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Research for Transport and Logistics Industry

Proceedings of the 10th International Research Conference

"The Next Generation of Transport and Logistics for a Smarter World"

Organized by
Sri Lanka Society of Transport and Logistics (SLSTL)

Jointly Organized with
SLIIT Malabe Campus, Sri Lanka

2nd August 2025
Colombo, Sri Lanka

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Message from the President

It is my great pleasure to extend a warm welcome to all participants of the 10th International Conference on Research for Transport and Logistics Industry (R4TLI) 2025, organised by the Sri Lanka Society of Transport and Logistics (SLSTL).

One of the core objectives of establishing the SLSTL was to foster a strong research culture in the fields of transport and logistics, supporting rational and evidence-based decision-making within the sector. In pursuit of this goal, the Society launched R4TLI—an annual research conference that, this year, proudly celebrates its 10th milestone. Each year, R4TLI provides an invaluable platform for professionals in academia and industry to share their latest research findings and insights with a broad community of stakeholders.

The theme for this year's conference, "The Next Generation of Transport for a Smarter World," highlights innovative research and development efforts from both local and international contributors. We are honored to welcome you all to this distinguished event and look forward to the rich exchange of ideas and knowledge.

I also wish to express my sincere appreciation to the Conference Committee for their dedicated efforts in organizing this event in collaboration with the Sri Lanka Institute of Information Technology (SLIIT). We are equally grateful to our sponsors for their generous support. With the valuable contributions of all participants, I am confident that R4TLI 2025 will be a resounding success.

Dr G.N. Samarasekara

B.Sc.Eng. (Hons) (Moratuwa), M.Eng. (Saitama, Japan), Ph.D. (Saitama, Japan), MIE Sri Lanka,
Senior Lecturer, Department of Civil Engineering, University of Sri Jayewardenepura
President - SLSTL

Message from the Conference Chair

It is with great pleasure and immense pride that I extend a warm welcome to you all for the 10th International Conference on Research for the Transport and Logistics Industry (R4TLI 2025), the annual conference dedicated to advancing research and innovation in transport and logistics. The theme for this year's conference, "The Next Generation of Transport and Logistics for a Smarter World", invites us to explore innovations and transformative strategies in how goods and people move across the globe, reflecting our collective ambition to embrace and shape the future of this rapidly evolving industry.

As we gather once again, scholars, practitioners, policymakers, and industry leaders, this forum provides a timely platform to engage with the dynamic challenges and emerging opportunities shaping the logistics and transport sectors, both locally and globally. Sri Lanka, positioned strategically in the Indian Ocean and rich with a heritage of trade, is uniquely placed to host this important dialogue. The R4TLI conference continues to serve as a bridge between cutting-edge research and real-world application, encouraging critical discourse, knowledge exchange, and interdisciplinary collaboration. In an era where technological advancement, environmental sustainability, and resilience are paramount, our discussions must lead to practical solutions and policy insights that are both visionary and grounded.

We are excited to announce that this year's conference will be held in collaboration with the Sri Lankan Society of Transport and Logistics (SLSTL) and the Sri Lanka Institute of Information Technology (SLIIT). This collaboration marks a significant milestone, bringing together a broader spectrum of expertise and fostering a more dynamic exchange of ideas. The synergy between these two pioneering organisations promises to deepen our conversations and enhance our collective understanding of the challenges and opportunities ahead.

I extend my heartfelt appreciation to all authors who submitted their valuable research, to the reviewers who ensured the quality and integrity of the proceedings, and to the dedicated organising committee whose efforts have brought this event to life. My sincere thanks also go to our sponsors and institutional partners for their unwavering support. I encourage each of you to engage actively in the diverse sessions and events lined up for the conference. Let us make the most of R4TLI 2025—as a space to connect, to learn, and to drive meaningful change in building smarter, more connected transport and logistics systems for the future. I hope this conference will also foster lasting connections that will contribute to the continued progress of our industry and inspire future collaborations.

Thank you for your continued support. I look forward to a productive and inspiring conference.

Dr. Chathumi Kavirathna
B.Sc. (TLM) Hons (University of Moratuwa-Sri Lanka), D.Eng & M.Eng (Tokyo Institute of Technology-Japan),
Senior Lecturer, Department of Industrial Management University of Kelaniya, Sri Lanka.
Vice President - SLSTL

Message from the Founding President of SLSTL

It's a pleasure to convey my sentiments to the Sri Lanka Society of Transport and Logistics (SLSTL) on its 10th International Conference on Research for Transport & Logistics Industry (R4TLI). The continuity of a conference that interphases academia and practitioners is vital for the infusion of innovation and creativity in tacking evolving issues in the transport and logistics industry with scientific solutions. The theme, '*The Next Generation of Transport and Logistics for a Smarter World'* is a pivotal discussion in modernizing the industry to meet the service requirements and aspirations of the emerging generations. I also congratulate the Conference Committee for having partnered with the Sri Lanka Institute of Information Technology (SLIIT) as the Hosting Partner for the conference. Their support and expertise will undoubtedly contribute to the success of the conference. I also thank long-standing sponsors for their trust and belief in the continuity of research for transport and logistics industry. I send my best wishes and blessing for a successful 10th anniversary conference.

Prof. Amal S. Kumarage
B.Sc. Hons Eng. (Moratuwa), Ph.D. (Calgary), FCILT, FNASSL, MIE(SL), CEng
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Tracks, Sessions, and Papers

Track	Transport Planning	Urban Transport	Maritime and Logistics	Smart Mobility	Aviation and Logistics	**Total**
Session	A1	B1	C1	D1	B2	
Number of Papers	4	5	4	5	5	**23**
Session	A2		C2			
Number of Papers	4		4			**8**
Total	8	5	8	5	5	**31**

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ASSESSING THE TRAVEL SPEED VARIATION AND DELAY OCCURRING IN THE PUBLIC TRANSIT SYSTEM: A CASE STUDY OF THE VAVUNIYA TO JAFFNA ROUTE

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ABSTRACT The urban community depends on public transportation because it enables economical, environment-friendly, and quick transportation solutions. The speed variability of the transit system directly affects how reliable and satisfactory the service delivery becomes. An investigation based on GPS-tracked trips with statistical analysis examines the connection between velocity variations and travel delays on Sri Lanka's A9 highway's Vavuniya to Jaffna segment. Merging OLS regression analysis on 111,427 observations shows speed difference as a factor that accounts for 1.4% delay fluctuation ($R^2 = 0.014$) and confirms statistical significance. Speed difference variation produces negative impacts on delays according to research results, while an analysis of F-statistics and IBD and FIBD coefficients establishes its statistical significance. The residual analysis indicates a correlation between observations as well as non-normal distribution, which indicates the need to incorporate variables related to traffic patterns. Visual data analysis confirms a steady pace, along with occasional spikes followed by delays that result from external influences. The prediction of transit delays requires more than speed data because speed remains an insufficient standalone variable to determine delay outcomes.

Keywords: Public Transportation; Speed Variation; Travel Delay; Urban Mobility.

1. INTRODUCTION

In modern cities, public transport remains an affordable, eco-friendly commuting option. Its capacity and usage increase when it becomes faster, while its attractiveness declines due to delays, which directly impacts the economy. Speed plays a major role in evaluating the public service level in urban areas. Thereby, it is a milestone in urban mobility development to identify and understand the speed variations and their impacts on overall public transportation management that can directly affect the quality, efficiency, and sustainability. Enhancing consistency through more research and investments can improve its attractiveness and user appeal.

Several studies have identified the importance of speed variation and delay in public transport. Lijesen (2014) suggests that the responses of travellers due to unexpected delays are affected by the transport frequency, while Pistsov & Zakharov (2021) indicate that people give priority to other transport modes to avoid delays. Similarly, Naeem *et al.* (2018) emphasise the importance of route geometry in identifying the timing delays. Schmidt *et al.* (2016) found that the overall performance of public transport is improved by elevating the operational speed. Furthermore, Martin *et al.* (2021) pointed out that demand for alternative transport modes can be directly influenced by various access times, which can build a relationship between travel speed and duration.

In a developing country such as Sri Lanka, focusing on the highways and transportation development brings significant enhancements that can significantly contribute to economic growth (Chen *et al.*, 2023). Most importantly, since Highway A9 serves almost the complete northern half of the island, its enhancement has brought remarkable social and economic upliftment (Gunasekera *et al.*, 2008). This study further assesses the travel speed variation that occurs in the public transit system's top segment of A9 road from Vavuniya to Jaffna to propose a relationship between delay and speed variation, where

the travel delay propagation for every second is assessed against speed variation, identifying the practical insights that can aid transport planning in developing regions while addressing a key gap in the previous studies.

2. MATERIALS AND METHODS

2.1. Data analysis

After a clear investigation of the travel route, each trip was tracked using a GPS tracking application, "Geo Tracker". The GPX file was extracted and decoded, and further assessments were done using Python software. Finally, the statistical relationship between speed variations and travel delays was checked.

2.2. Calculations

The haversine formula is used to calculate the changes in distances; meanwhile, the time delay accumulation in each second of the trip is calculated using the following equation.

$$\Delta t_{total}(T) = \frac{1}{v_{expected}} \sum_{t=1}^{T} (d(t) - v_{expected} \cdot t)$$

3. RESULTS AND DISCUSSION

3.1. OLS Regression results

Table 1. OLS Regression Table

OLS Regression Results

Dep. Variable:	delay_seconds	R-squared:	0.014
Model:	OLS	Adj. R-squared:	0.014
Method:	Least Squares	F-statistic:	1608.
Date:	Wed, 18 Dec 2024	Prob (F-statistic):	0.00
Time:	19:44:04	Log-Likelihood:	3.0039e+05
No. Observations:	111427	AIC:	6.008e+05
Df Residuals:	111425	BIC:	6.008e+05
Df Model:	1		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[0.025	0.975]
const	0.1522	0.011	14.171	0.000	0.131	0.173
speed_diff	-0.3052	0.008	-40.099	0.000	-0.320	0.290

Omnibus:	294949.042	Durbin-Watson:	1.281
Prob(Omnibus):	0.000	Jarque-Bera (JB):	120631693 24.445
Skew:	31.499	Prob(JB):	0.00
Kurtosis:	1613.680	Cond. No.	1.41

This study analyses the effects of speed differences and delays using OLS regression, which is based on 111,427 data points consisting of both distance and time, allowing for a detailed second-level analysis of speed variation and delay. Speed differences account for just 1.4% of delay variability, which corresponds to an R^2 value of 0.014 and $F = 1608$, $p < 0.001$, suggesting the multifaceted nature of travel delay that can be affected by various factors like passenger loading time, road geometry, traffic density, signal timing and weather conditions. The coefficient for speed_diff (-0.3052) reveals that higher speed differences lead to shorter delays. The reliability of the model receives support through the significant IBD coefficient of 0.282 and the FIBD coefficient value of 0.428. Residual diagnostics show that the data suffers from autocorrelation with a Durbin-Watson value of 1.281 alongside significant skewness and kurtosis figures of 31.499 and 1613.680, respectively, which demonstrate non-normality. A more effective prediction model requires the inclusion of additional factors such as traffic conditions or road statuses as well as applying generalised least squares (GLS) or robust regression techniques, addressing nonlinear patterns.

3.2. Speed variation with other parameters

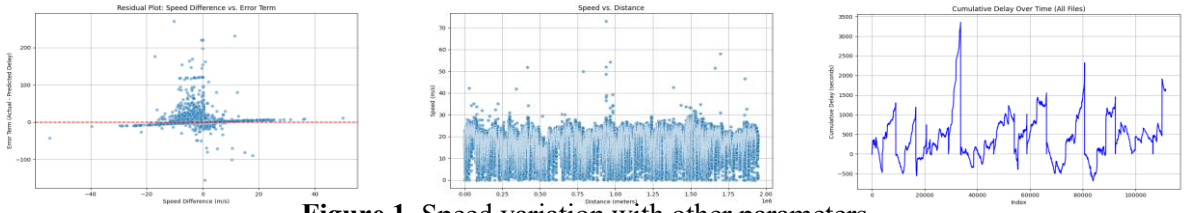

Figure 1. Speed variation with other parameters

The first graph denotes the significant variability with densely packed small speed variations, reflecting a modest inverse relationship between speed difference and delay. Similarly, the second graph reveals clusters of observations where speed remained consistent, ranging for between 10 to 30 m/s, whereas occasional spikes over 50 m/s suggest short bursts of high velocity. The dense vertical band represents

repeated measurements over a particular distance. The third figure indicates that delay increases at several instances and falls at other times, which is indicative of lengthy halts, sluggish motion and interferences, with peaks over 3000 seconds showing the inefficiencies likely caused by traffic, terrain and various speed conditions.

4. CONCLUSION

Based on the relationship between speed difference and delay, it is relatively subtle, but it is statistically important, and speed remains a poor sole indicator of delays, which can be influenced by other variables like traffic, terrain, and inefficiencies of the network. However, although speed is mostly consistent, delay patterns reflect traffic or stoppages. The results point out the significance of integrating the contextual variables in the model of the public transport to maximise the reliability and efficiency of the system in such developing regions as the A9 highway.

ACKNOWLEDGEMENT

I sincerely thank all those who contributed to the completion of this study, including my research supervisor and other panel staff. I am especially grateful to my friends who supported me in collecting this GPS data.

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A MULTIDIMENSIONAL GIS APPROACH FOR IDENTIFYING AREA-SPECIFIC ROAD DEVELOPMENT STRATEGIES

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ABSTRACT
The road network primarily influences the accessibility, connectivity, socio-economic growth, and regional development. Although the common road development strategies consider standard variables such as traffic congestion, population, transportation modes, and road types, they do not equally work everywhere. Accordingly, this study aims to identify clusters for area-specific road development strategies in the Homagama DS Division. The multivariate cluster analysis has been utilized to identify the specific clusters based on six indices, which are nodes, edges, intersection density, gamma index, population density, and building density. As a result, three clusters and the specific socio-economic and infrastructural characteristics have been recognized. Accordingly, cluster 1 showed high population, building, and intersection densities, requiring strategies to improve the road accessibility and connectivity further. Cluster 2 identified that the average population and building densities, high intersection density, nodes, and edges, is essential to balance the urban development plan. Cluster 3, characterized by low values in each index, needs a proactive rural mobility planning to enhance people's daily mobility. The spatial autocorrelation analysis further confirmed, these clusters spatially correlated with each other, as the P value is below 0. The study demonstrates the necessity of area-specific strategies for sustainable road development and urban planning.
Keywords: Geographic Information System (GIS), Road Development Strategies, Multivariate cluster analysis, Spatial Planning

4. INTRODUCTION

The road network is a significant element in a city because it influences urban accessibility and connectivity, economic activities, and enhances people's daily mobility [1]. Accordingly, several road development projects have been established to improve the road network quality and for regional development and planning. However, most countries mainly focus on ensuring the connectivity, accessibility, and sustainability of the road network through core/standard road development strategies like widening the roads, building flyovers, subways, traffic lights, and so on. Accordingly, those core road development strategies mainly consider the central/common variables like traffic data, road types, population, accident rate, service area data, and natural resources, to configure the road development projects. [2, 3]. In referencing the local empirical studies, the most common variables like biodiversity, population, traffic congestion data, connectivity, transportation modes, and natural resources are mostly considered elements in the road development projects [4,5]. But, the consideration of the common factors for every region is not equally suitable to get the benefits from the road network. Accordingly, the area-specific factors in road development project must be considered to plan the unique strategies and gain positive impacts from the road development projects. Accordingly, this study aims to identify clusters for area-specific road development strategies.

5. MATERIALS AND METHODS

Homagama Divisional Secretariat Division, including rapid development of socio-economic conditions, is a suburban area in the Colombo District. It covers an area of 121.0 km², includes 81 Grama Niladhari Divisions (GNDs). According to the population census data, the population in the study area gradually increased from 186,050 in 2001 to 237,905 in 2012 [6,7]. Thus, this region has been selected as the

study area to identify the clusters for forming the road development strategies. This study primarily relies on secondary data. Figure 01 represents the data collection and data analysis methods to achieve the objective. Moreover, the road network has been validated through the My Map software, available at;

https://www.google.com/maps/d/u/0/edit?mid=1_DxCpxmI_Uaah9l77CowDwJCXzIFGhg&usp=sharing

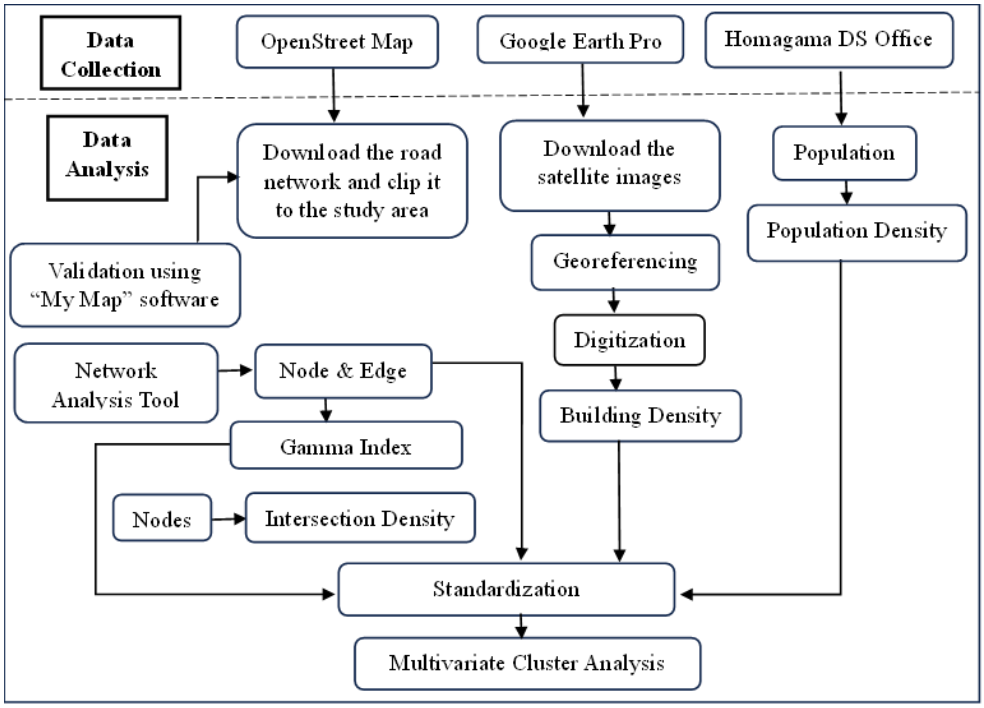

Figure 01: Summary of the Methodology.

