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2025

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Department of Civil Engineering

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Message from the Conference Chair

Prof. H.R. Pasindu
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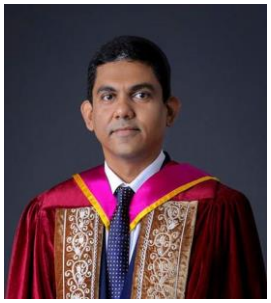

Dear Participants and Esteemed Colleagues

I extend a warm welcome to the 18th Transport Research Forum 2025, organized by the Transportation Engineering Division of the Department of Civil Engineering at the University of Moratuwa. This annual forum continues to be a key platform for knowledge sharing, discussion, and collaboration among academics, researchers, and professionals in Sri Lanka's transportation sector.

This year, we are excited to introduce a new session within the TRF-the Transport Leaders Forum-where key industry stakeholders from diverse organizations will come together to discuss a common theme. The inaugural session will focus on road safety, reflecting the growing importance of this critical area in the national transportation sector. The discussions from distinguished speakers representing various sectors of the transport industry foster a multidisciplinary approach to addressing challenges and opportunities in transportation.

This year's conference also accepted over 20 research abstracts for presentations and for the poster session.

I wish to thank the Vice-Chancellor, Prof. Niranjan Gunawardana; the Dean of the Faculty of Engineering, Prof. Jagath Manatunge; the Dean of the Faculty of Graduate Studies, Prof. Ruwan Gopura; and Prof. Udeni Nawagamuwa, Head of the Department of Civil Engineering, for their steadfast support for the conference. Their commitment has been instrumental in advancing our efforts.

I am also grateful to the organizing committee for their dedication in planning this forum and to our academic and industry reviewers for their careful evaluation of the submissions. To our invited speakers, presenters, and participants, thank you for your contributions, which make this event a vibrant and meaningful exchange of ideas.

As we commence the conference, I encourage you to actively participate, engage with your peers, and share your insights. This is an opportunity to explore solutions to current challenges and contribute to shaping the future of transportation in Sri Lanka.

On behalf of the organizing committee, I look forward to a productive and engaging forum. Let us make the most of this opportunity to learn, collaborate, and advance our shared goals in transportation research.

Thank you.

Transport Leaders Forum

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Secretary of the Ministry of Transport, Highways, Ports and Civil Aviation

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Sin Wai (Angel) Chong
Transport Specialist, Transport Sector Office, Asia Development Bank

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Deputy Director General (Infrastructure, Road Safety & Traffic Management)
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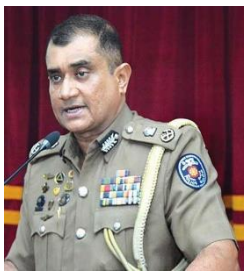

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Study on Road User Safety Issues in Road Construction Work Zones in Sri Lanka

K.H.G.S Madushanka, Nalaka Jayantha, H.R. Pasindu

Abstract

Critical road user safety deficiencies within road work zones across Sri Lanka are addressed in this research, where the construction and maintenance of transportation infrastructure significantly influence risk exposure. A comprehensive nationwide analysis revealed that widespread non-compliance with the national guidelines on traffic control for road work areas primarily contributed to elevated hazards. Core safety challenges identified include inadequate traffic control measures, insufficient illumination, absence or inadequacy of warning signage, inconsistent enforcement of safety protocols, and adverse geographic or environmental conditions. Crucially, the study diagnosed a fundamental methodological gap: inconsistent risk assessment by consulting engineers due to varying levels of expertise, subjective judgment, and the lack of a standardized, quantitative framework. This inconsistency impedes accurate identification of risk levels (high, medium, low) and hinders effective mitigation planning. To overcome these limitations, this study introduces a novel, intelligent risk assessment platform leveraging machine learning (ML) for the automated, objective, and consistently classified work zone safety levels. The core innovation lies in integrating mathematical rigor with real-world engineering validation. The methodology employed a mixed-method strategy across 40 representative work zones. Data encompassed detailed field surveys capturing physical conditions, traffic parameters, and compliance metrics, alongside expert insights. Risk was quantified along three key dimensions: severity, exposure, and likelihood. These indices were derived using a weighted Likert-scale system applied to observed risk factors. The calculated risk index level was identified through a clustering algorithm (K-means), which was then applied to these indices to empirically define high, medium, and low-risk categories, providing a data-driven baseline. Subsequently, multiple supervised ML algorithms were trained and optimized using the field data and the cluster-derived risk labels as ground truth. The primary task was classification into the predefined risk categories based on the input risk factor assessments. Crucially, model validation incorporated rigorous comparison against independent safety evaluations conducted by experienced engineering professionals. This ensured the ML platform's outputs aligned with practical, on-ground engineering judgment, bridging the gap between algorithmic prediction and real-world applicability. Results indicated a concerning prevalence of medium to high-risk classifications across the surveyed zones, confirming significant non-compliance with national standards, particularly regarding signage, lighting, and protective barriers. Among the ML models evaluated, the random forest algorithm demonstrated superior performance, achieving the highest classification accuracy while maintaining strong interpretability through feature importance analysis, making it optimal for field deployment. This research delivers a validated, intelligent ML-based platform that provides scalable, consistent, and objective safety assessments for road work zones in Sri Lanka. It directly

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addresses the identified problem of inconsistent engineer evaluations by offering a standardized, data-driven methodology. The platform calculates a composite risk index for work zones by integrating predictions from a random work zone model with an audited work zone database. This index, derived from input risk factors, classifies work zone risk into three levels: low ($0 \leq$ index < 0.204), medium ($0.204 \leq$ index < 0.298), and high ($0.306 \leq$ index ≤ 1). Using the established classification levels and developed platform, a comprehensive risk identification system was formulated based on variations in the risk index and its relationship with key factor combinations. This approach enables a dual-path risk identification method that enhances accuracy and reliability. The platform functions as a powerful decision-support tool for engineers, policymakers, and contractors, facilitating targeted and data-driven safety interventions. By integrating advanced analytics with domain expertise validation, the study delivers a significant technological advancement in road safety management. This robust solution holds particular relevance for Sri Lanka's extensive ongoing and planned highway infrastructure projects, supporting more informed and effective safety strategies.

Keywords: *machine learning, safety, road construction work zones, rural, urban*

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Real-Time Multi-Lane Speed Measurement Edge Module with License Plate Recognition

Anuki Pasqual, Dulan Lokugeegana, Manimohan Thiriloganathan, Nuthya Rathnayake, Sampath Perera, Kithsiri Samarasinghe

Abstract

Overspeeding is a leading cause of road accidents. In 2024, Sri Lanka police reports indicated that over 90% of serious crashes were due to reckless driving. Automated speed enforcement systems have been adopted in many countries to address this issue, typically using radar or LiDAR to estimate vehicle speed and capturing images of vehicles that violate speed limits. Currently, in Sri Lanka, only handheld speed guns are used to detect speed violations. Installing fixed speed cameras in addition to speed guns can improve speed enforcement through fully automated operation and detecting speed violations of multiple vehicles simultaneously. Studies on fixed speed camera systems in other countries show that they lead to a notable reduction in severe and fatal crashes. However, implementing such systems in Sri Lanka presents several challenges. Most commercial solutions are designed for roadways where vehicles usually adhere to their lanes. On normal roads in Sri Lanka, this lane discipline is not strictly followed, and there might be multiple vehicles parallel on the same lane. Furthermore, smaller vehicles such as motorbikes are common in the country and are harder to detect. Existing systems are not customizable for these scenarios and are highly costly for a developing country. Hence, there is a need for a robust and low-cost static speed measurement device that can be easily deployed on Sri Lankan roads. This project presents a stationary edge module for multi-lane speed measurement and license plate recognition, customized for the above-mentioned challenges of Sri Lankan roads. The dual approach of capturing speed and license plate information allows automatic collection of speed violation data, enabling better enforcement of speed regulations and traffic management without increased manpower. Furthermore, the module performs real-time processing within 100 ms such that the speed and license plate number of passing vehicles can be instantly shown on an overhead display, serving as a visual deterrent for overspeeding. The device utilizes 77 GHz frequency-modulated continuous wave (FMCW) radar for speed and position estimation of multiple target vehicles. License plate recognition is done by passing camera-captured images into custom deep learning models for license plate detection followed by character recognition. A data fusion algorithm that involves time synchronization, spatial calibration, and point matching is used to accurately combine radar and image data. The hardware platform is built around the Zynq Ultrascale+ system-on-chip (SoC) with an integrated FPGA fabric, and it uses the Texas Instruments IWR1843 radar module. The FPGA is used for hardware acceleration of the deep learning models and data fusion unit, enabling real-time processing while keeping overall system power and cost low. To address the limitations of existing datasets when training the license plate recognition models, we created a dataset by capturing images from normal roads and expressways in Sri Lanka. The dataset contains 2970 multi-lane road images and 3425 unique license plate images. When trained on this dataset, the license plate detection model achieved 93.2% mAP and the character recognition model

