Research Leads to Advancement

Transport Research Forum

2021

UNIVERSITY OF MORATUWA

DEPARTMENT OF CIVIL ENGINEERING
TRANSPORTATION ENGINEERING DIVISION

Transport Research Forum
2021

Abstracts

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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 organised 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 career and to share their research findings with other colleagues and the industry. Practitioners, researchers and academics including a number of international experts in the areas of Highway Engineering, Transportation Engineering and Planning are the participants for this event. Representatives from the industry and the related government institutions are also invited every year.

Department of Civil Engineering conducted the first ever Sri Lanka Transportation Forum in 1983 and since late 90's the Transportation Engineering Group have organised many Transport Research Conferences at local and international level. Later, the Transport Research Forum (TRF) was established and two conferences were held initially and since 2010 TRF was held consecutively every year. Therefore, TRF 2021 is the 14th Transportation Research Forum conducted by the Transportation Engineering Division. Many of the research findings presented in Transport Research Forums have been put in to practice and the one of the main objectives of Transport Research Forum is to come up with solutions to address transport related problems in the country and disseminate to the industry. Last year (2020), TRF has achieved a great 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.

Message from the Conference Chair

Prof. W.K. Mampearachchi

University of Moratuwa

As the Chairperson of the research committee, I am delighted and honoured to bring this message to the Transportation Research Forum 2021.

We the Transportation Engineering Group, have decided to hold this prestigious conference as a virtual conference for the second consecutive year due to the COVID-19 pandemic situation.

I hope that this conference will allow the participants a productive discourse. Our technical program is rich and varied with Keynote speeches from expertise in foreign countries and around 30 technical papers split between 2 afternoon sessions on October 28th and 29th in year 2021. Some of the underlying issues in the transport sector in Sri Lanka will be covered in-depth in 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. Nalin Wicramarachchi, who have a very clear desire to upgrade research in the community in which we live in.

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 by your presence. As is a tradition with the conferences, I hope you will enjoy the content, 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 virtual conference.

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Methodology to Prioritize Road Safety Improvements for Low Volume Roads

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Abstract

Low volume roads (LVRs) play a crucial role in providing mobility and accessibility to people to perform their economic activities and satisfy their social needs. However, safety in low volume roads is not given adequate importance as in the case of highways. Funding is generally allocated to improving road safety in highways as they are considered more prone to road crashes. Road crashes in LVRs in Sri Lanka have significantly increased lately with an increase in vehicle volume. Currently in Sri Lanka, there is no formal road safety treatment prioritization tool available for the use of relevant authorities. Prioritization is done based on budget availability and other political and social factors. Therefore, it is vital to address the safety issues on LVRs by evaluating the risk at hazardous locations and proposing the appropriate safety treatment for those locations. The six main road safety treatments proposed in this study are providing road safety barriers, installing sign boards, providing pedestrian crossings, vegetation clearing, providing street lighting, and providing speed humps. This study aims to identify the relevant risk parameters addressed by the above road safety treatments, define the road and operational characteristics and finally ranking the hazardous locations based on risk rating. High risk locations will be identified using safety performance index called the Cumulative Safety Index (CSI), which is derived from the exposure, likelihood, and severity of road crashes. The CSI is an indicator of the safety performance of road. The objective of the study is to prioritize high risk locations to implement the road safety treatments based on their risk rating. The safety performance rating derived from the model will be validated by conducting user response surveys. These surveys will be conducted among experienced engineers in several highway agencies and the experts will be asked to give a performance rating for the locations based on perceived risk. These performance rating values will be compared against the CSI values obtained for the purpose of validation. The cost of implementation of a given road safety treatment is considered a constant, therefore prioritization of locations for safety treatment projects will be based on the risk rating only. The effectiveness of the road safety countermeasures will be evaluated by calculating the CSI values again after the implementation of a given road safety treatment. Since the risk factors related to exposure, likelihood and severity of crashes will change after the implementation of a safety countermeasure, a significant change can be observed in the CSI values. This change can be termed as the safety effectiveness in this study.

Keywords: *road safety treatments, low volume roads*

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Developing a Mode Choice Model using Stated Preference Data for Sri Lanka

Amila Silva[1] and Dimantha De Silva[2]

Abstract

Developing travel behaviour models are important for forecasting travel demand and, consequently, for planning transportation systems. In Sri Lanka, few studies have been done on analyzing mode choice behaviour of individuals. As a result, in most of the studies, transport planners have been struggling to analyze behaviour of people when a new transport mode is introduced or and existing mode is improved. In this study, travel data collected based on a stated preference survey is used to develop a mode choice model. 6834 observations were available for the estimation. Stated preference survey can be used to not only analyze the existing travel modes but also to analyze the new travel modes introduced to a system. The choice of individuals for private modes including, car, three-wheeler, motor bike and public transport including, bus, conventional rail and Light Rail Transit (LRT) modes were analyzed using their attributes. Train mode was further classified on accessibility as bus to train (Bus-Train) and walk to train (Walk-Train). The LRT mode was further classified as walk to LRT, bus to LRT (Bus-LRT), Park and Ride and LRT (PR- LRT). Only the mode attributes and network attributes were used to estimate the user sensitivity. The multinomial nested logit model structure was used where the coefficients of the attributes were estimated using ALOGIT software. The parameters were estimated using number of nesting structures until it reaches a good model fit. It was found that the travel time, distance and cost are significant parameters for all the modes and number of transfers and waiting time are significant parameters in the LRT and Train utility functions. Value of time (VOT) for users of each mode was calculated using coefficients of travel time and cost, an indirect way of estimating the VOT. It was estimated the value of time of users for Car, Motorbike, Three-wheeler, Bus, Train and LRT are Rs.718, Rs.340, Rs.392, Rs.396, Rs.258, and Rs.423 per hour respectively. The estimated mode choice model can be used in the aggregate transport demand models since it is does not have personal attributes of the people who selects the mode. It is identified that importance of inclusion of personal attributes also in a mode choice model. The future studies could include personal attributes and tour attributes which can be used in the activity-based model development. However, the estimated mode choice constants can be calibrated in transport demand modelling to analyse the existing and future travel patterns.

Keywords: *mode choice, value of time, LRT*

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Establishment of PCU Values for Urban Intersections Using Drones

Pramodh Senanayake[1] and Loshaka Perera[2]

Abstract

Passenger Car Unit (PCU) is used to convert heterogeneous traffic conditions into a uniform traffic flow rate when designing roads and intersections. The impact generated by mixed traffic condition, especially in developing countries, makes it different from factors used in similar countries and also vehicle operating characteristics, road-related parameters & environmental condition makes it more country-specific. Since the PCU factors currently practiced in Sri Lanka are older than 20 years (seems outdated), a revision is needed to establish a new set of PCU factors to represent the real context. In general, practical difficulties associated with data collection and complexity in methodologies have hindered such timely revisions, especially in developing countries. However, some studies were carried out recently to identify appropriate PCU factors for four-lane & two-lane roads in Sri Lankan but not for intersections. The application of drones for traffic engineering purposes is becoming more common now and it has proven records to eliminate many obstacles we had before such as cost for data collection using multi-video cameras, observers & providing the other facilities. Also, it minimizes the practical difficulties that occurred in data collection & processes. The level of accuracy of video footage is higher in a stable bird eye view mode and thus unmanned aerial vehicles (Drone) are been used effectively in various applications in traffic engineering. Therefore, the objective of this research is to develop a methodology to develop PCU factors using drone videos. In this study, the area occupancy of different categories of vehicles at various traffic compositions is compared with the passenger car only traffic conditions having the same stream speed. Since video-based traffic data could provide accurate information with respect to vehicle movement and related characteristics, drone videos were used to collect traffic data at an intersection. Overcoming the difficulties had with drones like short flight time, the effect of the weather & drone Wireless Problems, Basic headway method was used in this study to develop a framework to calculate PCU factors. Applying the method developed, PCU factors for ten (10) vehicle categories were developed. There is a significant variation in Three Wheelers, Motorcycles & the Commercial Vehicles, compared to the literature. The study was limited to the development of PCU factors for intersection only (for traffic signal design). However, considering the accuracy of the method proposed and other practical advantages (less cost and easy to collect data) there is a high possibility to extend the same method to determine the PCU factors on other road sections, such as arterials, highways, and freeways in the future.

