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Global Trends in Predicting Pavement Distress: A Systematic Review

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ABSTRACT

Road pavement deterioration has become increasingly complex due to growing traffic loads, the impacts of climate change, and limited maintenance budgets. In response, the present study explores how recent global advances in pavement condition prediction, particularly Dynamic Bayesian Networks (DBN) and Artificial Intelligence (AI) can be adapted to the Indonesian context. A Systematic Literature Review (SLR) was conducted following the PRISMA 2020 protocol, covering publications from 2020 to 2025 across international databases (Scopus, Web of Science, ScienceDirect, IEEE Xplore, Google Scholar) as well as with national sources (ASTONJADRO, Rekayasa Sipil, Jurnal Media Publikasi Terapan, Jurnal Syntax). The initial search yielded 200 articles, which were screened by title, abstract, and full-text reviews, resulting in a final selection 52 articles. The review classifies prediction methods into four key categories: index-based approaches (IRI, PCI, SDI), which are practical yet insufficient for capturing temporal dynamics; probabilistic models (Markov Chain, Bayesian Network, DBN), which enable the modelling of uncertainty; AI-based methods, which provide high accuracy but offer limited interpretability; and hybrid models combining probabilistic methods with AI to enhance reliability. The study synthesizes global trends and the Indonesian context, indicating that DBN holds notable potential for supporting road maintenance policies when underpinned by robust time-series data and cross-institutional integration. The review further recommends the development of DBN–AI hybrid models and the enhancement of local data infrastructure as strategic priorities for future research and policy in Indonesia.

Keywords: road deterioration, infrastructure modelling, pavement condition prediction, Dynamic Bayesian Network (DBN).

INTRODUCTION

Road pavements are the most critical part of the transportation network, but they are very vulnerable to damage from increased traffic loads, climate change, and lack of funding. This situation raises maintenance costs and puts road users' safety, comfort, and efficiency at risk [1], [2]. Therefore, predicting pavement performance is essential. It helps road managers reduce the potential of accidents, optimize budget allocation, and create effective maintenance plans [3], [4].

Numerous methods have been established to evaluate and predict road conditions. The Surface Deterioration Index (SDI), Pavement Condition Index (PCI), and International Roughness Index (IRI) are examples of index-based methods that are frequently employed. They are relatively easy to understand and measure, especially in Indonesia [3], [5], [6]. Nevertheless, these techniques have trouble capturing how road conditions change over time [1]

To address this problem, recent research has looked at probabilistic techniques like Bayesian Networks (BNs) and Markov Chains. According to transition probabilities between shifting road states, these can estimate road conditions [7], [8]. These techniques have also developed into Dynamic Bayesian Networks (DBNs), which track the progression of pavement deterioration over time and offer significant advantages. As a result, predictions become more accurate and trustworthy. [9], [10].

Over time, computational technologies have become one of the dominant aspects of research within pavement. Thanks to machine learning and artificial neural networks, praiseworthy advancements

have been made in pavement crack detection with Ashraf et al., leaving no stone unturned to reach high accuracy [11] and in estimating Pavement Condition Index (PCI) values ([12], [13]. Furthermore, if you are curious about how confident those predictions truly are, Bayesian Neural Networks now step in to quantify uncertainty [14]. On a broader scale, pairing remote sensing with data-mining techniques has opened the door to real-time monitoring of entire national road networks—no longer do we have to rely solely on periodic, manual inspections [15], [16]. Back at street level, fuzzy logic methods help us untangle the ambiguous, noisy field data that often trips up more rigid algorithms [17].

However, most pavement-deterioration research in Indonesia still leans on traditional index-based approaches [3], [5], Probabilistic and AI-driven models are starting to appear, but they are mostly confined to simulations or small pilot studies [18]. Key challenges remain, particularly the limited availability of time-series data, inconsistencies in data collection, and the difficulty of incorporating model outcomes into actual maintenance decision-making processes. Yet, global literature indicates a clear shift toward hybrid models that combine probabilistic approaches with AI to enhance prediction accuracy and reliability [19], [20].

Building on this context, the present study conducts a Systematic Literature Review (SLR) of 52 articles published from 2020 to 2025. This review attempts to map the development of road pavement deterioration prediction methods. We examine the strengths and weaknesses of each approach—from index-based, probabilistic, and artificial intelligence-based to hybrid models. Furthermore, the review explores the potential application of Dynamic Bayesian Networks (DBN) and hybrid AI-probabilistic models to strengthen road management practices in Indonesia.

