Transport Research Forum 2023

Abstracts

08th December 2023

University of Moratuwa, Sri Lanka

Transportation Engineering Group

Department of Civil Engineering

University of Moratuwa

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Session 05

Introduction

Transport Research Forum (TRF) is an annual conference organized by the Transportation Engineering Division of the Department of Civil Engineering, University of Moratuwa. The prime objective of this conference is to create a platform for researchers in the transportation field to build up their research careers and to share their research findings with other colleagues and the industry. Researchers and academics, including several international experts in highway engineering, transportation engineering and planning, are the participants in this event. In addition, representatives from the industry and related government institutions are also invited every year.

The Department of Civil Engineering conducted the first-ever Sri Lanka Transportation Forum in 1983, and since the late 90's, the Transportation Engineering Group has organized many Transport Research Conferences at local and international levels. Later, the Transport Research Forum (TRF) was established; two conferences were held initially, and since 2010, TRF has been held consecutively every year. TRF 2023 is the 16th Transportation Research Forum conducted by the Transportation Engineering Division. Many of the research findings presented in Transport Research Forums have been put into practice, and one of the main objectives of the Transport Research Forum is to come up with solutions to address transport-related problems in the country and disseminate them to the industry.

Message from the Conference Chair

Prof. J.M.S.J. Bandara

University of Moratuwa

Dear Participants and Esteemed Colleagues,

I extend a warm welcome to the Transportation Research Forum 2023.

Hosted by the Transportation Engineering Group at the Department of Civil Engineering, this year's conference promises to be a platform of intellectual exchange and collaborative exploration. Our program is planned in a manner to offer valuable insights, featuring keynote speakers from around the world and approximately 30 technical papers addressing pertinent issues in Sri Lanka's transport sector.

I am grateful for the support of Vice-Chancellor Prof. Niranjan Gunawardana, Dean, Faculty of Engineering, Prof. Udayanga Hemapala, and Head, Department of Civil Engineering, Prof. Chintha Jayasinghe, who share a clear commitment to advancing research in our community.

Special thanks to the committee for their invaluable contributions and to our academic and industry partners for their thorough reviews of the papers.

To our presenters, thank you for enriching the conference with your expertise. I encourage you to actively engage, connect with peers, and contribute to the depth of discussions.

In the spirit of collaboration, let's make the most of this opportunity to exchange ideas, foster new connections, and collectively contribute to the advancement of transportation research.

On behalf of the conference committee, I eagerly anticipate a fruitful and collaborative experience at the Transportation Research Forum 2023.

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Keynote Speech 01:
Modelling the Demand for Dockless Electric Scooter Sharing Services

Dr. Merkebe Demissie

Assistant Professor, Department of Civil Engineering, University of Calgary

Dr. Merkebe Demissie is an Assistant Professor in the Department of Civil Engineering at the University of Calgary. Prior to his current role, he held positions as a Research Associate and a Postdoctoral Fellow at the University of Calgary. He also served as a Postdoctoral Fellow at the University of Coimbra, Portugal. Dr. Demissie earned his PhD in Transport Systems through the MIT-Portugal program, a collaborative effort between the Massachusetts Institute of Technology (MIT) and select Portuguese Universities. He holds an MSc in Transport Systems from the Royal Institute of Technology (KTH), Sweden. Dr. Demissie's research program is focused on assessing the impacts of Emerging Transportation Technologies and Mobility Services to enhance the sustainability of Transportation Systems.

Keynote Speech 02:
Performance Specifications for Balance Mix Design: Marshall Mix Design Approach

Dr. Ankit Gupta

Associate Professor & MoRTH Chair Professor,

Department of Civil Engineering, IIT (BHU)

Dr. Ankit Gupta presently serves as Associate Professor & Ministry of Road Transport and Highways (MoRTH) Chair Professor in the Department of Civil Engineering at the Indian Institute of Technology (Banaras Hindu University) Varanasi, India. He obtained Doctoral degree in Civil Engineering (Major: Transportation Engineering) from Indian Institute of Technology Roorkee and Master of Technology degree in Earthquake Engineering (Major: Structural Dynamics) from Indian Institute of Technology Roorkee. He holds a Bachelor of Engineering degree in Civil Engineering from Government Engineering College Kota under Rajasthan University, India. His experience is in pavement maintenance and performance modeling, mechanistic analysis and design of pavements, traffic flow modeling and safety.

Invited Speech:
GNSS in Industrial Automation - Vulnerabilities and Search for Alternatives

Dr. Chaminda Basnayake

Principal Engineer, Market Development,

Locata Corporation

Principal Engineer at Locata Corporation Dr. Chaminda Basnayake received his Ph.D. in geomatics engineering from the University of Calgary, Canada, and his B. Sc. (Honours) in civil engineering from the University of Moratuwa, Sri Lanka. Dr. Basnayake is acknowledged for spearheading the global market development of the ground-breaking Locata technology. Dr. Basnayake is an experienced researcher with over 20 foreign patents and 16 US patents. His talents go beyond Locata; he worked for General Motors as a GPS subject matter specialist. Among his many accomplishments are six GM OnStar Advanced Engineering Technology Excellence Awards and the esteemed "Bob Kettering Award". His illustrious career spans roles at Renesas Electronics America, General Motors OnStar, and the University of Calgary.

Development of an Economical Level of Service Estimation Model using GPS Data in a Mixed Traffic Condition

Sankha Jayawardhana[1] and Loshaka Perera[2]

Abstract

This research presents the development of an economical Level-of-Service (LOS) estimation model using GPS data in a mixed traffic condition, with a specific focus on defining clusters based on the categories within the existing Highway Capacity Manual (HCM) definitions of motorized LOS for practical application. The study aims to enhance the representation of Sri Lankan traffic conditions, predominantly observed on 2-lane roads, particularly within the LOS D and E categories where the majority of typical Sri Lankan traffic situations occur. The data collection scope encompasses the entirety of Sri Lanka to ensure the generation of more representative values for the defined clusters. As clusterization parameters, Average Travel Speed, which is a reflection of mobility, Percentage Time Spent Following another vehicle and the Percentage Free Flow Speed, which is a ratio of current speed to the posted speed limit, were used in the same manner as HCM 2016 - 15-2. The deviations observed in the study from the classical Level of Service (LOS) approach, which traditionally relies on the volume/capacity ratio, are intentional and rooted in the need to better capture the nuances of Sri Lankan traffic conditions. Unlike the conventional focus on volume-related metrics, this methodology incorporates the aforementioned parameters and factors in road class-specific considerations. It showcases the utilization of two CNN-based image processing models developed, one for assessing the ‘following’ and ‘non-following’ states and the other to assess the types of road (road classes) using the Google Colaboratory platform for the analysis of geo-tagged video collected through the Transcend DrivePro 250 and their combination with 1 Hz GPS data collected by the Qtravel GPS device, which includes parameters such as speed, heading local date and time. The study's economic efficiency stems from the use of GPS data, replacing traditional video camera setups. This shift reduces costs and logistical complexities. Additionally, open-source software, specifically on Google Colaboratory, streamlines data analysis, emphasizing affordability. Additionally, the application of unsupervised KMeans clustering, which finds k centroids and then assigns each data point to the closest cluster while minimizing the size of the centroids to define clusters corresponding to the HCM definitions. This is particularly advantageous since it is possible to define the number of clusters required before hand and offers higher computational efficiency. The proposed methodology and model aim to provide an improved representation of LOS in Sri Lanka's traffic conditions, considering the unique characteristics of the road network and the predominant traffic scenarios observed in the country. The research findings produce a table containing parameters similar to HCM 15-2 (Motorized LOS parameters for 2-lane roads), meaning that the table has 5 clusters each for the three road classes under parameters relevant to each class as per the HCM guideline, but in a practical sense instead of a planning tool. Some notable deviations in the table produced include Percentage Free Flow Speed exceeding 100% due to speed limit choice (50 km/h) for class 03 roads and FCD noncompliance. Additionally, Cluster 5 needs to be checked against road capacity levels. Adjusting limits in the clustering model can eliminate any potential issues. However, the primary objective has been achieved for representative LOS clusterization from

GPS and geo-tagged video data. Possible future improvements to the model include the utilization of a bigger data pool of about 3 million data points and higher amounts of distinct training data for the image processing models to increase their accuracy.

Keywords: *Level of Service (LOS), Convolutional Neural Network (CNN), KMeans Clustering, GPS Data, Highway Capacity Manual (HCM)*

Authors Details;

1. Postgraduate Student, Department of Civil Engineering, University of Moratuwa, Sri Lanka. 180287h@uom.lk
2. Traffic Engineer, City of Rockingham, Australia. perera.loshaka@gmail.com

A New Approach for the Network Development of an Alternative Rail Transit System

Buddhika Patikirimudiyanselage[1] and Saman Bandara[2]

Abstract

Developing a methodology to build a network plan for an alternative rail system with fewer implications for future demand changes is a challenging yet critical task in transportation planning. This research proposes a comprehensive methodology for developing such a network plan, with a focus on the Western Province of Sri Lanka as a case study. While rail systems are known for efficiently transporting high volumes of passengers, heavy rail is not always appropriate for short-distance travel, to which alternatives such as LRT and monorail are better adapted. The key research questions considered in this study are: Identify the parameters that need to be considered in developing a rail track network, determine the nodes that should be directly connected to minimize the cost without compromising other parameters, establish the optimum chronology for linking nodes, define the most efficient number of links that should be connected and develop a strategy for staged construction. Linking an extensive demand model to transportation planning is a strategic approach that needs to consider many different variables and requires a large quantity of detailed data. The unavailability of this information, the sensitivity of such variables to socio-economic variations, and time consumption are matters of concern. Demand changes that occurred due to the COVID pandemic, economic downturns, and fuel price fluctuations are some examples of this. As such, developing a methodology to build a network plan for an alternative rail transit system with reduced sensitivity to demand variations is a prudent approach. Network indices have mainly been applied to measure the performance of developed rail networks. Thus, it has been attempted to use network indices as a decision-making criterion during the planning stage in terms of connecting nodes. The proposed network development plan consists of four stages: transport zoning, quantification of stations, positioning of stations, and the final stage, linking nodes (stations). Therefore, it is assumed that the transport zoning, quantification, and positioning of station stages have already been completed before they reach the station linking stage, which is the core issue being focused on in this research. To accommodate the demand aspect, the gravity model is utilized to identify the “Demand-based connected network” (GDBCN). The highest-demand pair is connected first and then the next until all nodes are connected while avoiding the potential crossing of edges and the formation of loops. The minimum spanning tree (MST) is employed to establish the minimum cost network. First, the minimum spanning tree based on the link cost is determined using Kruskal's algorithm. This represents the minimum cost network (GMCN). Superimposing the identified Demand-based connected network (GDBCN) into the GMCN of the given sets of nodes is the next milestone of this network development methodology. The output network of this is denoted as the GSEN. The duplicated edges of the GSEN are guides in identifying the nodes that must be connected to satisfy both higher demand and lower cost. This will be the initial phase of the network (GBN) development for a given set of nodes. To minimize the total network travel length, the immediate next link of the basic network (GBN) is connected using minimum journey lengths calculated from one node to each of the other nodes using Dijkstra's algorithm. This calculation is repeated iteratively until the link that results in the highest journey length reduction

is determined while avoiding the formation of crossings or loops. The outcome of this step is utilized to make the immediate next link (GBN+1). The remaining network links (GBN+1 onwards) are sequentially connected using the same iterative approach that centers on minimizing journey length, with the exception that loop formation is allowed, and it determines the optimal point to conclude network expansion based on the marginal benefit of adding new links before reaching maximum connectivity. It is evident that network indices, such as the meshedness coefficient, graph density, and average cluster coefficient, show improvement as the network evolves from GMST. There is a notable reduction in journey length and a significant decrease in the marginal reduction of journey length per marginal network length, especially from GMST to GSEN+1. Subsequently, this trend continues with a gradual decline in gradient. In conclusion, the development of a methodology for creating a rail transit system with reduced sensitivity to demand variations presents a strong avenue for improving the stability and efficiency of transportation networks. Also, the proposed methodology facilitates developing a new alternative rail network in an optimized phased-out plan and extending an existing network or integrating it with an existing transit system. It is argued that when the developed network layout is robust and less sensitive to input parameters, it is possible to take care of operation efficiency and passenger convenience with an appropriate route plan. This way, any future demand variations could also be accommodated without changing the network layout.

Keywords: *Network Development Methodology, Phased Network Development, Transportation Network Efficiency, Rail Transit Network*

Authors Details;

1. Postgraduate Student, Department of Civil Engineering, Faculty of Engineering, University of Moratuwa, Sri Lanka. qsbuddhika1976@gmail.com
2. Senior Professor, Department of Civil Engineering, Faculty of Engineering, University of Moratuwa, Sri Lanka. bandara@uom.lk

An Exploration of Publicly Supported Vision on Non-Motorized Transport- A Case Study of Jaffna City, Sri Lanka

Yogalingam Arthy[1]

Abstract

Non-motorized transport is important for sustainable living. The features of sustainable transport are comfortable, safe, and effective in relation to economic and energy use and minimize environmental pollution. With transforming urbanization trend along with socio-economic development, a transport need in the urban area of Jaffna is growing promptly. A sustainable transport system should meet people's accessibility and mobility requirements by providing safe and environmentally friendly forms of transportation. Non-motorized transportation meets these aims of sustainability as it utilizes indigenously offered human and animal energy, which is safe, affordable, non-polluting and user-friendly and needs only a slight fraction of the wealth essential for motorized transport. Looking into the current day walking and cycling status, the transportation systems in Jaffna have shown a deprived image because of traffic congestion, accidents, lack of access to public transport and carbon emissions to the atmosphere of space, contributing to environmental pollution and imbalance in terms of quality of life in general mobility. This research was carried out in the city of Jaffna's municipality area. Focusing on research methodology, research was done based on adopting mixed methodology with the combination of qualitative and quantitative methodology. Data such as the growth of the population of Jaffna city, the road lengths, and the land usage distributions were collected and analyzed. In addition to that, focus group discussions and questionnaires were used to obtain public perception of the usage of non-motorized transportation. This research aims to propose sustainable transport in terms of non-motor vehicles for Jaffna city, which implies a better city for future generations. It presents choices to transform the choice of transport modes to street users of motor vehicles to non-motor vehicles through the integration of nonmotorized transport with prevailing public transport. The results revealed that the use of sustainable non-motorized transport in Jaffna may uplift environmental responsiveness. However, it is not easy to implement due to the congestion of central business districts and the recent economic crises. Jaffna people stated that Jaffna city needs to focus on designing networks in local areas and emphasize connecting with prevailing road networks to improve non-motorized quality. Enhancing pedestrian trails and cycling areas would help to increase non-motorized travel and reduce motor vehicle travel. The use of non-motorized transportation such as walking and cycling is not only to reduce carbon footprint and minimize environmental impacts but also to encourage healthy life.