Keywords: *PCU, intersection, drone, signal design*

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Development of a Guideline to Determine Structural Capacity of Demolition Waste as a Road Construction Material

Waruna Jayasooriya[1], Wasantha Mampearachchi[2] and Nalaka Jayantha[3]

Abstract

The use of demolition waste as pavement base material is a promising but unproven technique for road rehabilitation and construction. The scarcity of natural resources for construction industry-related activities was rising over the past few years. However, demolition waste is not frequently being used in pavement construction, primarily due to a lack of knowledge about the engineering properties of the material used. This research study focuses on evaluating the strength and durability characteristics of such waste in Sri Lanka and determining the applicability of crushed concrete material (CCM) in pavement base construction. Laboratory testing component in the study includes preliminary material tests including flakiness index, elongation index, Los Angeles abrasion value (LAAV), aggregate impact value (AIV), and unconfined compressive strength (UCS). In addition, a laboratory-scale prototype model testing was carried out to compare the characteristics of CCM with respect to conventional base materials. This setup was subjected to a plate load test and a dynamic cone penetration test to determine its properties. The results of the prototype model testing demonstrated that the CCM base layer was susceptible to stiffness changes due to the changes in moisture levels. The layer coefficient of CCM was calculated using deflection data and it was equal to 0.134. However, the variability of material properties was significant in the case of CCM compared to conventional dense graded aggregate bases (DGAB). Therefore, the authors recommend using CCM as a base material for the pavements where light wheel loads operating, preferably 20kN or less. The present practice of flexible pavement design in Sri Lanka is based on the Transport Research Laboratory method (RN31-1993) but modified to suit local conditions. Even though RN31 provides different aggregate base layer types, DGAB is the common practice of base construction. Therefore, a guideline and a design chart have been developed for the process of replacing DGAB with CCM. The equivalent thickness of CCM required for DGAB thicknesses varying from 4-10 inches could be obtained from the developed design chart.

Keywords: *concrete crushed material, aggregate bases, pavement design, layer coefficients*

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Application of Data Science Technologies to Take Proactive Decisions to Control Road Crashes

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Abstract

Traditionally, road traffic crash analysis and accident modeling resorted to regression models and discrete choice models. Many countermeasures have been identified and implemented but still, the number of crashes and severities are increasing every year. Since road traffic crashes occur across space and time, conventional approaches have failed to provide alerts and insights in relation to geospatial regions, enabling proactive prevention measures. Aggregation of other data sources such as real-time weather, traffic flow counts and congestion levels etc. to alert authorities on increased crash risks is another gap that needs attention. The lack of geospatial analysis or visualization on available crash data (e.g., crash hotspots identification) limits road agencies' abilities in prioritizing funds allocation to more impactful improvements. The enforcement authorities also find it difficult to deploy their staff strength to high-risk areas. The latest advancements in programmatic geospatial analysis, interactive map visualizations and open-source software offer a unique opportunity to fill these gaps in a cost-effective way. This paper presents an application of data science and data visualization technologies to analyze road crashes. Popular packages written in Python programming language were used for the analysis. GeoPandas library provided the ability to process GPS locations (latitude and longitude) while Matplotlib was used to generate static maps. Folium library and the underlying Leaflet.js library were applied to generate interactive maps to help visualize crash hot spots. The study developed algorithms to combine GPS location data from crash records with boundary and attributes data from geospatial files to generate road crash density maps by administrative division areas and population. Interactive maps that allow authorities to drill down (or zoom in) to hot spots were also developed. Unlike GUI-driven analysis tools such as ArcGIS or QGis, the programmatic approach developed in this study enables the repeatable application of the analysis and visualization to new and old datasets with minimal effort. The application of existing geospatial analysis tools to road crash data is the key contribution of this study. The findings from the study lay the foundation for a digital system that can become an online platform for road and enforcement agencies to obtain reports and alerts on road crash risks and hot spots. The application was tested using crash data in Sri Lanka and outcomes are presented in this study. Future work such as real-time prediction of crash risk using machine learning technologies and fusion of multiple data sources onto the same platform can bridge the current gaps in crash prevention measures.

Keywords: *road crashes, geospatial analysis, interactive maps, crash prediction*

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Evaluation of Commercial Land Price Change in Response to Transport Infrastructure Improvement: A Case Study on Proposed LRT line in Sri Lanka

Sulaimaan Iqbal[1] and Dimantha De Silva[2]

Abstract

Transportation and Land Use are part of a wider activity system where the interaction between them is part of a complex framework. While the changes in Land Use characteristics would lead to change in activity patterns influencing the Transportation System, the changes in the Transportation Infrastructure have a direct impact on the change in overall accessibility levels as well as the relative accessibility of the specific locations. Thus, it is expected that any change in Transportation Infrastructure would lead to change in Land Use demand reflected with the changes in land prices. This research is targeted to capture the impact of Transport Infrastructure on Commercial Land prices. The proposed Colombo Light Rail Transit (CLRT-JICA) project has been selected as a case study to obtain the sensitivity of the Commercial Land prices under 3 stages, Pre-Introduction (2010-2014), Planning/Designing phase (2015-2019) and the Construction stage (2020-2021). Although the project was suspended in the year 2020, the research was extended beyond 2020 to observe the impact it has on Commercial Land prices which increased solely due to the CLRT. The Commercial Land price data obtained from two of the most prominent online web advertising agents, "Lanka Property Web" and "ikman.lk", within a 2 km radius of four proposed main stations; Malabe, Battaramulla, Rajagiriya and Borella have been used in the evaluation. Narahenpita area (with an existing Railway Station) has been selected as the base to consider the prevailing trend of Commercial Land prices. A Multiple Regression Analysis using SPSS was carried out to find the relationship between the Commercial Land price per unit area as the Dependent Variable, explained by several Independent Variables such as the Distance to the nearest station, Distance to the main road, features of the property such as parking availability. The analysis is expected to explain how the price of Commercial Land is expected to have different sensitivity based on the independent attributes and the variation based on the stage of the Transport Infrastructure Project.

Keywords: *commercial lands, LRT, stations, distance, SPSS*

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An Experimental Study to Evaluate the Effective Specific Gravity Estimation on Percent Air Voids of Asphalt Mixture Design

Hashen Chamodya[1] and Wasantha Mampearachchi[2]

Abstract

Asphalt concrete is one of the most widely used surfacing compounds consisting of mineral aggregates with asphalt (Bitumen) binder. Various types of bituminous mixtures such as cold mix asphalt, hot mix asphalt, plant mix, and warm mix asphalt are used with relevance to the environment while tropical countries like Sri Lanka use hot mix asphalt mixes for surfacing. In hot mix asphalt mixes, the theoretical maximum specific gravity (Gmm) value plays a significant role when considering the performance and durability. The impact of theoretical maximum specific gravity (Gmm) can be noticed directly on properties of paving mixtures like bleeding, rutting, raveling, and fatigue. Precise calculation of Gmm is critical in the mix design process in determining exact values of percent air voids in a compacted mix (VIM), percent voids filled with bitumen (VFB), and optimum asphalt binder content in a compacted mix. Manual Series-2 published by Asphalt Institute recommends determining Gmm directly by performing the standard test method called RICE method (AASHTO T209, ASTM D2041) for every binder content or by performing the RICE test for a selected binder content around optimum binder content to obtain effective specific gravity (Gse) of aggregate mix and then to calculate Gmm for other binder contents using a back-calculation method as an indirect method. Sri Lankan road industry used to determine Gmm for every binder content using the effective specific gravity (Gse) which is pre estimated as the average of apparent and bulk specific gravities of the aggregate mix. It has been found that the measured air voids content using the Gmm value measured by rice test is lower than the average estimated method used in Sri Lanka in about 20% and 9% for limestone and basalt, respectively. This research aims to study the impact of the effective specific gravity estimation method for asphalt mixture on the percent air voids and other characteristics of asphalt mixes when using granite as the aggregate. To achieve this objective, an extensive experimental program was designed using 10 different sample projects. Maximum theoretical densities of the samples were determined using the rice method according to ASTM D2041, while bulk and apparent specific gravities were taken from the mix designs which were done for the same hot bin and bitumen samples. Based on the results, the impact on percent air voids and optimum binder content was evaluated to determine the accuracy of the average estimated method compared to the standard rice test method.