RESEARCH METHODS

The research materials consist of scientific literature relevant to pavement condition and deterioration prediction, collected from reputable international databases including *Scopus, Web of Science, ScienceDirect, IEEE Xplore, and Google Scholar,* as well as national sources such as *ASTONJADRO, Rekayasa Sipil, Jurnal Media Publikasi Terapan, Jurnal Syntax*, and several other Indonesian journals in civil and transportation engineering. The publication range spans from 2020 to 2025 to capture recent studies examining pavement prediction methods, including International Roughness Index (IRI), Pavement Condition Index (PCI), Surface Distress Index (SDI), probabilistic models such as Markov Chain, Bayesian Network (BN), and Dynamic Bayesian Network (DBN), as well as artificial intelligence algorithms such as Machine Learning (ML) and Artificial Neural Networks (ANN). The search strategy was designed using Boolean logic and tailored to the requirements of each database, combining keywords such as “pavement road”, “condition prediction”, “deterioration”, “damage”, “Dynamic Bayesian Network or Bayesian Network”, “Markov Chain”, “machine learning”, “Artificial Neural Network”, “pavement management”, and “road maintenance”. Searches were carried out across article titles, abstracts, and keywords, with the publication period restricted to 2020–2025 to capture the most recent developments in pavement prediction research. Only peer-reviewed journal articles and conference proceedings that fulfilled rigorous quality standards were included in the systematic review [21]

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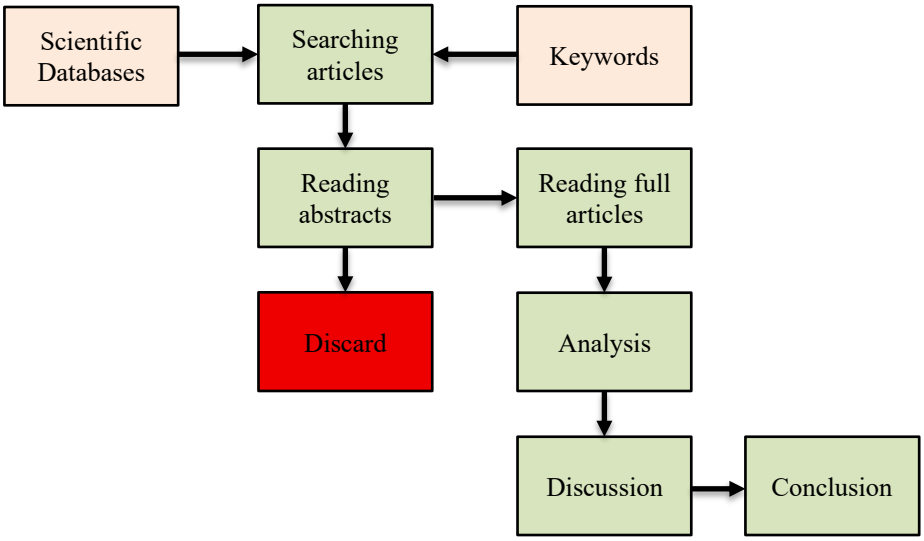

Figure 1. Systematic Literature Review

This research adopted a Systematic Literature Review (SLR) following the PRISMA 2020 guidelines to ensure transparency, rigor, and replicability in the review process [21]. The initial search identified around 200 articles, which were subsequently filtered through three main stages. In the first stage, titles and abstracts were screened to evaluate their relevance to pavement condition prediction. The second stage involved removing duplicates and excluding studies that did not meet the inclusion criteria, such as opinion papers or publications without predictive methods. The final stage assessed the eligibility of the remaining studies, retaining only those that applied pavement condition prediction techniques and were relevant to probabilistic models, Dynamic Bayesian Networks (DBN), Artificial Intelligence (AI), or hybrid approaches. After this screening process, 52 articles were selected for detailed analysis.