Keywords: *Cycling, Non-Motorized Transport, Sustainable Transport, Urbanization, Walking*

Authors Details;

1. Town Planner, Urban Development Authority. arthy156@gmail.com

Review Of Walkability Enhancing Neighbourhood Environment Attributes In Urban Tropics

Udya Abeysinghe[1], Shamain Saparamadu[2], and Chamali Hewawasam[3]

Abstract

The usage of private vehicles has grown rapidly, especially in urban areas of developing countries, which has led to many environmental and socio-economic issues such as congestion, high fuel consumption, and air pollution. Traffic congestion and delays continue to be a problem in mega, large, and even small cities due to the excessive volume of private cars. An important strategy to reduce the use of private cars is by offering high-quality public transport services and by encouraging pedestrian mobility. Improving walkability could discourage the use of motorized vehicles, and that will reduce greenhouse gas emissions, improve air quality, decrease congestion, and be beneficial for human health. Walkability is defined as the quality of a neighbourhood that supports and encourages people to access their destinations on foot. A better understanding of what factors create a more walkable environment would enable planners and engineers to develop more comprehensive and practical urban transportation plans that ultimately lead to a user-friendly city for walking, which is lagging in developing countries. The objectives of the study are to explore the most significant walkability-enhancing Neighborhood Environment Attributes (NEAs) in urban areas of Sri Lanka. To identify the Strengths, Weaknesses, Opportunities, and Threats (SWOT) in existing transportation policies in the country for effective integration of walkability-enhancing NEAs. Proposing how to integrate them into transport planning. As the literature review, SCIENCEDIRECT and GOOGLE SCHOLAR databases were chosen to study the peer-reviewed documents published between 1993 and 2021 May in the tropical context. The first step in the selection involved literature on walking/ walkability research. Then, articles that related to NEAs on walking preference/ influence were selected. A brief review of the abstracts and introductions served to exclude non-related articles. Thirdly, screened articles were thoroughly studied, and a set of NEAs were identified using 56 published research papers. As the fourth step, a field survey was conducted at Nugegoda, Wijerama (n=372), and a set of significant attributes and elements were identified. Pedestrians were randomly stopped and were asked to scale NEAs identified from the literature review from 1 to 5 (1=strongly disagree to 5=strongly agree), with higher scores indicating a more favourable value. Photographing was avoided during the field observation and surveying since it might hinder the privacy of the participants, and photographs were taken on separate occasions. The 3 main attributes and 24 elements under them were identified as the most significant NEAs in the urban Sri Lankan context. The road is safe from crime (53.5%), the road is full of people (48.4%), and the availability of residences along the street (39.5%), were identified as the most significant factors as most participants strongly agreed (5) which encourage the walkability, while block size, block length, and number of dead ends, were identified as insignificant. A comprehensive review of existing urban and transport policies, acts, and plans was reviewed, and a SWOT analysis was conducted. Based on the findings, an innovative framework was proposed to integrate walkability-enhancing NEAs into urban planning in Sri Lanka effectively. The review could be helpful for researchers and urban planners in developing walkability studies and in defining policies to improve walkability. Further, this

will provide additional insights into how built NEAs influence walkability and identify gaps and issues that should be analyzed in-depth in the future. Nevertheless, results can be utilized to develop a walkability index for the country as well.

Keywords: *Walkability-Framework, Sustainable Mobility, Urban Transportation, Urban Planning*

Authors Details;

1. Research Scholar, Department of Town and Country Planning, University of Moratuwa, Sri Lanka. abeysingheum.21@uom.lk
2. Senior Lecturer, Institute of Technology University of Moratuwa, Sri Lanka. saparamadud@itum.mrt.ac.lk
3. Senior Lecturer, Department of Town and Country Planning, University of Moratuwa, Sri Lanka. chamalih@uom.lk

Developing Trip Generation Model for Mixed-Use Building in Dhaka

Fariha Chowdhury[1], Annesha Enam[2], Tanmoy Nath Ananda[3]

Abstract

Travel demand forecasting is the prerequisite to transportation system design and policy planning. Trip generation comes first in the four-step travel demand forecasting process. Generally, Trip generation for land use is estimated using the Institute for Transportation Engineers (ITE) trip generation manual, developed in the USA context. Trip rates from the ITE manual are not fully applicable in Bangladesh as there are noticeable differences in socio-economic characteristics and road infrastructures. Moreover, the ITE manual provides trip rates for single-use buildings, underestimating trips by non-motorized vehicles (NMV) and pedestrians. Recently, mixed-use buildings (a combination of residential, commercial, or institutional functions into one building) have become prominent in Dhaka – the capital city of Bangladesh. In recent years, a few studies have started addressing the ITE manual's weakness in Dhaka. Ahmed et al. estimated peak hour trip rates for six land use categories: residential, commercial, educational, healthcare, office, and garment manufacturing. Rahman et al. and Uddin et al. studied the trip generation rate for commercial land use. Mamun et al. estimated trip attraction rates of shopping centers having shops, offices, and restaurants—however, Mamun et al. developed a trip generation model only for shopping malls. Javed et al. established a model for estimating trip rates considering the shopping center as a single-use building. It can be noted that none of the above studies considered mixed-use buildings per se. To determine the impact of mixed-use buildings on transportation demand and roadway capacity, this study aims to develop trip generation rates for mixed-used buildings, i.e., the buildings that host different facilities such as shops, restaurants, hospitals, banks, and educational institutions concurrently. Surveys are conducted to collect primary data for this study. The data collected during the survey can be grouped into two primary categories. The first questionnaire survey of the business owners is conducted to collect data about the functional characteristics of the selected mixed-use sites. The information collected during this survey includes Gross Floor Area (GFA), parking space, number of employees, number of seats (for restaurants), number of beds (for hospitals), freight vehicle ownership, and peak hours of the business. Second, the vehicle and pedestrian counts at all entry and exit points of the selected sites, and vehicle occupancy information is gathered through observational and intercept surveys. The vehicle count data is collected during the peak hours of the business. After data collection, a model is developed to analyze and predict trip generation rates for the selected sites. Different analytical approaches, such as linear regression and weighted average, are compared for data analysis. The estimated trip rates are checked against the values provided in the ITE manual and Ahmed et al. The developed model might need to be calibrated to increase the predictive accuracy and decrease the anomaly with the observed data. The developed model can be used as an effective tool to establish trip generation rates for mixed-use buildings in the context of densely populated developing countries like Dhaka. The estimated trip generation rates will help transportation planners forecast the future trip generation of the proposed mixed-use buildings. This is crucial for the transportation impact assessment of major development projects.

Keywords: *Trip generation, mixed land use, demand forecasting, Dhaka, Bangladesh*

Authors Details;

1. Undergraduate student, Bangladesh University of Engineering and Technology. farihachowdhury408@gmail.com
2. Assistant Professor, Bangladesh University of Engineering and Technology. annesha@ce.buet.ac.bd
3. Undergraduate student, Bangladesh University of Engineering and Technology. tanmoynathananda@gmail.com

Identification of Influence of Vehicle Age and Accumulated Mileage on Tailpipe Emission–A Review

MSD Nimali[1], Thusitha Sugathapala[2], Manoj Ranaweera[3]

Abstract

Concerns regarding the sustainability of the environment and the quality of air are becoming more prevalent as a result of the heavy reliance on fossil fuels to meet the ever-rising global energy demand. The transport sector contributes significantly to this demand growth and to the consequential global emission inventories with the rapid acceleration of global urbanization and corresponding growth in vehicle population. Pollutants produced by vehicle exhaust cause numerous environmental and health issues. Vehicle parameters, fuel parameters, vehicle operating conditions, and environmental factors are known to influence vehicle emission levels. It is expected that the engine gradually wears out and emits higher emissions as the vehicle ages and its mileage grows. In addition, due to the degradation of the engine controls, the catalyst, and possibly the particle filter, vehicle exhaust emissions tend to rise with vehicle age. The technology change also significantly affects the exhaust emission level because modern engines are different from those made in the past and must adhere to stricter emission regulations. Despite this complex influence that vehicle age and millage have on emissions, only very little research has been done to investigate the matter. The aim of this review is to identify the state-of-the-art of research studies conducted to investigate the influence of vehicle age and accumulated mileage on tailpipe emissions of different vehicle categories. Therefore, this paper presents a critical review and a synthesis of empirical studies from both developed and developing countries such as Oregon, Switzerland, Indonesia, India and China, investigating the impact of vehicle age and accumulated mileage on exhaust emissions across different vehicle categories and research purposes. Most of the studies use inspection and maintenance data for their regions for this analysis. While some studies have directly assessed the impact of these two parameters on tailpipe emissions, others have examined the relationship between them to develop vehicle failure probability models, considering emission violations. Additionally, certain studies have aimed to develop emission factors. The results of the studies commonly show a direct influence of vehicle age and accumulated mileage on tailpipe emission constituents, mainly CO, HC, and NOx for all the selected vehicle categories. These emissions tend to increase as both vehicle age and accumulated mileage increase, however, following different trends. Some studies have observed linear relationships of change in emission constituents with these parameters, while others demonstrate logarithmic or polynomial regression trends. Similar patterns have been observed in the studies for both CO and HC emission changes with vehicle age and accumulated mileage. However, one study, which evaluated the test results for bus accumulated mileage only for a 2-year span, doesn't show any clear upward or downward trend of emissions change with vehicle mileage, but only a decrease in fuel economy. Additionally, another study reveals higher emissions during idle test conditions compared to fast idle, following similar trend lines for both CO and HC change with respect to both vehicle age and accumulated mileage of different models of petrol Maruti passenger cars. In addition, one of the studies highlights that vehicles having engine sizes smaller than 2000 cc, older than ten years and odometer reading over 100,000 miles would significantly increase the

probability of identifying high polluting vehicles. Further, it shows that the increase in exhaust emissions is greater in non-passenger vehicles than in passenger cars. Compared to technological changes in vehicles, one study shows that Euro 2, 3, and 4 vehicles demonstrate emission improvements and show a linear increase in emissions with vehicle age. Nevertheless, Euro 1 vehicles still show the lowest level of stable emissions with respect to the vehicle age. In contrast, another study reveals emission improvements in Euro 1, 2, 3, and 4 vehicles in sequence, following linear emissions change with respect to the vehicle age. These findings demonstrate how newer vehicle technology has improved emissions compared to older ones. In conclusion, this review confirms that vehicle age and accumulated mileage have a direct influence on exhaust emissions, and the emissions increase as both vehicle age and accumulated mileage grow. However, due to the variation in factors such as vehicle category, emission test data, tested region, and conditions across different studies, it will not be possible to establish a common trend for emission changes or directly apply the findings to make required policy decisions to control emissions for other regions. Nevertheless, these results encourage us to carry out high-quality research in these domains to gain a better understanding of the local priorities and, consequently, design the necessary emission reduction strategies appropriate for the country. Thus, these factors must be considered for future studies.

Keywords: *Accumulated mileage, Air quality, CO, Vehicle age, HC, Health issues, NOx, Tailpipe emissions*

Authors Details.

1. Postgraduate Student, Department of Mechanical Engineering, Faculty of Engineering, University of Moratuwa, Sri Lanka. nimalimsd.22@uom.lk
2. Senior Lecturer, Department of Mechanical Engineering, Faculty of Engineering, University of Moratuwa, Sri Lanka. thusitha@uom.lk
3. Senior Lecturer, Department of Mechanical Engineering, Faculty of Engineering, University of Moratuwa, Sri Lanka. manoj@uom.lk

A Simulation-Based Framework for Connected Vehicle Cybersecurity Impact Assessment

Don Nalin Dharshana Jayaratne[1], Suraj Harsha Kamtam[2], Qian Lu[3], Rakib Abdur[4], Muhamad Azfar Ramli[5], Rakhi Manohar Mepparambath[6], Siraj Ahmed Shaikh[7], Hoang Nga Nguyen[8]

Abstract

As connected vehicle technologies become increasingly prevalent, offering groundbreaking capabilities for vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications, the promise for improved traffic safety, efficiency, and sustainability has never been higher. However, this new frontier of transportation also brings unprecedented cybersecurity challenges that can compromise not just individual vehicles but entire traffic ecosystems. Vulnerabilities in these systems have the potential to cascade through transport networks, causing disruptions that extend beyond the initially affected vehicles to impact public safety, traffic flow, and operational efficiency. Incidents like the 2015 Jeep Cherokee hack by Miller and Valasek and the 2022 cyberattack on Russia's Yandex Taxi service demonstrate the severity of these challenges. In both cases, individual vulnerabilities escalated to disrupt broader systems—whether that meant remote control over a single vehicle's functions or sending hundreds of taxis to a single location, paralyzing a city's transportation grid. The ISO/SAE 21434 standard for Road Vehicles — Cybersecurity Engineering has emerged as a critical guideline in response to the growing threats posed by cyber vulnerabilities in the automotive sector. ISO/SAE 21434 focuses primarily on the in-vehicle system and delineates the structure of cybersecurity processes, providing detailed guidance on risk mitigation. However, this current framework has limitations. For instance, its risk assessment clause mainly addresses components within or on the vehicle's perimeter and is not designed to consider the systemic impact on broader transport networks. Additionally, the risk quantification based on the standard predominantly relies on assessor expertise, posing challenges for evaluating risks at the complex, interconnected transport systems level. To address these gaps, our study introduces a novel simulation-based framework to assess cybersecurity threats' operational impact on intelligent transport systems. While the existing ISO/SAE 21434 standard serves as a vital starting point, it falls short of capturing the cascading effects of cyber threats across an entire transportation network. Our framework aims to overcome this limitation by simulating realistic attack scenarios and their ripple effects throughout a transport system, capturing the immediate and cumulative operational impacts. The framework would offer insights to transport planners and automotive cybersecurity analysts, allowing for the development of more effective mitigation strategies. Our proposed simulation-based framework is designed to incorporate real-world cyber-attack scenarios from incident reports and academic literature for impact assessment. Currently, our development efforts are concentrated on the traffic layer simulation; however, it is planned to extend the framework to incorporate the network layers to create a robust representation of a connected vehicle ecosystem. The simulation has attacker models that interact with the simulated environment to trigger specific attack scenarios, which in turn gives rise to damage scenarios. We derive incident impact metrics based on the fundamental traffic flow parameters: speed, flow and density, focusing on operational disruptions within the transportation network. These metrics provide an impact assessment that captures the consequences of a cyberattack, offering critical insights into

the potential cascading effects on a transport system's operational integrity. In summary, our simulation-based framework provides an innovative approach to assess the operational impact of cybersecurity threats on intelligent transport networks. By integrating real-world attack scenarios, multi-layer simulations, and a tailored attacker model, the framework offers a deeper view of the potential consequences of cyber threats. This enables a more in-depth understanding of vulnerabilities and informs the development of more effective, context-sensitive mitigation strategies. Given the increasing prevalence and complexity of connected vehicle technologies, our framework will be valuable for researchers and industry stakeholders in evaluating the potential consequences of cyber-attacks on intelligent transport systems.