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achieved 91.2% plate-level accuracy on test data. The models showed accurate performance in complex road scenarios and on motorbike license plates. Speed estimation was validated against vehicle speedometers, with a maximum error of 3 kmph. The system is theoretically capable of detecting speeds up to 250 kmph based on the radar specifications. Furthermore, in the field tests conducted in normal road, busy road, and expressway scenarios, the data fusion process matched the speed and license plate data with accuracies of 90.8%, 71.6%, and 94.5% respectively. Accuracy in busy road scenarios can be further improved through precise calibration. Using a camera operating at 10 FPS, the complete system achieved real-time speed estimation and license plate recognition with a maximum processing time of 70 ms per frame. These results demonstrate the effectiveness of the developed module as a reliable and affordable speed deterrent and enforcement system for Sri Lankan Road environments. Future work will focus on thorough verification of the speed estimation accuracy, integration with a cloud database for data storage and analysis and using IR-capable cameras to enable accurate nighttime license plate recognition.

Keywords: *automated speed enforcement, vehicle speed estimation, license plate recognition, real-time performance*

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Integrated Analysis of Skid Resistance, Texture, and Geometric Factors for Enhanced Road Safety on the Southern Expressway

Wimukthi Jayasinghe, Nalaka Jayantha, Wasantha Mampearachchi

Abstract

Road safety remains a critical concern worldwide, especially on high-speed roads such as expressways, where traffic flow is dense and road geometries are complex. The Southern Expressway in Sri Lanka, the country's first expressway, has contributed significantly to reducing travel time and promoting economic development. However, it has also been associated with a considerable number of road accidents, which raise serious concerns regarding road safety. This research aims to explore the factors contributing to the severity of accidents on the Southern Expressway, focusing on the impacts of road geometry, surface conditions, environmental factors, and lighting. This study investigates a decade of data from 2012 to 2022, collected from the Expressway Operations Maintenance and Management Division (EOM & M). The data encompasses various accident characteristics, including accident time, location, weather conditions, and lighting conditions, as well as road geometry parameters such as horizontal curvature, vertical alignment (K-value), and surface texture. The research applies a combination of statistical techniques and machine learning models to identify key factors influencing accident severity and predict accident outcomes. The study found that road geometry, especially curves, gradients, and poor lighting conditions, significantly influences the severity of accidents. Wet weather conditions were also identified as a key factor, as they reduced the effectiveness of skid resistance, leading to increased accident risk. The analysis highlighted the role of road surface conditions such as skid resistance, which is essential in preventing accidents under adverse weather conditions. Principal Component Analysis (PCA) and K means clustering were employed to reduce the dataset's dimensionality and identify the most significant contributing factors. Additionally, machine learning models, including Random Forest, Logistic Regression, and Support Vector Machines (SVM), were used to predict accident severity. The Random Forest model achieved an accuracy rate of 91.5%, demonstrating its potential to accurately predict accident severity and identify high-risk zones. The study emphasises the importance of improving road design, particularly in high-risk areas. Enhancing road surface conditions, such as improving skid resistance, and upgrading lighting in poorly lit zones, could significantly reduce accident severity. Furthermore, integrating real-time traffic and weather data into predictive models would enable timely interventions and better safety management. The research also advocates for the use of advanced technologies such as GIS-based hotspot analysis and digital road signs to increase driver awareness and promote safer driving behaviors. In conclusion, this research underscores the need for a comprehensive approach to road safety management on expressways, combining better road design, predictive modelling, and real-time data integration. By implementing these recommendations, the Southern Expressway's safety performance can be significantly improved, ultimately reducing accident severity and contributing to safer transportation. The findings provide valuable insights for road safety

management, particularly for expressways in emerging economies like Sri Lanka, and can serve as a model for other regions facing similar challenges.

Keywords: *accident severity, hotspot analysis, machine learning, K-mean clustering*

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Enhancing Road Accident Information Management through the Development of a Web GIS-based Road Accident Information System

Pasan Rodrigo, Pavithra Jayasinghe

Abstract

Road accidents have become a significant issue worldwide, and they are a leading cause of death and injury. According to the World Health Organization (2024), approximately 1.19 million lives are lost annually due to road accidents. Globally, 20 million to 50 million people are injured, causing many to suffer permanent disabilities. In Sri Lanka, it is reported that 19.5 males out of 100,000 lose their lives annually due to road accidents. However, little attention is paid to enhancing road safety through GIS based tools in Sri Lanka. Road accident details are collected through the 297–B form by the Sri Lankan Police, and that data is then entered into the Modular Accident Analysis Program (MAAP) software. Even though the data collection systematically takes place, the limited use of data is observed, and its potential in the decision-making process is also neglected by employing data only for statistical purposes. The only method employed by individual police stations to identify high-risk locations and peak accident periods involves manually plotting accidents on physical maps and time charts. Additionally, the Modular Accident Analysis Program (MAAP) software previously used by the Sri Lanka Police suffers from significant limitations, including reliance on an outdated offline base map from 1999, which is incompatible with the current road network. Due to these technical inefficiencies and data reliability issues, the police discontinued the collection of geolocation data (East and North coordinates) for accidents after 2019. Accordingly, this study proposes the development of a Web GIS-based road accident information system, with the Mirihana Police Area serving as the case study location. The Web GIS-based system was developed using the ArcGIS Online platform, leveraging Survey123 for structured, field-based data collection and Web App Builder for creating interactive web applications without the need for coding. Survey123 was configured to capture detailed road accident information, including attributes such as date, time, location, type of collision, severity, and contributing factors. The survey form was optimized for mobile device usage, enabling real-time data entry by field officers. The collected data was automatically integrated into the ArcGIS Online environment, where Web AppBuilder was utilized to design a customized web application featuring dynamic maps, dashboards, and query tools. These tools allow users to visualize accident hotspots, filter data by time periods, and analyze spatial patterns interactively. The system architecture ensures centralized data storage, ease of access for multiple stakeholders, and supports decision-making through real-time spatial analysis and visualization. This system made the data insertion process significantly efficient, given the capabilities of Survey123, such as precisely locating accident locations through a mobile device or the web in real time. Efficient data filtering options greatly increased data retrieval, and the existing data downloading option made this system useful for research purposes. Furthermore, the availability of spatial statistical analysis tools such as Hot Spot analysis, Point Density analysis, Outlier analysis, and point cluster analysis makes decision making processes prompt, which enables the identification of concentrations of severe accident

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locations, enabling authorities to organize mitigation strategies in a speedy manner compared to the use of manual methods. Ultimately, this Web GIS-based system not only improves the local-level accuracy and efficiency of accident data management but also serves as a decision-support tool for policymakers. Being modular in nature and easy to deploy, it is scalable to deploy in other police divisions of Sri Lanka, facilitating a more data-driven and proactive nationwide response to road safety.

