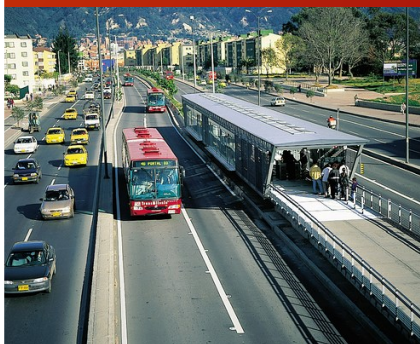




*Research  
Leads to  
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# Transport Research Forum

## 2022



UNIVERSITY OF MORATUWA

DEPARTMENT OF CIVIL ENGINEERING  
TRANSPORTATION ENGINEERING DIVISION

# Transport Research Forum 2022



## Abstracts (Revised)

03<sup>rd</sup> December 2022

University of Moratuwa, Sri Lanka

Transportation Engineering Group  
Department of Civil Engineering  
University of Moratuwa

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## 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.

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 2022 is the 15th 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. 2020, TRF achieved a significant milestone by publishing its selected proceedings (full papers from selected studies presented at TRF 2020) in the IESL 'The Engineer' journal as a special edition and hoping to do the same this year as well.

## Message from the Conference Chair

**Prof. W.K. Mampearachchi**

**University of Moratuwa**

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As the Chairperson of the research committee, I am delighted and honoured to bring this message to the Transportation Research Forum 2022.

We, the Transportation Engineering Group, have decided to hold this prestigious conference at the Dept. of Civil Engineering.

I hope that this conference will allow the participants to have a productive discourse. Our technical program is rich and varied, with Keynote speeches from experts in foreign countries and around 25 technical papers. Some of the underlying issues in the transport sector in Sri Lanka will be covered in-depth at our conference by our invited speakers and guest speakers. I extend my heartfelt appreciation to them.

As a conference chair, I know that the success of the conference depends ultimately on the many people who have worked with us in planning and organizing the conference. I take this opportunity to acknowledge the support given by the Vice-Chancellor, Prof. Niranjan Gunawardana and our Dean, Prof. Udayanga Hemapala, who have a very clear desire to upgrade research in the community in which we live.

In particular, I thank the committee for their wise advice and brilliant suggestions for organizing the conference. All recognition should go to the committee members who have all worked extremely hard on the details of important aspects of the conference programs. A note of appreciation to the academia and industry partners for their thorough and timely reviewing of the papers.

Most of all, I thank you, the presenters, for enriching the conferences with your presence, as it is a tradition with the conferences. I hope you will enjoy the content, and new fellowships, get new ideas, and above all, have a great deliberation.

On behalf of the Conference Committee, we're looking forward to seeing you at the conference.

# **TRF 2022 Organising Committee**

## **Conference Chair**

Prof. W. K. Mampearachchi

## **Conference Secretary**

Dr H L K Perera

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## Keynote Speech



***Prof. (Mrs) Regine Gerike***

*Head of the chair of Integrated Transport Planning and Traffic Engineering, Dean of the "Friedrich List" Faculty of Transport and Traffic Sciences, Technische Universität Dresden, Germany.*

Regine Gerike is the head the chair of Integrated Transport Planning and Traffic Engineering and dean of the “Friedrich List” Faculty of Transport and Traffic Sciences at Technische Universität Dresden, Germany. Before joining TU Dresden, she chaired the Institute for Transport Studies at the University of Natural Resources and Life Sciences (BOKU) in Vienna, Austria. Regine Gerike did her PhD at TU Dresden in the field of modelling transport and its environmental effects. From 2008 to 2012, she was an assistant professor at Technische Universität München, head of the Research centre mobility and transport (Mobil. TUM) and of the PhD-program “Mobil. LAB – Sustainable Mobility in the Metropolitan Region of Munich”. Her research interests include transport planning from the strategic level to urban street design with a focus on traffic safety and vulnerable road users, empirical research on travel behaviour and holistic approaches to evaluating sustainable mobility.

**Topic: Visions and Strategies for Urban Transport: Function, Form, Fairness, Forever**

### **Abstract**

The Sustainable Development Goals (SDGs), as approved by the United Nations in 2015, provide the overarching normative framework for all sectors of society, including transport. A closer look at the SDGs with relevance to transport reveals their focus on the negative effects, such as accidents or emissions of environmental pollutants. The complementary framework of “responsible mobility” is suggested in order to comprehensively account for transport systems’ positive and negative effects based on four pillars: Transport systems should deliver accessibility (function), contribute to vibrant streets and livable cities (form), they should be fair (fairness), and they should fulfil these requirements today and in the future (forever). Strategies for meeting these ambitions are discussed, considering constants and dynamics in travel behaviour. The combination of push and pull approaches is of the highest relevance, as is the targeted coordination of urban and transport planning.



## **Identifying the Grade Separation Requirement for Railway Level Crossings in Sri Lankan Urban Context**

*Randula Amarathunga<sup>1</sup> and H.R Pasindu<sup>2</sup>*

### **Abstract**

Railway level crossings are a major consideration that road agencies often need to pay attention to in managing the issues related to safety, traffic, and land use in the road segment where it's located. Though grade separation is the ideal alternative since it completely separates the road and rail traffic, it carries a downside due to the high project cost and maintenance by making it impossible to grade separate all the level crossings. Allocation of funds for a single grade separating structure could restrict the funds available for other development projects. With the increasing number of road users and the higher demand for the railway, increased congestion is more than certain in the absence of proper improvements to the network. have been proposed in many countries how to identify and prioritize potential level crossings for grade separations which leads to effectively utilizing the funds allocated. A knowledge gap was identified in the Sri Lankan context, where the lack of a guiding framework leads to ad hoc decision-making and inefficient allocation of funds. The study aims at developing a criterion that can be used to identify the grade separation requirement in Sri Lankan urban context. The literature review, it was identified that accident cost under safety impact, delay and vehicle operating cost under the economic impact, Average Daily Traffic (ADT) under traffic impact, project cost under financial constraints and emission cost under the environmental impact are the key parameters that have been used in many studies. Limiting ADT was identified as the threshold value for grade separation decisions in an urban context, and an economic analysis was then carried out to check the suitability of the identified limiting criterion for the local urban context. Existing flyovers were selected representing four-lane and two-lane grade separations. Survey data was collected from the Transportation Engineering Division, the University of Moratuwa and the daily train schedule was taken from the Sri Lankan Railways to incorporate the train frequency and gate closures of delay at the level. Crossings were done with VISSIM microsimulation software for different ADT levels. Travel time, vehicle operating, and emission costs due to grade separating the level crossing were considered as the economic benefits, but the savings from accident costs were not considered due to lack of data availability. Benefits were compared with the project cost and the maintenance cost of the grade separation. Project Benefit-Cost Ratio was then calculated for the previously considered ADT levels, and a sensitivity analysis was carried out considering different cases of changing benefits and costs to assess the economic strength of the selected criterion. On the above results, a limiting ADT value to identify the four-lane and two-lane grade separation requirements are proposed. In future studies, it is recommended to obtain more comprehensive results by incorporating train speeds, the number of rail tracks and savings from accident costs.

**Keywords:** *Level Crossing, Grade Separation, Economic Evaluation, Economic Benefits*

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## Identification of Attributes on Selection of a Departure Airport in Sri Lanka

*Osanda Daluwatta<sup>1</sup> and Dimantha De Silva<sup>2</sup>*

### Abstract

The world has become a smaller place through the expansion of the aviation industry. Commercial airports enable millions of people to travel for business, go home for the holidays, take vacations around the globe, or travel to other important events. Most contemporary airport management studies and research focus on airport efficiency, effectiveness, processing speed, and ranks on international league tables. These policies appear to favour airports that can efficiently transport most travellers and their luggage. Identification of passenger airport choice determinants may be of great value to airport managers as it can assist with determining passengers' demand at the Airport. These studies include different airports and different segmentations of passengers. Air passengers usually choose airports after considering multiple factors such as airfare, frequency of flights or flight schedule, access time, airport delay, and modes of the Airport. The choice may be influenced by the socio-economic characteristics of the individuals and the purpose of the travel. However, there is no general approach to model how air passengers will choose their origin airport in response to attributes of the air travel, attributes of inside and outside the terminal based on their travel purpose. It is important to identify the attributes that will influence a departure passenger to select a departure airport because it is a crucial component when planning passenger redistribution policies. This paper adds to the body of knowledge by providing a deeper understanding of the variables affecting air traveller's experience as expressed by travellers depending on their trip purpose, whether it is business, leisure, pilgrimage or migrant worker trip. The objective of this paper is to identify the influential factors for selecting a departure airport by air travellers based on their travel purpose, which is fulfilled based on the data collected from air travellers who visited Bandaranaike and Mattala International Airports. For this purpose, 350 individuals were sampled using a special questionnaire through internet-based and direct personal interviews. The analysis presented in this paper has shown the important role of Air Ticket Price, The Access Time to the Airport, The Number of Transfers to the Destination and The Number of Flights per Day to the Destination were found to have a consistently significant effect on Business, Leisure and Migrant travellers while Air Ticket Price, The Cost of Getting to the Airport, The Number of Flights per Day to the Destination and Availability of multiple transport modes to the Airport were significant for Pilgrimage travellers in airport selection. As a further study, the selected attributes will be used on the SP survey to estimate a logit choice model for the selection of a departure airport. The findings of the research can be used by the airport authority and various transport operators for evaluating the changes in the service attributes in international airports improving the discounted airfares, ground access mode services, airport facilities, and airport efficiency for increasing the competitiveness of the Airport.

