot be converted into financial value has made the use of multi-criteria decision-making models necessary in road management. The most important result and achievement of this thesis is the presentation of a new model for prioritizing urban road improvements based on project and paving operation types, using fuzzy decision-making hierarchy analysis integrated with Expert Choice software and MATLAB fuzzy logic. The study concluded that "passing traffic" and "PSI index" are the most critical parameters affecting the choice of "repair and maintenance method" of roads, and also the criteria of "axle load", "road width", and "drainage quality", respectively, are of the most significant importance in decision-making.

Then, the priority of any of the above items alone cannot be a suitable criterion for prioritizing options and selecting the appropriate method for the type of pavement repair operation; other items are also needed. In the prioritization system for road construction projects, due to disagreements between authorities, the selection of a project operation that is more urgently needed than others, and the optimal execution method are determined. It is difficult, and making decisions on these issues carries a high risk, which forces officials, inspectors, and experts to conduct further research and reach more accurate conclusions about the types of damage to the surfaces of communication roads.

The method proposed in this thesis, in addition to processing all opinions of respected authorities and prioritizing necessary outputs, can also combine their opinions into a pairwise comparison matrix, yielding more comprehensive results and extracting more critical information. Also, using a model designed in MATLAB software and fuzzy logic, it is possible to define various road construction operations that include different types of road surface damage of different qualities, allowing the person to Without any worries, introduce the desired street or roads with their current state of damage to the software and view the optimal result of prioritizing the type of road paving operation after processing in the software.

Road pavements are considered national assets of Iran, and each year a large portion of the development budget is spent on their repair, improvement, and maintenance. By implementing the proposed model, annual costs can be reduced by billions of rials, and roads and paths can be maintained in good condition.

Conflict of Interest

The authors declare no conflict of interest.

Data Availability

All data are included in the text.

Funding

This research received no specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

References

[1] Liu, Y., Yu, C., Guo, F., Zhao, X., Shan, J., Lu, T., … & Yuan, D. (2024). Multi-criteria decision-making framework (AHP-TOPSIS): Pavement preventive maintenance case study for ordinary national trunk highways. *Buildings*, *14*(10), 3048. https://doi.org/10.3390/buildings14103048

[2] Fawzy, M. M., Elsharkawy, A. S., Hassan, A. A., & Khalifa, Y. A. (2025). Prioritization of Egyptian road maintenance using analytic hierarchy process. *International journal of pavement research and technology*, *18*(2), 391–404. https://doi.org/10.1007/s42947-023-00351-6

[3] Gunasoma, H. D. S., Pasindu, H. R., Ling, K. H., & Min, L. K. (2016). *Model development for optimization and prioritization of pavement maintenance for provincial road networks* [presentation]. 10th asia pacific conference on transportation and the environment (pp. 8–10). https://b2n.ir/bh7790

[4] Farhan, J., & Fwa, T. F. (2014). *Evaluation of environmental sustainability of pavement preservation strategies using analytic hierarchy process* [presentation]. 9th Asia pacific conference on transportation and the environment apte9-2014 (p. 129). https://b2n.ir/xf6387

[5] Orugbo, E. E., Alkali, B. M., DeSilva, A., & Harrison, D. K. (2015). RCM and AHP hybrid model for road network maintenance prioritization. *The baltic journal of road and bridge engineering*, *10*(2), 182–190. https://doi.org/10.3846/bjrbe.2015.23

[6] Sulistyowati, S., Lestari, D. A. P., Nurcahyo, A., & Haryono, A. R. H. T. (2025). Pengaplikasian metoda AHP Untuk Pemeliharaan Saluran Drainase di Kelurahan Lamper Lor Kota Semarang. *journal pengabdian kepada masyarakat nusantara*, *6*(3), 4211–4218. https://doi.org/10.55338/jpkmn.v6i3.6508

[7] Asma Th. Ibraheem, & Noor S. Atia. (2016). Applying decision making with analytic hierarchy process (AHP) for maintenance strategy selection of flexble pavement. *Global journal of research in engineering*, *16*(E5 SE-Articles), 25–34. https://engineeringresearch.org/index.php/GJRE/article/view/1526

[8] Nugraha, M., Muhidong, J., & Soma, A. (2025). Multi-criteria decision-making in road maintenance: An AHP-Gis approach. *International journal of the analytic hierarchy process*, *17*. https://doi.org/10.13033/ijahp.v17i3.1307

[9] Milad, A., Basri, N. E. A., Younes, M. K., Abdelsalam, H. M., & Rahmat, R. A. A. B. O. (2018). Selecting the Affected factors on pavement distress problems using analytical hierarchy process [AHP]. *International journal of engineering & technology*, 7(2.29), 716-718. https://doi.org/10.14419/ijet.v7i2.29.14004%0D

[10] Judhono, M. A. P., Sjafruddin, A., & Wibowo, S. S. (2025). Model prioritisasi penanganan Jalan Kota Jambi Berbasis metode analytical hierarchy process. *Journal talenta sipil*, *8*(2), 629–637. https://talentasipil.unbari.ac.id/index.php/talenta/article/view/896