Keywords: *accident information system, web GIS, spatial data analysis, road safety*

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Modelling the Accessibility to On-Demand Taxi Services in Colombo, Sri Lanka

Hansika Deivendra, Sachini Balasooriya

Abstract

On-demand taxi services have rapidly become a key component of urban mobility systems worldwide, particularly in developing cities where traditional public transport often struggles to meet the demand for flexible and reliable travel options. In Sri Lanka, the introduction of app-based taxi services such as PickMe and Uber in 2015 has significantly altered urban travel behavior, especially in dense zones like the Colombo District. While these platforms offer convenience through real-time ride matching and app based booking, there is limited understanding of how accessible these services truly are across different parts of the city. This study aims to fill that gap by developing a spatial model to assess and quantify accessibility to on-demand taxi services in Colombo. Accessibility in this context refers to the ease with which users can obtain a ride, primarily determined by average waiting time and service availability. The study seeks to model the influence of socio-economic, spatial, and infrastructure-related factors on this accessibility. A quantitative modelling framework grounded in spatial analysis was adopted. The Colombo District was divided into thirteen neighborhoods to capture intra-district variation. Data was sourced from a leading on-demand taxi service provider, including waiting times, trip counts, and service coverage for each neighborhood. These data were combined with socio-economic indicators such as population density, household income, unemployment rates, household size, vehicle ownership, and transport infrastructure indicators like bus stop density and road network availability. Spatial regression analysis was carried out using R to model accessibility as a function of socio-economic and infrastructural variables. A single model was developed based on statistical fit, spatial logic, and predictive accuracy. The results show that accessibility is strongly influenced by both urban structure and socio-economic conditions. Shorter waiting times were associated with neighborhoods that had higher vehicle ownership, better road networks, and higher income levels. Conversely, areas with low density, fewer public transport connections, and higher unemployment showed poorer accessibility. Interestingly, population density was not consistently linked to better service availability, suggesting that density alone does not guarantee access if other supportive infrastructure is lacking. The model offers both predictive and diagnostic value—highlighting areas that are underserved and uncovering the key factors behind these gaps. For service providers, the insights can inform operational strategies like fleet allocation, dynamic pricing, and service expansion. For city planners, the model provides a tool to better integrate digital mobility services within broader transport planning frameworks. From a policy perspective, the findings stress the need for inclusive transport strategies that bridge digital services and spatial equity. As app based taxi platforms become embedded within urban mobility systems, ensuring equitable access will require deliberate, data-driven planning. In conclusion, this study presents a location-specific, rigorous methodology to model accessibility to on-demand taxi services. It contributes to the growing research on app-based mobility in the Global South and offers a transferable framework for analyzing accessibility in other urban environments. As cities continue adapting to digital

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mobility transitions, such models are vital for fostering sustainable, inclusive, and efficient transport systems.

Keywords: *accessibility modelling, app-based mobility, Colombo, on-demand taxi services, spatial analysis, spatial regression*

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A New Metric for the Estimation of Dynamic PCU's in Intersections under Heterogeneous Traffic Conditions

Salawavidana Arachchige Suneth Thushara Salawavidana, H.R Pasindu, J.M.S.J Bandara, Rohan Munasinghe

Abstract

Most of the traffic signal design manuals currently in use across the globe have been developed based on traffic conditions typically found in developed countries. These conditions are generally characterized by car-dominant, lane-compliant, and nearly homogeneous traffic flows. As such, the foundational parameters used in these manuals—Passenger Car Units (PCU) and Saturation Flow (SF)—reflect these structured and disciplined conditions. However, applying these parameters to traffic systems in developing countries, which often exhibit vastly different characteristics, raises critical concerns regarding their validity and accuracy. In developing countries such as Sri Lanka, traffic conditions are far more heterogeneous and lack the consistent lane discipline that is a hallmark of developed-world traffic. This heterogeneity is marked by the coexistence of a wide range of vehicle types, including motorcycles, three-wheelers (tuk-tuks), cars, vans, buses, trucks, and even non-motorized vehicles. There is typically no single dominant vehicle class, and smaller vehicles tend to cluster at the mouth of intersections in an attempt to squeeze through gaps in traffic, often disregarding marked lanes. The resulting traffic flow is highly unstructured, and behaviors such as overtaking within a lane, frequent lane changing, and non-uniform vehicle movement are commonplace. Given these unique characteristics, the direct application of PCU and SF values derived from structured, homogeneous conditions is highly questionable. Several attempts have been made in the past to adapt or recalibrate PCU values for heterogeneous traffic conditions. However, these approaches often suffer from multiple drawbacks, including the inability to accurately measure average speeds under congested conditions, the neglect of safety spacing between vehicles, the omission of critical geometric parameters at intersections, and a dependence on costly or technically complex data collection equipment. In response to these challenges, the present study proposes a new and simplified methodology to determine the equivalent traffic impact of different vehicle types under heterogeneous conditions. This approach introduces the concept of Temporal Area Occupancy (TAO), which captures the time a vehicle takes to traverse the critical area of an intersection, from the point where its tail enters the intersection zone to the point where its entire body clears the mouth of the intersection. This method enables a more realistic estimation of each vehicle's impact on intersection capacity. To implement this approach, video footage from a congested urban intersection in Sri Lanka was analyzed. Each vehicle was modeled using three parameters: effective width, effective length, and time of traversal. These parameters collectively allowed for a comprehensive representation of a vehicle's dynamic spatial and temporal footprint. Based on this data, a new unit of measurement called the Standard Vehicle Unit (SVU) was introduced as a substitute for the conventional PCU. The SVU better represents the actual influence of each vehicle type in a heterogeneous, non-lane based traffic stream. Additionally, a Heterogeneity Index was developed to quantitatively assess the degree of traffic heterogeneity at the

intersection. This index accounts for the distribution and behavioral dynamics of various vehicle classes and provides a means to classify traffic streams based on their deviation from homogeneous conditions. To align the derived SVUs with international standards, particularly those specified in the Highway Capacity Manual (HCM), a correction was applied to match the ideal saturation flow of 1900 PCU/hr/lane. The most probable SVUs for each vehicle type - such as motorcycles, three-wheelers, and heavy vehicles - were then calculated. These corrected values offer a more realistic and standardized basis for intersection capacity analysis under mixed traffic conditions. This study ultimately establishes the dynamic and context-sensitive nature of SVUs in heterogeneous traffic environments. The proposed method offers a more robust and cost-effective alternative for traffic engineers and planners working in the developing world. It provides a practical pathway to designing signalized intersections that are more reflective of local traffic realities, leading to improved safety, efficiency, and operational effectiveness in urban transport systems.