**Keywords:** *Airport Choice, Multinomial Logit Model, Discrete Choice Model, Stated Preference Method*

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## Multi-Criteria Analysis to Prioritize User Expectations at Traffic Signal

*Pakkiyarajah Saranjan<sup>1</sup>, Saman Bandara<sup>2</sup> and Isuru Gamalath<sup>3</sup>*

### Abstract

Traffic signals regulate complex traffic situations and minimize conflicts to enhance the safety of all road users. Further, traffic signals aim to provide an orderly flow of traffic to minimize delays. However, poorly designed traffic signals can result in user inconvenience. Discrepancies between road users at traffic signals can have an impact on the smooth flow of traffic and the effectiveness of travel. The objective of this study was to identify and prioritize the user expectations at traffic signals considering different user groups, such as drivers, pedestrians and passengers, to provide a resource for agencies that are responsible for implementing and managing traffic signals. From the literature review, three main categories of issues and their relevant parameters concerning traffic signals were identified: safety, delay and ease of use. Key parameters identified for safety are conflicting turning movements, red light violations, jaywalking, and lightings at the pedestrian crossing at night time. Effects of the near-side bus stop, the higher number of intersecting approaches at signals, number of heavy vehicles, peak hour and on-street parking were identified as delay-related parameters, while the visibility of traffic signals and countdown timers were identified as ease of use, related parameters. These issues arise because of the conflicts of the behavioural and expectation difference among different road users. A survey was conducted to understand the priorities for the above-identified categories and their parameters for different road users. The questionnaire is distributed online and shared among different groups of people via social media. This study obtained responses from 357 participants via the online questionnaire. A scoring method was used to identify the participant's expectations on each parameter. The weightage of each parameter was calculated according to the score given for each parameter by participants. Collected data were analyzed using the multi-criteria analysis. The final weightage values obtained from the analysis are used to prioritize the parameters. From the analysis, it was found that all road users prioritize their safety more at the traffic signal than delay and convenience of use. Further, road users are giving slightly higher importance to ease of use than delay. Drivers and passengers give more importance to red-light violations, jaywalking and high speed at the end of the amber period for the safety parameter. According to drivers, far-side bus stops and noise from vehicles have the least priority. Pedestrians stated that the lighting at the pedestrian crossing (for night-time use) and conflicting turning movement of vehicles are having the highest impact. Pedestrians are given the least priority for longer cycle times and emissions from vehicles. Further, expectation differences in each subset of groups were analyzed by considering age, gender and mode of travel.

**Keywords:** *Multi-criteria analysis, Traffic Signals, Simple Additive Weightage (SAW), Safety, Delay, Ease of Use*



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## **Model to Identify the Optimum Feeder Bus Route for an Urban Rail Transit Station Based on Capacity of Feeder Buses**

*Umalexman Kanagasingam<sup>1</sup> and Saman Bandara<sup>2</sup>*

### **Abstract**

Urban rail transit systems are very cost-effective as compared to other transit modes though they cannot provide wider service coverage for the users. Feeder buses play a major role in filling the service gaps left by urban rail transits. The effectiveness of the feeder bus of an urban rail transit depends on its bus route length, frequency, capacity, and travel time. As all parameters are interconnected, changing one will impact others. This study discusses a mathematical model to identify the optimum feeder bus route for an urban rail transit station. The effectiveness of the feeder bus can be optimized by reducing the total cost of /the feeder bus service. The total cost includes both the user's costs and the operator's costs. Several service parameters influence the components of the total cost equation. The parameters discussed in this study are route length, frequency, bus capacity, travelling and waiting times, walking distance and passenger behaviour characteristics. Assumptions were made regarding passenger behaviour because it varies for every passenger according to several factors. For example, bus stop spacing and maximum walking distances were assumed to be constants, and all roads were assumed to be in grid mesh format. First, a simple model was developed that has one trip generated to the railway station. Then it is further extended to one bus stop from which several trips are directed to a railway station. After that, a model that has several bus stops in a feeder bus route that connects to a railway station was developed. From there, an optimized many-to-one feeder service model was identified. In different instances, there will be changes in the values of the parameters in the mathematical model. By using the mathematical model, we can check which set of parameters best suits the optimized route. This can be further extended to a many-to-many demand model that has several railway stations and bus stops that are interconnected with each other.

***Keywords:*** *Feeder Bus, Urban Rail Transit, Cost, Mathematical Model*

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## Neural Network-Based Approach to Adaptive Traffic Signal Controlling

*Chathura Chamikara<sup>1</sup>*

### Abstract

Machine learning and neural networks have been the last decade's central topics in the tech world. Today we can observe many day-to-day used cases of machine learning and related technologies in our lives. Some of them have been part of our lives without even us realizing it. Machine learning and neural networks are good at solving problems that usually don't have straightforward solutions. The primary use case of machine learning within the realm of traffic control comes from visual-based vehicle identification. This is a subject field that has been thoroughly researched. This research aims to find the feasibility of having neural network-controlled traffic signals in isolated and coordinated arrangements in a road corridor. It is intended to give the decision power of a traffic signal to a machine learning algorithm that has been trained on that specific task. The method is also intended to address two drawbacks in signal timing calculation. The first one is the lack of a mechanistic-empirical approach to a traffic signal timing design, where the trained machine learning algorithm can act as the mechanistic component to check or verify the empirical design. The other downside of traffic signal timing design is it is essential to conduct a traffic survey for every specific junction. And every design should follow with calculation for phase design, amber time calculations, determination of cycle length, and other empirical tasks. This method could replace all that effort with the concept of "train once and deploy anywhere". The first neural network was created for a four-way junction with four input nodes for queue length in four directions, twelve hidden nodes, and four output nodes. The sigmoid activation function was used on the hidden nodes, and the softmax activation function was used on the output nodes. Softmax activation ultimately outputs which direction the traffic light should be set to green depending on the input queue length data. This method uses an unsupervised learning technique that selects the best outcome out of 25 simulations that run parallelly and advance it to the next generation. The algorithm creates 25 new parallel simulations with the selected best neural network from the previous generation by adding random changes to the neural network parameters. Each generation runs for a fixed time frame (10000 frames) before it gets reset, and the best neural network gets to advance to the next generation. This simulation is carried out until the number of cars that pass through the junction within the given time frame is levelled off, and the best-performed neural network can be saved. The predominant objective of this research is to introduce an all-in-one solution to automate signal controlling where traffic surveys and scenario-specific calculations for phase timing are not required. Rather than having a fixed set of rules for the given queue length, this neural network can be trained and deployed into inexpensive hardware like Arduino or Raspberry-pi to control a traffic signal adaptively. And with some improvements, this technology can be extended to carry out the signal control timing of a road corridor or a road network where a single neural network can control all the traffic signal timing in a road grid adaptively. This neural network will be able to adapt to different traffic scenarios and other external factors, such as different weather conditions and rush hour traffic.

