15th International Conference

on

TRANSPORTATION PLANNING & IMPLEMENTATION

METHODOLOGIES FOR DEVELOPING COUNTRIES

(TPMDC)

18 – 20 December 2024

Transportation Systems Engineering
Department of Civil Engineering
Indian Institute of Technology Bombay
Powai, Mumbai – 400076, India

Day 1 (18 December 2024)	
Time (IST)	**Event**
8:30 to 10:00	Registration
10:00 to 11:00	Inauguration
11:00 to 11:45	High Tea
11:45 to 12:30	Keynote Session - 1
12:30 to 14:00	Networking and Lunch
14:00 to 15:30	Lecture Session - 1
15:30 to 16:00	Tea Break
16:00 to 17:30	Lecture Session - 2

Day 2 (19 December 2024)	
Time (IST)	**Event**
9:30 to 11:00	Lecture Session - 3
11:00 to 11:30	Tea Break
11:30 to 13:00	Keynote Session - 2
13:00 to 14:00	Lunch
14:00 to 14:55	Poster Session - 1
15:05 to 16:00	Poster Session - 2
16:00 to 16:30	Tea Break
16:30 to 18:00	Lecture Session - 4

Day 3 (20 December 2024)	
Time (IST)	**Event**
9:30 to 11:00	Lecture Session - 5
11:00 to 11:30	Tea Break
11:30 to 12:30	Valedictory
12:30 to 13:30	Lunch

Note: All the lecture sessions include parallel sessions

ABSTRACT BOOKLET

PREFACE

The earliest roots of the Conference on Transportation Planning and Implementation Methodologies for Developing Countries (TPMDC) can be traced back to the International Workshop/Conference series started by The Transportation Systems Engineering (TSE) group of IIT Bombay about 30 years ago by making the first announcement in the WCTRS (World Conference on Transport Research Society) Newsletter. The first Workshop of the series was organized in December 1994 on "*Impact Evaluation and Analysis of Transportation Projects in Developing Countries,*" IEATP-94. Riding on the success of the workshop, the second of the series, Transportation Planning, and Implementation Methodologies for Developing Countries (TPMDC-96) was conducted in December 1996. Starting from year 1996, international conference on TPMDC is conducted biennially.

The practical problems associated with transportation systems engineering in many developing countries including India are different and complex. Therefore, researchers and agencies have been working to analyse the challenges and to identify implementable solutions for various transportation engineering related problems as per prevailing conditions. The TSE group of IIT Bombay is actively involved in the national and local level transport planning, traffic operation and management, pavement design, materials characterization, highway safety, geometric design, intelligent transportation systems and freight transport activities in India. Likewise, many of the agencies in developing countries have gained lot of expertise in transportation planning and significant innovations have been made to address the current issues. TPMDC 2024 brings an ideal platform for researchers, practitioners, and agencies to share and exchange the experience among the transportation professionals of the developing and developed nations.

The three days of conference sessions are consisted of more than 200 selected presentations by the students and delegates. The major themes of the conference are Pavement Systems Engineering, Transportation Planning, Policy and Economics, Traffic Management, Operations, and Safety, Emerging Transportation Technologies, Sustainable Transportation and Logistics.

Organizing Committee
TPMDC 2024

IIT BOMBAY

IIT Bombay, set up by an Act of the Parliament, was established in 1958, at Powai, a northern suburb of Mumbai. Today the institute is recognized as a leader in the field of engineering education and research. Reputed for the outstanding calibre of students graduating from its undergraduate and postgraduate programmes, the institute attracts the best students from the country for its bachelor's, master's and doctoral programmes. Research and academic programmes at IIT Bombay are driven by an outstanding faculty, many of whom are reputed for their research contributions internationally. The idea and ideals on which such institutes are built evolve and change with national aspirations, national perspectives, and trends worldwide.

CIVIL ENGINEERING DEPARTMENT

Indian Institute of Technology Bombay was established in 1958, and the Department of Civil Engineering has been an integral part of the institute since its inception. The department, with its multifaceted faculties, continues to maintain and cultivate its strong links with the building and construction industry and academic and research institutions, both within and outside the country. Beside high-quality teaching and instruction, the department is actively involved in the basic and applied research consultancy and provides high quality technological advisory support through various research and development projects and consultancies to various organizations.

The Department of Civil Engineering offers B. Tech., Dual Degree B. Tech., M. Tech. Ph.D. programmes in the following seven specializations: Transportation Systems Engineering, Geotechnical Engineering, Structural Engineering, Ocean Engineering, Construction Technology and Management, Water Resource Engineering and Remote Sensing Engineering.

TRANSPORTATION SYSTEMS ENGINEERING GROUP

Transportation Systems Engineering (TSE) group started its post graduate programme in 1988. Now it is one of the strongest groups of Civil Engineering Department with ten faculties working in various fields of transportation such as Transportation Planning, Traffic Engineering, Transportation Infrastructure Design, Intelligent Transportation Systems, Highway materials and design. The TSE group is actively involved in the national and local level transport planning activities in India and is now recognized as one of the major research entities in the country.

LABORATORY FACILITIES

The Transportation Systems Engineering laboratories hold many traditional and advanced equipment for testing drivers (Driver Testing Units). These devices include high-fidelity motorized two-wheeler and truck simulators, fixed base car simulators, and in-house developed desktop-based car simulators. The labs are also equipped with high-tech physiological sensors such as eye-trackers, brain, and cardiac activity recording devices along with other instruments such as Radar gun, VBOX, sound meter, pedal sensors, and GPS receiver. Further, we have been using drones and high-definition cameras for field traffic data collection.

Advanced Pavement Laboratory includes advanced research instruments to characterize, analyse and design pavement materials for road constructions. Some of the instruments are Dynamic Shear Rheometer, Bending Beam Rheometer, Aggregate Image Measurement System, Hamberg Wheel-Tracking Device, Universal Testing Machine (UTM), Asphalt Mixture Performance Tester (AMPT), Superpave Gyratory Compactor (SGC), Rotary Evaporator, Loaded Wheel Tester, Cohesion Tester, Wet Track Abrasion Test, Indirect Tensile Asphalt Cracking Test (IDEAL-CT), and Marshall Rutting Test (Marshall RT).

The transportation studio lab features a wide range of software tools for transportation planning and traffic simulation (VISSIM, Paramics and CUBE), pavement analysis, design and management (IITPave, KENPAVE and HDM –IV), Highway geometric design (MX-Road) and GIS (ArcGIS) to analyse the various models related to transportation engineering.

ORGANIZING COMMITTEE

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	Prof. Dharamveer Singh
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	Prof. Sangram Nirmale
	Prof. Archak Mittal
	Prof. S. L. Dhingra

WORKING COMMITTEE MEMBERS

Student Co-ordinators	Members	Members
Ashutosh Pandey	Meenu Tomson	Angshuman Baruah
Rajdeep Kar Choudhury	Irfan Ali	Praveen B L
Anusha Toshikhani	Dr. Akshay Gupta	Aayush Kumar Verma
Ritika	Kirtesh Ajay Gadiya	Ajay Dobhal
Shanoop P	Akant Yadav	Kunal Singh
Akash kumar Naik	Muskan	Abhijeet Kumar Gaurav
Vinayak Gaur	Suraj Gupta	
Rizwan Ul haq	Chaganti Sudha	**Mentors**
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Richa Patel	Dr. Suchismita Nayak	Monik Gupta
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Mohan Kumar Somavarapu	Parth Loya	Abhijna M
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CHIEF GUEST

Mr. Anshumali Srivastava is the Chief General Manager and Regional Officer - Mumbai of the National Highways Authority of India. He holds a bachelor's degree in civil engineering from IIT Roorkee, an MBA from FMS Delhi & Executive MBA from MIT SLOAN, USA. He is a recipient of the Chancellor's Silver Medal at IIT Roorkee, the best paper award in IRC 2024 at Raipur, an appreciation certificate from the Hon'ble Minister for excellent work in Maharashtra each year from 2016 to 2021, and an appreciation certificate from the Chairman NHAI for work as GM Bihar 2011. He is an accomplished technocrat backed by strong 30+ years of end-to-end leadership experience in the Infrastructure/Highways space. He played a pivotal leadership role in fast-tracking India's Highway sector development and expansion. He was specifically tasked by the Government of India to fast-track award of complex multi-million-dollar projects before key general elections in Bihar in 2015. He has also delivered financial modeling/analysis of highway projects, worked out EIRR, FIRR, and mode of project execution (EPC /HAM/Toll) for more than 300 projects working with the Ministry of Road Transport and Highways (MoRTH), Government of India, National Highways Authority of India (NHAI). He has carried out multi-million dollar infra project bidding and implemented multiple projects with sizes varying from 10 -350 Million USD in the last 12 years. He has delivered expedited completion of delayed projects through quick decision-making, fast payments, and issue resolution in a mission mode. He has received an appreciation certificate from Hon'ble Minister for excellent work in Maharashtra each year from 2016 to 2021. He has also received an appreciation certificate from Chairman NHAI for work as GM Bihar 2011.

Mr. Anshumali Srivastava
Chief General Manager and Regional officer, NHAI

KEYNOTE SPEAKER 1

Topic: A Decade of India's Transportation Infrastructure Evolution, Challenges & Opportunities

Mr. R K Bansal holds a degree in Civil Engineering from the University of Bombay (1993 batch) and is currently heading the Roads, Bridges & Formations SBG, Transportation Infrastructure IC, L&T Construction. He has completed his Post Graduate Executive Management Programme from SP Jain Institute of Management & Research (2003) and has further done an Advanced Management Programme from Columbia University, U.S.Mr. Bansal started his career in L&T as a Graduate Engineering Trainee (GET) in the year 1993 when the Roads business was in its growing stages. He has more than 30 years of experience predominantly in the Roads, Bridges & Airports.Mr. Bansal with his expertise in projects execution, construction planning, project management, business development, etc. has served the company in construction of several fast-track projects, number of which were completed in record time. He was part of the team which executed the first Modern Road Project- Sambalpur Rourkela. He spearheaded the Project Planning of L&T's first Expressway- Mumbai Pune Expressway and brought laurels to the company. During his tenure, as a Project Manager, he was instrumental in completing some of the prestigious projects - Surat Manor Road Project, Satara Kolhapur Road Project and Hyderabad Airport Project.

Mr. R K Bansal
Executive Vice President & Head, Road Bridge & Formation SBG TIIC

Under his stewardship, 2 new world records have been created:
1. Highest quantity (51,896 MT) of Bituminous Concrete laid in 100 hours
2. Longest length (112.5 Km) of Bituminous Concrete laid in 100 hours

KEYNOTE SPEAKER 2

Topic: Four decades of Structural evaluation of Pavements in India - Some thoughts

Prof. Kusam Sudhakar Reddy obtained his B.E. in Civil Engineering from Malaviya Regional Institute of Technology, Jaipur (now NIT Jaipur) in 1983, followed by an M.Tech in Highway and Traffic Engineering from IIT Kharagpur in 1985. He earned his Ph.D. in 1993 from IIT Kharagpur, specializing in the analytical design of flexible pavements. Prof. Kusam Sudhakar Reddy has been a faculty member in the Department of Civil Engineering at IIT Kharagpur since 1994 and has held several leadership roles, including Head of the Department of Civil Engineering, Head of the Ranbir and Chitra Gupta School of Infrastructure Design and Management, and Head of the Vinod Gupta School of Management for one year.

Prof. Kusam Sudhakar Reddy
Professor, Indian Institute of Technology Kharagpur

An accomplished academician and researcher, he has authored approximately 190 research papers in international and national journals and proceedings and has guided 20 Ph.D. students to completion. He has handled significant research and consultancy projects sponsored by organizations such as the National Highways Authority of India (NHAI), the Ministry of Road Transport, and other prominent agencies. He has been honored with prestigious awards, including Indian Roads Congress medals, commendation certificates, and the Jawaharlal Nehru Birth Centenary Award of the Indian Roads Congress. He is actively involved as a member/convener of various committees under the Indian Roads Congress, the National Rural Roads Development Agency, and other organizations. His contributions have significantly advanced the fields of civil engineering, infrastructure design, and transportation research in India.

KEYNOTE SPEAKER 3

Topic: Some Comments on Infrastructure for Electric Vehicles: Nevada, USA vis-*à*-vis India

Prof. Shashi Nambisan is the Director of UNLV's Transportation Research Center, interdisciplinary research, educational, and outreach hub. Dr. Nambisan has also served as a civil engineering faculty member at UNLV for more than 22 years, and another 13 years at other universities in the US. With over 35 years of experience in developing research enterprises, Nambisan has led efforts on more than 180 projects, grants, and gifts to develop innovative, technology-based strategies that enhance transportation safety, capacity, and travel time reliability. Along with colleagues and students, he has addressed a broad range of topics such as safety, data analytics, and policy support. His activities have been funded by various federal, state, and local agencies, the private sector, and not-for-profit organizations. Professor Nambisan's services have been recognized by Nevada's Governor Jim Gibbons, who proclaimed January 31, 2007, as Professor Shashi Nambisan Day. Students he advised and mentored serve in professional leadership roles across the U.S. and internationally.

Prof. Sashi Nambisan
Director, Transportation Research Center
Professor, University of Nevada, Las Vegas, USA

INVITED SPEAKERS

Prof. Abdul Rawoof Pinjari
Professor, Indian Institute of Science, Bangalore, India

Title of the Talk: Choice Models with Random Coefficients and Stochastic Variables

Dr. Abhishek Mittal
Principal Scientist, Central Road Research Institute, New Delhi, India

Title of talk: A System's Perspective on The Reliability Analysis of Asphalt Pavement

Ms. Aishwarya Raman
Executive Director, Ola Mobility Institute (OMI)

Title of the Talk: Shaping Cities with The Ease of Moving Index: A People-Centric Approach

Prof. Akhilesh K. Maurya
Professor, Indian Institute of Technology, Guwahati, India

Title of the Talk: UAVs in Lane Free Traffic Research: Data Collection Challenges and Interaction Dynamics

Prof. Anna Charly
Assistant Professor, University of Liverpool, United Kingdom

Title of the Talk: Driving Sustainable Mobility: Harnessing Technological Advancements for A Greener Future

Prof. Bandhan Bandhu Majumdar
Associate Professor, Birla Institute of Technology and Science Pilani, Hyderabad Campus, India

Title of the Talk: Electric-Bicycle Adoption in India: Motivators, Barriers, and Way Forward

Prof. Gourab Sil
Assistant Professor, Indian Institute of Technology Indore, India

Title of the Talk: Investigation of Horizontal Alignment Data Extraction Methodologies in Terms of Cost and Time

Prof. Prabin Kumar Ashish
Assistant Professor, Indian Institute of Technology Kanpur, India

Title of the Talk: Handling Ice on Roads in Sub-Zero Temperature Regions

Prof. Pranamesh Chakraborty
Assistant Professor, Indian Institute of Technology Kanpur, India

Title of the Talk: Evaluation of Data Collection and Notations of Driver Gaze Dataset

Dr. Rajesh Krishnan
CEO of ITS Planners and Engineers Private Limited (ITSPE) and Professor at Birla Institute of Technology and Science Pilani, Hyderabad Campus, India

Title of the Talk: Future Traffic Control with CAVs

Prof. Shriniwas S. Arkatkar
Professor, Sardar Vallabhbhai National Institute of Technology, Surat, India

Title of the Talk: Emerging Travel Technologies: Data Analytics and Applications

Prof. Surender Singh
Assistant Professor, Indian Institute of Technology Madras, India

Title of the Talk: Dominating Parameters Affecting the Suitability of Recycled Aggregates for Concrete Pavements

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Emerging Transportation Technologies

Sustainable Mobility in Transportation

Note: This booklet contains only the abstracts of the consents provided by the authors for inclusion in the Conference Proceedings or the Special Issue Journal.

Pavement Systems Engineering

Paper ID: 4

Performance Evaluation of High Recycle Asphalt Pavement content: A Comprehensive Analysis

Dudhwala Rinkal[1] and Dr. Rajesh Gujar[2]
[1] Phd Scholar, Pandit Deendayal Energy University, Gandhinagar, Gujrat, India
[2] Associate Professor, Pandit Deendayal Energy University, Gandhinagar, Gujrat, India

Abstract. Reclaimed Asphalt Pavement (RAP) has emerged as a promising sustainable solution in pavement recycling. Concerns about global warming and environmental pollution, increase in energy price, and limited financial resources have made pavement engineers to explore various types of technologies such as warm mix asphalt (WMA) technology and alternative materials such as reclaimed asphalt pavement (RAP) in the construction of pavements. As the infrastructure sector grapples with environmental concerns and the need for cost-effective alternatives, RAP offers a compelling proposition by repurposing existing asphalt materials. Through careful processing and blending, RAP can be incorporated into new asphalt mixes, reducing the demand for virgin materials and minimizing waste disposal. The report involves material characterization of VG- 30 bitumen, virgin aggregates, and RAP materials. Mix designs are developed for the Marshall mix design procedure, and samples are prepared for various tests, including Marshall stability, indirect tensile strength (ITS), and tensile strength ratio (TSR). The results demonstrate that the incorporation of high RAP content significantly influences the mechanical properties and durability characteristics of asphalt mixtures. The study identifies the optimal binder content for each RAP percentage, balancing stability, air voids, voids in mineral aggregate (VMA), and voids filled with asphalt (VFA). Overall, this research contributes to the understanding of sustainable pavement construction practices and provides a foundation for the effective incorporation of RAP in asphalt mixtures, paving the way for a more environmentally responsible and cost-effective road construction industry.
Keywords: Bitumen, Reclaimed Asphalt Pavement, High RAP Content, Marshall Mix Design, Indirect Tensile Strength, Tensile Strength Ratio, Cost effective

Paper ID: 9

Influence of Circulating Fluid Temperature and Snow Thickness on Snow Melting Performance and Energy Assessment of Hydronic Pavement System

Pratik Jaiswal[1], Umesh Chandra Sahoo[2], and Anush K. Chandrappa[3]
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[2] Associate Professor, School of Infrastructure, IIT Bhubaneswar, Odisha, India
[3] Assistant Professor, School of Infrastructure, IIT Bhubaneswar, Odisha, India

Abstract. This study examines the snow melting performance and energy assessment of Hydronic Pavement System (HPS), a sustainable system that utilises hot fluid flowing through embedded pipes to remove the snow from the pavement surface. The research investigated the duration of snow melting and energy usage by utilising a validated 2-D transient HPS model as a function of circulation fluid temperature and snow thickness. The findings revealed that increasing the fluid temperature from 40°C to 70°C significantly reduced the time to melt snow, from 2.61 hours to 1.72 hours. However, this temperature increase resulted in a higher energy consumption from 674 kJ to 846 kJ. In addition, the melting time of snow increased by a factor of 2.58 and the energy consumption increased by a factor of 1.83 when the snow thickness was increased from 8 mm to 24 mm. The ideal temperature for the flowing fluid to achieve a balance between snow melting efficiency and energy consumption has been determined to be 50°C. The study developed a regression model with a R^2 of 0.989, demonstrating its ability to rationally forecast the energy use based on fluid temperature and snow thickness. This research contributes significantly to the evolution of more efficient and sustainable snow melting technology. It gives valuable information that may be utilised to enhance the design and implementation of HPS in snow bound regions of India, resulting in safer and more cost-effective winter roadways.
Keywords: Hydronic Pavements, Snow melting, Energy assessment

Paper ID: 17

Cost Analysis for Flexible Pavement using Reclaimed Asphalt Pavement (RAP) for base/subbase

Dulal Chandra Saha[1], Sanjivani D Nigadesaha[2] and J. N. Mandal[3]
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[2] Executive Engineer, Public Works Department, Maharashtra– 400706, INDIA.
[3] Professor (Retd.), Civil Engineering Department, Indian Institute of Technology Bombay

Abstract. The present study focusses on assessment of comparative cost analysis of flexible pavement with alternative options of reclaimed asphalt pavement (RAP) and conventional crushed aggregates in subbase/base layer. Majority of India's vast road network is of bituminous type. One of the main characteristics of bituminous pavement is its frequent maintenance/rehabilitation/reconstruction requirement based on future traffic needs & assessment of its residual strength. Substantial quantities of RAP are generated during this maintenance/rehabilitation/reconstruction process of flexible pavement and this RAP material has potential to be used in new construction of subbase/base course of flexible pavement. However, the strength of RAP is lesser in comparison to that of conventional subbase/base materials (1-3,6-10). Hence, RAP materials need suitable reinforcement for using in subbase/base course of alternative flexible pavement. Bamboo/Polymer geogrid & geocell, separately or in combination, can be used as reinforcement in RAP to enhance its strength and accordingly, bamboo/polymer reinforced RAP can be used as an alternative pavement material for construction of subbase/base course of flexible pavement (2,9). The present study is an attempt to explore the cost effectiveness of bamboo/polymer reinforced RAP in subbase/base course of alternative flexible pavement. Besides its cost effectiveness, it helps in maintaining sustainability in flexible pavement construction.
Keywords: Reclaimed Asphalt Pavement (RAP), Bamboo/Polymer geogrid/geocell, Rehabilitation, Residual strength, Flexible pavement

Paper ID: 20

Utilization of High RAP Content in Hot Mix Design

Manasvi Katiyar[1], Swati Verma[1], Yadav Radhika[1], Aditya Kumar Anupam[2] and Yogesh Shah[3]
[1] B. Tech Student, NIT Uttarakhand India
[2] Assistant Professor, NIT Uttarakhand India
[3] Associate Professor, IITRAM, Ahmedabad, Gujarat

Abstract. A robust road network is indispensable for a country's economic and social advancement. The utilization of Reclaimed asphalt pavement (RAP) in Hot mix asphalt (HMA) has emerged as an environmentally sustainable approach for road construction and maintenance. By incorporating RAP into HMA, old asphalt pavements are reused, mitigating disposal issues and conserving asphalt binders and aggregates, leading to substantial cost savings and societal benefits. This study investigates the volumetric properties and performance of asphalt mixes with varying RAP proportions. RAP sourced from five-year-old pavements in Dehradun is utilized; with approximately 4.5% bitumen content extracted using the Abson and Centrifuge extraction methods. Marshall Mix design produces control mix (0% RAP) and mixes with 66%, 60%, and 50% RAP, conforming to Bituminous Macadam (BM) graded layer specifications. Volumetric analysis ensures compliance with specifications. The Marshall Stability test identifies 50% RAP as unsuitable due to failure in Voids filled with bitumen (VFB) parameter. Subsequent Indirect tensile strength (ITS) tests reveal that 66% RAP offers optimal replacement of original materials.
Keywords: Reclaimed asphalt pavement (RAP), Hot mix asphalt (HMA), Bituminous Macadam (BM), Voids filled with bitumen (VFB), Indirect tensile strength (ITS)

Experimental Studies on UV aging of Asphalt using Rheological and Image Analysis

Adyasha Mohanty[1] and Anush K. Chandrappa[2]
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[2] Assistant Professor, School of Infrastructure, IIT Bhubaneswar, Odisha India

Abstract. An inherent characteristic of asphalt is aging. Apart from thermo-oxidative aging, photo-oxidative aging predominantly causes the aging of asphalt in Asian countries due to its higher exposure to UV radiations, which constitute 3-5% of the solar spectrum. To investigate the UV aging in different binders in India, which included VG40 and PMB 70-XX binders were exposed to UV aging in the laboratory and natural exposure conditions after short-term aging. In the laboratory, 1.0 mm thin asphalt film was aged, while for natural exposure conditions, 0.1, 0.5-, and 1.0-mm thickness were considered. A 1.0 mm thick specimen in the laboratory was aged at 70^oC for a duration of 7 days at a UV intensity and wavelength of 63.66 W/m^2 and 365 nm, respectively. During lab aging, the wind speed was maintained at 15 kmph. For natural exposure conditions, the binders were aged for 1-, 3-, and 6-months duration. The appearance of the binder surface after UV aging depicted a loss of luster in the lab while depicting significant cracking in the natural exposure condition. The cracked area was quantified using image analysis, which indicated a steep increase as the binder film became thinner. The rutting parameter of UV-aged binders in the lab almost increased by 100% compared to STA-aged binders after 7 days of UV aging. Further, %recovery reduced with UV aging indicating damage to the polymer chains in PMB. Overall, the study recommends that UV aging plays a major role in constructing climate-resilient pavements and should be considered in selecting appropriate asphalt types.
Keywords: UV aging, Natural exposure aging, Image Analysis

Influence of Incineration Biomedical Waste Ash on the Characterization of Cement-Treated Road Bases

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[3]National Institute of Technology, Warangal, 506004, India.