Keywords: *PCU factors, dynamic PCU's, saturation flow, heterogeneity index, traffic signal design*

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Sustainable Innovation of Colored Bitumen via Naphthalene Modified Base and Aesthetic Enhancement in Pavement without Asphaltene Disruption

Ushani Wijenayake, Anuruddha Kumara

Abstract

Due to the high asphaltene content, traditional bitumen is opaque and exhibits a deep black hue, attributable to the dense molecular matrix comprising asphaltenes, resins, and complex aromatic hydrocarbons. This structural composition facilitates extensive light absorption across the visible spectrum (400–700 nm), which reduces the visible pigmentation. Typically, all the bitumen grades widely used in Sri Lanka present several limitations for colored applications, which manifest inherent limitations for aesthetic functionalization, driven by the light-scattering and absorptive properties of their polycyclic aromatic frameworks. Nonetheless, the escalating demand for visually distinctive and functionally zoned pavements, such as high-visibility urban corridors, vehicle parks, walking paths, model roads, and colored lanes for non-motorized traffic, has significantly grown, and that will improve and step up the road construction field and even city developments. Furthermore, the poor pigment compatibility of unmodified bitumen leads to dull coloration, unstable dispersion, and rapid weathering. Attempts to incorporate pigments directly into unmodified bitumen often result in phase separation or compromised mechanical performance. This study addresses the central research question: How can naphthalene modified bitumen (NB) be engineered to produce pigmented bitumen and ensure long-term aesthetic durability in colored asphalt without perturbing the bitumen's intrinsic chemical composition and giving an equal dispersion of pigment throughout the base bitumen? The primary objective is to evaluate the efficacy of naphthalene, a polycyclic aromatic hydrocarbon with a conjugated electron system, as a chemical modifier to partially disrupt the colloidal stability of bitumen while preserving critical asphaltene fractions. One of the most compelling aspects of this study is that humans tend to recognize colors and shapes more intuitively than written signs. As a result, colored bitumen (which can produce colored asphalt mixes with heat-resistant pigments) can serve as a visual communication tool. This allows even individuals who cannot read road signs to understand the meaning or function of specific colored pavement areas. Naphthalene is introduced as a chemical modifier to partially soften the colloidal structure of the bitumen while maintaining the critical asphaltene content. This modification enhances fluidity and pigment dispersion without sacrificing strength, elasticity, or thermal resistance. Unlike clear synthetic binders or low-viscosity emulsions, NB provides a cost-effective and locally adaptable alternative for durable colored pavement materials using a modified moderate shear thermal mill. NB was blended with appropriate pigments such as Iron oxide (red), chromium oxide (green), a suitable plasticizer, and matched white oil in the modified mill under a specific speed and heat to incorporate all particles into the NB matrix. The resulting samples underwent physical and chemical testing as UV aging, temperature susceptibility, and pigment stability were also examined to simulate real world Sri Lankan conditions. Road infrastructure in Sri Lanka largely depends on conventional asphalt concrete, with minimal focus on visual demarcation, dedicated lanes for cyclists and pedestrians, or temperature-moderating pavement

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solutions. The introduction of colored NB for colored asphalt surfaces presents numerous benefits in this setting. It allows for clear differentiation of low-traffic zones, such as designated areas for pedestrians, bicycles, and schools, particularly in rural and peri-urban regions. Colored asphalt contributes to greater road safety, especially in areas prone to heavy rainfall or poor lighting, by making key zones more visible. The technology is also compatible with the existing hot mix asphalt methods, requiring no major shifts in current practices. Additionally, the use of light-colored, reflective surfaces could help in addressing urban heat concerns. Most importantly, this innovation supports modernization and visual enhancement of roadways, aligning with broader goals in smart city planning and tourism-focused infrastructure development. By incorporating color into current pavement systems without the need for complex redesign or costly imported materials, NB-based solutions offer both functional and aesthetic upgrades to Sri Lanka's transportation landscape. Future work engaging with NB based productions will explore large-scale field trials, environmental assessments of modifier usage, and the development of bio-based or green modifiers as sustainable alternatives.

Keywords: *naphthalene modified colored bitumen, aesthetic pavement designs, pigment dispersion, advanced road construction*

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Utilization of Pyrolysis Carbon Black in Bitumen Modification

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Abstract

The constant demand for improved pavement performance and sustainability has influenced researches into alternative materials for bitumen modification. Pyrolysis Carbon Black (PCB), derived from waste tire pyrolysis, represents an environmentally friendly and economically viable additive for enhancing bitumen properties. Utilizing PCB not only offers a promising solution to tire waste management but also has the potential to improve the physical and rheological behaviour of bituminous binders used in road construction. This study investigates the influence of PCB particle size and mixing speed on the physical and chemical characteristics of PCB-modified bitumen. Bitumen samples were prepared with a fixed percentage of PCB, while varying key modification parameters such as particle size and shear mixing speed. The objective is to understand how these parameters impact binder properties and to provide a foundation for optimizing PCB-modified bitumen formulations. Physical properties including penetration and softening point were measured to evaluate the consistency, stiffness, and temperature susceptibility of the binders. Penetration tests provide a measure of binder hardness, which relates directly to performance characteristics like flexibility and deformation resistance. The softening point test complements this by indicating the temperature at which the binder transitions from a solid to a semi-fluid state, informing on temperature susceptibility and high-temperature performance. To investigate chemical interactions between PCB and bitumen, Fourier Transform Infrared Spectroscopy (FTIR) analysis was performed. This technique identifies functional groups and molecular structures, helping to reveal whether chemical bonding or significant molecular changes occur during modification. Understanding these interactions is crucial for interpreting how PCB affects binder performance and durability. The study further explores the effects of aging on PCB-modified binders, an important consideration since bitumen in pavements undergoes oxidative aging during service life. Long-term aging simulations were conducted using a Pressure Aging Vessel (PAV), which accelerates oxidative hardening under controlled temperature and pressure conditions. Penetration and softening point tests were repeated after aging to assess changes in physical properties, thereby evaluating the aging resistance imparted by PCB modification. The results provide insights into the relationship between PCB particle size and mixing speed on the modification effectiveness. Different particle sizes affect the specific surface area and dispersion of PCB within the bitumen, which in turn influences the binder's physical properties. Mixing speed, representing the shear energy input during modification, affects the uniformity and integration of PCB particles in the binder. The results showed that using finer PCB particles led to a 33% decrease in penetration value—from 60 to 40 (0.1 mm)—indicating enhanced stiffness, while softening point changed only slightly. Investigating these factors helps in optimizing processing parameters to achieve the desired binder characteristics. The aging assessment highlights how PCB modification impacts the durability and long-term behaviour of binders. This aspect is vital for ensuring that the modified bitumen maintains desirable performance under the environmental and loading conditions

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experienced by pavements over time. In summary, this research contributes to the growing body of knowledge on sustainable bitumen modification using waste-derived materials. By examining the effects of particle size, mixing speed, and aging on PCB-modified bitumen, the study lays the groundwork for developing optimized designs that balance performance improvement with environmental benefits. The findings support the potential of PCB as a cost-effective and eco-friendly modifier for enhancing pavement binder properties, encouraging further research and industrial application in asphalt technology.

Keywords: *bitumen modification, Pyrolysis Carbon Black (PCB), particle size, mixing speed, ageing resistance, FTIR analysis*

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Evaluation of Internal Curing in Roller Compacted Concrete Using Brick Waste as a Partial Aggregate Replacement

Ashen Shaminda, Nalaka Jayantha

Abstract

Even though there are some countries manufacturing internal curing aggregates, they are a bit expensive to utilize in industry. The reason is that the scarcity of raw materials and some amount of processing have to be done before using the material. Therefore, scientists and research enthusiasts are experimenting to seek the best alternative substances for internal curing aggregates using industrial waste. In this study, brick waste is taken to check whether there is a possibility to be used as a partial aggregate replacement for roller-compacted concrete using an internal curing approach. Quantifying internal curing characteristics of brick waste, behavior of microstructure of concrete matrix during water desorption, and determining the suitability of brick waste as partial aggregate replacement are aims to accomplish in this study. Generally, concrete takes its strength from hydrating reactions. Therefore, supplying water to the concrete continuously is a must. In the presence of water in concrete, it will reach its maximum strength. This chemical phenomenon is known as curing. Curing can be categorized in two ways. They are conventional curing and internal curing. Ponding, sprinkling, and wet gunny bags are some practical approaches for conventional curing. Depending on the situation, these curing techniques will be utilized according to our desire, but the problem behind that is water will be able to travel a couple of inches into concrete since the concrete shows less permeability as a result of that cracking; spalling can occur in concrete. On the other hand, internal curing is a process by which the cement paste will be hydrated in the presence of internal reservoirs that assist in providing water to the cement paste, but this water is not a component of mixing water. Thus, normal aggregates are replaced with aggregates that consist of pores that are considered as internal reservoirs that allow water to release into the concrete for curing. Since there are two possible outcomes, brick waste can be used as a partial replacement for fine aggregate or coarse aggregates. Therefore, this investigation will run along two different paths to quantify the physical properties of aggregates and chemical properties of internal curing aggregates with a couple of mixture proportions until we catch up to what is the optimum mix proportion that suits brick waste. Meanwhile, the finite element analysis (FEM) will be developed to make a computational model to see whether the pattern of water absorption and water desorption into the concrete by using ABACUS or ANYSIS software. In order to assess and compare the compressive strength of internal curing concrete cubes and conventional curing concrete cubes, they are taken out in 7 days, 14 days, and 28 days, respectively, according to the ASTM standards. After that, the cube strength values will be taken to draft a graph with time to understand the strength development with time. Not only compressive strength but also water absorption and desorption capacities, pore sizes, the arrangement of pore structure, and splitting tensile strength will be evaluated after the testing process, and then these data will be taken to tabulate finally to conclude whether this material can be utilized as a partial aggregate replacement or not. Under this research study, it reveals that the quality of internal curing of