Table 1. Overview of Related Studies on Road Condition Prediction

Author (Year)	Method	Location/ Case Study	Dataset/ Data Input	Main Findings
Bayat et al., 2023	ANN	Iran	Flexible pavement test data	Application of ANN for performance prediction
Osman et al., 2022	ANN	Saudi Arabia	Urban road condition data	Road condition assessment using ANN
Alatoom & Al-Suleiman, 2022	ANN	Middle East	National road roughness data	ANN for roughness prediction
Cui & Wang, 2025	Bayesian Network	USA	Historical climate data, asphalt condition	Damage prediction due to climate change
Soetjipto & Simorangkir, 2024	Bayesian Network	Indonesia	Road damage causal factors data	Causality analysis of road damage
Philip & AlJassmi, 2024	Bayesian Network	United Arab Emirates	Road network performance data	Bayesian DSS for maintenance optimization
Lumba, 2022	Bayesian Network	Indonesia	Motorcycle accident data	Accident factor analysis
Philip & Jassmi, 2022	Bayesian Network	UAE	Road deterioration factors data	Factor relationship model of deterioration
Hasugian & Rahmawati, 2021	Bayesian Network	Indonesia	Ship accident data	Risk analysis of ship accidents
Zhang et al., 2024	Dynamic Bayesian Network	UK	Multiyear IRI data	Probabilistic prediction of IRI
Vagdatli & Petroutsatou, 2024	Dynamic Bayesian Network	Europe	Roughness time-series data	DBN-based roughness prediction

Author (Year)	Method	Location/ Case Study	Dataset/ Data Input	Main Findings
Leu et al., 2023	Dynamic Bayesian Network	Taiwan	Transportation project cost data	Cost overrun prediction of projects
Sun & Yan, 2023	Decision-making framework	China	Provincial road segment data	Maintenance recommendation framework
Olowosulu et al., 2020	Fuzzy logic & data mining	Nigeria	Flexible pavement performance field survey data	Pavement performance prediction using fuzzy logic
Rosaria et al., 2022	Geometric Design	Indonesia	Post-disaster road geometry design data	Horizontal alignment design study
Karballaeezadeh & Zaremotekhases, 2020	Hybrid ML prediction models	Iran	Road inspection and traffic data	Intelligent road inspection with hybrid ML
Liu et al., 2022	Integrated optimization	Taiwan	Road lifecycle data	Maintenance budget optimization
Sun et al., 2025	Intelligent decision framework	China	National road network data	Intelligent maintenance decision framework
Aziz et al., 2025	IRI	Indonesia	IRI survey data	Damage analysis & maintenance recommendation
Sandamal & Pasindu, 2020	IRI	Sri Lanka	National road roughness data	Roughness prediction model development
Al-Samahi et al., 2024	IRI	UAE & Middle East	Road roughness climate data	Comparative roughness prediction model
Cui et al., 2024	Markov Chain Process	Global	Historical pavement condition data	Pavement deterioration model development
Isradi, 2024	Markov Chain Process	Indonesia	Road performance & standard performance data	Development of performance standard models
Isradi et al., 2024	Markov Chain Process	Indonesia	Periodic road condition survey data	Prediction of condition values during maintenance
Togatorop & Tarigan, 2023	Markov Chain Process	Indonesia	Provincial road condition data	Pavement condition modeling with Markov chain
Ashqar & al., 2025	ML - class prediction	Global	PCI dataset from various cities	Pavement Condition Index (PCI) prediction
Ashraf et al., 2023	ML Crack Detection	Global	Various crack image datasets	ML review for crack detection & classification
Amir, 2020	ML for network & project level maintenance	Japan	Road network & maintenance project data	ML-based maintenance management system
Ali et al., 2025	ML for PCI	Pakistan	City/district PCI data	City-level PCI prediction
Li et al., 2025	ML Framework data & knowledge driven	China	Traffic & pavement condition data	Data-driven automatic maintenance strategy
Heo et al., 2024	Multi-hazard assessment	Indonesia	Geospatial flood/landslide data	Multi-hazard assessment for new capital city
Farida & Anenda, 2022	Network planning PERT/CPM	Indonesia	Road construction project data	Network analysis & project crashing
Hu, 2023	Non-stationary IRI Markov	USA	Transportation network IRI data	Project bundling integration & IRI model
Liu et al., 2021	Optimization for pothole repair	Taiwan	Pothole repair data & resource allocation	Optimization of pothole repair
Chen & Zhao, 2024	Optimization framework PPP	China	Toll road tariff & pavement condition data	Optimization of pricing & pavement management
Pramesti et al., 2021	PLS-SEM	Indonesia	Bridge maintenance factor survey data	Bridge maintenance factor model