Abstract. This study investigates the influence of incinerated biomedical waste ash (IBMWA) on the properties of cement-treated road base materials (CTRB). IBMWA, a by-product of high-temperature (850–1100°C) incineration of biomedical waste, contains inorganic components that could potentially enhance or modify the characteristics of road construction materials when used as a partial replacement for cement. CTRB was prepared by replacing OPC with 0%, 20%, 40%, 60%, 80%, and 100% IBMWA in order to determine the recommended maximum dosage of IBMWA, without compromising its effectiveness. The laboratory performance of CTRB with IBMWA was assessed, which includes unconfined compressive strength (UCS), indirect tensile strength (IDTS), resilient modulus (MR) and wetting and drying (W-D) resistance. The research results demonstrated that the incorporation of IBMWA had a positive influence on the characterization of CTRB. The strength characteristics of CTRB containing IBMWA increased with increase in curing time. However, the strength of CTRB decreased with the increase of IBMWA content. The 7 days UCS of CTRB containing 20% IBMWA met the specification of base course as set by IRC: 37-2018. Additionally, after 12 cycles of wetting and drying, considered mixtures exhibited weight loss below the thresholds established by IRC: 89-2018.The concentrations of heavy metals in these mixtures remained below the limit set by United States Environmental Protection Agency (US EPA) standards. Thus, partially replacing OPC with IBMWA in CTRB can mitigate heavy metal leaching issues, with 20% IBMWA identified as the suggested maximum dosage for effective performance.
Keywords: Incineration Biomedical waste Ash, Stabilization, strength, Durability, and Heavy metals

Paper ID: 32

Investigation of Volumetric Properties of Recycled Mixtures with Waste Engine oil as Rejuvenator: Emphasis on Cost Analysis

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Abstract. In the pavement industry, the use of reclaimed asphalt pavement (RAP) material is increasing due to its cost-effectiveness. However, substituting RAP for virgin aggregates and binder can lead to poor workability and degraded overall performance of the pavement. To address these issues, rejuvenators are being employed. This study explores the effect of waste engine oil (WEO) as rejuvenator on the volumetric properties of recycled mixtures (RMs) with different RAP contents in the direction of sustainable pavements. The study investigates the optimum dosages of WEO through Marshall stability criteria for different RAP contents. Additionally, a comprehensive cost analysis is performed to evaluate the cost of different mixtures and hot mix asphalt (HMA). Results indicates that the inclusion of RAP significantly affects the volumetric properties of bituminous mixtures which can be restored using WEO. The optimal dosages of WEO exhibits the volumetric properties of different RMs similar to the properties of HMA or within the limits suggested by specifications. Furthermore, 12 to 29% of cost saving can be achieved associated with virgin and waste materials, their transportation, and production of bituminous mixture with using 20 to 50% RAP. This study highlights the role of WEO as sustainable rejuvenators, enabling increased utilization of RAP

Keywords: Reclaimed asphalt pavement, Waste Engine oil, Volumetric Properties, Cost Analysis

Paper ID: 33

Effect of RAP Fractionation on Stiffness Behavior of Cold Asphalt Mix

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Abstract. This study investigates the impact of fractionating Reclaimed Asphalt Pavement (RAP) on the stiffness properties of cold asphalt mix (CAM). The RAP material was divided into fine (passing through 2.36 mm) and coarse (ranging from 19 mm to 2.36 mm) fractions, along with an unfractionated type. For each type of fractionation, four RAP dosage levels (25%, 50%, 75%, 100%) were evaluated. CAM was prepared with the optimal emulsion content at an air void of 10±1% for all 13 mix combinations. The Indirect Tensile Stiffness Modulus (ITSM) was conducted at three temperatures (15℃, 25℃, and 35℃) for all 13 mix combinations. The Indirect Tensile Strength (ITS) and Resilient Modulus (RM) tests were also conducted at 25℃. Based on the findings, ITSM of CAM dropped with temperature for all fractionations. Regardless of temperature, the ITSM increased with the dosage of RAP for all fractionations. Compared to coarse and unfractionated mixes, fine fractionated mixes showed a 31% and 30% reduction in stiffness, respectively. Tensile strength improved by 53% for the coarse fraction (at 100% RAP) and by 38% for the unfractionated mix (at 50% RAP), but there was no appreciable change when fine RAP was added up to 50%. The RM values improved by 24%, 83%, and 92% for fine, coarse, and unfractionated mixes at increasing RAP doses. This study recommends using coarse fractionation over unfractionated and fine-fractionation of RAP in CAM for better tensile strength and stiffness characteristics.

Keywords: Cold Asphalt Mix, RAP Fractionation, ITSM

Paper ID: 47

Assessment of Strength and Long-Term Durability Properties of Stabilized Granular Lateritic Soil for Use in Base and Sub-Base layer of Pavement

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Abstract. This study explores the potential of stabilized granular lateritic soil as a viable alternative to high-quality aggregates in pavement layers. Laboratory tests were conducted to comprehensively assess the strength and long-term durability properties of stabilized lateritic soil using varying cement content. Notably, increasing the cement content to 3% resulted in a remarkable threefold increase in unconfined compression strength compared to untreated samples. Moreover, significant improvements were observed in soaked California Bearing Ratio and indirect tensile strength, highlighting the effectiveness of stabilization. Long-term durability was rigorously evaluated through wetting-drying (W-D) cycles, revealing that the stabilized soil met established performance criteria. This confirms its suitability for use in both low and high-volume road construction projects. These findings underscore the improved material performance achievable through proper stabilization techniques. In conjunction with existing literature, this study supports the ongoing research and development of cost-effective and durable road construction materials utilizing locally available resources. By leveraging stabilized lateritic soil, infrastructure projects can potentially reduce dependency on scarce high-quality aggregates, mitigate environmental impacts associated with aggregate mining and transport, and promote sustainable construction practices.
Keywords: Stabilization, Granular lateritic soil, Durability, Unconfined compressive strength, In-direct tensile strength

Paper ID: 48

Development of Flow Number Specification for Rutting of Bituminous Mixes

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Abstract. Rutting refers to the permanent deformation or depression along the wheel path in the pavement surface caused by repeated traffic loading, particularly in hot climates or under heavy traffic conditions. Different candidate tests were established by agencies globally, consequently, different rutting specifications were available in terms of bituminous mix and binder parameters. Flow number test is one of the methods used to evaluate the rutting potential of bituminous mixtures. The present study was conducted to examine the relationship between wheel tracking rut depth and flow number and to develop flow number specifications for the rutting of bituminous mixes typically used in surface course layers for Indian highways. Nine different mixes with nine different binders and one dense-graded surface course gradation were designed and their rutting susceptibility was evaluated, in terms of wheel tracking rut depth and flow number. Using the field rutting performance data collected in an earlier study and the wheel tracking specification developed for different traffic levels, the flow number specification has been proposed for two levels of limiting field rut depth (10 mm and 20 mm) with the help of the relationship between wheel rut depth and flow number.
Keywords: Wheel tracking rut depth, flow number, field rutting performance data, wheel tracking specification, limiting field rut depth

Effect of Waste Transformer Oil (WTO) and Waste Engine Oil (WEO) on the performance of 100% RAP mixes at reduced mixing temperatures

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Abstract. Using sustainable materials in pavement construction becomes essential nowadays to conserve material resources. This paper discusses the effect of Waste Transformer Oil (WTO) and Waste Engine Oil (WEO) on the performance of 100% RAP mixes produced at reduced mixing temperatures and compaction efforts. The mixing temperatures selected in the study are 125 °C, 135 °C, 145 °C, 155 °C, and 165 °C. Compaction efforts selected are 75 and 50 blows. The rejuvenator dosages used are 0.5% and 1% by weight of RAP content. Marshall samples were cast and tested for Marshall stability and flow. Volumetric properties (air voids, VMA, and VFA) are also determined for all the samples. 0% oil dosage could satisfy all the Marshall properties at 125 °C at 75 blows. 0% oil dosage at 155 °C & 165 °C and 0.5% WEO dosage at 135 °C could satisfy all the Marshall properties at 50 blows. It is concluded from the results that adding WEO at 0.5% dosage improves the workability of the mix, leading to better compaction, and helps in producing mixes at reduced temperatures and compaction effort. 100% RAP can produce mixes at reduced mixing temperatures and compaction efforts with WEO as the rejuvenator. Testing of RAP mixes by adding fresh aggregates with or without a fresh binder may be tried to check the effectiveness of WTO as a rejuvenator for the future scope of the work. Performance-based testing of 100% RAP mixes may also be tried as the future scope of work.

Keywords: Reclaimed Asphalt Pavement (RAP), Mixing temperature, Waste Transformer Oil (WTO), Waste Engine Oil (WEO), Marshall stability, Flow, Air voids, Voids in Mineral Aggregate (VMA), Voids Filled with Asphalt (VFA)

Evaluation of Rheological Master Curve Models for Rice Husk Ash-Modified Asphalt: Goodness of Fit Approach

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Abstract. Master curve, a tool for predicting and characterizing asphalt's rheology, utilizes master curve models. The accuracy of a master curve model varies when neat asphalt is modified, attributed to the changes in rheology which necessitates the selection of an appropriate master curve fitting model for modified asphalts. In this direction, an effort was carried out in this research work to analyse the reliability and accuracy of two popular rheological models, the Christensen Anderson (CA) model and the sigmoidal model for Rice husk ash Modified Asphalt (RMA) through statistical goodness of fit indicators. In order to arrive at this objective, rheological characterization of RMA was carried out by performing temperature and frequency sweep tests. Shift factors were determined using the Williams–Landel–Ferry equation, and master curves for the complex modulus of the binders were developed. Further, a detailed goodness of fit analysis was carried out on the CA and sigmoidal model fitting techniques. The research results showcased that both models exhibit lower accuracy at high temperatures compared to intermediate and low temperatures. When comparing the precision of the models, the sigmoidal model exhibits greater accuracy than the CA model. However, the rate of error accumulation with the increase in RHA dosage is higher in the sigmoidal model in comparison with the CA model. Overall, it can be concluded that RHA modification significantly influenced the performance of the CA and sigmoidal models.

Keywords: Non-recoverable creep compliance, zero shear viscosity, recycled asphalt binder

Paper ID: 76

Machine Learning-Enhanced Soil Stabilization Using Multiwalled Carbon Nanotubes and Fly Ash for Road Construction

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Abstract. This study investigates the effects of multi-walled carbon nanotubes (MWCNTs) on the engineering properties of soil-fly ash mixes, with a focus on enhancing California Bearing Ratio (CBR) for potential use as subgrade material in pavement construction. Soil-fly ash mixes were treated with various concentrations of MWCNT, SHMP (Sodium Hexametaphosphate), and cement. An optimal model and an alternative model were developed using CART regression analysis, with R^2 values of 0.95 and 0.84 for training and testing of the optimal model, respectively. A 13-node CART model was selected over a 26-node model to balance predictive accuracy and interpretability. The maximum CBR value observed was 50.78% for a mix of 0.01% MWCNT, 2% SHMP, and 3% cement (20% soil replacement with fly ash), compared to a minimum CBR of 4.39% for untreated natural soil. The findings suggest that adding MWCNT and cement to soil-fly ash mixes significantly enhances CBR, supporting the use of these stabilized materials for developing resilient subgrade layers.
Keywords: MWCNT, CART regression, Predictive modelling, Pavement engineering

Paper ID: 77

Prediction of Deflection Bowl Parameters of Asphalt Pavements Using Machine Learning Techniques

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Abstract. Accurate prediction of deflection bowl parameters is crucial for the effective maintenance and rehabilitation of asphalt pavements. The given study explores the prediction of deflection bowl parameters (DBPs) for asphalt pavements using various machine learning algorithms. A dataset comprising 2001 sample units was utilized, incorporating various numerical input variables, including cracking, Plasticity Index (PI), Maximum Dry Density (MDD), California Bearing Ratio (CBR), Bituminous and Granular layer Thickness, and Pavement Temperature. The objective was to establish a robust correlation for estimates of the DBPs, crucial indicators of pavement structural integrity. The algorithms investigated include Decision Tree, Multiple Linear Regression (MLR), Support Vector Machine (SVM) Regressor, and Gaussian Process Regressor (GPR). The data undergoes rigorous training, testing, and validation across all selected algorithms. Evaluation metrics, particularly R^2 values were employed to compare the performance of each of the selected models. Other metrics, such as MAE, MSE, RMSE, and MAPE, were also used. Results indicated that GPR achieved the highest accuracy, demonstrating its effectiveness in predicting DBPs. The Decision Tree, MLR, and SVM Regressor models, while also effective, demonstrated lower predictive accuracies compared to GPR. The effectiveness of GPR is due to its ability to model complex, non-linear relationships in the data. The given study focuses on the potential of machine learning techniques, particularly GPR, in enhancing the prediction accuracy of deflection parameters, thereby contributing to more efficient pavement management systems. Future work may focus on integrating additional input variables and exploring advanced machine learning algorithms to improve prediction performance.
Keywords: Deflection Basin Parameters, Decision trees, Multiple Linear Regression, Support Vector Machine Regressor, Gaussian Process Regressor

Paper ID: 78

Comparison of structural performance of low volume roads in Kerala using Falling Weight Deflectometer

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Abstract. The study aims to evaluate the structural adequacy of Low-Volume Roads (LVRs) in Kerala using the Falling Weight Deflectometer (FWD). The analysis of pavement deflection data involves a back-calculation process, where pavement layer moduli are derived from deflection values obtained via FWD. This process utilizes specialized software and customized programming. Specifically, the KGPBACK software package is adopted for back-calculation, and a Python pro-gram is employed to perform back-calculation using the BISAR (Bitumen Stress Analysis in Roads) method in MATLAB. For this study, LVRs with a surface type of Open Graded Premix Carpet (OGPC) and Bituminous Concrete of thickness 40 mm (BC-40) are selected. These roads are constructed directly above a granular layer and have a thin bituminous surface layer. Estimating the remaining life of LVRs involves evaluating their current condition and predicting future performance under anticipated traffic loads and environmental conditions. The remaining life in the base year has been estimated in accordance with IRC: 115-2014 and IRC: 37-2018, based on the rebound deflection obtained using FWD. The selected LVRs for the study are found to be safe against fatigue and rutting criteria. The back-calculated moduli using KGPBACK and the BISAR method reveal that pavement layer moduli can be accurately simulated by both methods. Furthermore, the BISAR method can be adopted as an alternative to KGPBACK software. The validated moduli values also provide a good model fit when comparing the deflection values.
Keywords: Low-volume Roads, Falling Weight Deflectometer, KGPBACK

Paper ID: 81

Fatigue Life and Durability Analysis of Waste Glass-Enhanced Cold Bitumen Emulsion Mixtures

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Abstract. The use of hot mix asphalt (HMA) and conventional aggregate in road construction has the unintended consequence of accelerating resource depletion, environmental impact, and the consumption of fossil fuels. Building pavement sustainably is essential to prevent this. One kind of Cold Mix Asphalt (CMA) that provides a sustainable route ahead is Cold Bitumen Emulsion Mixtures (CBEMs). Waste issues are addressed, and flexible pavement development is promoted by using waste materials as fine aggregates in cold-mix asphalt. This study examines the mechanical performance of replacing virgin fine aggregate with WG at different percentages (0% to 100%, in 20% increments), with a focus on fatigue life and resistance to moisture damage. Up to 60% WG content in CBEM-WG mixes showed mechanical performance that was on par with that of conventional HMA and normal CBEM (NCBEM), increased continuously beyond 60% addition, and showed maximum performance at 100% dosage. Moisture damage resistance declines as WG concentration rises but is at par with HMAA statistical analysis was done to show the feasibility and accuracy of using waste glass in place of virgin materials in terms of mechanical properties. The coefficient of determination $R2 > 0.9$ for all criteria indicates a significant effect of waste glass addition on fatigue performance
Keywords: Cold Mix Asphalt, Waste glass, Sustainability, Environment Friendly, Cleaner Production

Evaluating the Impact of Hydrophilic Nanoclay at Binder and Mastic Scale: A Comparative Study

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Abstract. The underlined study focusses on investigating the rheological properties of bitumen binders VG-30 and bituminous mastic modified with hydrophilic Nano Clay (NC). Varied dosages (0%, 2%, 4%, 6%, and 8% by weight of bitumen) of NC were blended with VG-30 using a high shear mixer (HSM). Various performance assessments, including high temperature performance grading (PG), Multiple Stress Creep Recovery (MSCR), frequency sweep, along with scanning electron microscopy (SEM), were conducted. SEM micrographs show that the agglomeration problem arises beyond 6% of NC addition at the binder scale. High PG results indicate that the PG grade of binder reaches 76 from 70, while that of mastic goes as high as 82. Frequency sweep test results show that complex shear modulus (G*) and shift phase angle (δ) improve at both scales; however, the improvement is more pronounced at the mastic scale. Further, the result of MSCR tests show that incorporation of NC leads to enhanced rutting resistance for binders and mastic; however, rutting resistance deteriorated at the binder scales beyond 6% NC. The difference in enhancement for different rheological parameters shows that nano clay modification works better at the mastic scale.
Keywords: Bitumen binders, mastic, hydrophilic nano clay, performance evaluation

Review Article on the Effect of Wireless Charging System for EVs on Pavement

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Abstract. Utilizing electric vehicles (EVs) appears to be a viable way to create a road transportation system that is sustainable. Electrified road systems or road system is one of the many intriguing ideas under consideration at the moment. This engineering review article aims to offer key insights into the potential impacts of wireless EV charging systems on pavement performance and its broader implications for transportation infrastructure. The idea of inductive power transfer (IPT) technology is covered in detail in this review, highlighting the fundamental ideas behind it. While IPT-based roads for wireless charging of EVs offer significant technological advances, they also pose engineering challenges in terms of heat management, material compatibility, and structural performance. This study highlights the potential advantages and challenges of wireless EV charging along with its implications for pavement infrastructure. It also provides insights into both the promising efficiencies of IPT-based eRoads and the engineering risks associated with integrating these systems into roadway structures, such as thermal strain, fatigue, and load-induced deterioration. Understanding these impacts is essential for developing resilient eRoad designs that maintain structural integrity while accommodating emerging charging technologies. Also, recommendations have been made to focus more on prospective solutions for overall improvement in pavement performance.
Keywords: Electrified roads, inductive power transfer, pavement performance

Combine Effect of Sulphur-Chitin on Aging Susceptibility of Asphalt Binder

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Abstract. Modifying asphalt profoundly impacts the oxidation of asphalt considering the performance characteristics for high and intermediate temperature conditions. Aging significantly impacts the inherent properties of asphalt concerning intermolecular properties, which are responsible for the service life of the asphalt mix. Thus, it is important to have a constructive understanding of the role of modifiers in asphalt aging behavior before consideration. Therefore, this present study utilizes a comprehensive laboratory approach to the aging behavior of asphalt and to understand the impact of chitin as a modifier. The aging behavior of chitin-modified asphalt was investigated using different aging indices concerning different physical, rheological, and chemical parameters, tested at high and intermediate temperatures. The investigated parameters inferred that the inclusion of chitin can enhance the resistance of base asphalt and can be more effective at high dosages of chitin.
Keywords: Chitin, asphalt, aging, physical parameters, rheological parameters, carbonyl index

Influence of GGBFS and Processed Coarse RAP in Pavement Quality Concrete

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Abstract. Due to a scarcity of virgin aggregates, the use of reclaimed asphalt pavement (RAP) as a substitute for natural aggregates has gained popularity. Despite the fact that RAP is recycled in asphalt pavement, there is still excess RAP, and its use in concrete pavements has expanded in recent years. According to a survey, 95 percent of India's pavements are bituminous pavement. As a result, the maintenance and reconstruction of such pavements generate RAP, which can be reused in concrete pavements as well as surface course, base course, and subbase of flexible pavements. Various studies on the properties of reclaimed asphalt pavement and its optimal requirements for usage in concrete has been conducted throughout the years. In this study, a total of 8 concrete mixes with various proportions of process coarse RAP (20%, 40% and 60%) and a fixed percentage (40%) of GGBFS with different proportions of processed coarse RAP were prepared to enhance the interfacial transition zone in PQC. A study of fresh properties like slump value, hardened properties like density, mechanical properties like compressive strength, split tensile strength, and flexural strength, durability properties such as abrasion resistance, and time-dependent properties such as shrinkage of PQC mixes was carried out in the present study. The new processing technique enhanced the properties of RAP inclusive PQC mixes and the strength of all the concrete mixes was above the design target strength. It was observed that there was a reduction of more than 60% in the binder content of RAP aggregates as a result of the processing of RAP. The partial replacement of cement by GGBFS also enhanced the properties of concrete mixes. However, with the increase in the percentage of replacement levels of RAP, the properties of concrete mixes were slightly reduced, but the reduction was much less. Based on the strength and durability properties of PQC, it was concluded that GGBFS with Processed coarse RAP aggregate up to 40% can be used in pavement quality concrete (PQC). Hence, this study proves to be effective in the utilization of process RAP aggregates with GGBFS in PQC.
Keywords: Processed RAP coarse aggregate, GGBFS, Compressive strength, Flexure strength, split tensile strength, Drying Shrinkage and Abrasion Resistance

Paper ID: 95

Study on pavement response considering actual tyre contact area on flexible pavements

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Abstract. The conventional approach to designing flexible pavements relies heavily on practical experience and simplified two-dimensional computer analysis. However, there is a growing trend in the transition towards more advanced mechanistic design methods, which aim to overcome the limitations associated with stress, strain and displacement predictions in pavement analysis. This study examines the critical implications of departing from a circular contact area assumption in pavement design, as the Layered Elastic Theory proposed. Accurate tire-pavement interaction is essential to evaluate the pavement damage caused by various tire configurations. Actual tire measurements in this study revealed substantial deviations between the assumed circular contact area and actual contact areas for dual axle with reductions of 3.4% and three-axle trucks with reductions of 5.6%, leading to concentrated loads on smaller surface areas. This concentration results in elevated stress levels on the pavement surface, increasing the risk of damage and fatigue failure. The study revealed that. The study also identifies increased strain values, indicating a greater likelihood of rutting. Finite Element Analysis (FEA) using AbaqusFEA software was used to analyze the pavement responses. The study recommends considering actual contact areas, highlighting the importance of precision in engineering calculations and paving the way for more resilient and sustainable transportation infrastructure.

Keywords: Finite Element Analysis, Actual tire contact area, pavement responses

Paper ID: 99

Quantification of Tire-Pavement Interaction Noise Using Frequency Analysis

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Abstract. Tire-pavement interaction noise (TPIN) significantly contributes to overall vehicular noise, especially at higher speeds, stemming from the interaction between vehicle tires and road surfaces. To quantify TPIN, researchers employed various measurement methods to accurately assess TPIN levels under different conditions and on multiple types of road surfaces. Efforts to reduce TPIN help realize quieter pavements, optimize tire designs, and implement effective road surface maintenance practices. In this study, a novel methodology employing frequency analysis for TPIN quantification has been proposed and compared using the established logarithmic subtraction method. The TPIN increased with an increase in speed, irrespective of the type of pavement. The TPIN crossovers observed for asphalt and cement concrete pavements at different frequencies could not be observed in the subtraction method. Thus, it is essential to consider the noise levels captured at specific frequencies, as each noise source exhibits a specific frequency range signature. Further, the subtraction method overestimates the TPIN compared to the frequency approach. Relations have been developed between TPIN values calculated using the subtraction and frequency approaches. These relations will be useful in estimating TPIN values at specific frequencies, especially if the sound level meter lacks a spectrum analyzer. The research findings provide valuable insights for developing targeted TPIN reduction measures and improving overall transportation noise management.

Keywords: Asphalt Pavement, Cement Concrete Pavement, Noise, Speed, Sound Level Meter

Paper ID: 102

Optimization of Factors Influencing Performance Properties of Bitumen Stabilized Materials using Design of Experiment

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Abstract. Pavement construction sector is exploring possibilities of using bitumen-stabilized material (BSM) due to its environmental benefits, cost-effectiveness, and convenience of application. Based on laboratory investigations, this study analyzes the effect of aggregate temperature (AT) and bitumen emulsion content (BEC) on performance of BSM. The mix design parameters, including BEC and AT, were optimized using a central composite design (CCD) using the response surface methodology (RSM). Furthermore, additional experiments were performed to validate the optimum solution given by the model. The results indicate that the effect of AT on mechanical and volumetric properties of BSM is more significant at lower BEC. Validation of optimum design method showed that RSM optimization is a successful method for BSM mix design.