Keywords: *Intelligent Transportation Systems, Automotive cybersecurity, traffic simulation, transport network impact*

Authors Details.

1. Research Intern, A*STAR Research Institute, Singapore. nalin.jayaratne@gmail.com
2. Student, Centre for Future Transport and Cities, Coventry University, United Kingdom, kamtams@uni.coventry.ac.uk
3. Assistant Professor in Connected and Autonomous Vehicles, Centre for Future Transport and Cities, Coventry University, United Kingdom, ad5271@coventry.ac.uk
4. Associate Professor (Systems Security), Centre for Future Transport and Cities, Coventry University, United Kingdom, ad9812@coventry.ac.uk
5. Deputy Dept Director & Principal Scientist, Institute of High Performance Computing, A*STAR, Singapore, ramlimab@ihpc.a-star.edu.sg
6. Senior Scientist, Institute of High Performance Computing, A*STAR, Singapore, rakhimm@ihpc.a-star.edu.sg
7. Professor in Systems Security, Computer Science, Systems Security Group, Department of Computer Science, Swansea University, United Kingdom, s.a.shaikh@swansea.ac.uk
8. Associate Professor in Cyber Security, Computer Science, Systems Security Group, Department of Computer Science, Swansea University, United Kingdom, h.n.nguyen@swansea.ac.uk

Develop a Demand-Based Intelligent Parking Management System (IPMS) to Implement in Urban Areas

Methmal Dissanayake[1], Saman Bandara[2]

Abstract

Parking congestion is a major issue in urban areas globally, particularly in areas with high-demand. However, less crowded parking spaces can be discovered in low-demand areas, and sometimes, parking demand varies significantly over time depending on roadside land use. Traditional parking management systems often rely on sensors and cameras, which can be costly and require complex infrastructure. In recent years, the emergence of crowdsourced data has opened up new possibilities for parking management. This research aims to develop an efficient Intelligent Parking Management System (IPMS) based on local demand that utilizes an integrated approach for urban roadside parking strategy using Galle Road Corridor in Sri Lanka as a case study area due to the well-organized existing parking slots in this particular road section. The strategy combines non-sensor-based crowdsourcing methods, mobile applications, and data analytics to optimize parking availability and enhance the overall parking management system. Through the literature review, an exploration was undertaken to identify cost-effective parking management solutions that do not rely on sensor/camera-based methods. The methodology includes several key components. As an initial consideration, a mobile application system should be designed to enable users to access real-time parking information and check parking availability using their smartphones. Thereby, users can receive information on parking availability in the surrounding area before entering their desired parking location. The strategy included a coding system for easily identifying the parking slots and ensuring accurate and reliable data. Each roadside parking space is assigned a unique code, which is prominently displayed. If a user enters the parking space, the mobile application will mark the parking slot as unavailable. When the user exits the parking slot, they have to pay their parking fee, and the parking space is then re-marked as available. Similarly, through a mobile application, any user can check the availability of a desired roadside parking location. If the desired parking slot is full, this strategy also provides information about adjoining roadside parking locations. To achieve the objectives, it is necessary to identify on-street parking demand in a particular location. The strategy also utilized data from a variety of sources, including historical parking data from traffic data of Municipal Councils, to analyze past parking demand patterns. A road section in the Galle Road corridor was divided into a number of zones, and parking usage was analyzed by identifying demand, rush hours, and day variations of parking through a survey. To retrieve real-time vehicle average speed data, Google Maps API services are used, which are then combined with data gathered from a physical survey to verify demand in a particular road segment. These data assist in anticipating parking demand and optimizing parking allocation in advance. The utilization of parking spaces during the day, along with the types of vehicles parked, was monitored in the road sections. Parking pricing mechanisms can be used to optimize parking distribution further. Parking fees can be adjusted based on demand and availability by implementing dynamic pricing strategies. At specific times, a fixed parking rate is in effect, with the option to offer discounted rates during peak hours to encourage drivers to choose lower-demand parking areas. This pricing mechanism, which can also be conveniently displayed for the users through a mobile app, allows vehicles to be distributed more evenly across the parking

infrastructure. This would not only reduce congestion in high-demand areas but also encourage the utilization of idle parking spaces. In conclusion, the evaluation results measure the strategy's effectiveness and offer valuable insights and recommendations for policymakers, urban planners, and parking operators aiming to develop efficient and sustainable parking management systems in urban roadside parking.

Keywords: *Intelligent Parking System, Demand-Based Parking, Parking Management*

Authors Details.

1. Postgraduate Student, Department of Civil Engineering, Faculty of Engineering, University of Moratuwa. dissanayakedmsmb.23@uom.lk
2. Senior Professor, Department of Civil Engineering, Faculty of Engineering, University of Moratuwa. bandara@uom.lk

Investigating the Impact of Motorcycles on Urban Traffic

Ruwantha Wimalasiri[1], Nalin Jayarathne[2], Loshaka Perera[3]

Abstract

In many countries in the South Asian region, the traffic is significantly different, including aspects such as the variety of vehicles, driving behaviours and traffic volumes from that of many other countries. The Motorcycle (MC) is one of the widely used and accessible forms of transportation in those countries and has shown rapid growth over the years. As a south Asian country, the MC composition in Sri Lankan urban traffic flow has surged to 30%, driven by a notable 30% increase in registered MCs at an annual growth rate of 8% over the past few years, according to data from the Department of Motor Traffic. MCs, with their high manoeuvrability, have significant impacts on traffic, safety, and the environment. According to the World Health Organization (WHO), almost 30% of road accident fatalities involve powered two and three-wheeled vehicles, such as MCs, scooters, and electric bikes, and these numbers are going up in the world. Additionally, in the Southeast Asian Region, this percentage is at around 43%. In Sri Lanka, MC-related fatalities have consistently accounted for over 40% of total annual fatal accidents, contributing to approximately 34% of all road accidents in recent years. Sri Lankan roads often witness erratic driving behaviour and a lack of lane discipline among MC riders. These riders frequently engage in zigzag manoeuvres, slow progression to the front at intersections, and disrupt traffic flow, affecting the start of other vehicles. Additionally, as per some studies, the prevalence of a high number of MCs on urban roads significantly contributes to emissions in these areas. Therefore, it is crucial to closely monitor and regulate MC behaviour on Sri Lankan roads. From these various types of impacts, this research's main focus is to assess and quantify the traffic impacts of MCs on urban traffic flow in Sri Lanka. In this research, Camera devices are used to collect data at mid-block road sections and signalized intersections. The sites were selected considering several crucial parameters such as MC composition, Average daily traffic and less disturbance from other unrelated factors. A total of seven urban mid-block road sections and five signalized junctions were carefully selected for videography, conducted during good weather conditions, specifically during peak traffic hours. Both manual and software-based methods were employed for accurate data extraction. One primary objective of this research is to investigate the dynamics of MCs under different traffic and roadway conditions, analysing aspects such as trajectory, lane position, speed, headway, and overtaking manoeuvres. Additionally, the research aims to assess the traffic impact of MCs on urban traffic by considering variations in Passenger Car Units (PCUs) under different traffic and road conditions. The PCU values were determined using the spatial headway methodology. Using this approach, the PCU of MCs were assessed through three distinct methods, determined by the positioning of the MCs in relation to passenger cars. Generally, the Road Development Authority (RDA) Design Guideline recommends a PCU of 0.4 for MCs, while the Highway Capacity Manual (HCM 2000) does not provide a specific value. This study reveals that PCU values for MCs range from 0.35 to 0.60 in low MC compositions (0%-25%) and between 0.40 to 0.75 in high MC compositions (25%-50%) under varying traffic flow conditions. Furthermore, the study focused on assessing the traffic impact of MCs at signalized intersections, particularly considering saturation headway and start-up lost time. The research revealed that the average

saturation headway at these intersections is approximately 2.5 seconds. Moreover, the results show that the presence of MCs in the queue significantly affects the attainment of saturation headway with an associated delay of approximately 5.7 seconds. Additionally, by considering the Pearson correlation coefficient, a strong positive correlation was observed between Start-Up lost time and the number of MCs in the queue. Furthermore, each MC was found to contribute 0.5103 seconds to Start-Up Lost Time, resulting in 3.9 seconds of lost time in the absence of MC storage, as per the analysis. This study helps to understand the driving behaviours of MCs and quantify their impacts on the traffic flow at the mid-block road sections and signalized intersections. Moreover, the outcomes of this research would facilitate accurate PCU factors for MCs that are related to different traffic conditions and MC compositions. This will help designers to improve their designs using the most suitable PCU factors for MCs, considering the specific road and traffic characteristics. Ultimately, this study would facilitate future studies on quantifying the traffic impacts of MCs on roads with similar characteristics.

Keywords: *Motorcycle, Driving Patterns, Lane Position, Overtaking manoeuvre, Headway, PCU, Road Safety, Saturation headway, Start-up lost time*

Authors Details;

1. Postgraduate Student, Department of Civil Engineering, University of Moratuwa. ruwanthageeshan@gmail.com
2. Research Intern, A*STAR Research Institute, Singapore. nalin.jayaratne@gmail.com
3. Traffic Engineer, City of Rockingham, Australia. perera.loshaka@gmail.com

Evaluating the Accuracy of Micro Simulation Models for Unsignalised Intersections in Sri Lanka

Malaka Prasad[1] and Kelum Sandamal[2]

Abstract

Traffic congestion is a major problem in most of the cities around the world; hence, there is a need to find effective solutions to minimize prevailing excessive traffic. The nature of traffic is diverse in developing countries; thus, to find solutions for traffic-related issues, micro-simulation tools have gained popularity in the recent past due to their adaptability to the local context. However, there are still various unknown factors when modelling heterogeneous traffic, especially in developing countries. In the Sri Lankan context, the VISSIM microsimulation tool is used widely to model traffic conditions. However, there is limited research conducted to simulate traffic behaviour in unsignalised intersections in Sri Lanka at the moment. Therefore, this study was conducted to fulfill the research gap by identifying relevant calibration parameters and quantifying them. For the simulation, five unsignalised three-leg intersections, which are located in the Colombo district, were selected. The evening peak hour was identified based on the past traffic data, and then a video survey and manually classified count were conducted to calculate the directional flow values. Moreover, intersection geometry data such as the number of lanes, lane width, shoulder width, and center median geometry were measured. Further, queue length and travel time were measured using manual measurements and validated using video survey data. Afterwards, the collected data was used to generate micro-simulated models for five selected intersections. Eleven calibration parameters were identified for the calibration based on state-of-the-art studies in Sri Lanka and other developing countries where heterogeneous traffic conditions exist. The calibration parameters were included as average standstill distance, additive part of safety distance, multiplicative safety component distance, looking ahead distance, looking back distance, waiting time before diffusion, minimum headway, safety distance reduction factor, distance standing at 0 kmph, distance driving at 50 kmph, maximum deceleration for cooperative braking. In the analysis, a total of 90 sets of parameters were used for the simulation with 18 sets of parameters used for one intersection. The performance evaluation has been conducted for queue length and travel time analysis separately. The optimum calibration factors were identified by using an optimization process corresponding to a minimum mean absolute error in both queue length and travel time analysis. Furthermore, The Pearson correlation value was used to identify the most sensitive parameter, and it was found that five key parameters were based on the sensitivity values. The sensitivity parameters were identified where the Pearson correlation value was greater than 0.2. The sensitivity parameters identified based on the queue analysis include multiplicative safety component distance, looking ahead distance, and safety distance reduction factor with Pearson correlation coefficient values of 0.36, 0.31 and 0.27, respectively. To identify the best input values, these five parameters were further simulated by considering the queue length and travel time separately. This resulted in the lowest percentage error for the difference between the observed and simulated queue lengths and travel time. The best calibration values for calibration purposes are also developed using the GEH statistic for turning movements. The methodology is composed of calibration and validation procedures. Regarding the five unsignalised three-leg intersections in the Colombo district, the

best set of parameter values for the previously mentioned parameters were identified under the queue length and travel time separately. The identified parameters and respective values were future validated using two unsignalised three-leg intersections in the Colombo district. The mean absolute percentage value will decide the identified parameters and respective values' suitability. Future traffic and transportation microsimulation studies can adopt the parameter values that were successfully calibrated using two unsignalised three-leg intersections in Sri Lanka.