Keywords: *rice test, percent air voids, optimum asphalt content, granite aggregate*

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Barriers in Adoption and Operation of Electric Buses into the Existing Public Transit Network

Thisaiveerasingam Thilakshan[1], Thusitha Sugathapala[2] and Saman Bandara[3]

Abstract

Transportation has been identified as a major contributor in terms of increase in air pollution and related impacts resulting in climate change and global warming amongst other threats to the world and people. The nature of transportation related pollution has been caused by increasing motorization along with the absence of targeted policies especially in developing countries and frameworks for cleaner transportation options. Many types of measures to fight transportation related pollution are adopted globally including modal shift towards public transport, electrification, low-carbon fuels and energy vectors, demand management, innovation and up-scaling, and improved design, operations and planning of transport systems. Electrification of vehicles has been globally accepted as a transfer of high potential due to the absence of tailpipe emission and the possibility to generate electricity from renewable energy sources has more potential to make electric vehicles cleaner in an overall context. Sustainable transportation mainly comprises of development of public transit and transfer of private vehicle users to public transit modes. It is evident that public transit is one of the most preferred sustainable options in transport but it's contribution to the overall transport emission scenario is significant at present, especially in developing countries, due to higher model share. The use of cleaner technology in public transport can make a substantial impact on the reduction in emissions. This study concentrates on public bus services and the replacement with or introduction of electric buses which is currently being initiated globally. The adoption of electric buses (e-buses) includes its set of positive outcomes but is a challenge in the initiation and implementation process. The adoption of e-buses is not an easy transition which is impacted by a number of barriers including high initial procurement costs, issues related to charging and related infrastructure development, still relatively new/novel in terms of technology, scarcity of skilled labour, unavailability of data amongst others. The outcome from the study with respect to the barriers and the related mitigation measures to facilitate adoption and operation of electric buses is attained via a comprehensive review of the available sources published including research papers, national/non-governmental reports and relating documents which discuss on the air quality levels especially in the urban context and the contribution of the transport sector to the overall air pollution ratio. This study identifies the barriers, elaborates the reasons behind the barriers and recommends mitigation strategies to accommodate these barriers in the best possible manner to ensure transition to electric buses can be facilitated in a smooth manner with no considerable impacts to any stakeholders. The infrastructure related to electric buses operation is a major part of operating a viable electric bus network. Thus, identifying the stakeholders and the related barriers in adoption and operation of e-buses, development of effective operational strategies and development of an efficient evaluation mechanism are important parts of the e-buses framework considered in this study. The study discusses the identification of the right technology & viable business models, the framework for the development of an optimization model for electric bus operation subject to resource constraints which include planning of routes,

development of schedules and charging intervals in compliance with the available infrastructure. Outcomes from the study are expected to facilitate and educate operators of electric buses in the public transit network with the positioning of electric buses in the right framework so that the service can be provided with no disruptions to adoption and operation along with the prime goal of maximizing the expected outcome of the total reduction of emission and promotion of e-buses in an economically viable manner.

Keywords: *electric buses, public transit, electric mobility, sustainable transportation*

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Enhancing Road Safety with Cost-Effective Wireless Technologies

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Sameera Sandeepa[5], Suyama Dias[6], Tilan Wickramarachchi[7],
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Abstract

Intelligent Transport System (ITS) applications are imperative for improving safety and efficiency on the road; for instance, accidents at railway and pedestrian crossings with fatal outcomes are frequently reported. According to the Department of Railways, more than 200 deaths due to railway accidents have occurred every year since 2018, and the Ministry of Transport statistics reveal more than 3000 deaths reported annually in road accidents, most of which are due to negligence of drivers and pedestrians. To address this problem, we present Active Road Signs (ARS), a system that delivers roadside alerts to the interior of vehicles in the vicinity, for the immediate attention of drivers. Alerts may include information such as a signal light about to turn red, a train approaching a level crossing, a dangerous bend, or pedestrians waiting to cross a road. We also demonstrate that ARS can be implemented with low-cost, off-the-shelf components. ARS consists of two components; sensing for the acquisition of dynamic roadside information, and communication, to relay the sensed information to relevant road users. The sensed information can be used locally, for example, to control signal timing for pedestrians at an intersection. Similarly, the information may also be conveyed to alert vehicles, for example, at a railway crossing. To illustrate ARS, we present a pedestrian safety application based on a novel use of the ubiquitous WiFi technology. Pedestrians are detected through a wireless mechanism, and alerts are conveyed to approaching vehicles. WiFi Channel State Information (CSI) processed through a Deep Neural Network (DNN), is used to estimate up to12 waiting pedestrians with 92% accuracy. Our communication technique is capable of relaying the sensed information to a vehicle at a distance of approximately 150m in under 50ms, satisfying the relevant performance standards for ITSs. This allows a vehicle travelling at 50 km/h, a minimum of 2.6s to come to a complete stop at the crossing. The current standard for vehicular communications in ITSs is Dedicated Short Range Communications (DSRC). DSRC is still a costly technology with a low penetration rate even in modern vehicles. Thus it is prohibitive for retrofitting older vehicles, and for three-wheelers and motorcycles. However, WiFi and DSRC standards have a common root. Accordingly, our design and experiments show that WiFi is able to function effectively in ITS applications such as ARS. Traditionally, pedestrian detection is achieved via vision-based techniques which cost approximately 130USD for equipment per installation, while DSRC will add a further 700USD for communication. However, our proposed system with off-the-shelf WiFi components will only cost 76USD for detection and 18USD for delivering warnings to end users. ARS is suitable for suburban or rural settings to reduce the risk of accidents, particularly those involving vulnerable road users. The components of ARS overcome privacy concerns and have no dependency on lighting and weather conditions associated with vision-based techniques. The vehicle-mounted equipment in ARS is affordable to be used even in three-wheelers and motorcycles, statistically the most susceptible to road accidents.

Keywords: *ITS, DSRC, WiFi, CSI, pedestrian, road signs*

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Decision-making Framework for Effective Trip Planning Based on Travel Time Reliability

Chathura Vidanapathirana[1] and Saman Bandara[2]

Abstract

Decision making is a key element in trip planning. As the vehicle volumes on road networks increases, the uncertainty of traffic and roadside situations grows resulting in unreliable travel times. Hence, planning a trip becomes a challenging task, especially in situations where there are alternate routes and no reliable data (i.e.: travel times, real-time traffic levels) to make sound decisions. Since a trip possesses a monetary value that can be measured in terms of time and/or cost, trip planning and related decision-making have become key aspects of contemporary transportation. Traffic data collection had been a conventional practice until the recent advances in research work introduced many technology-based automated solutions. These inventions facilitated real-time large-scale data collection and provided access to such data revolutionizing the field of transportation. The analyses conducted on travel conditions generate useful information that aids the trip planning and decision-making process. The objective of this study is to aid the users of transport systems with the trip planning process through a systematic decision-making process. The methodology of the research involves developing a data-driven decision-making framework to fulfil the said purpose. Travel time reliability which is defined as the dependability of travel times is the key parameter incorporated in the proposed framework and it is measured using indicators: the cumulative probability of arriving at the destination at the desired arrival time (primary measure), and coefficient of variation of the travel time distribution of the selected route (as a secondary measure if needed). The basis of the decision is â€˜the risk of experiencing an unpunctual arrival' which is measured in terms of cumulative probability as stated before. The risk can be a late arrival as well as an early arrival. The outputs are generated based on the user requirements namely departure time, arrival time, and route choice. Hence, this is a user-specific (or scenario-specific) decision-making tool that produces solutions for an exact trip-making instance. In other words, this framework does not produce general solutions. This paper presents the final framework developed in this research for the decision-making process. It requires historic travel time data of road segments to determine the cumulative probability for reliability measurement. Provided that such information is available, this framework can be effectively utilized to assist the users in the decision-making process of trip planning. The latter part of the study demonstrates the applications of the proposed decision-making framework using several scenarios that represent different expected departure and arrival time conditions. For situations such as selection of the most suitable route for a trip from the available alternatives and determination of the most probable arrival time for a trip, this method can be applied. The outputs can assist the user to make choices rationally thereby avoiding unnecessary delays and/or losses. The outputs generated based on the proposed methodology are simple and straightforward; thus, this method can be directly adopted in the trip planning process. Even for the users with less technical knowledge and analytical skills, this framework can provide guidance to methodically arrive at a decision (e.g.: distinguishing the most suitable route and the optimum departure time for the trip, the decision on the optimum departure time based on a fixed arrival time or when there are limitations on the latest arrival time, determination

of a desirable arrival time based on a set departure time or when there are limitations on the earliest departure time) regarding the trip. The access to more accurate data will further improve in the future and the technological breakthroughs will pave the way for the development of a user application for day-to-day trip planning needs. The transport planners, authorities, and regulators can also benefit from this framework as it allows them to establish traffic management decisions (e.g.: identification of reliability-related high-priority links on the road network and implementing suitable traffic plans) based on the generated outputs.

Keywords: *data-driven decision-making, decision-making framework, travel time reliability, trip planning*

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Applicability of Standard Density in QC and QA of Asphalt Surfacing

Pivindu Rathnasiri[1] and Wasantha Mampearachchi[2]

Abstract

The significance of quality control and quality assurance at the compaction operation in the asphalt pavement has long been recognized by the industry since the compaction maintains the volume of air in the asphalt, which has a profound effect on pavement performance and pavement service life. As a compaction quality control parameter, the degree of compaction, expressed as a percentage ratio between field density and the reference density, is used in the pavement industry. There are several methodologies to establish the reference density to formulate the degree of compaction in the present. However, for decades, measuring densities from daily laboratory compacted samples during construction (Marshall Density) has been the mainstream practice to establish the reference density in Sri Lanka. The major drawback of establishing Marshall laboratory density as a reference density is its inability to represent any unnoticed material or plant variations in the field. This study focuses on solving the aforementioned constraint by developing a new systematic approach called the 'Standard density method' to establish the reference density. The standard density is determined as the mean value of densities of Marshal test specimens from morning and evening operations only for a specified number of days after the commencement of construction. This study aims to evaluate the feasibility of the concept of standard density method by comparing current practice with the proposed method. In-place density readings and their respective Marshall laboratory density measurements were collected from different road projects, and the compaction performance was evaluated according to the degree of compaction (at least 97 percent of reference density) in both the existing and proposed methods. To increase the reliability of this comparison, method comparison hypothesis testing (student t-test) was developed for both the existing method and the proposed method to analyze the compaction performance. This t-test was designed to support the alternative hypothesis 'in-place density > 97% of reference density (from Marshall density & standard density)'. According to hypothesis test results, the analysis reveals a significant correlation in compaction rates between the current and proposed methods (significant at a 5% level of significance). Moreover, the study shows that the hypothesis mentioned above can be rejected only in the standard density method if any material or plant variations have occurred in the project; in addition, these hypothesis rejections appear after a considerable time period from the commencement of the construction.