Keywords: Bitumen Stabilized Material, Sustainability, Bitumen Emulsion, Aggregate Temperature, Response Surface Methodology

Paper ID: 103

Physical and rheological properties of high-float emulsified asphalt residues for chip seal applications

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Abstract. Asphalt surface treatments using asphalt emulsions are widely used in the road industry for pavement preservation, with chip seal being particularly popular due to its low initial cost and ease of construction. High float asphalt emulsions (HFAE) have been developed as an alternative to traditional asphalt emulsions to mitigate common issues such as bleeding, draining, and aggregate chip loss associated with chip seals. Unlike traditional asphalt, residue from HFAE exhibits unique characteristics, traditionally assessed through float tests. This study investigates the behavior of HF emulsified asphalt residues using alternative physical and rheological tests. Visual flow and drain down experiments were conducted to evaluate asphalt's resistance to flow and draining, while a stress sweep test measured the viscosity of HF emulsified asphalt residue. The results showed that HFAE residue demonstrated significant resistance to flow and drain down. Rheological evaluation via the stress sweep test revealed that HFAE residue exhibits a yield stress nature not present in the original asphalt, contributing to its high float characteristics. Understanding how yield stress varies with the type or percentage of emulsifier used can provide valuable insights, enabling researchers to select appropriate HF emulsifiers based on specific field requirements.

Keywords: Asphalt emulsions, chip seal, yield stress, rheology

Paper ID: 111

Impacts of Design Variables on Pavement Design: Sensitivity Analysis for Flexible Pavement

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Abstract. This study investigated the sensitivity of design inputs, namely, resilient modulus of asphalt layer and base layer and thickness of base layer on the performance of flexible pavement. A total of 15 pavement sections were considered in this study and the sensitivity analysis was conducted based on the horizontal tensile strain at the bottom of asphalt layer and fatigue life. Study findings revealed that when the modulus of asphalt mixture was lower than the target or design level, it resulted in higher horizontal tensile strain at the bottom of the asphalt layer. In addition, if the thickness of base layer is lower than the design thickness due to construction variability, the fatigue performance of the pavement system would be significantly reduced. Thus, any divergence in material properties and thickness of layer from the target or designed level would potentially alter the overall performance of flexible pavement system. Overall, it was envisioned that the findings from this study would help researchers, engineers, practitioners, and other stakeholders to quantify the change in design variables and determine its associated impacts on pavement performance.

Keywords: Flexible Pavement, Design inputs, Pavement Design, Sensitivity Analysis, Resilient Modulus, Fatigue life

Paper ID: 130

Estimation of Carbon Footprint using Life Cycle Assessment for Flexible Pavement: Emphasis on User Stage

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Abstract. The amount of carbon dioxide released into the atmosphere from pavements during their lifespan measures the sustainability of the structures. The objective of this study is to quantify the greenhouse gas in terms of $kgCO_2eq$ released during the user stage of flexible pavement. The scope of this study includes the synthesis of relevant databases, collection of the International Roughness Index (IRI), computation of the life-cycle of analysis and estimation of $kgCO_2eq$ during various stages of pavement service time. To differentiate and identify the impacts of design variables on carbon emission, two pavement sections with different design variables were chosen in this study. Though several research studies had explored the carbon emission potential from different pavement systems, this study offered a first-of-its-kind understanding that emphasized the carbon emission incurred during the user stage in the context of IRI and Average Annual Daily Traffic (AADT). In this study, two models were developed based on LTPP data to understand the variation of IRI and AADT in terms of PCU. Furthermore, the Monte Carlo Simulation technique was used to predict variation of IRI for 20 years. A statistical analysis F-test was carried out and it was found that there is a significant disparity in total emissions despite both pavement sections having identical layer thicknesses. It can be concluded that in flexible pavement, road roughness results in higher fuel consumption of vehicles which consequently leads to higher emissions of greenhouse gases. Overall, it is envisaged that this study would provide important insights into the sustainability features of flexible pavement during the user stage, and thus advancing the state-of-the-art pertaining to the construction and maintenance of flexible pavement.

Keywords: Flexible Pavement, $KgCO_2eq$, IRI, Monte Carlo Simulation, F-test

Assessing Intermediate Temperature Cracking Performance of Chitin Treated Asphalt

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Abstract. The goal of the current study is to evaluate chitin's impact on asphalt binder's resistance to intermediate temperature cracking. To produce modified asphalt binder specimens for the investigation, a conventional grade asphalt binder (VG-30) and chitin (Ch) is used as modifiers. By the mass of VG-30, the Ch doses were chosen as 0%, 0.5%, 1%, 1.5%, 2%, 2.5%, and 3%. Temperature sweep and linear amplitude sweep (LAS) tests were used to assess the intermediate temperature cracking performance of conventional and modified bitumen. The results of the investigation on cracking performance parameters showed that the Ch contributes favorably to the bitumen binder's resistance to fatigue cracking. According to the Superpave fatigue factor, adding Ch can enhance the ductile property of modified bitumen, which results in increased resistance to fatigue cracking. Similarly, the fatigue cycle parameter showed that the Ch-modified bitumen can withstand strain better, hence postponing the bitumen binder's fatigue damage for a longer period.

Keywords: Chitin, bitumen, aging, fatigue performance, linear amplitude sweep

Effect of Mineral-Stabilized Black Cotton Soil Subgrade on Flexible Pavement Analysis and Design

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Abstract. Being one of the most expansive soils, black cotton soil is not considered as a foundation material for any civil engineering infrastructure. However, due to the unavailability of good soil, the researchers and practitioners are motivated to identify methodologies to improve the engineering properties of black cotton soil for its use in civil engineering construction. Among the various possible methods of ground improvement, soil stabilization is chosen by a majority of engineers due to its multitude of advantages. In this direction, the research study investigates the effect of mineral-stabilized black cotton soil on flexible pavement analysis and design. To achieve the objective, black cotton soil was stabilized at various percentages of mineral stabilizers at 0, 2, 4, and 6 %, and the engineering properties of the stabilized soil were determined from the laboratory studies, including, standard proctor, unconfined compressive strength, and California bearing ratio. At the optimum stabilizer dosage derived from laboratory studies, pavement analysis using the Plaxis 3D software was carried out to understand the improvement in the mechanistic behavior of mineral-stabilized soil. Further, pavement design in accordance with IRC 37:2018 was performed to quantify the reduction in overall pavement thickness with subgrade stabilization. The results showcased that the stabilization of black cotton soil with mineral stabilizer significantly enhanced the engineering properties of the soil and thus, resulted in a better-performing pavement structure with reduced construction cost. Overall, it can be concluded that the mineral stabilization of black cotton soil is a promising solution for pavement subgrade improvement.

Keywords: Black Cotton Soil, Subgrade stabilization, Pavement Design, Plaxis 3D, Economic Analysis

A Study on the Variability of Viscoelastic Response of Unmodified Asphalt Binder

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Abstract. This study investigates the inherent variability in viscoelastic properties, specifically the complex modulus and phase angle of unmodified asphalt binder. Understanding these properties is essential for highlighting the performance-based behavior of asphalt binders. Despite the very controlled environment in which tests for these properties are done, variability persists due to its complex nature. This might contribute to uncertainties in the pavement response. In this research, fifteen unmodified VG10 asphalt binders were subjected to frequency sweep tests across various temperatures and loading frequencies. The experimental data enabled the construction of frequency and temperature master curve using WLF equation and a sigmoidal model. The temperature master curve was also drawn using a modified version of the WLF equation. Variability in the complex modulus and phase angle values was quantitatively evaluated using statistical indicators, which include coefficient of variation, interquartile range, inter decile range, and inter percentile range. The results for frequency master curves indicated significant variability in the lower reduced frequency for complex modulus and the reverse trend for phase angle. While in temperature master curves, the variability was relatively higher in lower temperatures for both complex modulus and phase angle. These findings underscore the necessity for enhanced understanding and control of binder properties to mitigate the impact on pavement performance.
Keywords: Master curve, Complex modulus, Phase angle, Frequency, Temperature, Uncertainty

Assessment of Dispersion and Physical Characteristics of Asphalt Binders Enhanced with Graphene

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Abstract. This study investigates the dispersion and physical performance of VG30 asphalt binders modified with reduced graphene oxide (rGO) and graphene nanoplatelets (GNP). These nanoparticles were blended with the asphalt binder in varying proportions (0%, 0.5%, 1%, and 1.5%) using a high-shear mixer. Softening point tests were performed on both unaged samples and samples aged for two and six hours using the Rolling Thin Film Oven (RTFO). Storage stability was assessed over 48 hours at 163°C, and fluorescence microscopy examined the uniformity of the nanomaterials within the binder. Results showed that rGO and GNP significantly influenced the physical characteristics of the binder. All modified asphalt samples exhibited increased softening points with aging. However, the addition of rGO or GNP initially reduced the softening point increment (SPI), which increased again when the content exceeded 1%. Storage stability tests indicated that incorporating up to 1.5% of rGO and GNP maintained uniformity during high-temperature storage, indicating compatibility. Fluorescence microscopy confirmed that rGO and GNP were uniformly dispersed in the binder up to a concentration of 1%.
Keywords: Asphalt Binder, Fluorescence Microscopy, Graphene, Softening Point, Storage Stability.

Paper ID: 151

Evaluating the Impact of Plain and Porous Concrete Coverings on Electromagnetic Induction Generated by a Basic Coil Setup

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Abstract. Integrating wireless charging into road networks represents a major leap in transportation engineering, enhancing sustainability and supporting the widespread use of electric vehicles (EVs). This innovation mitigates range anxiety and simplifies the charging process, reducing reliance on dedicated charging stations. Incorporating renewable energy sources like solar panels turns roads into energy-generating assets, further boosting sustainability. EV charging systems primarily use two techniques: conductive and inductive charging. Conductive charging requires physical contact to transfer energy, whereas inductive charging uses electromagnetic fields to transfer energy wirelessly. The latter operates based on Faraday's law of induction, where a changing magnetic flux generates an electromotive force (EMF) in a coil, driving current to charge the vehicle. The study examines the design of primary and secondary coils, evaluating their performance when connected to individual or shared power sources. It analyses light transfer efficiency in secondary coils with different diameters, assessing the impact of vertical magnetic flux ranges and horizontal distances between primary coils. The study also investigates various barrier materials, finding pervious concrete plates more effective than plain cement concrete (PCC) plates for magnetic flux transmission. These insights are crucial for coil designing in wireless energy transfer technology, advancing sustainable transportation systems, and shaping the future of electric mobility.
Keywords: Inductive coil, Inductive charging circuit, Charging infrastructure prototype

Paper ID: 158

Effects of Building Demolition Waste Materials as Filler on Performance of Mastic and Asphalt Mix

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Abstract. Preserving natural resources and mitigating environmental issues is one of the important reasons for repurposing waste materials in pavement construction. Typically, aggregates, fillers, and asphalt binders are combined to create the asphalt mix used to build the pavement's surface layer. In the Northeastern region of India, the availability of conventional aggregates is scanty. Therefore, it creates the platform to work on using different building demolition wastes to replace traditional fillers in asphalt mixtures. This research looks at using three types of building demolition waste such as brick dust, plaster dust, and concrete block dust along with conventional fillers i.e. stone dust and lime dust. To determine the physical and chemical properties of employed fillers, tests such as uncompacted bulk mass, particle size distribution, methylene blue, X-ray diffraction, and specific gravity are performed. Fillers and asphalt binder are combined in three distinct filler/binder (F/B) ratios (0.6, 0.8, and 1) to create asphalt mastic. On these mastics, rheological characteristics (complex modulus, storage modulus, loss modulus, phase angle, and complex shear modulus) are examined. To further examine the performance of the asphalt mix, moisture susceptibility, creep tests, and cantabro abrasion tests are performed. The results of the entire study indicate that, aside from traditional filler, or stone dust, plaster dust performs better, with an F/B ratio of 0.8 due to its cementitious properties.
Keywords: Asphalt Mastic, Filler/binder Ratio, Storage Modulus, Loss Modulus, Phase Angle, Complex Shear Modulus, Indirect Tensile Strength Test, and Creep Test

Paper ID: 161

Optimizing Hydrological and Mechanical Properties of Pervious Concrete: A Statistical Approach

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Abstract. Permeable concrete is an innovative material developed for environmentally friendly pavements. It provides considerable environmental advantages, including enhanced water infiltration and reduced soil erosion. This study examines the impact of mixture design factors—aggregate size, cementto-aggregate ratio, and water-to-cement ratio—on pervious concrete's compressive strength, permeability, and porosity. The analysis of 17 mix designs was conducted using a Box-Behnken Design and a response surface methodology. The results suggest that the material's porosity ranged from 41.73% to 48.85%, and the permeability was between 0.3 cm/s and 0.9 cm/s. Porosity was consistently reduced as the water-cement ratio was increased. Aggregate gradation and the cement-to-aggregate ratio substantially influenced compressive strength and permeability. The optimised mix design met general standards and was closely aligned with predicted values, achieving an average permeability of 0.892 cm/s and a compressive strength of 15.439 MPa. This investigation illustrates that response surface methodology can efficiently optimise mixture designs by balancing permeability and strength, thereby improving performance in practical applications.
Keywords: Pervious Concrete, Response Surface Method, Mix Design, BoxBehnken Design, Statistical Modelling.

Paper ID: 162

Performance Assessment of Asphalt Binder Enhanced With Plastic Pyrolytic Char And Waste Engine Oil

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Abstract. For modern researchers, waste materials such as plastic and oil have become a serious issue for environmental pollution and health risks. This work aims to analyze various engineering properties of asphalt mix and investigate the impact of pyrolytic char on the partial replacement of asphalt binder. In different proportions of 6%, 8%, 10%, and 12% by weight of asphalt binder, pyrolytic char takes the place of asphalt binder. The outcome of the experiment demonstrates that the binder stiffens and gets stronger. The asphalt binder has demonstrated the best results in terms of strength, hardness, and stiffness at 8% replacement. Certain properties of the binder are negatively impacted by increased stiffness. Hence, waste engine oil is used as a modifier for reducing the stiffness properties, and the outcome is favorable. By weight of the partially replaced binder 3%, 5%, and 7% of the waste engine are added. According to test results, 5% of the binder's initial characteristics have been recovered. Indirect tensile strength has increased, and creep deformation decreased along with improvements in Marshall Stability values. Different binder mixes' FTIR results revealed an IR spectrum that is similar, indicating minimal structural and chemical changes. Additionally, the tensile strength ratio is below the allowable threshold. Multiple test results indicated that a combination of 8% pyrolytic char and 5% waste engine oil i.e., COMB 8-5 meets every requirement as VG30.
Keywords: Plastic char, Waste engine oil, Indirect tensile strength, creep deformation, Marshall stability, FTIR

Influence of RAP binder and Waste Oil on the performance of Conventional binder containing Warm Mix Additives

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Abstract. The utilization of reclaimed asphalt pavement material (RAP) is restricted due to the rigidity and maneuverability challenges linked to RAP. This problem is resolved by employing warm mix asphalt (WMA), which enhances the amount of RAP utilized by creating mixtures with equivalent or superior characteristics, such as improved workability and reduced viscosity compared to hot mix asphalt (HMA) at lower temperatures. The aim of this work is to analyze the rheological properties and impact on aging mechanism of asphalt binders mixed with large amounts of Artificial Reclaimed Asphalt Pavement (RAP) produced using Warm Mix Asphalt (WMA) additive and Waste Industrial Oil (IWO) using Fourier transform infrared spectroscopy (FTIR). The VG30 asphalt underwent partial replacement with Rejuvenated RAP, with a weight proportion of 50%. The rheological properties were assessed by the use of a Dynamic Shear Rheometer (DSR), which allowed for the measurement of complex viscosity and PG grading. Additionally, aging simulation was performed utilizing the rolling thin film oven (RTFO) and Oven aging methods. The RTFO test was used to measure the loss of volatiles, while the FTIR test was conducted to analyze the oxidation characteristics. The FTIR spectra investigation revealed the formation of extra C═C, C–O, C═O, and OH bonds as a result of the aging process.

Keywords: Reflection cracking, Short-term aging, Long-term aging, Texas overlay tester

Enhancing OGFC Performance with Polymer-Modified Binders: Rutting Resistance and Durability Evaluation

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Abstract. The Open Graded Friction Course (OGFC) asphalt mix is known for its uniform grading, predominantly containing single-sized coarse aggregates with minimal fines, typically applied in thin layers (around 20 mm) over impermeable road surfaces. OGFC offers notable advantages in regions with heavy rainfall, enhancing pavement surface infiltration capacity and lateral water drainage due to the underlying surface's impermeability. However, challenges such as raveling and rutting have impacted the consistency of pavements using OGFC mixes. This study aims to mitigate raveling concerns by incorporating Polymer Modified Binder into OGFC mixes. Crumb Rubber (10%, 15%, 20%, and 25% by weight of bitumen) and Reclaimed Polyethylene (2%, 4%, 6%, 8%, and 10% by weight of bitumen) were utilized to modify conventional bitumen. The optimal polymer quantity was determined by comparing drain down and abrasive resistance among OGFC mixes at different binder levels. Rutting susceptibility of both conventional and modified mixes was assessed at the optimum binder content. The findings revealed that OGFC mixes prepared with modified binders exhibited enhanced abrasive resistance compared to those using conventional binder. Specifically, the OGFC mix incorporating 6% reclaimed polyethylene modified binder demonstrated a remarkable 7.5% decrease in abrasion loss compared to the conventional mix. Additionally, it exhibited a 35.2% improvement in rutting susceptibility, surpassing the performance of the 20% crumb rubber modified mix. Consequently, reclaimed polyethylene modified mixes proved more effective in enhancing the rutting resistance of the OGFC layer.

Keywords: Open Graded, Pavement Drainage, Rutting, Reclaimed Polyethylene, Crumb Rubber First Section

Paper ID: 186

Performance Evaluation of Bitumen with Waste Oils as Rejuvenator: State of the Art Review

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Abstract. Flexible pavement comprises of multiple layers designed to adapt to traffic loads and environmental conditions. Bitumen, a key binder in flexible pavements, provides cohesion and waterproofing, ensuring durability and load distribution. The depletion of petroleum sources has resulted in increased bitumen expenses, limiting its availability, hence reinforcing the necessity for an alternative binder. Henceforth, there is a growing interest in recycling and rejuvenating the aging asphalt pavements due to the increased emphasis on sustainable construction. Bitumen undergoes degradation as it ages, resulting in increased rigidity and brittleness, hence compromising the performance of the pavement. Rejuvenators, including waste motor oil and waste vegetable oil, in amalgamation with high-density polyethylene, thermoplastics, used tires, coal fly ash, diatomite powder, etc., have been found to be efficient in restoring the qualities of aged bitumen. This paper assesses the effectiveness of using waste oils to rejuvenate bitumen, focusing on the chemical interactions between the two and the subsequent enhancements in flexibility and durability. The studies indicate that waste oils can significantly enhance the bitumen's capability to withstand cracking at low temperatures and increase its durability under repeated stress. However, the effectiveness of this improvement depends on the type and dosage of the oil utilized. This study also discusses issues such as the possibility of excessive softness, variations in the content of oil, and the requirement to optimize the amount of rejuvenator used.

Keywords: Bitumen, review study, waste engine oil, rejuvenator, pavement

Paper ID: 198

Effect of Waste Plastic on Moisture Damage Resistance of Warm Mix Asphalt Mixtures

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Abstract. The present study aims at investigating the effect of waste plastic coupled with warm mix asphalt additive (WMA) on moisture susceptibility of bituminous mixes. Bituminous concrete-II gradation (i.e., BC-II) was selected to prepare the bituminous mix. Viscosity grade binder (VG-30) and basalt aggregate were used for the study. At first, a wet process was adopted, i.e., waste plastic was added to bitumen with 7.5%, 10.0%, and 12.5% dosage of plastic by weight of bitumen to prepare a set of plastic modified bitumen. Secondly, bitumen was modified with 6% WMA additive, i.e., zeolite which was further treated with 7.5%, 10.0%, and 12.5% dosage of waste plastic by weight of bitumen to prepare another set of waste plastic-WMA modified bitumen. Using the prepared binder sample, bituminous mixes were designed following Marshall method of mix design. The moisture susceptibility of the prepared mixes, namely control mix, waste plastic modified mix, and plastic-WMA modified mixes were tested using Indirect Tensile Strength (ITS) and Boiling water tests. Results revealed that plastic modified mixes were found to have higher resistance to moisture damage compared with control mix. It was found that tensile strength ratio (TSR) based on ITS test has highest value of 90.42% for 10% plastic modified bituminous mixes compared with control mix (TSR = 84.99%) indicating improved resistance to moisture damage. In addition, 10% plastic modified bituminous mixes showed 99% coating of bitumen retained after boiling water test. It was also interesting to note that incorporation of zeolite did not improve the performance of mix against moisture damage. Hence, based on the findings of the present study, it may be concluded that addition of 10% plastic may be used to improve the moisture susceptibility of bituminous mixes.

Keywords: Moisture damage, Waste plastic, Zeolite, Indirect Tensile Strength, Tensile Strength Ratio

Paper ID: 203

Evaluation of Cracking Performance of Bituminous Concrete Mixes Containing High Percentage of RAP Material

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Abstract. Cracking is one of the most common pavement distresses that affect the design life and durability of hot-mix asphalt pavements. The evaluation of cracking resistance is essential in pavement design. Several laboratory tests and performance indicators are used to evaluate cracking resistance. The objective of this study is to utilize the Texas Overlay Tester (TOT) to evaluate the effect of reclaimed asphalt pavement (RAP) on the cracking resistance of Bituminous Concrete (BC-II) mixes. Utilizing the Marshall Mix Design method, asphalt mixes with RAP contents of 0% (Control), 30%, 40%, 50%, and 60% were prepared and tested at their Optimum Binder Content (OBC). The ITS results indicated that the control mix had an ITS value of 1.1 MPa, with slight decreases observed in mixes containing up to 60% RAP, although these changes were not statistically significant ($p=0.478>0.05$). The TSR tests demonstrated that all mixes exceeded the minimum requirement of 80%. The Texas Overlay Test (TOT) was employed to evaluate cracking performance, revealing that higher RAP contents negatively impacted fatigue resistance. The 50% RAP mix has the highest CFE, suggesting that it has the best resistance to crack propagation, even though it has a lower number of cycles to failure. All mixes fall into the Soft-crack-resistant quadrant, indicating that they can resist crack propagation but are more susceptible to crack initiation.

Keywords: RAP, BC-II, Hot mix asphalt, Cracking

Paper ID: 214

Hydro-Mechanical and Chemical Interactions of Red Mud in Pavements: Challenges and Opportunities for Circular Economy

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Abstract. The integration of red mud (RM), an alkaline by-product of alumina production, into pavement construction has both promising opportunities as a potential bulk utilisation route and substantial challenges as well. RM's high alkalinity pose environmental hazards if not managed correctly, yet its potential as a raw material in construction could mitigate these risks. Recent research has explored the transformation of RM into advanced construction materials such as geopolymer concrete and grouting materials for pouring semi-flexible pavements. Sensitivity analyses and microstructural evaluations indicate that RM-based materials, when optimised with additives like ground granulated blast furnace slag and alkali activators, demonstrate improved fluidity, early strength, and heavy metal encapsulation, thereby minimizing environmental threats. Laboratory studies have demonstrated that RM, when incorporated into pavement materials, improves their mechanical properties and durability. RM-blended asphalt mixtures exhibit improved stiffness, rutting resistance, and moisture resistance. RM has also been found to augment the mechanical properties and sustainability of geopolymer concrete by improving its strength, durability, and environmental benefits when combined with materials like blast furnace slag, metakaolin, fly ash etc. These findings address the dual challenge of disposing of RM and improving pavement performance. However, ensuring the long-term durability and environmental safety of RM-based materials remains a critical challenge. Issues such as moisture susceptibility and the leaching of toxic components necessitate further investigation into RM's material properties and associated mechanisms. Thus, a critical review is presented laying focus on effective co-utilisation coupled with material properties of RM in recent reports contributing towards sustainable pavement construction.