**Keywords:** *Machine Learning, Traffic Signal, Big Data, Neural Network, Traffic Engineering*

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## **Study of Driver Behavior at Entrance Ramps of Expressways in Sri Lanka**

*Dhammika Ratiyala<sup>1</sup> and Wasantha Mampearachchi<sup>2</sup>*

### **Abstract**

Driver behaviour characteristics have a significant influence on the design of an expressway interchange ramp terminal in relation to traffic safety. In general, ramp terminals are more prone to accidents because of their function, which includes traffic merging, diverging, and changing lanes more frequently. These factors increase driving anxiety and lead to more accidents. In addition, due to the adoption of various design standards in various projects, the ramp terminal lengths of Sri Lankan expressways differ from one to another. The primary goal of this research is to examine how drivers behave at the entrance ramp terminal in relation to crucial influencing elements such as vehicle entry speed, ramp terminal entry zone, and expressway through traffic speed at the proximity of the entrance ramp terminal, as well as to examine ways to enhance drivers' behaviour there. Six interchanges, Kerawalapitiya, Kothalawala, Kottawa, Galanigama, Pinnaduwa, and Godagama, were selected for further study based on the variation in acceleration lane lengths among them. The study was conducted utilizing video data from a CCTV camera installed at the Kottawa Interchange on 27th February 2020, and since there was no CCTV camera available at the other five Interchanges, a drone survey was carried out in other places on 14<sup>th</sup> October 2020. The analysis was carried out based on two important parameters, which were identified through the literature survey: 1. Vehicle entering speed to the expressway and 2. Vehicles entering the zone to the expressway through the entrance ramp terminal. The speed of the vehicles as they enter the expressway is significantly lower than the speed of expressway vehicles, except at Godagama Interchange, according to the analysis. The entry speed into the expressway is 60 kmph on average for all six interchanges. This necessitates a larger space between oncoming expressway traffic and entering traffic using the acceleration lane. Another significant aspect was that the vehicles entering the expressway did not use the expressway acceleration lane as anticipated. At the Kottawa Interchange, a higher percentage of vehicles entering the expressway (20%) was observed beyond the ramp's tapering. In violation of the safety regulations, 27% of vehicles at the Godagama Interchange entered the expressway in the chevron area. When all interchanges are considered, only 50% of the vehicles entered the expressway through the designated zone, while the remaining 50% used the ramp taper, the chevron region, or beyond the ramp taper. The research results support the conclusion that drivers lack the necessary knowledge to use the expressway ramp terminal based on a careful investigation of driver behaviour, including how they enter the expressway and at what speed. In order to educate the drivers before they enter the expressway, The phrase "Prepare for the Expressway Speed" has been selected as the appropriate wording for the signboard as a result of a survey that was conducted among design engineers and experts involved in the field of geometric design of roads in Sri Lanka. Additional variable speed signboards displaying ramp speed to expressway speed along the ramp have been identified as a secondary measure to promote uniform speed at the expressway entrance. Based on the research results, it is recommended to notify drivers of the expected way to enter the expressway through the entrance ramp terminal by signboards, publicity through television programs, or printed media.

**Keywords:** *Expressway, Entrance Ramp Terminal, Entering Speed, Driver Behavior*

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## **Analysis of Suitability of Dry-Back Process in Sri Lankan Road Pavement Construction**

*Vinothan Vasavan<sup>1</sup> and Wasantha Mampearachchi<sup>2</sup>*

### **Abstract**

Moisture content is an important component in the Compaction of pavement layers in road construction. Moisture content in pavement layers is varied by precipitation and environmental factors in the construction and operational stages. If the measured moisture content of the pavement layers exceeds the optimum moisture content, it causes premature pavement failures, such as traffic compaction in the wheel path. Also, this excess moisture content leads to the formation of undulation in the pavement. Therefore, the Dry-back process is widely used in Australia and New Zealand to prevent such pavement failures. The dry-back process is required to prevent the pavement from moisture-related failures. Water is added to the pavement material to achieve a specified density in the construction stage. If the moisture content of the pavement layer exceeds the optimum moisture content, pavement material must be allowed to dry to a certain level below the optimum moisture content. It is known as the dry-back process. Before laying one pavement layer over the other, the water content of the laid pavement must be checked. This is the quality measurement activity for the dry-back process. This research mainly focuses on the dry-back Requirement in Sri Lankan Road pavement construction. The research was carried out using four methods such as survey, material comparison, case study, and practical analysis. First, based on carried out industrial surveys, it was found that the dry-back method is followed in Sri Lankan pavement construction practices without understanding the exact process of it. Second material comparison, In Australia, higher quality materials are allowed for pavement construction when compared with the Sri Lankan Standards. In Australia, field compaction is maintained at a higher value, whereas California Bearing Ratio (CBR) is kept lower than the Sri Lankan materials specification. Various testing methods are practised in Australian Construction processes to ensure the quality of materials compared to Sri Lanka. The third Case study, weather reports, and testing summaries were interpreted to identify the pavement layers with high moisture content, specifically during the rainy season. On the other hand, failures on the pavement surface were identified. Professionals were interviewed regarding these pavement failures, while weather reports and material testing-related data were analyzed. Both approaches clearly illustrate that high moisture content might increase the possibilities of reconstruction of layers, obstruction in the pavement compaction, and pavement failures. Further, this finally practical analysis was carried out in the road sections where cracks are formed on pavements due to moisture content above the optimum moisture content. The moisture content of the pavement layer should be below 60% degree of saturation is preferable for the Sri Lankan pavement condition. This condition is derived from the literature survey and practical analysis of this research. Hence it can be concluded that the dry-back process is a primary requirement in Sri Lankan Road pavement construction.

**Keywords:** *Dry-back, Optimum Moisture Content, traffic Compaction, Degree of Saturation*



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## **Framework to Incorporate Safety Performance in Highway Asset Management System- Case Study on Provincial Roads**

*Shobitha Tharmarajah<sup>1</sup> and H.R. Pasindu<sup>2</sup>*

### **Abstract**

According to the functional and management obligations, the road network in Sri Lanka is classified into national, provincial, and local authority roadways. Provincial roads in Sri Lanka are considered class C and D, which serve as connections between urban and rural areas to ensure social and economic necessities. Even though a developing country, the majority of these roads are in poor condition, and safety concerns are in minimal condition. Lack of accurate accident data and road conditions are reported as major factors for poor road conditions and minimum safety concerns. This study proposes a methodology to determine a safety index to evaluate safety performance on provincial roads in Sri Lanka with the maintenance scheme using an optimization approach. A cumulative safety index (CSI) is computed with the fundamental elements such as exposure, probability, and consequences identified from the safety audit. The volume of motorists and non-motorist is used to calculate exposure. The probability component of risk is obtained by using the guidelines developed for each safety issue and by making an assessment of each road feature using the point scale, and the consequences factor is calculated with the posted speed at the safety issue. The Computed Cumulative Safety Index (CSI) is validated by using available crash data. All severity levels in the crash data, such as fetal, grievous, and non-grievous, are translated to a single scale termed Equivalent Property Damage Only (EPDO) to validate the results. Once the actual EPDO is calculated, multiple regression analysis tools are used to determine the relationship between the actual EPDO and a computed CSI composed of identified safety issues in the road segments. Actual EPDO and estimated EPDO were compared using Root Mean Square Error (RMSE). Safety treatments are implemented to identify safety issues at the given location. All of the safety treatments are unable to be implemented in the area due to a lack of funds. Low-risk safety treatments, high-risk safety treatments and combinations of low and high-risk treatments were categorized. A framework is proposed to include safety performance in the Highway Asset Management System, particularly in the optimization analysis, which comprises the objective of minimum average network CSI. The results from the study show that roads with safety concerns are prioritized in budget allocation with a feasible combination of safety treatments. This methodology provides a crucial and cost-effective analytical tool for the Highway Management System, which simplifies the process of including road safety performance in provincial road network management.