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Author (Year)	Method	Location/ Case Study	Dataset/ Data Input	Main Findings
Nataadmadja et al., 2024	Preliminary deterioration model	Indonesia	Multiyear toll condition data	Early deterioration model development for toll roads
Liu & Arifin, 2021	Preventive maintenance	Indonesia	School building maintenance data	Preventive maintenance model
Fiorentini et al., 2020	PS-InSAR + ML	Italy	Satellite InSAR & ML remote sensing data	Prediction & mapping of surface cracks
Politis et al., 2020	Remote sensing & data mining	Europe	Satellite/remote sensing images & road condition data	Framework for pavement network condition assessment using data mining
Amani et al., 2024	Safety Impact	Global	Road accident literature & condition data	Road condition impact on safety
Wicakrani & Widayanti, 2024	SDI Surface Distress Index	Indonesia	Road distress data (link 166)	Road damage analysis & treatment
Haldiana et al., 2024	SDI Surface Distress Index	Indonesia	District road SDI survey data	Distress level analysis & crack assessment
Prayudyanto et al., 2024	SDI Surface Distress Index	Indonesia	Data SDI lubang jalan	Evaluasi & penanganan lubang jalan
Yang et al., 2021	Smartphone sensor-based identification	Indonesia	Pothole SDI data	Pothole evaluation & repair treatment
Satria, 2021	Spatial GIS	Indonesia	Traffic accident data	Spatial accident analysis
Shahid & al., 2025	Stochastic models	Global	Literature on stochastic models	Review of stochastic models for road performance
Obunguta, 2023	Stochastic road management	Uganda	National road infrastructure data	Implementation of stochastic management in practice
Syaiful et al., 2023	Sustainability Model	Indonesia	Transportation literature & policy data	Sustainability model for transport management
Pour et al., 2023	Technology-driven DSS	Europe	National road maintenance data	Adaptive DSS for maintenance
Sammas, 2025	Theoretical & computational	Middle East	Laboratory & simulation data	Theoretical asphalt damage modeling
Mulyanto et al., 2025	Vision-based AI	Global	Various crack/distress image datasets	Review of automated distress inspection

RESULT AND DISCUSSION

The analysis was carried out using a thematic approach and methodological classification. Each article was extracted for information, including the prediction methods applied, research location, type of field dataset, strengths, and limitations. The studies were then grouped into four main categories: index-based methods, probabilistic models such as Markov Chain, BN, and DBN, artificial intelligence, and hybrid models. The analysis also included the distribution of publications by year and region, making it easier to identify global trends, research gaps, and opportunities for application in Indonesia [10], [25] The findings from this process were used to formulate recommendations for developing prediction models, including the integration of DBN and AI, to support national road maintenance policies.

Index-Based Methods

Developing countries, including Indonesia, still use index-based road condition assessments. This is because the method is straightforward, and data provision is straightforward. This approach only uses an index to measure the road surface's level of damage or roughness. There are three frequently used index approaches: the International Roughness Index (IRI), the Pavement Condition Index (PCI), and the Surface Distress Index (SDI) [1], [3], [6]. Previous research has stated that this index-based method can provide a quick overview of road damage conditions that can be used as a guideline for routine and periodic maintenance [5]. Despite the advantages of the index method, there are still limitations, namely the inability to predict changes in road conditions over time due to

various factors such as climate change, the decline of supporting infrastructure, long-term traffic loads, and others [1]. Therefore, this index method is only suitable as an early monitoring tool. At the same time, strategic decision-making still requires refinement with other methods that can accommodate the uncertainty and variability of road condition data and the factors that influence it..

Probabilistic Models

Stochastic models, such as Markov chains and Bayesian networks (BNs), are increasingly used to predict road pavement conditions because they can handle uncertainty while clearly depicting cause-and-effect relationships. This method can improve on index methods that only assess road surface conditions. The BN method is capable of analyzing road damage conditions and influencing factors in more detail and comprehensively, such as traffic volume, road construction quality, environmental conditions, and others. Previous studies have found that the BN model can predict road damage due to various dominant factors. Road managers can use this BN model to determine maintenance strategies based on potential critical risks that cause road damage [25]

The limitation of the BN model is its inability to predict road conditions based on changes over time. Therefore, BN has been developed by incorporating the time-varying factors of road conditions and their causes, called the Dynamic Bayesian Model (DBN). This DBN model is capable of more dynamic predictions than BN, so the DBN model can perform predictive analysis that is more adaptive to changes in factors causing road damage, namely, environmental changes, climate variations, and increased traffic volumes [9], [10]. However, BN and DBN models must provide more data than the index model: data on road conditions and the factors that influence them. Providing good quality and consistent road condition data is the biggest obstacle in Indonesia, as the continuous road condition monitoring system is still limited.