Keywords: *asphalt concrete, quality control, degree of compaction, reference density*

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Development of Decision Framework for Dynamic Signal Timing Design

Sudara Withana[1], Loshaka Perera[2]and Saman Bandara[3]

Abstract

The traditional fixed time traffic signal systems use a static signal timing or in other words, a pre designed signal timing developed based on past traffic data. The signal timing design assumes the traffic levels to be similar for a given time period, but the traffic levels are highly fluctuating and dynamic in reality. Therefore, the next step in traffic signal timing designs is the dynamic designs where the timing will be varied in real time. This type of signal time designs will be mainly used in Adaptive Traffic Signal Systems which are designed to operate using real time information. A dynamic signal timing design requires a decision framework for real time operations and information management. Therefore, this study is aimed at development of a decision framework to minimize the delay time and to maximize the traffic flow in an intersection under unsaturated conditions. Analyzing many parameters used in literature, two main parameters were considered in this study, namely, critical lane flow and stop delay. Impact from pedestrians are incorporated by using the pedestrian delay time. The behavioural patterns identified in the individual parameters, when releasing traffic during the green time period in an intersection, was used to develop the framework. The behaviours of individual parameters in real scenarios were shown deviated results from theoretical studies mainly due to mixed traffic conditions. Motorcycles have contributed significantly for such deviation and as well as the capacity of the intersection. The decision framework was developed by integrating the individual parameters and their limits to communicate among phases in the traffic cycle. The cycle time was kept as a variable in the decision framework. This decision framework was simulated using PTV VISSIM software to observe unsaturated conditions in Piliyandala- Maharagama bypass Junction as a case study. The simulation results were obtained for different unsaturated flow conditions. They were in line with the expected outcomes. The flow through the intersection was slightly increased and average delay time was reduced slightly

Keywords: *dynamic signal timing, signal design, adaptive traffic control system, traffic flow*

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Study on Peak-hour Traffic Reduction and its Influence on the Pasyala Junction.

Isuru Wijesinghe[1] and Osanda Muthuhewa[2]

Abstract

When traffic demand meets or surpasses the highway system's available capacity, there are more vehicles on the road than there is sufficient space on the road. The volume of traffic varies according to the time of year, the day of the week, and even the hour. This research was carried out to find an appropriate method to reduce traffic congestion. And this study is based on the Pasyala junction which is an un-signalized skew intersection where there is huge traffic congestion during rush hour. On Colombo Kandy road, the Pasyala intersection is located. At this four-way intersection, the Colombo Kandy road and the Attanagalla Giriulla road meet. Both roads are two-lane roads with one lane on each side in this location. The intersection is congested during rush hour with vehicles from office transit systems, public and private buses, school buses, personal vehicles, and other utility vehicles. Primary data were collected by conducting a reconnaissance survey around the junction. As well as secondary data was gathered by CCTV video-based manual traffic count survey by implementing CCTV cameras close to the junction. CCTV Cameras are specially mounted to conduct a manual classified traffic count survey from 6 AM to 9 PM. According to survey results, obtained and evaluate traffic characteristics such as peak periods, vehicle contributions by each turning movement, vehicle volumes, major and minor condition and compared results with 2016 manual classified survey which was conducted by RDA and obtained growth differences related to the junction. The traffic data were extrapolated based on these growth rates. Following past studies, several alternatives were studied as alternative solutions. Established on the data, observations, and results, evaluate traffic signal implementation through VISSIM simulation to forecast and recommend alternative solutions. The considerable parameters such as design speeds were used for the VISSIM simulation and they were validated according to the existing traffic behavior.

Keywords: *skew intersection, growth rate, peak hour, traffic signal*

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Corridor Level Traffic Management Through Variable Messaging Systems: A Case Study on East West Links Entering Colombo

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Abstract

Increasing traffic volumes on the major road corridors result in building up traffic congestion during the peak hours. Even in a congested road network, some route options are relatively lower congested while some are overly congested. This implies that drivers are not always well-informed about all the route options they have, and the road network is not in a full equilibrium state. When temporary road closures, partial closures for road maintenance, etc. happen chaotic traffic congestion can be seen as drivers try to find alternative routes without proper information about traffic condition in other roads and possible delays.

Drivers currently can use vehicle in-built navigational system or smart devices with navigational applications to get real time traffic information. But in a country like Sri Lanka, majority rely on their experiences rather than the digital navigational aid. Displaying the dynamic travel time information and route options using Variable Message Sign (VMS) boards as an adaptive traffic control system, is tested to be simple but highly effective by several researchers. Providing information about the real time congestion level on regular routes and possible delays will help the drivers to avoid the overloaded routes and balance the road network which will ultimately optimize the system performance.

One of the key parameters to be considered while implementing an effective VMS system is identifying the locations where the signboards should be erected. These places should be determined considering the route alternatives, possible diversions, and ease of the drivers. This study looks at finding optimal locations to achieve corridor level diversions for the vehicles entering Colombo from east to west direction. The Low-level Road, High-level Road and Kaduwela Road/ Sri Jayawardenapura Mawatha (SJP) corridors are considered the main three corridors from east west direction, connecting the Outer circular expressway and Baseline Road in North-South direction. Among the three corridors SJP is one of the critical corridors where demand exceeds capacity now.

A calibrated macro-model covering Western Province of Sri Lanka, was used for the analysis. Select-link-analysis were done to identify the major origin destination pairs of and the route analysis was done separately for each origin links to identify their destination zones and potential diversion volumes. 6 major locations for corridor level diversion using VMS and 7 minor locations to support the major diversion using auxiliary signage boards were identified. From each major diversion locations potential number of vehicles to divert were identified. The results show that with 30% of potential diversion vehicles directed through VMS, a 10% vehicle reduction in Rajagiriya section and 18% in Malabe could be achieved.

This method can be adopted to any larger corridor level diversions as well as to local diversions inside the city limits and implemented using movable or fixed VMS with real time traffic information system such as M-TRADA, (A travel time estimator using Google API)

Keywords: *variable message signs, dynamic travel time, traffic diversion, macro-modelling, CUBE Voyager, M-TRADA*

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Identification of Impact Area, Critical Road Sections and Important Intersections for Traffic Impact Assessments

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Abstract

In conducting traffic impact assessments (TIA), there are limited guidelines available to identify the impact area for proposed property developments. A circular buffer of a pre-determined distance is very common in literature. In addition, the next major signalized intersection, the first center median opening, all roads and intersections where the development traffic exceeds 5% of the base traffic etc. are also being used. In Sri Lanka, Urban Development Authority defines the impact area as the project site and area covering 1km radius area from the boundary of the project site. However, the actual impacts will depend on the road network of the surrounding area and type of development and there is a need to identify the critical road links and intersections systematically. In addition, it is important to estimate the distribution of additional traffic due to the proposed development. This highlights the vast discrepancy in practice and a proper approach should be established for impact area identification. The study focusses on developing a model for the identification of a reasonable impact area. The methodology was developed under two stages to identify the critical road sections, important intersections and impact area for any property development. The proposed methodology considers all the main junctions which will have an impact due to the development without considering predefined buffer as existing method. The road network applicable for the impact assessment will be decided by the environment, type and the scale of the development. For developments focusing on national connectivity, A and B class road network will be selected whereas for developments targeting the local community local road network will be considered. To select critical road sections, a buffer will be identified based on major intersections beyond the mandatory local guidelines. Stage 1 focuses on the identification of critical road sections and important intersections. The main access road links within a 2 km radius from the proposed development were considered for the initial step. The radius can be varied according to the type and the size of the development. Further, the radius of the buffer was defined in this study, based on the regulations of the country regarding the TIA process and the distance to the closest main intersection. Later, the nodes where the main access roads intersect with the 2 km radius buffer were identified and the shortest distance and minimum travel time paths between the identified nodes at the 2km boundary and the proposed development are to be identified. The links in the shortest paths adjoining the site up to a major road intersection from all directions and those major road intersections are considered as the critical links and nodes respectively for the proposed development. To identify the catchment of each important intersection, which will be affected due to the proposed development, the study area was subdivided by allocating each location to its closest intersection. The catchment identification was done utilizing the Thiessen Polygon approach. In stage 2, the identification of the impact area of the proposed development was done. This study considered a 500m service area for analysis purposes. Based on that, the nodes were selected where the service area boundary intersects with all main access routes identified in Stage 1. Then a 5km service area from each of the identified nodes were considered as the possible catchment area

for the development. The service area demarcation radius can be varied according to the type and the magnitude of the development. The analysis was conducted utilizing the open street map data. The spatial analysis was done using Network Analysis Tools in ArcMap 10.8. The methodology was applied to evaluate two proposed developments; a mixed development and a residential development, located in Colombo Metropolitan Area. The impact areas for the two case studies were successfully identified using the developed methodology. In some situations, intersections beyond 1 km radius were identified as the critical intersections and also when short cuts are available catchment areas shift from the main corridors. Using the same model, a criterion could also be developed to identify the additional trip distributions from the proposed developments. This can be useful in identification of the impact to nearby road links and intersections, when the development is operational, allowing the designers to address the bottlenecks beforehand. The developed model can be further expanded to cater for other transportation areas such as catchment identification for bus stop locations, transit stations etc. in the future.