Keywords: Red mud, pavement construction, geopolymer concrete, environmentally friendly

Paper ID: 221

Quantification of Dissipation due to Damage of Bituminous Materials

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Abstract. One of the major distresses affecting the bituminous pavement is fatigue, which is studied at multi-scale levels using various post-processing methods. One such method is energy dissipation. However, on fatigue damage, this energy dissipation constitutes dissipation due to viscous and damage effects. Owing to the fact that only the damage dissipation is responsible for fatigue damage in a material, it is necessary to separate this value from total dissipation. In this context, this study aims to look at different methods to apportion fatigue and viscous dissipation from total dissipation for bitumen and mastic. These methods include the use of linear viscoelastic parameters obtained from a linear viscoelastic model and experimental data and the ratio of dissipated energy change approach. For this, time sweep experiments for 20000 cycles are carried out on unaged and long-term aged bitumen and mastic at 20 ℃, 10 Hz and two strain levels. The fatigue damage is determined using the damage dissipation computed using the linear viscoelastic parameters and the ratio of dissipated energy change approach. The results show that the ratio of dissipated energy change approach underestimates the fatigue life of the material.
Keywords: Mastic, Large amplitude oscillatory shear, Energy dissipation, Damage dissipation, Fatigue, Linear viscoelastic model

Paper ID: 235

Effect of Moisture Conditioning on Rheological Properties of Two-phase Hot Mix Asphalt

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Abstract. The reduction of aggregate-bitumen bond caused by moisture damage is a major cause of premature failure of asphalt pavement. This failure is mainly caused due adhesive failure, which involves weakening of bond at aggregate bitumen interface. This becomes more dominant if bitumen film is thin or improper coating of bitumen over aggregate surface occurs. In conventional mixing of aggregate and bitumen, coarse aggregates receive thin bitumen film as compared to fine aggregates. The large difference among the specific surface area of different sizes of aggregates leads to non-uniform distribution of binder. To avoid this, a new mixing technique known as "two-phase mixing" was adopted in the study. In this technique, coarse aggregates were initially mixed with partial binder. After its pre-coating, fines were mixed with it followed by adding remaining binder.

A comparison between asphalt mixes prepared using one-phase and two-phase mixing have been done in terms of tensile strength ratio (TSR) and dynamic modulus. These tests were performed at various freeze-thaw (0, 1, 3 and 6) cycles. Also, the effect of moisture conditioning on rheological properties of two-phase mixes were studied and compared with that of conventional one-phase mixes. The moisture resistance of the mixes was compared using a damage factor introduced in sigmoid function adopted for dynamic modulus master curve fitting. Using this, the extent of shifting of master curve in downward direction was estimated. Both elastic and viscous properties of asphalt mixes were decreased by moisture conditioning. The adopted two-phase was found to produce more moisture resistant asphalt mixes. Lastly, a correlation between TSR and damage factor introduced in sigmoid equation for moisture damage was done, which showed a good correlation.
Keywords: Hot mix asphalt, Rheological properties, Two-phase mixing, Moisture damage

Characterization of Cement-Asphalt Mortar for Ballastless Track of High-Speed Rail

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Abstract. Cement Asphalt Mortar (CAM) is a viscoelastic composite material comprised of cement, emulsified asphalt, sand, water, and auxiliary agents. CAM material is extensively used as a cushion layer in high-speed railway (HSR) in various countries to curtail the damping. High-speed railway networks experience massive vibrations due to movement at greater speeds. This CAM layer is placed as an interlayer between the concrete track slab and the bottom concrete track bed of HSR. CAM materials can be broadly divided into two categories: CAM I and CAM II based on the Asphalt- cement ratio(A/c ratio). For CAM I, the A/C ratio ranges from 0.7 to 1.2 whereas for CAM II, the A/C range is 0.1 to 0.6. CAM materials majorly comprise cement and asphalt emulsions of 29% and 32% of total weight respectively. In this study, Trials were conducted on CAM 1 by altering the combinations formed by A/c ratios ranging from 0.7 to 1.2, Sand cement ratio (S/c ratio) ranging from 0.5 to 2, and W/C ranging from 0.65 to 0.85. From those trials, Combinations with A/c – 0.8, S/c – 0.5 and W/c – 0.85 and A/c - 0.9, S/c – 0.5, and W/c – 0.85 were found to be satisfactory as per their preliminary test performance evaluated on the fresh CAM paste. Those combinations are named A8 and A9 respectively. Mechanical properties of CAM material evaluated through compressive strength test.
Keywords: Cement Asphalt Mortar, Ballastless slab track system, High-Speed Rail, Asphalt-Cement ratio

Advanced Pothole Detection Using Smartphone Sensors and Dynamic Time Warping Technique

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Abstract. Potholes are a potentially dangerous problem that easily actuates into a serious hazard to the safety of both the road and its users. Existing traditional methods for pothole detection may face challenges in exactness, real-time execution, and resources. This research proposes a new approach that uses the Dynamic Time Warping technique which is often used in artificial intelligence and machine learning systems for comparing and aligning time series data. This framework ensures rigorous validation using smartphone sensor data and has an impressive 89% accuracy rate in detection. Threshold optimization ensures adaptability across a wide range of driving conditions for maximum performance with minimized false alarms. This work underpins the technology enabling real-time driver alert systems, efficient road maintenance, and optimum resource allocation to contribute towards road safety and targeted pothole repairs. Future research will center on growing the system's capabilities to include different sensor modalities and integration with the smart city framework.
Keywords: Road Safety, Smartphone Sensors, Dynamic Time warping, Pothole Detection, Threshold optimization, Infrastructure management

Transportation Planning, Policy and Economics

Paper ID: 7

Modelling Mode Choice Behavior Between City Bus Services and Shared Motorized Three-Wheeler Services in Hyderabad City

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Abstract. The present study aims to model the mode choice behaviour between city bus and motorized three-wheeler services in Hyderabad city. A questionnaire survey was carried out to obtain the socio-economic and travel characteristics of individuals. Correlation matrix for socio-economic and travel characteristics were developed to check the multicollinearity between the variables. Binary logistic regression was conducted using the choice of transport mode as the outcome variable, with socio-economic and travel characteristics serving as the predictors. The results of the model show that high income groups are preferring shared motorized three-wheeler when compared to city bus, while low income groups are preferring city bus. As the age increases preference to bus increases when compared to shared motorized three-wheelers. For short distance trips shared motorized three-wheeler services are used when compared with the city bus services. Therefore, to optimize transportation services in the city, an integrated plan for both bus and motorized three-wheelers networks should be developed. This plan would focus on enhancing bus services for longer trips and journeys with extended wait times, while paratransit would be designed to offer frequent services tailored for shorter trips. Such an approach aims to improve overall efficiency and convenience in urban mobility, meeting diverse travel needs across different trip lengths and waiting times.

Keywords: City Bus, Motorized Three-wheeler, Mode Choice Modelling, Binary Logistic Regression

Paper ID: 10

Investigation of the travel mode choice for work trip in Class I cities/urban agglomerations: a case study of Imphal

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Abstract. Mode choice for cities with population less than a million exhibit choice behaviors which is governed by universally common factors like cost, convenience, comfort. In the current paper the mode choice in the study region of Imphal is investigated. A Multinomial Logit Model (MNL) is developed, the prediction accuracy, direct and cross elasticity as well as the acceptable travel time cost and acceptable distance of the trip has been evaluated. The acceptable travel time cost of the various modes is as anticipated with the car users having a highest value. The absolute values of direct elasticity for a 1% change in out of pocket costs indicate a relatively inelastic change in choice probabilities of the modes. The results indicate that public policies such as increase in the out of pocket costs or reduction in in-vehicle times has small effect on the usage and ridership. It also means that the revenue can be increased by raising out of pocket costs. A hierarchy within the choice of alternatives is modeled using Nested Logit (NL). It is seen that car, two wheelers, non-motorized transport, auto form a subset of alternatives whose choice is conditional on choosing the non-shared mode. The marginal choice is between non-shared mode, pooled services, bus, share auto, and tata magic. Based on the willingness to pay survey a choice between the existing shared services (share auto, tata magic) and E- Auto, is explored.

Keywords: Multinomial Logit model, Nested Logit model, class 1 urban agglomeration

Paper ID: 14

Evaluation of Factors Affecting the Service Quality of Mobility Hubs in Developing Economies

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Abstract. Mobility hubs are revolutionizing urban transportation by offering seamless connections between diverse transit modes. However, maximizing their potential hinges on ensuring high service quality to attract riders and enhance user satisfaction. This study adopts a comprehensive approach, divided into two key parts. Firstly, this study identifies indicators for measuring service quality at the Mobility Hub in Vyttila, Kochi. Through an extensive examination of 19 indicators, the study categorizes them into five latent constructs via exploratory factor analysis. Perceived service quality emerges as a second-order latent construct, revealing that service quality is derived from five essential variables: 'transport services and information systems', 'accessibility', 'transfer environment', 'public utilities and other facilities', and 'safety and security'. Confirmatory factor analysis further validates these factors. Secondly, employing Structural Equation Modelling, the study investigates the relationships between service quality attributes and overall service quality. The findings underscore the significance of transfer environment and accessibility, with standard regression weight values of 0.28 and 0.25 respectively. External validation tests confirm the model's robustness, showing that service quality remains consistent within an acceptable error range. These insights offer valuable guidance for government officials, operators, and transport planners, enabling them to formulate informed policies to enhance service quality at the mobility hub and promote public transport usage.
Keywords: Mobility Hub, Factor Analysis, Structural Equation Modelling (SEM), Service Quality

Paper ID: 40

Development of mode choice model of parkers in Alappuzha City

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Abstract. Parking is the act of stopping and leaving a vehicle in a particular place, typically for a period. It's an essential aspect of urban transportation management, crucial for maintaining traffic flow and ensuring accessibility. This study aims to assess existing parking characteristics, develop a suitable discrete choice model to predict commuters' mode choice behaviour. Alappuzha municipality, the selected study area, situated in the most western portion of Alappuzha district in Indian state of Kerala. A user opinion survey was carried out among customers and visitors along a chosen road stretch to gain a full understanding of travel behaviour and factors impacting mode and parking choices. The purpose of the survey was to find out the most important factors influencing parking in Alappuzha city. The analysis is based on data collected from 1393 samples in a user opinion survey. These include a variety of personal information, travel-related data, parking patterns, and fictitious events. IBM SPSS was the software used to analyse the data samples. Vehicle category is chosen as the dependent variable and the socio-economic and travel data are independent variables. Multinomial logit model was developed separately for different modes using SPSS software. The overall prediction percentage of developed model is 73.1% and that of validation model is 77%. Since the difference of overall prediction percentage between original model and validation model is 3.9% which is less than 5%, the developed mode choice model is proved to be good. From the analysis, the parking policies are also framed for the study area for enhancing sustainable transport solutions.
Keywords: Transportation planning, mode choice model, smart parking, Multinomial logit model

Application of Eco-friendly Submerged Vanes for Developing Inland Water Transport

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Abstract. Inland Water Transport (IWT) has many environmental benefits compare to other modes i.e., road or rail and there is a great potential of developing IWT in countries like India with several alluvial rivers. To develop IWT, the most critical factor is maintaining depth during non-monsoon period and eco-friendly submerged vanes is a potent and innovative solution. Submerged Vanes are small hydraulic structures, and they can also be used as effective intervention for fairway development by harnessing natural flow energy for improving depth of navigational channel for vessel movement. This paper is based on a field study, conducted on a particular location on one of the major alluvial rivers in northern India. Results are shared and discussed in the paper after analyzing the pre and post monsoon changes after implementing the intervention at the site.
Keywords: Inland Water Transport (IWT), Submerged vanes, Fairway development, Channel stabilization, Sustainable transport

A Comparative Study of trip generation using traditional Multilinear Regression and Machine learning technique for Bhopal city

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Abstract. The objective of this study is to create a trip generation (TG) model for Bhopal, a rapidly growing city in Madhya Pradesh, India, by comparing the traditional multilinear regression (MLR) technique with a machine learning approach using artificial neural networks (ANN). Data was collected through a questionnaire survey of 450 households (HH) in Bhopal, and 403 valid responses were used in the analysis. The MLR results showed that three variables significantly influenced household trip generation: number of family members, four-wheelers and two-wheelers. Using the same dataset, three ANN models were built, trained, and analyzed. The study discovered that Artificial Neural Networks (ANN) may be effectively utilised for trip generation modelling and can surpass the standard Multiple Linear Regression (MLR) method by providing more precise predictions. The ANN 2 model, with 20 hidden neurons, was found to perform better than the other ANN models. The results of the trip generation model are useful for engineers and planners to calculate trip generation and appropriately design transport infrastructure facilities.
Keywords: Trip Generation, Household Survey, Multilinear Regression, Artificial Neural Network

Paper ID: 74

Commute Distance and Residential Characteristics: Weathering the Storm
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Abstract. Commuting distances in developing countries have received little attention, creating a significant gap in research. This study aims to address this crucial gap by utilizing the 76th NSSO round on 'Drinking water, sanitation, and housing conditions'—a nationally representative dataset for our analysis. Research conducted in developed countries has shown that residential self-selection (RSS) has a negligible role in determining commute distance. In the context of a fast-developing country like India, this article investigates whether this phenomenon holds true. Our primary focus is on understanding the explanatory power of location and physical characteristics of households. Our analysis reveals that over two-thirds of job-related trips in India cover a maximum distance of less than five kilometers, which holds true for both males and females. Additionally, when examining reasons for relocation, it becomes evident that relocation for employment-related reasons is rare, with residence being the core focal point. The association of these variables with commute distances indicates a negligible to weak relationship. Based on our results, we conclude that the inclusion of location and physical characteristics of households need not significantly contribute to the explanatory power of the model, and the FSM, or the Four-Step Model, cannot be the sole basis for transport planning.
Keywords: Household location; Residential Characteristics; Commute Distance

Paper ID: 98

Development of Commuter Mode Choice Model Using Traditional and Latent Class Approaches

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Abstract. The commuter trips contribute to a significant share while estimating the distribution of trips based on purposes. For understanding future transportation needs, mode choice models deliver accurate directions. The present study aims to understand commuter behaviour and develop their mode choice model using traditional and latent class approaches. The required data were collected from Thiruvananthapuram Municipal Corporation, the capital of Kerala state, India. The questionnaire survey form was prepared to capture the socio-economic characteristics, travel details, and spatial characteristics. The questionnaire survey was conducted by directly interviewing the individuals. A preliminary analysis process and correlation tests were conducted to understand commuters' behaviour on mode choice behaviour on their journey. The mode choice model was developed by adopting the multinomial logit technique. As a function of the systematic proportion of all options, the created model calculates the choice probabilities and usefulness of each alternative. The detection of the existence of heterogeneity in commuting choice behaviour based on different model specifications was explored. Further, to establish the association between discrete observable data and discrete latent variables, a latent class model was created which accommodated the preference heterogeneity. The latent class modelling approach facilitates in identification of categories of travellers who share similar preferences. The outcomes of this study will aid in the formulation of more appropriate strategies and policies for diverse demographic groups.
Keywords: Commuting, Latent variable, Latent class, Mode choice, Preference heterogeneity, Multinomial logit

Paper ID: 105

Transit Operational Assessment with Modified Level of Service-based Measures

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Abstract. The transit operational efficiency is evaluated based on frequency, passenger load, and total operational hours. Current measurement definitions for these variables typically use one transit parameter at a time, lacking comprehensive macro-level assessment tools. Frequency and hours of operation represent the supply side, while passenger load reflects demand side of the system. This study aims to bridge the measurement gap for policymakers and practitioners by using the Level of Service (LOS) framework. By comparing seat supply per hour with actual demand, the study identifies the absolute gap between supply and demand. Additionally, using passenger load variation instead of simple passenger load values provides more realistic view of resource overuse or underuse. The study methodology combines the Transit Capacity and Quality of Service Manual (TCQSM)'s LOS measurement guidelines with the proposed absolute difference and passenger load variation-based LOS measurements. The study examines thirteen routes in Surat, India, passing through Rander TAZ. The frequency and passenger load-based measurement show a minimum LOS-B for all routes. However, including the absolute difference and passenger load variation reveals a minimum of LOS-D, with some routes at LOS-E/F. The comprehensive LOS assessment shows that six out of thirteen routes fall below LOS-B, prioritizing them for future policy interventions through macro-level assessment. With a stagnant ridership of 0.25 million per day over past four years, resulting in 2.5% transit mode share and lower LOS on half of the selected routes, the primary cause of low usage is evident. Proposed framework offers more accurate representation of system operations.
Keywords: Transit, Level of Service, Frequency, Passenger Load, K-means

Paper ID: 110

Travel Mode Shift Analysis of Commuters in a Work Centre Campus to Impending Light Metro Transport Facility

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Abstract. Urban productivity is increasingly hampered by rising traffic congestion and the rapid growth of automobile population, which significantly contribute to environmental pollution. As a result, this pollution negatively affects the health of city dwellers. This research focuses on work trip travel patterns in Trivandrum, which is a city facing congestion issues especially during peak hours. In order to gain a deeper understanding of the changing dynamics of workrelated travel before and after the COVID-19 pandemic, an extensive study is carried out in the urban area of Trivandrum. In order to find noteworthy changes in work trip pattern and new trends, this study entails analyzing a variety of work trip characteristics and comparing data from before and after the pandemic. We will also investigate the viability of switching to a light metro rail system along the NH66 route through Kazhakkoottam-Akkulam-Enchakkal-Killipalam for work trip commutes. This evaluation will be conducted based on a scientific methodology of surveys and data collection and further analysis using binomial logistic regression. Travel preference surveys based on user opinion collected by distributing questionnaires is adopted for collection of realistic data on travel preferences.The objective is to assess the acceptability and viability of light metro rail as a sustainable transportation option. The study intends to offer useful insights and suggestions by carefully examining the data and the results of analysis.
Keywords: work trip characteristics, mode shift analysis, light metro, logistic regression

Prioritizing Improvement of Service Attributes of Water Metro using Impact Asymmetry Analysis

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Abstract. This study investigates the impact of various service attributes on customer satisfaction within the water metro system, utilizing the Impact Asymmetry (IA) Index to categorize these attributes into frustrators, dissatisfiers, hybrids, satisfiers, and delighters. The goal is to identify key areas for improvement and strategic focus to enhance overall service quality. The analysis identifies several critical frustrators, including jetty platform protection and punctuality of boat arrival and departure, which exhibit significant negative impacts on customer satisfaction. These areas are essential for immediate improvement efforts to address major sources of customer frustration. Attributes such as comprehensibility of passenger information system (display) and awareness regarding the usage of life jackets fall into the satisfiers category, positively influencing customer perceptions and indicating areas were maintaining or enhancing service quality is beneficial. The findings highlight the need for a strategic approach to service management. Prioritizing improvements in frustrators and dissatisfiers while leveraging the strengths of satisfiers and delighters can optimize service quality and elevate customer satisfaction.
Keywords: Service Attributes, User Perception, Water Metro, Impact Asymmetry Analysis

Effects of Transit Quality of Service Satisfaction and Demographics of Users on Perceived Accessibility

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Abstract. This research delves into a comprehensive study of passenger satisfaction with city bus services in a metropolitan city; Vadodara, India, primarily focusing on perceived accessibility and its direct impact on overall satisfaction. Using Latent Variable Causal Analysis, specifically Structural Equation Modelling (SEM), as the fundamental analytical framework, the study meticulously explores the intricate relationships among various transit system variables, including demographics, that significantly influence the city's transit system. Data from 700 passengers, collected through perception-based questionnaires, are analyzed to assess passenger satisfaction with Vadodara bus services. The variables used in this study were identified by thoroughly examining relevant factors employing the Systematic Literature Review (SLR) method. The SEM analysis uncovers significant findings, highlighting the pivotal role of systemlevel facilities in shaping passengers' perceived accessibility scores, thereby contributing to more gratifying transit experiences. Notably, the study identifies positive associations between stop-level facilities and in-vehicle amenities with perceived accessibility. However, demographic variables (Age) demonstrate an inverse impact on perceived accessibility, underscoring the need for targeted strategies to ensure an inclusive and equitable transit system that caters to the diverse needs of different passenger segments. Through the application of SEM, this research provides valuable insights into the intricate relationship between passenger satisfaction and perceived accessibility concerning city bus services in metropolitan cities in India.
Keywords: Quality of Service, Passenger Satisfaction, Principal Component Analysis, Structural Equation Modelling, Perceived Accessibility, Transit, Public Transport.

Improving First Mile Connectivity of Multimodal Transport System in Bhopal, India using Multinomial Logit Model

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Abstract. First mile connectivity, the initial leg of a journey connecting a trip's origin to the main public transport network, plays a crucial role in the overall efficiency and attractiveness of multimodal transport systems. In Indian cities, where rapid urbanization and population growth have led to increased traffic congestion and air pollution, improving first mile connectivity is essential for promoting sustainable mobility and reducing dependence on private vehicles. This study aims to develop access time index and average accessibility index for enhancing first mile connectivity in Indian cities by applying the multinomial logit model, a discrete choice model that predicts the probability of individuals choosing proportion of access mode of transportation. The study will assess the current state of first mile connectivity in selected Indian cities, identify key factors influencing commuters' choice of first mile modes, and propose targeted interventions to improve the integration of various modes, such as walking, private, and feeder modes, with the main public transport network. Access time index is 0.52 and average accessibility index is 0.48 determined of the Bhopal city, which shows the first mile connectivity of Bhopal city is in poor connectivity. The findings of this study will contribute to the development of evidence-based policies and strategies for enhancing first mile connectivity in Indian cities, ultimately promoting sustainable urban mobility and improving the quality of life for city dwellers.

Keywords: First mile connectivity, average accessibility index, multinomial logit model

Investigation of the Impact of Policy Awareness, Technical Knowledge, and Environmental Consciousness on EV Adoption: Evidence from Four Indian Cities

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Abstract. India has been actively promoting electric vehicles (EVs) as a strategy to decarbonise the road transport sector. Key initiatives, such as purchase subsidies under the FAME scheme and state-level incentives including road tax exemptions, registration fee waivers, and additional purchase subsidies, have been pivotal in driving EV adoption in the country. This study aimed to examine the influence of policy awareness, technical knowledge, and environmental consciousness on EV adoption. The impact of these factors was assessed based on the stated preference of potential vehicle owners in Surat, Kolkata, Pune, and Coimbatore. A random sampling method was used to collect data via interview surveys of 1,555 individuals across these cities. A binary logit model was built to understand the effect of various factors on a buyer's likelihood of opting for an EV in the next 5 years. Age; gender; education; household monthly income; occupation; vehicle ownership; environmental consciousness; and knowledge of EVs, FAME subsidy, and road tax waiver were independent variables. The results from the model indicate that age, income, employment, and current vehicle ownership significantly influence an individual's decision to purchase EVs. However, gender and education are insignificant in the decision-making process. Awareness about road tax waiver significantly influence an individual's choice, whereas awareness about FAME subsidy is insignificant. Further, knowledge about EVs and environmental consciousness positively influence an individual's likelihood of purchasing EVs.

Keywords: Electric Vehicles, Incentives, Binary Logit Model, Latent Factor

Paper ID: 174

Do Trip Length Models Effectively Account for the Trade off Between Speed and Cost for Daily Commuters?