concrete and suitability of brick waste as partial aggregate replacement address sustainable construction practices.

Keywords: *internal curing, finite element analysis, roller compacted concrete, sustainable construction, brick waste*

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Developing Criteria for Periodic Road Marking Maintenance in Sri Lanka

Achala Perera, H.R. Pasindu

Abstract

Road markings are important for traffic safety and guidance. In Sri Lanka, markings are mostly maintained in a reactive way, i.e. repainting is based on complaints or accident data and not on a regular, planned maintenance. Since there are no criteria based on quantitative criteria, resources are misallocated and more lives are lost due to delayed maintenance, i.e. the markings are less visible for the drivers since the lane demarcations are blurred. The goal of the present study is to derive scientifically based threshold values and approaches that can be used for the routine maintenance planning and the repainting intervals for road markings in Sri Lanka. The research starts with a review of the current situation, and it can be concluded that there are no standardised thresholds for repainting. Practitioners usually act on visual observations that occur irregularly and without proper quantitative support. This leads to premature or late painting, which has an impact on road safety and maintenance costs. Given this situation, our study aims to replace the current reactive approach with a proactive approach that will systematically assess the condition of markings using conventional and new techniques. The study will use a two-pronged condition assessment approach. The first component is a conventional visual condition process. This will be supplemented with automated evaluation tools. High-resolution imaging techniques combined with classical image processing algorithms will be used to quantify the condition of lane marking in terms of retroreflection and wearing pattern. The resulting technical metrics will be used to develop a measurable quality parameter for road markings. In parallel, data on environmental and operational parameters, i.e. traffic and weather data, will be collected from meteorological stations, a traffic management agency and road material suppliers. The main part of the methodology is the development of statistical models that relate the condition of the marking to influencing factors. Regression techniques and multivariate modelling techniques will be used to determine the rate of deterioration over time. The analysis will consider the influence of the history of exposure to weather conditions and heavy traffic loads. Where possible, the use of sensor data will be considered. It is expected that the statistical models will yield clear deterioration profiles, and these will be used to develop repainting thresholds. In addition, the study will use a multi-criteria decision analysis (MCDA) approach to consider multiple criteria, i.e., visibility, durability and cost effectiveness. This will not only identify optimal intervals for painting but also ensure that the proposed maintenance guidelines are practicable for the different types of roads in Sri Lanka. Engagement with Stakeholders is an important aspect of the study. Structured interviews with experts such as officials from the Road Development Authority, experienced contractors and transportation planners will be carried out to validate the technical findings and to ensure that the maintenance framework is practicable as well as recognisable within the local context. Their findings will refine the quality parameters and also provide further context to the statistical findings in the operation of roads in Sri Lanka. Expected outcomes from this research are identified repainting thresholds, in terms of a summary quality index, an improved maintenance cycle, and a practice-based road marking maintenance guide.

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The local maintenance practices in Sri Lanka will be aligned with the best practices followed internationally, thereby minimizing unnecessary repainting, reducing maintenance costs, and improving road safety by enhancing marker visibility. Eventually, the framework developed in this study will assist in data-informed decision-making and policy development for sustainable maintenance of road assets in Sri Lanka.

Keywords: *road markings, quality metrics, automated assessment, traffic safety*

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A Review on the Effects of Artificial Lighting on Marine Ecology in Seaport Terminals

S.S. Wanniarachchi, P.M. Perera

Abstract

In recent years, excessive or improper application of artificial lighting has had resulted serious environmental consequences, scientifically known as Light Pollution. The night sky and ocean close to transportation terminals are illuminated by a variety of artificial lights, including high-mast lights, navigation lights, security/emergency lights, crane and equipment lighting, LED floodlights, and dock lighting, in addition to the primary natural light sources of sunlight, moonlight, stars, and bioluminescent light. These high-intensity lights have been shimmering along the coastlines, creating a pathway for light pollution and its effects. Research on optical oceanography and ALAN (Artificial Light at Night) impact is expanding globally. However, there is a great dearth of research regarding light pollution related to seaport terminals in Sri Lanka as ALAN is relatively a new area of analysis. The aim of this narrative review paper is to address the question, "what are the ecological impacts of artificial lighting from seaports on marine life" and to raise policymakers' awareness on potential threats marine ecology. Scopus, Google Scholar databases and IMO publications were used for the scientific literature search. Terminal lighting is crucial factor in a seaport for safety, security, and efficiency of movement of people and commodities during around-the-clock operations and the vertical and horizontal light in buoys and beacons are crucial for hazard avoidance in ships. Standards of IMO and International Commission on Illumination (CIE), minimum illumination levels, color temperature levels, and Color Rendering Index are maintained at sea ports for safer navigation and operations. Terminal light emissions beyond shorelines, disrupt delicate underwater ecosystems in pelagic zones and coastal areas. According to literature, around 2 million km² of the world's ocean at a depth of 1 m are affected by light pollution. ALAN impacts include changes in predator- prey interaction patterns of fish, coral spawning, zooplankton diel vertical migration (DVM), and seabird / sea turtle navigation. LED lights' white illumination, adversely affect the recruitment and colonization of marine epifaunal communities like sessile and mobile invertebrate species. Regulations mandate light intensities, luminous intensity, and spectral power distribution units, focusing on human vision, but similar visual metrics should be developed considering the marine and nocturnal animals for more sustainable and environmentally friendly practice. The scientists have developed the Light Pollution Index (LPI) to measure the ALAN impact at night sky. Additionally, strategies like WWF earth hour, green space management and light flow control also used to mitigate the ALAN impacts in infrastructure development. Effective mitigation strategies further include proper placement/direction of vertical beam spread, removing excess lights, reduce uplighting & residual effects, installing timers or dimmers, and using shielded lighting fixtures. Additionally, raise awareness on light pollution, as the DarkSky International, have shown measurable impacts on urban light levels. Inarguably the night sky and marine ecosystems are at threat due to ALAN impact caused by seaports and nearby urban structures. There's a

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growing need to include the effects of light pollution analysis in port master plans. This study emphasizes that careful analysis and preventive strategies exist to constrain and to reduce the ALAN impact of seaports while ensuring safe and efficient operation.