Keywords: *traffic impact assessment, impact area, catchment area, thiessen polygon*

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Review of Sampling Strategies in QC and QA of Asphalt Surfacing and Methods of Acceptance

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Abstract

Sampling is a key component of any quality assurance (QA)/ quality control (QC) plan; it significantly affects the determination of quality and acceptance of work done. To determine density and compaction, core samples are taken from asphalt pavement, and their results highly contribute to final acceptance. In Sri Lanka, this is done according to the guideline given in ICTAD specifications. In clause 506.6 of ICTAD, a re-coring procedure is given for thickness deficiencies. But not given any procedure for compaction deficiencies. So, the practice of most road construction projects is, if samples obtained from the relevant sections are unable to achieve specified compaction limit, reject the whole section. Also, since any special procedure is not specified in ICTAD specifications, samples are mostly taken on the direction of the engineer. When core samples are taken intentionally and directionally at lower density locations by visual observation, the contractor is compelled to compact more so that conforming density is achieved at every location deviating from the procedure established during trial section. This leads to bad practices in the industry as well as directly affects the quality of the asphalt pavement. The objective of this study is, produce a review of successful practices used for asphalt sampling and acceptance. Standard and international practices of sampling and acceptance were studied in the literature survey. And Questionnaires and interviews were used to get attitudes of industry about existing practice and standard sampling practices. Although standard practices for random sampling are set out in ASTM D3665, many countries seem to use their own stratified random sampling practice, using random number tables for generating random numbers to select sampling locations. Among them two commonly used methods of acceptance were discovered: (1) Taking at least 3 samples from each section rather than testing one location only and calculating PWL factors based on results. Here final acceptance is done using PWL factors of asphalt content and gradation and roughness factors together. (2) using contractor's QC test results which obtain using stratified random sampling, after ensuring those accuracies using f and t-test methods. And get an average of results. Currently, most contractors are performing hot bin grading daily in asphalt batching plants. By analysis of asphalt content and gradation of different road constructions projects, clearly shows those values do not much deviate from specified limits. Therefore, it can be assumed no issues of sampling practice for asphalt content and gradation. Based on these findings, it is recommended to modify clauses in ICTAD specification for sampling on compacted asphalt surface; use contractors' test results obtained from stratified random sampling, should be used after verifying their accuracy for final acceptance.

Keywords: *asphalt sampling, quality control, quality assurance, acceptance plan*

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Development of Construction Standard for Semi-Rigid Pavement Construction

Indika Dahanayaka[1] and Wasantha Mampearachchi[2]

Abstract

The drawbacks of the conventional Asphalt and concrete pavement mixtures such as rutting, cracks formation in modern construction practices have been given the tendency to discover an excellent composite mixer that achieves the required properties to increase the life cycle of the roads due to continuous loading. This research mainly focuses on developing construction standards to prepare a project specification to comply with every stage of the preparation of the mixtures up to laying the mix at the site. The report involves the literature review on the research, all material selection, and their methodology to prepare the proper gradations and grout mixture, data collection, and analysis of pavements mixtures properties, compressive strengths of cement grout, and comply the results. Here, two paving tests were conducted subjected to different gradations and different site environmental conditions. Paving operations were observed closely with the different rolling patterns to monitor the range of Air voids of 20%-30% under certain conditions. The data were kept finalizing the temperature ranges, both mixing and paving, no of roller passes and type of roller specified, compaction factor, etc. The final results of the experimental studies were tabulated in the graphs, especially with the field density vs. passes, void in field sample vs. passes. Then it compared the difference of gradation in field samples and design and their impact on void and other parameters of specific limits, which have to be incorporated into the final specifications. As laboratory experiments, the marshal mixtures were conducted with 20 No of blows of compaction as many researchers done, to obtain the density, voids to compare with field data. Here, the air voids calculations were done by applying the formula of Ï€r2h as cylindrical volume calculation for core samples and as well as using the Core lock method, which gives more accurate values for void ratio than depending on the other current calculation process. The grout was prepared using 150mg Silica fume, 0.45 water/cement ratio, and 2.58ml/kg admixture to adhere to the semi-rigid mixture design criteria. Also, this approach involves not only technical evaluation but also the study of the possibility to adapt to the local construction field, which gives more benefits to the country economy such as reduce the cost of mixed production and paving, time-saving and locational demands of optimal usage, mitigation of environmental impact, increases durability, etc.

Keywords: *semi rigid pavement, voids ratio, aggregate gradation, density calculation, plant adjustment, compressive strength*

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Use of the Digital Image Analysis in Determination of Deterioration of Thermoplastic Road Marking

Manoma Ranawaka[1] and Saman Bandara[2]

Abstract

Road safety is a major component of the highway sector and it should be well considered in highway planning, designing, construction and maintenance. The visibility of road marking is essential for efficient traffic flow and road safety. There are complaints that road markings of many roads in Sri Lanka have poor visibility and no effective remarking process in action. The major reason for the poor visibility is the low reflection levels of road markings. The visible area of road marking is the main factor for visibility. It is necessary to determine the deterioration patterns of road marking to maintain an adequate remaining area of road marking on the road surface. However, there is no guideline or methodology available for road agencies in Sri Lanka to follow when deciding on the road marking repainting period. It is difficult to allocate funds, resource management along with stock material, manpower and machinery utilization in the most effective manner without a well-established guideline. The main objective of this research is to obtain a comprehensive study of digital image analysis in the determination of deterioration rate of lane marking which will help to; identify the optimum frequency of time for repainting. The measurements are taken in the selected section on Colombo - Horana (B084) road, Etulkotte - Mirihana - Kohuwela (B120) road, Galagedera - Horana (B123) road and Colombo - Galle - Hambanthota - Wellawaya (A002) road which are considered as urban roads. Digital images are captured on specific locations over a considerable period of time such as one month for deeply analyzing purposes on Colombo - Horana road. The GPS coordinates are checked to verify the specific locations. The relationships between the time period and the remaining area of paint are developed based on digital photo-based measurements according to types of lane marking. The software of 'ImageJ' is used to analyze digital photos. The percentages of road marking remaining areas are taken using the software. The mathematical relationships between percentages of remaining areas of road marking on different types of lanes with respect to the time period after the initial application of thermoplastic paint are found by using digital image analysis. The behaviour of road marking wearing pattern is also be found relevant to the type of lane marking with respect to time period.

Keywords: *visibility of road marking, deterioration of road marking, digital image analysis*

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Development of Evaluation Criteria for Routine Maintenance Work in Performance-Based Road Maintenance Contracts

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Abstract

Abstract Road Maintenance is the key element for the preservation of a road network condition, implementing further improvements and corrections during the lifespan of the road, through continuous monitoring of the condition of all assets and assessments of further needs. Performance-based road maintenance contracts fully depend on the contractor and contractor's capability of managing the projects. PBMC has had a substantial success record in countries over the last decades. This paper aims to provide a framework for the prioritization of the performance-based road network maintenance related to routine maintenance and to ensure that the asset is preserved to maximize the value of the investment in Sri Lanka. PBMC is already practicing in Sri Lanka, but based on the findings conducting road work according to PBMC does not achieve its objective. Criteria used in Integrated Road Investment Program (iRoad), funded by Asian Development Bank (ADB) are used in the study, such as potholes, missing or destroyed signs, grass cutting, and vegetation and litter control which fall in the category of routine maintenance. Major issues in selected criteria are, not having a relevant selection method and not having any research or literature for the evaluation of selected performance criteria available. To overcome the issues and reach the maximum benefits from a project, suitable indicators and evaluation frameworks must be established. The main focus of this research is on routine maintenance activities because periodic maintenances, such as resurfacing and resealing processes require more time to collect data. Therefore, pavement (potholes) and non-pavement (roadside clearance and signage corrections) categories that are related to routine maintenance activities are the main focus of the study. The gathered information will be used to identify the performance indicators for roadway, shoulders, signage corrections, and road safety. The findings are only applicable for the national highways type in the road-class category. The data collection was carried out using visual inspection, video logging, and instant messenger methods. This was done at Executive Engineer's Division Hambanthota at a one-month frequency over a period of ten months. A database is developed to store all the collected data. A practical performance evaluation mechanism is proposed with the use of the database for future planning intentions. Preliminary data collection suggests that roadside cleaning be arranged once a month, vertical clearance of road to be done approximately once in six months. Road signage to be corrected in one-month intervals. Results help to develop better evaluation criteria and the paper discusses the issues to be considered in performance-based road maintenance contracts.