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Abstract. This study evaluates the effectiveness of trip length models in capturing the trade-off between speed and cost for daily commuters in Guwahati, India. Trip length models are crucial in transportation planning, predicting travel distances based on various factors. Traditional models often used fixed cost coefficients, assuming a direct relationship between trip length and cost. Recent models incorporate utility-based approaches, integrating both travel time and monetary cost. This study uses a mixed-method approach, combining quantitative and qualitative research techniques. A detailed questionnaire survey gathered data from 420 respondents, focusing on factors influencing trip length, speed, and cost. The findings indicate a predominant preference for 2-wheelers, with work trips being the most common purpose. Females are found to be more centric towards electric vehicles (EVs) than males. The study examines mode specific trip costs and preferences among commuters, revealing a higher preference for two-wheelers and cars for longer distances. The study highlights the economic efficiency of bicycles and e-rickshaws for shorter trips, while buses and e-buses are more economical for public transport. The results show that trip lengths in Guwahati are generally between 1 to 7 km, with an average trip length of 5.69 km. Understanding the limitations and strengths of current trip length models can help stakeholders develop more accurate tools for forecasting travel patterns, optimizing transportation networks, and making informed decisions on infrastructure investments and policy interventions.
Keywords: Trip Length Models, Speed-Cost Trade-off, Transportation Planning, Travel Behavior

Paper ID: 179

Journeying safely critical systematic review of women's security in Public Transportation systems worldwide

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Abstract. Women face numerous challenges while using public transportation This review explores the critical issue of women's safety and security in public transportation systems across various global contexts. It addresses the multifaceted challenges faced by women, including harassment, assault, and unsafe conditions, which impact their mobility and access to essential services. The study employs a systematic review method to analyze peer-reviewed articles using Preferred Reporting Items for Systematic Reviews and meta-analyses (PRISMA) guidelines. Moreover, the STROBE approach was implemented to assess the quality of selected studies. Over 421 studies were found through literature search on academic and research databases, out of which 38 studies were included in the final review. The review concludes that enhancing women's safety in public transport requires comprehensive strategies, including improved security infrastructure, policy implementation, and increased representation of women in transport planning. This approach aims to create a safer, more inclusive public transport environment that encourages women's participation and access to opportunities.
Keywords: Gender, inequality, public transport, safety, women commuters

Paper ID: 182

Road Transport Connectivity in Indore's Mixed Land-Use Areas: A Focus on Peri-Urban Development

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Abstract. Population growth and migration from rural areas for employment make the modern world more urban. Government authorities' failure to anticipate the quantum of migration in any urban area causes the proliferation of slums in the core areas and peri-urban growth in the periphery of any city. Delays and lapses in the planning process prompt unplanned peri-urban growth with a paucity of nearby infrastructure facilities. Out of many basic factors of infrastructure, the transport system is a vital issue in urban areas. Due to haphazard growth, the road transport network and connectivity in the peri-urban areas and the fringes of the cities cause hurdles insystematic urban development. From a review of the literature, it is clear that much work needs to be done on the peri-urban growth and proper transport network. The present study focuses on the evaluation of road transportation network analysis for a part of the largest metropolitan city Indore in the state of Madhya Pradesh in India. A composite land use of urban, rural, and peri-urban character has been chosen on the North Eastern side of the city which has most fastest rate of city expansion. The indices chosen to assess the connectivity issues are from the Graph Theory applied in transportation geography. The techniques like GIS and remote sensing have been usedto map the area and for computation of the parameters for the calculations of the various indices for the evaluation. The present study concludes that the present network lacks proper connectivity thus there should be more links to connect the urban area to the rural and per-urban areas.

Paper ID: 197

Methodological Approach for Identification of Green Freight Corridor Through Regional Freight Demand Assessment: A Case Study of Visakhapatnam Port Region, India

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Abstract. Road freight transit is growing at an exponential rate, and its environmental impact is becoming more pronounced. Conventional diesel-powered trucks contribute significantly to greenhouse gas emissions and air pollution, jeopardising climatic stability and human health. Green freight corridors, also known as E-Corridors, have emerged as a promising alternative for integrating sustainable technologies and practices into critical freight routes. However, there is relatively little literature on how to scientifically and rationally identify potential corridors for green freight movement. To overcome this gap, the current work presents a systematic methodology for identifying possible freight corridors based on regional freight demand assessment. Visakhapatnam, a significant port city in the east, is used as a case study in the research. The primary, secondary, and tertiary hinterlands of the study region are determined through primary and secondary surveying, including Origin and Designation surveys. Furthermore, these hinterlands are delineated into 31 freight zones, which are used to estimate freight demand. Furthermore, spatial and network analysis techniques in Arc GIS were utilised to detect important freight flow between zones in order to discover prospective green freight corridors. The vehicular turnover on these specific roadways was anticipated and modelled for the year 2047, and the results reveal a reasonably high count of "Multi Axle" and "Two Axle" vehicles, followed by "Three Axle" and "Light Commercial" vehicles. These studies identify four such corridors that have the ability to accommodate alternative fuel cars and can be converted into a "E-Corridor" using existing infrastructure.
Keywords: Green Freight Corridor, Freight Demand Modelling, Freight Electrification, Sustainable Technologies

Paper ID: 224

GIS-Based Performance Evaluation of Bus Routes in Thiruvananthapuram City

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Abstract. In a rapidly developing city like Thiruvananthapuram, the efficient operation of public transportation systems is vital for ensuring sustainable mobility. This study evaluates the performance of city circular bus routes of Thiruvananthapuram, focusing on the effectiveness of existing routes in meeting passenger demands and operational efficiency. The city circular services are designed for daily commuting inside the city on a hop-on-hop-of manner. The key performance indicators such as route coverage, population served, passenger load factor and link load, utilization and proximity analysis were analyzed. The analysis revealed that while a few of the routes efficiently cover the critical urban zones, underutilized capacity of certain routes was also observed during both peak and off-peak hours. Also, the results indicate a significant variation in the utilization of services across different time periods and segments. Both overcrowding and under-utilization of resources were found for different segments and routes. The results offer practical suggestions for improving the city's public transportation system, adding to a framework for more sustainable and effective urban mobility.

Keywords: City Circular Service, Performance Evaluation, Public Transportation

Traffic Management, Operation and Safety

Paper ID: 11

Spatial accessibility and User travel characteristics influencing utilization of public healthcare facilities in Indian rural district. A case study of Hapur District

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Abstract. Equity in health and healthcare is widely accepted as an essential function of public policy. Healthcare has seen the advantage of spatial analysis supported by GIS technologies and road networks & healthcare utilization have a positive relationship. In rural regions, people experience distance barriers due to healthcare provisions. Previous studies have emphasized physical reach as the primary determinant of access however, scholars have overlooked the hierarchy of healthcare facilities and modes of transport that influence travel characteristics in the region. A comparison between user travel behavior and the general accessibility model using GIS is presented highlighting hierarchy-wise catchment area gaps in the region. Also, a comparison between the most suitable modes of transport at different hierarchies is presented. The survey was conducted at each hierarchy of facility in the district and for GIS analysis the road network data is accessed from BB Bikes. The Geographic location of all facilities is tagged by physically visiting all the facilities at the district level & all the infrastructure present is noted by the author and validated through interviews with key professionals of the healthcare facilities. The best and least performing blocks of Hapur district in terms of health accessibility are identified based on the spatial analysis. It is proposed to increase the number of facilities in the region or the capacity of the existing facilities.
Keywords: Rural Accessibility, Public Health, Healthcare Delivery, Spatial Barriers.

Paper ID: 16

Uncovering the Implicit Relationships Between Key Risk factors and Speeding Behavior Among Long Haul Truck Drivers Circulating in India: Application of XGBoost and SHapley Additive exPlanations Technique

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Abstract. Speeding is one of the most common risky driving behaviors among professional drivers, especially Long-Haul Truck Drivers (LHTDs). The objective of the present study is to predict speeding behavior among LHTDs circulating in India and investigate the underlying factors and their influential patterns contributing to speeding. Face-to-face interviews were conducted among LHTDs using a questionnaire consisting of sociodemographic, work, vehicle, health-related lifestyle, and speeding-related characteristics in Salem city, Tamil Nadu, India. While traditional statistical methods like binary logit regression (BLR) lacked predictive power, Extreme gradient boosting (XGBoost) algorithm from machine learning family was adopted to predict speeding behavior among LHTDs. The analysis results showed that XGBoost exhibited better performance in predicting speeding behavior than BLR with accuracy (0.78), F1 score (0.7), and Area Under Receiver Operator characteristic curve (AUROC) (0.76). In addition, SHapley Additive exPlanations (SHAP) were implemented to interpret the developed XGBoost model results and to reveal the importance of individual features. Moreover, SHAP values were utilized to investigate the hidden patterns for major factors affecting speeding behavior. These findings serve road safety authorities and Indian trucking companies to outline suitable policies and help to introduce effective interventions to combat speeding behavior among LHTDs.
Keywords: Speeding, Truck Drivers, Driver Behavior, Safety, Machine Learning

Capacity and Level of Service Estimation of a Roundabout: A Case Study in Silchar

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Abstract. Population growth in Silchar has necessitated the development of efficient transportation systems to alleviate traffic congestion and enhance mobility. This research project focuses on the capacity and level of service (LOS) estimation of a critical roundabout in the city, which is crucial for regulating traffic flow and ensuring smooth vehicular movement. The study aims to evaluate the roundabout's capacity and LOS to identify areas for improvement and optimization. A comprehensive analysis was conducted using field observations and traffic engineering methodologies, including Indo-HCM 2017, IRC: 65-1976 and Highway Capacity Manual (HCM) 2010 guidelines. Capacity and LOS estimation involved calculating critical gaps and clearance times between minor and major road vehicles using the INAFOGA and clearance time methods for the Indo-HCM method. The IRC method estimated roundabout capacity based on weaving traffic proportions, while HCM 2010 used average control delay. Findings indicate that the roundabout's capacity, as estimated by Indo-HCM, is 2414 PCU/h with a corresponding LOS B, reflecting efficient functionality with moderate delays. IRC: 65-1976 methodology suggests a capacity of 2884 PCU/h, essential for effective traffic flow. HCM 2010 analysis shows varying capacities for different approaches varying between 792 PCU/hr to 977 PCU/hr, with LOS of C, A, B, and A for four approaches. The outcomes are expected to guide urban planners, traffic engineers, and policymakers in making informed decisions to enhance the transportation network of Silchar, contributing to the city's sustainable development. Integrating three methodologies enhances accuracy and reliability in transportation planning and traffic management.
Keywords: HCM, Indo-HCM, IRC, Critical Gap, Follow-up time, Capacity, LOS, Delay.

Pedestrian Safety Perceptions at the Crosswalks of Unsignalized Intersections: A case of Hyderabad city, India

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Abstract. Pedestrian safety at intersections remains a critical issue. Though pedestrian crosswalks are providing a prioritized right of way to pedestrians, nearly 14% of total road accidents in 2018 involved pedestrians (MoRTH, 2022). A better understanding of pedestrian behaviour at unsignalized intersections and increasing pedestrian safety are becoming a major concern worldwide. In this context, the present study aims to analyze factors influencing the pedestrian perceptions of safety towards crosswalk facilities at unsignalized intersections by considering Hyderabad, India as a case study. In this process, a questionnaire was designed, and a survey was administered at six different locations to capture the heterogeneity and collected data from 1500 pedestrians with 250 samples from each location. The impact of sociodemographic characteristics like age, gender, and education level on pedestrian perceptions related to safety at the crosswalks and safety enhancements has been analyzed. Further, Principal Component Analysis (PCA) has been performed and it identified three key factors that explain nearly 60 percent of the total variance. For further understanding of the pedestrian safety perception, an ordered logit model has been developed. The model results indicate individual education level has a positive correlation with perceived safety, which suggests that educational programs can significantly enhance pedestrian safety awareness. Additionally, frequent jaywalking has a positive correlation with safety perception, which possibly indicates an irresponsible attitude among pedestrians. Awareness of crosswalk signs also positively affected safety perceptions. Policymakers and urban planners can use these insights to implement targeted interventions, such as educational campaigns, strict enforcement of laws, and infrastructural enhancements, to create a safer walking environment at unsignalized intersections.
Keywords: Pedestrian safety perception, Unsignalized intersections, Crosswalk awareness, Ordinal logit model.

Paper ID: 24

A Cognitive Study on Community Perception of Speed Bumps at Urban Dwellings

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Abstract. Reduced speed zones and infrastructural modifications are carried out to lessen accidents and increase user mobility in areas with large pedestrian traffic. These measures may have the opposite impact in case of faulty design or improper location. Recently, vandalism of speed bumps was noticed on the streets of Chandigarh city, where either the public or the concerned authority had partially removed them. This study examines road users' behavioural aspects regarding community perception towards traffic calming and identifies the key factors influencing their credibility and compliance. An online questionnaire was distributed among the road users of Tier-1 and Tier-2 cities of northern India, wherein 303 valid responses were analysed. Exploratory Factor Analysis (EFA) and a Second-Order Confirmatory Factor Analysis (SCFA) were employed to prove the hypothesized model. The analysis revealed that familiarity, need, and comfort with these measures significantly contribute to the credibility and lead to a positive perception by the road user. In contrast, compliance was affected by factors such as traffic congestion, sudden speed reduction, and unrecognizable signage on traffic-calmed streets, which incorporated a negative perception. By considering the community's perception, policymakers can improve the effectiveness of speed-reducing measures that meet the requirements of all road users.
Keywords: Traffic calming, speed bump, cognitive study, questionnaire

Paper ID: 45

Estimation of Side Friction Score and Its influence on Average Traffic Stream Speed on Four-Lane Urban Roads

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Abstract. Urban roads in developing countries often experience diverse traffic conditions and lax regulatory frameworks, leading to significant side friction activities that impact road capacity and operational speeds. Managing these elements is crucial for optimizing transportation systems. This study focuses on mixed traffic conditions, where side friction components are exceptionally high and often interact with one another. The primary aim is to develop a methodology for quantifying the impact of multiple friction elements into a single metric, termed the Side Friction Score (SFS). The relative importance of each friction variable is determined by assigning weights to them. Two techniques, namely the multiple regression method and relative weight analysis, were used to obtain the relative weight factors. Additionally, the study investigates the sensitivity of speed reduction to SFS levels at different traffic volumes.
Keywords: Roadside friction, Urban midblock, Pedestrian flow, On-street parking, Access roads, Bus stops, Side friction score, Speed reduction.

Paper ID: 59

Impact of Mobile Use and Travel Behavior on Perceived Crash Risk Among Two-Wheeler Riders

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Abstract. This study investigated the relationship between mobile usage, travel habits, and perceived crash risk. A survey conducted in Surat and Ahmedabad used home interviews, face-to-face surveys, and online questionnaires. Starting with a pilot survey of 40 responses, the final survey collected 246 responses, of which 235 were valid for analysis. The survey mainly used Likert scales to assess demographics, driving profiles, risk perception, travel behavior, and mobile usage. SPSS and SEM modeling were applied to analyze the data, revealing a strong correlation between Mobile Travel Behavior (MTB) and risky riding behavior, which significantly impacts crash confidence. MTB was also linked to variables such as Wrong Driving Habits (WDH) and Disobedience of Traffic Rules (DoTR). The study highlights the increased perceived crash risk from mobile use, especially video watching while driving, emphasizing the need for stricter regulations on mobile usage during driving to improve safety policies and compliance.
Keywords: Mobile use, Travel behavior, Perceived risk, Structural equation modelling.

Paper ID: 65

A Structural Equation Modelling Approach to Assess the Factors Affecting the Adaption of Digital Freight Forwarding of MSME in New Delhi: A Case Study of Gandhinagar Wholesale Market

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Abstract. The implementation of digital goods forwarding is critical for MSMEs to remain competitive in the fast-changing logistics industry. In an uncertain market, this transformation is crucial for boosting supply chain efficiency, cutting costs, and increasing customer satisfaction. However, relatively little research is available on this aspect, especially in developing countries such as India. To address this gap the current study investigates the factors affecting the adoption of digital freight forwarding among Micro, Small, and Medium Enterprises (MSMEs) in New Delhi, with a particular emphasis on the Gandhinagar Market, New Delhi. The research aims to identify these factors, analyze existing digital freight forwarding practices in Gandhinagar, and employ Structural Equation Modeling (SEM) to explore the complex relationships between various influencing factors. Key factors and variables investigated include awareness, human resources, business resources, technology resources, transportation cost, time savings, cost savings, visibility/transparency, customer satisfaction, trust, collaboration, and changes in communication. The constructs in the study include adaptability, performance, and relationships. The SEM analysis reveals significant positive relationships between performance metrics (cost saving, visibility/transparency, transportation cost, time savings) and adaptability. Additionally, relationship metrics (customer satisfaction, changes in communication, trust and collaboration) also exhibit significant associations with adaptability. This study provides valuable insights into the dynamics of digital freight forwarding adoption among MSMEs in the Gandhinagar Market. The findings contribute to the development of strategies and recommendations aimed at optimizing the adoption of digital freight forwarding practices among MSMEs, thus enhancing supply chain efficiency and competitiveness in the region.
Keywords: MSMEs, SEM, Freight, Digital, Adaptability, Performance, Efficiency.

A stochastic delay modelling in a multi-channel queue with random arrivals and departures

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Abstract. The most commonly used analytical delay models for signalised intersections, namely Webster's or Ackelick's, are based on the assumptions of random arrivals and deterministic discharge with one queue per lane. This may not be true under different traffic conditions. This study starts with checking these assumptions. Analysis of traffic patterns from a selected study site reveals that both arrivals and departures are random, prompting the use of an M/M/n queueing system for delay formulation. Based on this, a new analytical delay model rooted in queueing theory, designed to address the unique characteristics of multi-class and lanefree (MCLF) traffic, including multiple vehicle classes, lane-free movement, multiple number of servers, and arrival and service processes, is developed. The uniform delay is derived from the cumulative arrivals and departure curves, while the random delay term is by using the properties of the M/M/n queueing system. Empirical evaluations indicate that the proposed model significantly improves delay estimation, highlighting the critical need for developing delay models that are specifically adapted to traffic conditions.

Keywords: MCLF traffic, queueing theory, M/M/n, G/G/n, analytical delay model.

Study on Behavior of Social Groups in Pedestrian Flow at Staircase of Foot-Over Bridge of a Railway Station

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Abstract. Most of the pedestrian facilities with pedestrian flow is not specifically governed by traffic rules but is more based on the social and psychological aspects of individual pedestrians. The pedestrian crowds generally consist of social groups and the group interactions greatly affect crowd behavior thus, it is necessary to understand the effect of groups on pedestrian flow. However, most of the research in this area has not considered group dynamics of pedestrian flow on pedestrian facilities like staircase of foot over bridge of railway station. The characteristics of pedestrian flow while moving up and down stairs of foot over bridge at railway stations in Villupuram, India, have been studied. Using the video graphic method, data is collected during morning and evening peak periods. The movement trajectories were extracted using a semi-automated pedestrian trajectory extractor. The individual and group characteristics were further compared to study the effect of social groups on walking behaviour of pedestrian flow. The inferences from this study can be further used to understand crowd dynamics and improve pedestrian facilities. The design requirements may be amended to meet the demands of pedestrians and to provide effective management of pedestrian flows at the train station's staircase of foot over bridge.

Keywords: Social groups, Crowd dynamics, Lane formation, Walking behavior, Staircase of foot over bridge, Pedestrian flow characteristics

Paper ID: 71

Developing Base Saturation Flow Model and Adjustment Factors for Signalized Intersections under Non-Lane based Mixed Traffic Conditions

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Abstract. Estimating capacity in non-lane based mixed traffic streams has always been a challenge due to the haphazard behaviour of vehicles. The present study aims at developing a saturation flow estimation methodology for non-lane based mixed traffic streams, which is necessary for the capacity estimation and signal design of signalized intersections. The methodology involves formulating a base saturation flow model for mixed traffic streams and adjusting it to the site conditions using various adjustment factors. Base saturation flow is described as a function of width using the concept of unit saturation flow. Further, the traffic characteristics affecting this base saturation flow are developed as adjustment factors. The proposed model is calibrated using field data collected from sixteen signalized intersections across five cities in India. Here, saturation flow from the field is determined using an optimization technique, which estimates the Passenger Car Unit (PCU) value of vehicles in addition to the saturation flow values. These saturation flow values from the field are used to calibrate the width-based base saturation flow model. Further, adjustment factors for bus blockage, blockage by right-turning vehicles and initial surge are developed considering the discharge behaviour of vehicles in mixed traffic conditions. Agreement of the model with the field observed saturation flow value indicates the reliability of the developed saturation flow model in mixed traffic streams. The developed model is specifically helpful for engineers and planners dealing with non-lane based mixed traffic conditions wherein the discharge pattern in the field does not comply with the ideal discharge curve.
Keywords: Saturation Flow, Adjustment Factors, Mixed Traffic, Non-Lane Discipline, Initial Surge, Signalized Intersection.

Paper ID: 75

Analysis of curve based head-on crashes using a decision tree-based approach on rural mountainous highways in India.

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Abstract. The study aimed to analyze the severity of curve based head-on crashes to identify potential high injury combinations for two lane rural mountainous highways. 533 curve based head-on crashes on national highways in the mountainous state of Himachal Pradesh were considered. Curve radius and length which was extracted from GIS using Road Curvature and Analyst tool (ROCA) along with at-fault driver characteristics and cross sectional data, to develop a decision tree based on a Chi-squared Automatic Interaction Detection (CHAID) algorithm. A train-test split of 80%-20% was adopted and appropriate hyperparameter selection was done to avoid overfitting. Model evaluation based on the overall accuracy along with class-wise sensitivity and specificity showed a good overall train and test accuracy (67.6% and 57.3% respectively) along with a reasonable test set sensitivity (61.2%) and specificity (54.1%) for killed and severely injured crashes. Vehicle type was found to be the most important factor. Several high risk combinations resulting in severe head-on crashes were identified. Heavy vehicle drivers navigating curves with narrow pavements and shoulders were at increased risk of severe head-on crashes. Drivers navigating curves less than 90m in length showed a 76% increased risk in severity necessitating proper warning signs. Appropriate recovery space through wide pavements and valley side shoulders along with appropriate night-time visual guidance through proper retro-reflective lane and edge markings should be ensured. The study provides in-depth insights into severe head-on crashes and can help design appropriate risk reduction measures based on combinations of multiple factors.
Keywords: Mountainous, rural, decision tree, interaction, curves. head-on crashes.

Effect of pedestrian crossings on traffic flow parameters at mid-block sections

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Abstract. Pedestrians are a crucial component of urban transportation but are vulnerable at unprotected mid-block locations, especially under mixed traffic conditions. At these locations, some vehicles may yield to pedestrians at crosswalks, but others may use forced gaps to cross the road. This behaviour can reduce vehicle flow and affect traffic conditions. This study aims to investigate the impact of pedestrian crossings on traffic flow characteristics, including speed, capacity, and level of service. To analyse these effects, six-lane divided mid-block sections in urban areas were chosen. Videos were recorded at seven sites, including base and non-base sections, during peak and off-peak hours to collect data on traffic volume and speeds. The analysis shows that as traffic flow increases, speed reduces. The most pronounced speed reductions are at ECIL (18.04%) section, followed by Raj Mahal (17.02%), Rama Devi (RD) college (14.68%), and Unit-I (13.32%). Capacity reduction is greatest at Unit-I (56.06%) due to frequent stops and high pedestrian activity, followed by ECIL (32.56%), Raj Mahal (22.29%), and RD college (19.05%). Also, a model has been developed for the number of pedestrians crossing the road and capacity reduction. The level of service (LOS) also degrades from LOS C to LOS D. Based on speed and capacity reductions and the level of service degradation, it is recommended to improve pedestrian crossing infrastructure and facilities.

Keywords: Pedestrian crossings, midblock, vehicle speed, capacity, and level of service.

Evaluating Safety of Powered Two-Wheelers During Overtaking in Urban Mixed and Weak-Lane-Disciplined Traffic: A Proactive Safety Approach

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Abstract. This study investigates the safety of powered two-wheelers (PTWs) during "on the fly" and "oblique maneuver" type overtaking behaviors in urban mixed and weak-lane-disciplined traffic using the proactive approach. A twodimensional conflict indicator, Anticipated Collision Time (ACT), was employed to detect conflicts involving PTWs during overtaking. The crash risk for each type of PTW overtaking maneuver was then estimated using the extreme value theory (EVT) approach. The study findings reveal that PTWs predominantly perform "on the fly" overtaking maneuvers compared to "oblique maneuver" type overtaking and show a preference for left-side overtaking in urban traffic, although right-side overtaking also occurs frequently. PTWs maintain smaller lateral gaps when overtaking from the right side compared to the left, regardless of the overtaking maneuver type. Importantly, the crash risk associated with "oblique maneuver" type overtaking was found to be more than twice that of "on the fly" maneuvers. These findings highlight the need for targeted safety measures to mitigate the increased crash risk associated with specific overtaking maneuvers and lateral gap management. Public awareness campaigns can further educate PTW riders about high-risk overtaking maneuvers and promote safer riding practices.

Keywords: Powered Two-Wheelers, Overtaking, Surrogate Safety, Extreme Value Theory, Anticipated Collision Time.

Evaluating Speed Limits for Enhanced Road Safety: A Study of Inter-Urban Roads in India

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Abstract. Speed limits and their enforcement are critical for road safety. This study examines the impact of speed limits based on the 85th percentile speed on traffic safety and driver behavior across inter-urban roads, specifically NH-52 in central India, NH-65 and NH-44 in the southern region, and NH-49 and NH-20 in the southeast. Data on spot speeds, and accidents were collected and analyzed. Findings indicate that high violations were prevalent in sections with low-speed limits, which correlated with an increase in accidents. Graphs illustrating this relationship show that as speed violations increase, so do the number of accidents. Conversely, reducing speed limit violations results in fewer crashes. This study underscores the importance of setting realistic speed limits and enforcing them effectively to enhance road safety, providing valuable insights for traffic management strategies

Keywords: Speed Limits, 85th Percentile, Spot speed, Crashes, Violation.