**Keywords:** *Provincial roads, Safety Index, Cumulative Safety Index, EPDO, Optimization*

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## **Review of the Road Sector Investments in the Last Decade: Its Economic Impact and Sustainability**

*M.J. De Silva<sup>1</sup>, H.R. Pasindu<sup>2</sup> and Y.M.S.S. Mahinda Bandara<sup>3</sup>*

### **Abstract**

The Sri Lankan government allocates a significant amount of its yearly capital expenditure toward road infrastructure projects. Since the end of the war terror in 2009, the Road Development Authority (RDA) has invested around 6% of the government's total construction budget for road projects. A significant proportion of financial resources voted for Provincial Councils, and nearly one-third of what RDA obtains has been committed to road infrastructure expansion. When assessing the economic feasibility of a particular road section, a threshold Project Impact Rate of Return, EIRR (Economic Internal Rate of Return), of 10-12% is typically used. Given the country's GDP, this would be a substantial amount of money for a developing country like Sri Lanka. So, determining how effectively capital funds are provided in contrast with the benefit utilization is critical for a sustainable economy. Moreover, the per capita expenditure under transport administrative overheads is drastically high in the country, which has created an unsustainable expenditure for the government of Sri Lanka with a fragmented set-up in road construction. At the same time, this study shows whether these road investments have been effectively materialized in the last decade toward the country's sustainable economic growth. The data collection for study was done through primary and secondary data collection, mainly focusing on RDA, PRDA, and rural road projects. In the methodological approach, the performance of road sector investments over the previous decade was analyzed with an emphasis on how money was transferred for road network construction. Identification of how total investments were aggregated across multiple state agencies in Sri Lanka was carried out along with a multi-year benefit calculation in comparison with VOT (Value of Time), VOC (Saving on Vehicle Operating Cost), Accident Cost Saving and Regional Benefits. Funding patterns and scenarios were established while investment distribution by province, road class, and geographic locations was taken into account to compare the GDP growth rate of each province and subsequently to identify growth potentials in respective areas. The calculation was done considering the total expenditures where all these projects would have been feasible under a Minimum EIRR of 10-12%. The study determined whether these projects could provide the expected benefits for the country and if it is reflected in the natural GDP Growth rate. The Macro-Economic approach of the Harrod-Domar (HD) Model of Economic Growth and Development Theory was applied to this concern. Descriptive statistics and regression analysis were carried out in the context of project EIRRs, financial investments, NPV, road length, and road class wise, and subsequently, several relationships were developed. The findings revealed that predicted benefits in the road sector over the previous decade had been overstated since the underlying assumption of estimated economic benefits that would convert into economically productive activities and economic growth has not been properly materialized. The research findings are beneficial in prioritizing which road investments with adequate growth potentials are yielding the highest return. Correspondingly, for understanding how budget allocations could be done for the next 5-10 years so that there would be a better return on investment and

diversifying road sector investments to yield the maximum benefits for Sri Lanka. Additionally, the findings are advantageous to ensure whether there is a better balance between infrastructures and sectors that will contribute to the overall economic development of a particular area.

**Keywords:** *Road Sector Investment, Benefit Utilization, Growth Potentials, Budget Materialization, Sustainable Economy*

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## **Axle Load Distribution for Mechanistic-Empirical Pavement Design in Sri Lanka**

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### **Abstract**

The AASHTO Mechanistic-Empirical (ME) method of pavement design seeks to combine physical causes such as stresses, strains, and deflections within a pavement structure and empirical mathematical models. The pavement responses under the ME method are computed using detailed traffic loading, material properties, and environmental data and are used to predict incremental damage over time. The design of pavements under the ME method is an iterative process using analysis results based on trial designs postulated by the designer. The basic advantage of the combined ME method over a purely empirical method is the ability to accurately characterize in-situ material. Hence it can be used for both existing pavement rehabilitation and new pavement construction, and also, the ME method accommodates changing load types and allows the designers to optimize the pavement designs. However, in Sri Lanka, the design references frequently used for local road designing purposes are the Overseas Road Note 31 and AASHTO method, which do not allow the designers to utilize the in-situ material characteristics in the design process in order to utilize the readily available materials effectively. Therefore, in most scenarios, the economy of road construction is affected detrimentally. Therefore attempting to adopt the ME design method in Sri Lanka is worthwhile investigating. For the pavement design using the ME method, the axle load spectrum data is required. In general, traffic volume is more convenient to obtain than load spectrum, considering the time and resource consumption in gathering data. The historical traffic counts and vehicle classifications are more likely to be available on many existing routes. However, for a new route, historical traffic data may not exist at all. Under these circumstances, it is necessary to estimate load spectra based on indirect information. Therefore, there is a need to develop default or representative axle load spectra that can be used with some level of confidence in the design process. Therefore, this research is aimed at deriving region-specific axle load spectra that will allow the generation of more appropriate inputs for pavement designs from the ME method. This study uses hierarchical clustering methodology and Euclidean distance matrix to identify geographical zones having similar characteristics in axle load frequency distributions. For single axle/ single tires axle loads, three geographical zones and for single axle/dual tires axle loads, four geographical zones have been identified for having similar characteristics in axle load frequency distributions. The axle load zones derived in this research will allow the estimation of traffic input to the ME pavement design approach from limited site-specific traffic data and will support the implementation of the ME design method in Sri Lanka.

**Key Words:** *Mechanistic-Empirical Pavement Design, Axle Load Distribution, Traffic Load Zoning Design*

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## **Incorporating Value of Travel Time Reliability for Transport Sector Project's Economic Feasibility**

*W.A.M. Induni Lakshika Abeysinghe<sup>1</sup> and H.R Pasindu<sup>2</sup>*

### **Abstract**

Travel Time Reliability has a fundamental impact on travel behaviour. Based on previous studies, in general, reliability is considered the degree of uncertainty that travellers experience in moving between any two nodes in a network. Travel time reliability is one factor that is very important for travellers in order to make their journeys more effective with time and cost. In many countries that are improved and implemented advanced transport methods, major infrastructure projects are evaluated using cost-benefit analysis, after which specific guidelines are applied. The reliability of travel time is a factor that is less spoken about, as travel time has not been directly included in cost-benefit analyses in most of the studies. Hence it is difficult to find suitable valuation methods for inclusion in cost-benefit analysis. It is important to consider both monetary values of reliability as well as reliable forecasting models when analyzing the cost-benefit ratio of infrastructure projects. A major focus of the paper is to find a method to incorporate the value of Travel Time Reliability, which is also the topic of most existing literature on modelling and valuing Travel Time Reliability for Economic Feasibility when Transport infrastructure is planned. In recent years, based on the literature reviewed and evaluated by the Dutch Ministry of Transport, it found that the Reliability Ratio is a key concept that should be included in the preliminary economic analysis. The reliability ratio is determined by dividing the value of reliability (VOR) by travel time, and the Value of Reliability is measured as the Standard Deviation of Travel Time. The reliability of travel modes has been found to be one of the most significant attributes of transportation systems. But it observed that only a few attempts had been made to use these findings. Changes in travel time reliability are not included in the standard evaluation and appraisal process of transport infrastructure projects and policies in Sri Lanka. Transport projects have been observed to affect not only by the average travel time but also their distribution. Previously, increased travel time reliability for road projects was included in the Dutch Cost-Benefit analysis. This was done by incorporating the travel time benefits that have been gained by reducing congestion. Hence it was observed that the reason for most of the delays is the traffic congestion of the roads. Therefore, here it is assumed delays are mostly due to the congestion, and the relationship is when the congestion decreases, the reliability increases. This research focuses on deriving empirical relationships between travel time, the standard deviation of travel times, mean delay (Mean Delay is the difference between mean travel (MTT) time and the free flow travel time (FFTT)), and route length by using the Dutch national model and a predictive model for travel time reliability for the Sri Lankan context. This was already incorporated in the Netherlands and German guidelines for Cost-benefit analysis and economic analysis for transport infrastructure projects.

**Keywords:** *Travel Time Reliability, Feasibility Study, Economic Analysis*



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## **Impact of Autonomous Vehicles on Road Safety in Heterogeneous Traffic Conditions**

*Kasun Chathuranga<sup>1</sup> and Saman Bandara<sup>2</sup>*

### **Abstract**

Autonomous vehicles (AVs) can sense their environment and operate without human involvement. These AVs are implemented with a lot of Advanced Driver Assistance Systems (ADASs). Six levels of driving automation have been defined by the Society of Automotive Engineers (SAE), ranging from Level 0 (no driving automation) to Level 5 (full driving automation). Most of the ADAS features can be seen on vehicles belonging to the SAE level 2 or above. A few features, such as Lane Centering (LC)/ Lane Keeping Assist (LKA), Adaptive Cruise Control (ACC), and Automatic Parking, are categorized at level 2. The majority of vehicles in Sri Lanka belong to levels 0 and 1, and some vehicles that belong to level 2 are also available. However, vehicles that belong to Level 3 or above are hardly seen. Autonomous vehicles and ADAS features are fairly new subject areas in the local context. Sri Lanka does not have a developed road network that can fully accommodate autonomous driving. Further, the vehicle composition on Sri Lankan roads is very different compared to that in developed countries, as there is a higher percentage of light vehicles such as three-wheelers and motorcycles. Despite the above differences and challenges, for a country with high congestion in urban areas, many advantages can be obtained from facilitating an A system. These benefits include accident reduction, improved fuel economy, increased lane capacity, reduced travel time, etc. It is proven that automated vehicle technology could result in greater efficiency in fuel/time savings and a significant reduction in congestion without the need for additional capacity. The main purpose of this study is to study the effect of the different ADAS categories and ADAS combinations against the identified accident types to compare the effectiveness of the safety features in the Sri Lankan context. In addition to that, by identifying theoretical and practical road safety issues in a hybrid system where different levels of ADAS vehicles are present, the road safety outcomes can be analyzed with respect to the autonomous levels and the different percentages of each type. Subsequent to the identification of safety features and ADAS categories, accident types, and the causes of the accidents, an organized database was created. An online survey form was developed to gather vehicle and accident details from the public. A descriptive introduction and a set of identified accident categories were included in the survey form so that respondents could provide their vehicle details along with the ADAS features and past accident details. Responses for 200+ vehicles were collected, including around 40% responses with details about one or more accidents that have happened during the last five years. The second stage of this study was to focus on secondary data sources such as accidents recorded by police and the expressway management division of the Road Development Authority. Vehicles involved in fatal accidents were filtered out, considering only cars manufactured after 2005 to accommodate different autonomous levels for accidents recorded in police reports for 2017. Expressway accident records available from 2016 show that the number of fatal + grievous + non-grievous accidents in total is around 100 per calendar year. Around 250 cases were chosen for further study after sorting them by the severity of the accident. For