Key Words: *Microsimulation, Unsignalized intersections, Traffic congestion, Optimization*

Authors Details;

1. Undergraduate, Sri Lanka Institute of Information Technology. malakaprasad000@gmail.com
2. Lecturer, Sri Lanka Institute of Information Technology. kelumsanadamal@gmail.com

Utilization of Natural Fibers and Geosynthetics in Improving the Pavement Subgrade Strength – A Review

Upeksha Divyangani[1], Chamod Hettiarachchi[2]

Abstract

The improvement of subgrade strength by reinforcing the soil dates back centuries. The weak subgrade is a common problem that engineers often encounter, and they resort to constructing pavements in areas with problematic soils that are difficult to work with. To overcome such issues, subgrade modification technologies are adopted. Soft soils such as silts and clays are the most problematic soils due to their characteristics of high swelling shrinkage and low bearing capacity. Although the modification of subgrade is traditionally done through the 'excavation and replacement' technique, it is inarguably costly and time-consuming. Therefore, alternatives should be considered in modifying such subgrade. Such alternatives for modifying the subgrade are natural fiber reinforcement, synthetic reinforcement and chemical stabilization of the soil. Geosynthetics that are most commonly used as subgrade reinforcement in increasing strength characteristics are; polypropylene fibers (PP), Polyester fibers (PET), Polyethylene fibers (PE), Glass fibers, Nylon fibers, Steel fibers and Polyvinyl alcohol fibers (PVA). Coir fibers, sisal fibers, palm fibers, jute fibers, flax fibers, bamboo fibers and cane fibers are the most commonly used natural fibers due to their eco-friendliness, renewability and low costs. The durability of natural fibers in subgrade improvement is known to be around 20 to 30 years in time for them to decompose and biodegrade fully, relevant to the soil condition they are mixed with. The use of both natural and synthetic reinforcement is known to increase soil properties. The arrangement and composition of various fibers and geosynthetics will be another key factor as of how well the soil may improve. The objective of this paper is to review the use of different fibers and geosynthetics in improving existing soil and their benefits. A number of studies have been conducted on problematic soils, such as clay or silt being reinforced with fibers. Most literature has adopted different lengths of fibers from 1cm to 5cm (with a variation of 1cm), whereas the composition of 0.2% to 1.5% of the weight of soil (with an increment of 0.1%) that is used was adopted in their studies. In some studies, the arrangement of fiber was also shown to be a variable in improving the soil, so the soil was mixed in layered arrangements at the top and bottom of the soil sample as well as random distribution of fiber in the soil. The soil was initially tested with the aid of several laboratory experiments such as sieve analysis, sedimentation analysis, Atterberg limits, and Standard Penetration Cone (SPC) tests where the soil was classified; this was considered the control sample. The soil that was reinforced with different fibers of varying lengths and compositions was tested against triaxial tests and soaked/unsoaked CBR (California Bearing Ratio) tests. The studies that were conducted on the soil by adopting the mentioned varying length, composition, and arrangement of different fibers showed promising results in the improvement of the soil's strength. According to studies, the soil behaved well and increased shear strength and the axial strain to failure, increased load bearing capacity and increased the CBR strength; and furthermore, the studies present a range of optimum lengths and composition percentages where maximum strength is attained. The studies reviewed in this paper show that the CBR strength of the soil effectively increased by a factor within the range of 2.3 to 4.6. From the review, it is concluded that the expansive problematic soil can be efficiently stabilized for

the placement of road pavements using both natural and synthetic fibers. In this paper, an extensive review of the available studies and their improvements are analyzed and presented.

Keywords: *Subgrade Modification, Geosynthetic, Fiber, Reinforcement, Pavements*

Authors Details.

1. Undergraduate, SLTC Research University. upekshad@sltc.ac.lk
2. Senior Lecturer, SLTC Research University. chamodh@sltc.ac.lk

Using Clay Tile Waste as an Internal Curing Aggregate (ICA) to Replace Aggregates in Roller-Compacted Concrete (RCC)

Sashini Ekanayake[1], Sandali Dilsara[2], Nalaka Jayantha[3], Wasantha Mampearachchi[4]

Abstract

The high demand for natural resources has become a significant problem in the construction industry. Therefore, the construction industry is searching for sustainable and eco-friendly alternatives, leading to a burgeoning interest in incorporating waste materials into concrete production. Considering the strength gained from concrete, proper curing is a crucial aspect. Lack of proper curing causes disturbances to the hydration process of cement, and it leads to a lot of problems such as reduction in strength, shrinkage cracks, and durability issues. Conventional curing methods have some weaknesses in providing uniform curing throughout the full depth of concrete. Therefore, the industry is moving towards alternative methods. Among those alternatives, using an internal curing agent is an innovative approach being researched widely, especially for concrete with a low water/cement ratio. Roller compacted concrete (RCC) is a type of concrete that has a low water/cement ratio, and it is gaining prominence as a durable and cost-effective construction material for a wide range of applications, including pavements, dams, and industrial floors. Its composition typically comprises coarse aggregates, cementitious materials, and fine aggregates. Since it has a low water/cement ratio, curing is vital to the hydration process of cementitious materials. Considering the water absorption and desorption capacity of materials, attention has been focused on the use of waste materials as internal curing agents. This study explores the feasibility of utilizing clay tile waste as an internal curing aggregate (ICA) in roller-compacted concrete (RCC). The aim is to investigate the potential of clay tile waste as an ICA and evaluate its effect on the properties of RCC. Since the particle size of the clay tile waste can affect the concrete properties, two studies have been done. One study investigates the use of clay tile waste to replace fine aggregates in RCC, and another investigates the use of clay tile waste to replace coarse aggregates. In both studies, a series of experiments are done to check the potential of clay tile waste to be used as an internal curing aggregate. The physical properties of clay tile waste, such as water absorption and desorption capacities, specific gravity, pore structure, and chemical properties, are studied in these experiments. After checking the potential to use as an ICA, RCC mixtures are prepared with different clay tile waste replacement ratios. Then, the mechanical properties of concrete, such as compressive strength, splitting tensile strength, and durability properties, are checked using laboratory experiments. Finally, all the results will be analyzed and compared with the control mixture that does not contain clay tile waste. The optimum replacement ratio for fine and coarse aggregates will be determined using analyzed results. With the positive results of the study, the construction sector will significantly improve sustainability by replacing either fine or coarse aggregate with clay tile waste material. Additionally, the possibility of early-age cracking owing to autogenous shrinkage is addressed using clay tile waste as an internal curing agent in
RCC construction. This inherent quality of the waste material increases the durability and service life of the RCC structures, enabling long-term performance and cost-effective maintenance and repair. In the broader context of sustainable construction practices, integrating clay tile waste

into RCC applications is a significant stride toward achieving environmental, economic, and performance-related objectives.

Keywords: *Roller Compacted Concrete, Clay Tile Waste, Internal Curing, Sustainable Construction, Waste Utilization*

Authors Details.

1. Undergraduate, Department of Civil Engineering, University of Moratuwa, Sri Lanka. ekanayakeemsk.19@uom.lk
2. Undergraduate, Department of Civil Engineering, University of Moratuwa, Sri Lanka. dilsaravgs.19@uom.lk
3. Lecturer, Department of Civil Engineering, University of Moratuwa, Sri Lanka. jayanthawran.20@uom.lk
4. Senior Professor, Department of Civil Engineering, University of Moratuwa, Sri Lanka. wasanthak@uom.lk

Evaluation of Pavement Management Funding Requirements for Rural Road Network in Response to Climate Change-Induced Flooding Impacts: A Focus on Accessibility Loss Restoration

K.W.A. Kariyawasam[1] and H.R. Pasindu[2]

Abstract

Climate change poses a challenge to the resilience of road networks. In recent years, the increasing frequency and intensity of extreme weather conditions have made road networks highly vulnerable to natural disasters. Moreover, the increasing unpredictability of climate-related events highlights the necessity of developing adaptive strategies to ensure their resilience. Road network plays a vital role in the socio-economic development of a country. The accessibility of rural areas is vital for the emergency response, and overall community well-being. Nevertheless, frequent flooding events, landslides, and the falling of large trees onto road surfaces due to adverse weather conditions can isolate entire communities, interrupt emergency response services, limit transportation of goods, and isolate individuals from healthcare, education, and economic opportunities. One of the critical aspects of road network resilience is the effective allocation of funds for pavement maintenance and rehabilitation. Several models and frameworks can be found in the literature for effective fund allocation in road asset management systems focusing on regular maintenance and rehabilitation works. Less priority has been given to fund allocation in terms of disaster-related rehabilitation. This raises the need to integrate disaster resilience into asset management systems as climate change continues to intensify extreme weather events, including heavy rainfall and storm surges. Resilient road networks can withstand and recover rapidly in the occurrence of such disruptive natural events. This study aims to evaluate the pavement management funding requirements for rural road networks in the context of climate change-induced flooding impacts, focusing on accessibility loss restoration. To achieve this, employed a comprehensive methodology that incorporates a damage estimation of roads following a flood event using depth damage functions to quantify the extent of damage incurred. To identify the inundated road sections utilized a GIS (Geographic Information System) approach, integrating flood hazard maps and exiting road network layers. Next, assessed the network conditions before and after a flood event using centrality measures. Network centrality, measured through indices such as betweenness and closeness centrality, offers insights into the criticality of individual road segments. It illuminates which roads play pivotal roles in maintaining connectivity, even under adverse conditions like flooding. Thereafter, prioritized the links by ranking them according to the potential impact on accessibility loss. Finally, an optimization model was employed to allocate the available budget for pavement management, ensuring that the most critical road links are restored first, thus maximizing the overall accessibility of the rural road network while taking into account the severity of the damage and the cost of repairs. This approach ensures that limited resources are used effectively, maximizing the restoration of accessibility across the rural road network.

This research aims to provide valuable insights for decision-makers and road authorities in rural areas facing climate change-induced flooding challenges to enhance the resilience of rural road networks. By adopting a systematic approach, that integrates damage estimation, network analysis, and budget optimization, this study offers a practical framework for addressing accessibility restoration needs in the face of climate change-induced flooding events. Ultimately,

this approach aims to make road networks better prepared to withstand and recover from flooding, contributing to more resilient and sustainable rural road networks.

Keywords: *Disaster Resilience, Climate Change, Rural Roads, Accessibility Restoration, Flooding Impact*

Author Details;

1. Research Assistant, Department of Civil Engineering, University of Moratuwa, Sri Lanka. kariyawasamkwa.21@uom.lk
2. Professor, Department of Civil Engineering, University of Moratuwa, Sri Lanka. pasindu@uom.lk

Comprehensive Review on Performance of Internal Curing Aggregates

Sandali Dilsara[1], Sashini Ekanayake[2], Nalaka Jayantha[3], Wasantha Mampearachchi[4]

Abstract

The curing of concrete is essential for cement hydration, which is a series of chemical reactions that require an adequate, constant water supply and stable, proper temperatures over time. Curing is maintaining moisture and temperature conditions in a freshly placed concrete mixture in order to allow hydraulic cement hydration. External curing techniques are frequently used to cure conventional concrete. In that method, external curing water is applied at the surface, and the quality of the concrete governs the depth of penetration. As a result, external curing may not satisfy demand since external curing water is only able to act on the surface layer of concrete and cannot reach the inside of the concrete. As a result, external treatment is ineffective in preventing the ongoing reduction of interior humidity. Therefore, Internal curing is used as a method of maintaining the relative humidity within the concrete. Internal curing allows the water to be spread more evenly throughout the cross section by releasing water eventually into the concrete mixture. This literature review provides a comprehensive examination of internal curing methods, mechanisms, and their impact on the properties of concrete. Internal curing is the technique of introducing curing elements that act as a curing agent, to the concrete mixture to serve as a water reservoir. It is a viable method for providing additional water for curing cement-based materials with low water-cement ratios, and it does not adversely affect the fresh or hardened properties of concrete mix. It differs from the externally applied curing. In the internal curing process, once the concrete is hardened, the water intended for internal water curing is dispersed within the concrete mixture and facilitates the hydration process. Internal curing is used to minimize autogenous, plastic, and drying shrinkage, which increases the probability of shrinkage cracking of the concrete, to reduce the permeability of concrete and the modulus of elasticity, to improve the strength and permeability at the interface transition zone (ITZ), to obtain reduced moisture gradient along the concrete section results in less warping in concrete pavements and reduced coefficient of thermal expansion (CTE) and thermal conductivity, resulting in lower temperature gradients across the concrete section and less curling in concrete pavements etc. In past studies, internal curing methods are explored in detail, ranging from techniques like pre-soaked lightweight aggregates such as crushed clay brick waste, and ceramic tile waste to more recent innovations such as superabsorbent polymers, which act as internal reservoirs, supplying an internal source of water needed to replenish moisture lost due to chemical shrinkage and self-desiccation in various concrete types such as normal weight concrete, high- performance concrete, Roller compacted concrete etc. A wide variety of studies have been done to check the potential of different kinds of material to use as internal aggregates to replace conventional aggregates. Also in some studies, the effect of the particle size of internal curing aggregates on the performance of concrete has been checked. Practical applications of each method are critically evaluated, offering insights into their effectiveness and feasibility in different construction scenarios. The optimum amount of each internal curing aggregate and the impact of internal curing methods on various concrete parameters such as strength development, shrinkage, cracking, and durability characteristics such as chloride penetration, air permeability, and water absorption are investigated in this paper. A thorough examination of laboratory results

and real-world case studies demonstrates the practical advantages that internal curing can impose on concrete performance. In a nutshell, this literature review synthesizes the wealth of information available on internal concrete curing, offering a thorough understanding of its concepts, methods, mechanisms, and impacts. Internal curing emerges as a possible option for improving the durability and performance of concrete structures while reducing their environmental imprint as infrastructure demands continue to rise. This review's information and insights contribute to a better understanding of internal curing's potential and pave the way for its wider implementation in the building sector.