Table 01 shows the indices used in this study.

Table 01: Indices in the study.

Index	Equation	Variable Explanation
Intersection Density	$D_i = \frac{N_i}{A}$	D_i: Intersection Density (intersections per unit area) N_i: Number of intersections (nodes with ≥3 connecting roads) A: Total area (km²)
Gamma Index	$\gamma = \frac{e}{3(v-2)} \times 100$	γ: Gamma Index (%) e: Number of edges v: Number of vertices
Population Density	$D_p = \frac{P}{A}$	D_p: Population Density (people per unit area) P: Total Population A: Total area (km²)
Building Density	$D_b = \frac{N_b}{A}$	D_b : Building Density (buildings per unit area) N_b: Number of buildings A: Total area (km²)
Edges	All road segments between two nodes	e: Total number of edges
Nodes	All intersections	v: Total number of vertices

Source: *Sahiya & Prasad, 2021; Berghauser Pont et al., 2021.*

In particular, the calculated indices were standardized to set the data on the same scale using equation 01. Si is the standardized value for the original value (Xi). Xmin and Xmax are the lowest and highest original values [8].

$$Si = \frac{Xi - Xmin}{Xmax - Xmin}$$

Accordingly, the multivariate clustering tool, in ArcGIS Pro has been utilized to identify the clusters based on the area-specific indices to understand the patterns of the spatial infrastructure [8, 9]. Moreover, K-means algorithms and Euclidean distance in ArcGIS Pro were utilized to group the spatial areas based on six indices and measure the similarity based on spatial proximity, respectively.

6. RESULTS AND DISCUSSION

Three clusters (Figure 02) have been recognized in the study area. Table 03 represents the variations of the relevant indices according to clusters.

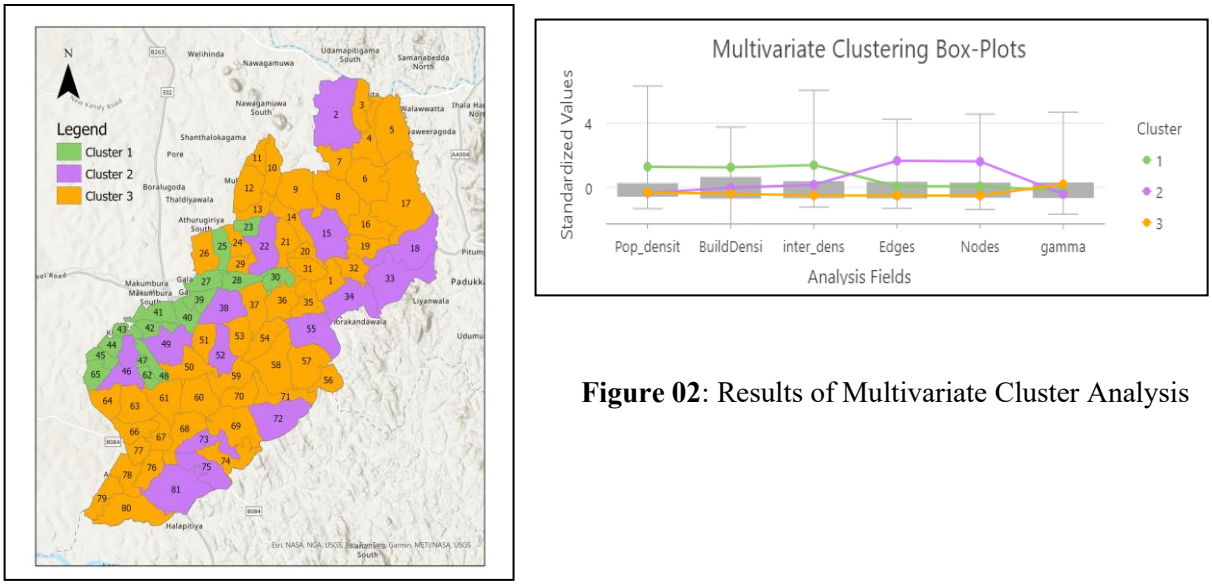

Figure 02: Results of Multivariate Cluster Analysis

Table 02: Summary of the Clusters

Clusters	Number of GNDs	Population Density (square km)	Total Road Density (square km)
1	16	112,668.13	0.1919
2	15	89,714.36	0.4028
3	50	32,794.88	0.4491

Accordingly, these clusters have included the different specific characteristics along with the considered indices (Table 03);

Table 03: Characteristics of the Clusters

Clusters	Characteristics
1	This cluster is characterized for higher population density, building density, and intersection density. Edges and nodes are slightly above the average. However, the Gamma index is approximately near the average. This cluster seems dense. Even though the intersection density is higher, the road network is not well-connected.
2	This cluster is identified for average population density, building density, but higher intersection density, Edges, and Nodes. However, the Gamma Index is low in this cluster, possibly because of more dead ends, identified by the topological node-edge analysis in ArcGIS 10.8. In particular, nodes with only one connecting edge (degree = 1) were marked

	as dead ends. As a result, more dead ends reduce the connectivity due to limited routes within the cluster.
3	This cluster shows generally low values in each variable, including population density, building density, intersection density, edges, nodes, and gamma index, symbolizing the undeveloped areas in the study area compared to other GN divisions.

Furthermore, the Moran I statistics records that the GN divisions in the above clusters are spatially correlated and shows a clustered pattern with a less than 1% likelihood that this clustered pattern could be the result of random chance (P value < 0.01).

Overall, this study recommends cluster-specific urban planning and transport development strategies.

Cluster 1 could focus on improving road capacity and connectivity to reach the demand of higher population density in the area, further improving transport facilities located within this cluster. Cluster 2 is highly likely to populate considering the development in the infrastructure. As this area is not yet densely populated, this study highly recommends the need for a well-designed urban development strategy to better absorb growth in this area. There could be less demand for highly modernized transport facilities as the population density is moderate in this cluster. Thus, careful implications are needed. Cluster 3 has the full potential to embrace properly planned urban design before this region gets densified. And improvements to the rural mobility are recommended in this cluster rather than improving a fully urban transport system.

Accordingly, this study fills the research gap by highlighting the consideration of area-specific strategies and the establishment of unique road developments instead of traditional road development approaches. This procedure leads to preventing inefficient resource usage and optimizing the infrastructure development plans.

4. CONCLUSION

This study mainly emphasizes the necessity of localized and adaptive urban planning and road development strategies for each cluster. For future studies, the number of considered variables can be increased, like income, employment, and land use mix, to identification of the micro characteristics of the clusters and form the most appropriate strategies. A comparative study across different clusters in various DS Divisions is a crucial approach to eliminate the spatial heterogeneity in Sri Lanka's development zones.

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QUANTUM-INSPIRED PEDESTRIAN MOBILITY MODELING: A PROBABILISTIC FRAMEWORK FOR SIMULATING URBAN MOVEMENT UNDER UNCERTAINTY

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ABSTRACT - This research presents a quantum-inspired pedestrian mobility model for urban environments, combining static urban features and dynamic behavioral factors under uncertain conditions. Traditional mobility models often fail to capture the probabilistic and adaptive nature of pedestrian behavior. Leveraging quantum mechanics concepts such as superposition, potential fields, and wavefunction collapse, a composite urban potential landscape was formulated and solved using the Variational Quantum Eigensolver (VQE) on a hybrid quantum-classical architecture. The University Junction area of the University of Moratuwa, Sri Lanka, served as the case study. Model validation against observed pedestrian data using Pearson's correlation (0.7672), Moran's I (0.7787), and Spearman's rank (0.7269) confirmed the framework's superior adaptability and spatial sensitivity. The findings suggest that quantum-inspired modeling offers a paradigm shift for simulating pedestrian movement within complex urban systems.

Keywords: quantum-inspired modeling; pedestrian simulation; urban informatics; probabilistic movement; Schrödinger equation.

1. INTRODUCTION

Human movement within cities reflects complex adaptive behaviors influenced by spatial and environmental conditions [1][2][8]. Traditional pedestrian modeling frameworks, including gravity models, space syntax, and classical AI methods, typically rely on deterministic assumptions and therefore struggle to effectively capture dynamic variability, uncertainty, and the probabilistic nature of pedestrian decision-making processes [2][3][5][6]. This study explicitly addresses this research gap by introducing a quantum-inspired pedestrian movement framework. By analogizing urban pedestrian movement with quantum concepts such as superposition, wavefunction collapse, and potential energy landscapes [4][7], the model aims to predict probabilistic pedestrian distributions more realistically. The research objective was to develop and validate a computational framework capable of simulating dynamic pedestrian movement using quantum mechanics principles and quantum computing [4][7].

2. MATERIALS AND METHODS

The figure below illustrates the summary of the workflow pipeline used as the methodology to achieve the research objectives. The process is structured into two main stages.

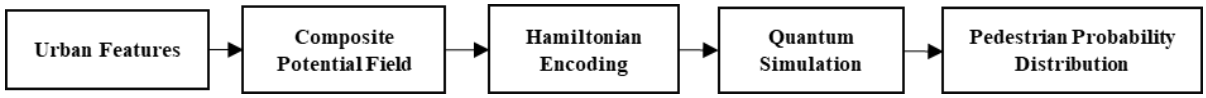

Figure 1. Summarized workflow pipeline

Developing Potential Field and Find the probabilistic pedestrian distribution are there.

2.1 Developing Potential Field

The modeling process reinterprets urban spaces as composite potential fields V(x,t) = Vurbs(x) + Vcivitas(x,t), where Vurbs encodes static urban features (building density, spatial integration, shadow

Figure 2. Map of the study area

intensity, point of interest (POI) density, wall constraints, vehicular density, pedestrian accessibility, and visibility (isovists)) and Vcivitas represents dynamic behavioral factors (crowd density and shadow attraction). Author define the study boundary based on current computational limitations of 32*32 grid. The study area geometry, including traffic signals, pedestrian sidewalks, crosswalks, and bus stops, was clearly illustrated in an accompanying figure, providing contextual clarity. Each static and dynamic factor was meticulously collected through comprehensive field surveys, GIS digitization, and manual observations at defined intervals (morning, afternoon, and evening hours) at the University Junction, University of Moratuwa, Sri Lanka. Data collection procedures considered pedestrian movement within the predefined study area of the junction, ensuring comprehensive spatial coverage.

2.2 Solving Schrodinger's Equation to find probabilistic pedestrian distribution

The potential field was encoded into a quantum Hamiltonian matrix, and the Schrödinger equation was solved using the Variational Quantum Eigensolver (VQE). This process done by converting Hamiltonian matrix into quantum devices compatible circuit structure. Data were collected via field surveys and GIS digitization at University Junction, with spatial grids normalized to a 32×32 quantum-compatible resolution. Optimization of potential field coefficients and quantum simulation were conducted on IBM's Quantum backend.

3 RESULTS AND DISCUSSION

3.1 Quantum Coefficient Optimization

Table 1. Optimized coefficient values using VQE

Index	Factor	Value
U1	Building Density	0.138852
U2	Building Height	0.229278
U3	Shadow Intensity	0.127974
U4	POI Density	0.090927
U5	Wall Constraint	0.15178
U6	Integration	0.121113
U7	Isovist	0.114626
U8	Vehicle Density	0.02545
C1	**Crowd Density**	**0.586935**
C2	**Shadow Attraction**	**0.413065**

The quantum-inspired pedestrian model was applied to the University Junction area at the University of Moratuwa using a 32×32 spatial grid. The model computed pedestrian distributions via the Schrödinger equation over a composite urban potential field $V(x,t) = V_{urbs}(x)+V_{civitas}(x,t)$. Optimization using the Variational Quantum Eigensolver (VQE) revealed that **dynamic factors such as crowd density (weight = 0.5869)** and **shadow attraction (weight = 0.4131)** significantly influenced pedestrian movement, exceeding the impact of static built features. While the majority of pedestrians at the University Junction are university students, their movement behaviors such as preferring shaded paths, avoiding congested zones, and responding to environmental stimuli are representative of general pedestrian tendencies observed in similar urban contexts. Therefore, although the model is trained on a specific demographic, the underlying behavioral responses captured by the quantum-inspired framework are broadly applicable to wider urban populations with comparable mobility preferences.

3.2 Pedestrian Probability Distribution

Simulation outputs yielded pedestrian probability maps that aligned closely with observed real-world movement patterns. Pearson correlation values for morning, afternoon, and evening were 0.7657, 0.7087, and 0.7672 respectively, indicating strong spatial agreement between predicted and observed data.

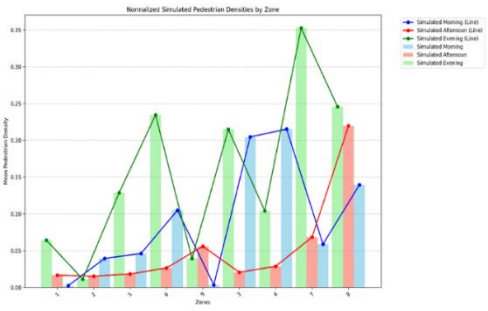

Figure 3. Simulated Pedestrian Density - Zone-wise

Model validation framework included comparison between 3 different model; Quantum, Classical, and Space Syntax. Figure 3 uses a color gradient where blue indicates low pedestrian density and red indicates high density, with green and yellow representing intermediate levels.

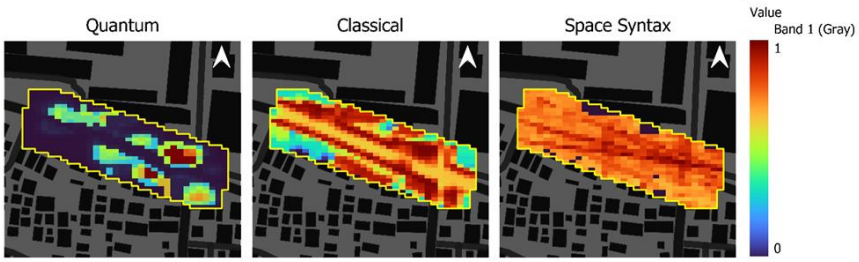

Figure 4. Comparison of validating models

It's demonstrated strong correlations between simulated and observed pedestrian densities (Pearson r = 0.7672; Moran's I = 0.7787; Spearman's ρ = 0.7269). Dynamic factors — particularly crowd density and shadow attraction — emerged as the most influential components, highlighting the adaptive behavioral response of pedestrians to environmental comfort and social dynamics. The quantum-inspired approach successfully captured temporal shifts and spatial disruptions (e.g., roadblocks), offering greater predictive flexibility than classical models.
This study acknowledges limitations such as spatial constraints due to computational capacity and the current absence of validation at alternative locations. Future research should expand the model to larger spatial extents, validate the approach in diverse urban contexts, and integrate real-time data streams for enhanced dynamic responsiveness.

4. CONCLUSION

The study demonstrated the feasibility and value of applying quantum mechanics principles to model pedestrian movement in urban environments with the computational support of Quantum Computers which include predicting pedestrian flow changes during urban events such as roadblocks or protests, informing urban design decisions by highlighting areas needing improved pedestrian accessibility and comfort, enhancing disaster preparedness through accurate simulations of pedestrian evacuation routes and behavior, and supporting real-time pedestrian flow management in congested urban areas. By embracing probabilistic, non-deterministic simulations, planners can better anticipate dynamic crowd behaviors. Future work will explore expanding the framework to larger spatial scales and integrating real-time data for adaptive urban mobility.

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DO DEVELOPMENTS FOLLOW PARKING REGULATIONS - COMPLIANCE AND DEVIATIONS IN URBAN AREAS?
A CASE STUDY OF PILIYANDALA, SRI LANKA

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ABSTRACT
Urbanization, population growth, and increasing vehicle ownership have led to increased demand for parking spaces. As a result, parking management has emerged as a critical challenge in urban areas [1]. To address these challenges traditionally urban planners and policymakers have attempted through regulations that establish minimum parking requirements for urban developments [2]. Parking regulations aim to balance the parking supply with the demand generated by their use, yet their effectiveness depends on developer compliance and their contextual adaptability. Discrepancies between approved parking layouts and on-ground implementation may also contribute to parking shortages leading to unauthorized parking and congestion. However, systematic research analyzing the extent of regulatory compliance remains scarce. This study examines regulatory compliance with mandated parking regulations in urban developments using Piliyandala as the case study to assess whether developments meet or fall short of required minimum parking supplies and identifying reasons for noncompliance. Findings reveal significantly low compliance in commercial and mixed-use developments, especially along B-Class roads, and residential developments showed high adherence, indicating that non-compliance is concentrated in specific development types and locations.

Keywords: Parking Issues, Minimum parking requirements, Regulatory misalignment, Parking regulatory compliance

1. INTRODUCTION
Standardized minimum parking regulations may not be suitable for every urban area; for instance, town centers with high land values and strong public transport networks might benefit from more flexible parking policies. Globally developed cities have shifted away from the minimum parking regulation framework by adopting context sensitive frameworks such as parking maximums or reduced parking minimums [3], [4] & [5]. Parking regulations are established to ensure that developments provide adequate parking facilities to meet the demand generated by their use, yet their effectiveness depends on developer compliance and their relevance to the urban context (whether parking requirements reflect the actual parking demand). This study focuses specifically on assessing compliance (the required number of parking spaces as stipulated by UDA regulations) with the number of parking spaces provided by developments as this is a critical indicator of regulatory compliance.

2. MATERIALS AND METHODS
The data are obtained from secondary data sources, satellite images, field observations, and interviews with identified non-compliant developments' users of the study area. Field data were collected between March and April 2025 during daytime hours (typically between 9:00 AM and 4:00 PM).