Keywords: *performance-based road maintenance contracts, evaluation criteria, road network maintenance*

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Incursion Risk at Rapid Exit Taxiway Taxi-outs

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Abstract

Aircraft safety in the airport maneuvering areas is one of the key objectives in air transport. One factor that threatens airfield safety is incursion accidents. ICAO Runway and Ground Safety Working Group has identified runway incursions as a high-risk accident category. The number of runway incursion incidents remains at a rate of 1 per day. The three main causes for incursions are operational incidents, pilot deviation, and vehicle/pedestrian deviations. According to the historical accident investigations, pilot errors, air traffic control (ATC) faults, communication errors, ground vehicle driver faults, visibility, sight distance, and sight angle issues are causal factors. According to the Transportation Safety Board of Canada (TSB), the majority of incursions occur when the exiting aircraft crossed the holding position stop-bar in the completion of the exiting maneuver. Changing designs and positions of the rapid exits were some of the top recommendations to the Greater Toronto Airports Authority. Planning and designing taxiways are important aspects in minimizing incursions. The present design guidelines cover the rapid exit taxiway design elements at taxi-in in terms of aircraft safety. Nevertheless, aircraft incursion risk at taxi-out locations is not focused on design guidelines. Considering this research gap and the emerging demand for rapid exit taxiways, this paper developed a methodology to evaluate incursion risk at rapid exit taxiway taxi-outs. Considering two aircraft that both are approaching to the intersection of rapid exit taxiway -parallel taxiway. One aircraft is coming from the rapid exit taxiway and the other one is on the parallel taxiway. At any given moment, the aircraft on the parallel taxiway is a certain distance from the intersection and the aircraft on the rapid exit taxiway is also a certain distance from the intersection. Using the fundamental equations of motion, a mathematical formula is developed to evaluate the distance between two aircraft when the high-speed taxiing aircraft is at the intersection. Accordingly, this mathematical formula is further extended to the following criteria that the distance between two aircraft is not less than the required minimum separation to not to conflict them together. A conflict between two aircraft depends on the aircraft's performance and dimensional characteristics, taxiway configurations. These factors are included in the mathematical condition and they could be adapted to any rapid exit taxiway configuration to evaluate the related conflict probabilities. Here, the term “conflict” is evaluated as potential conflicts may appear even though pilot or controller interventions may stop them to grow up to incursions. Using the methodology, the rapid exit taxiway with the associated least conflict probability at the taxi-out was found. Accordingly, 45-degree acute angle taxiways cause the minimum incursion risk. The greatest conflict probability is given by the 20-degree super acute angle. This seems that conflict probability decrease when the acute angle increases. This is in line with the FAA recommendation for larger taxiway angles such as 90-angle as much as possible to avoid runway incursions. Even though conflict probability decreases with the increasing acute angle, conversely, when the acute angle increases, excursion risk increases at the taxi-in location of the rapid exit taxiways. Therefore, the best suitable rapid exit taxiway configuration should be chosen by considering both excursion and incursion risk.

Keywords: *runway, excursion, incursion, rapid exit*

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Analysis on Design Standards of Bus Terminals in Sri Lanka

Viduni Medawatte[1] and Namali Sirisoma[2]

Abstract

Transportation has become a major component in a countries' development. Improvement of public transportation along with their infrastructure is a timely need to address its demand. The comfort, safety, and attractiveness of a public transport mode should be ensured in order to promote it among citizens. Buses are one of the main public transport modes in Sri Lanka, which has accessibility to a wider area of the country. In order to attract more people to utilize buses, passengers should be offered with necessary services. Bus terminal is a main component of bus transport network, where bus trips are generated or halted. These bus terminals are utilized by a massive number of passengers daily. Therefore, infrastructure should be developed at these stations under proper standards in order to ensure the quality of service provided. However, the existing terminals are unable to fulfill the basic amenities required by passengers and are not sufficiently designed to ensure comfortable movements inside the terminal. Many passenger-bus conflicts, bus-bus conflicts are commonly experienced in terminals. Entry and exit points creates negative traffic impacts at terminal locations. The main reason for this is the absence of a proper set of guidelines that can be referred to, when constructing bus terminal structures and infrastructure. Currently a set of design standards to be reffered for a bus terminal design within the Sri Lankan context does not exist. The main objective of this study is to introduce systematic bus terminal design guidelines ensuring the supply of complete infrastructure facilities needed for bus passengers. Western Province has been selected as the study area for this research. Western province bus route data is obtained from National Transport Commission (NTC), Western Province Passenger Transport Authority (WPPTA), and Sri Lanka Transport Board (SLTB). The origins and destinations of the bus route data were used to identify the bus terminals within the study area due to the absence of a centralized database. The basic features of these identified bus terminals such as total number of bus routes generated, number of long-distance and short-distance bus routes, number of A/C and non-A/C bus routes generated, and the availability of multimodal facility was obtained by classifying the collected data. A total of 44 bus terminals were recognized within Western Province, disregarding the terminals which generate less than 5 bus routes. A terminal classification was developed considering the nature of the identified bus terminals. The terminals were categorized into four main categories namely Category A, B, C and D. Along with the above classification, a terminal ID was developed considering the basic features identified for terminal classification along with its location details. A questionnaire survey was carried out with a total sample size of 300 respondents distributed among bus passengers and bus terminal staff covering 3 bus terminals from each category (12 bus terminals). The objective of the questionnaire survey was to identify the passenger requirements and the standards of the existing terminal facilities. The passengers' tendency to use these facilities while traveling and additional facility requirements apart from the available were taken into consideration. Literature related to existing bus terminal guidelines in other countries and the design standards currently used by architects for terminal construction in Sri Lanka were referred. The features of the Sri Lankan bus transport network, such as types of

buses and passenger behaviors were taken into consideration. Based on the research finding a guide book was developed to be used in Sri Lankan bus designs. It includes a set of design guidelines are submitted for the drafting of bus terminal designs under several sections. Basic building construction guidelines, layout factors such as bus bays, turning radii, parking requirements, pedestrian space requirements, passenger amenities such as seating requirements, queue lines, terminal staff requirements, information, signages, demand of differently-abled passengers and safety standards were taken into consideration. This code of guidelines would be beneficial as there are no proper designing instructions for bus terminals available for the Sri Lankan context at present. Other than that, certain functional requirements for bus terminals are separately identified as mandatory and optional requirements according to the terminal categories. It would prevent the over-allocation of resources in construction of terminals based on the terminal category. This study recommends to follow the guidelines presented in constructing new terminals considering the features of the terminal facilities. It can also be referred to prioritize the facilities to be addressed in the refurbishment of existing terminals.

Keywords: *bus terminal design, design guidelines, terminal operations, transport infrastructure*

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Evaluate the Effect of Segregation in Road Materials on Performance of a Road

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Abstract

Gradation is a key parameter when selecting a suitable road material for sub-base, base, and asphalt courses. Selected gradation of the pavement material considerably affects the performance and service life of a pavement. Even though many studies had focused on the effect of segregation in asphalt mix; only few studies found the evaluation of sub-base and base materials. This paper presents research aiming to evaluate the effects of gradation segregation on individual properties in base, sub-base, and asphalt wearing coarse materials. Since segregation in each material may possible in different forms and due to difficulties in simulating in a laboratory as it is to site condition; segregation levels are defined as the difference between segregated and controlled gradations. For sub-base soil; center, lower limit (coarser mixtures), upper limit (fine mixtures), 5% coarse and 5% fine gradations are selected while for base material (Aggregate Base Coarse-ABC) 10% coarse and 10% fine gradations are also selected than that of sub-base. Since simulating of gradual change in segregation of asphalt is difficult; total mix separated through each sieve and individual asphalt coated aggregates blended for Marshall specimens. Then the levels of segregations are found by bitumen extraction tests and those are from fine side 56%, 44%, 34% and from coarse side 15%, 7%, and 6% relative to the trial mix gradation. Based on those segregation levels; California Bearing Ratio (CBR) values and Maximum Achievable Degree of Compaction (DOC) values are observed for sub-base and base materials while cantabro loss and Marshall properties are observed for asphalt wearing coarse. The results are compared to requirements stipulated in Standard Specifications for Construction and Maintenance of Roads and Bridges (ICTAD, 2009). CBR values are gradually decreased from coarse segregation to fine and at 5% fine segregation; CBR drop from the required limit of 30% for sub-base soil. For ABC; CBR values drop from both coarse and fine sides than the center and at 5% fine segregation drops from minimum limit of 80%. Maximum achievable degree of compaction drops from both fine and coarse segregations of ABC; while gradually increase from coarse side to fine side than that of for sub-base. In the case of asphalt, cantabro loss increases from fine to coarse segregation on average. Bitumen content increases gradually from coarse to fine segregation and at both ends exceeds the minimum and maximum requirements respectively. Marshall stability increases at coarse segregation than that of fine segregation and vice versa in the case of Marshall flow values. According to this study; fine segregation (increase of fines) of sub-base and base materials negatively effect to the layer strength. Fine segregation of asphalt leads to corrugation and coarse segregation leads to raveling during the service.