Keywords: *marine ecology, ALAN impact, seaport terminals*

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Utilization of Varied Grades of Coir Fibers to Enhance the Subgrade Strength of Rural Roads Constructed on Soft Soils

Upeksha Divyangani, Chamod Hettiarachchi

Abstract

With the continuous development of the urban areas in Sri Lanka, the shortage of land for the construction of pavements has become as a major issue. In such instances, Engineers are supposed to resort to constructing pavements in areas with soils that are known to be problematic. These problematic soils are most commonly known to be clays and silts due to their high swelling and shrinkage characteristics along with poor load-bearing behavior. The current method of "excavation and replacement" for altering the subgrade, is unquestionably expensive and time-consuming. Therefore, alternatives should be considered in modifying such subgrade. Such alternatives in modifying the subgrade are natural fiber reinforcement, synthetic reinforcement of the soil. Glass fibers, nylon fibers, steel fibers, polyvinyl alcohol fibers (PVA), polyester fibers (PET), polypropylene fibers (PP), and polyethylene fibers (PE) are examples of geosynthetics that are currently in use for subgrade modification. Natural fibers like palm, coir, sisal, jute, hemp, bamboo, and kenaf are becoming increasingly popular since they are more affordable and environmentally beneficial. The durability of natural fibers in subgrade enhancement is known to be 15 to 30 years in time for it to biodegrade fully, according to the soil condition it is reinforced with. The objective of this paper is to study the load bearing characteristics of soft soil when reinforced with different grades of coir fiber. Various studies have been conducted on soft soils such as clay or silt, reinforced with fibers. The most common length of fiber adopted for subgrade modification was seen to be within the range of 1cm to 5cm whereas the composition of fiber varied between 0.2% to 1.5% of the weight of soil. Hence, current studies on fiber reinforced subgrades were used to adopt the length and percentage of fiber in this study. Two commonly available grades of brown coir fiber, which are Mattress fiber and Bristle fiber were used in this study, with composition varying from 0.25% to 0.75% (with 0.25% increments) and lengths varying from 1cm to 3cm (as short fibers in random arrangement). The soil, that was collected from the flood prone area around the Kelani River basin was initially tested for the physical and mechanical properties with the aid of several laboratory experiments such as sedimentation analysis, Atterberg limits and Standard Proctor Compaction (SPC) tests where the soil was classified; this was considered as the control sample. The soil was classified as a fat clay (CH) with a liquid limit of 76% and a plasticity index of 41.34%. The compaction test results showed that the clay bears an optimum moisture content of 27.4% and a maximum dry density of 1.39g/cm3. The 96-hour-soaked California Bearing Ratio (CBR) test on the unreinforced sample showed a low CBR value of 1.21%. The clay was then reinforced with both mattress fibers and bristle fibers and were tested against a soaked CBR test. The sample of fat clay possessed a CBR value of 1.77% with 0.25% bristle fiber which was 1.46 times greater than that of the control sample. 0.50% composition of bristle fiber gained a strength of 2.09 times with a CBR value of 2.54%. The inclusion of 0.75% bristle fiber recorded a 2.61% CBR value by a factor of 2.15 times of

unreinforced clay. In the inclusion of mattress fiber, the 0.25% fiber sample recorded a CBR value of 1.68%, 0.50% fiber sample with a CBR value of 1.80% and 0.75% fiber sample with a CBR value of 1.98%. the strength gained were 1.39, 1.49 and 1.64 times respectively. The optimum percentage of fiber was observed as bristle fiber of 0.75% due to its stiff texture and good load distribution characteristics in the clay fiber matrix. The mattress fiber was as effective, in lower quantities due to its smooth texture. From this study, it was concluded that the use of bristle fiber from coir can be used to enhance the load bearing characteristics of soft soils to a considerable extent, with more room for improvement.

Keywords: *subgrade modification, geosynthetic, fiber, reinforcement, pavements*

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Development and Evaluation of an Interactive Road Safety Education Module for Secondary School Students in Sri Lanka

Lahiru Prasad Gunathunga

Abstract

Vehicular accidents remain a major cause of fatalities and serious injuries worldwide, affecting both developed and developing nations. According to the World Health Organization (2024), annual road traffic fatalities have slightly declined to 1.19 million. Despite this reduction, road crashes remain the leading cause of death for children and young adults, with over 3,200 fatalities occurring daily. A significant proportion of child fatalities are linked to high-risk road use behaviors, exhibited either as pedestrians or vehicle occupants. This global issue is also evident in Sri Lanka, where, according to the Sri Lanka Police (2024), 24,589 road accidents were recorded, resulting in an average of six fatalities per day. Notably, 80% of these fatalities involved vulnerable road users. Among these, approximately 838 pedestrian fatalities were reported, averaging two deaths per day. In total, 2,368 accidents resulted in fatalities, with many more causing severe and often lifelong injuries. These statistics highlight the urgent need for targeted interventions to mitigate high-risk behaviors and improve road safety. “Age” has been identified as a significant factor influencing road accident involvement, underscoring the importance of early education in promoting road safety in Sri Lanka. One of the most effective strategies to address this issue is the implementation of a school-based road safety education program, which fosters safer behaviors among young drivers and vulnerable road users. This study focuses on secondary school students (ages 14–16), a key demographic for early intervention. Data samples will be collected from selected schools within the Colombo District to assess the impact of the educational initiative. The study aims to evaluate students' existing knowledge and attitudes toward road safety, introduce an interactive road safety education module, and assess its effectiveness using pre- and post-assessments. A preliminary literature review was conducted, followed by structured interviews with three road safety professionals and three educational experts/psychologists. The interviews, conducted in a semi-structured format using questionnaires, allowed for in-depth discussions on key road safety challenges, educational gaps, and potential interventions. Responses were analyzed using thematic analysis and the Relative Importance Index (RII) method to identify key themes and priorities. Based on these findings, a web-based road safety education (RSE) module was developed, focusing on the following key areas: Introduction to Road Safety, Knowledge of Traffic Rules & Symbols, Safe Driving & Passenger Habits, and Emergency Response Skills As part of the pilot study, the module was distributed to 50 students, and feedback was collected to refine and optimize the content before commencing the full-scale study. Six schools in the Colombo District were selected based on willingness to participate and student population size, ensuring a diverse representation of students with varying exposure to road safety risks. Students from three schools were designated as the “Control Group,” and students from the remaining schools as the “Treatment Group.” Both groups were initially granted access to the module, and responses were recorded through a pre-assessment survey. After this phase, only the Treatment

Group retained full access, allowing them to engage with interactive content and activities over the designated period. The Control Group had no further access beyond the initial assessment, ensuring a comparative analysis of knowledge retention and behavioral changes. After one month, a final questionnaire was administered via the web module, allowing participation from both groups to assess the impact of the intervention. Participants' responses were analyzed using statistical methods such as mean, median, and standard deviation, enabling a comprehensive interpretation of the findings. The outcomes of this research are expected to provide valuable insights for educational and road safety authorities in Sri Lanka, contributing to potential enhancements in the secondary school curriculum to improve road safety education.

Keywords: *road safety, secondary school students, interactive road safety education module, web-based education*

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Using a Machine Learning Approach to Develop a Macroscopic Passenger Flow Model for Departure Passengers at an Airport Terminal