Artificial Intelligence AI Models

Computing technology is developing rapidly, allowing it to be utilized as a research tool. Some technologies already in use include artificial intelligence (AI), machine learning (ML), and artificial neural networks (ANN). Previous research articles have demonstrated that these algorithms can solve highly complex computational problems. This computing technology has been able to automatically detect road surface damage and predict Pavement Condition Index (PCI) values with high accuracy [11], [12], [13]. One interesting development is the Bayesian Neural Network (BNN), which can handle non-linear relationships and provide uncertainty estimates in prediction results [14]. The main advantage of the AI approach lies in its ability to process big data and manage complex variables. However, limited model interpretability and the need for large datasets still pose challenges to practical application in the field.

Hybrid Models and Supporting Technologies

New ideas in study change fast, & mix lots of ways to get the best look. This mix makes the good bits of one way better, & helps with its not-so-good bits with other ways. These mix ways use chance ways, brain-like tech (AI), & far-see tech to guess road bits more on point. Mixing far-seeing tech with data digging ways has been seen to check the road network in a land fast & with care [15], [16]. On the other hand, soft thought can help read field info, which has lots of maybes [17] A study by Karballaeezadeh & Zaremotekhases (2020; Pour et al., 2023) has put DBN with learn tech to keep things stable & right in the guess look. However, this mixed way brings good bits; it still has complex parts, like the need for big count stuff & cross-area info back for good & long-lasting use.

World studies now show a big move from old-school ways to use chance models & smart tech in road shape guessing. More and more works point to using ways like the Markov Chain, Bayesian Net (BN), and Dynamic Bayesian Net (DBN). They are liked for dealing with uncertain things, showing cause links, and tracking road wear over time [4], [10], [56]. Of these, DBN is top for its skill in showing long wear, to help more quick & competent road care as cars grow & weather shifts [14]. At the same time, smart tech ways—like machine learn, brain-like nets, & Bayesian Brain Nets—have shown excellent results in eyeing hard, bent ways, more so when mixed with big data & far-seeing tech [11], [12], [14]. The latest trend moves further toward hybrid models that integrate

probabilistic methods with AI, enhancing predictive accuracy while facilitating large-scale monitoring of road networks [15], [16], [20].

In Indonesia, however, a different pattern persists. Index-based methods such as IRI, PCI, and SDI remain the primary tools for road maintenance decision-making, largely due to their procedural simplicity, lower data requirements, and suitability for contexts constrained by budgets and monitoring infrastructure [1], [3], [5], [6]. While several studies have begun to explore probabilistic models and machine learning algorithms, the implementation of DBN and hybrid models remains limited [7], [8], [25]. The primary challenges involve the availability of consistent time-series data, limited sensor-based real-time monitoring, and the lack of integrated databases across agencies [43], [53]

The gap between advanced global developments and Indonesia's current practice underscores the urgency of strengthening data acquisition systems, enhancing technical capacity, and establishing policy frameworks that support the adoption of probabilistic and AI-based prediction methods. By synthesizing global and local findings, this study not only maps recent methodological advances but also identifies opportunities for applying DBN as a relevant approach in Indonesia. The proposed comprehensive framework, which connects global innovations with national priorities, provides valuable direction for future research and policymaking, paving the way toward a more adaptive and data-driven pavement management system.

CONCLUSION

Recent global developments in pavement deterioration prediction (2020–2025) reveal a significant shift from conventional index-based methods (IRI, PCI, SDI) toward more advanced probabilistic models and artificial intelligence (AI). Probabilistic approaches such as the Dynamic Bayesian Network (DBN) have shown strong capability in handling uncertainty, modeling cause–and–effect relationships, and capturing long-term deterioration trends, while AI techniques, including machine learning and neural networks, demonstrate high accuracy in crack detection and pavement condition forecasting, especially when combined with big data and remote sensing technologies. The latest trend points toward hybrid models that merge probabilistic and AI methods, offering greater predictive accuracy and enabling large-scale pavement management. In Indonesia, however, practice remains dominated by index-based methods due to their simplicity and lower data requirements, while the use of DBN and hybrid systems is still limited, constrained by the lack of consistent time-series data, minimal real-time monitoring technologies, and fragmented institutional coordination. To transition toward a more adaptive, data-driven pavement management system that optimizes resources and enhances safety and service life, Indonesia must strengthen data acquisition and technological capacity, advance model development, establish supportive policies and cross-sector collaboration, and invest in technical expertise.