Keywords: *Internal curing, Internal curing aggregate, water-cement ratio, Durability characteristics, Shrinkage cracking*

Authors Details;

1. Undergraduate, Department of Civil Engineering, University of Moratuwa, Sri Lanka. dilsaravgs.19@uom.lk
2. Undergraduate, Department of Civil Engineering, University of Moratuwa, Sri Lanka. ekanayakeemsk.19@uom.lk
3. Lecturer, Department of Civil Engineering, University of Moratuwa, Sri Lanka. jayanthawran.20@uom.lk
4. Senior Professor, Department of Civil Engineering, University of Moratuwa, Sri Lanka. wasanthak@uom.lk

Integrating Climate Impact into Road Maintenance Planning in Developing Countries

Tharindu Rangajeewa[1], Sachini Shashiprabha Madushani[2], Kelum Sandamal[3]

Abstract

Recently, there has been an increased frequency and intensity of extreme climate events such as flooding and landslides and this has significantly increased the vulnerability of road infrastructures to potential climate events. In practice, the measures to mitigate climate change need to be put prior to major events to yield maximum benefit. However, there is a lack of studies that incorporate climate impact into road maintenance and rehabilitation programs. This study addresses the urgent need to integrate the impact of climate change into road maintenance and rehabilitation programs to enhance the resilience of road infrastructures using a genetic algorithm (GA) based optimization approach. The approach involves developing a climate risk index (CRI) considering the criticality of the road, the probability of occurrence of a climate event, and the existing severity level of the pavement. Criticality level is defined by road functional class, availability of alternative routes and land use. Probability is determined by historical data and topography, while severity is defined by existing pavement conditions. The CRI is then incorporated as a generic constraint in the GA-based optimization model, which aims to maximize the average network condition under a given budget. The input data used in the optimization model includes road network data, calculated CRI values, existing roughness value measured in International Roughness Index (IRI), cost of adopted maintenance strategies. Moreover, three generic constraints deployed in the study namely CRI threshold value, rehabilitation threshold value and annual maintenance which limited to once in a year. Finally, the outputs generated in terms of a maintenance report and a cost report. The GA based system to optimize the proposed framework of climate impact was developed using Analytical Solver platform. A case study in Sri Lanka, involving a road network of 326.53 km, including class A and class B roads, demonstrates the effectiveness of the approach. The existing average network IRI value was 7 m/km while having 6 m/km for priority road's IRI. The GA model run with the optimum GA parameter which was found from several trials as; constraint convergence of 0.001, mutation rate of 0.8, population size of 100, random seed generation of 10 and the maximum iterations of 300. There are three maintenance strategies adopted in the case study such as routine maintenance, periodic maintenance and rehabilitation. The results shown that, the objective function versus budget plot depicts the decrease in IRI after raising the budget to select a maintenance plan. The total required budget was found as Rs. 2500 million to apply rehabilitation for all roads. The model results shown that in 25% and 50% of total budget conditions there is a clear separation between priority roads' IRI and non-priority roads' IRI due to the imposed generic constraint. This is an indication that the optimization model effectively prioritizes roads, particularly when there is a budget constraint. This concludes that the proposed approach can be utilized to make the most of the available budget for road maintenance by prioritizing highly vulnerable roads for climate events without compromising the overall network condition. Further, the proposed maintenance optimization approach can be extended to long term maintenance planning in an economical way especially for developing countries. At the initial maintenance stage, priority roads can be selected for maintenance by capping non-

priority road’s condition by utilizing available funds. Later, non-priority roads can be selected to maintenance program accordingly to available future funds.

Keywords: *Pavement management, Climate impact, Genetic algorithm, Optimization, International roughness index*

Authors Details;

1. Undergraduate Student, Sri Lanka Institute of Information Technology. rgterangajeewa@gmail.com
2. Assistant Lecturer, Sri Lanka Institute of Information Technology. sachinism.94@gmail.com
3. Lecturer, Sri Lanka Institute of Information Technology. kelumsanadamal@gmail.com

Development of Pavement Performance Prediction Model for Local Roads by Using Statistical Analysis and Machine Learning Techniques

Abdul Nizar Nafrees Ahamed[1], Kelum Sandamal[2]

Abstract

Sri Lankan Road network consists over 117,000 kms of roads which are comprised of national roads and highways (10.4%), provincial roads (16.3%) and the remaining are local roads. In general, local roads are managed by local authorities such as urban or municipal councils. Even though traffic volume is low in these roads, pavement condition is deteriorated with the time hence timely maintenance is a vital factor to consider. There are numerous pavement condition evaluation metrics available to measure the pavement condition such as roughness, distress and skid resistance. Recently, several countries have developed their own pavement performance models to predict roughness progression during lifetime by considering several factors such as distress condition, pavement age, environmental factors etc. Therefore, this research aims to develop an accurate pavement performance prediction model for Sri Lankan local roads.

Moreover, this study aims to close the gap of not having proper pavement performance model for local roads by using statistical analysis and machine learning techniques that consider the distinctive features of Sri Lanka's local roadways. International roughness index (IRI), cracks and raveling density are considered as pavement performance indicators while these indicators compared with pavement age and environmental factors such as temperature and annual precipitation. The research methodology comprised with several steps including data collection, data pre-processing, statistical model development and machine learning model development. The predictor variable is IRI and distress densities (cracking % and raveling %) while using latest rehabilitation year, road inventory data and environmental data as independent variables. IRI data and distress data were collected from local road authorities and using manual data collection methods along with road inventory data. Environmental data such as annual precipitation, average temperature was collected from open-source weather forecasting software and metrological department. Data analysis was carried out using both regression analysis and machine learning techniques. Firstly, a linear regression analysis was conducted between IRI, cracks and raveling with pavement age separately to identify whether there is a significant relationship among those. The results reveal that IRI as the most suitable metric to predict pavement condition against pavement age with a coefficient of determination (R2) value of 0.76. The second-best predictor variable found as raveling with an R2 of 0.65 while cracks shown the least R2 of 0.54. However, all dependent variables show a good relationship with pavement age with R2 more than 0.5. Further, a multiple linear regression analysis has been carried out by using IRI, crack% and ravelling % as the dependent variables while using pavement age, temperature and annual precipitation as independent variables. The multiple regression models shown increment in model predictability compared with individual variables having 0.78, 0.58 and 0.59 of R2 values separately for IRI, crack% and ravel %. Furthermore, a machine learning model was developed using a random forest (RF) regressor as the machine learning algorithm to predict IRI progression against the predictor variables. In the training data, 70% of the data was used while others were used for testing data. The results show that R2 of 0.79 for testing data with a mean absolute error (MAE) of 0.67 for the RF model. Shapley's Additive explanations

(SHAP) analysis showed that pavement age as the most influencing variable with a feature importance of 0.9 while pavement type, temperature and precipitation come afterward with a mean SHAP value of 0.55, 0.35 and 0.27 respectively. Providing precise justifications for the decision-making mechanisms within accurate models through SHAP analysis enhanced the confidence of both road users and domain experts in the machine learning models' predictions. Additionally, this research showcases the superior effectiveness of AI-based techniques over traditional regression analysis in predicting IRI. In summary, by adopting this methodology, road authorities can strategies for prompt maintenance, thus preventing expensive and extensive rehabilitation efforts.

Keywords: *Machine learning, AI based methods, pavement condition evaluation, local roads, international roughness index*

Authors Details;

1. Undergraduate, Sri Lanka Institute of Information Technology. nafreesahamed@gmail.com
2. Lecturer, Sri Lanka Institute of Information Technology. kelumsanadamal@gmail.com

A Novel Approach to Transit Level of Service: Headway Level of Service of a Bus Route

Kaushan Wimalasiri Devasurendra[1]

Abstract

The ability to measure and report the level of the quality of public transport service provided is important for customers to assess the level of service they receive and for the transit agency to assess the effectiveness of the service as well as improvements made. The public transit industry, however, lacks a set of efficient, accepted, and widely applicable level of service (LOS) measures. Specifically, the ones that can assess and compare the attribute level quality of service (QoS) of transit lines and those that can compare different operational performances of the same transit line. Existing measures fall short of incorporating a combined view of both the passenger and operator. A new approach to evaluate Transit LOS is proposed that has the potential to address these drawbacks.

This study proposes an approach to measure the Headway LOS (HLOS) based on the passengers' value of ride time (VoRT) distribution. First, an analytical model of optimum operation minimizing the generalized cost of waiting of passengers and operating cost is used. Then, an implied VoRT representing the performance of headway attribute is derived from the analytical model. The implied VoRT is compared with the VoRT distribution of the passengers to obtain the HLOS. An approach to distinguish LOS grades depending on the standard deviation (SD) of the VoRT distribution is proposed. Numerical examples are presented explaining the calculation of the HLOS of a bus route under different operating conditions. Finally, the developed methodology is applied to a bus route in Calgary, Canada.

Authors Details;

1. Senior Policy Analyst, BC Ministry of Transportation and Infrastructure, Canada. kaushan.devasurendra@gov.bc.ca

Optimum Spacing for Bus Stops for Local and Rapid Bus Routes

Pubudu Damsara[1], Saeid Saidi[2]

Abstract

This research revisits the issue of determining the appropriate number of bus stops and optimal spacing for a bus route, which is crucial for enhancing transit efficiency and passenger satisfaction. The study adopts a comprehensive approach by initially approximating passengers' likelihood to choose between local buses, rapid transit, or a combination of both for their journeys. Secondly, it optimizes the overall cost function to determine the optimal number of bus stops along the route for both local and rapid transit buses. The study extensively reviews the existing literature on Discrete Choice Models (DCM), Utility Theory, and Objective functions pertinent to total transit cost. The methodology involves calculating the probability of passenger demand for given alternative options, minimizing the total cost function, determining the optimal number of bus stops along the route, and calculating the optimal spacing between the bus stops based on the total length of the route. A stated preference survey can be used to collect data for the actual development of the choice model and identify the probabilities for five alternative options: (i) Walk + Rapid bus + Walk, (ii) Walk + Rapid transit + Local bus + Walk, (iii) Walk + Local bus + Rapid transit + Walk, (iv) Walk + Local bus + Rapid transit stop + Local bus + Walk, (v) Walk + Local bus + Walk. A multi-level nested logit model is proposed to estimate the parameters of the utility function, and the overall fit of the model can be assessed using the trial and retrial method based on the maximum likelihood technique. The probability of choosing each alternative option to travel from origin to destination for a bus passenger can be identified based on the multi-level logit structure. The total cost of bus transit services depends on operator costs and user costs. Transit users aim to reduce their out-of-vehicle travel time, while transit operators aim to reduce operating costs. This study uses the total cost function proposed by Tirachini (2014), which considers the number of stops for the optimization.

$$C_t = c.f[\frac{L}{V_0} + \frac{\beta.N}{f} + st_s] + P_a\frac{L}{2.V_w s}N + P_w\frac{1}{2f}N + P_v\frac{l}{L}[\frac{L}{V_0} + \frac{\beta.N}{f} + st_s]N$$

N In this equation, the total cycle time considers the summation of the running time (L/V_0) and the delays due to stopping at bus stops [(?N/f)+st_s]. The objective of this study is to identify the optimal number of bus stops for a route that has both local and rapid transit buses in operation. To accomplish this, the above function is modified based on a scenario that includes transfers between local and rapid transit buses for certain alternatives. The total cycle time is modified as the sum of the running time, the delays due to stopping at bus stops, and the transfer time (t_f) between buses. Transfer time is a function of traffic congestion and route efficiency. To consider both local and rapid bus routes, the total cost function is modified as follows.

$$C_{t,i} = c_i.f_i[\frac{L_i}{V_0} + \frac{\beta.p_i.N}{f_i} + s_i t_s + t_f] + P_a\frac{L_i}{2.V_w s_i}p_i.N + P_w\frac{1}{2f_i}p_i.N + P_v\frac{l}{L_i}[\frac{L_i}{V_0} + \frac{\beta.p_i.N}{f_i} + s_i t_s + t_{f,i}].\ p_i.N$$

The optimal number of bus stops can be identified by minimizing the objective function for the total cost. The optimal number of bus stops for rapid routes (s_01) and for local routes (s_02) can be determined by taking the first derivative of the total cost function, setting it to zero, and

solving for s_i [$s_i = L_i/(s_i - 1)$]. The ratio between the number of local bus stops and the number of rapid bus stops can also be calculated using these equations, providing valuable insights into how many local bus stops are required in between rapid bus stops to cater to passenger demand. By using the ratio of optimal bus stops, transit planners can strategically place rapid and local bus stops along a route to meet the needs of different types of passengers. This approach can help increase the efficiency and effectiveness of public transport services, ultimately resulting in improved mobility and accessibility for commuters. Upon analysis, it has been concluded that when demand for buses increases at a constant frequency, it would be advisable to increase the number of bus stops along a particular route. This research not only contributes to the theoretical understanding of transit planning but also offers practical implications for urban transportation systems. The research findings are substantiated with a detailed numerical example, utilizing specific assumptions of the probabilities of choosing a rapid bus route as 0.15 and a local bus route as 0.85. The optimal spacing between bus stops for the rapid and local routes is determined to be 1 km and 0.273 km, respectively. This results in a local-to-rapid bus stop ratio of 4, indicating that to maintain the optimal spacing between bus stops, there should be one rapid route bus stop for every four local route bus stops along a given route. It is important to note that local and rapid bus stops may not necessarily coincide with each other. The obtained results for the bus stop spacing align with industry norms, illustrating the application of the proposed methodology and ensuring a comprehensive and practical understanding for practitioners and researchers alike. In conclusion, this study significantly advances the field of transit planning by integrating passenger choice modeling, cost optimization techniques, and empirical analysis. The insights derived from this research not only enrich academic discourse but also offer actionable strategies for transit agencies and urban planners, thereby contributing to the enhancement of public transportation systems in urban areas.

Keywords: *Bus stop spacing, DCM, Total cost function, Bus stop optimizations*

Authors Details;

1. PhD Student, University of Calgary. donpubududamsara.kap@ucalgary.ca
2. Assistant Professor, University of Calgary. ssaidi@ucalgary.ca

Development of a Method for Bus Arrival Time (to bus halt) Prediction Model Using Machine Learning

M P V P Medawatte[1], H.L.K Perera2, A.B Jayasinghe3, K A S N Sumathipala4

Abstract

The pursuit of innovative methods to enhance various aspects of the transportation field continues to evolve over the years. Intelligent Transportation Systems (ITS) have played a pivotal role in integrating next-generation technologies and advancements into transportation. In recent years, a substantial volume of transportation data has been collected from various sources, including road sensors, probes, GPS, CCTV, and incident reports. Similar to many other industries, transportation has entered the generation of big data. With a rich volume of traffic data, it is challenging to build reliable prediction models based on traditional data analysis techniques. Accurate real-time bus arrival information is a critical component of a public bus transport network, influencing passenger experience, ridership reliability, reduced waiting times, dwell times, and operational efficiency. The Sri Lankan public transport system currently relies on static data to predict bus arrival times, lacking real-time data and factors affecting predictions. This study aims to identify unique factors impacting bus arrival times in Sri Lanka's road system and create precise travel time predictions that consider these factors. Using GPS data and Machine Learning techniques, the study focuses on developing an accurate real-time bus arrival time prediction model. While previous methods like Historical Average Models, Regression, and Kalman Filtering have been used for short-term travel time estimations, Machine Learning techniques show greater accuracy due to their capacity to handle intricate data relationships, large volumes of data, and nonlinear connections among predictors.