Osanda Rathnayake, Varuna Adikariwattage, Chanaka Senanayake

Abstract

Effective passenger flow management is a cornerstone of airport terminal operations, directly impacting service quality, resource allocation, and traveller satisfaction. As global air traffic demand continues to grow, airport systems must contend with increasingly complex, dynamic, and high-volume environments. Traditional modelling methods—such as queuing theory, regression models, and discrete event simulation (DES)—have provided valuable frameworks for analysing terminal processes. However, these methods often struggle to deliver scalable, flexible, and real-time solutions required for modern operational decision-making. In particular, simulation-based approaches, while robust, are computationally intensive and often impractical for day-to-day operational use. This study introduces a hybrid methodology that integrates discrete event simulation with machine learning to develop a macroscopic passenger flow model focused on departure processes. The aim is to provide a predictive, data-driven framework capable of capturing the temporal and behavioural complexity of passenger movement through an airport terminal. The research begins with an extensive literature review to identify the key determinants of congestion and flow disruptions. These include temporal arrival patterns, check-in modalities (e.g., counter, kiosk, online), counter allocation strategies, processing times, and passenger characteristics such as group size and baggage quantity. A comprehensive DES model was developed using Simio software, simulating the full departure journey—from curb side check-in to security clearance at the boarding gate. Grounded in empirical data collected from Bandaranaike International Airport, Sri Lanka, this simulation replicates realistic system behaviour and serves as a high-fidelity synthetic data generator. This approach overcomes a common limitation in aviation analytics: the lack of consistent, large-scale real-world datasets. The synthetic data generated through DES was used to train and evaluate machine learning algorithms, with a focus on forecasting short-term fluctuations in passenger flow and terminal congestion. Among the models tested with a sample data set, Long Short-Term Memory (LSTM) networks outperformed both Support Vector Regression (SVR) and Random Forest (RF) in terms of predictive accuracy, generalization capability, and robustness against overfitting. The LSTM model achieved the lowest mean squared error and root mean squared error, demonstrating strong potential for operational deployment. The proposed DES-ML framework offers a scalable, interpretable, and efficient solution for airport stakeholders. It enables near real-time delay prediction and flow estimation, supporting more agile resource planning and enhancing passenger service levels. Moreover, the modular nature of the framework allows for adaptation to varying airport configurations and operational policies. In conclusion, this research demonstrates the value of integrating simulation and machine learning to develop a macroscopic, predictive passenger flow model that bridges the gap between high-fidelity analysis and real-world applicability. The hybrid model not only

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advances academic understanding of terminal dynamics but also provides a practical decision-support tool for improving operational performance in airport environments.

Keywords: *passenger flow modeling, discrete event simulation, machine learning, lstm, simio*

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Cost-Effective Prioritization of Road Networks for Post-Flood Recovery: A Network Robustness Framework

Methmini Kulathunga, H.R. Pasindu

Abstract

An increase in the occurrence and intensity of flooding events is posing significant damage to worldwide road infrastructure. Their consequences include reduced movement, loss of accessibility, and lower economic activity, which disrupt both community and regional transportation systems. For a swift post-flood recovery, it is important to decide the best repair actions for damaged roads and to keep the network strong, within the budget levels. The study introduces a new framework that helps choose the best repair options for flood-damaged roads by prioritizing the robustness of the network. It helps transportation agencies find the least-cost set of links to repair while maintaining a specified level of post-repair network robustness. The authors suggest a three-part approach for determining which sections of a road network should be recovered first. To start, various flood cases are defined by progressively dropping some road sections, symbolizing the extent of the flood. Second, network robustness is measured by computing the proportion of the Giant Connected Component (GCC) is with the whole population of nodes. It refers to the required level of network operations after repairs. A genetic algorithm (GA) is used to ensure the selection of the best links for repairing the network so that the target robustness can be achieved at the lowest overall cost. The optimization model aims to minimize the total reconstruction cost while ensuring the repaired network meets the robustness threshold. The approach forms the problem as a binary combinatorial optimization, where each road segment is assigned a bit (1 for reconstruction and 0 otherwise). The GA procedure starts by choosing a random initial population and then assesses fitness by summing reconstruction cost and network robustness, selects individuals based on a tournament process, performs crossover and mutation operations and finishes when the population converges or reaches the set number of generations. All road links are assumed to have uniform costs for reconstruction per kilometer. The model was used on artificial networks as well as actual road networks with differences in density and structure. In synthetic networks, reconstruction costs were shown to rise with both the extent of damage and the target's strength. Due to the less redundancy, sparse networks were more easily affected by disruptions and required more investment when damage was moderate. However, comparatively denser networks kept functioning strongly even when large parts were destroyed, so the reconstruction cost was lower. Despite the difference in value scale, actual road networks emerged with similar patterns against the damage levels and the target robustness levels. The model identified cost-effective repair strategies for both hypothetical and actual networks, validating its applicability to real-world infrastructure planning. Notably, the results revealed exponential cost growth with increasing damage levels, particularly at higher target robustness values, where small increments in damage led to disproportionately higher costs. This makes it clear that early improvements or upgrades can prevent large expenses in recovery after a disaster. This study aims to provide an effective approach for selecting cost-effective repair methods for roads

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damaged by floods by analyzing the impacts of different kinds of damage on the road network. Using the model, transportation authorities can detect vulnerable parts of the system and calculate the minimal budget necessary to provide suitable repair strategies after a flood. Results reveal that proactive measures are important because the cost of reconstruction rises fast with each level of damage. Under fiscal constraints, authorities can select appropriate robustness targets that balance adequate functional restoration with available resources. The framework provides a systematic approach for developing scenario-based contingency plans, enabling more effective decision-making in post-flood road network recovery.

Keywords: *network robustness, genetic algorithm (GA), post-flood recovery, cost-effective repair strategies, prioritization modelling*

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Performance Evaluation of Aspha-min Modified Warm Mix Asphalt

Sandali Dilsara, Chamod Hettiarachchi

Abstract

Hot Mix Asphalt (HMA) has long been the main material for flexible pavement, and it is mixed and compacted at high temperatures, usually between 150 and 170 degrees Celsius. HMA has been valued for its durability and strength for a long time, but its production process leads to high fuel consumption and emissions of greenhouse gases. Additionally, Short-term aging of the materials is a major concern linked to HMA. Over the past few years, countries around the world have been moving towards making construction more sustainable, which has led to the creation of Warm Mix Asphalt (WMA) technologies. WMA can be produced and compacted at temperatures that are 20–40 degrees lower than those used for HMA which saves energy and reduces emissions without affecting the quality of the pavement. Adding Aspha-min, a synthetic zeolite, is a key technology used to help bitumen foam during WMA production. As a result, aggregates are more easily coated and become more compactable at lower temperatures, which also helps to reduce the amount of energy used. While several studies have examined the performance of Aspha-min modified WMA, no study has evaluated its behavior under Sri Lankan environmental and operational conditions. Moreover, the existing literature does not present a consistent trend regarding the performance impact of Aspha-min. This study focuses on evaluating the performance of Aspha-min modified WMA under local environmental and operational conditions. The primary objective is to determine the optimal dosage of Aspha-min and mixing temperature that would provide performance comparable to conventional HMA while offering environmental benefits. For this purpose, the study tested three Aspha-min dosages, which are 0.25%, 0.30%, and 0.35% by weight of asphalt mix at three mixing temperatures: 125 °C, 130 °C, and 135 °C. A control HMA sample was also made at 150 °C of mixing temperature for comparison. Specimens were prepared and evaluated using the Marshall mix design method, following the requirements of ASTM standard specifications. The main performance parameters analyzed were Marshall stability, bulk specific gravity (G_{mb}), and air void content. The results were checked against the SSCM guidelines for wearing course applications in Sri Lanka to assess the suitability of each Aspha-min dose and mixing temperature. The results showed that a mix with 0.30% Aspha-min and a mixing temperature of 130 °C gave the best combination of workability, stability and void structure. This mix achieved a high Marshall stability value, acceptable density values, and air voids within the recommended range. Furthermore, the compaction properties of the Aspha-min mix were similar to those of the standard HMA mix which means that Aspha-min did not negatively impact density or durability. The research shows that using Aspha-min modified WMA is a possible and lasting choice for constructing flexible pavements in Sri Lanka. Because it reduces the production temperature by up to 20 °C, it helps save fuel and cut emissions, making construction more environmentally friendly. In addition, the optimized mix guarantees the structure's strength, making it suitable for use in local roads. Future efforts may consist of long-term testing in the field and cost analysis to confirm that large-scale adoption is feasible.