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REFERENCES

[1] H. Haldiana, M. N. Prayudyanto, and R. Rulhendri, "Analysis of road damage levels using the surface distress index method and handling cracked roads," *ASTONJADRO*, vol. 13, no. 2, pp. 463–476, 2024, doi: 10.32832/astonjadro.v13i2.15053.

[2] M. J. Amani, A. Alampoor, M. Piri, and A. Golroo, "A review on the impact of pavement condition on traffic safety," *SSRN*, 2024.

[3] H. A. A. Aziz, V. A. K. Dewi, and P. N. Prameswari, "Analysis of Damage Levels and Maintenance Using IRI on the Pandaan–Malang Toll Road," *Rekayasa Sipil*, pp. 297–305, 2025, [Online]. Available: https://rekayasasipil.ub.ac.id/index.php/rs/article/view/1296

[4] B. Philip and H. AlJassmi, "A Bayesian decision support system for optimizing pavement management programs," *Heliyon*, vol. 10, no. 2, p. e25034, 2024, doi: 10.1016/j.heliyon.2024.e25034.

[5] D. C. Wicakrani and A. Widayanti, "Analisis kerusakan jalan dan penentuan penanganannya dengan aplikasi pada link 166 di Kabupaten Jombang," *Jurnal Media Publikasi Terapan*, 2024.

[6] M. N. Prayudyanto, R. Rulhendri, S. Syaiful, and R. N. Ramadan, "Analysis of road damage levels using the SDI (Surface Distress Index) method for evaluation and handling of potholes," *ASTONJADRO*, vol. 14, no. 1, pp. 1–13, 2024, doi: 10.32832/astonjadro.v14i1.15015.

[7] M. Isradi, "Markov decision process for development of highway minimum standard performance," *Journal (unspecified)*, 2024.

[8] E. P. Togatorop and A. P. M. Tarigan, "Pemodelan kondisi perkerasan jalan dengan metode probabilistik rantai Markov," *Jurnal Syntax Admiration*, vol. 4, no. 3, 2023, [Online]. Available: https://jurnalsyntaxadmiration.com/index.php/jurnal/article/view/553/959

[9] T. Vagdatli and K. Petroutsatou, "A dynamic Bayesian network for pavement roughness prediction," in *Bituminous Mixtures and Pavements VIII*, CRC Press, 2024, pp. 901–909. doi: 10.1201/9781003402541-106.

[10] Y. Zhang, A. M. d'Avigneau, G. Hadjidemetriou, I. Brilakis, and M. Girolami, "Bayesian dynamic modelling for probabilistic prediction of IRI," *Eng Fail Anal*, vol. 144, p. 114978, 2024, doi: 10.1016/j.engfailanal.2024.114978.

[11] A. Ashraf, A. Sophian, A. A. Shafie, and T. S. Gunawan, "Machine learning-based pavement crack detection, classification and characterization: a review," *Bulletin of Electrical Engineering & Informatics*, 2023, [Online]. Available: https://beei.org/index.php/EEI/article/view/5345

[12] H. I. Ashqar and et al., "Software for predicting Pavement Condition Index (PCI) using ML — class prediction approach," *Journal of Infrastructure Software / Engineering (or SoftwareX/SSRN)*, 2025.

[13] M. A. Ali, M. A. Afridi, and others, "Predicting Pavement Condition Index using ML at municipal level," *Journal of Pavement Engineering / ASCE Conference Paper*, 2025.

[14] B. Cui and H. Wang, "Predicting Asphalt Pavement Deterioration Under Climate Change Uncertainty Using Bayesian Neural Networks," *Transportation Research / IEEE Transactions on Intelligent Transportation Systems (reported across repositories)*, 2025.

[15] N. Fiorentini, M. Maboudi, P. Leandri, M. Losa, and M. Gerke, "Surface motion prediction and mapping for road infrastructures management by PS-InSAR measurements and machine learning algorithms," *Remote Sens (Basel)*, 2020.

[16] S. S. Politis, Z. Zhang, and S. Kouchaki, "Framework for network-level pavement condition assessment using remote sensing and data mining," *J Appl Remote Sens*, vol. 14, no. 3, p. 034501, 2020, doi: 10.1117/1.JRS.14.034501.