2.1. Analysis Methods
Phase 1 - Quantitative Analysis: Examined adherence patterns across development types and road classifications. The Chi-square test was used to statistically validate disparities in compliance behavior. 1,590 buildings located within the 500-meter study area (Source: Open Buildings, Google), The sample

size of 310 buildings is sufficient to represent the study area (95% confidence level, ±5% margin of error). A total of 786 developments located along the roads were analyzed, selected using Cochran's formula. Compliance was measured by comparing the actual number of parking spaces provided with UDA-mandated minimums.

Phase 2 - Qualitative Analysis: Identified systemic factors explaining why non-compliance occurs using data derived from interviews. The interviews were conducted in person and the responses were manually transcribed afterward (Frequency analysis was carried out using Excel to identify the most frequent factors). Cochran's adjusted formula was applied to the 354 non-compliant developments identified in the quantitative analysis, resulting of 185 non-compliant developments for the qualitative phase. Due to limited sample sizes in certain categories, only Mixed-Use, Commercial, and Residential developments were considered for thematic analysis.

2.2. Calculation of Parking Requirements & Compliance Rates

Parking requirements calculated based on the UDA Planning & Development Regulations. Compliance rates were calculated for each development category by comparing the actual parking supply with the mandate parking requirement.

$$\text{Compliance Rate} = \frac{(Parking\ Supply)}{(Parking\ Requirement)} \times 100\%$$

Table 2: Regulatory Compliance based on Development Accessibility

Road Classification	Number of Developments	Adhered	Not Provided	Provided Less	Mean Compliance Rate %
B Class Road	249	65	154	30	30.479
Local Road	537	367	133	37	70.349

Table 3: Regulatory Compliance based on Development Type

Use	Number of Developments	Adhered	Not Provided	Provided Less	Mean Compliance Rate %
Mixed Use	64	3	39	22	13.228
Commercial	265	33	200	32	16.765
Residential	416	376	36	4	90.575
Health	11	5	3	3	54.818
Education	15	6	7	2	45.167
Industry	9	5	0	4	79.700
Recreation	3	1	2	0	33.330
Religious	3	3	0	0	100.000

3. RESULTS AND DISCUSSION

3.1. Chi-square Statistic Results

Indicating a statistically significant difference between development type ($\chi^2 = 529.61$, $p < 0.001$) and accessibility type ($\chi^2 = 125.71$, $p < 0.001$) with regulatory compliance behavior.

3.2. Thematic Analysis Results

Table 4: Percentage Impact of Themes on Regulatory Noncompliance by Development Category

Themes	By Road Type		By Use		
	B Class	Local	Mixed Use	Commercial	Residential
Community and Demand Dynamics	2.3	15.4	4.5	4.4	32.1

Cost and Feasibility Barriers	7.3	15.4	10	7.7	22.6
Enforcement Gaps	25.5	19.2	25.4	21.4	16.7
Externalization of Parking Burden	18.9	9	10.9	13	3.6
Non-Compliance Culture	9.8	2.4	7	5.3	2.4
Profit-Driven Non-Compliance	29.3	18.6	26.4	33.5	3.6
Regulatory Mismatch	1.8	16.2	9.5	13.4	16.7
Temporal and Contextual Factors	5.1	3.8	6.5	1.4	2.4

Principal themes emerged for each development category such as spatial limitations, enforcement gaps, economic motivations, and regulatory mismatches explaining non regulatory compliance behavior. Mainly regulatory noncompliance occurs in commercial, mixed-use development typologies along the main accessibility corridors such as major roads (developments compliance along B-Class Roads at 30.48% and Local Roads at 70.35%, Residential developments exhibited high adherence (90.6%) while Mixed Use (13.2%) and Commercial (16.8%)). To improve adherence to regulations, it's better first to acknowledge commercial and mixed-use developments along major roads as these development typologies and spatial contexts have identified as major hotspots where non-compliance occurs.

4. CONCLUSION

According to both the quantitative & qualitative results, two recommendations can be made. 1) If we need to prioritize the existing regulations intended objectives then enforcement should be strengthened in identified hotspots of noncompliance. 2) According to the existing literature and by looking at these results, in reality even regulations imposed, people don't follow, then is it necessary to keep these regulations as it is? Or can't policy makers revise regulations according to the reality?

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TEMPORAL URBAN MOBILITY PATTERNS IN CROSS CITY COMPARISON USING MOBILE POSITIONING DATA (MPD)

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ABSTRACT
This study analyses urban mobility patterns using mobile positioning data (MPD) across 50 Western Sri Lankan cities. A novel method is introduced to examine 15-minute population density changes, enabling the identification of mobility dynamics without reliance on traditional transport data. The approach detects activity patterns by comparing weekday and weekend population curves, revealing distinct urban mobility behaviours. Key findings include: (1) clear weekday weekend variations, with more complex commuting patterns on weekdays; (2) identifiable city-specific mobility signatures; and (3) measurable differences in peak activity timing. The 15-minute resolution captures micro-mobility shifts that are not visible in daily aggregated data. This research offers a cost-effective tool for mobility analysis, particularly valuable in data-scarce regions. The framework supports evidence-based transport planning and infrastructure decision making using readily available MPD. Future research may expand temporal coverage and integrate land use data to enhance analytical depth.
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Keywords: urban mobility; mobile data; population density; temporal patterns; transport planning

1. INTRODUCTION

The growing complexity of urban systems has made it increasingly important to understand human mobility for transportation planning, infrastructure development, and sustainable urban design. Traditional approaches to studying urban mobility such as origin–destination matrices, travel surveys, or mode-specific tracking (e.g., GPS data from vehicles or transit cards) suffer from significant limitations in terms of scale, resolution, and coverage. These shortcomings are particularly evident when attempting cross-city comparisons or capturing high-frequency temporal patterns.

As an innovative alternative, this study proposes the use of temporal population density patterns derived from mobile positioning data (MPD) as a proxy for urban mobility dynamics. Recent advances in MPD analytics have demonstrated its potential in tracking diurnal rhythms of urban activity (Ahas et al., 2010) and identifying functional urban zones based on characteristic density signatures (Calabrese et al., 2011). Despite these advancements, a systematic framework for comparing mobility patterns across cities using MPD remains lacking especially in regions with informal transport networks and fragmented data availability (Zhao et al., 2022).

To address this gap, a novel framework has been developed to analyse and compare temporal mobility patterns across diverse urban contexts using MPD. The core objective is to decode mobility through density dynamics, exploring how temporal variations in population density can serve as robust indicators of mobility, independent of mode-specific data. The ultimate aim is to translate these insights into actionable tools that inform urban transportation planning and infrastructure decisions based on observed, rather than assumed, human movement patterns.

The relevance of this research extends across multiple domains of urban planning. By inferring mobility patterns from anonymised population density data, the proposed framework provides a scalable and low-cost solution particularly suited for data-scarce regions. Furthermore, the ability to conduct systematic comparisons across cities facilitates the identification of best practices, while the focus on real-world application ensures direct utility in transport design and policy formulation.

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2. MATERIALS AND METHODS

The study investigates temporal urban mobility patterns across 50 cities in Western Sri Lanka using anonymised mobile positioning data (MPD) collected by a network service provider over a one-week period. A three-stage methodological framework is employed:
Temporal segmentation: A change-point detection algorithm is used to identify significant transitions in urban activity throughout the day. These transitions delineate periods of increased or reduced mobility, reflecting behavioural shifts in population flow. Mobility signature extraction: Distinct weekday and weekend activity curves are generated for each city to highlight differences in movement behaviour. The number and timing of detected change points serve as indicators of urban dynamism. Cross-city comparison: Quantitative metrics such as peak timing, population dispersal rate, and density fluctuation are computed to facilitate systematic comparisons. The 15-minute temporal granularity enables a high-resolution view of urban activity, capturing micro-mobility trends that are typically masked in daily aggregates.

3. RESULTS AND DISCUSSION

The urban activity curve representing population density changes over time emerges as a primary output of the analysis. Within individual cities, weekday curves exhibit greater dynamism, reflected by a higher number of change points compared to weekends. This suggests more complex commuting behaviours and work-related travel during weekdays.

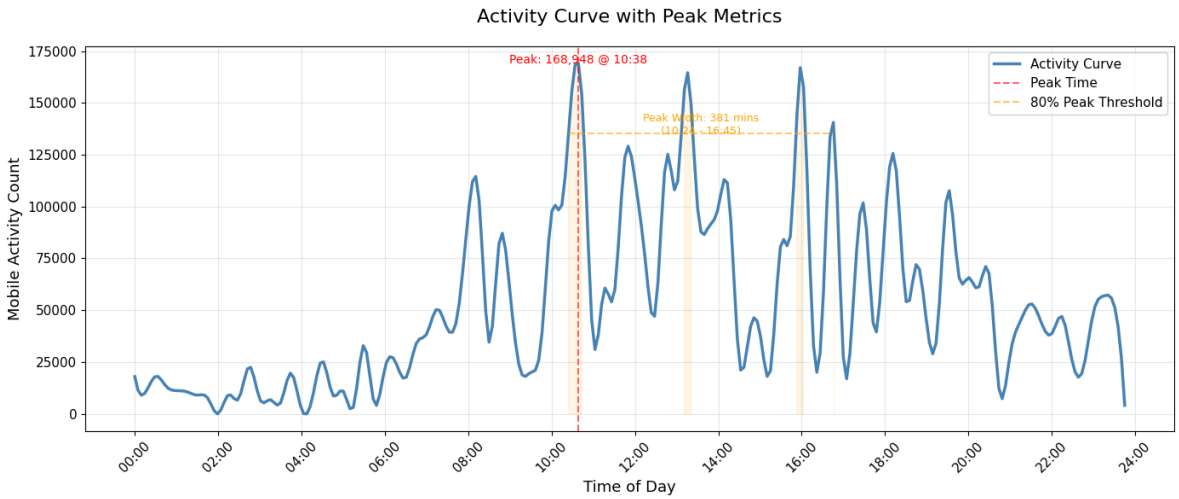

Figure 2. Activity Curve-Weekday Colombo

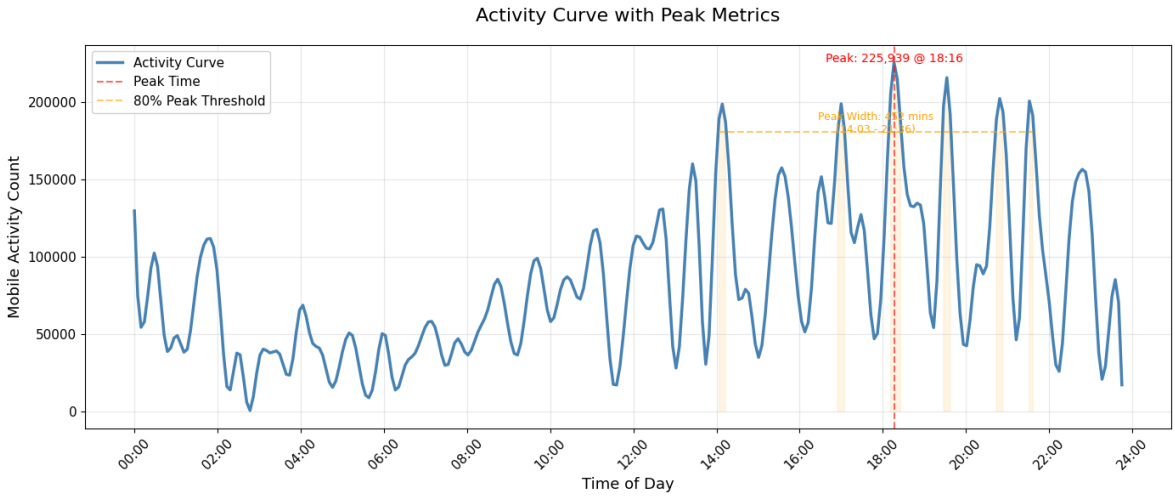

Figure 2. Activity Curve-Weekend Colombo

Comparative analysis across 50 cities reveals distinct temporal mobility signatures, with variations in the timing and frequency of peak activity. Cities with high informal economic activity display prolonged daytime peaks, while others show sharp morning and evening transitions. These insights enable categorisation of urban centres based on their temporal mobility profiles.

Preliminary efforts to associate mobility signatures with land-use types (e.g., commercial, residential, mixed-use) suggest potential for further spatial analysis. However, deeper investigation into spatial overlays and ground-truth validation is necessary to substantiate these correlations.

4. CONCLUSION

This study demonstrates the viability of using high resolution temporal population density data derived from MPD to decode urban mobility dynamics. The proposed framework enables analysis and comparison of mobility across 50 cities without the need for transport mode specific data.

The 15-minute temporal resolution captures subtle mobility fluctuations, offering a nuanced view of urban life that supports more responsive transport planning. Moreover, the identification of city-specific mobility signatures lays the groundwork for adaptive transport interventions.

For urban planners and policymakers, these findings offer a cost-effective and scalable tool to inform infrastructure design, optimise transit scheduling, and prioritise investment. Future work should extend the temporal scope, integrate detailed land-use classifications, and include spatial validation to further strengthen policy applications.

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PREDICTING TRAFFIC DELAYS CAUSED BY LANE-CHANGING BEHAVIOR ON MULTILANE HIGHWAYS

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ABSTRACT - This study examines the impact of lane change maneuvers on the time delay experienced by target lane following vehicles (TLFVs) in mixed traffic using machine learning. Based on the HighD dataset which includes naturalistic trajectory data from German highways over 3500 valid interactions involving both cars and trucks were extracted. Key features such as vehicle types, velocities, steering angle, minimum gap, traffic density, and lane change duration were considered. Time delay was computed by comparing predicted and actual TLFV trajectories during each maneuver. Two ensemble models, Random Forest, and XGBoost were developed and compared with a baseline Linear regression model. XGBoost yielded the highest performance ($R^2 = 0.87$, RMSE = 1.33 s), with Minimum gap and LC duration identified as the most influential features. Truck-involved Lane changes led to consistently higher delays, with average time delay increasing by 14–21% in mixed vehicle scenarios compared to car–car interactions. The findings offer practical value for traffic management and autonomous vehicle systems, especially in the context of developing countries with heterogeneous traffic.

Keywords: Lane-changing; Traffic delay; Machine learning; HighD dataset; Predictive modeling

1. INTRODUCTION

Lane-changing behavior is a critical component of traffic flow dynamics, often causing disruptions that impact safety, efficiency, and overall road capacity. Numerous studies have examined the implications of lane changes, with research by Chen et al. (2020) indicating that such maneuvers account for 4–10% of traffic incidents. Nagatani & Yonekura (2014) further highlighted the potential for rear-end and side collisions during lane changes, emphasizing their role in initiating crash chains. While existing literature, including works by Yang et al. (2021) and Hou et al. (2024), have explored the influence of lane-changing on traffic flow and safety, most studies have focused on general effects or congested conditions. However, under free and moderate flow conditions, the specific time delay imposed on TLFVs remains underexplored. This research addresses this gap by quantifying the delay experienced by TLFVs during adjacent lane changes under free and moderately congested (<20 veh/km) highway conditions. In contrast to earlier studies, this work adopts machine learning methods to model complex non-linear interactions, offering new insights into delay mechanisms and enabling improved real-time traffic management strategies.

2. METHODS

2.1 Data Source and Preprocessing

The HighD dataset is a high-resolution naturalistic vehicle trajectory dataset recorded on six structurally similar rural highway sections near Cologne, Germany. Captured using drones over 16.5 hours of daylight traffic, it includes nearly 10,000 documented lane-change events under free to moderately congested conditions. The dataset features both passenger cars and trucks, with clear vehicle type labeling.

Data pre-processing involved identifying and extracting valid lane-changing events. Lane changes were initially detected by identifying changes in each vehicle's lane ID, which updates when half of the vehicle's width enters a new lane. To capture the full maneuver, the trajectory data were further examined to identify the true start marked by the onset of lateral movement and the endpoint, defined by the vehicle's stabilization in the new lane. Events with missing data, incomplete maneuver, or exiting the observation area were excluded. Delay outliers were removed using the interquartile range method. This process yielded 3651 high-quality lane change scenarios suitable for delay prediction modeling.

2.2 Delay Estimation

The time delay experienced by the TLFV was estimated by comparing its actual trajectory to a predicted trajectory assuming no lane change occurred. The start of the lane change was defined as the onset of lateral movement by the lane-changing vehicle (LCV), with a 0.5-second lead time included to account for driver reaction. Within this window, the TLFV was assumed to travel at uniform velocity or acceleration, and a linear trend was fitted to its velocity data to forecast its expected motion. The predicted distance the TLFV would have traveled by the end of the lane change was then calculated and compared to the actual distance covered. The difference between these values represented the distance loss due to the lane change. This loss was converted into a time delay by dividing it by the TLFV's average speed before the maneuver.

2.3 Model Development

Three machine learning models were developed and compared to predict the delay.

- Linear Regression was used as a baseline model, assuming additive and linear relationships between features and delay, with coefficient analysis used to interpret feature influence.
- Random Forest Regression, an ensemble method based on multiple decision trees, was employed to capture complex interactions and non-linear patterns.
- XGBoost Regression, a gradient boosting algorithm known for its high accuracy and efficiency, was also implemented; it builds trees sequentially.

The dataset was split into training (80%) and testing (20%) sets using stratified sampling to preserve the vehicle type distribution. Features were scaled where appropriate to improve model stability.