selected accidents from expressway reports and police reports, the vehicle model and the manufactured year were identified for each vehicle using the database available on the Sri Lanka Motor Traffic Department website. As the next step, accident type combinations and the corresponding ADASs were categorized. Potential accident reduction percentages for each ADAS-accident type category were found. The results show that most of the time, these features individually have the potential to reduce the severity of the accident by around 15%. When two or more ADAS features work together, not only reduces the severity but high accident prevention percentages can also be achieved. Two scores for the safety level and the autonomous level were then obtained by assigning weights to the corresponding ADAS features. In the absence of any detailed studies, those assumed weights were derived by studying the impact that each ADAS can have according to the results of the above study done for ADAS and relevant crash patterns. According to the selected data set and the assigned weights, it is found that the average safety score of the Sri Lankan context for urban, suburban and expressway road sections is 10.7%, and the autonomous level is only 1.8%. Finally, considering the results and the current vehicle composition, advanced driver assistance features were categorized and lined up in the order of being the most effective in the Sri Lankan context.

**Keywords:** *Autonomous vehicles, Road Safety, Traffic Management, Accident Prevention, Safety Features, Advanced Driver Assistance Features*

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## Implementation of Warm Mix Asphalt in Sri Lanka: Case Study

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Chamod Hettiarachchi<sup>4</sup>, Jennifer Weerakoon<sup>5</sup> and Iromi Ranasoma<sup>6</sup>*

### Abstract

Warm Mix Asphalt (WMA) is the technology that allows a reduction in the production and paves temperature of Asphalt. WMA can be produced using four different technologies; chemical additives, organic additives, water-bearing additives and water-based processes. Adaptation of WMA may reduce the production cost, paving cost, and emission of greenhouse gases and allow longer paving season. Therefore, implementation of WMA in Sri Lanka is vital as WMA can be an answer to the economic crisis and has been recognized as the future of Asphalt. Organic additive technology or chemical additive technology was decided to select for the implementation of WMA in Sri Lanka as the minimum plant modifications in these technologies. Sasobit®, which is an organic WMA additive, was selected for the implementation as it is available in the south Asian region, and further, this was successfully implemented in India. Sasobit® is a synthetic wax which decreases the viscosity of the bitumen in lower temperatures. However, below 90°C, Sasobit® creates a crystalized lattice structure allowing the modified bitumen to stiffen and increase the rutting resistance. The optimum Sasobit® percentage was determined as 2.5% by mass of binder by analyzing the results of viscosity against the Temperature curve. A Series of samples with bitumen modified by optimum Sasobit® percentage shall be prepared in different mixing temperatures and different compaction temperatures falling under the WMA temperature range. The mixing temperature and compaction temperature shall be selected where the optimum density was achieved, and results are within the limitations stated in ICTAD specifications for Marshal Test. The mixing temperature was found as 140°C, and the compaction temperature was 130°C. The section selected for the study is 500m in Mawanella. A paving trial was conducted near the selected study area for 57 m, and it was observed that the required degree of Compaction was achieved with lower roller compaction coverage. The bitumen decentering plant was modified to achieve the modification by Samsonite®. Bitumen was circulated through the plant for 2 hours after Sasobit® was added, and the temperature was maintained at 140°C. The mixing of Asphalt was maintained at 140°C, and the Compaction at the field was started when the temperature was 130°C. One breakdown roller coverage was able to be reduced, and four intermediate roller covers were ably reduced from typical roller coverage, and still, the required degree of Compaction was achieved. Further, it was observed that the temperature drop to 60°C in the WMA is 120 minutes (2 hours). Temperature is lowered in WMA bitumen production by 10-15°C allowing cost saving duet lowered use of fuel in heating of materials. Further, the required degree of Compaction was achieved by lower roller coverage. Moreover, the road can be open to traffic less than 2 hours from the time of the paving. Therefore, the paving season can be increased /which is beneficial for roads with heavy traffic flow. Implementation of WMA in Sri Lanka is vital at this stage, and it is evident WMA can be used as absolution for the current economic crisis. However, there are more options for modification methods, and the use of recycled Asphalt is more feasible in WMA. Hence, it is recommended to study more along these avenues.

**Keywords:** *Warm Mix Asphalt, Organic Additive, Cost, Roller Coverage, Paving Season*

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## Development of an Economic Driving Cycle for Motorcycles and Estimate Emission

*Prasad Wijekoon<sup>1</sup> and Loshaka Perera<sup>2</sup>*

### Abstract

It is estimated that the transportation sector is responsible for almost a quarter of global energy consumption. When fossil fuels are burned, they release high amounts of greenhouse gases (GHG) which have a severe impact on the environment and humans. Since the number of vehicles is growing rapidly, control of such fuel combustion is essential. Therefore, new policies are to be formulated, especially in developing countries. In developing countries like Sri Lanka, motorcycles (MC) are a popular mode of transportation due to their economic implications. This study looks at how an MC operates under various traffic conditions in Sri Lanka and the content of combustion gases emitted to propose emission policies. For this purpose, the driving cycle for the motorcycle was developed in the first stage. A Driving Cycle (DC) is a speed-time profile, and it represents the driving characteristics of a selected region. DCs is widely used to estimate transport air pollutants and for building emission inventories. Thus, knowledge of the driving cycle is essential for the evaluation of exhaust emissions. Driving Cycles can be used for different purposes, such as setting up emission standards and determining the behaviour of the driver and the traffic condition of the selected route. As driving cycles are dependent on the driver's behaviour, mode of transportation, traffic condition, and road conditions factors, existing driving cycles developed for other vehicle types in Sri Lanka or developed for MCs in other countries cannot be used in Sri Lanka because they are different due to above said reasons. One of the main objectives of this study is the development of a driving cycle for motorcycles. For this study, the most popular types of motorcycles ranging from 100cc to 150cc engine capacities, were used. Motorcycles with these engine capacities were more suitable for this study as they are widely used in major cities as well as sub-major cities of the country. For this study, driving data is collected by motorcycle riders who are frequently riding the motorcycle in urban and suburban areas using a handheld GPS device. During the data collection, special attention is paid to the peak times because the traffic is significantly higher during such times, and thus the amount of combustion gases emitted is also high. This GPS-based data collection is more economical than other methods of collecting data for the driving cycle development. The collected data was filtered and removed the unusual characteristics were by using python code, and after that, data was divided into micro trips, including idle time. Micro trip-based cycle development is suitable for developing a driving cycle to estimate emissions. The micro trips thus created are randomly attached to create several candidates driving cycles. From those driving cycles, the best-representing driving cycle is selected by comparing the Speed Acceleration Frequency Distribution (SAFD) graph. The final DC selected has an average speed of 27.26 km/h, an average running speed of 35.31km/h, an average acceleration of  $0.284\text{ms}^{-2}$  and an average decelerate of  $0.2846\text{ms}^{-2}$ . Since there are no facilities in Sri Lanka to run the DC developed on a chassis dynamometer to measure the respective emissions, an approximate method was used in this study by referring to similar studies carried out elsewhere. Based on such comparison, the proposed emission factors for motorcycles are CO 0.5-3.0g/km and HC

0.25-0.4g/km for Sri Lankan conditions. These threshold values are suitable for setting up new emission standards for MCs in Sri Lanka or, in other words setting up local emission goals and adopting a carbon tax for MCs. On the other hand, these policies may encourage users to invest in low-carbon transport modes. It can save fuel by performing periodic emission tests for motorcycles and removing or restoring the engines. It helps to minimize fuel and energy wastage.