[17] A. T. Olowosulu, J. M. Kaura, and A. A. Murana, "Data mining and performance prediction of flexible road pavement using fuzzy logic theory: A case of Nigeria," *Sustainable Issues in...*, 2020.

[18] M. Isradi, J. Prasetijo, A. Irfan, and H. Andraiko, "The prediction of road condition value during maintenance based on Markov process," *International Journal on (unspecified)*, 2024.

[19] N. Karballaeezadeh and F. Zaremotekhases, "Intelligent road inspection with advanced machine learning: Hybrid prediction models for smart mobility and transportation maintenance systems," *Energies (Basel)*, 2020.

[20] S. M. Pour, A. M. Masoumi, and N. S. Dujardin, "Towards a technology-driven adaptive decision support system for integrated pavement and maintenance strategies (TDADSS-IPM)," *Transportation Research Procedia*, vol. 69, pp. 130–139, 2023, doi: 10.1016/j.trpro.2023.01.115.

[21] M. J. Page *et al.*, "The PRISMA 2020 statement: An updated guideline for reporting systematic reviews," Mar. 29, 2021, *BMJ Publishing Group*. doi: 10.1136/bmj.n71.

[22] R. Bayat, S. Talatahari, A. H. Gandomi, and M. Habibi, "Artificial neural networks for flexible pavement," *Information (MDPI)*, vol. 14, no. 2, p. 62, 2023, doi: 10.3390/info14020062.

[23] S. A. Osman, M. Almoshaogeh, A. Jamal, and F. Alharbi, "Intelligent assessment of pavement condition indices using artificial neural networks," *Sustainability*, vol. 14, no. 20, p. 13234, 2022, doi: 10.3390/su142013234.

[24] Y. I. Alatoom and T. I. Al-Suleiman, "Development of pavement roughness models using artificial neural network (ANN)," *International Journal of Pavement Engineering*, vol. 23, no. 5, pp. 623–635, 2022.

[25] J. W. Soetjipto and A. P. Simorangkir, "A Bayesian network approach to causation analysis of road damage," *AIP Conf Proc*, 2024.

[26] P. Lumba, "Fatigue factor on motorcyclists' accident: Analysis using Bayesian network," *Suranaree Journal of Science and Technology*, 2022.

[27] B. Philip and H. A. Jassmi, "A Bayesian approach towards modelling the interrelationships of pavement deterioration factors," *Buildings*, 2022.

[28] S. Hasugian and M. Rahmawati, "Analysis of ship accident risk in Indonesia with Bayesian network model approach," *Annals of the (unspecified)*, 2021.

[29] S. S. Leu, C. Y. Lu, and P. L. Wu, "Dynamic-Bayesian-network-based project cost overrun prediction model," *Sustainability*, vol. 15, no. 5, p. 4570, 2023, doi: 10.3390/su15054570.

[30] H. Sun and Y. Yan, "A decision-making framework for recommended maintenance of road segments," 2023. [Online]. Available: https://arxiv.org/abs/2307.10085

[31] A. T. Olowosulu, J. M. Kaura, and A. A. Murana, "Data mining and performance prediction of flexible road pavement using fuzzy logic theory: A case of Nigeria," *Sustainable Issues in...*, 2020.

[32] L. R. Rosaria, A. I. Rifai, and J. Prasetijo, "The geometric design of horizontal alignment: A case of post-harvest infrastructure corn drying center, Tuban, East Java," *Indonesian Journal (unspecified)*, 2022.

[33] N. Karballaeezadeh and F. Zaremotekhases, "Intelligent road inspection with advanced machine learning: Hybrid prediction models for smart mobility and transportation maintenance systems," *Energies (Basel)*, 2020.

[34] S. S. Liu, M. F. A. Arifin, and W. T. Chen, "An integrated optimization model for life cycle pavement maintenance budgeting problems," *IEEE Access*, 2022.

[35] H. Sun, X. Yi, Z. Pan, N. Cheng, and P. C. Shih, "How to build a reliable framework to make intelligent decisions about road maintenance," *Proceedings of the 8th International... (ICICT 2025)*, 2025.

[36] R. M. K. Sandamal and H. R. Pasindu, "Development of pavement roughness prediction model for national highways in Sri Lanka," *Journal of the Institution of Engineers, Sri Lanka*, 2020.

[37] S. Al-Samahi, W. Zeiada, and G. G. Al-Khateeb, "A comparative study of pavement roughness prediction models under different climatic conditions," *Journal (unspecified)*, 2024.