3. RESULTS AND DISCUSSION

3.1 Model performance

Table 1: Performance of models

Model	RMSE (s)	MAE (s)	R^2
Linear Regression	2.37	1.37	0.60
Random Forest Regression	1.44	0.72	0.82
XGBoost Regression	1.33	0.59	0.87

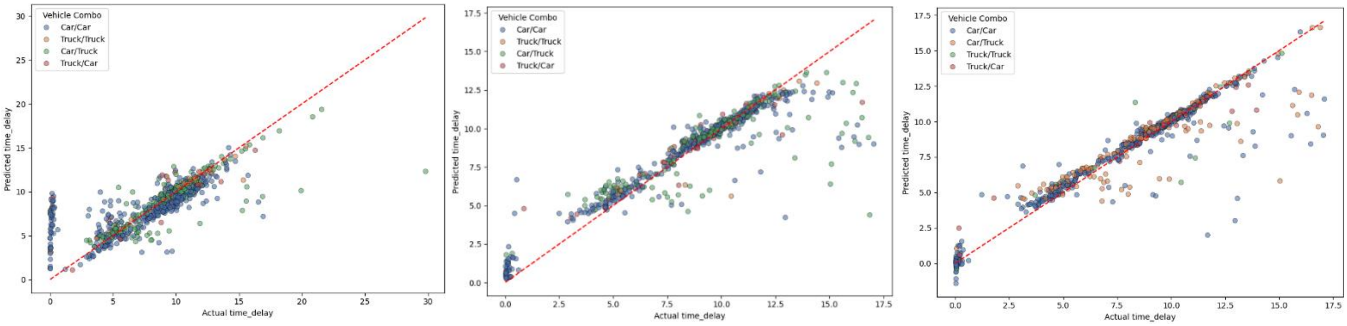

Figure 1: Predicted vs. Actual time delay by Linear Regression, RFR and XGBoost models respectively

Linear Regression showed the poorest performance, with the highest error and lowest R^2, highlighting its inability to capture complex patterns in the data. Scatter plots of predicted vs. actual delays showed in Figure 1 revealed wide dispersion, especially for higher delays and certain vehicle types. Random Forest improved accuracy noticeably, with reduced error and better alignment in predictions. XGBoost performed the best, demonstrating tight clustering in predicted vs. actual plots across all vehicle combinations.

3.2 Discussion

Table 2: Average time delay of different vehicle types

LCV / TLFV Combination	Actual average Delay (s)	Average delay predicted by LR (s)	Average delay predicted by RFR (s)	Average delay predicted by XGB (s)
Car / Car	7.95	7.84	7.86	7.83
Car / Truck	9.25	9.02	9.18	9.23
Truck / Car	9.04	9.16	8.79	8.90
Truck / Truck	9.59	10.22	9.36	9.38

These results show that vehicle type combinations significantly impact TLFV delay during lane changes. Car/car interactions resulted in the lowest delays, while truck/truck combinations caused the highest average delay. Truck-involved maneuvers increased delay by 14–21% compared to car/car cases, highlighting the disruptive nature of heavy vehicles.

4. CONCLUSION

This study showed that machine learning models, especially ensemble methods like Random Forest and XGBoost, significantly high accuracy in predicting traffic delays caused by lane-changing maneuvers. XGBoost delivered the highest accuracy, closely followed by Random Forest, capturing complex non-linear relationships. Minimum gap and lane change duration emerged as the most influential features in all models. Delay varied across vehicle type combinations, with car/car interactions producing the lowest delays, while truck/truck interactions caused the highest, reflecting the challenges posed by larger vehicles and greater gap requirements. These results emphasize the need to account for vehicle types, spatial gaps, and maneuver durations in traffic delay modeling.

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EVALUATING PEDESTRIAN BEHAVIORS AND SAFETY RISKS AT UNSIGNALIZED MID-BLOCK CROSSINGS IN COLOMBO

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ABSTRACT

Fast changes of urbanization have increased pedestrian movements, with pedestrians accounting for 21% of global fatalities, as reported by WHO in 2023. In Sri Lanka, pedestrian fatalities contribute to 40% of road deaths, escalating to 70% in Colombo[1]. This study aims to evaluate pedestrian behaviors and safety risks at unsignalized mid-block crossings in Colombo. Previous studies have focused on some special pedestrian behaviors. But this research analyzes many behaviors. Also, compares pedestrian behaviors at unsignalized mid-block crossings with signalized crossings. Mixed methods were used to achieve these goals. Pedestrian' accident data was first extracted from between Colombo-Galle Road, like Wellawatte, Dehiwala, Mount Lavinia, and Moratuwa, using records from the road traffic police division. This study was conducted by identifying Moratuwa as an additional accident location through this dataset and capturing video footage of five pedestrian crossings there (4 unsignalized, 1 signalized - this is included for comparison.). To achieve objectives, analytical tools such as thematic, descriptive, cross-tabulation, risk assessment, and chi-square tests were used. Most pedestrians don't pay attention to the oncoming vehicle. It is a major safety issue. This research findings will contribute to the development of more effective pedestrian safety measures and urban planning strategies design to the Sri Lankan situation.

Keywords: Pedestrian Safety; Mid-Block Crossings; Un-signalized; Pedestrian Behaviors and Risks

1. INTRODUCTION

Globally, pedestrian safety is still an important issue because urban areas are particularly at risk due to the rise in traffic. Midblock crosswalks facilitate crossings to places that people want to go[2]. Pedestrians account for 21% of global road traffic fatalities, making them one of the most vulnerable groups on the roads[3]. The distribution of pedestrian fatalities varies significantly by region, with the Western Pacific Region reporting the highest percentage of pedestrian deaths[3]. According to the World Health Organization (WHO), Sri Lanka belongs to the Southeast Asia Region[4]. In Sri Lanka, the number of accidents, deaths, and injuries involving pedestrians has been steadily increasing over the past three years[5]. Pedestrian fatalities contribute to 40% of road deaths, escalating to 70% in Colombo[1]. According to the Sri Lanka police, about 3,165 pedestrian-motor crashes occurred in 2020 due to failure to use marked pedestrian crossings in Sri Lanka. In 2023, there were 110 pedestrian accidents at pedestrian crossings in Colombo[6]. Previous studies on pedestrian safety at midblock crossings often focus on some factors like mobile phone usage, pedestrian characteristics, land use, location, age, time, carrying things, and speed of pedestrians[7], [8], [9]. However, most research doesn't analyze many behaviors. This study considers many behaviors.

In Colombo, population density and annual deaths on pedestrian crossings have gradually increased over the years[10], [11]. So, Evaluating Pedestrian Behaviors and Safety Risks at Unsignalized Mid-block Crossings in Colombo is important to pedestrians' safety in the future.

This study aims to analyze pedestrian behaviors at unsignalized mid-block crossings in Colombo. Additionally, the research attempts to identify the safety risks associated with pedestrian movement at these crossings. Furthermore, this study compares pedestrian behaviors at unsignalized mid-block crossings with signalized crossings. Understanding these behaviors is important for assessing pedestrian safety.

2. MATERIALS AND METHODS

2.1 Study Area

Colombo district was selected as the study area because it has a high population density and is the area with the highest road accident rate among Sri Lankan police divisions [6], [10]. Colombo District is in the southwest of Sri Lanka and has an area of 699 square kilometers. Special attention is being paid to the Colombo-Galle Road, which has traffic congestion. In this, secondary data was collected in Wellawatte, Dehiwala, Mount Lavinia, and Moratuwa.

2.2 Site selection

Based on the analysis of pedestrian accident data from 4 locations within the study area, the location with the highest number of pedestrian accidents was selected as the primary study site. Identified Moratuwa in this manner. Land size was not considered in the selection process. The selected site includes the following five specific sites of locations in this research, Katubedda Keells, Rawathawatta Junction, Karadana Traders Vegetable Market, Rawathawatta NDB Bank, and the Moratuwa University signalized crossing (used for comparison purposes).

2.3 Data collection

Both primary and secondary data sources were used in the data collecting process for this study. A mixed approach provides the basis of the research's overall strategy. Therefore, to carry out this research, both qualitative and quantitative data are needed.

- **Primary data sources**

Video-based observations of pedestrian behavior at signalized and unsignalized mid-block crossings were used to collect primary data. Here, Qualitative data aims to identify unsafe behaviors by analyzing pedestrian decision making patterns and behaviors at real locations. Quantitative data includes counting the number of people crossing at different times, locations and assessing the level of compliance with traffic rules. Here, hand-written notes taken directly at site locations and Excel help to extract the data.

- **Secondary data sources**

Secondary data were collected to build the conceptual framework and support the literature review. This included qualitative data from online resources such as WHO reports and academic literature, as well as quantitative data from city traffic police station records, Sri Lanka Police Division statistics, and location-specific traffic police datasets. These data helped to gather data about pedestrian accidents and to select the study area and site selection for the study.

2.4 Data Analysis

Data was analyzed using Excel software. A total of approximately 700 pedestrian crossing occurrences were analyzed, collected through systematic observations at four unsignalized mid-block crossings and one signalized crossing in the Moratuwa area. The primary data were collected by observing behavioral patterns such as use of mobile phones, umbrella usage, carrying things, use of crossings, walking or running, walking speed, crossing alone or in groups, and whether pedestrians looked for oncoming vehicles before crossing. Quantitative data were analyzed using descriptive statistics, cross-tabulations, risk assessment, and chi-square tests, while qualitative insights were supported by thematic work analysis.

3. RESULTS AND DISCUSSION

The analysis revealed that pedestrian behavior at unsignalized mid-block crossings in Colombo is often affected by distractions, randomness, and group dynamics, which contribute to increased safety risks.

The thematic analysis identified several risky behaviors that are prevalent in unsignalized areas, including group crossings, mobile phone use, and disregard for traffic. According to descriptive statistics, 42% of pedestrians did not look for oncoming vehicles, and 37% of them used mobile phones. While females preferred to cross in groups, men tended to walk faster and cross alone. Compared to unsignalized pedestrian crossings. Average walking speed at unsignalized crossings was higher (1.4 m/s) compared to the signalized site (1.2 m/s), with longer crossing times observed at signalized sites. A risk assessment matrix categorizes behaviors into low, medium, and high risk. Notably, 28% of all behaviors were classified as high-risk, mostly at unsignalized crossings due to distractions and lack of vehicle awareness. Finally, chi-square analysis showed significant associations ($p < 0.05$) between mobile phone use, carrying objects, and reduced visual attention. These are indicating higher vulnerability for distracted pedestrians.

4. CONCLUSION

The results showed an elevated rate of unsafe behaviors, such as mobile phone use and lack of visual attention, not looking for incoming vehicles, not using the crossings, and crossing in big groups without using enough safety. Because there were no effective traffic control measures at unsignalized crossings, these behaviors were frequently observed there. Chi-square analysis and descriptive statistics revealed strong correlations between various behaviors that raise safety issues, such using a mobile phone and not focusing enough attention to the situation that. Younger pedestrians are more likely to be distracted and have risky crossing practices, according to thematic research. Compared to signalized locations, the presence of signals reduced risk and had a beneficial impact on pedestrian behavior. Specifically, in high level risk urban areas, it is recommended that public education campaigns be implemented to provide safe crossing techniques to pedestrians, given these findings. Furthermore, it is expected that these risks can be reduced by improving infrastructure such as improved road signs, and pedestrian safety islands placed in the mid-block crossings.

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INTERVENTIONS TO MINIMIZE TRAFFIC ACCIDENTS IN SRI LANKA

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ABSTRACT Traffic accidents in Sri Lanka significantly impact the nation's development, economy, and public health. This research includes a comprehensive investigation focused on analyzing accident patterns, identifying factors contributing to accidents, and evaluating the effectiveness of international interventions adopted in Sri Lanka to reduce traffic accidents. The study analyzes data from Sri Lanka's traffic headquarters to identify temporal variations in road accidents. It thoroughly examines the causes of traffic accidents, emphasizing different vehicle categories to identify the primary contributors. Additionally, the study assesses the feasibility of implementing international interventions and strategies within the specific context of Sri Lanka. This assessment is carried out using a SWOT analysis in collaboration with experts from the country's transportation and law enforcement sectors. The examination of annual accident data reveals a declining trend in crashes over the study period. Vehicle type-specific accidents underscore the necessity for tailored measures, with motorcycles consistently exhibiting the highest incidence of accidents, requiring prompt intervention. Specific causes of accidents within each vehicle category were identified, and ultimately, this research recommends interventions applicable to each vehicle category to enhance road safety and reduce fatalities, injuries, and property damage, thereby contributing to improved public health, reduced economic losses, and overall societal well-being.

Keywords: Traffic accidents; Accident trends; Contributing factors; International interventions; SWOT analysis

1. INTRODUCTION

Road traffic injuries are a significant cause of morbidity and mortality, ranking among the top 10 global causes of death and accounting for over 1.3 million fatalities annually. These accidents are the number one killer of people between the ages of 5 and 29 [1]. The risk of traffic accidents is higher for vulnerable road users in countries like Sri Lanka, and traffic accidents play a significant role in the country's development path. According to [2], Sri Lanka has an annual crash death rate of about 3000 deaths, which is twice the average rate of high-income countries and five times that of best-performing countries. Therefore, taking measures to minimize accidents in Sri Lanka is essential. It is important to have strict law enforcement, improved road infrastructure, better public awareness and education, and the latest technology [3]. This highlights the importance of adopting interventions to minimize accidents. Many systematic reviews have attempted to identify effective interventions. Based on a systematic review, eight types of interventions have been identified: Driver Education, Enforcement, Legislation, Mixed interventions, Public Awareness, Structural improvements, Vehicle design improvement, and other interventions [4]. Identifying appropriate interventions in Sri Lanka can help minimize future accidents. Although many previous studies have focused on accident trends in Sri Lanka, studies focusing on finding suitable interventions for Sri Lankan traffic accident profiles are rare, to the author's knowledge. This study thus attempts to fill this research gap by finding suitable interventions to minimize the most frequent traffic accidents in Sri Lanka. The research objectives are:

a. Identify the accident patterns and contributing factors for traffic accidents involving each vehicle category in Sri Lanka. b. Explore the potentially effective strategies to reduce accidents in Sri Lanka. c. Suggest measures to reduce accidents involving various types of vehicles.

2. METHODOLOGY

The Sri Lanka Police maintains a database of traffic accidents based on details reported to individual police stations all over Sri Lanka. A summary of accident data from 2016 to 2022 was analyzed to identify the key accident patterns and factors contributing to traffic accidents for each vehicle category through descriptive statistics. A set of effective accident reduction interventions applicable to Sri Lanka was identified and proposed through a comprehensive literature review by the research team, followed by an expert opinion survey. A SWOT analysis identifying the Strengths, Weaknesses, Opportunities, and Threats associated with implementing each intervention was conducted by two research team members. The gaps in this SWOT analysis were further refined based on the feedback from two external experts experienced in accident reduction. Afterward, an expert opinion survey was conducted to verify the effectiveness of the proposed interventions in Sri Lanka and to assess the accuracy of the SWOT analysis through structured questionnaires. Accordingly, 15 experts from RDA/PRDA representing the road infrastructure sector and 15 Sri Lankan police officers representing law enforcement voluntarily participated in the survey. Based on their expert opinions, 16 interventions were proposed for adoption. Among these, appropriate interventions for high-risk vehicle categories were suggested based on each vehicle category's top five causes of accidents.

3. RESULTS AND DISCUSSION

a. Annual road accident trends in Sri Lanka and accident causes

The accidents during the study period show an overall declining trend that began with an average drop from 2016 to 2018, followed by a rapid decrease from 2019 to 2020, and concluded with a minor reduction from 2021 to 2022. An overall declining trend has been observed globally over the past decade. According to [5], global deaths from vehicular crashes dropped by 5% between 2010 and 2021, whereas South Asian countries experienced a 2% decline. The authors noted that COVID-19 significantly impacted crashes and related injuries [6]. The second phase of rapid decline can be attributed to COVID-19, where the number of accidents in 2020 was reduced by 22.1% compared to 2019.

Recent data covering six years indicated that motorcycles were associated with the highest number of accidents, accounting for 30.4% of total accidents and 41% of fatal accidents. It emphasizes the need for targeted interventions and educational campaigns to address motorcyclists' unique challenges. Three-wheelers are the second most vulnerable vehicle group to accidents, contributing to 17.3% of total accidents. The third and fourth highest accident percentages are from the category of cars and dual-function vehicles, while the fifth category is lorries. When considering the buses, private buses account for higher accident numbers compared to government buses. As per the police records, hit-and-run incidents also indicate a notable level of accidents, and it specifies the need for enhanced law enforcement measures, such as increased surveillance, stricter penalties, or public awareness campaigns to discourage such behavior since hit-and-run incidents expose pedestrians, cyclists, and motorcyclists to increased susceptibility to traffic accidents [7]. An empirical study done in China revealed that the ratio between serious and minor crashes is 1:1.32 [8]. For this study Major Crash: Minor Crash ratio stood at 1:1.93 for total accidents, indicating nearly a similar trend.

The researchers identified the top five causes of accidents based on the dataset. In terms of total accidents, the leading five causes were overtaking across the white line, riding without helmets, malfunctioning vehicle lights, traffic violations, and driving without a valid license or insurance certificate. Motorcycles are responsible for a significant number of overtaking incidents, accounting for 41.2% of these instances. Driving above speed limits increases the risk of accidents due to reduced reaction time and aggravates the severity of resulting collisions.

b. Effective interventions in the Sri Lankan accident context

Through a thorough literature survey, 16 internationally practiced interventions were identified. Evidence of potential applications based on literature and previous adoption, implementation challenges, and advantages was filed for each intervention, and then it was investigated by the experts'

survey (Annex 1). Random road inspections by police were the intervention that was identified with the highest frequency. This is a human-based intervention that can help prevent accidents of all vehicle categories. SWOT revealed that it may improve overall safety as well as the safety of all users. Educational interventions included road safety campaigns, mass media campaigns, post-licensure driver education, and school-based driver education, which focuses on education at various stages of driver education in different forms. Regarding weaknesses and strengths, campaign fatigue, public resistance, resource constraints, and sustainability challenges have been identified. According to the SWOT analysis, although public resistance and misinterpretation issues may arise, interventions such as the installation of red-light cameras, photo radar, and speed cameras can be credible for people. At the next level, the three forms of alcohol testing have been identified, and they can contribute to minimizing accidents with three-wheelers and bicycles. Electronic message boards have also been found to be effective for most of the vehicles considered. There may be challenges to installing them. A previous study [3] has highlighted the importance of improving road infrastructure, education, and campaigns, and using technology to minimize accidents in Sri Lanka.