Speed and Acceleration Characteristics of E-rickshaw on Urban Roads in India

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Abstract. This study analyses the speed and acceleration characteristics of ERickshaws on the Urban Roads of Indian cities. Study also examines the effect of passenger count on acceleration and speed rate and effect of level of battery charge on performance of E-Rickshaws. Data were collected from urban areas of Roorkee (Uttarakhand) and Noida (Uttar Pradesh) encompassing 538 observations for acceleration and 253 observations for speed analyses. To analyse the acceleration characteristics second-degree polynomial curves were fitted. After that comparison was made to examine the effect of passenger count and battery charge level using ANOVA and t-test statistics. To examine the effect of passenger, count on speed characteristics ANOVA test was performed. The acceleration analysis showed that with the increase in the passenger count acceleration decreases also t-test indicated better battery performance in the morning. ANOVA test confirmed significant speed differences across passenger loads. These findings offer insights for optimizing E-Rickshaw performance, enhancing design, policy-making, and sustainable urban transport planning.

Keywords: Speed · Acceleration · Electric Vehicle (EV) Electric three-wheeler (E-3W) Two-wheeler (2W) · Electric Rickshaw (E-Rickshaw).

Paper ID: 97

Calibrating Volume Delay Functions for Urban Roads in Delhi, India

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Abstract. Volume Delay Functions (VDFs) are essential for predicting congestion levels and are crucial for infrastructure planning and traffic management. They help quantify the impact of traffic volume on travel times, allowing planners to make informed decisions about road network improvements and traffic management interventions. This study calibrates VDFs using crowd-sourced data with videography data, focusing on urban mid-block sections in Delhi. Unlike traditional approaches, this research determines free-flow speeds using real-time crowd-sourced data and establishes road capacity from field data using five-minute volume observations. The methodology is applied to 8 different locations in Delhi. The results indicate that among the tested VDFs, which include the Bureau of Public Roads (BPR), Conical, and Akcelik models, the calibrated BPR model provided the best fit. This model reduced the mean absolute percentage error (MAPE) for all locations by approximately 60%. Additionally, the BPR model was validated at a separate location, confirming its accuracy. By incorporating real-time crowd-sourced data, this research provides insights for more accurate traffic modelling.

Keywords: Volume Delay Functions, Crowdsourced Data, Free-Flow Speed, Vehicle Mix, Traffic Modelling, Transportation Planning

Paper ID: 100

Analysis of Self-reported Driving Behavior Pattern in the Indian Context

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Abstract. The present study aims to analyze self-reported driving patterns in the Indian context using the Driver Behavior Questionnaire (DBQ). By focusing on aberrant driving behaviors (ADB), violations of traffic rules, human errors, and distractions while driving, the research seeks to identify the determinants influencing these behaviors. The study examines the effect of five latent variables and forty indicators, providing insights into the factors contributing to road safety issues. Four hypotheses are formulated based on an extensive literature review. Responses from 604 users in the western-central and southern parts of the country were collected through predetermined structured questionnaires to derive structural equation models. After removing missing data and outliers using Mahalanobis D-square, 583 samples were used to develop the model. Confirmatory factor analysis (CFA) confirmed the five latent factors and their indicators, and hypotheses were tested through path analysis. The SEM models derived in this study reveal that socio-demographic factors, violations of traffic rules, human errors, and distractions while driving positively influence aberrant driving behaviors. Consequently, these latent factors should receive proper attention during the planning and defining of policies aimed at enhancing road safety. Field investigation were conducted to validate the DBQ responses, capturing the movements of two-wheelers and car drivers to show the frequency distribution of driving behavior. The study provides recommendations to improve drivers' behavior in India.

Keywords: Aberrant Driving Behavior, Errors, Violations, Distractions, Road Safety, Structural Equation Modeling (SEM)

Paper ID: 106

Identifying Critical Safety Issues on 4-Lane National Highways in India Using Reactive and Proactive Methods: A Case Study from NH30 Mohania to Bakhtiyarpur.

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Abstract. Globally, traffic-related deaths amount to 1.37 million per year, or nearly 3,800 per day. In India, the severity of accidents has increased by 32.5% over the past decade, with 38.3 fatalities per 150 accidents. In 2023, there were 512,432 reported accidents in India, resulting in approximately 522 deaths daily and 163,992 fatalities on Indian highways. The safety performance of National Highways is crucial in developing countries like India. This research paper focuses on the four-lane NH-30 (Mohania to Bakhtiyarpur Road, a national highway approximately 230 kilometers long that surrounds the city of patna, India. Safety performance of four lane highway is a primary concern for developing countries such as India. This paper examines the advantages of the Mohania to Bakhtiyarpur Road, highlighting improvements in commuter travel time, goods transportation, accident reduction, and economic growth. Additionally, it underscores the importance of monitoring road conditions to ensure a safe, efficient, and adaptable transportation system. This process includes collecting data on road safety and performance and pinpointing areas needing improvement. So, a study on the identification of risk factor on such as highways is of immense interest in mitigating road accidents. The paper highlights the role of trained professionals and community stakeholders in conducting road observations and ensuring that transportation infrastructure meets the needs of local communities. This case study presents crucial observations made at specific locations on the Mohania to Bakhtiyarpur Road. The study aims to analyze traffic flow, identify potential bottlenecks, and propose solutions to improve the road's efficiency and safety.
Keywords: Design Guidelines, Accident risk factor, National Highway-30, Road Marking, Road Safety

Paper ID: 109

Assessing Safety Perceptions at Roundabouts in India: Using Multiple Correspondence Analysis and Regression Analysis

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Abstract. The potential of roundabouts to improve safety and operational efficiency has led to their widespread adoption throughout India. Even with their acknowledged advantages, roundabouts are still viewed critically by the general public, which makes it difficult to evaluate how they affect driving behavior and overall safety. The present study investigated the safety perceptions at roundabouts among its users in India, emphasizing how socio-demographic factors, vehicle types, and roundabout usage patterns influence perceived safety. A structured questionnaire survey was conducted to examine the safety perceptions of a sample of 1,250 participants by analyzing user demographics, driving experience, and varying roundabout geometric configurations. Multiple Correspondence Analysis (MCA) was employed to identify patterns among respondent categories, and an ordered probit model was developed to assess factors influencing perceived roundabout safety. Key findings revealed that male users aged 26–35 years with greater roundabout familiarity perceived roundabouts to be safer, while females, motorcyclists, and bicyclists perceived roundabouts as dangerous. Roundabout entry and complex lane configurations were perceived as hazardous, with users reporting higher risk perceptions in double- and multi-lane configurations. The ordered probit model achieved an overall prediction accuracy of 72.64%, highlighting significant relationships between demographic factors, roundabout design, and safety perception. The results of the study underscored the need for user-centered design improvements and robust safety education to foster greater roundabout usability and safety in low- and middle-income countries.
Keywords: User Perception, Roundabout Safety, Questionnaire Survey, Multiple Correspondence Analysis, Ordered Probit Model

Paper ID: 138

Identification and Prioritization of Accident Blackspots in Surat, India using Geographical Information Systems

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Abstract. India has one of the highest road fatality rates globally, making the identification and treatment of high-risk accident locations (blackspots) essential to improving road safety. This study focuses on identifying and prioritizing blackspot treatment in Surat, India. Using GIS, Kernel Density Estimation (KDE), and Spatial Density Function, sixteen blackspots were identified according to Ministry of Road Transport and Highways (MoRTH) standards. Each blackspot was assigned a Total Severity Score (TSS), allowing for prioritized treatment based on crash severity and frequency. The results underscore the importance of targeted interventions at high-risk locations and offer a practical framework for identifying and ranking blackspots, which can be applied to improve safety in similar urban settings. A case study of Khatushyam Intersection improvement is presented as a case study highlighting the use of crash data for focused interventions. The study highlights a data-driven approach for prioritizing accident blackspots and reducing crashes and injuries in rapidly urbanizing areas.
Keywords: Kernel Density Estimation; Spatial Density Function; Crash Analysis; Accident Blackspot

Paper ID: 142

Development of Conflicting Flow Model for Unsignalised Intersections: Tier II Cities of India

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Abstract. India's highways and urban streets have a highly diverse traffic pattern, with noticeable variations in vehicle dimensions and speed characteristics. It is common for drivers to disregard traffic movement priority laws and breach lane discipline at unsignalised intersections. Drivers often become more impatient and ignore competing traffic as they pass unsignalised crossings; pedestrian crossing and bicycle movement pose additional anxieties. These considerations significantly affect the efficiency and capacity of traffic navigation, rendering the situation at unsignalised intersections exceedingly intricate. Data were gathered at prominent three-legged and four-legged unsignalised intersections in tier-II cities likewise Ranchi, Dhanbad city in Jharkhand state, and Patna city in Bihar state during peak hours on five consecutive weekdays in India using the video-graphic technique. The vehicles being evaluated were classified into seven distinct categories: two-wheelers (2W), three-wheelers (3W), slow-moving three-wheelers (SM3W), standard cars (SC), large cars (LC), mini commercial vans (MCV), and heavy vehicles (HV). Field video recordings provide the percentage distribution of different maneuvers executed by different cars at an unsignalised crossroads. In the present study, the fundamental equations for evaluating the conflicting volumes for different movements in unsignalised intersections were certainly revised for India's tier II cities. The modified equations obtained in the study can be implemented by traffic engineers and practitioners to assess the capacity of unsignalised intersections in heterogeneous traffic scenarios.
Keywords: Unsignalised intersection, Conflicting Flow, Heterogenous traffic, Tier-II city

Assessment of Child Pedestrian Safety in School Zones: An UAV Driven Approach

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Abstract. The school going children are one of the most vulnerable groups of road users due to their lesser developed cognitive skills and small physical structure. During morning school drop-off and afternoon pickup times, a large volume of pedestrians and vehicles interact with each other within a shorter time frame. Thus, the children are often exposed to very risky situations. In developing countries like India, other factors like heterogenous traffic conditions, lane indiscipline coupled with poor road infrastructure and enforcement aggravate the situation further. This paper presents a case study conducted in an Indian city for a typical school zone. To circumvent the limitation of data collection using a fixed camera setup, an Unmanned Aerial Vehicle, (UAV) was used for video data collection. The video data processing was done using advanced image processing techniques and computer vision. As the availability of crash data for safety assessment is an intricate issue for developing countries, proactive means of safety assessment have been utilized to evaluate the safety of children. Different surrogate safety indicators such as time-to-collision, post-encroachment time and instances of heavy braking were extracted to identify the conflict points within the selected school zone. Thresholds for mild and serious conflicts were verified using 85th percentile data. Further conflict maps and heatmaps were developed to get insights to the exact conflict locations. Significant differences between the morning and afternoon situations were observed. The findings emphasize on the utility of UAV technology in providing a comprehensive overview of traffic behavior and critical interactions in school zones. This study offers a detailed understanding of crash causal scenario in the school zone where child pedestrian crashes are prevalent. Further, it provides a methodology for an extensive safety assessment method, which can serve as an invaluable tool for traffic engineers, policymakers, and transport planners aiming to implement effective safety improvements around schools.

Keywords: Child Pedestrian, Surrogate Safety Measures, School Zone, Unmanned Aerial Vehicle, Mixed traffic

Assessment of Geometric Enhancements at Intersections on National Highway Using Microsimulation Approach

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Abstract. Transportation networks depend on efficient and safe management of national highway crossings. These crossroads have high emissions, delays, and traffic congestion. This study evaluates these crossings' emissions and emission modeling, assessing their environmental impact and operating efficiency. The research evaluates traffic restrictions and proposes traffic control and geometric enhancements to improve operations and reduce emissions. The PTV-VISSIM microsimulation model simulated intersection traffic. Model validation and calibration using spot speeds, volume counts, and UAV scans. We used the Wiedemann-74 car-following model to correctly mimic traffic. The study assessed the solutions' efficacy and environmental effects using detailed emission modeling. Intersections with an F LOS imply heavy congestion. The suggested improvements reduce pollutants and delays, raising the LOS to C and ensuring sustainability till 2031. Emission modeling revealed 50–70% fuel and CO savings. This considerable drop indicates the proposed measures' environmental benefits. Microsimulation optimizes traffic operations at complex crossings and addresses environmental sustainability, according to the study. It also stresses the relevance of traffic and environmental factors in establishing and evaluating national highway interchange traffic management policies.

Keywords: Traffic Simulation, Intersection Improvement, Heterogeneous Traffic, Geometric Improvements, Emission Modelling, Microsimulation

Paper ID: 164

Safe Speed Limits for National Highways in India

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Abstract. India has one of the highest rates of road crashes in the world, resulting in over 0.15 million deaths annually. One factor that contributes significantly to accidents is speeding and lack of enforcement of speed limits. In India, the speed limits were developed decades ago and still are in use. In a considerable amount, most of the roads are within statutory limits, not meeting the road geometry and upgraded vehicle standards. Warning signs accompanied by recommended speed limits are placed at specific road sections, junctions, and bends. While this approach enhances user safety and enables higher velocities in other areas, the ultimate goal is to improve the overall speed limit to a more suitable level. Hence, the present study aims to revisit the posted speed limits for Indian traffic conditions on the National Highway (NH). The video data was collected on NH-48, and the vehicle class-wise speed data was extracted. The speed limit is then decided either by the traditional method of the 85th percentile speed by alternative methods detailed in the study as speed management programs, traffic engineering studies, road characteristics evaluation, surveys and public input. The present study thus presents suggestions for new speed limits that are decided on the basis of existing speed used by drivers on particular NHs. The study revealed significant discrepancies between posted speed limits and actual speeds. While the posted speed limits were 60 km/hr for cars, and 40 km/hr for buses and heavy vehicles (HV), the average free-flow speeds were much higher: 80.55 km/hr for cars, 74.22 km/hr for buses, and 54.76 km/hr for HV. The 85th percentile speeds were 98.00 km/hr for cars, 86.50 km/hr for buses, and 64.50 km/hr for HV. The modal speeds are considered safe speeds were observed to be 80.50 km/hr, 74.20 km/hr, and 54.80 km/hr for cars, buses, and HV respectively.
Keywords: Speed Limits, Safe Speed limit, Road Safety, Enforcement

Paper ID: 167

Estimation of Mode-Wise Delay at a Signalized Intersection in Hyderabad Using PTV Vissim.

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Abstract. Urban intersections in Hyderabad face severe traffic delays, adversely affecting economic viability, fuel consumption, and urban mobility. This study focuses on mode-wise delay estimation for various vehicle types, analyzing the impact of different signal timings and assessing the potential benefits of grade separated intersections like underpasses. Using the PTV VISSIM simulation tool, vehicle delays are quantified under heterogeneous traffic conditions, and the effectiveness of various traffic management strategies is evaluated. The methodology includes detailed data collection through videographic surveys, calibration of the simulation model with field data, optimization of signal timings, and comparative analysis of cycle durations and intersection configurations. Key findings reveal that a 240-second signal cycle reduces average delays by 57.21% and improves average speeds significantly compared to 180-second and 120-second cycles. Annually, approximately ₹4.54 million is wasted due to idling fuel consumption for Leg 1, underscoring the critical need for implementing measures to optimize fuel efficiency and reduce operational waste. Additionally, grade-separated intersections achieve the least delays and highest average speeds, underscoring their efficacy as long-term solutions for mitigating congestion. This research provides actionable recommendations for traffic management strategies to enhance intersection performance and urban mobility in Hyderabad.
Keywords: Delay Estimation, Signalized intersection, Heterogenous Traffic, PTV Vissim, Microscopic simulation

Critical Gap Estimation and its Effects on Capacity and Safety at a High-Speed Uncontrolled T – Intersection

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Abstract. Unsignalized intersections are critical locations in terms of the risk and vulnerability involved in incorrect assessment of gaps by drivers on minor roads and higher speeds of vehicles on major roads. The speed profile of minor road and major road vehicles with subject movements under consideration is analysed. Right-turning movement from a minor road is a critical manoeuvre with several conflict points. This paper examines the performance level and risk associated with right turn movements from minor roads by estimating the critical gap and capacity with due consideration to the vehicle types. Analysing drivers' gap acceptance behaviour is essential for designing safer and more efficient intersections in terms of performance. The model is formulated for gap acceptance of right turn movements from minor roads by logistic regression. The critical gap, the minimum time interval deemed safe by drivers, is crucial for estimating intersection capacity and associated risk towards planning prospective traffic management measures. By analysing critical gaps for different vehicle types, estimating the probability of gap acceptance, and developing predictive models, this research aims to enhance traffic flow and safety at unsignalized intersections. The findings will inform urban traffic planners, contributing to enhancing the design and overall traffic efficiency of an unsignalized intersection.
Keywords: Unsignalized intersection, Critical gap, Capacity, Gap acceptance, Risk

Modelling Lateral Placements in Heterogeneous Non Lane-Based Traffic using UAV based Vehicular Trajectories

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Abstract. This study investigates the unique traffic dynamics on Indian roads, characterized by a diverse mix of vehicle types and non-lane-based driving behavior, using a section in Delhi-Panipat route as a case study. Unlike the strictly lane-disciplined traffic in Western countries, Indian traffic involves complex interactions among vehicles, making accurate prediction and modeling challenging. This research leverages high-fidelity trajectory data collected via UAVs, capturing detailed vehicular movements on an eight-lane divided highway. The vehicles in the data set is categorized into six types, providing a rich basis for analyzing lateral positioning, speed, flow, and density distributions. The study employs exploratory data analysis to illustrate the relationship between speed, lateral position, and vehicle density for different vehicle types. One-way ANOVA tests reveal significant differences in driving behaviors across lanes, while Games-Howell post-hoc tests identify specific lane pair distinctions. Furthermore, multiple linear regression (MLR) models highlight key predictors of lateral positioning, including vehicle speed, local density, flow rate, and vehicle type, with R-squared values of 0.695 for the northbound and 0.612 for the southbound sections. The findings demonstrate that vehicle types like cars, buses, and three-wheelers significantly influence lateral placement, with cars showing the highest lateral placement predictability. Variance Inflation Factors (VIF) indicate low multicollinearity among most predictors, confirming the robustness of the model. This research enhances the understanding of lateral placement patterns in heterogeneous, non-lane-based traffic environments, providing a foundation for future studies to explore further variables and broader traffic scenarios.
Keywords: Lateral placement, Position, UAV, Trajectory, Heterogeneous, Mixed traffic

Paper ID: 175

Lateral Safety Analysis of Vehicles in Roundabouts

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Abstract. This research investigates the lateral safety of vehicles navigating roundabouts by utilizing surrogate safety measures and extreme value theory. To capture vehicle interactions at the Kasna Gol Chakkar roundabout in Greater Noida, India, we employed drone technology to gather high-resolution aerial footage. Our main goal was to quantify conflict probabilities and set safety thresholds under different traffic conditions using metrics like Time to Collision (TTC) and Post Encroachment Time (PET). Traditional safety analysis methods often overlook near-misses and other critical incidents because they primarily focus on collision data. To address this, we used advanced data collection and processing techniques for a more proactive safety assessment. The data was processed using Data from Sky (DFS) software, which excels at extracting vehicle trajectories and identifying conflict points. DFS's advanced trajectory analysis features, including TTC and PET calculations, enabled a thorough evaluation of conflict severity and frequency. We identified distinct interaction patterns during peak and off-peak hours, with a significant rise in rear-end conflicts during peak periods due to increased traffic density. Additionally, we applied the Generalized Pareto Distribution (GPD) to model TTC values and estimate severe conflict probabilities, providing a statistical framework for assessing high-risk scenarios. The study's findings emphasize the importance of implementing targeted safety measures, such as enhanced lane markings, signage, and intelligent traffic management systems, to mitigate risks and improve overall roundabout safety.

Keywords: Lateral Safety, Roundabouts, Surrogate Safety Measures, Extreme Value Theory, Time to Collision, Post Encroachment Time, Traffic Conflict Analysis

Paper ID: 194

A Methodology to Evaluate Safety and Mobility Factors to Develop Complete Streets in Small Towns: A Case Study from Nevada, USA

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Abstract. This paper presents a methodology to evaluate safety and multimodal mobility factors when prioritizing investments to develop Complete Streets (CSs). Its focus is on small towns in rural Nevada (USA) and to illustrate the application of this methodology. The paper also summarizes the findings of this case study. CSs is a transportation design approach in the USA, similar to India's Cycles4Change and Streets4People National Challenges. It is developed to ensure safety and convenience for all road users by improving, revamping, and providing infrastructure for alternative transportation modes and encouraging their use. The methodology to evaluate road segments focused only on safety and multimodal mobility considerations. Safety-related considerations included crashes on the roadway segments and their proximity including the injury severity outcomes of each crash. Further, the economic impacts of these crashes were weighed using the value of a statistical life (VSL). The multimodal mobility consideration combined five elements: public transit, means of transportation to work, Average Daily Traffic (ADT), existing infrastructure, and pedestrian and bicyclist volumes. The evaluation considered segment-specific data and data proximate to the segment. An application of this methodology is illustrated using four roadway segments in Nevada (USA). The segments are located in Ely (White Pine County), Tonopah (Nye County), Hawthorne (Mineral County), and Yerington (Lyon County). The safety outcomes showed that the segments in Ely and Hawthorne offered greater benefits from CSs than those in Tonopah and Yerington.