Keywords: *gradation, sub-base, base, asphalt, segregation,*

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Benchmarking: An Tool to Evaluate the Performance of Information and Fare Integration in a City

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Abstract

Rapid urbanization, a rise in population, and a booming economy have stimulated the growth in cities and resulted in higher dependence on private vehicles for personnel mobility. This has raised issues over the sustainability of transport infrastructure in cities. Public transportation systems (PT) can help achieve the goal of sustainable transportation, but they face tough competition from other private and informal modes of transport. Hence, to ensure sustainability, the existing transport systems, i.e., both public and private, need to re-plan their operations to complement each other. To achieve this aim, the development of multimodal transportation has emerged. Technically, a multimodal transport system (MMTS) has five levels of integration, i.e., physical, operational, institutional, information and Pricing or fare setting. Among these, the Informational and fare setting (I&F) can be achieved easily by developing a trip planner and unified fare collection system. As a result, various cities across the globe have tried to achieve I&F integration and developed trip planners. However, if we evaluate these trip planners, they have considerable variations in their features and characteristics. With this background, the present paper attempts to evaluate the performance of trip planners of twenty-six cities across the globe using benchmarking technique. For the evaluation of I&F integration, based on the detailed literature review, the checklist was designed to measure the degree of I&F integration. The checklist contained six major components, i.e., design of Trip Planner, Information available in Status Updates, Availability of Maps, fare integration, help & contact, and other information. Twenty Indian (Surat, Vadodara, Kolkata, Nasik, Nagpur, Chennai, Chandigarh, Bhopal, Bangalore, Ahmedabad, Kanpur, Prayagraj, Agra, Varanasi, Indore, Amritsar, Pune, Mumbai, Bhubaneswar, and Delhi) and six international cities (London, Singapore, Hong Kong, Paris, New York, and Munich) were evaluated. Finally, their composite information & fare performance index was obtained. To design the I&F performance index of the city, the information available in the mobile-based application was compared with the available checklist. It was observed that Indian cities lag in status updates and other information components. Further, a composite information & fare integration index for all cities was calculated (CI&FII), representing the information and fare integration level achieved in the cities. The CI&FI values of only two Indian cities, i.e., Delhi and Mumbai, were competitive with international cities while the other Indian cities were lagging. Availability of dynamic real-time information of transit stops and transit routes, development of distance-based fare structure for all the public modes of transport, and designing a definitive guide book related to I & F setting are the essential recommendations proposed to improve the MMTS of the (cities).

Keywords: *multimodal transport system, information and fare integration., sustainable transport system*

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Evaluation of Impact of Access Roads on Traffic Flow on Arterial Roads in Colombo

Malaka Hetti Mudalige[1] and Dimantha De Silva[2]

Abstract

The rapid development of Colombo city has resulted in growth in urban traffic. The arterial roads that provide accessibility to Colombo city are experiencing traffic congestions, especially during peak times. The vehicles that enter these arterial roads through closely spaced access roads and exiting vehicles to access roads from the arterial, can be considered as a major contributor to causing traffic congestion. This paper analyses how the close-distance access roads affect the traffic flow on arterial roads. A virtual scenario for a 1km multi-lane arterial road section with separated two lanes in one direction and access roads were connected from the both sides of the arterial road, was created in VISSIM software based on a case study of Galle-Colombo arterial road to replicate local conditions. The flow rate on the arterial road was varied to understand the total delay of the network system and the flow rate of the major arterial roads with varying access road distances. Furthermore, identify the combined impact that can occur within the road network was evaluated by defining an index. The index was defined by considering the total delay of the network system and the flow rates of the major arterials. The recommended distance between access roads to arterial roads was identified as a part of the study. It is recommended that access roads may connect with a minimum of 250m-275m distance between their center lines in a 1km arterial road section for 1000veh/hr to 4000veh/hr volume of arterial flow. One of the findings of this study was when future planners designing urban road network systems, access roads should be connected in above mentioned distance range between their center lines, regardless of the vehicle volume of arterial roads, to minimize total delay of the road network and maximize the through vehicle flow of arterial roads.

Keywords: *arterial roads, delay, VISSIM, un-signalized intersection*

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Development of a Driver Assessment Test: Evaluation of Critical Road Safety Factors

Sanjana Senanayake[1] and Loshaka Perera[2]

Abstract

When considering causes for the road traffic accidents in world as well as in Sri Lanka, driver behaviour has been highlighted as a significant contributory factor. When it comes to Sri Lanka, three wheelers (3W) and motorcycles (MC) has been found as the most susceptible vehicle types to meet with an accident and as mentioned above the driver contribution towards the root causes of such accidents are also found to be high in the recent literature. It is a well-known fact that most of the 3W and MC drivers in the country are representing the younger generation and the aberrant behaviour of such drivers can be observed daily on SL roads. One of the main reasons for such behaviour could be the lack of experience but by monitoring their behaviour more closely it can be observed that young driver's knowledge in rules and regulations is also limited. As a result, their driving standard has fallen below the acceptable levels and also it is observed that their reaction to on road situations is unsatisfactory. When looking at the big picture, it can be stated that all these issues stem from one source, that is poor learning and assessment techniques/procedures used in the country when issuing the driver's license. This study is mainly focused on finding out how prominent these observed issues are among young drivers and a simulation based test material was developed to achieve the said objective. 3W and MC drivers were focused in this study and two different tests were developed since the conditions may vary with vehicle type. In these tests, a serious of situations are simulated and questions were asked from the drivers, who already have a drivers' licenses, to evaluate their response to different conditions. Different conditions for tests were selected from the literature, based on a systematic literature review carried out to screen the situations where drivers have underperformed over the years. In each test, multiple video questions with multiple choices (15 approximately) were given to a driver to mark a choice. For each question a weighted score was assigned based on an expert judgement, mainly considering the severity of the anticipated outcome with a wrong decision. These weights were introduced because the severity expected and complexity of the situation may vary form one question to another. From a sample study with 150 participants (75 drivers form each category) it was found that on average 50% of the drivers (both categories) have failed to provide the correct answer for each question. More importantly, these tests revealed more information (based on the answers provided for each question) about driver behaviour and knowledge which are important to identify in order to uplift the driving standards of the young (new) drivers. On the other hand, this testing mechanism and the principle can be used as a tool to strengthen the testing mechanism of driver's license issuing with further modifications.

Keywords: *driver assessment, driver simulation testing, three wheels, motor cycles, vulnerable road users, road safety*

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Enhanced Probe Vehicles for Vehicular and Road Data Collection and Analysis

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Abstract

Information collection and analysis play a key role in transportation system planning, implementation, and operation. Accurate information on average speed, fuel consumption, road condition (a measure of rider comfort level) of different road segments can be used in route planning to minimize travel time, costs and to increase rider comfort. Furthermore, such information is crucial in driving cycle estimation, greenhouse gas emission estimation and road development. Conventionally, the required data is acquired using manual surveys, probe vehicles with global positioning system (GPS), and with specialized vehicles. These processes can be time consuming, costly, and the information can be outdated unless updated regularly. In this work, we propose a cloud platform to acquire, store and process data related to transport system planning, implementation, and operation. The main novelty of the proposed work is that it can transform any vehicle into a probe vehicle which can collect and transmit real-time data such as average speed, acceleration, fuel consumption, and road roughness of predetermined road segments. The collected data is processed using statistical models and supervised machine learning algorithms to provide information to estimate driving cycles, route planning and international roughness index (IRI) prediction. The main components of the proposed work include a smartphone-based vehicle and road condition data acquisition and transmission platform, a cloud hosted data storing and analytics platform and a web based, real-time information retrieval platform. Vehicle and road condition data are acquired using smartphone sensors such as GPS, accelerometer, and magnetometer as well as from inbuilt vehicle sensors through the control area network (CAN) bus. The CAN bus data is fed to the smartphone through the onboard diagnostic II (OBD II) interface of the vehicle. Signal processing techniques are used to condition the data and filter out the effects of the ambience. The smartphone and CAN bus data are compressed using dictionary coding, and securely transmitted to the cloud hosted storage and analytics platform real-time via a mobile network using a client-server architecture. The communications are designed to minimize the data charges and energy consumption of the smartphone. Typical energy consumption is around 350mAh per 30mins. The received data are processed using micro trip method and K-means clustering to estimate driving cycle, calculate the average speed, number of ‘stop and go’ events, and average fuel consumption of defined road segments. A supervised learning model of four-layer perceptron neural network with L2 regularization is trained using IRI data obtained from the road development authority (RDA) is used to predict the IRI of a road segment based on the vehicle speed, GPS, accelerometer, and magnetometer readings. The results of the analysis is used to select routes based on multitude of criterion, in addition to duration of travel based routing. For an example, the data retrieval application can provide recommendation on routs based on fuel consumption and rider comfort. The proposed platform has numerous applications in fleet management, road development and overall efficiency improvement in transportation systems.