4. CONCLUSION

This study attempted to propose a set of interventions to minimize accidents in Sri Lanka by identifying potential interventions and verifying their applicability through expert opinions. The study identified key trends depicted through road accidents, their severity levels, high-risk vehicle categories, and accident causes. This research provided a path for a safer and more secure road environment, highlighting the need for evidence-based approaches in addressing the complexities of traffic accidents.

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Annex 1: Expert opinion on the Effectiveness of interventions and Strengths, Weaknesses, Opportunities, and Threats of each intervention

Intervention	Level of agreement on effectiveness (%)			SWOT categories/ aspects (S – Strength, W – Weakness, O – Opportunities, T – Threats)		Level of agreement as a S/W/O/T (%)			Overall acceptability
	RDA	Police	Overall			RDA	Police	Overall	
Installing a red-light camera	77	93	85	S	Reduces red light violations	81	93	87	Y
					Enhances intersection safety	84	83	83	Y
				W	Initial high installation cost	81	83	82	Y
					Possible privacy concerns	52	0	26	N
				O	Improved intersection safety	84	90	87	Y
				T	Public resistance	42	7	24	N
					Legal challenges	45	3	24	N
Road Safety Campaigns	94	100	97	S	Raises awareness of road safety	100	97	99	Y
					Influences positive behaviour changes	94	60	77	Y
				W	Requires continuous funding and support	74	70	72	Y
					May take time to see the measurable impact	74	23	49	N
				O	Behaviour changes in road users	87	80	84	Y
				T	Campaign fatigue	55	7	31	N
					Resistance from targeted groups	35	3	19	N
Mass Media Campaigns	90	97	93	S	Wide reach and influence	97	53	75	Y
					Reinforces road safety messaging	97	90	93	Y
				W	Can be costly	71	77	74	Y
				O	Increased awareness and behaviour change	94	90	92	Y
				T	Overexposure and desensitization	45	3	24	N
					Difficulty in measuring effectiveness	58	0	29	N
Converting Intersections to Roundabouts	32	47	39	S	Improved traffic flow and safety	65	40	53	Y
				W	High initial implementation costs	74	93	84	Y
				O	Reduced intersection accidents	68	80	74	Y
				T	Public resistance	52	10	31	N
Post-license driver education	87	97	92	S	Enhances driving skills and knowledge	100	90	95	Y
					Targets high-risk drivers	97	37	67	Y
				W	Limited participation and accessibility	81	70	75	Y
				O	Safer and more responsible drivers	94	90	92	Y
				T	Resource constraints	81	63	72	Y
					Sustaining long-term impact	81	0	40	N
School-based driver education	94	93	94	S	Early road safety education	100	57	79	Y
					Targets young and novice drivers	100	97	99	Y
				W	Limited curriculum and resources	61	50	56	Y
				O	Establishes safe driving habits	97	90	93	Y
				T	Varying effectiveness among students	61	13	37	N

					Resistance from schools and parents	29	0	15	N
Photo Radar	87	97	92	S	Automatic enforcement	90	83	87	Y
					Reduces speeding incidents	90	93	92	Y
				W	Public perception and opposition	65	30	47	N
				O	Discourages speeding violations	90	73	82	Y
				T	Legal challenges	55	10	32	N
					Misinterpretation and errors	68	13	40	N
Random road inspection by police	81	93	87	S	Enhances overall road safety	90	83	87	Y
				W	Potential traffic congestion	84	83	83	Y
					Resistance from motorists	84	67	75	Y
				O	Improved all road user's safety	84	73	78	Y
				T	Negative impact on emergency response times	61	17	39	N
Visual changes	87	90	89	S	Enhances road visibility	100	87	94	Y
					Increases road user awareness	100	83	92	Y
				W	Costs associated with road modifications	74	73	74	Y
				O	Improved driver awareness	100	90	95	Y
				T	Maintenance and sustainability challenges	94	70	82	Y
					Limited effectiveness in adverse weather conditions	61	70	66	Y
Redistributing traffic	55	87	71	S	Slows down vehicle speeds	94	97	95	Y
					Increases pedestrian safety	97	77	87	Y
				W	Potential resistance from drivers	71	57	64	Y
				O	Reduced severity of accidents	94	80	87	Y
				T	Inadequate enforcement and compliance	84	60	72	Y
Alcohol testing									
Alcohol testing Random Breath Testing	87	93	90	S	Deters drunk driving incidents	100	97	100	Y
					Enhances road safety	97	73	85	Y
				W	Requires significant enforcement efforts	94	73	83	Y
Alcohol testing Selective Breath Testing	71	93	82	O	Reduces alcohol-related accidents	94	90	92	Y
				T	Limited resources and staff	77	77	77	Y
Alcohol testing Sobriety Checkpoints	74	93	84		Public perception and opposition	61	7	34	N
Infrastructure solutions Electronic Message Boards	68	97	83	S	Improves road safety	94	93	93	Y
					Encourages appropriate speeds	97	70	84	Y
				W	High implementation and maintenance costs	84	77	80	Y
				O	Enhanced traffic management	90	90	90	Y
				T	Public resistance	68	0	34	N
					Challenges in retrofitting existing roads	84	67	75	Y
Vision screening of older drivers	81	97	81	S	Enhanced Road Safety	87	83	85	Y
				W	Limited Scope	84	10	47	N
					Resource Intensive	87	73	80	Y
					Accessibility Challenges	94	7	50	Y
				O	Technology Advancements	90	30	60	Y
					Public Awareness Campaigns	90	40	65	Y
				T	Privacy Concerns	74	3	39	N
					Opposition from Older Drivers	68	37	52	Y

Installing Speed cameras	94	97	95	S	Reduces speed-related accidents	87	93	90	Y
					Enhances overall road safety	90	83	87	Y
				W	Potential traffic congestion	84	83	83	Y
					Resistance from motorists	84	67	75	Y
				O	Improved safety of all users	84	73	78	Y
				T	Inadequate driver compliance	81	67	74	Y

Legend

Interventions		**SWOT aspects**		**Acceptability**
0- 25%	Not effective at all	0- 25%	Not agree at all as a S/W/O/T	Y
25-50%	Not effective	25-50%	Not agree as a S/W/O/T	Yes
50-75%	Less effective	50-75%	Agree as a S/W/O/T	N
75-100%	Effective	75-100%	Fully agree as a S/W/O/T	No

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ECONOMICAL APPROACH OF CONGESTION ALLEVIATION ON A NATIONAL SUBURBAN HIGHWAY AT AN INTERNATIONAL SCHOOL FRONTAGE

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ABSTRACT - Traffic congestion around educational institutions along suburban highways presents significant challenges, including prolonged travel times, traffic conflicts, and compromised road safety. This study examines an international college along Pannipitiya – Battaramulla (B47) Road, Sri Lanka, where congestion arises due to on-street parking, unregulated drop-offs, and inefficient intersections control. Using video-based data collection surveys and traffic simulations (PTV Vissim), the study evaluates traffic conditions and mitigatory measures. Findings show that on-street parking at four lane urban highway, reduces road capacity, while disorganized stoppages and closely spaced junctions increase congestion. High pedestrian demand at crossings near junctions further disrupts traffic flow. Proposed implementations include rearranging parking, restrictions of parking at certain zones, improving junction traffic management, enforcing lane marking controls, restrictions and specifications to turns, and implementing pedestrian controls through cost-effective, data-driven designs. The study confirms that while the main road has sufficient capacity, roadside parking and school activities significantly reduce traffic flow speeds. Public involvement through structured awareness programs are essential for smooth implementation. By integrating scientific traffic analysis with practical solutions, and proposed implementations of design solutions in this research provides a sustainable congestion alleviation strategy for school zones along major highways, improving urban mobility and road safety.

Keywords: Congestion alleviation; On Street Parking Control; Economical benefits; Drop-off and Pick-up; School Traffic

1. INTRODUCTION

Traffic congestion near schools along suburban highways is a growing concern due to increasing urbanization and limited infrastructure. The selected international college along Pannipitiya-Battaramulla Road (174 Bus Route) experiences severe congestion during peak hours (6:30-8:30 A.M and 1:00-3:00 P.M), primarily due to on-street parking, unregulated drop-offs and pick-ups, and conflicting vehicle movements at key junctions at close proximity besides the school entry. Such congestion not only delays commuters but also compromises pedestrian safety, particularly for schoolchildren. This study aims to identify traffic congestion factors, analyze traffic behavior based on the major and inherent traffic issues at the locality by using collected traffic data analysis and simulation modeling, compare improvement options, and develop cost-effective interventions to enhance mobility and safety within the impacted length of the national urban highway segment.

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2. MATERIALS AND METHODS

A structured methodology was followed to evaluate congestion patterns and potential solutions. Data was collected through video-based traffic surveys, analysing traffic volumes, vehicle types, pedestrian movements drop-off and pick-up activities, and parking demand. The recorded data was analysed to identify the major traffic issues, revealing a peak volume of 2229.8 pcu/h/ln towards Battaramulla and 1494.6 pcu/h/ln towards Kottawa. The analysis also highlighted significant impacts caused by commuter activities, particularly the high volume of school-related vehicles and turning movements at nearby junctions. After identifying key issues through a series of traffic analyses, integrated traffic management solutions were proposed and simulated using PTV VISSIM to determine the best combination of solutions for the school frontage. This enabled an in-depth analysis of traffic flow conditions, congestion points, and driver behavior while also dwindled the travel time and overall congestions. The methodology included data collection, traffic flow analysis, including traffic volumes, parking behavior analysis, simulation and modeling, evaluation of proposed solutions, and economic cost-benefit analysis.

3. RESULTS AND DISCUSSION

The simulated model identified critical congestion areas, including on-street parking in front of the school, pedestrian crossing, Dewala Road Junction, and Araliya Uyana Road Junction. Behavioral patterns, which include U-turns, abrupt lane changes, and excessive waiting time at drop-off points, were key contributors to traffic congestion.

3.1 Proposed Solution

The proposed interventions for this congestion include prohibiting on-street parking to reduce maneuvering conflicts and capacity constraints, providing dedicated drop-off and pick-up zones, introducing junction boxes at Dewala and Araliya Uyana Road to reduce delays by giving way contributions, and removing U-turns in front of Dewala Road Junction to prevent traffic conflicts. The detailed design plan shown is in Figure 1.

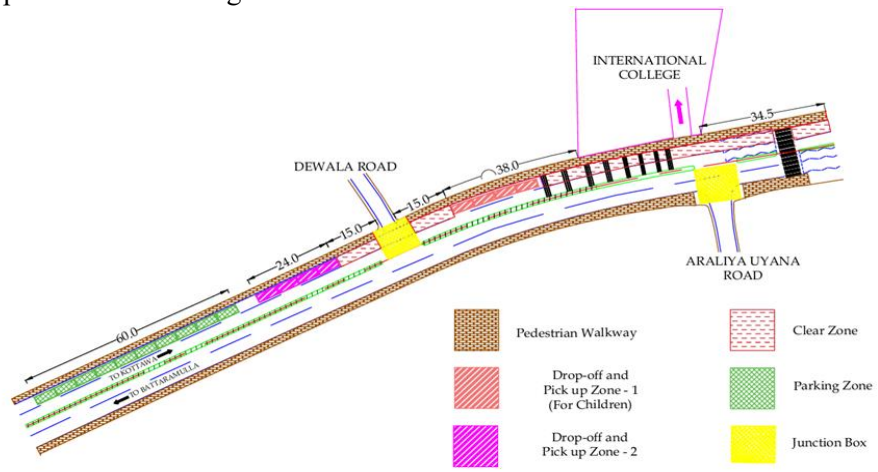

Figure 1. Detailed Plan of Proposed Integrated Traffic Management Solution

3.2 Comparison between before and after condition

Simulation results showed travel speed improvements up to 36 km/h, with a 2-minute reduction in average travel time in the development front over a length of 350 meters as shown in the Figure 2. The cost-benefit analysis indicated a 75% reduction in emissions and significant economic savings as indicated in the following Figure 3. Public involvement through awareness programs is essential for effective implementation.

4. CONCLUSION

This study provides an economical approach to alleviating school-related congestion on Pannipitiya Road, Sri Lanka. By integrating comprehensive traffic analysis with practical interventions, the findings highlight the effectiveness of parking regulations, traffic flow optimizations, and intersection management in reducing congestion. Future studies should explore post-impact evaluations to sustain long-term improvements.

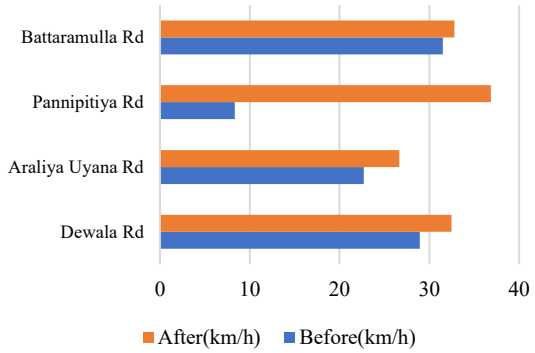

Figure 2. Comparison of average Travel Speed before and after at Impact area

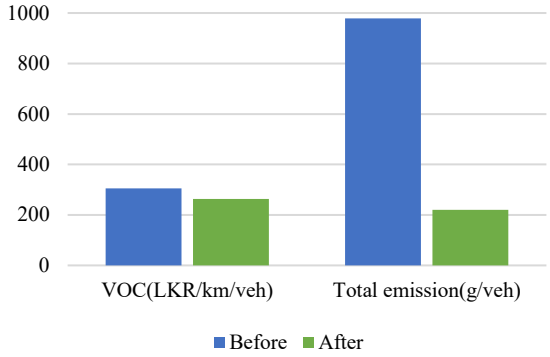

Figure 3. Comparison of Proposed and Observed Economic benefit and Pollution Reduction

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NAVIGATING URBAN CONGESTION: A STRATEGIC APPROACH TO TRAFFIC AND PEDESTRIAN SAFETY AT KOTTAWA JUNCTION

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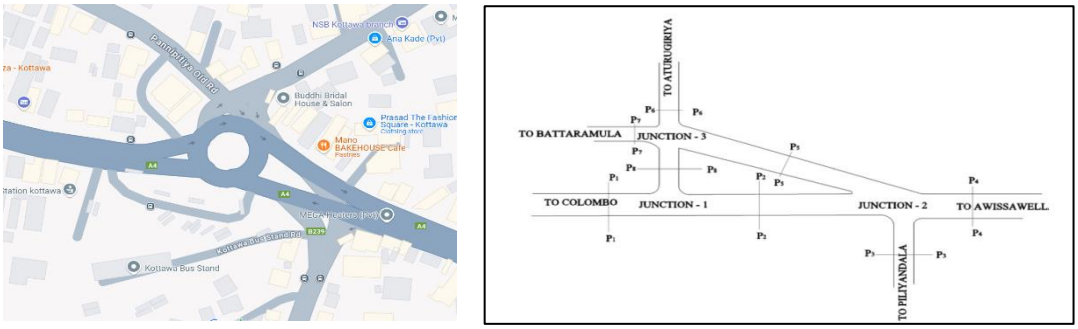
ABSTRACT- Kottawa Junction, a critical five-way intersection in Sri Lanka, experiences severe traffic congestion and pedestrian safety concerns due to unregulated traffic management and insufficient infrastructure. This study investigates the root causes of these issues by analyzing traffic flow patterns, pedestrian behavior, road capacity, and accident data over a three-month period. Capacity analysis, pedestrian movement surveys, and accident data evaluation identify key factors such as over-capacity traffic volumes, improper signaling, and a lack of designated pedestrian pathways. Findings reveal that actual vehicle flows exceed permissible road capacity by up to 30% during peak hours, while pedestrian crossings remain unregulated, posing significant safety risks. This paper proposes a multi-faceted approach, including traffic management system implementation, pedestrian infrastructure improvements, and sustainable transportation promotion. These findings provide actionable insights for urban planners and policymakers, offering a scalable framework to enhance urban mobility and pedestrian safety in similar settings.

Keywords: Infrastructure improvement; traffic flow analysis; traffic congestion; pedestrian safety; urban planning.

1. INTRODUCTION

Kottawa Junction (**Figure 5**) is a major urban intersection in Sri Lanka, connecting five key roads: Colombo Avissawella Road (A4), Piliyandala Road (B239), Athurugiriya Road (B45), Battaramulla Road (B47), and a one-way street. It suffers from severe congestion and pedestrian safety risks due to the lack of an organized traffic management system [1]. Most studies on urban congestion and pedestrian safety in Sri Lanka focus on macro-level transport policies and infrastructure planning without addressing the real-time, intersection-specific issues that impact pedestrian safety and vehicle flow [1]. While various traffic control strategies exist in urban planning literature, very few studies provide localized, data-driven solutions for high-congestion intersections like Kottawa Junction.

This study fills this gap by analyzing real-time data, providing specific congestion reduction strategies, and quantifying the impact of potential solutions. The results offer direct policy guidance for Sri Lanka and other developing urban regions facing similar challenges. By adopting a structured traffic



management approach and integrating pedestrian safety improvements, the study provides a replicable model that can be applied to other urban centers experiencing similar mobility challenges.

Figure 5: Kottawa Junction

Study Objectives

- To assess real-time traffic flow and identify congestion hotspots.
- To analyze pedestrian movement and evaluate safety conditions.
- To evaluate the frequency and causes of accidents in the area.
- To propose intersection-specific, scalable solutions for congestion mitigation and safety improvement.

2. MATERIALS AND METHODS

2.1 Data Collection

The study collected data over three months (July–September 2024) through traffic volume surveys, pedestrian movement tracking, accident report analysis, and capacity assessments [2]. Observation times covered peak (7–9 AM, 5–7 PM) and off-peak (10–12 AM, 2–4 PM) hours. Surveys were conducted from 6:00 AM to 8:00 PM in 1-hour intervals. Vehicle movements were counted per approach and direction. Pedestrian data focused on crossing behavior. Accident data from the Kottawa Police Station were analyzed by type, frequency, and cause.