GPS data from the Moratuwa to Colombo bus route (100) was collected for the study for 30 days covering weekdays, weekends, and public holidays using five GPS units at various times of the day. This included the data of 330 bus turns giving more than 17500 GPS data points. The route consists of 53 bus stops and data filtering was performed based on GPS locations relative to each bus stop to calculate travel times between each stop separately. To improve accuracy, the total route was segmented, considering the number of bus stops, allowing for more precise travel time predictions by identifying speed changes in each section. The literature review highlighted several key factors influencing bus travel time, encompassing road section, time and day variations, peak/off-peak hours, bus lane availability, distance traveled, traffic flow, weather conditions, signalized intersections, and crossings. Data collection was conducted to encompass all of these factors. Out of the available Machine Learning models, the Support Vector Regression Model, Adaboost Model, K-Nearest Neighbors (KNN) Model, Random Forest Model, XG Boost Model, and Gradient Boosting Regression Model were identified as the models giving the most accurate results for the prepared data set. By using the model performance evaluation parameters like Mean Absolute Error (MAE), R2 Value, and Root Mean Square Error (RMSE), the model prediction accuracies can be compared to select the most explanatory model. Out of the selected Machine Learning models, the Support Vector Regression Model and XG Boost Model were not selected due to their R2 values being less than 0.5 and higher mean absolute errors. In contrast, the Random Forest Model, KNN model, and Gradient Boosting Regression Model yielded lower mean absolute errors and demonstrated

higher R2 values above 0.6. Consequently, these models were chosen for further analysis. The selected factors for prediction can be further narrowed down by performing feature selection before running the above models to further narrow the data collection needed for future studies. The proposed model aims to accurately predict bus arrival times at each stop given the trip's starting time from the origin. Apart from the mentioned models, further exploration of Long Short-Term Memory (LSTM) models using the dataset is suggested. Once finalized, this model can be extended to other routes within Sri Lanka's road network by updating the dataset with specific route characteristics. Future improvements can include incorporating real-time traffic and accident data to enhance prediction accuracies and provide precise arrival times for passengers across the public transport network. This selected travel time prediction model for Sri Lanka's public bus operations holds practical applications, offering fast, advanced, and accurate results.

***Keywords**: Machine Learning Techniques, Travel time prediction, Factors for short time travel predictions*

Authors Details;

1. Graduate Research Assistant, Department of Civil Engineering, University of Moratuwa, Sri Lanka, viduniprамodya@gmail.com
2. Traffic Engineer, City of Rockingham, Australia. perera.loshaka@gmail.com
3. Senior Lecturer, Department of Town & Country Planning, University of Moratuwa, Sri Lanka, amilabj@uom.lk
4. Senior Lecturer, Department of Computational Mathematics, University of Moratuwa, Sri Lanka, sagaras@uom.lk

Alternative Fare Policy for Public Bus Transport in Sri Lanka

Ananda Tennakoon[1], Sabeen Sharic[2], Saman Bandara[3]

Abstract

An efficient, reliable, and cost-effective public transport service plays a vital role in the development of the country's economy in many ways. According to National Transport Statistics, bus transport services contributed about 35% of the daily need for transportation in 2019. An affordable bus fare is an influential factor in attracting more passengers to public bus transportation in Sri Lanka. Simultaneously, the fare policies should be capable enough to optimise the revenue of the transport operators to preserve a reliable service. The Sri Lankan bus transportation service is currently practising the distance-based fare policy. The fare increases are calculated based on the percentage increase in the weighted average of the vehicle operating costs of ten route categories. However, obtaining the weighted average would not reflect the actual scenarios for such different routes. The existing method calculates vehicle operation cost based on twelve cost components such as fuel cost, crew cost, service, and lubricant cost, tires and tubes, air conditioner maintenance and overhaul, repairs, daily overheads, monthly overheads, annual overheads, depreciation, financing, and provision for risk. These cost components have not been revisited for an extended period. In addition, no consideration of the fixed and variable cost aspects in the calculations can result in less accuracy of the vehicle operating costs. The current fare for air-conditioned service is relatively higher than the normal fare. The frequent variations in fuel costs result in changes in operation costs causing frequent fare revisions. Hence, the operators receive criticism from the passengers about the clarity of the fare revisions as well as the fare levels of the air-conditioned service. Also, no clear mechanism is adopted in the current fare structure to identify and accommodate the transfer costs. Thus, this research attempts to establish an alternative bus fare model for operators and passengers to overcome such issues. It is proposed to calculate the operation costs based on the fixed and variable cost aspects, which realistically reflect changes in the variable operating costs of an operator while maintaining the correct fixed costs for the operation. The twelve existing cost components are reviewed and revised. The revised cost components are categorized into administrative costs, operation and maintenance costs, and finance costs. The expected profit margin is separately identified for each cost component to distinguish the profitability of the bus operators. Also, a simplified fare revision mechanism is introduced to calculate the fare revisions during frequent changes in fuel costs, consumer price indexes, wage levels, and bank interest rates depending on the weights of each parameter to the cost components. The bus routes are classified into seven different services, such as urban, suburban, rural, hill country, and long distance, as per the operation costs. The different fare strategies are determined for each service type to maximise the operators' profitability while minimising the fares for passengers and any transfer penalty. Notably, the air-conditioned service is treated as a separate category, further classified into medium-distance, long-distance, and hill country routes based on operational cost variances. This refinement anticipates a significant fare reduction for air-conditioned services compared to the current structure. In conclusion, this research offers a comprehensive and adaptable fare model that not only ensures the economic viability of bus operators but also prioritizes affordability and clarity for passengers.

Keywords: *bus transport, cost optimization, fare policy, bus operation cost, profitability*

Authors Details;

1. Postgraduate Student, Department of Civil Engineering, University of Moratuwa, Sri Lanka. anandatennakoon@gmail.com
2. Senior Lecturer, General Sir John Kotelawala Defence University, Sri Lanka. sabeen@kdu.ac.lk
3. Senior Professor, Department of Civil Engineering, Faculty of Engineering, University of Moratuwa, Sri Lanka. bandara@uom.lk

Factors Affecting Willingness to Use Transfer-Based Public Transport Network

Pakkiyarajah Saranjan[1], Saman Bandara[2]

Abstract

Urban public bus transport systems, especially direct routes, face challenges of inefficiency and a limited capacity to meet passengers' needs. In response, transfer-based solutions are being explored to enhance service quality. However, passengers often perceive transfers as inconvenient, posing a barrier to acceptance. Understanding passenger preferences and willingness is crucial for the success of any public transportation system, especially in the context of transfer-based networks. Willingness to use signifies a person's readiness to adopt a specific mode or transportation system, considering factors like accessibility, availability, and alignment with their preferences. It recognized a significant research gap in the current knowledge and a lack of understanding regarding passenger priority expectations when utilizing such networks. Understanding the factors that influence passengers' willingness to use transfer-based public transport networks is vital for optimizing transportation systems. It allows for tailored improvements to enhance the user experience, increase acceptance, and allocate resources effectively. An extensive and detailed literature review is conducted to look into current studies, articles, and academic journals connected to public transportation systems. This thorough review enables us to recognize and bring out the important factors that are crucial in determining the efficiency and user experience of these systems.

These considerations include features like accessibility, dependability, and price that are relevant to both transfer-based and direct routes. Aspects that are specific to transfer-based networks are identified, such as issues with interchange locations, wait durations, and information accessibility. The preferences of the passengers for the identified factors are collected by the questionnaire surveys to get a quantitative judgment. The pilot survey serves as an initial exploration, providing valuable insights into the potential preferences of the factors and the socio-economic values. In this study, including multi-criteria decision-making procedures is an important methodological advancement. This method enables us to assess and weigh various factors affecting passengers' preferences to use transfer-based public transport networks. It entails using mathematical models and analytical tools to evaluate all of these factors objectively, following specified standards. The results of this study are essential for developing and enhancing public transport systems that satisfy the needs and preferences of users. Our study starts the process of really understanding and addressing these objectives by conducting a comprehensive study. This project attempts to produce transit options that complement the concept of sustainable urban travel while also operating more easily and being more appealing.

Keywords: *Passengers, Transfer-based networks, Public transport*

Authors Details;

1. Research Assistant, Department of Civil Engineering, Faculty of Engineering, University of Moratuwa, Sri Lanka saranjanp.23@uom.lk
2. Senior Professor, Department of Civil Engineering, Faculty of Engineering, University of Moratuwa, Sri Lanka. bandara@uom.lk

Seasonality Patterns in Dry Bulk Cargo Handling at the Port of Galle, Sri Lanka

G.G.P. Pinsara[1], A.M.C.P. Atapattu[2], S.S. Wanniarachchi[3]

Abstract

The dry bulk cargo trade plays an important role in international trade by assisting the delivery of the dry bulk cargo demanded by different nations. Dry bulk cargoes cover a wide variety of produce/ raw materials and are transported using a wide range of ships from Mini Bulkers to Very Large Bulk Carriers (VLBC). Regarding both econometric and economic purposes, it is important to understand the differences between various seasonality patterns in the main dry bulk cargo types that arrive at the port in order to conduct operations more effectively and profitably. The study aims to analyse trends in dry bulk cargo unloading, mainly Clinker and Gypsum, under different months of the year to understand port congestion patterns at the Galle port, which operates primarily as a bulk cargo port, with a focus on dry bulk cargo unloading process. This study has used a longitudinal research approach with a quantitative design. This data includes the name of the vessel, capacity, the amount of cargo unloaded, the type of cargo, and the achievement rate over the previous ten (10) years employed for the time series analysis. The descriptive analysis of data shows that the number of vessels arriving increased from sixteen (16) to ninety (90), and the annual handling tonnage has sharply increased by 88.2%. In order to determine the nature of the phenomena represented by the sequence of data to predict the pattern of vessel arrival and handling tonnage, time series analysis has been applied. Data for Clinker and Gypsum were initially examined for stationary behaviour and analysis proved that Clinker and Gypsum are time-invariant and the model will not become spurious. The linear model test in Clinker and Gypsum displayed that Clinker has a volatility clustering and Gypsum does not. Further analysis using ARCH and GARCH models provided that there is no volatility effect on the Gypsum market, but the Clinker market has the volatility effect. The Dummy variables' regression model shows the months of January have the highest Clinker unloads, while April has the lowest and the Gypsum unloads are high in October and August and minimum unloads are observed in the month of May. This analysis reveals clearly that the Gypsum unloading at the port of Galle can be forecasted with a pattern but the Clinker unloading pattern is associated with uncertainty. The limitations of the study face challenges due to random sample formation and assessing the single event impact due to multiple events occurring simultaneously at the port, making it difficult to determine the most intractable problem. The study is mainly focusing on the unloading quantity of the dry bulk and other factors may have an impact on data that are not being addressed in this study. Ship owners and charterers may find it useful when making choices about shipping operations to consider the kind and size of fluctuations in bulk cargo markets. Additionally, the study's findings will be contributed to use by local businesses involved in dry bulk cargo unloading operations at the Port of Galle to comprehend patterns and put into place the necessary adjustments to determine safety standards, demurrage, and the efficiency of unloading operations.

Keywords: *Port of Galle, Dry bulk, Unloading*

Authors Details;

1. Air Traffic Controller (Prob.), Airport & Aviation Services Sri Lanka Ltd, Katunayake. pasindu942@gmail.com
2. Senior Lecturer, Faculty of Management & Finance, University of Colombo, Colombo. cpatapattu@gmail.com
3. Lecturer, Division of Management Studies, University College of Ratmalana, Ratmalana. ssewvandi@gmail.com

A Comparative Study of Economic and Performance Parameters of Conventional Concrete and Recycled Concrete Aggregate Roller Compacted Concrete (RCA-RCC)

Anjana Abeynayake[1] , Nalaka Jayantha[2]

Abstract

To reduce the environmental impact while encouraging recycling and reuse of materials on construction industry in Sri Lanka, effective construction waste management is essential. Using roller compacted concrete for pavement construction is an innovative alternative either it should be environmentally friendly if we can use waste concrete aggregate. The interesting world of RCC is explored in this abstract, along with its mechanical and physical characteristics when aggregates are completely substituted to waste concrete portions. The viability of this unique approach is explained in the paper, along with its consequences for sustainability objectives and infrastructure growth for the future Sri Lanka construction sector. However, the necessity for more environmentally friendly construction approaches and minimizing the industry's environmental impact have sparked interest in reassessing the materials used in preparation for RCC. Tons of waste are generated by rapid urbanization that leads to the demolition of structures reaching the end of their service life. Reusing recycled aggregates in concrete production reduces environmental pollution by decreasing the disposal of this waste material in landfills and preserving unreasonable exploitation of natural resources. To face this economic inflation in Sri Lanka, we should focus on these types of reuse methods for construction. This study focuses on the suitability of RCC as a sustainable and economical construction material. The first step is to identify the mechanical properties of the raw material and then do the mix design. The maximum dry density method was adopted to prepare RCC mixtures with 200 kg/m3 of cement content and coarse natural aggregates in the concrete mixture. Based on this purpose, our target 28-day strength is 30 N/mm2. Then ordinary concrete is made using normal course aggregates and waste materials, and also RCC is similarly made using normal raw materials and waste materials and then their samples are taken. The physical properties of RCC were evaluated by means of water absorption and gas permeability tests, while the mechanical properties were evaluated using compressive, tensile splitting and three-point flexural tests. The comprehensive analysis of the mechanical characteristics of RCC with full aggregate replacement is one of the study's main focuses. Among the important parameters evaluated are compressive strength, flexural strength, and tensile strength of both traditional concrete and RCC concrete with and without conventional aggregates. Tests done related to road pavements consist of the qualities of shrinkage, porosity, and density. The findings demonstrate that RCC maintains a desired density and low porosity even when all conventional materials are completely replaced. Additionally, RCC's shrinking behavior stays within acceptable bounds, proofing its long term stability and durability. The results of this study show that RCC may keep its strength and structural integrity even when aggregates are totally substituted. This finding challenges the standardized use of natural aggregates and has important implications for the use of RCC in a wider variety of construction objectives. RCC with fully replaced aggregates is a potential option that not only satisfies but also exceeds the industry's evolving needs while preserving the environment for future

generations as sustainability becomes increasingly important in construction practices in Sri Lanka.