[38] B. Cui, C. S. Shahid, and M. Khajehvand, "Development of pavement deterioration models using Markov chain processes," *Civil Engineering Journal*, vol. 10, no. 9, pp. 1–12, 2024, doi: 10.28991/CEJ-2024-010-09-012.

[39] A. Amir, "Rational maintenance management system for road infrastructure applying machine-learning at the network and project levels," 2020. [Online]. Available: Shibaura Institute Repository (report)

[40] W. Li, L. Chen, X. Chen, R. Chen, and Z. Qian, "A data-and-knowledge-driven framework for automated generation of asphalt pavement maintenance strategies," *International Journal of Pavement Engineering*, vol. 26, 2025, doi: 10.1080/10298436.2025.2458731.

[41] S. Heo, W. Sohn, S. Park, and D. K. Lee, "Multi-hazard assessment for flood and landslide risk in Kalimantan and Sumatra: Implications for Nusantara, Indonesia's new capital," *Heliyon*, 2024.

[42] Y. Farida and L. P. Anenda, "Network planning analysis on road construction projects using evaluation review technique (PERT)-critical path method (CPM) and crashing method," *International Journal of Integrated...*, 2022.

[43] P. J. Hu, "Incorporating project bundling, non-stationary IRI Markov models, and equivalence testing in transportation infrastructure asset management," *Journal (unspecified)*, 2023.

[44] S. S. Liu, A. Budiwirawan, M. F. A. Arifin, and W. T. Chen, "Optimization model for the pavement pothole repair problem considering consumable resources," *Symmetry (Basel)*, 2021.

[45] X. Chen and Y. Zhao, "An environmentally-friendly optimization framework for road pricing and pavement management under public-private-partnership," *Transportmetrica B: Transport Dynamics*, 2024.

[46] N. P. Pramesti, H. Priyosulistyo, and A. Aminullah, "The bridge maintenance factors model: A PLS-SEM approach," *Age (Omaha)*, 2021.

[47] A. D. Nataadmadja, J. L. Lie, and K. A. Sudiyono, "The development of preliminary pavement deterioration model (Case study: Tangerang-Merak toll road, Indonesia)," *AIP Conf Proc*, 2024.

[48] S. S. Liu and M. F. A. Arifin, "Preventive maintenance model for national school buildings in Indonesia using a constraint programming approach," *Sustainability*, 2021.

[49] C. L. Yang, H. Sutrisno, A. S. Chan, and H. Tampubolon, "Identification and analysis of weather-sensitive roads based on smartphone sensor data: A case study in Jakarta," *Sensors*, 2021.

[50] R. Satria, "Spatial analysis of traffic accidents using GIS: The case of Banda Aceh, Indonesia," *Journal (unspecified)*, 2021.

[51] C. S. Shahid and et al., "Stochastic-based pavement performance and deterioration models: Review and applications," *Engineering Structures / Elsevier*, 2025.

[52] F. Obunguta, "Stochastic road infrastructure management with empirical implementation in Uganda," 2023. [Online]. Available: https://repository.kulib.kyoto-u.ac.jp/bitstream/2433/283688/5/dkogk05075.pdf

[53] S. Syaiful, P. Pratikso, and S. W. Mudjanarko, "Literature study of the sustainability model of transportation facilities and infrastructure in the management of public transportation with the concept of inter-regional cooperation (Case in the City and District of Bogor)," *ASTONJADRO*, vol. 12, no. 2, pp. 613–634, 2023, doi: 10.32832/astonjadro.v12i2.14114.

pISSN 2302-4240
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DOI: http://dx.doi.org/10.32832/astonjadro.v15i2.21669 http://ejournal.uika-bogor.ac.id/index.php/ASTONJADRO

[54] Y. A. A. Sammas, "Experimental investigation of pavement deterioration using theoretical models and computational methods," *Middle East Journal of Pure and Applied Sciences*, 2025.

[55] A. Mulyanto, R. F. Sari, A. Muis, and R. Harwahyu, "Vision-Based Automated Pavement Distress Inspection: A Review," *IEEE Access*, vol. 13, pp. 115474–115502, 2025, doi: 10.1109/ACCESS.2025.3582976.

[56] T. Vagdatli, K. Petroutsatou, P. Panetsos, and ..., "Probabilistic pre-estimation of life-cycle costs of road bridges using dynamic Bayesian networks," *Structure and ...*, 2024, doi: 10.1080/15732479.2024.2396603.