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Keywords: *sustainable roads, warm mix asphalt, foaming technology, water-based additive, aspha-min*

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Optimizing Freight Transportation through E-Mobility Integration: A Case Study from Sri Lanka

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Abstract

The transportation sector globally faces growing pressure to adopt sustainable practices, as freight transport significantly contributes to greenhouse gas emissions and diesel consumption. In Sri Lanka, freight systems exacerbate environmental degradation, with transport-related activities accounting for a substantial portion of air pollution. Electric vehicles (EVs) present a transformative opportunity to reduce emissions and operational costs, yet their integration into freight systems, particularly in developing countries, remains underexplored. This research investigates the optimization of freight transportation through e-mobility integration, addressing challenges such as rural routes, limited charging infrastructure, variable demand, and time-sensitive delivery requirements. While the study focuses on a case involving perishable goods logistics, its findings aim to be broadly applicable to freight transportation, developing a scalable mixed fleet model that combines EVs with conventional vehicles. The research is driven by inefficiencies in Sri Lanka's freight systems, characterized by dispersed collection points, variable loads, and geographical challenges, which lead to elevated costs and reduced productivity. Transitioning to EVs aligns with national e-mobility goals and global sustainability targets, offering a pathway to lower environmental impact. The primary objective is to determine an optimal strategy for introducing e-mobility into freight transportation, focusing on enhancing the efficiency of collection and distribution networks. The methodology unfolds in five stages. Initially, the current freight system is evaluated by collecting data on route characteristics, fleet performance, and operational metrics to establish a baseline for comparison. Next, accessible EV technologies are investigated, assessing their operating costs, performance parameters such as range and payload capacity, and infrastructure needs like charging solutions. A cost model is developed to compare EVs with conventional vehicles, providing a financial basis for integration. The third stage involves a feasibility assessment to identify routes suitable for EV deployment, considering range limitations, charging infrastructure availability, and payload requirements. In the fourth stage, mixed fleet scenarios are modeled using the Capacitated Vehicle Routing Problem with Time Windows (CVRPTW) and Mixed Integer Linear Programming (MILP), testing various fleet compositions while factoring in route lengths, terrain challenges, and charging constraints. Finally, the best-performing scenario is selected based on cost efficiency, emission reductions, and operational feasibility, validated through global case studies of successful EV integration in urban logistics. Preliminary findings suggest that EVs, such as electric light trucks and three-wheelers, are well-suited for shorter rural routes, complementing conventional vehicles for longer hauls. Technological advancements, including improved battery ranges and solar-powered charging, help overcome rural infrastructure gaps. International examples of EV adoption in urban freight logistics demonstrate significant emissions reductions and cost savings on optimized routes,

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though challenges like range anxiety persist, which this study addresses through localized modeling.

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Integrating Type Approval and Mileage Data to Estimate NOx Emissions : A Case Study of Newly Registered Motor Cars in Sri Lanka

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Abstract

Nitrogen oxides (NO_x) are major hazardous air pollutants originating from internal combustion engine vehicles, which significantly induces the decline of urban air quality as well as respiratory diseases and environmental pollution. In a country like Sri Lanka, with recent growth in motorization, the accurate prediction of NO_x emissions due to road transport is necessary to guide air quality management and climate action programs. However, the lack of a localized and integrated emission baseline and especially for separated vehicle classes, has constrained the development of rational policies. This gap addresses in this study by presenting a data-driven approach to estimate NO_x emissions only for registered new motor cars in Sri Lanka, which combines Type Approval emission factors for vehicles and on-road vehicle mileage data. The core of this approach lies in combining two key data sources: (1) Vehicle Emission Test (VET) data obtained from the Department of Motor Traffic (DMT), which includes odometer readings for individual vehicles, and (2) NO_x type approval emission factors sourced from international repositories such as the Vehicle Certification Agency (VCA) and the Car Emissions Testing Database. VET data from 2016 to 2023 were processed to estimate the average annual mileage of newly registered motor cars, while the type approval data provided standardized NO_x emission factors based on vehicle manufacturer, model, fuel type, and production year. A matching algorithm was developed to associate vehicles in the VET database with the corresponding emission factors. The estimated NO_x emissions for individual vehicles were then extrapolated to represent the entire population of newly registered motor cars using a weighted average method based on manufacturer distribution and registration trends. The results offer a credible baseline for annual NO_x emissions from newly registered motor cars, highlighting the variation in emissions across fuel types, model years, and manufacturers. This methodology is particularly valuable for contexts like Sri Lanka, where advanced emission testing infrastructure such as chassis dynamometers is unavailable. By utilizing existing administrative data and internationally recognized emission factors, this framework provides a cost-effective, scalable alternative to direct measurement methods. Beyond its specific focus, the study demonstrates a transferable approach that can be extended to other vehicle categories or developing countries facing similar data limitations. It contributes to the advancement of national emission inventories and supports evidence-based policy development aligned with the findings are expected to guide regulators, environmental agencies, and transport planners.

Keywords: *vehicular emission, NOx emission, vehicle type approval data*

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A Data-Driven Framework for Predicting National Vehicular Emissions Using Regulatory EmissionsTest Databases of Sri Lanka

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Abstract

This study presents a data-driven framework for forecasting national vehicular emissions in Sri Lanka using emissions testing records maintained by the Department of Motor Traffic (DMT). These databases, originally collected for compliance verification, remain largely underutilized despite their potential for informing long-term environmental policy. Focusing on passenger cars with internal combustion engines as a case study, a Tier 2 bottom-up emissions estimation methodology is implemented, integrating annual mileage of tested vehicles on a monthly basis and vehicle vintage-size composition. The developed model forecasts pollutant loads including carbon monoxide (CO), non-methane volatile organic compounds (NMVOC), nitrogen oxides (NO_x), nitrous oxide (N_2O), and ammonia (NH_3), in an annual spanning monthly basis. The methodology begins with the derivation of average annual mileage values per vehicle by cross-referencing test entries from the same vehicle across consecutive years. A structured data pre-processing pipeline was developed to extract relevant vehicle characteristics and to clean and align data across multiple testing providers. To assign appropriate emission factors, a hybrid classification scheme was implemented based on both engine horsepower (sourced using a custom web-scraping and fuzzy matching algorithm) and vehicle manufacturing year, which determines its Euro emissions standard category. These parameters were then matched to Tier 2 emission factors from the EMEP/EEA guidelines. To predict future mileage, a Long Short-Term Memory (LSTM) neural network was trained using annual spanning monthly average mileage as the target variable. Input features included real GDP, fleet size of passenger cars, and the proportional distribution of Euro vehicle categories. Additional enhancements such as cyclical encoding of months, moving averages, and MinMax scaling were applied to improve model performance and generalizability. The LSTM model achieved a high predictive accuracy with an R^2 score of 0.899, confirming its capability to capture temporal trends in vehicular mileage patterns. Future emissions were forecasted by integrating the predicted mileage values with projected fleet compositions and matched emission factors. The fleet composition proportions were extrapolated using Holt-Winters triple exponential smoothing. The model predicts that CO will remain the dominant pollutant, with emissions ranging between 2,104.96 and 2,604.00 metric tonnes on an annual spanning monthly basis. NMVOC emissions are expected to range from 630.07 to 705.53 metric tonnes, and NO_x from 289.38 to 359.99 metric tonnes. N_2O and NH_3 emissions, though lower in volume, remain significant contributors, with projected ranges of 11.56–19.41 and 36.39–46.60 metric tonnes respectively. The framework's modularity allows for straightforward adaptation to other vehicle categories such as motorcycles, three-wheelers, and commercial vehicles, with adjustments to input parameters and emission factor sets. Although hybrid and electric vehicles were excluded due to the lack of centralized testing data, their future inclusion would require only minimal modifications. This research highlights how institutional data, when carefully restructured and modelled, can

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yield high-utility tools for national-scale emissions forecasting. The proposed framework not only enhances the value of existing regulatory data but also supports the development of evidence-based transport and environmental policies, particularly in developing countries.

Keywords: *vehicular emissions, emission factors, LSTM prediction*

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