Keywords: *driving cycle, international roughness index, route planning, supervised learning*

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Emissions from Road Transportation, Spatial Distribution and Policies

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Abstract

Air pollution has become one of the main global issues resulting climate changes, temperature rising, more frequent extreme whether events as well as increased number of mortality due to respiratory issues. Vehicle emission is one of the major contributory factors for air pollution which emits CO2, NO2, SO2, and Particulate Matter (PM) along with other pollutants. Although there are international agreements and some targets being set to limit the concentration levels of those harmful pollutants around the world, there is no clear mechanism to achieve such targets yet, especially in Sri Lanka. When developing such mechanism or policies in the transportation sector it is important to know the base case first and then what are the impacts on people's day-to-day transportation needs with new policies. As a starting point, the objective of this research is to analyze the level of road side air pollutants in Western Province of Sri Lanka and to identify the annual variation of road side air quality parameters. In addition, investigating impacts on road side air quality due to imposed policies or development of new policies to improve the road side air quality has been considered in this study. Air quality data (measured monthly using passive sampling technique) from 40 fixed locations from year 2013 to 2018 were collected and spatial analysis was carried out. NO2 and SO2 concentrations of all the measured locations are analyzed using spatial analyze tools in Arc GIS software and maps were generated visualizing the spatial distribution in Western Province of Sri Lanka in order to identify critical locations with low air quality. In order to improve the accuracy of the spatial analysis Western Province boundary is used as a mask. Based on the spatial analysis results it was observed most of the urban area having very high concentration levels of NO2 and SO2 which exceeds more than twice the standard concentration level. It was also observed that from year 2013 to 2017 a gradual decrease of NO2, SO2 levels in Western Province although in year 2018 there is a sudden increase of NO2, SO2 concentration levels but no possible explanation for such an increase has found yet. Results of spatially analyzed concentration levels are correlated with vehicular traffic volumes at selected locations in order to identity the relationship between traffic volumes and the air quality. Average emissions factors were calculated for vehicles in Sri Lanka using Vehicle Emission Testing (VET) data for each vehicle category and used to develop a relationship between air quality concentration levels and vehicular traffic volumes. Based on the analysis, various policies that can be implemented in order to reduce the concentration levels of emissions are discussed.

Keywords: *vehicle emissions, air pollution, air quality, policy, spatial distribution*

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Development of Intercity Travel Demand Models for a Highly Industrialised Regional Corridor

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Abstract

Transport connectivity is one of the critical factors for developing any city, state, or Country. Proper Transport connectivity at the local or regional level always ensures sufficient mobility of passengers and freight movement. Efficient mobility of passengers and freight has a tremendous societal, economic, and environmental effect; hence, transport connectivity leads to the regionâ€™s sustainable development if implemented better. This study considers 6 Rail corridors that connect the three cities Surat, Ahmedabad, and Vadodara, of the Gujarat state. The corridors have been named as the pair of cities such as Surat- Ahmedabad (ST-ADI), Surat-Vadodara (ST-BRC), etc. All three cities have well-established industries such as textiles, diamond bourse, chemical, machinery, metal products, pharmaceuticals, engineering, plastics, electrical appliances, electronics, biotechnology, petrochemicals, and construction. The current study aims to model the rail passenger travel demand and its forecasting up to 2030. Historical railway passenger travel demand (from 2009 to 2019) for the above corridors has been collected from the railway board, New Delhi. Surat-Ahmedabad & Ahmedabad-Surat is the consistently highest demanded rail corridor with an annual passenger of 0.6896 million and 0.7755 million in 2019. In contrast, the Vadodara-Ahmedabad & Ahmedabad-Vadodara rail corridor has the highest CAGR of 13.81% and 15%, respectively. Two approaches can be used (i) aggregate approach (ii) disaggregate approach to model the travel demand. The disaggregate approach is typically used for urban passenger travel demand, such as four-stage modelling, where we need more specific data. The aggregate approach is helpful in the case of regional (intercity) passenger travel demand modelling, such as the direct demand model, which requires lesser data comparably. This study takes the reference of the kraft-shaft model, which is an elasticity based direct demand model. Different explanatory variables such as socio-economic variables (total population of the city & annual income per capita) and level of service parameters of transit (travel time, travel cost, and annual frequency) have been used to develop the direct demand models. Considered variables show higher collinearity among them (>0.75). Ridge Regression approach was considered to establish the demand models. This regression approach works based on the collinearity characteristics of the variables. The collected time series data shows more significant seasonality and dependency with the past time span. To predict the future demand based on the actual behaviour of the time series data, the ‘Autoregressive Integrated Moving Average (ARIMA)’ approach was considered in this study. The correlation between the total travel cost and annual income per capita is very high, reflecting the positive elasticity concerning travel cost to travel demand. However, the general practice always indicates the negative correlation of cost with demand. A long span of time (here ten years) experienced more remarkable economic growth in the study area. A higher correlation between cost and per capita income shows the increased ability of people on travel expenditure. The increased ability is one of the reasons for positive elasticity for total travel cost. The forecast has shown that the passenger demand will grow around 1.6 times on ST-ADI & ADI-ST rail corridor whereas BRC-

ADI & ADI-BRC rail corridor will face around three times rise in passenger demand by the year 2030.

Keywords: *direct demand models, level of service, ridge regression, time series model, elasticity.*

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The User Perception on Introducing Road Pricing to Enter Colombo City

Tharindu Kumarathunga[1] and Dimantha De Silva[2]

Abstract

Road pricing is an effective economic instrument to reduce congestion and to limit the growth in private vehicle travel demand. Road pricing has been successfully implemented in cities such as Singapore and London, resulting in substantial improvements in the urban environment and transport system. The largest barrier for road pricing is the public opposition by private vehicle users. Thus, it is important to study about user perception about road pricing before implementation. The aims of this research are, (a) to identify what factors are to be considered when introducing road pricing to Colombo (b) to reveal user perception about road pricing and factors needed to be addressed. The survey questionnaire was designed to derive the participants' opinions about road pricing been implemented in Colombo. Because of pandemic situation due to Covid-19 the questionnaires were distributed randomly using Google Forms. The survey consisted of 17 Likert scale questions about their opinion about road pricing and alternatives that they may use, if road pricing is implemented in Colombo. Scale varied from strongly disagree to Strongly agree with 5 levels. A total of 647 valid responses were obtained. Respondents consist of 318 private vehicle users, out of which 88% owned a vehicle in car/van/suv category, 22% owned a motorcycle and 1% owned a three-wheeler. Sample had a 95% confident level with 5.5% margin. According to the results, only 31% believe that road pricing is required while 53% believes improving public transport alone, is enough to solve the current congestion. A strong opinion that road pricing should be implemented only with improvement of public transport was demonstrated with 78% agreeing. The general mode shift to public transport if road pricing is implemented seems low with only 17% positively ageing to make a model shift while 55% of the respondents demonstrated that they are more likely to pay the toll and still drive while 28% remained neutral. The same observation was demonstrated by 60% responding that they would not change to public transport at current options and service quality. However, it was observed that they are ready to change to public transport with 72%, 73% and 80% responding positively with a modernized bus service, modernized rail service and a new LRT service respectively showing that a modernized rail-based transport has a slight edge over the bus service to attract private vehicle users. According to the study 44% were willing to pay Rs. 100.00 per entry while 36% were willing to pay between Rs 100 and Rs. 150 if congestion will be reduced through road pricing. The sensitivities of the decisions based on the socio demographics based on age group, monthly income, employment status, gender, distance travel per day, main transport mode, number of entries per day to Colombo and typical number of days per month that enter Colombo were also identified. The results shows that private vehicle userâ€™s level of acceptance of road pricing, the conditions, and the alternatives that they would choose and shows that the existing public transport must be modernized together with introduction of new transport modes to have successful implementation of road pricing in Colombo.

Keywords: *road pricing, public acceptance, Colombo City*

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