Keywords: *Roller Compacted Concrete*

Authors Details;

1. Postgraduate Student, Faculty of Graduate Studies, General Sir John Kotelawala Defence University, Rathmalana, Sri Lanka. abeynayake.l.a.r@gmail.com
2. Lecturer, Department of Civil Engineering, University of Moratuwa, Sri Lanka. jayanthawran.20@uom.lk

Assessment of Suitability of Emission Trading Schemes (ETS)

Sajini Nawela[1] and Loshaka Perera[2]

Abstract

The Emission Trading Scheme (ETS) stands as a pivotal global policy mechanism aimed at addressing the urgent challenge of climate change. This comprehensive strategy operates on the fundamental principle of assigning a monetary value to carbon emissions, intending not only to curb greenhouse gas emissions but also to incentivize the adoption of cleaner technologies. Within this context, the application of ETS within the transport sector assumes significant importance. Given that the transport sector is a major contributor to carbon emissions, especially through vehicles powered by fossil fuels, the implementation of ETS within this domain creates a financial incentive for companies and individuals to reduce their emissions. This, in turn, promotes the transition to cleaner transportation alternatives such as electric vehicles, public transportation, and alternative fuels. Globally, numerous countries have implemented ETS, or analogous carbon pricing mechanisms, to address emissions within the transport sector. For instance, the European Union has extended its ETS to encompass aviation, demonstrating a broadened scope of application. Similarly, California has established a cap-and-trade system specifically targeting transportation emissions. These initiatives exemplify the international acknowledgement of the transport sector's crucial role in achieving emission reduction targets and combating climate change on a broader scale. This research delves into the suitability assessment of Emission Trading Schemes (ETS) in the context of Sri Lanka, with a specific focus on land transportation. Acknowledged as one of the most cost-effective strategies for controlling greenhouse gas (GHG) emissions, ETS has gained global adoption, tracing its origins back to the Kyoto Protocol and Clean Development Mechanism. The primary objective of this study is to conduct a nuanced analysis of various ETS implementations worldwide and their compatibility with their respective local contexts. To achieve these objectives effectively, a methodological framework has been devised, incorporating both qualitative and quantitative approaches. The qualitative aspect involves a thorough examination of global ETS practices through a series of interconnected components. The research scrutinizes the worldwide expansion of ETS, revealing that ETS now covers a substantial 17% of global GHG emissions. This study identifies 25 active ETS systems and an additional seven in various stages of development, with regions such as Europe, North America, and the Asia Pacific actively considering the incorporation of land transportation into their respective ETS frameworks. Additionally, the research delves into the regulatory frameworks underpinning ETS schemes in different countries, evaluating their current status, whether in force, terminated, or under development. A common set of regulatory principles encompassing scope and coverage, emission caps, and the allocation of allowances is identified. Key aspects such as monitoring, reporting, verification, emission compliance, and offset mechanisms are also illuminated. Furthermore, the study identifies critical elements for the successful implementation of ETS, including factors like ETS penalties, emission trading prices, limitations (caps), and fuel consumption regulations. The quantitative facet of the research involves a questionnaire-based survey conducted through expert interviews and public perceptions. Expert interviews provide insights into the suitability of vehicle types for piloting ETS in Sri Lanka's transport sector,

assess the adaptability of predetermined ETS frameworks to the local context, and determine whether urban or urban plus regional areas are more suitable for pilot implementation. On the other hand, a public perception survey offers invaluable insights into awareness and preferences related to ETS among the general populace. Although initially, 64% of respondents were not familiar with Emission Trading Schemes (ETS), it is noteworthy that, following a detailed explanation of its features and significance, an impressive 96% expressed a strong preference for its implementation in Sri Lanka. This shift in perception highlights the potential for widespread support and acceptance once the public is informed about the positive impact and importance of ETS in mitigating climate change and reducing carbon emissions. The significant increase in support underscores the importance of comprehensive awareness campaigns to educate the public and garner backing for sustainable environmental initiatives. Respondents predominantly favoured decisions on emission quotas based on vehicle type and fuel consumption, with monitoring mechanisms involving user-provided updates and integration with fuel quotas being highly favored. In conclusion, this research underscores the global momentum for adopting ETS to combat pollution, especially within the transportation sector. The study provides valuable insights into the potential applicability of ETS to Sri Lanka's land transportation sector, with strong public support for its implementation. However, the effectiveness of ETS in this context will depend on the careful consideration of regulatory frameworks and key success factors identified in this research. Further studies and pilot implementations are warranted to tailor ETS to the local context and maximize its benefits in reducing emissions and addressing environmental challenges. A more nuanced analysis of the functions and key differences between various ETS systems will be crucial in assessing their applicability and suitability in the unique context of Sri Lanka.

Keywords: *Emission Trading Schemes (ETS), Transportation Sector, Green House Gas Emission, ETS Cap, ETS Penalty*

Authors Details;

1. Assistant Manager - Special Projects, Financial Analysis & Business Development, AGC Innovate (Pvt) Ltd. sajini.nawela@gmail.com
2. Traffic Engineer, City of Rockingham, Australia. perera.loshaka@gmail.com

Comprehensive Analysis of Public Perceptions for Developing a Congestion Charging Framework for Private Vehicles within the Colombo Municipal Council Limits

Hasitha Kalahe[1], Saman Bandara[2] and Loshaka Perera[3]

Abstract

Global traffic congestion is a pressing issue, incurring trillions of dollars in economic losses each year due to lost productivity and increased fuel consumption. Rapid urbanization, inadequate infrastructure, poor urban planning, and an increase in private vehicles are the main factors that contribute to global traffic congestion. To address this, various strategies have been adopted by transport planners, such as expanding road networks, improving infrastructure, and bolstering public transportation systems. Congestion charging out of many has emerged as an effective tool for mitigating traffic congestion in urban areas. Being the commercial capital of Sri Lanka, Colombo City is not an exception to this global issue. The city has adopted many traffic management strategies, but none have yielded significant reductions in congestion. Even though prior studies have considered congestion charging as an alternative to Colombo's traffic problem, none have conducted a thorough investigation. Therefore, the main objective of this study is to identify the macro-factors and their impacts on setting up a congestion charging system for private vehicles within Colombo Municipal Council (CMC) limits. In addition, the study also aims to identify the most preferred charging mechanism, payment mechanism, time-based charge, and the appropriate discounts for residents of CMC limits. According to the O-D matrix developed for peak periods, considering the traffic analysis zones (TAZs) within the Western Province, the concentration of traffic within CMC limits was one of the main reasons for selecting CMC as the study area. Further, the availability of the geographic and administrative boundaries of CMC was the other reason to select it as the study area. To gauge public opinions on congestion charging, the study employed a survey of 317 respondents from the Colombo district using convenience and snowball sampling methods. The respondents' perceptions of eleven key macro-level factors: vehicle category, charge, public transport quality and capacity, travel time improvements, travel activity disturbances, privacy of trips, equity, environmental protection, faith and leadership in government, transportation technologies, and enforcement policy were collected. The responses were rated using a Likert scale. Furthermore, respondents' demographic information, their preferences for charging mechanisms, payment methods, discounts for residents, and their preferred charges were gathered. An ordinal regression model was developed to analyze the data. The model exhibited a significant fit, and the factors: vehicle category, charge, public transport quality, travel activity disturbances, and equity were highly significant. Further, the charge displayed a strong positive correlation with the perception of congestion charging. The results revealed that "charge based on time travel within the cordon" as the most preferred, while electronic post payment was the most popular payment mechanism. Moreover, the preferred charge for a 30-minute travel time inside the charging zone was identified as Rs. 110, and the preferable discount for residents within the charging zone stood at 70%. According to the results of the study, when a congestion charging scheme is developed for private vehicles within CMC limits, vehicle category, charge, public transport quality and capacity, travel activity disturbances, and equity should be considered as

primary factors, along with time-based travel charges and electronic post-payment. Private vehicle users are willing to pay around Rs. 110 for a 30-minute journey inside the CMC limits, and equity concerns among CMC residents can be addressed by offering a 70% discount. However, the sample size of the study and the consideration of only private vehicle users in the Colombo District were identified as limitations. Future research should be conducted to investigate the influence of demographic factors on congestion charges, its impact on other vehicle types (public transport, emergency, goods, taxis, green vehicles), and its effects on occasional users and visitors to enhance the congestion charging mechanism.

Keywords: *Congestion charging, Traffic congestion, Public perception, Colombo Municipal Council*

Authors Details;

1. Civil Engineer, Sri Lanka Land Development Corporation. hasee.sahan92@gmail.com
2. Senior Professor, Department of Civil Engineering, Faculty of Engineering, University of Moratuwa. bandara@uom.lk
5. Traffic Engineer, City of Rockingham, Australia. perera.loshaka@gmail.com

Headway Distribution on Urban Roads under Heterogeneous Traffic Condition

Pasan Madura Yahampath[1], Saman Bandara[2]

Abstract

This study examines time headway distributions on urban roads in Sri Lanka, emphasizing the impact of heterogeneous traffic conditions. Headway, which refers to the temporal gaps or spacing between consecutive vehicles on the road, plays a pivotal role in shaping traffic flow, congestion, and road safety, making its understanding essential for effective traffic management and urban planning as a microscopic parameter offering insights into macroscopic traffic behaviors. This parameter finds application in capacity analysis, safety evaluations, accident investigations, car-following behavior models, and lane change propensity studies. The problem lies in the lack of comprehensive research on headway distribution in urban traffic settings marked by significant heterogeneity. The prevailing focus on homogeneous traffic conditions in conventional traffic research, often limited to low and medium flow situations within lane-based vehicle flow scenarios. However, urban road networks in Sri Lanka frequently encounter highly diverse traffic conditions due to the presence of diverse vehicle types like three-wheelers, motorbikes, mini-lorries, buses, and heavy vehicles, each with varying physical attributes, axle configurations, weight distributions, power ratios, varying driver behaviors, and multitude road users. Moreover, road discipline issues and truncated inter-vehicle distances due to aggressive driving further complicate traffic analysis. The primary aim is to determine appropriate distribution models for various traffic flow ranges and leader-follower pairs on different road segments and rigorously evaluate their statistical validity through a range of goodness-of-fit tests. The data collection involves videographic surveys to capture headway data from selected road sections. The selection process for these road sections involves considering several crucial factors, such as the absence of side hindrances (e.g., parking lots, gradients, bus stops, intersections), the straight and flat nature of the road, the availability of ample shoulder space, favorable weather conditions, good visibility, Optimal driving surface, geometric and functional homogeneity for at least 1 kilometer upstream and downstream. Selected road sections are A004 road at Pannipitiya, A001 road at Kegalla, Marine Drive at Wellawatta and AB -042 road at Hirasagala. For each road section videographic surveys were carried out at three peaks periods during the day, namely 7.00-9.00 am, 12.00-2.00 pm and 4.00-6.00 pm, which were identified during the initial observations of the road sections and also based on the findings of the literature review. Each time interval was sub divided into 15 min intervals in order to identify the variation of flow and calculate the flow rates. Sub-time intervals were defined in such a manner that sample size (number of headways) was large enough for all flow ranges. Time stamps during the entry of the front bumper, vehicle type and speed of each vehicle were extracted from video recordings manually by image processing using software “Traffic Extractor” developed by IIT Bombay to compute time headways. Accordingly, headways between successive vehicles were determined by the time gap between the entry times of front bumpers of successive vehicles. A total of 24,201time headways were collected through the data collection. The analytical framework encompasses two scenarios: studying headway variations across diverse traffic flow conditions and exploring headway data for different leader-follower pairs. The data is

categorized into three flow ranges—below 400 veh/hr indicating free-flowing conditions (Level of Service A and B), 400 to 1200 veh/hr representing moderate flow with some restrictions (Level C), and above 1200 veh/hr denoting highly congested conditions with reduced speeds and potential stoppages (Level D and E) based on computed flow rates. Frequency and cumulative frequency distributions are constructed for each flow range and road section. Distribution model selection relies on established empirical models, with goodness-of-fit assessments carried out using the K-S test, Anderson-Darling test, and chi-square test. Statistical tools such as Easy Fit, NCSS, and SPSS aid in these evaluations. The K-S and Anderson- Darling tests assess the fitness of theoretical distribution models to observed data by comparing cumulative distribution functions, with the chosen model yielding the least discrepancy as the best fit. Easy Fit software aids in conducting these tests, and rejection of the null hypothesis occurs if calculated statistics surpass critical values at a chosen significance level. The study examines various flow ranges across different road sections and tests the goodness-of-fit of several distributions, including Generalized Extreme Value, Johnson SU, Pearson, Generalized Gamma, Beta, and Burr. In conclusion, the research findings suggest that the "General Extreme Value" distribution consistently emerges as a strong and versatile candidate for describing traffic flow behavior in the flow range below 400 veh/h. For flow rates between 400 and 1200 veh/h, the Gen. Gamma (4P) distribution proves to be the most suitable choice. In the flow range above 1200 veh/h, the Gen. Gamma distribution also performs well. Moreover, the study reveals varying degrees of variability, skewness, and kurtosis in leader-follower relationships across different vehicle classes, indicating the need for tailored approaches to traffic management and safety analysis. The research contributes to a deeper understanding of headway behavior in diverse traffic scenarios, offering practical implications for transportation engineering and management, safety analysis, and infrastructure planning. It underscores the importance of tailoring headway distribution models to specific traffic conditions and vehicle relationships, providing valuable insights for traffic management and infrastructure planning in Sri Lanka and similar urban environments.