Keywords: Transportation, Complete Streets, Policy, Mobility, Safety, Equity, Small Towns

Analysis of Overtaking Behaviour on Undivided Two-lane Roads in Hilly Region

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Abstract. Indian roads experience heterogenous traffic conditions with variations in static and dynamic features of vehicles. The major problem that the roads face is that the vehicles do not adhere to the strict lane discipline and readily occupy the lateral spaces on the road. Overtaking process involves lane changing maneuvers, acceleration and deceleration actions and also estimation of speed and distance of the oncoming vehicles. The analysis of overtaking maneuvers revealed distinct trends among vehicles pairs. Predominantly, the highest frequency of overtaking instances occurred between cars and two-wheelers, accounting for 26.49% of occurrences with cars being the prevailing overtaking vehicles. Following this, car-car pairing exhibited 20.51% of overtaking occurrences. Moreover, the study underscored that overtaking times are influenced not only by the type of vehicles overtaken but also by the road gradient. Generally, overtaking durations correlated positively with increased road gradient, except notably at site 4, where a 1.343% gradient showcased an unexpected trend. Furthermore, the outcomes derived from the Multiple Linear Regression (MLR) model underscored the significant impact of road gradient, type of overtaking vehicles, speed of overtaking vehicles and acceleration on overtaking duration, reflected in their respective coefficient values of 1.122, -0.25, -0.16 and 0.13 respectively. This highlights their substantial role in shaping overtaking dynamics on roadways. Overall, this research underscores the substantial impact of road gradient on the calculation of overtaking sight distance, emphasizing the crucial need for Transportation Engineering to prioritize the inclusion and analysis of road gradients in their assessments.
Keywords: Overtaking Sight Distance (OSD), Hill Roads, Road Gradient Multiple Linear Regression (MLR) model

Effect of on-street parking manoeuvre on traffic speed

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Abstract. Currently, the urban transportation planners are experiencing more challenges when identifying suitable places for allowing on-street parking to ensure efficient operation. In this study, on-street parking locations and their effects on traffic speed is studied. The interaction between approaching vehicles and vehicles parked in on-street parking locations on urban roads can greatly influence the performance of traffic networks. Parked vehicles contribute to traffic congestion in urban areas, leading to delays for approaching vehicles. The average speed of approaching vehicles at the site of on-street parking is also studied lane wise. Analysis of the traffic speed in different lanes at on-street parking locations shows that occurrence of parking manoeuvres (both in and out) has resulted in a decrease in the speed of various types of vehicles including Two Wheelers (TW), Auto rickshaws (Auto), Standard Cars / Small Cars (SC), Big Cars / Vans (BC), Buses, Light Commercial Vehicles (LCV). At on-street parking locations, Lane 3 (near median side) consistently has highest speed across all flow levels because of less interference with maneuverability. Lane 2 (middle lane) shows a gradual decrease in speed as flow level increases, indicating moderate congestion because this is closer in connection with both Lane 3 and Lane 1 (curbside lane). Lane 1, which experiences the most significant reduction in speed, decreases from 27.95 km/h at the lowest flow level to 14.69 km/h at the maximum flow level due to more manoeuvrable operations.
Keywords: On-street parking, approaching vehicles, mid-block, manoeuvrable operations

Traffic flow characteristics of an undivided two-lane road with Inclusive Motorised Two-wheeler lanes: A Case study

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Abstract. Motorized two-wheelers are on the rise in Kerala and across India. This mode offers flexibility with door-to-door access, making it a popular choice among people for its ability to navigate through congested roads. However, their involvement in road accidents is a significant concern due to their vulnerability compared to other vehicles. As an engineering intervention, providing dedicated two-wheeler lanes can be a practical and effective solution to reduce the interaction between two-wheelers and heavy vehicles, thereby enhancing the safety of two-wheeler riders. Kerala in its intial step towards it, has implemented an inclusive motorised two-wheeler (MTW) lanes on State Highway 8 between Muvattupuzha and Vengalloor. While traffic segregation has been piloted in various locations worldwide, its potential benefits have not yet been sufficiently studied. This work is a case study of the selected corridor where inclusive MTW lanes are implemented which attempts to understand the traffic flow characteristics of the roadway to understand the effect of inclusive MTW lanes. The study primarily focuses on investigating the traffic variables like traffic flow, density, and speed on this road with inclusive MTW lanes. It has been found that implementing dedicated MTW lanes can improve traffic flow, but careful consideration of roadside conditions is crucial for optimal performance. The results and findings in this research can help in understanding operational performance of a road with MTW lanes and also provide insights to improve any shortcomings.
Keywords: Motorised Two-wheeler lanes, speed, density, traffic flow, percentile speed

Evaluation of Road Safety Condition near School Zone

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Abstract. School zones are areas around schools where children are present, and due to their smaller size and lack of traffic awareness, children are more vulnerable to traffic accidents than adults. Therefore, extra precautions must be taken to ensure their safety in these zones. Children's unpredictability, such as running into the street without looking or crossing at undesignated crosswalks, makes them particularly susceptible to accidents. Additionally, their smaller stature makes them less visible to drivers, and they often cannot judge the speed and distance of approaching vehicles or react quickly enough to avoid danger. To protect children, school zones typically have lower speed limits and other traffic calming measures. However, studies show that a significant number of children still suffer injuries or fatalities near school zones, prompting research into improving these measures. This research will use a statistical and dilemma zone approach, including road inventory surveys of school sites, and speed and volume surveys, to identify factors contributing to road safety near schools. These factors include road design, traffic speed, driver and child behavior, and traffic law enforcement. The research aims to propose effective strategies for improving road safety in school zones, thereby protecting children from traffic accidents and raising awareness about the importance of road safety in these areas.
Keywords: Road accident; School children safety; School zone; Speed Calming; Vigilant zone

Safety Appraisal of Multi-Lane Roundabout under Mixed Traffic Using Microsimulation

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Abstract. The study developed microsimulation (VISSIM) models and utilized the Surrogate Safety Assessment Model (SSAM) to assess traffic safety in the case of a three-lane unsignalized roundabout under mixed traffic conditions. The roundabout network was constructed in VISSIM using drone images, and traffic characteristics extracted from the aerial videos were used as input in the simulation model. Subsequently, vehicular trajectories exported from VISSIM were analyzed in SSAM to identify conflict points (setting TTC=1.5s and PET=2s). A total of 1,194 conflicts were identified, of which 77.5% were rear-end conflicts, 21.18% were lane change conflicts, and 1.25% were crossing conflicts. A Generalized Linear Model (GLM) with Negative Binomial (NB) distribution and a log link function were used to predict simulated conflict frequency based on hourly traffic volume. The model showed high predictive accuracy (R^2=0.86). The study yielded a simple, easy-to-interpret and -use formulation to find the total hourly conflicts utilizing only traffic volume.
Keywords: Microsimulation, Roundabout Safety, VISSIM, SSAM, Mixed Traffic, Traffic Conflict

Modelling Class-Wise Delay and Approach Queue Length at Signalized Intersections in Mixed Traffic

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Abstract. This study develops class-wise delay and approach queue length models at signalized intersections. Using videography, class-wise N-curves and delay curves were extracted from multiple approaches of signalized intersections from two different cities. Relative delay curves were built to highlight the delay differences for each vehicle class, with bikes experiencing reduced delays due to their ability to seep through gaps while bigger vehicles suffer longer delays. This is confirmed with the Bike delay and relative delay curves that displayed concave shape during the red time indicating seepage or gap utilization by some of the smaller vehicles. The delay models developed for different vehicle classes in this study demonstrated strong to moderate fit with metrics such as R2 (0.71 to 0.99) MAE (2.4 to 5.4 seconds), RMSE (3.1 to 6.7 seconds), and MAPE (5-18%). Additionally, it was found that the buses and the trucks significantly contributed to queue length, with high R-square (0.91 to 0.96) and errors around 14% at studied intersections. This research underscores the importance of considering vehicle composition and signal timing in mixed traffic for accurately estimating delays and queue lengths. These findings can guide developing strategies to enhance efficiency at signalized intersections in urban areas.
Keywords: Delay, Remaining Red Time, Vehicle Classes, Delay Models, Queue Length

Paper ID: 240

Analysis of acceleration data to detect dangerous driving hotspots

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Abstract. The study of a driver's purposeful and unintentional traits and actions while operating a motor vehicle is known as driver behaviour. Several drivers have different driving styles depending on their personality features and driving habits. Aggressive driving can take many different forms. Speeding, disobeying traffic restrictions, etc. are common indications of aggressive driving. One way to identify dangerous driving hotspots; i.e., the areas on the road where there is an increased risk of accidents, collisions, and other traffic-related incidents is by analyzing the driving behaviour patterns of drivers. By collecting data on the driving style of multiple drivers and mapping out their behaviours, researchers can identify areas where drivers exhibit aggressive driving behaviours. These aggressive driving behaviours can include sudden braking, and rapid acceleration. Work needs to be done for the identification of dangerous driving hotspots using the driving style of drivers. The present work aims to find the driving maneuvers for acceleration and finding the relation between driver behaviour and identification of hotspots. In this study data was collected using VBOX video data logger. The study highlights the importance of understanding driver behaviour and driving patterns in identifying dangerous driving hotspots. The authorities can take proactive measures to reduce the risk of accidents and improve road safety. Also, the government intends to mandate GPS devices in all vehicles. Thus, without incurring any additional costs, this data might be utilised to locate dangerous driving hotspots and to create a driver warning system that would alert drivers to potentially hazardous stretches.

Keywords: Acceleration Maneuver; Principal Component Analysis; k-means clustering; Dangerous driving hotspots

Emerging Transportation Technologies

Paper ID: 44

A Comprehensive Review of Image Segmentation Architectures for Autonomous Navigation and Intelligent Transportation Systems

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Abstract. Segmentation architectures are essential in computer vision, enabling the precise extraction of meaningful information from images and videos by breaking them down into understandable parts. This paper explores six key segmentation architectures: Fully Convolutional Network (FCN), U-Net, DeepLab, YOLO (You Only Look Once) and Mask RCNN, focusing on their unique methods, strengths, and applications, especially in autonomous navigation. In autonomous vehicles, tasks like lane detection, road segmentation, and identifying objects such as pedestrians and other vehicles rely heavily on semantic segmentation, instance segmentation, and object detection. FCN and U-Net are great at semantic segmentation, making them suitable for understanding the overall scene. DeepLab stands out in tasks that need high-resolution and fine detail. YOLO is preferred when for dynamic environments. This review aims to help researchers and practitioners choose the right architecture based on their specific needs, such as available computational resources, required precision, and the need for real-time processing. By doing so, it seeks to advance the development of smarter transportation systems and better autonomous navigation technologies.
Keywords: Autonomous Navigation · semantic segmentation · instance segmentation

Paper ID: 72

Evaluating Synthetic and Real-World Driving Cycle on Various Mechanical Parameters through Simulation

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Abstract. Drive cycle is a speed vs time relation, which represents localised data of driving pattern, which is mostly depends on local traffic, Individual behaviour, Type of highway, Geometry of highway and other factors such as seasonal variation and environmental factors. Drive cycles (DC) are used for estimation of mechanical requirements, Mileage and emission in two-wheeler and four-wheeler vehicles. This paper mainly focused on derivation of power requirement, total tractive effort (TTE) and torque requirement from two-wheeler DC and comparing the output to synthetic DC. Each output is derived by developing a MATLAB/SIMULINK model for each city. Real world DC of four cities (Izatnagar, Kaithal, Zirakpur and Hyderabad,) and comparing them side by side with synthetic DC (MoRTH DC) gave us our insight on variation in these DC. The results indicates that there is a significant variation in TTE, Power requirement and torque between real world DC from four cities and synthetic DC. MoRTH DC which has lowest parametric values when comparing them with Real world DC of various other cities. Power required for Hyderabad DC was 288.19%, Torque requirement was 448.84%, and Total Tractive effort required was 622.7% more than MoRTH DC output. Hence for vehicle designing (IC engine and Electric two-wheeler) and testing, It is concluded that real world DC gives us more practical and realistic output thus should also be used for measuring other parameters such as emission in order to adherence of benchmark emission norms laid for sustainable future
Keywords: Drive Cycle, Vehicle Dynamic Modelling, MATLAB/Simulink, CMEM, Emission Estimation

Driver Gaze Zone Estimation using Deep Neural Network

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Abstract. Driver gaze is important for detecting the driver's alertness, attention level, and situational awareness. Estimation of driver gaze is a prerequisite for driver gaze behavior analysis, which is further used for developing advanced driving assistance systems for intelligent vehicles. This study aims to build a driver gaze estimation model based on gaze zone classification using a deep neural network. The driver's visual field is divided into pre-defined gaze zones, where the driver frequently looks during driving. A benchmark driver gaze classification dataset named Driver Gaze in Wild (DGW) was used for this study, which consists of about 386 subjects' face images with an age range between 18-63 years. DGW consists of diverse illumination conditions, subjects with or without eyeglasses, with or without a cap on the head, etc. More than 150 subjects' face images were used to train the model, and the remaining images were used to validate and test our model. A convolutional neural network (CNN) EfficentNet-B7 model is built by using transfer learning for the driver gaze zone classification. A classification report and confusion matrix are plotted to show the result of model training and performance. Ultimately, we check the gaze classification model on the driver's face video driving data to track the driver's gaze.
Keywords: Driver gaze · Driver gaze estimation · CNN · EfficientNetB7

Understanding the driver performance for lower levels of ADAS using kinematic variables

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Abstract. Driver inattention and improper driving behavior are key causes of traffic incidents, including rear-end collisions and poor lane discipline in Indian traffic. This study explores the impact of Advanced Driver Assistance Systems (ADAS) in addressing these issues. ADAS features, such as Lane Departure Warning (LDW), Forward Collision Warning (FCW), and Pedestrian Collision Warning (PCW), provide timely alerts to improve driver performance. This study utilized ADAS warning data and kinematic variables such as speed, acceleration, and response time to evaluate the driver performance for lower levels of ADAS. Field Operational Tests (FOT) were conducted on a 65-km stretch in Guwahati, India, using an instrumented vehicle equipped with ADAS, V-boxes, and cameras. Data on speed, acceleration, and braking characteristics were collected across diverse driving environments in urban, hilly, and rural regions. Driver performance was evaluated in active (ADAS-enabled) and stealth (ADAS-disabled) modes. The results showed significant improvements in active mode, with fewer warnings generated (64, 132, 70, 54) compared to stealth mode (114, 190, 112, 111). Drivers demonstrated smoother braking (-0.25 to -3.75 m/s²) in active mode, compared to harsher braking (-4.5 m/s²) in stealth mode. Response times were shorter during rear-end events (0.5 to 2.2 seconds) and lane departure incidents (up to 3 seconds) in active mode, compared to longer times in stealth mode (up to 3 seconds and 7 seconds, respectively). Findings highlight ADAS's potential to reduce road fatalities and enhance driving conditions in India, emphasizing its role in fostering safer driver behavior.
Keywords: Driver assistance system, kinematic variables, driver safety, field operational test

Identifying Vulnerable Time Windows to Facilitate RealTime Warning Systems using Surrogate Safety Analysis

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Abstract. Understanding temporal variations is essential for implementing effective real-time warning systems, as the duration of warning messages significantly impacts driver behaviour and safety. This study aims to determine the time window for broadcasting warning messages at different times of the day using Surrogate Safety Measure (SSM) analysis. The traffic video data was collected continuously over an 8-hour period each day for 5 weekdays from two curved road sections, providing a total of eighty hours of data. Over ninety thousand vehicle trajectories were analyzed, and conflicts were estimated using the Time to Collision (TTC) measure. The cumulative distribution of conflict frequency was plotted to identify the timestamps with the highest conflicts through the analysis of the distribution curve's slope. To incorporate conflict severity, the Temporal Conflict Severity Indicator (TCSI) is introduced, defined as the ratio of the slope to the sum of TTC values for consecutive timestamps. This ratio effectively indicates the conflict severity over time. An increase in TCSI values highlights more severe timestamps, allowing us to emphasize critical time windows in terms of both conflict numbers and severity. Furthermore, the TCSI values are examined across all the days for both locations and identified the corresponding vulnerable time windows, which were found to be inconsistent. Additionally, the TCSI range is found to be varied across the days for both locations. These findings emphasize the importance of considering temporal variations in traffic conditions and to accurately determine the time resolution to real-time warning systems, thereby potentially reducing the crash risk.
Keywords: Temporal Variations, Conflict Analysis, Time Window

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Evaluation of Time Headway Maintenance of Bus Drivers and its Impact on Road Crashes Using ADAS Alerts

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Abstract. Road safety in India is significantly impacted by human factors, with rear-end collisions accounting for a substantial portion of crashes. In year 2022, rear-end crashes rose to 21.40 % of all crashes, with increased fatalities and injuries. Advanced Driver Assistance Systems (ADAS) offer a solution by providing timely warnings to maintain safe time headways. So, this study evaluated the impact of ADAS on headway maintenance behaviour among bus drivers and on road safety in an interurban National Highway (NH) corridor in Telangana state (India). By installing ADAS in 190 buses, the study analyzed 87,356 Headway Monitoring Warnings (HMW) alerts, that generates when the time headway between the subject vehicle (SV) and lead vehicle drops to 0.6 seconds. Data from HMW indicates inconsistent headway maintenance behaviour throughout the day and night, with most alerts occurring at moderate to high speeds. Analysis revealed that average gaps maintained by drivers are often significantly lower than the required braking distance, especially at higher speeds, highlighting a severe risk of rear-end collisions. Statistical models showed that frequent HMW alerts and smaller average gaps are strongly correlated with increased likelihood of fatal and injury crashes. The findings underscore the critical need for improved driver trainings and the continued use of ADAS to enhance driver behaviour and road safety.
Keywords: ADAS, HMW, Time Headway, Bus Driver, Fatal Crash

Understanding Focus and Attention of Drivers by his Head Pose Analysis using Artificial Intelligence

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Abstract. In an age of fast evolving technology, road safety remains a top priority worldwide. With an increase in vehicle numbers and changing driving circumstances, the need for proactive steps to prevent accidents and promote safe driving practices has never been greater. A facial expression recognizer and pose analysis for detecting tired drivers and intend prediction respectively usually use computer vision algorithms that analyse face features and expressions in real time to detect indicators of drowsiness or weariness. Driver head pose analysis is a critical field within computer vision with significant applications for automotive safety and driver assistance systems. By analyzing the position and orientation of the driver's head in an image or video stream, we can gain valuable insights into their visual focus of attention and mental state. Which are as driver distraction detection, fatigue monitoring and intent recognition. Head pose can reveal if a driver's gaze is diverted from the road, potentially indicating distraction due to phone use, drowsiness, or interacting with passengers. Consistent head tilts or drooping eyelids can signal fatigue, prompting alerts to encourage drivers to rest. Head movements can suggest the driver's intention to turn, change lanes, or check blind spots. Driver head pose analysis faces challenges such as illumination variations, occlusions (e.g., by sunglasses), and extreme head rotations. However, ongoing research aims to overcome these limitations and develop robust, real-time systems for accurate driver monitoring, ultimately contributing to safer roads.
Keywords: Road Safety, Driver Distraction, Fatigue and Intent, Pose Analysis

Driver Safety Index Utilizing Driver Monitoring System (DMS) Inattention Alerts

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Abstract. Driver inattention, including distractions, drowsiness, and falling asleep, poses a critical challenge to global road safety, typically caused by human errors, traffic, and road environment. It necessitates effective monitoring and mitigation techniques. Advanced technologies, such as Artificial Intelligence (AI)- powered Driver Monitoring Systems (DMS) play a pivotal role in real-time monitoring and alerting of drivers to ensure attentiveness and identify inattention behaviors. This study explores the application of AI-powered DMS to evaluate driver behaviour and road safety. A DMS device was installed in a public bus operating along the National Highway (NH)-65 interurban corridor between Hyderabad to Vijayawada. Driver inattention behaviours were analyzed over a 150- kilometer test corridor from Malkapur village to Kodad town. Geographic Information System (GIS) tools were employed for spatial visualization and characteristic analysis. Three months of driver's inattention alerts (Nov'23 to Jan'24) were collected with their roster data and it revealed that distraction accounted for 94% of inattention events, followed by drowsiness and falling asleep, emphasizing possible road safety issues. Notably, inattention events exhibited significant directional variation along the test corridor (LHS and RHS travel), influenced by road geometric conditions, traffic density, and road environment. Using the Probability Density Approach (PDA) with Normal Distribution (ND), a Driver Safety Index (DSI) was developed to classify drivers as 'Inattentive' or 'Attentive' based on probability density percentile values. Comparative analysis indicated increased inattention levels among drivers during daytime hours (12:00 to 18:00) on the left-hand side (LHS) direction of travel between Malkapur village and Kodad town. This study highlights the utility of AI-driven monitoring for real time identification of at-risk drivers and provides a statistical framework for assessing driver safety. The findings underscore the need for targeted interventions to train inattentive drivers, contributing to improved safety measures on interurban highways.
Keywords: Driver Monitoring System; Driver Behavior; Inter-Urban Roads; Normal Distribution; Driver Safety Index

Paper ID: 166

A Cost-effective Smartphone Application for Enhancing Road Safety through Speed Monitoring

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Abstract. In India, the escalating motorized transportation sector has led to a concerning rise in road traffic accidents and fatalities, imposing severe social and economic repercussions. Addressing this issue, we present a novel approach leveraging smartphone technology to develop a speed limit warning mobile application aimed at enhancing road safety. The application computes the real-time speed of vehicles and compares it with the government-posted speed limit, issuing warnings to drivers upon exceeding the limit. Field data collection of speed limits on major roads in Pune city was conducted. The application is written in Flutter and uses a location plug-in for GPS functionality. The application is also integrated with Google Maps for navigation purposes. Audio and visual alerts promptly notify drivers of speed limit violations, supplemented by advance warnings. Our application offers a cost-effective and accessible solution to curb excessive speeding, contrasting with existing road safety systems in India. The proposed system serves as a crucial tool to bolster road safety efforts, ensuring the well-being of Indian road users. Its implementation demonstrates a direct and positive impact on community road safety, underscoring its significance in mitigating the adverse effects of road traffic accidents. Through this paper, we contribute to advancing road safety initiatives in India and beyond, fostering safer transportation environments for all.
Keywords: Road Safety, Speed Monitoring, Mobile Application, Traffic Accidents, GPS Technology

Paper ID: 170

Data-Driven Three-Wheeler Delay Prediction in MixedTraffic conditions at Signalized Intersections Using YOLOv8 and Machine Learning

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Abstract. Signalized intersections they do make things quite difficult in traffics management, particularly in developing countries like India where explicit traffic controlling measures often are not there. These intersections then become the hotspots for a lot of conflicts and collisions because of the lack of defined priority movements. Spearman's correlation analysis and ANOVA test were performed to identify the variable with a significant impact on the Delay model, which in turn influences 3W Delay. Red time, Effective width of approach, Volume per effective width, Queue length, Effective green time per cycle Time, Volume per Capacity ratio and Average Three-Wheeled Vehicle Speed at the Intersection are significant parameters included in this study. Using these variables as model inputs, SVR approach is employed to develop Delay models for Signalized intersections and compared with proven MLR modelling approach. Based on statistical parameters like the coefficient of determination (R^2), the performance prediction of the best fit SVR model was evaluated.
Keywords: Motorized three-wheeler delay, Prediction model, Traffic Characteristic, YOLO

Paper ID: 181

Identification of driving behavior through steering entropy and In-Vehicle Sensor data analysis

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Abstract. On the road network, there's a diverse mix of drivers, each with unique driving styles. Evaluating an individual's driving profile and behavior is crucial for improving road safety, optimizing transportation systems, minimizing fuel usage, and achieving various other positive outcomes. The driver executes a series of maneuvers, including accelerating, steering, braking, speeding, or shifting gears, which directly influence the vehicle's response, but there is limited research on their holistic integration, particularly in the relationship between these parameters. This study investigated the characteristics of steering parameters and found that steering entropy (the extent of mental workload) can be a parameter to determine driving behavior and driver style recognition. The research explored the relationship of steering entropy with other vehicle dynamic parameters, including speed, fuel consumption, throttle position, engine speed (RPM), and acceleration, revealing a direct correlation among these parameters through the application of k-means clustering and Pearson Correlation. The analysis revealed that higher steering entropy values are typically associated with more aggressive and less predictable driving behaviors, such as rapid acceleration and higher speeds. This study underscores the utility of steering entropy as a reliable metric for driver behavior assessment, paving the way for applications in driver monitoring, road safety enhancements, and personalized driver feedback systems.

Keywords: Driving Behavior · OBD 2 · K-means · steering entropy

Paper ID: 187

Detection, Classification, and Trajectory Extraction of Vehicles under Indian Traffic Conditions

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Abstract. The extraction of vehicle trajectories is essential for understanding traffic flow characteristics and developing effective road traffic management strategies. For this, the present study proposed an end-to-end model to extract trajectory data from video footage, which includes vehicle detection and classification. As a first step, vehicle detection and classification models were trained by combining two existing datasets, IITM-HeTra and FGVD, achieving a mAP50 score of 0.91. Subsequently, vehicle trajectory was extracted using a model trained with YOLOv8, which involved tracking detected vehicles on the screen and obtaining pixel coordinates. The OpenCV library was utilized to convert the obtained pixel coordinates into latitude and longitude data, which were then mapped using Google Earth Pro. The developed model can be applied to any video data to obtain precise vehicle trajectory information, with Google Maps aiding in accurate mapping.