**Keywords:** *Motorcycle, Driving Cycle, Emission, Policy*

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## **Application of Sub-Ballast Embedded with Waste Rubber Tyres in Rail Infrastructure in Sri Lanka**

*Pasindu Sandaruwan Silva<sup>1</sup> and Udeni Nawagamuwa<sup>2</sup>*

### **Abstract**

Railway transportation has become one of the most popular modes for transporting freight and passengers all over the world due to factors such as increased road traffic on highways, urbanization, and population growth. Maintenance of rail tracks consumes a considerable cost. A ballast is introduced to bear loads, facilitate water drainage and prevent underlying vegetation from surfacing. While transferring the imposed loading uniformly to subgrade soil at a stress tolerable for the subgrade material, it provides the necessary degree of elasticity and resilience to absorb vibrations and shocks. However, ballast degradation is one of the major issues in the rail substructure due to excessive stresses and vibrations. Increasing the durability of the rail substructure will minimize the cost needed for maintenance and replacement. Geogrid and geocells can be placed below the ballast layer to prevent the frequent maintenance of the ballast layer. The three-dimensional cylindrical shape of the rubber tyre and the material properties match with the ground improved with geocells. Further, rubber tyre is a wasteland and cause numerous environmental and health hazards when dumped inappropriately. This research is a numerical study done with Finite Element Analysis using ABAQUS software. The traditional rail substructure, which contained the Ballast, Sub ballast, and Subgrade layers, is considered in the analysis. Proposed rubber tyres are embedded in the sub-ballast layer filled with sub-ballast material. 250kN and 350kN axle loads with the frequency of 10Hz dynamic load conditions are applied on the sleepers, considering the rail speeds in Sri Lanka. The impact of the sub-ballast embedded with filled rubber tyres subjected to cyclic loading is observed by varying the tyre sizes. Sizes of rubber tyres were selected based on the available waste quantity of such tyres in Sri Lanka. Sub-ballast embedded rubber tyre layer reduces the vertical stresses which are transferred to the subgrade, causing settlements. According to the results of the analysis, the most effective tyre size for reinforcement is 165/55R14 among the analyzed tyre sizes. The effectiveness of the tyre layer is increased with the decrease in the tyre section height. The number of rubber tyres that are needed to reinforce the 1km of rail track is also calculated in this study

**Keywords:** *Sub-ballast, Waste Rubber Tyres, Rail Infrastructure,*



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## **Factors which Influence Non-recreational Cycle Use in the Urban Context of Sri Lanka**

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### **Abstract**

Non-recreational cycling has been promoted for Colombo and other urban areas in Sri Lanka mainly through promotional campaigns and the provision of cycling infrastructures such as bicycle lanes or paths. However, there are no studies on real factors which influence the non-recreational cycling behaviour in the Sri Lankan context, suggesting that most of these infrastructure developments are not supported by studies. Information on non-recreational cyclists' preferences and behaviour is important for the effective planning of cycling infrastructure. This paper presents the findings to identify the most relevant factors which influence non-recreational cycling behaviour in the urban context of Sri Lanka. The factors which influence non-recreational cycling behaviour were initially captured through a comprehensive literature survey, and following that, the most influential cycling infrastructure-related factors as applicable to Sri Lankan urban context were identified through an online questionnaire survey. About 60 influential factors were identified in the literature, and among these, 16 cycling infrastructure-related factors, which were assumed to be applicable to a context where cycling is in the promotional stage, were selected to include in the questionnaire survey in the form of ranking questions. The questionnaire survey covered a sample of 400 online respondents, including 15% of existing non-recreational cyclists and 33% of existing recreational cyclists. The sample consisted of 61% of female respondents and 63% of respondents belonging to the age category of 26-35 years and 14% the 36-45 years. 79% of respondents were full-time employed either in the public or private sector. 44% of respondents use a car, van or jeep as the main mode of transport, while 32% use public transport. The selected 16 influential factors were divided into four categories, and the respondents were supposed to rank the set of factors in each category and finally assign the ranking for the four categories separately. Results revealed that the 'type of road facility is the most important category of influential factors, followed by 'safety attributes', 'supportive cycling facilities' and 'characteristics of cycling facilities. Among the four types of road facilities, 'riding on a dedicated bicycle pathway free of pedestrians or any other traffic' was the most preferred having 61% of respondents ranking it as their 1st choice and 'riding in mixed traffic' was the least preferred having 82% of respondents ranked it as their 4th choice. 2nd and 3rd ranked were 'riding on a demarcated bicycle lane on the road' and 'riding on a bicycle pathway shared with pedestrians' respectively. Among the three safety attributes, 'having a smooth, non-slippery riding surface' was ranked 1st, followed by 'having adequate lighting on bicycle pathways during night-time' and 'having overpasses to avoid complex intersections'. Among the six attributes under the 'cycling supportive facilities' category, 'availability of secured parking facilities at destinations' ranked 1st, followed by; 'availability of relaxing areas with basic facilities, 'availability of bicycle-friendly public transport', 'availability of locker facilities at the destinations', 'availability of a bicycle renting and sharing system' and 'availability of showers and changing facilities at destinations. The remaining six attributes under the 'characteristics of cycling facilities' had been

ranked in the order of; 'having adequate shade and trees' as 1st followed by 'direct connection to the target destinations via shortest paths', 'the route having direct connections to multiple uses like banks, shopping and schools etc.', 'having a continuous route without gaps in between, 'the route to ply along pleasant scenic views' and 'high security guaranteed with CCTV monitoring' as 6th. In the overall ranking of attributes regardless of the category of influential factors, 'having a smooth, non-slippery riding surface' was ranked 1st, having a relative score of 11.3% and factors such as 'adequate lighting' (9.2%), 'having overpasses' (7.7%), 'secured parking facilities' (5.0%), 'adequate shade and trees' (4.2%) and 'direct connection to the target destinations via shortest paths' (4.0%) were among the first top ten ranked influential factors along with the four types of road facilities for cycling. However, respondents had given relatively less priority in their preference for attributes such as 'availability of relaxing areas with basic facilities' (3.8%), 'bicycle-friendly public transport' (3.5%), 'route having direct connections to multiple uses such as banks, shopping and schools etc.' (3.3%), 'bicycle renting and sharing system' (3.1%), 'locker facilities' (3.1%), 'showers and changing facilities at destinations' (3.0%), 'having a continuous route without gaps in between' (3.0%), 'having pleasant scenic views' (3.0%) and 'high security guaranteed with CCTV monitoring' (2.3%), although most of these are perceived as important factors in similar studies conducted in contexts where non-recreational cycling is a more frequent mode of transport. The reason why some of the factors, such as availability of lockers, showers, changing facilities, direct connections, relaxing areas with basic facilities, bicycle-friendly public transport and bicycle renting and sharing systems which are highly demanded in other bicycle-friendly cities, had been given less importance by the respondents could be because they are not existing cyclists and that they may find it important once they start non-recreational cycling. The future works of this study include a stated preference survey and analyzing stated preference observations with logit choice estimations in order to identify the relative importance of identified most relevant influential factors.