2.2 Data Analysis

The collected data were analyzed using basic evaluation methods to assess congestion levels, pedestrian movement, and accident occurrences. A capacity analysis was performed by comparing the actual vehicle flow with the allowable road capacity to determine congestion levels. Traffic flow analysis involved assessing peak-hour vehicle movement and identifying bottlenecks caused by unregulated traffic flow. A comparative analysis was conducted between road capacity and traffic flow to highlight the impact of exceeding the designed infrastructure limits. Pedestrian movement data were evaluated by analyzing crossing patterns and pedestrian flow at key locations, while accident analysis focused on identifying common causes and frequency of incidents at pedestrian crossings and intersections.

3 RESULTS AND DISCUSSION

3.1 Capacity Analysis

Capacity analysis compared the actual vehicle flow against the allowable limits, revealing that during peak hours, actual vehicle flow exceeded allowable capacity by up to 30%, leading to significant congestion. Capacity analysis demonstrated that for multi-lane roads, the morning peak-hour vehicle flow reached 1100 vehicles per hour per lane per direction, exceeding the allowable limit of 1000 vehicles per hour per lane per direction [3], while in the evening, the actual vehicle flow surged to 1300 vehicles per hour, worsening congestion. The findings indicate that the existing infrastructure is insufficient to accommodate the increasing traffic demand, leading to severe delays and inefficiencies.

3.2 Traffic Flow Analysis

Traffic flow analysis highlighted the unregulated vehicle flow from five different directions, causing bottlenecks and inefficient space utilization. Traffic flow analysis showed that without a proper control system, confusion and inefficiencies increased, leading to unnecessary delays and chaotic movements. The unregulated vehicle flow contributed to bottlenecks, while the absence of prioritization for buses and emergency vehicles further exacerbated congestion. Introducing traffic signals and road signs could significantly improve traffic distribution and efficiency.

3.3 Comparisons Between Capacity and Traffic Flow Analysis

By comparing capacity analysis and traffic flow analysis, it was evident that the junction's infrastructure was operating beyond its designed limits. The misalignment between actual vehicle flow and allowable road capacity resulted in excessive congestion, delays, and unpredictable traffic patterns. This comparison further highlighted the urgent need for an improved traffic control system to manage the intersection's high traffic volume effectively.

3.4 Pedestrian Analysis

Pedestrian analysis indicated the need for designated crossings, as the highest pedestrian volume reached 3254 crossings in the evening rush hour from 5 PM to 6PM, with significant safety risks. Pedestrian analysis revealed a high volume of foot traffic, particularly during evening peak hours. Despite the high pedestrian flow, the lack of designated pedestrian pathways and crossings posed a significant safety risk. The study's findings suggest that implementing traffic control measures, such as pedestrian signals, underpasses and overpasses, could reduce congestion and improve safety [4].

3.5 Accident Analysis

Accident analysis identified common causes, including improper signal use, excessive vehicle speeds, and pedestrian carelessness. The accident data which were collected from the Kottawa police station showed that most accidents were minor but frequent, primarily occurring at pedestrian crossings and vehicle intersections. The major causes included improper use of signals, increased traffic volume during peak hours, and distractions such as mobile phone use while driving. The study highlights that pedestrian-involved accidents were highest during evening peak hours, necessitating improved pedestrian safety measures [5].

Accident Type	Frequency	Primary Causes
Pedestrian-Involved	25	Careless crossing, high speed
Vehicle Collisions	18	Improper signaling, congestion
Minor Incidents	30	Distractions, signal violations

4. CONCLUSION

The study provides clear evidence that Kottawa Junction is operating well beyond its designed capacity. Peak-hour traffic volumes exceed the allowable limits by up to 30%, while pedestrian movements reach over 3,250 crossings per hour without any designated infrastructure or traffic controls. These figures highlight a significant mismatch between demand and available road capacity, demonstrating the severity of congestion at the junction. The findings strongly justify the inadequacy of the existing infrastructure. The current layout lacks essential elements such as traffic signals, designated pedestrian crossings, and directional flow management. This not only compromises safety but also contributes to inefficient use of road space, increased delays, and heightened accident risk.

Moreover, the absence of regulation has led to systemic inefficiencies, where vehicle and pedestrian movements occur without coordination or prioritization. This results in unpredictable traffic patterns, frequent bottlenecks, and safety conflicts. Addressing these challenges requires an integrated traffic management strategy involving signal coordination, pedestrian infrastructure, and sustainable mobility planning [4]. The solutions proposed in this study offer a practical and scalable approach to improving traffic flow and safety at similar high-density intersections in urban Sri Lanka and other developing cities.

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EVALUATING FORMAL AND INFORMAL PUBLIC TRANSPORT INFORMATION SYSTEMS IN SRI LANKA: A SOCIO-TECHNICAL PERSPECTIVE FOR STRATEGIC IMPROVEMENTS

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ABSTRACT - This study critically evaluates the fragmented structure of Sri Lanka's public transport information systems by assessing both formal and informal platforms through the lenses of Actor-Network Theory (ANT), System Theory, and the Information System Success Model (ISSM). Using a triangulated qualitative approach comprising structured interviews, field observations, and digital content analysis, five key platforms RDMNS, Magiya.lk, Bus Part of Journey LK (FB), WhatsApp Alerts (138/3, 138/4), and the Road Passenger Transport Authority (RPTA) were analyzed across eleven parameters. Findings reveal that formal systems offer administrative stability but lack adaptability and user engagement, while informal systems are agile and participatory but lack integration and sustainability. Key issues identified include weak subsystem integration, poor multilingual and inclusive design, inconsistent real-time responsiveness, and absence of feedback loops. The study advocates a hybrid, user-centric information ecosystem supported by open APIs, community moderation, and inclusive digital frameworks. These insights offer strategic implications for building resilient, equitable, and scalable transport information infrastructure aligned with sustainable urban mobility objectives.

Keywords: Public Transport; Information Systems; Sri Lanka; Socio-Technical; Sustainable Urban Mobility

1. INTRODUCTION

Sri Lanka's public transport sector, especially its bus transit network, remains central to daily mobility. However, information delivery within this domain is fragmented, non-integrated, and varies significantly across formal (e.g., government-run) and informal (e.g., crowd-sourced) platforms. Existing research highlights the potential of real-time systems to reduce waiting time and improve commuter experience, but few studies contextualize these findings within Sri Lanka's unique socio-technical and infrastructural realities. This study addresses that gap through the lens of selected theories and applies them in evaluating multiple platforms to develop strategic planning implications tailored to Sri Lankan conditions.

2. MATERIALS AND METHODS

The study employed multi-stage qualitative research design. A weighted score method identified five platforms across formal and informal categories. Data collection included 84 user surveys, 10 expert and developer interviews, and field observations across Colombo's main terminals. Platforms were evaluated using a framework derived from Actor-Network Theory, System Theory, and ISSM across eleven parameters such as feedback loops, network centralization, actor agency, system quality, and scalability. Narrative and thematic analyses were applied using Braun & Clarke's (2006) six-step coding methodology.

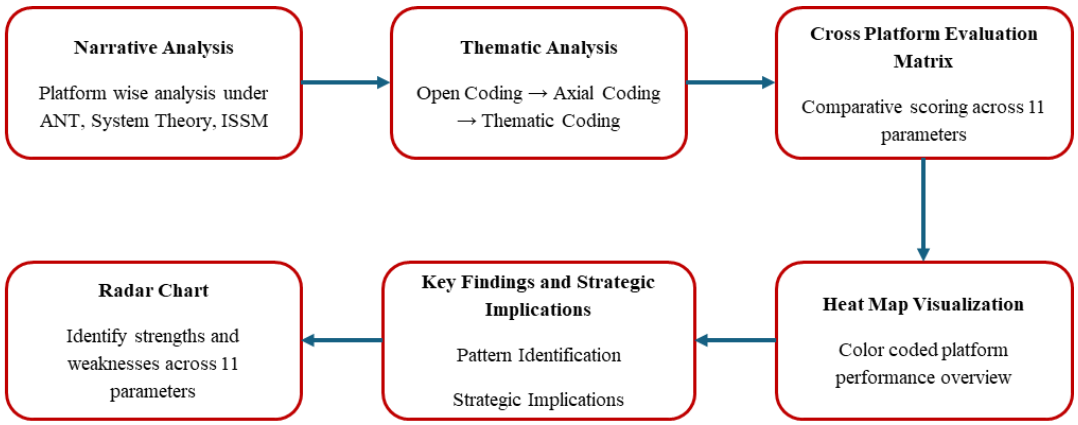

Figure 1. Analysis flow diagram

3. RESULTS AND DISCUSSION

Informal platforms such as WhatsApp Alerts and Facebook communities showed higher levels of user satisfaction and engagement but lacked structural integration and feedback responsiveness. Formal systems like RPTA exhibited strong data administration but failed in adaptability, user agency, and multilingual support. RDMNS and Magiya.lk offered better digital structure but lacked integration with broader systems. Thematic synthesis indicated that real-time capabilities and digital inclusivity remain the weakest areas across all platforms. The radar and heatmap visualizations confirmed the fragmented and unbalanced nature of the ecosystem.

3.1. Cross Platform Heatmap Visualization

Note: Abbreviations used in the Figure 2: NSC - Network Structure and Centralization; AIA - Actor Interaction and Agency; TM - Translation Mechanism; SI - Subsystem Integration; FLA - Feedback Loops and Adaptability; SS - Scalability and Sustainability; SQ - System Quality; IQRTC - Information Quality and Real-Time Capabilities; SEA - Service Effectiveness and Accessibility; USE - User Satisfaction and Engagement; NB - Net Benefits.

Figure 2 illustrates the heatmap visualization of platform performance across eleven evaluation criteria. Informal platforms such as WhatsApp alerts (138/3,138/4) and Bus Part of Journey LK (FB) exhibit strong user engagement (AIA, USE), while formal platforms like RPTA show consistency in structure (NSC, SQ) but lower adaptability and feedback mechanisms (FLA, SI). The heatmap highlights the trade-offs between structural robustness and participatory responsiveness within Sri Lanka's public transport information systems.

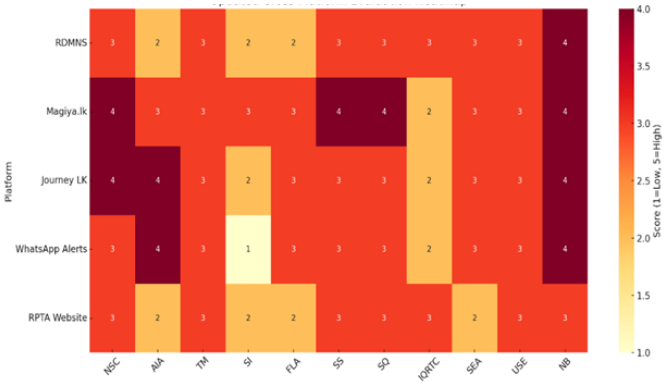

Figure 2. Presents a visual heatmap comparing platform performance across the evaluation criteria.

3.2. Platform Evaluation Radar Chart

Note: Abbreviations used in the Figure 3: NSC - Network Structure and Centralization; AIA - Actor Interaction and Agency; TM - Translation Mechanism; SI - Subsystem Integration; FLA - Feedback Loops and Adaptability; SS - Scalability and Sustainability; SQ - System Quality;

IQRTC - Information Quality and Real-Time Capabilities; SEA - Service Effectiveness and Accessibility; USE - User Satisfaction and Engagement; NB - Net Benefits.

As shown in Figure 3, the radar chart compares platform performance across key socio-technical criteria. Magiya.lk and RDMNS display structural balance with high scores in system quality (SQ) and net benefits (NB), while Bus Part of Journey LK and WhatsApp Alerts (138/3, 138/4) emphasize actor interaction (AIA) and user satisfaction (USE). RPTA demonstrates moderate uniformity but lower adaptability and subsystem integration (SI, FLA) underscoring the varied strengths and limitations of formal and informal systems.

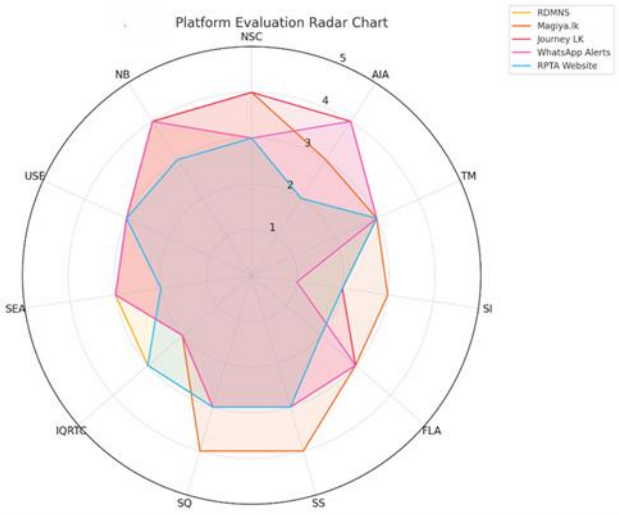

Figure 3. Platform Evaluation Radar Chart

4. CONCLUSION

The study demonstrates that Sri Lanka's public transport information systems are marked by a structural dichotomy: formal platforms exhibit administrative consistency yet lack adaptability and user engagement, whereas informal systems offer real-time responsiveness but face significant challenges in integration, standardization, and long-term sustainability. By applying Actor-Network Theory, System Theory, and the Information System Success Model, the research underscores the necessity of an integrated information system that unifies the institutional robustness of formal mechanisms with the participatory dynamism of community-driven platforms. To enable this transformation, the study proposes strategic implications including hybrid governance models to balance authority and engagement, standardized open API frameworks for system interoperability, IoT-enabled real-time data tracking, inclusive and multilingual user interfaces to bridge digital divides, and sustainable public-private-community partnerships. These targeted measures area critical for cultivating a resilient, inclusive, and commuter-oriented public transport information ecosystem in Sri Lanka.

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DEMAND-SUPPLY GAP ANALYSIS OF SCHOOL TRANSPORTATION IN SRI LANKA : A SOCIO-ECONOMIC AND SERVICE IMPROVEMENT STUDY

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ABSTRACT – Since many socio-economic studies have examined the broad aspects of school transportation, this study focuses on a gap analysis between the demand side and supply side, while providing better solutions to improve the school transportation sector as a better service in Sri Lanka**.** Kandy District was selected as the study area, and data collection was done through distributing questionnaires and conducting in-person interviews. By integrating quantitative and qualitative data from the survey with students, parents, and transport service providers in the Kandy District, the study examines diverse factors on both the demand and supply sides. The collected data were analyzed using analytical tools to determine the significant relationship between transport mode choice and other factors like gender, age, and distance between home and school, to determine the gap between the demand and supply sides, and to provide better solutions for improving travel-to-school in Sri Lanka.

Keywords: School Transportation; Socio-economic analysis; Sri Lanka; Demand side & supply side factors; Improved services

1. INTRODUCTION

Free education for all in Sri Lanka has enabled significant improvements in educational performance and living standards.[1] The student population in Sri Lanka is about 4 million, and it's about 20% of the total population. With those school and student populations, Schools have become major trip generators in urban areas, and school trips may largely contribute to the congestion, particularly during morning peak hours. [2]. In Sri Lanka, the daily commute of students has far-reaching implications on safety, cost, and overall accessibility. [2],[3],[4] Despite the government's commitment to free education, the school transportation system faces inefficiencies due to mismatches between demand and supply. This study addresses a research gap by examining both demand-side (user) and supply-side (provider) perspectives through a socio-economic lens. Using a mixed-method approach, it identifies existing system deficiencies, analyzes demand-supply gaps, and proposes improvements for better service design.

2. MATERIALS AND METHODS

2.1 Questionnaires

The survey evaluated five primary transport modes for Sri Lankan school children: public transport, Sisu Seriya, school bus/van, private vehicle, and walking. The questionnaires are based on key quality parameters identified in the Literature Review, fulfilling the objective of identifying demand-side and supply-side characteristics: availability, punctuality, reliability, accessibility, safety, efficiency, comfort, convenience, and affordability. It included five sections: (1) general user/supplier information (e.g., school details, travel time, costs, fleet capacity), (2) importance ratings of quality parameters (1-5 scale), (3) supplier performance assessment (1-5 scale), (4) mode-specific importance of quality factors, and (5) challenges and future improvements for both users and suppliers.

2.2 Data Collection

To represent Sri Lanka, the Kandy District was chosen as the study area. Data collection was conducted through the distribution of questionnaires and in-person interviews for both the demand side and the supply side. As the sample of the demand side parents and students in four selected schools in Kandy (as a major city), in Pilimathalawa (as a smaller city), and in Hiddaula (as a rural area) were chosen while Central Provincial Transport Service Authority, Sri Lanka Transport Board Depots (Yatinuwara and Kandy South), and private school van/ bus operators chose as school transport service providers in Kandy District in supply side.

3. RESULTS AND DISCUSSION

Microsoft Excel was used for descriptive analysis, while IBM SPSS software was used to examine the significance of such prospective variables.

3.1 Demand Side

According to the analysis under the overall model's share of demand, it was identified that walking, private vehicles, and public buses are more popular than other modes. As Figure 1 illustrates in rural areas, where schools are often close by, walking to school is common. In contrast, city areas tend to use public buses, school vans/buses, or private vehicles.

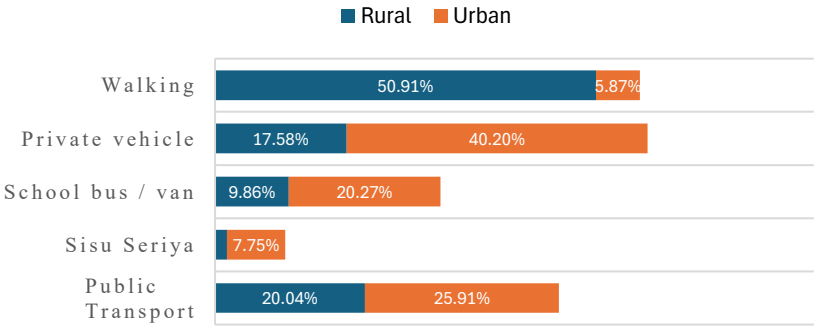

Figure 1. Modal share - Rural vs Urban

As the students get older, both males and females prefer to use public buses. Sisu Seriya is the most affordable mode, whereas private vehicles are the most expensive. No matter what mode they use, users demand factors like availability, punctuality, reliability, accessibility, safety and security, efficiency, comfortability, ease of use, and affordability of these transport modes.