Keywords: Vehicle Trajectory · IITM-HeTra · YOLOv8 · Vehicle Classification

Cellular Automata in Traffic Flow: Evolution, Current Trends, and Future Directions for Mixed Traffic Modelling

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Abstract. Cellular Automata (CA) modelling has emerged as a promising approach to address the computational challenges associated with microscopic traffic flow models, especially under mixed traffic conditions. CA models offer advantages in terms of flexible evolution rules and high computational efficiency. The inherent discreteness and localized cell computations provide a unique capability to connect micro-level dynamics to macro-level traffic behaviour. This paper presents a comprehensive review of CA models and provide directions for improvements to the state-of-the-art practice to capture the features of heterogeneous and mixed-traffic environments. The paper outlines the fundamental principles of CA, emphasizing its relevance in mixed traffic flow modelling. It explores how CA models can be customized to address the complexity of mixed traffic by modifying parameters such as cell size, cell structure, and randomization rules, adopting ideas from physics and biology literature. It reviews lane change modelling, focusing on the nuances of lane-changing behaviours in both homogeneous and heterogeneous traffic scenarios. It also explores the representation of heterogeneity within CA models through various dimensions, including cell representation, vehicle representation, and driver behaviour representation. Each of these aspects is critically evaluated, highlighting the strengths and limitations of existing models and proposing potential enhancements to better replicate scenarios marked by a diverse range of vehicle types and driver behaviours. Thus, this comprehensive review highlights the state-of-the-art research and practice regarding the cellular automata models, their limitations, and underscores future directions that hold potential for more accurate replication of mixed traffic environments.
Keywords: Cellular Automata, Traffic Flow Modelling, Mixed Traffic

Sustainable Mobility in Transportation

Paper ID: 21

Qualitative Reliability Index based Examination of Passenger Walkway Facilities of Hybrid BRT System

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Abstract. Transportation is a critical component of urban planning, fostering social mobility, economic expansion, and employment opportunities. As urban transportation networks rapidly expand, ensuring high-quality infrastructure is essential. One key aspect of transit infrastructure that influences passengers' choice of a transit system is the walkway facility. Ensuring a proper walkway facility enhances ridership and increases trust in the transit system. This study assesses walkway facilities using an index-based approach, focusing on the Hubballi Dharwad Bus Rapid Transit System (HDBRTS) as a case study. Three indices were developed: WAQI (Walkway Accessibility and Quality Index), WTI (Walkway Time Index), and CI (Connectivity Index). The main highlight of this study is the proposal of WTI as a performance measure for walkway facility assessment. To understand the relationship between these indices and ridership, Multiple Linear Regression (MLR) was employed, resulting in an R^2 value of 0.850 and an Adjusted R^2 value of 0.790, indicating the model's high efficiency. The strong fit of the model depicts a robust relationship between the reliability indices and bus station ridership. This research paves the way for future studies on transit infrastructure assessment and the reliability of transit systems for commuting, emphasizing the critical role of walkway facilities in enhancing overall transit system performance.
Keywords: Hybrid BRTS, Passenger Walkway Facilities, Pedestrian Safety

Paper ID: 28

Analytic Hierarchy Process for Predicting Customers' Patronage of Inland Water Transport Towards a Sustainable Urban City

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Abstract. Unprecedented urbanization and increased private vehicle ownership in India have led to the issues of traffic congestion and pollution. To meet the global emission targets set for the transportation sector towards sustainability, developing nations like India are in desperate need of a preferred sustainable public mode of transport. The paper discusses potential influencing factors considered by the users in their affiliation towards sustainable Inland Water Transport (IWT) systems within an urban context. An extensive literature review was carried out to identify the probable leveraging attributes of the public. A total of 20 qualitative and quantitative metrics from eclectic published resources were selected for the user perspective survey. Both stated and revealed preference queries were included in the questionnaire. The urban city of Kochi in the state of Kerala was selected for the study. The hypothetical situations required were analyzed using stated preference questions. The multi-criteria decision-making (MCDM) technique of the Analytic Hierarchy Process (AHP) was carried out to reckon the pairwise weights of different characteristics on the final decision. Safety and comfort were the aspects given the highest priority contrary to the intuitive belief of the economy being the dominating one. This study is unique in its exploration of the under-researched area of IWT in India and the application of MCDM technique to this issue. The methodology and criteria employed in the study can be replicated in any other cities of similar terrain and demographics, albeit the conclusions arrived at may not be considered universal.
Keywords: Inland Water Transport (IWT), Analytic Hierarchy Process (AHP), Multi-criteria decision making (MCDM)

Paper ID: 30

Policies to target optimum transport sustainability index of National Capital Territory of Delhi

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Abstract. The study attempts to evaluate certain policy measures for achieving the optimum value of transport sustainability index (TSI) of National Capital Territory (NCT) of Delhi. Before that, it discusses estimation of TSI at a city level by considering 29 transport sustainability indicators. The addition of technological, besides the traditional pillars makes TSI estimate more realistic. Since it is improbable to achieve the extremum value of TSI (i.e. 1.0), this study determines an optimum value of TSI, which also helps in conservation of resources. The optimization parameters selected are three independent variables that influence all the 29 indicators. Regression equations are evolved between the indicators and influencing variables and non-linear programming technique is used to an optimum value of TSI. The optimum value of TSI for NCT of Delhi is estimated as 0.66, which is 34% higher than the TSI for the reference year (2023). The study demonstrates that if the city planners target the optimum values of indicators instead of the extremum values, conservation of resources to the tune of 43% is possible. Finally, evaluation of the impact of policy measures such as enhancement of Intelligent Transport System deployment, increase in share of alternate fuel vehicles in vehicle fleet and improvement in public transport services, considered one at a time, reveal that the TSI value of reference year increases by 8- 10%. It is found that the impact of these policy measures taken compositely pushes the reference year's TSI up to 92% of the optimum level.
Keywords: Transport sustainability index; technological pillar; regression equations; optimization; resource conservation; policy measures

Paper ID: 39

Economic Sustainability to Promote Non-Motorized Transport (NMT) Infrastructure – Case of Chennai City, India

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Abstract. Due to rapid growth of urbanisation, travel needs of the people are evolving day by day. The motorised transport leads to many issues including social and environment. As Non-Motorised Transport (NMT) is a sustainable mode of transport, will be addressing not only environmental issues but also keeping healthier lifestyle of the people. In a way, this study targets to explores the economic sustainability of NMT infrastructure for Indian context. The objective of the study is to investigate the barriers to NMT promotion and evaluates the effectiveness of policies and stakeholder involvement in achieving sustainable urban mobility. Chennai Metropolitan Area (CMA) has been considered as a study area. CMA is the first city in India to adopt NMT policy and executed the NMT infrastructure on streets. From the literature, it is understood that economic benefits of the NMT projects were always been overlooked. In order to understand and analyse the economic benefits, various stakeholders such as municipal bodies, funding agencies, research institutes, NonGovernment Organisations (NGOs) and private developers have been considered. A sample size of 20 stakeholder interviews data has been collected. BestWorst Method (BWM) has been used to analyse the data. BWM reveals that the economic indicators 'reduction in travel cost' is the most critical factor with the highest weight of 28.7%, followed by "travel time benefits" at 11.3%. In conclusion, the study emphasises that the importance of multi-stakeholder participation is vital in addressing the challenges of economic and financial sustainability.
Keywords: Non-motorized transportation (NMT), Sustainable urban transport, Economic sustainability

Paper ID: 53

A Comprehensive Review of IoT-Based Smart Parking Systems

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Abstract. The optimal solution to the parking challenges in large cities is provided by the "Smart Parking System" program, which implements an IoT-based smart parking system. The sudden increase in vehicle density, especially during peak hours, makes it difficult for users to find available parking spots. This study proposes a smart parking system that leverages Arduino technology and a mobile application. The proposed system includes the on-site deployment of slot modules to monitor and signal the availability of each parking space. Additionally, users can check the availability of parking spaces and reserve a spot through a smartphone application. By reducing fuel consumption, smart parking systems can also contribute to economic benefits.
Keywords: Ultrasonic-sensors, Parking lot, Big data, and the Internet of Things (IoT)

Paper ID: 54

Mobility as a service (MaaS) and its potential to revolutionize sustainable transport

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Abstract. Mobility as a Service (MaaS) is a concept that has emerged in recent years as a po-tential solution to the challenges facing sustainable transport. MaaS is an integrated approach to mobility that seeks to provide travelers with a seamless and convenient experience across different modes of transport, including public transport, ride-hailing, bike-sharing, and car- sharing services. By combining different modes of transport into a single, integrated service, MaaS aims to reduce the reliance on private cars and promote more sustainable modes of transport.This paper explores the poten-tial of MaaS to revolutionize sustainable transport. Drawing on a review of the litera-ture and case studies from around the world, the paper examines the key features of MaaS, including its potential to reduce congestion, improve air quality, and enhance the overall travel experience for users. The paper also examines the challenges associ-ated with implementing MaaS, including issues related to data privacy, interoperabil-ity, and the need for strong public-private partnerships. The results of the paper sug-gest that MaaS has the potential to significantly transform the way we think about sustainable transport. By providing travelers with a more convenient and integrated mobility experience, MaaS can encourage greater use of public transport and other sustainable modes of transport. However, to realize the full potential of MaaS, there is a need for strong collaboration between governments, transport operators, and tech-nology providers. Overall, this paper provides insights into the potential of MaaS to revolutionize sustainable transport and highlights the need for continued research and investment in this important area.
Keywords: Mobility as a Service (MaaS), sustainable transport, transportation revolution, integrated mobility, shared mobility, sustainable urban mobility

Paper ID: 68

A study on comparative analysis of walkability indices in Indian Context

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Abstract. A crucial component of urban sustainability, walkability has an impact on social interaction, public health, and environmental quality. Even though walking is the predominant form of transportation in Indian cities, there is still a lack of suitable pedestrian infrastructure. In order to assess pedestrian environments in Indian cities, this study compares three different walkability indices: The Sidewalk Accessibility Index (SAI), Modified Global Walkability Index (MGWI), and Local Walkability Index (LWI). Data was gathered via pedestrian interviews and field surveys using Hanamkonda as a case study. The findings showed notable differences in how each index represented several walkability factors, including user perception, safety, and infrastructure quality. While the MGWI concentrated on more general social and environmental aspects that reflected pedestrian comfort and perceptions, the LWI prioritized accessibility and safety. Although the SAI provided information on sidewalk infrastructure, it did not provide a thorough analysis of urban walkability. In order to improve walkability in Indian cities, this study emphasizes the necessity of an integrated strategy that strikes a balance between objective metrics and user experience. The results highlight areas that need improvement, including accessibility, infrastructure quality, and pedestrian safety, and offer insightful suggestions for urban planners.
Keywords: Pedestrian Accessibility, Walkability index, built environment, pedestrian safety

Paper ID: 80

Enhancing Kochi Water Metro Ridership: A Study of User Satisfaction Indicators and Perceptions

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Abstract. Worsening congestion conditions, high energy consumption and environmental crises have paved the path for water transportation to re-emerge in the transportation industry after being neglected for many decades. Kochi, as one of the major port cities in India, which is enriched with navigable waterways has taken the initiative to launch the first water metro system of India, an integrated electric ferry transportation system, becoming the first of Asia in the same category. The newly emerged public transport facility is designed to cater both recreational riders and commuters. However, ridership data indicates that while recreational users have accepted the system, commuter riders remain hesitant. Therefore, this study will specifically focus on assessing the service quality of the system, with a particular emphasis on its suitability for commuter riders. The study considered twenty-five factors that may influence the user's satisfaction with water metro. Using machine learning techniques, a predictive model was developed for identifying the influencing factors on the passengers' overall satisfaction of the Kochi water metro system. The study revealed that the water metro fare aligns with passenger expectations and identified water metro awareness as a key factor among other factors. Additionally, the Random Forest machine learning model was found to be the most effective for predicting overall passenger satisfaction with the Kochi water metro. The study findings help the policy makers and operators to prioritize the improvement areas for increasing the water metro ridership.
Keywords: Water Metro, User Perception, Machine Learning, IPA Matrix

Paper ID: 82

Assessment of noise pollution in urban residential complexes and awareness of potential health risks among residents in noise-sensitive areas

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Abstract. Environmental noise constitutes a significant environmental challenge in metropolitan areas, wherein road traffic noise, a primary urban pollutant, remains substantially underestimated despite presenting considerable health risks. This study aims to evaluate noise levels within and around noise-sensitive urban areas and to assess public awareness of the associated health risks. Field measurements were collected to validate the applicability of standard noise models, which were subsequently employed to characterise the acoustic environment and to evaluate exposure levels within the residential areas. A questionnaire survey involving 1623 residents was administered to assess the impact of noise exposure and public awareness. Statistical analyses, including the chi-square test, Shapiro-Wilk test, and Kolmogorov-Smirnov test, were employed to validate noise levels and identify key determinants of public perception of increased noise pollution health risks. The results reveal excessive noise levels, with 61.9% of residents exposed to noise exceeding the safe limits. A strong correlation ($r^2 = 0.83$) was found between measured and modelled noise. Despite a relatively high literacy rate of 73.8% and a predominantly young population, the majority of respondents exhibited limited or no awareness of the significant adverse health effects of traffic noise, indicating a considerable knowledge gap. To effectively address this issue and to ensure regulatory compliance, it is imperative to prioritize public education, develop targeted communication strategies, and enhance local interventions. A strong emphasis on public awareness is crucial to mitigate the health impacts of noise pollution.
Keywords: Road traffic noise, Noise mapping, Developing countries, Awareness

Paper ID: 96

Advancing Public Transport Accessibility Assessment: A Case Study of Hubli – Dharwad

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Abstract. Public Transport Accessibility Assessment evaluates the ease of accessing public transportation services within a specific area. It considers factors such as proximity of stops/stations to key destinations, availability of transportation modes, service frequency and reliability, affordability of fares, and universal accessible infrastructure. Past assessments have focused on similar physical and service parameters. The assessment of public transport accessibility focused primarily on stop-level or corridor-level parameters, neglecting urban-level factors such as land use and building footprints. Additionally, user behavior and perception of public transport accessibility were not considered in most assessment methods. The literature review revealed a lack of a comprehensive framework that integrates public transport accessibility at the urban, corridor, and stop levels. This research aims to develop a framework that addresses this gap by integrating accessibility assessments across these different levels, hence a comprehensive framework for Advanced Public Transport Accessibility Index (APTAI) has been developed in this research. The Urban Network Analysis (UNA) was performed at urban level considering land use and building footprints along with network parameters. At corridor level, the service parameters like frequency, headway, stops, and routes were considered along with dynamic factor of availability of the PT service at the given time and Transit Network Analysis (TNA) was performed. At stop level, Transit Stop Analysis (TSA) was performed to capture the perception and behavior of people about the factors like bus frequency, waiting time, safety, comfort and distance and time to reach from POI (Point of Interest) to SAP (Service Access Point) was considered, and the transit stop accessibility level was calculated.
Keywords: Public Transport Accessibility Assessment, Perceived Accessibility, Urban Network Analysis, Transit Network Analysis, Transit Stop Analysis PTAL.

Paper ID: 133

Developing of Walkability Index for University Green Campus for the Evaluation of Existing Sustainable Pedestrian Walkability Infrastructure at PEC Campus in Chandigarh City for the Achieving of SDG-2030 Targets

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Abstract. In Developing countries like India, the walkability is an important concept in sustainable urban design approach. Sustainable urbanisation and technological advancements have significantly transformed city landscapes, emphasising the importance of sustainable living spaces in urban areas. The educational campuses, reflecting broader urban settings, are integral to this trend, with walkability index is developing as a key component. Walkability refers to how encouraging an area is to be walking, influenced by factors such as pedestrian infrastructure, safety, accessibility, and environmental quality. This study examines the linear walkability index scores system (LWI) of the Punjab Engineering College (PEC) campus, assessing its impact on students, faculty, and staff. The research aims to identify the strengths and weaknesses of the existing pedestrian infrastructure, understand campus users' perceptions, evaluate the environmental and aesthetic qualities of pedestrian spaces, and propose practical recommendations for improvements in university campus. Developing established frameworks like the Urban Walking Environment Context and the Pedestrian Level of Service (PLOS) model, the study employs surveys and observational methods to gather data. The findings reveal that while PEC boasts several strengths in existing pedestrian infrastructure, PEC Campus areas such as signage, aesthetic appeal, and sidewalk conditions need enhancement. The composite walkability score (CWS), calculated using the weighted scoring system, provided a quantitative summary of the overall walkability of the PEC campus. The final LWI score was 3.8 out of 5, indicating a generally positive but not perfect walkability environment.
Keywords: Walkability, LWI, CWS, PEC green campus, Pedestrians, SDG-2030

Paper ID: 137

Pedestrian Infrastructure and Accessibility in Urban Environments: An Analysis of Walkability, Connectivity, and Spatial Configuration in Kochi

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Abstract. Non-motorized transportation (NMT) such as walking, cycling, skateboarding, rollerblading, and non-motorized scooters provides various advantages for urban development, including environmental sustainability, improved health, and cost reduction. In light of the increasing global CO2 emissions, especially from the transportation sector, the role of NMT in addressing climate change is becoming increasingly crucial. Focusing on Kochi, Kerala, an influential commercial centre known for its cultural and economic significance, this study evaluates the current pedestrian infrastructure, identifies shortcomings, and provides recommendations for improvements. The selection of the study site in Kochi was based on diverse criteria, such as pedestrian accident rates, land use diversity, and the presence of key landmarks. Data collection methods included road inventories, pedestrian satisfaction surveys, volume counts, and user surveys. The findings revealed notable encroachments and connectivity issues that impact pedestrian satisfaction. The Walkability Score and Quality of Service assessments indicated average satisfaction levels. Space syntax analysis uncovered strong connectivity in specific areas but poor integration and accessibility. Additionally, pedestrian directedness analysis identified variations in pedestrian service coverage area based on the existing network and the actual service coverage area based on actual travel times, including delays. Overall, this study highlights critical areas requiring intervention and presents strategic recommendations to enhance pedestrian infrastructure. By addressing these issues, the study aims to create safer, more efficient urban environments that prioritize non-motorized transportation and improve the overall liveability of the city.
Keywords: Non-motorized Transport, Walkability Score, Pedestrian Route Directedness, Space Syntax

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Alternative Fuel Vehicles' Feasibility in Developing Countries: Current Challenges and Future Scope

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Abstract. As fossil fuel supplies are being depleted and their negative effects on the environment become more apparent, research into renewable energy sources and alternative fuels has increased. Developing countries face the dual challenge of rising energy demand from population growth and urbanization, alongside the necessity to reduce greenhouse gas (GHGs) emissions. In this regard, the present study reviews the viability, environmental effects, and infrastructure requirements of alternative fuels such as hydrogen, biofuels, electricity, methanol, natural gas, and ammonia. Although hydrogen and ammonia exhibit potential as carbon-free alternatives, issues with transport, storage, and manufacturing costs are impeding their uptake. Electric vehicles, while beneficial for short-distance travel, face limitations in range and resource availability. Biofuels offer a viable short-term solution but struggle with feedstock procurement and the food-versus fuel debate. The study also looks at how governmental assistance and technical developments could promote the widespread use of alternative fuel vehicles (AFVs). It also examines the role of ammonia as a promising carbon-free fuel with a mature infrastructure capable of mitigating hydrogen's key drawbacks. The insights aim to aid policymakers and researchers in making informed decisions to achieve sustainable mobility, thereby reducing reliance on fossil fuels and supporting global climate goals. The study underscores the urgency of a diversified approach to decarbonizing the transport sector, leveraging the strengths of each fuel type to overcome individual limitations and achieve significant reductions in fossil fuel dependency and carbon emissions.
Keywords: Carbon-free fuels, Fossil fuels, Greenhouse gas emissions, Sustainable mobility

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Delay Measurement and Analysis of Pedestrian Behaviour

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Abstract. Understanding pedestrian behaviour and its interaction with transportation infrastructure is crucial for ensuring safe and efficient urban environments. This study presents a comprehensive analysis of delay measurement techniques and their correlation with pedestrian behaviour within the context of urban mobility systems. The study begins by reviewing existing literature on delay measurement methodologies, encompassing traditional approaches and emerging technologies such as GPS tracking and computer vision. It identifies key metrics for delay measurement, including travel time, waiting time at intersections, and overall journey delay. Furthermore, the study examines various factors influencing pedestrian behaviour, ranging from individual characteristics such as age and gender to environmental factors such as weather conditions and built environment features. It explores how these factors impact pedestrian movement patterns, decision-making processes, and overall travel experience. The analysis integrates delay measurement techniques with observations of pedestrian behaviour to identify correlations and causal relationships. It investigates how variations in delay affect pedestrian choices, such as route selection, crossing behaviour, and mode of transportation. Additionally, it explores the role of infrastructure design and traffic management strategies in mitigating delays and enhancing pedestrian safety and satisfaction. The findings of this study contribute to the development of effective urban planning and transportation policies aimed at improving pedestrian mobility and enhancing the overall quality of urban life. By integrating delay measurement with insights into pedestrian behaviour, policymakers, and urban planners can design more pedestrian friendly environments and optimize transportation systems to better serve the needs of all road users.
Keywords: Pedestrian Behaviour, Delay, Uncontrolled Intersection

Evaluating External Network in the Catchment Area of Metro Interchange: Case City, New Delhi

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Abstract. Ensuring good accessibility at metro interchanges is crucial for creating an efficient, user-friendly public transportation network. Metro systems are extensively used as they help reduce journey times, making them essential for urban commuters. Assessing the performance of transport infrastructure and understanding user behavior provide valuable insights for policymaking and investment decisions. Traditional evaluation methods often rely on individual indicators, which can fail to capture the multidimensional nature of transportation systems. Metro interchanges are carefully planned to enhance connectivity and streamline networks, acting as essential hubs where passengers can switch between routes or directions to reduce travel time and increase flexibility. This study aims to develop a comprehensive assessment that identifies the key parameters influencing the choice of interchange stations over standard nodal stations, taking a holistic approach to transportation systems. A critical aspect of this analysis is last-mile connectivity—how effectively passengers can complete their journeys after leaving the metro network. This factor is essential for a robust public transportation system as it ensures passengers can reach their final destinations smoothly. Using SPSS software, the study evaluates important parameters through various statistical models, including logit models and factor analysis, using data collected from four metro interchange stations in Delhi. User feedback was gathered to rate the quality of service for each parameter, allowing for a detailed analysis of service levels. The findings offer valuable insights for planners, transportation authorities, and metro operators by pinpointing areas for improvement in interchange accessibility and user experience.

Keywords: Transport Infrastructure, Metro Infrastructure, Public Transportation Systems, Multinominal Logit

Congestion Pricing for Indian Cities: Challenges and Prospects Based on International Experiences

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Abstract. Congestion pricing has demonstrated significant effectiveness in managing traffic congestion in cities around the world. While numerous cities globally have implemented or explored various congestion pricing schemes, its potential remains largely untapped in Indian cities. This paper investigates the feasibility of congestion pricing as a tool to address traffic issues in India, focusing specifically on the city of Ahmedabad. By analyzing both successful and unsuccessful international cases, the study extracts critical lessons that can inform potential implementations in the Indian context. Through a theoretical assessment, this study identifies three distinct spatial characteristics in Indian urban environments that could facilitate effective congestion pricing: (1) well-defined charging zones, (2) advantageous geographical features, and (3) compact, densely built central business districts. These features, prevalent in Indian cities, could play a vital role in achieving successful outcomes similar to those observed internationally. In addition to spatial considerations, the paper addresses the unique challenges Indian policymakers may encounter, such as garnering public support, ensuring political feasibility, and developing the necessary technical infrastructure. To assist policymakers in overcoming these challenges, the study provides practical recommendations rooted in international best practices. Overall, the research extends the discussions on congestion pricing in the Indian context, resulting in identification of valuable insights to guide decision-making for the implementation of congestion pricing schemes, ultimately promoting sustainable urban mobility and addressing traffic congestion issues in Indian cities.

Keywords: Congestion pricing, road pricing, congestion charge, travel demand management, congestion tolls, transport policy

Quantifying Shippers' Modal Shift to Inland Water Freight Terminals: A Case Study of Varanasi (NW-1)

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Abstract. Navigable inland waterways offer a fuel-efficient, environmentally friendly, and cost-effective transportation mode that, despite its availability in India through 117 national inland waterways, remains vastly underutilized. This study examines the production of commodities in Varanasi and predicts shifts in transport modes to National Waterway 1 (NW1) based on a "willingness-to-shift" survey. Factors such as time, cost, efficiency and flexibility while choosing the modes influence the transition from road to inland water transport were assessed using the Analytical Hierarchy Process (AHP) to meet emerging market demands. By analyzing the accessibility of the Multimodal Terminal (MMT) at the district level through GIS-based catchment analysis, this study forecasts a modal shift by 2035, projecting that up to 50.65 million tons of freight primarily fertilizers, cement, and food grains could transition to NW1. The analysis highlights environmental advantages gained from the modal shift. Additionally, route optimization for industrial areas in the district demonstrates how improved infrastructure and governance can address transit time challenges, further supporting the viability of inland water transport. This study provides evidence to inform targeted policies, demonstrating the potential of IWT to optimize intermodal freight logistics and meet regional transportation needs effectively.

Keywords: Inland Water Transport (IWT), Modal Shift, Market Analysis, AHP

Assessment of sustainability of passenger transport: A case study of Chennai Metropolitan Area

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Abstract. This study aims to assess the sustainability of urban passenger transportation in Chennai, India to act as a tool for policymaking. The primary modes of transportation for people include walking, cycling, motorcycles, cars, buses, and the metro rail system. The assessment was done by estimating the tail-pipe emissions for the current mode share using published emission rates. In the base year, motorcycles contribute the most to the tailpipe emissions (57%), and buses are the least contributor (10%). A similar assessment was done for future years by creating three scenarios. The results show that the city will benefit from shifting the passengers to mass transportation reducing tailpipe emissions by at least 26%. LCA was also conducted for these modes since tailpipe emission estimation will be obsolete with the electrification of vehicles. The results were compared with the tailpipe emissions of respective modes and also between the modes. There are reductions in emissions from all road vehicles if they are shifted to electric vehicles from the current internal combustion engines. Scenarios were created with LCA results also for future years—even the results from LCA show significant benefits from shifting to mass transportation systems.

Keywords: Tail-pipe emission · micro-level emission, macro-level emission, sustainability of public transport, city transport, LCA of Public transport

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