***Keywords:*** *Non-recreational Cycling, Influential Factors, Cycling Infrastructure*

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## **Analysis of Optimal Expansion Level of a Single Runway Airport**

*Sajeewa Siriwardena<sup>1</sup> and Loshaka Perera<sup>2</sup>*

### **Abstract**

Air travel is rapidly increasing all over the world, and airport capacities are crucial when serving this growing demand. When it comes to airport capacity, whether it is passenger or freight, runway capacity is the key determining factor among many others. At the same time, adding a runway to existing airports is an expensive process, from the design itself to obtaining approvals, construction, and completion, compared to any other developments associated with an airport, such as passenger areas and other service areas. However, despite the cost and other negative external factors involved, most airport authorities tend to make a bold decision to add another runway to the existing Airport without looking at optimizing existing and future operations. This appears to be the case for Bandaranaike International Airport (BIA), which made plans to build a second new runway to accommodate future traffic. Therefore, the main aim of this research is to identify how to achieve the optimal expansion of a single-runway airport without adding a second runway. This is achieved by identifying critical parameters that affect runway capacity and analyzing ways to obtain the optimal capacity. Hence, the next appropriate solution to accommodate future traffic growth is to optimize current operations rather than physical expansion due to drawbacks such as high capital costs, long implementation times, community opposition, and so on. After collecting the necessary data, an analysis was carried out to determine the current capacity and the utilization of the runway at BIA. From the analysis, it was found that during a peak period, more than 50% of runway capacity is idle, meaning that it's been underutilized heavily at present. In other words, BIA can simply double the operations with the existing runway, and now the question is whether BIA expects a growth rate greater than this within the next 15-20 years. There are ways to optimize runway capacities in addition to determining the truly available runway capacity. One such option would be to assist air crafts in evacuating from the runway in the shortest possible time without any hindrance to RADAR and wake turbulence separations so that they can conduct the next operations. This was found to be the next largest bottleneck hindering runway capacity, and as a result, the implementation of high-speed exits has been considered in this study using the REDIM software. In addition, the best departure and arrival sequences were discovered using Python code to utilize the time more efficiently, as runway occupancy time (ROT) differs according to the aircraft category. It can be concluded that the existing runway capacity could be further improved by optimizing the current operations, as ROT was reduced by 10%. ROT reduction leads to a reduction in costs and delays, which would make a significant difference during peak hours. As the world's busiest Airport that operates with a single runway, Mumbai airport handles aircraft at 65-second intervals, and it's important that optimization strategies are implemented at such airports to avoid significant delays.

**Keywords:** *Single Runway, Runway Capacity, Optimization, Airport Capacity, Runway Exits, BIA, Arrival and Departure Sequence*

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## **A Quantity Estimated Method to Measure the Flow of Nodes in Hub and Spoke Network -Evidence from Courier Service Network**

*Arjuna Vishwanath<sup>1</sup>, Jayawi Gunawardhana<sup>2</sup>, Ovinya Siriwardhana<sup>3</sup>, Dilshan Yethmina<sup>4</sup> and Sabeen Sharic<sup>5</sup>*

### **Abstract**

Measuring the flow of any node to all other nodes in a hub and spoke network is important for tactical, operational, and strategic decision-making. To measure the flow of any node to all the other nodes, data on both the quantity transported and the travel time taken from the node to all the other nodes in the network is required. In the literature, the flow of any node to all the other nodes in a hub and spoke network has been measured using the known data on quantity transported and travel time taken. At times, getting reliable data on the quantity transported between nodes is difficult due to many reasons, such as confidentiality and lack of proper recording of data. Therefore, the quantity transported between nodes must be estimated. The objective of this study is to develop a quantity-estimated method to measure the flow of any node to all the other nodes in a hub and spoke freight network. As the first step, the distances of all nodes to their respective nearest main trip generators were found. Nodes could represent warehouses, and the trip generators could represent cities, villages, industrial zones etc. Then the lowest and highest distances were figured out among the entire distances range. Using the lowest, highest and respective distance for each node, a criticality factor was assigned to each node. The criticality factors were ordered from the highest to the lowest. Nodes were categorized into three sections such as highest, medium and lowest. Each category was set to have an equal number of nodes. Then the criticality factor of the hub node was multiplied by the capacity of the vehicle to estimate the quantity transported from the hub node to all the other nodes respectively. This resulted in the estimated quantity of goods received by each spoke node from the hub node. Using the estimated quantity of goods received by each spoke node from the hub node, each node category (based on the criticality factor) was given weights. Then the quantity transported between any pair of nodes was estimated based on the weights of the respective node category, vehicle capacity and the number of nodes in respective node categories. Using this method, the quantity transported from any node to all the other nodes was calculated. This calculated value was divided by the estimated summated travel time from the node to all the other nodes in the network. The travel time data was derived from Google Maps. This ratio of the estimated quantity transported from a particular node to all the other nodes and the respective travel time from the node to all the other nodes resulted in the estimated flow of the node in the hub and spoke network. This method of measuring the flow of nodes was applied to a local courier service network in Sri Lanka. This courier service had 27 spoke warehouses around the island and a hub warehouse in the Capital, Colombo. This method was applied to the highway network and expressway network at both peak and off-peak conditions. The results revealed that warehouses that were in Vavuniya and Jaffna had the lowest flow, with 0.8489 kg/h and 0.294 kg/h. These warehouses could be relocated or consolidated to minimize the total expenditure. The highest flows were obtained at Biyagama and Katunayake warehouses, with flows of 1.4052 kg/h and 1.4191 kg/h, respectively. These warehouses could be occupied with more material

handling equipment. The results yielded many recommendations for lowering the waiting time at warehouses, using the expressways etc. This research contributed to the domain of hub and spoke network by developing a quantity-estimated method of measuring the flow of nodes.

**Keywords:** *Hub and Spoke Network, Node Flow, Courier Service, Quantity Estimated*

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## **Identification of Attributes Influencing a Functional Park and Ride Systems for Colombo**

*Kithmal Samarasekara<sup>1</sup> and Dimantha De Silva<sup>2</sup>*

### **Abstract**

Colombo, being the commercial capital and largest city of Sri Lanka by population, is plagued with traffic congestion in most of the corridors. Improving public transportation has been identified as the foremost approach to solving the congestion considering private vehicles have a higher share of the vehicle composition and carry fewer amount of passengers. Authorities have come up with different solutions like providing flyovers, constructing bypass roads, introducing bus lanes, increasing taxes on private vehicles, and widening existing roads, yet an intact result has not been delivered to Colombo city. 'Park and Ride' has been identified as one of the functionalities to make public transport more attractive because it aims to influence travellers' attitudes and behaviour into shifting from private vehicle use to mix mode of transport. A questionnaire survey was carried out to understand the attributes that influence the choice of passengers to use the Park and Ride system. The set of attributes listed in the questionnaire was obtained from previous studies conducted in different regions under different conditions. Selected attributes were categorized in to 6 major categories as; 'parking facilities' which asks respondents to rank a list of characteristics related to the car park in a park and ride system, 'facilities and services provided at the park and ride station' which asks respondents to rank a list of characteristics related to the park and ride station, 'characteristics and facilities provided in public transportation mode', which asks respondents to rank a list of characteristics related to the mode of public transportation (i.e. train, bus LRT), 'travel time characteristics' where respondents find a list of different time components related to a park and ride system (i.e. time spent on public transportation, time spent walking to the destination), 'availability of public transport mode', which asks respondents preference regarding the availability of different combinations of public transportation modes (i.e. availability of bus only, availability of LRT and bus only, availability of bus, rail and LRT) and 'general characteristics of park and ride', where respondents find a list of attributes which does not lies under any of the previous categories. 5-10 attributes were listed under each category, and respondents were asked to rank the given list within the category based on their preference. Each attribute was given a score referring to the survey results. The number of respondents who have ranked a certain attribute as '1' is counted, and it was multiplied by a relatively higher number (multiplying factor) based on the number of attributes given under that category. The same procedure was followed to allocate scores for the rest of the ranks (2,3,4.) given for that certain attribute, and the multiplying factor was reduced when the rank reduces. Sum of the scores for ranking as '1', ranking as '2' and the rest is taken as the score for that attribute, and a score was given to all the attributes by following the above method. Further, as the last stage of this survey, respondents were asked to rank the given major categories based on their perspective. The same mathematical analysis method used for ranking the attributes within the category was followed to allocate a score for the categories also. A final score was obtained based on the 'scores given for attributes within the categories and the 'scores given for the categories itself. This leads to the identification of



the most prioritized attributes regardless of major category. Using the above set of prioritized attributes, a stated preference (SP) survey can be conducted with a sample size of around 400 to identify the user perception of the attributes. The initial survey was conducted to identify the most important characteristics from the long list of characteristics obtained from the literature, and the highest-ranked attributes of that initial survey can be used for the SP survey. 380 responses were obtained for the aforementioned initial survey, and the results of the questionnaire revealed that 'certain seating facility in the public transportation mode', 'availability of the washrooms at the station', 'secure parking at the station', 'time spent waiting in park and ride station' and 'displaying Information on services (bus route/time, etc.) in the station' were the highest ranked attributes. It also exposed that respondents have less concern about 'having free parking at the station' and 'having a low cost or public transportation. Moreover, the results showed that the respondents prefer to have more options as their public transportation mode instead of having a single mode. This ranking of attributes generates a clear view of approaching the planning and design stages of public transport projects by providing scientific evidence so that ad-hoc decisions will be avoided. Therefore, the findings of the study would provide useful insights into the feasibility assessment of public transport projects, especially in the Colombo region.