The Chi-Square test and hypothesis testing identified that grade, distance, vehicle ownership, monthly cost, travel time, and travel alone or not are significantly influential for the mode choice.

Table 5. Significance Value Summary

Mode with	Significance value	Influenced or not	Mode with	Significance value	Influenced or not
Gender	0.742	×	Monthly cost	<0.001	✓
Grade	0.023	✓	Travel alone or not	0.001	✓
Distance	<0.001	✓	Travel Time	<0.001	✓
Veh ownership	0.001	✓	Waiting Time	0.560	×

3.2 Supply Side

The supply-side analysis reveals key insights into Sri Lanka's school transportation sector, particularly in the Kandy District. Public bus services like Sisu Seriya face operational challenges, including worker shortages, fleet issues, and unmet demand. Private operators (vans/minibuses) report high satisfaction levels but struggle with financial constraints, irregular payments, and regulatory gaps. A gap analysis between the demand side assessments and supply side perceptions was done, as Table 1, and several gaps were identified that require attention.

3.3 Gap Analysis

Table 2 highlights service gaps by comparing user expectations with actual service quality across three transport modes. The highlighted cells display that Sisu Seriya and public transport show significant

negative gaps in most parameters, indicating poor alignment with student needs. School vans/buses showed better or positive alignment with user expectations**.**

Table 2. Gap Analysis

Attribute	Sisu Seriya	Public Transport	School van/bus
Availability	-1.31	-0.70	0.17
Punctuality	-0.30	-0.20	0.60
Reliability	-0.79	-0.68	0.29
Accessibility	0.19	0.33	1.29
Safety & security	0.19	0.28	1.13
Efficiency	-0.31	-0.72	1.05
Comfortability	0.02	-0.70	1.05
Ease of use	0.02	-0.70	1.05
Affordability	0.19	0.30	-0.69

To bridge this gap, targeted interventions are needed to improve service reliability, expand coverage, and ensure affordability. Strengthening coordination between transport providers, schools, and policymakers will be essential to create a more efficient, safe, and accessible school transportation system that meets the diverse needs of students across all regions.

4. CONCLUSION

This study demonstrates that there are notable discrepancies between supply-side performance and demand-side expectations in Sri Lanka's school transport system, especially for public buses and Sisu Seriya services. A more inclusive, reliable, and student-centered transportation network can only be established by addressing these gaps through focused improvement in service quality, affordability, safety, and regulation. Research is to be further analyzed to assess the significance of such prospective variables and to determine the gap between demand-side requirements and supply-side situations for a better school transport service in Sri Lanka.

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FACTORS AFFECTING DETRIMENTAL BEHAVIORS OF PRIVATE BUS CREW IN PRIVATE BUS TRANSPORTATION IN SRI LANKA

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ABSTRACT
This study investigated the factors contributing to detrimental behaviors among private bus crew in Sri Lanka. Recognizing the critical role of bus crews in public transportation and the historical prevalence of public complaints, the research employed a mixed methodology. Data was gathered from the National Transport Commission annual reports and surveys of bus crew who are responsible for behaviors that have given rise to public complaints at least once of their career journey in recent years. Descriptive analysis was used to analyze demographic background data and exploratory factor analysis was used to identify the factors affecting detrimental behaviors of bus crew of private buses, which was the primary objective of the study. The study revealed four key factors which are 1. Workplace environmental stress, 2. passenger aggression and inadequate training for bus crew, 3. financial strain and lack of facilities. and 4. Competitive operational pressure and crew conduct. The first factor explained the highest proportion of variance (28.819%), followed by the second factor (12.634%), the third factor (11.420%), and the fourth factor (8.548%). The finding aims to guide policy development, establish effective regulations and foster a more efficient and harmonious public transportation system in Sri Lanka.
Keywords: Detrimental behavior, Bus crew, public complaints, Factor analysis, strategies, private bus transportation.

1. INTRODUCTION

Public bus transportation is vital in Sri Lanka, but the behavior of bus crews, particularly conductors, has led to frequent public complaints regarding issues like overcharging, rudeness, and timetable violations. According to the empirical evidence there are number of research found several factors to affected to speed behavior of drivers and one research found misbehavior of bus crew affected the reduce quality of bus transportation in Sri Lanka. though many aspects of bus crew and driver behavior affected to quality of bus transportation have been studied by scholars, yet the factors affected detrimental bus crew behavior of public transportation in Sri Lanka remain unobserved. The research aims to uncover the root causes and underlying factors contributing to this undesirable conduct, specifically analyzing the influence of socio-demographic characteristics on negative behaviors such as overcharging, rudeness, and timetable violations, which are frequently reported through the NTC complaint unit. By examining patterns and trends of major offenses documented in NTC annual reports over the past decade, alongside a focused-on factor analysis of detrimental behaviors of private bus crew members, this study seeks to provide actionable insights for policymakers. Ultimately, the goal is to inform targeted interventions and strategies that can effectively improve the quality, safety, and overall effectiveness of private bus transportation in Sri Lanka.

2. METHODOLOGY

This study employed mixed methods with an exploratory design to identify factors contributing to detrimental bus crew behavior. Primary data was collected through questionnaires distributed to bus crews identified via public complaints who attended National Transport Commission (NTC) sessions. A convenience sampling strategy was used, and the author actively participated in these sessions to administer questionnaires, clarify questions, and gather additional insights through informal interaction. The questionnaire included closed-ended (using a five-point Likert scale to measure agreement on factors) and open-ended questions to collect both structured and in-depth data on demographics, the

nature of complaints, factors influencing behavior, and suggestions for improvement. Secondary data was obtained through document analysis of NTC annual reports to identify trends and patterns in reported detrimental bus crew behavior over past decades. The questionnaire was specifically designed to gather relevant data to meet the study's objectives by surveying bus crew members.

3. RESULTS AND DISCUSSION

Figure 1. "Major 8 offences committed by bus crew in public bus transportation in Sri Lanka (2011-2023)" presents a detailed overview of the percentage of various offences committed by bus crew over the years. The longitudinal data from 2011 to 2023 reveals distinct trends in bus crew behavior. Offenses such as 'charging extra fare or not returning the balance' and 'being discourteous to passengers showed a gradual decline, suggesting the potential influence of fare regulation and public complaint mechanisms. However, offenses such as 'reckless driving' and 'violations of the assigned timetable' have increased in recent years. This pattern may reflect the structural pressures inherent in Sri Lanka's deregulated bus industry, where drivers compete for passengers under time and revenue constraints. These trends underscore the need to evaluate how industry practices, policy enforcement, and training reforms have evolved over this 12-year period—an area not fully addressed in this study but crucial for interpreting these behavioral shifts. Future studies should explore these external factors to better understand what drives improvements or deterioration in specific behaviors over time.

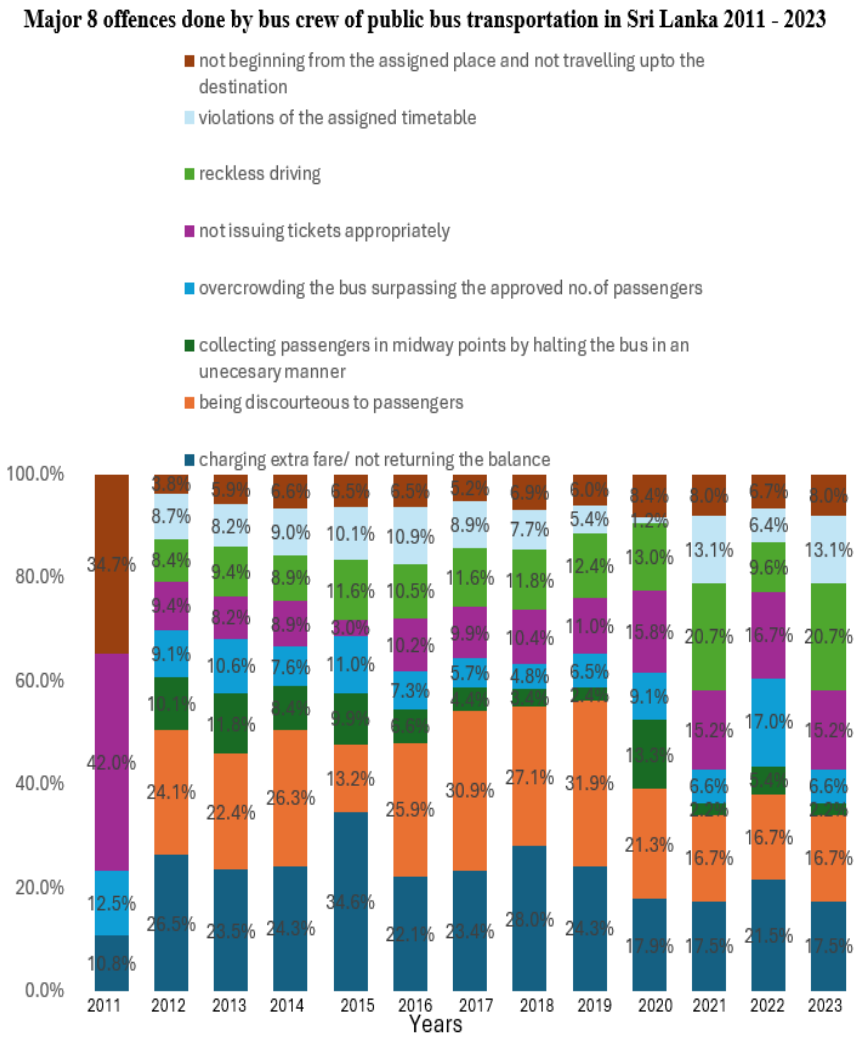

Figure 1. Major 8 offences done by bus crew of private bus 2011 - 2023

Source: National transport commission annual reports

Factor analysis was employed to reduce fourteen variables potentially influencing detrimental bus crew behavior into a smaller set of key factors. The suitability of this method was confirmed by a KMO value of 0.711 and a significant Bartlett's test ($p < 0.001$). Following varimax rotation, grouped twelve relevant variables into four distinct components, as all variables exhibited absolute loading values above the 0.50 threshold factors and 2 factors dropped due to threshold level 0.5.

Factors	Sub Factors
workplace environment stress	Unsupportive & Unwelcome workplace within bus crew leading to unpleasant work environment
	Communication between bus crew members & passengers, not positive at peak time
	Technical issues and sudden break downs during the journey
	Misunderstanding between passengers & bus crew contribute to errors, delays or safety incidents.
	Bus owners did not effectively address problems arise among bus crew
	The bus industry is unstable and likely to experience major job losses
Passenger Aggression and inadequate training for crew members	Aggressive behavior of passengers affected to the performance of bus crew
	Not received employment-oriented training or skill development from regulatory bodies.
	Not sufficient support from traffic control unit to controlling traffic
Financial Strain and lack of facilities	Receiving inadequate wage and benefits
	The scheduling system does not allow sufficient rest and recovery between shift
Competitive operational pressure and crew conduct	Heavy traffic congestion makes mentally stress and physically inconvenience to bus crew
	Crew members displaying unprofessional behaviors when they are talking
	Aggressive & competitive driving of other buses and drivers of other vehicle may affect to increase mental stress

Table 1: Factors and sub factors

The screen plot analysis for this study, examining fourteen variables, revealed four components with eigenvalues exceeding one, indicating them as strong underlying factors. The first component explained the highest proportion of variance (28.819%), followed by the second (12.634%), the third (11.420%), and the fourth (8.548%). This suggests that these four components collectively capture a significant portion of the variability within the data related to detrimental bus crew behavior. Reliability analysis using Cronbach's Alpha indicated acceptable reliability (above 0.6) for three of the four identified factors. The fourth factor, "Competitive operational pressure and crew conduct" had a lower Cronbach's Alpha of 0.474. However, considering McDonald's Omega of 0.506 for this factor and its relevance to the research question, the author believes it remains a pertinent factor in understanding detrimental bus crew behavior.

4.CONCLUSION

This study investigated the factors affecting detrimental bus crew behavior in Sri Lanka, collecting data from 110 bus crew members with a history of complaints. Quantitative analysis using SPSS revealed a recent decrease in overall public complaints, with extra charges and reckless driving being the most common offenses, often attributed to conductors. Exploratory factor analysis reduced 14 variables to four key factors explaining 60.2% of the total variance: "workplace environment stress," "passenger aggression & inadequate training for bus crew," "financial strain & lack of facilities," and " Competitive operational pressure and crew conduct." The study concludes by identifying these four consistent and reliable factors as contributors to detrimental behavior among bus crew in Sri Lankan public transportation.

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CRITICALLY ANALYSING THE EXISTING SRI LANKAN AIR FORCE CAPABILITIES TO CATER TO FUTURE MARITIME SEARCH AND RESCUE IN SRI LANKA.

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ABSTRACT -This study evaluates the Sri Lankan Air Force's (SLAF) capability to meet future maritime search and rescue (MSAR) demands over the next five years. Drawing from historical data (2017–2023), the research applies forecasting, risk assessment, probability modelling, and scenario planning to predict trends and assess preparedness. Forecasts project a rise in MSAR incidents from 340 in 2024 to 440 by 2028, with December emerging as the peak month (59 incidents projected in 2028). Technical breakdowns in fishing vessels are the most frequent incident type, averaging 104.33 annually, followed by communication failures and medical emergencies. Sri Lankan fishing vessels are the most vulnerable, with over 1200 incidents recorded. August and December show peak frequencies, emphasizing the need for seasonal readiness.While the SLAF is presently equipped to meet current MSAR demands, improvements in technology, inter-agency collaboration, and resource sustainability are essential to address future challenges. The study recommends investments in surveillance systems, communication infrastructure, and international partnerships. A SWOT analysis highlights strong training frameworks and human capital, but identifies gaps in equipment modernization and response time. These findings offer a data-driven foundation to strengthen SLAF's operational readiness and ensure maritime safety in Sri Lankan waters.

Keywords: Marine search and rescue, Sri Lankan Air Force, maritime safety, MSAR operations, maritime trade, Risk Forecasting.

1. INTRODUCTION.

Maritime search and rescue (SAR) operations are vital for addressing distress at sea, including vessel incidents, medical emergencies, and natural disasters. Historically, Sri Lanka's SAR capabilities have evolved from colonial times to the present, with significant contributions from the Sri Lanka Navy (SLN) and Coast Guard, enhanced by international collaborations, notably during the 2004 tsunami (Wijetunge, 2022; IMO, 2020). However, with growing maritime traffic and increasing threats, it is essential to adopt a sustainable approach to resource management and long-term capability development. This study evaluates the Sri Lankan Air Force's (SLAF) readiness to meet future maritime search and rescue (MSAR) demands, emphasizing sustainability, operational efficiency, and resilience in response systems. The research focuses on SLAF capabilities from 2017 to 2023, analysing accident types, vulnerable vessel categories, and peak accident periods. Forecasting models are employed to predict demand until 2028. The research also identifies capability gaps and offers evidence-based recommendations to enhance SLAF preparedness for complex maritime scenarios.

2. LITERATURE REVIEW.

Maritime safety and search and rescue operations are global concerns with far-reaching environmental, economic, and human impacts (Davies, 2018; Smith, 2019). The International Maritime Organization (IMO, 2020) emphasizes international collaboration, technological advancement, and standardized protocols for effective SAR response. The SLAF's role in SAR operations has grown in importance due

to its ability to provide rapid response and wide-area aerial surveillance (Perera, 2020; SLAF, n.d.). Theoretical frameworks such as Systems Theory highlight the importance of coordinated resource deployment, while the Resource-Based View (RBV) stresses the strategic value of both human and technological assets (Wu et al., 2020; Xiong et al., 2020). Despite ongoing efforts, significant capability gaps exist in resource sustainability, inter-agency integration, and surveillance technology.

3. MATERIALS AND METHODS.

A mixed-methods approach was adopted, combining quantitative forecasting and qualitative expert insights to evaluate the SLAF's readiness for MSAR operations. Quantitative data were sourced from the Maritime Rescue Coordination Centre (MRCC) annual distress reports (2017–2022). Forecasting was conducted using the Holt-Winters exponential smoothing model, chosen for its ability to model seasonal variation and long-term trends. Qualitative data were obtained through structured interviews with SLAF personnel. The sample included six officers selected based on rank, role in MSAR missions, and experience. Interview themes focused on operational capabilities, equipment readiness, inter-agency collaboration, and training. Ethical protocols were maintained by anonymizing identities and ensuring voluntary participation. The study integrated data triangulation and validity checks to enhance reliability. Scenario planning, risk assessment, and probability modelling were used to predict future incident trends and evaluate resource allocation efficiency.

4. RESULTS AND DISCUSSION.

Findings project a steady rise in MSAR demand, with incidents increasing from 340 in 2024 to 440 by 2028. December was identified as the peak month, with 59 incidents expected in 2028. Holt-Winters forecasts highlight technical breakdowns in Sri Lankan fishing vessels as the most common incident, with an average of 104.33 annually. Merchant vessels (223 incidents) and foreign fishing vessels (26 incidents) also showed vulnerabilities, although to a lesser extent. Probability modelling revealed the highest likelihood for fishing vessel breakdowns (0.390), followed by medical emergencies (0.167) and communication failures (0.110). Scenario planning indicated December, August, and November as critical risk periods.

The SWOT analysis identified SLAF's strengths in trained personnel and current response protocols, but exposed weaknesses in equipment modernization and inter-agency communication. Opportunities exist for international collaboration, particularly with nations like Australia and India, to secure training and technology support. Applying Systems Theory and RBV, the study affirms the importance of coordinated human resources and upgraded technological assets.

5. CONCLUSION.

The SLAF has demonstrated commendable capability in responding to MSAR operations, but future readiness will depend on strategic investment in advanced technologies, sustainable resource management, and stronger inter-agency frameworks. Training, legal improvements, public awareness, and long-term budget allocations must support operational sustainability. By adopting these measures, the SLAF can ensure national maritime safety while contributing to regional stability.