Keywords: *Time headway, Heterogeneous Traffic, Distribution Model, Flow range, Goodness of Fit*

Authors Details;

1. Design Engineer, Road Development Authority. pasan.yahampath@eng.pdn.ac.lk
2. Senior Professor, Department of Civil Engineering, Faculty of Engineering, University of Moratuwa. bandara@uom.lk

Developing a Railway Noise Model for Sri Lanka

K. Umaluxman and Loshaka Perera

Abstract

Railway noise is a significant environmental concern in many countries, including Sri Lanka. Railway noise pollution is becoming a more pressing issue with the expansion of railway networks and the increasing use of trains for transporting passengers and goods. It differs from road traffic noise, being distinct, rhythmic, and lower in frequency. Railway noise has continued impacts on the passengers during the journey and periodical impacts on the residents and workers who live or work nearby the railway stations and railway lines. Railway noise can have various adverse health impacts, including sleep disturbance, annoyance, cardiovascular effects, and cause hearing damage. The lack of noise-related impairment data highlights the issue, emphasizing the need for more research and attention to noise pollution's impact. Railway noise stems from four main sources: rolling noise, traction noise, aerodynamic noise, and other noise like horn noise and noises which are caused by the irregularities such as joints and switches. Factors like speed, track type, and train condition affect noise generation, while ground, terrain, atmospheric conditions, and urban or rural settings influence noise propagation. Understanding these factors is crucial for creating accurate noise models and effective noise management strategies. Countries employ distinct railway noise models, reflecting diverse approaches to addressing noise in rail systems. Existing noise models often overlook Sri Lanka's unique geographic and locomotive related factors, limiting their effectiveness in addressing railway noise pollution. The country's diverse terrain, from mountains to coastlines, amplifies and alters noise patterns due to sound reflections and refractions. This study is focused on developing a model that can accurately predict railway noise levels incorporating unique elements. Multiple variables influencing railway noise levels were considered in the development of mathematical model. Key factors considered are engine type, train speed, track geometry, sleeper type, environmental conditions, track maintenance, and distance. Because of the extensive nature of the railway network in Sri Lanka, data collection was done in a systematic way considering the key factors like diverse topographies, ground conditions, track formation condition, sleeper type, train types and locomotives. Noise levels measurements adjacent to the railway lines were collected with a noise level meter. Alongside noise readings, relevant data on various factors was gathered. Collected data was pre-processed to remove any outliers or errors, to data normalization, to ensure consistency and comparability. The Central Environmental Authority's rail transit system noise standards specify that the maximum noise level should not exceed 85 dB under various conditions, including residential and commercial areas, as well as day and night times and the equivalent continues noise levels should fall less than or within the range of 55 to 65 dB for compliance. The collected data revealed that the maximum noise levels of the railway lines were higher than 95 dB, surpassing the maximum sound level mandated by the CEA standard. And Survey Department of Sri Lanka states that, there should be no cutting or development of land within a 40-meter distance from a railway line. But there are places in Sri Lanka where we have unauthorized constructions within these limits. As a result, there is a pressing need to identify the noise levels and propose mitigation measures. The expected outcome of this study is to identify the factors which influence the railway noise levels and to

develop a mathematical model which can predict the noise levels near railway lines in Sri Lanka. The model needs to be validated and tested for its accuracy. The mathematical model allows to identify how changes in factors such as engine type, train speed, track geometry, sleeper type, environmental conditions, track maintenance, and distance influence the changes in the railway noise levels. It helps in designing effective noise reduction measures, ensuring compliance with noise regulations, and making informed decisions regarding railway planning and operations. Ultimately, the research outcomes are expected to contribute to a more sustainable and noise-sensitive railway system in Sri Lanka by enhancing the overall noise quality.

Keywords: *Noise levels, Noise model, Railway noise, Mathematical model*

Authors Details;

1. Research Assistant, Department of Civil Engineering, Faculty of Engineering, University of Moratuwa, Sri Lanka ukanagasingam@gmail.com
2. Traffic Engineer, City of Rockingham, Australia. perera.loshaka@gmail.com

Vehicle Classification and Detection from Video Image for Non-Lane-Based Heterogenous Dhaka Traffic

Nayeemur Rashid Nayeem[1], Annesha Enam[2] and Jishnu Mahmud[3]

Abstract

Traffic congestion is a significant problem in Dhaka – the capital city of Bangladesh. Traffic congestion is caused by several factors, including the high volume of non-motorized traffic, the lack of public transportation, and the poor road infrastructure. One of the challenges in mitigating traffic congestion is accurately estimating the volume and proportion of different types of vehicles during different periods. Manual vehicle counting is a state-of-the-art technique for traffic volume determination on the roads of Dhaka. However, it is a labor-intensive and time-consuming procedure. Automated counting of vehicles from videographic surveys has been proven to be less error-prone than manual counting. However, the state-of-the-art algorithms for automated traffic volume detection from video graphics data are not suitable for Dhaka city due to Dhaka's unique traffic conditions. First, the number of non-motorized vehicles, such as bicycles and rickshaws, plying on the roads of Dhaka is high. Second, the existing algorithms for automated vehicle detection have not been validated for non-lane-based traffic operations. This paper proposes a novel algorithm for automated traffic volume detection from video graphics data for Dhaka city. The proposed algorithm is based on a deep learning approach, YOLO - You Only Look Once, a state-of-the-art object detection algorithm. The existing YOLO algorithm was trained with traffic images from various key junctions in Dhaka, and the hyperparameters were tuned to enable the network to learn the nuances of the city's unique and complex traffic situation. Various techniques, such as data augmentation by rotation, flipping, and random cropping, were used to prevent the network from overfitting. The Cosine Learning Schedular, as opposed to Step Scheduler, was used to achieve better validation accuracy. The modified YOLO algorithm was benchmarked on a dataset of images extracted from a videographic survey of Dhaka's traffic. To determine the total vehicle volume, two methods were employed. In the first method, the number of vehicles in each frame was counted, and they were added. Then the summation was divided by the number of frames to get the average vehicle count per frame. This number was multiplied by the average time that each vehicle spends in the video to get the average vehicle volume. The second method utilized a line and the intersection over union (IoU) technique within adjacent frames of the video. In this approach, a bounding box was drawn around a vehicle using the YOLO v7 algorithm, and the vehicle count was incremented by one when the bounding box crossed the line. The line helped to keep track of how many vehicles crossed the junction. The count of vehicles was then divided by the duration of observation. The outcomes of both algorithms were then passed through a shallow artificial neural network. The final output value of this network was compared with the traditional method of counting. Google Collaboratory, which provides access to powerful computing resources, was used to train and deploy the model. The algorithm could also be used to develop new transportation applications, such as real-time traffic monitoring and navigation. The continuous count of the classified vehicle could also be used to calculate the saturation flow rate at intersections and determine the operational capacity of highways. Overall, the developed algorithm could help assess the performance and efficiency of the transportation system, identify

improvement areas, and improve the safety of heterogeneous traffic operations. It can be noted that to improve the robustness of the algorithm, it would be prudent to apply the developed algorithm to datasets collected from other developing countries, such as Sri Lanka. However, the authors do not have access to such datasets currently, and hence, it has been left as a future research endeavor.

Keywords: *Non-lane based traffic, Convolutional Neural Network, vehicle detection, vehicle classification, Dhaka Traffic*

Authors Details;

1. Student, Bangladesh University of Engineering and Technology (BUET). nayeemur.rashid.nayeem@gmail.com
2. Assistant Professor, Bangladesh University of Engineering and Technology (BUET). annesha@ce.buet.ac.bd
3. Lecturer, BRAC University, Bangladesh. jishnu.mahmud@bracu.ac.bd

Identification of Key Performance Indicators to Develop a Scorecard to Evaluate the Level of Safety in School Zones

Meral Qazi[1], Saman Bandara[2] and Ishani Dias[3]

Abstract

When it comes to road safety, the immediate vicinity of schools is a very sensitive region. According to WHO, a child is lost every 4 minutes on road with age ranging from 5-19 years. Statistics show that afternoon school pick-up hours are the most common time for crashes. In many countries, most crashes involving children happen within 500m from the school. Children are especially vulnerable in road traffic because of their unique physical, mental, and cognitive abilities. However, assessing the level of safety in school zones can be a complex task, given the numerous factors and variables involved. This abstract presents a proposal for the identification of Key Performance Indicators (KPIs) for the development of a comprehensive scorecard designed to evaluate the level of safety in school zones. The aim is to propose a cost-effective scorecard model that can be used remotely/online without physically going to site. A systematic and holistic approach to assessing school access safety, encompassing infrastructure aspects. In this study, the research problems in debate are incompliance of traffic laws in school zones and the location of the school not being significantly considered in school road safety while safety problems differ location-wise. The objective of this research involves identifying road safety issues faced by school children, identifying KPIs that can be used to measure safety risk and to evaluate different school zones. The methodology initiates with a thorough literature review to find research gaps and further improvements in the already existing assessment methods if any. This detailed literature review undertaken also involved various case-studies around the world. Then the identification of relevant parameters was carried out by proposing suitable indicators that are quantitative in nature to facilitate, evaluate and compare different school zones. The important parameters that need to be considered in evaluating road safety near schools include school location and nearby land use, crosswalks and pedestrian infrastructure, speed limits, school zone signs, traffic calming measures, drop-off and pick-up zones, proper visibility, bike lanes, parking facilities, etc. This scorecard consists of 16 (KPIs) each measures a specific aspect and evaluation criterion of school zone safety. These indicators are grouped into four key categories: school site, road network, parking/loading and active transport indicators. The indicators are identified with the help of literature review and a small-scale case study in New South Wales, Australia. Site visits were conducted and secondary data available online was obtained to analyze the road safety parameters in the school zone. Main indicators identified are location/entrance, fence around the school, land use, main roads in the school vicinity, school zone signage and pavement marking, speed limit signage, traffic calming measures, adequate sight distance, adequate pick-up/dropoff zones for private vehicles, availability of school crossing supervisors, sidewalks, crosswalks, bike lanes etc. All the indicators identified are further justified through a detailed literature review, supporting evidence and local standards. A numerical star rating system is used as an evaluation criterion to assess school zone safety levels across each category on a scale from 1 (lowest safety) level to 5 (highest safety level). The proposed scorecard model will assign weights to each indicator based on its relative importance, and schools will be evaluated against these indicators. Further analysis involves a pilot study on

a school in Sri Lanka in which few students will use the proposed scorecard model on a school zone remotely to observe the consistency of results. The final score will provide a comprehensive overview of the safety level of school access, helping schools, parents, and local authorities identify areas for improvement. The cumulative score will provide an overall safety rating, facilitating easy comparison and benchmarking against other schools Implementing this scorecard will not only serve as an assessment tool but also motivate schools and communities to prioritize safety in school access. Moreover, it will facilitate and fill the research gaps for data-driven decision-making, and interventions to enhance school access safety.

Keywords: *School Zones, Road Safety, School Children, Scorecard*

Authors Details;

1. Postgraduate Student, Department of Civil Engineering, Faculty of Engineering, University of Moratuwa. qazim.22@uom.lk
2. Senior Professor, Department of Civil Engineering, Faculty of Engineering, University of Moratuwa. bandara@uom.lk
3. Senior Lecturer, Department of Civil Engineering, Faculty of Engineering, Kotelawala Defence University, Ratmalana, Sri Lanka. ishanidias@kdu.ac.lk

Investigation of the Physical and Rheological Properties of Carbon Black Modified Bitumen

Sudharshi Jayasinghe[1], Chamod Hettiarachchi[2] and W.K. Mampearachchi[3]

Abstract

Traveling and transport is an essential part of the day to day life. All kinds of users from pedestrians to a vast range of vehicles, expect a comfortable and controllable movement through the road. To provide a smooth, durable and quality surface for these users, pavement performance is very important. But reasons such as different environmental conditions, tire pressure and high traffic volume may lead pavement to rutting, low temperature cracking and fatigue. As a solution to enhance the performance of pavements and avoid these distresses, modifying the bitumen properties has been considered from the earlier days of asphalt pavement technology. Vast range of studies have tried out on bitumen to eliminate the material properties and increase the overall performance. Further, polymer has become the commonly used medium for bitumen modification as a pavement performance enhancing method. Styrene butadiene styrene (SBS) and styrene butadiene rubber (SBR) are some frequently used modifier types. In Literature, it is clearly observable that both physical and rheological properties of the base bitumen have significantly improved by polymer modifiers. Although polymer modified bitumen types are effective in performance, they are economically less effective. The major imperfection of polymer modifiers is degradation of polymer due to aging and incompatibility. Therefore, the researchers pay their attention towards more effective modifiers. Vermiculite, waste oil modifiers, crumb rubber modified, rock asphalts, asphalt rubber and nano-particles/polymer are some of additives which were tried on bitumen as modifiers. Moreover, the capability to improve the pavement performance using mineral fillers; dust from crushing and screening of aggregates, lime, Portland cement, fly ash and carbon black (CB) has attracted the attention of the world nowadays. Among the above mineral fillers, Carbon black is a waste material which is extracted from waste tires or petrochemical waste. Carbon Black is a black power which has particles of irregular shapes and large specific surface area. Carbon elements are the main components while oxygen, hydrogen, sulfur and other impurities may be contained in Carbon Black. Modified bitumen with carbon black has a good influence on high temperature permanent deformation and aging properties. Several studies have mixed additional materials altogether with Carbon Black to address some issues in modified bitumen. Further, Carbon black is much cheaper and environmentally friendly than polymer modifiers. Therefore, diving more into these carbon black Bitumen modifications is important. This paper presents a series of experiments which performs to evaluate the properties of Carbon Black modified bitumen. Scanning electron microscope (SEM) and X-ray energy dispersive spectroscopy are used to observe the topography and the chemical composition of the Carbon black. Mixing time, mixing temperature and Carbon Black content varies while modifying by melt blending with a high shear mixer to obtain the optimum parameters. Penetration, Ductility, Softening Point, Viscosity, Dynamic shear rheometer (DSR) test, bending beam rheometer (BBR) test identify the physical and rheological parameters of modified bitumen. All the Tests perform according to the ASTM standards. It can observe significant impact on physical and rheological properties of the bitumen after analyzing these results. Father, low temperature cracking resistance of bitumen decreases

with the addition of Carbon Black and high- temperature deformation resistance has developed. This paper provides a thorough study of properties of carbon black modified bitumen and emphasizes the further research requirement regarding this area.

Keywords: *Bitumen modification, Carbon Black, high shear mixing, pavement performance*

Authors Details;

1. Research Assistnat, Department of Civil Engineering, Faculty of Engineering, University of Moratuwa, Sri Lanka. jayasinghesd1997@gmail.com
2. Senior Lecturer, SLTC Research University. chamodh@sltc.ac.lk
3. Senior Professor, Department of Civil Engineering, University of Moratuwa, Sri Lanka. wasanthak@uom.lk