***Keywords:*** *Park and Ride, Public Transportation, Attributes, Influencing Factors*

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## **Impact of Signalized Pedestrian Crossings near Un-Signalized Intersections**

*Nimesh Priyankara<sup>1</sup>, Nadeeka Jayasooriya<sup>2</sup> and Saman Bandara<sup>3</sup>*

### **Abstract**

Intersection control is the major function of the traffic flow. Its values increase when traffic flow becomes more severe. However, road authorities use some ad hoc methods to control intersections to reduce costs. Signalized pedestrian crossings near unsignalized intersections are one of the methods used by road authorities to control the intersection. This kind of arrangement can be found in Colombo and its suburbs. Some of the major issues observed at signalized pedestrian crossings near un-signalized intersections are as follows: Drivers coming from a by-road could not see the main road signal indications; vehicles from by-roads have to stop in the middle of the road due to vehicles queuing up in the merging lanes. In addition to the above, some other issues related to pedestrian signal operation are also identified. In situations where a push-button system for pedestrians is available, a significant delay for motorists can be experienced when the pedestrian flow is high. It creates delays and results in long queues. Though there are advantages with respect to pedestrian safety and partial control of intersections, some of the abovementioned issues result in many disadvantages as well. Therefore, this study aimed to evaluate the effectiveness of signalized pedestrian crossings near unsignalized intersections on both traffic and pedestrian movements. Five different intersection and signal arrangements are identified, covering four-way and three-way intersections, and issues related to each arrangement were identified based on the existing literature. A total of ten locations on Galle Road (A02) and Colombo Horana Road (B84) were selected for the analysis process. Geometric data of the intersection, manual and/or vision-based vehicle and pedestrian counts and queue lengths and details about the pedestrian phasing are collected during the data collection. Queue lengths and vehicle delay times, and safety considerations were analyzed to evaluate the effectiveness. These analysis results are to be validated using the open-source microsimulation software SUMO. It is found that it is better to go for a fully signalized intersection control for situations where pedestrian crossings are to be located on both sides of the minor road(s). For three-way junctions with single pedestrian crossings, it is better to locate the crossing at least 20 m from the intersection.

**Keywords:** *Un-Signalized Intersections, Signalized Pedestrian Crossing*

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## **Demand-based Roadside Parking Control Strategy for a Main Road Corridor**

*Methmal Dissanayake<sup>1</sup>, Isuru Gamlath<sup>2</sup> and Saman Bandara<sup>3</sup>*

### **Abstract**

Overcrowding in parking lots near high-demand locations is common in any main urban road, where parking demand often exceeds supply and parking spaces are distributed unevenly. This study aims to develop an effective roadside parking control methodology and strategy using the case study area of the Galle Road Corridor in Colombo, Sri Lanka. To accomplish this objective, it is necessary to identify various parking management strategies, identify parking fee methods and monitoring tools that are being used. In addition, the parking demand and supply on the selected section of the road are required. A single transportation corridor in an urban setting was studied, focusing on light and medium-duty vehicles. Instead of implementing a single uniform parking fee system for the entire region, we are proposing to implement a method where the parking fee varies based on the location and time of day so that demand can be distributed to less congested areas. Parking fees will be decided based on the above criteria. The methodology was developed using data such as parking location data and parking time data from the Colombo Municipal Council (CMC). Furthermore, the number of parking spaces was compared to what is currently being collected through Google Maps. The Galle Road section between Kollupitiya and Wellawatta was divided into 13 zones, and parking usage was analyzed by identifying demand, rush hours, and day variations of parking using CMC parking usage data. Following that, a physical survey was conducted to verify the past data that had been analyzed. The use of parking spaces during the day, as well as the vehicle type of parking vehicles, was monitored in the selected sections. Then identify, the pattern between those data and high, medium and low-demand sections was identified based on the time of the day and day of the week. Using CMC parking usage data, spot demand and parking variation by time and by day were identified. High parking was observed between 12.30 pm and 1.30 pm and 6.30 pm to 7.00 pm in the section from Pentrive Gardens to 5th Lane, as well as excess parking in the Alfred House Gardens to Bagathale Road section. As a result, pricing mechanisms can be used to distribute parking. The parking price and parking arrangements were adjusted according to the demand of the location. As a result of these changes, a new smart strategy for managing public parking in urban areas, such as a mobile app and features, was suggested, allowing for more efficient use of parking spaces in the city.

**Keywords:** *Roadside Parking, Parking Strategy, Parking*

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## Usage of Electric Vehicles to Deliver Groceries to End Customers

*Randula Abeyweera<sup>1</sup>, Mudith Witharama<sup>2</sup> and Loshaka Perera<sup>3</sup>*

### **Abstract**

Concerns about global warming caused by emissions from fossil fuels, as well as the depletion of energy sources, have prompted governments to encourage new transportation alternatives. As a result, new technologies such as Electric Vehicle (EV) technology have emerged. In comparison to conventional internal combustion engine vehicles (ICEV), the operation of an EV can be distinguished by zero CO<sub>2</sub> and NO<sub>x</sub> emissions, reduced noise, and higher energy efficiency. However, this is only true if electricity is generated through renewable sources only. Otherwise, it's a transfer of emissions from the transport sector to the energy sector. The demand for good delivery is fast increasing with a rising urban population and the explosive growth of E-commerce. As the number of delivery increases, so will the associated emissions. This establishes Electric Freight Vehicles (EFV) as a viable alternative to conventional internal combustion engine-powered freight vehicles. However, the inherent technical constraints of EV technology make adaptation more difficult. The biggest implementation challenges are expensive acquisition and maintenance costs, the restricted range per charge cycle, charging time and capacity constraints. The adoption of EVs for urban freight in developing nations is hindered by a lack of charging infrastructure and the variability of the freight vehicle mix, which poses operational challenges.

This study assesses the economic and environmental sustainability of deploying electric freight vehicles for last-mile delivery in developing countries. The electric car routing problem is evaluated using a genetic algorithm-based approach, and the model is tested in a case study in Colombo, Sri Lanka. According to the studies, the use of electric freight vehicles is economically feasible, and the assessment of environmental feasibility is subjective. If the transport sector is considered in isolation, then the adoption of EVs is more environmentally friendly, but in reality, energy is not carbon-free in Sri Lanka and thus, environmental feasibility is questionable under the current energy mix.

**Keywords:** *Electric Vehicles, Last Mile Delivery, Freight, Sustainable Transport, Optimum Routing*

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## **Estimating value of Travel Time Reliability**

*U.N. Matarage<sup>1</sup> and H.R. Pasindu<sup>2</sup>*

### **Abstract**

Travellers demand more needs to be met from a journey, from a certain origin to a destination. Therefore, one of the most crucial factors to take into account when travelling is how often the trip can be completed on time, every time, without any delays. The path shouldn't alter in an anticipated or predictable way, so the user can rely on it. It will lessen any late fees, travel-related stress, and any other reliability difficulties brought on by a trip with a lot of time variance. The user essentially assesses the reliability and consistency of travel times over time, either from day to day or at various times of the day. Users that rely on travel time reliability can maximize their own time. Decisions and benefits related to traffic management and operations will benefit from the quantification of journey time reliability. The Travel Time Reliability (TTR) rating is also crucial for transportation planners and system users. Therefore, characteristics like the purpose of the trip, travel habits, and time period of travel should be evaluated in order to determine travel time reliability accounting for the aforementioned situations. Standard deviation, variance, the 95th percentile, the buffer index, and other characteristics are used to quantify the TTR. The primary objective of this study is to establish a monetary value for the reliability of journey time using "Standard Deviation" as the reliability parameter. For this, a Stated Preference survey was carried out, and the results were used in the study. The reliability parameter and other variables that affect the TTR were then included in a multinomial logit utility model. The analysis was carried out using the statistical software "ALOGIT." The software was used to calculate the TTR's economic value. Additionally, the reliability of travel time has been assessed in relation to the socioeconomic traits of the respondents, such as their age, monthly income, and gender. After the analysis, the computed overall monetary value for travel time reliability was 10.27 Rs/min regardless of any socioeconomic considerations. Considering TTR according to the income level of the respondent, the travel time reliability value has been increased with the income. The high-income earners give priority to reliability in their journeys. Regarding the purpose of the journey, the TTR value for journeys for work is higher (16.41 Rs/min) than the other types of journeys. Therefore, the TTR value differs significantly according to the purpose of the journey. Also, the analysis depicts when the respondent gets older, more attention is paid to the reliability perspective of a journey.

**Keywords:** *Reliability, Deviation, Travel Time, Monetary Value*



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