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EFFECTS OF THE RED SEA CRISIS ON CONTAINER SHIPPING NETWORK AT THE PORT OF COLOMBO

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ABSTRACT - The Port of Colombo serves as a critical transshipment hub for global shipping networks by connecting East-West trade routes, making it one of South Asia's most strategically significant ports. The escalating geographical tension in the Red Sea has caused substantial disruptions in the global container shipping network, causing the major shipping lines to reroute from the Suez Canal to the alternative Cape of Good Hope. This study critically analyzes the effects of the Red Sea crisis on Colombo Port's container shipping network, focusing on the changes in transshipment and throughput volumes, transit times, and trade lanes. This research was conducted mainly by collecting data from the shipping line experts and websites, and from the industry experts and reports. Employing a mixed methodology approach, the research unified quantitative and qualitative data analysis to determine the changes in container flows through Colombo. Key findings include all the shipping lines deviating through alternative routes, an increase in transshipment and throughput volume and a rise in transit times for major shipping lines, emphasizing a need for capacity increase and infrastructure development at the Colombo Port.

Keywords: Red Sea crisis; Colombo Port; container shipping network; transshipment volume; transit times

1. INTRODUCTION

One of South Asia's most strategically important ports is the Port of Colombo, which serves as a critical transshipment hub for the global container shipping network, connecting East-West trade routes through its strategic location, advanced infrastructure, and handling capacities [1]. The escalating geopolitical tension in the Gaza region is the root cause of the Red Sea crisis, emerging as one of the most significant disruptions to global maritime trade in recent years. The Bab El-Mandeb Strait, a critical chokepoint at the Red Sea's southern end, has witnessed many attacks on merchant ships by Yemen's Houthi rebels, who support Palestine [2]. This has significantly impacted the major shipping lines that pass through the Red Sea route. Over 80% of the container ships that normally employ the Suez Canal route have rerouted via the Cape of Good Hope to avoid the attacks in the Red Sea [3] (Figure 6). That added an extra 3000 - 3500 nautical miles to complete their journey and significantly increased transit times by 8-12 days. This has greatly impacted the synchronization of the shipping schedules between East and West and leads to an increase in freight rates, delays in the supply chain, a lack of containers, and congestion at transshipment hubs, which are significant results of the crisis.

Figure 6. The Red Sea route and the alternative Cape of Good Hope route

The Port of Colombo became greatly congested due to preferred transshipment hub for the rerouted vessels of major shipping lines to do their transshipments. This has led to a notable increase in transshipment volume and container throughput at the Port of Colombo in 2024 compared to 2023. All terminals were handling higher than their usual transshipment volumes. Previous studies have shown the impact of the Red Sea crisis on the various areas of the global shipping network and the importance of the Port of Colombo. However, the lack of focus on how the container shipping route changes due to the Red Sea crisis impacts the Colombo Port remains unaddressed. This study aims to determine the changes in container shipping routes that have impacted on the specific trade lanes, transit times, and container flows through the Port of Colombo.

2. MATERIALS AND METHODS

2.1 Research Design

This study employs a mixed methodology approach to assess the impact of the Red Sea crisis on the container shipping network at the Port of Colombo, combining both qualitative and quantitative analysis. Quantitative analysis involves descriptive and comparative methods, while qualitative analysis uses thematic analysis. Descriptive analysis was conducted on the quantitative data, including percentage changes in transshipment and throughput volumes, as well as port calls. Shipping distances and transit times before and after the crisis, due to the route changes, were analyzed using comparative analysis. Thematic analysis was applied to examine open-ended responses regarding alternative routes, challenges, and expectations of the shipping lines, along with data collected from the SLPA experts and reports.

2.2 Data Collection

A structured survey questionnaire was administered to collect primary data from targeted major shipping lines that connect with the Colombo Port to obtain information about the changes in their container shipping network due to the Red Sea crisis. 80% of the container volume at the Port of Colombo belongs to six of the world's leading shipping giants. Responses were gathered from these six shipping lines to analyze the impact on the Port of Colombo. Since [4] has analyzed interviews, reports, industry publications, expert commentary and stakeholder opinions to understand ripple effect on global supply chains due to the Red Sea crisis, this study adopts a similar methodology to thoroughly analyze. The changes on the container shipping network at the Colombo port, due to the Red Sea crisis, were analyzed using data collected from an industry expert interview and several secondary data sources regarding the container shipping routes and network.

2.3 Data Analysis

Excel was employed to perform descriptive statistical analysis for the quantitative data collected from those shipping lines. Container line services of shipping lines from Asia to Europe or the East Coast of the US that pass through Colombo were analyzed using Excel to identify the average transit time difference resulting from the re-routing of vessels via the Cape of Good Hope route.
NVivo coding software was used to systematically identify, analyze, and illustrate themes and patterns in the responses of shipping lines regarding the alternative routes employed during the crisis, the challenges encountered, the changes required at Colombo port, and alternative solutions to reduce transit times through rerouting. Changes in shipping route maps before and after the crisis were analyzed through a comparative approach, visually representing the route maps of container services. Visual comparisons highlight geographical shifts in container shipping routes that diverge from the traditional Suez Canal route.

3. RESULTS AND DISCUSSION

Key findings of the study indicate that all the shipping lines have rerouted via the alternative Cape of Good Hope to avoid the disruptions at the Red Sea. Published articles included the transit time of container line services has increased from 8-12 days for one way voyage due to re-routing. This study determines an average transit time increase of 10.7 days, which aligns with the industry sources, reinforcing the accuracy and reliability of the analysis. The transshipment volumes handled by the Port of Colombo in 2024 increased by 9.7% from 2023, totalling 6.31 million TEUs. Transshipment volumes accounted for 81% of the Port of Colombo's total container throughput in 2024. The Port of Colombo recorded its all-time highest container throughput of 7.78 million TEUs in 2024, marking a 12.1% increase from 2023. In December 2024, the transshipment volumes climbed by 5.4% to 544,266 TEUs. The yard utilization exceeded 100% in late 2024 at all four terminals, leading to longer dwell times, operational congestion, and berthing delays.

The findings highlight the increased congestion, freight rates, longer dwell times, and limited transshipment capacity as the operational challenges faced at the Colombo Port. The study discusses that improving productivity and efficiency, enhancing terminal infrastructure, and improving connectivity between terminals are the changes that need to be made at the Port of Colombo to cater for the increased volume.

This study is subject to certain limitations. The scope of data collection has been mainly limited to major shipping lines, excluding other smaller shipping lines that resulting in the rest 20% of the volume at Colombo Port. Additionally, time series data was limited by constraining the potential for long-term trend analysis.

4. CONCLUSION

The Red Sea crisis highlighted both the strategic importance and challenges of the Colombo Port as a major transshipment hub. While the port experienced more congestion and operational challenges, it also demonstrated robustness and flexibility in handling global trade flows. With the planned completion of the Colombo East and West container terminals by the end of 2025, the Colombo port will be well-positioned to enhance its capacity and redefine its role in the post-crisis global container shipping network.

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ASSESSING CONTAINER PORT CONGESTION IN DIFFERENT REGIONS DURING THE RED SEA CRISIS: A COMPARATIVE STUDY

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ABSTRACT - The Red Sea crisis has disrupted global maritime trade, leading to significant port congestion in neighboring regions. This study examines the extent of container port congestion by analyzing key metrics such as average anchorage time, average vessel berthing time, average container dwell time, and queue to berth ratio across the selected ports in five selected regions - Southeast Asia, South Asia, Sub-Saharan Africa, Mediterranean Sea & the Persian Gulf. A comparative analysis is used to analyze congestion patterns during the crisis between the ports in the same region and across different regions. Data is collected from Beacon, a supply chain visibility software, and the port authorities' official websites. The analysis is conducted and visualized using Microsoft Excel and Maptive mapping software. The results reveal that the Port of Singapore demonstrated consistently lower congestion levels, showing superior efficiency, while other ports like Durban and Mombasa experienced a substantial operational bottleneck at sea or inland, highlighting clear regional disparities in port performance during the crisis.

Keywords: Port Congestion; Red Sea Crisis; Comparative Analysis; Supply Chain Disruption

1. INTRODUCTION

The Red Sea Crisis began on 19th October 2023 when Iran-backed Houthi militia in Yemen conducted a launch of missiles and an armed drone attack targeting Israel, requesting an immediate stop to the intrusion in the Gaza Strip. The crisis is entangled with ongoing geopolitical tensions, embracing the Gaza war as well as the larger conflicts among Israel, Iran, and the United States. Earlier, any Israel-linked ship was a target, including US and UK warships, but with time, they have also indiscriminately attacked the merchant and naval vessels of many nations with no connection to Israel. From October 2023 to March 2024, Houthis attacked more than 60 vessels in the Red Sea[1]. To avoid attack, hundreds of commercial ships have been rerouted to Africa. The Red Sea is a critical chokepoint, with 12% of global seaborne trade passing through it[2]. Moreover, most of the trade between Europe, Asia, and North America is conducted through the Suez Canal, connecting the Red Sea to the Mediterranean Sea, which functions as the shortest and most economical route. Any diversion from such a route, such as the present crisis, makes the shipping lines commit their vessels to a longer route, often around the Cape of Good Hope, therefore, increasing transit time along with fuel burn and shipping cost overall.[3]

This study attempts to assess the crisis's impact on port congestion in neighboring regions by looking at how disrupted traffic, vessel rerouting patterns, as well as economic/logistical outcomes. Because of the Red Sea's strategic significance, the unfolding of its crises is vital for maritime stakeholders, including shipping lines, port authorities, and policymakers. The Red Sea crisis has had a lot of effects on the global maritime trade. Due to this crisis, the Shipping lines' usual shipping services and schedules were changed. Because of that, the neighboring ports got congested, especially the major transshipment hubs.

2. MATERIALS AND METHODS

2.1 Research Design

The research adopts a structured comparative analysis approach to evaluate the impact of the Red Sea crisis on port congestion across five strategically selected regions near key maritime routes. Ports were chosen based on highest container throughput in 2022 and 2023, with monthly data collected from August 2024 to February 2025 on metrics such as vessel berthing time, anchor time, container dwell time, and vessel counts. The methodology includes inter-regional, intra-regional, and port-wise comparisons to assess congestion variations. Data is sourced from Beacon, port authority websites, and maritime databases, and is analyzed and visualized using Microsoft Excel and Maptive software to identify and present congestion patterns and trends comprehensively.

2.2 Data Collection

The data collection process for this study involves gathering container throughput and port congestion data to assess operational impacts during the Red Sea crisis. Container throughput figures for 2022 and 2023 were sourced from Lloyd's List and official port websites to identify the top two ports in each region. Port congestion data from August 2024 to February 2025 were obtained via the Beacon Global Port Congestion platform[4], focusing on key metrics such as average vessel berthing time, anchor time, container dwell time, and queue-to-berth ratios. These metrics, selected based on expert opinions and industry sources, offer critical insights into port performance and congestion trends influenced by vessel rerouting and instability in the Red Sea region.

2.3 Data Analysis

The data analysis in this study is structured around three levels of comparison: inter-regional, intra-regional, and port-wise. Inter-regional analysis involves averaging congestion metrics from two ports per region to assess overall regional performance and enable equitable comparisons. Intra-regional analysis focuses on comparing two ports within each region using key congestion metrics and visualizing monthly trends through line charts and spatial patterns via proportional symbol maps generated using Maptive software. Port-wise analysis involves calculating mean values for each congestion parameter over the study period and mapping them geospatially to highlight congestion intensity at individual ports. This multi-layered analytical approach provides a comprehensive understanding of congestion dynamics and regional disparities influenced by the Red Sea crisis.

3 RESULTS AND DISCUSSION

The study revealed clear regional disparities in port congestion during the Red Sea crisis, with Sub-Saharan Africa experiencing the highest delays due to rerouted vessel traffic, particularly at Mombasa and Durban. In contrast, Southeast Asia, led by the Port of Singapore, maintained efficient operations with minimal congestion across all metrics. South Asia showed mixed performance - Mundra remained efficient, while Colombo faced increasing anchorage and dwell times. In the Mediterranean, Tanger Med outperformed Piraeus in most areas, despite higher dwell times linked to transshipment. The Persian Gulf showed moderate congestion, with Salalah recovering quickly from temporary disruptions. Overall, the findings highlight the importance of resilient infrastructure and operational readiness in managing the impact of maritime crises on global trade flows.

Figure 1. Proportional symbol map of Average Vessel Berthing Time

Figure 2. Proportional symbol map of Average Vessel Anchor Time

Figure 3. Proportional symbol map of Average Container Dwell Time

Figure 4. Proportional symbol map of Queue to Berth Ratio

4. CONCLUSION

This study conducted a comparative analysis of port congestion across five maritime regions during the Red Sea crisis, revealing notable differences in performance. Ports like Singapore demonstrated high efficiency, while other ports such as Durban and Mombasa faced severe congestion. Although the study effectively assessed the crisis period from August 2024 to February 2025, a key limitation was the lack of pre-crisis data, which prevented a full before-and-after comparison. Future research is recommended to adopt a longitudinal approach for a deeper understanding of the crisis's long-term impact.

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EVALUATING THE IMPACT OF TRANSSHIPPING ON INTERNATIONAL TRADE OF SRI LANKA

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ABSTRACT - This research has conducted to evaluate the impact of transshipping on international trade of Sri Lanka. Sri Lanka is currently competing with Singapore, Taiwan and Malaysia for handling of transshipment containers in South East Asia as Singapore is the highest transshipping container handling country in the region and followed by Taiwan and Malaysia. Accordingly, the impact of transshipping on international trade of Sri Lanka will be evaluated by computing the service export income generating through transshipping to Sri Lanka. Mean transshipping terminal handling charges and monthly transshipping throughput of Port of Colombo during the period of 2015 – 2024 will be considered while computing the service export income generating through transshipping under the independent variables of this research and computed service export income will be the dependent variable of this research under international trade. Transshipping terminal handling charges are obtained by SLPA tariffs book and transshipping throughput data was collected by CBSL reports respectively to conduct this research.

Keywords: Transshipping, International Trade, South East Asia, Transshipping Terminal Handling Tariff, Export Income

1. INTRODUCTION

The main objective of this research study is to evaluate the impact of transshipping on international trade of Sri Lanka to measure the contribution of transshipping on international trade of Sri Lanka. Accordingly, research will attempt to compute monthly generating service export income through transshipping and discuss how to increase service export income generating through transshipping thereafter. Export income to Sri Lanka is received through merchandise exports and service exports and transshipping is concerned under service exports. Service exports includes financial service exports, legal service exports, communication service exports, ICT service exports and transport service exports(Pattnayak & Chadha, 2022). Container operation is consisted several types of transport networks. These networks includes direct shipment and transshipment. Direct shipment refers to transporting cargo through a carrier from origin to destination using a single service whereas transshipment refers to transporting of cargo from origin to destination by combining multiple vessels (Tagawa et al., 2021; Hsu and Hsieh, 2005). As per to Shi and Li (2016) container shipping's contribution to world's international trade in 2015 is over 80 per cent by volume and over 70 per cent by value. Terminal operators charge transshipment terminal handling charges for transshipping containers for the providing export service of unloading a transshipping container from a vessel; for storing a transshipping container until reloading to the connecting vessel and to reload the transshipping container to the other vessel to carry to its final destination (Sarmmah, 2025).

2. METHODOLOGY

In the process of computing the service export income generating through transshipping, research considers the period of past ten years from 2015 – 2024 and transshipping terminal handling charges during the period of 2015 – 2024 with monthly transshipping throughput from 2015 – 2024. Monthly handled transshipping container throughput will be considered as the independent variable under transshipping and computed service export income generated through transshipping will be the

dependent variable in this research under international trade. Accordingly, two mean transshipping terminal handling charges will be computed as below from 2015 – 2022 and another mean transshipping terminal handling charge will be computed for 2022 onwards and multiplied by monthly transshipping container throughput from 2015-2024 to compute the service export income generated through transshipping.

Table 6. Computed mean tariffs for handling transshipping containers

	SLPA Tariffs for handling transshipping containers (in USD)			
	20ft	40ft	Over 40ft	Mean tariff value
2015 -2022	41	62	75	59.33
2022 onwards	46.5	71	80	65.83

(SLPA tariff book, 2022)

As per the above table, Sri Lanka Ports Authority (SLPA) has published transshipping terminal handling charges for handling of 20 feet transshipping containers, 40 feet transshipping containers and over 40 feet transshipping containers in 2015 and SLPA has revised the rates in 2022 as above. Anyhow, SLPA publishes the transshipping container throughput in twenty – foot Equivalent Units (TEUs) regardless the number of 20 feet, 40 feet and over 40 feet containers transshipped. Therefore, research has computed mean transshipping terminal handling charges as above while computing the service export income generated through transshipping.

3. RESULTS AND DISCUSSION

Accordingly, computed service export income generated through transshipping can be presented as below from 2015 to 2024. As discussed in the methodology chapter, monthly transshipping container throughput in TEUs from 2015 – 2024 has multiplied from computed mean transshipping terminal handling charges to obtain below service export income generated through transshipping.

Table 7. Computed monthly transshipping income generated (2015-2024)

COMPUTED MONTHLY TRANSSHIPPING INCOME – USD (Mn)					
MONTH	**2015**	**2016**	**2017**	**2018**	**2019**
JANUARY	18.55	20.63	21.50	25.89	28.79
FEBRUARY	18.08	19.65	20.01	24.64	26.29
MARCH	18.86	22.73	23.71	28.30	30.35
APRIL	18.35	19.95	21.89	26.19	28.65
MAY	18.65	21.51	23.56	26.93	28.70
JUNE	19.22	21.52	22.66	28.00	28.50
JULY	20.88	21.69	23.90	28.48	27.64
AUGUST	21.16	23.45	24.17	29.95	31.44
SEPTEMBER	19.95	21.41	24.16	27.24	28.67
OCTOBER	19.42	21.35	24.69	29.74	29.54
NOVEMBER	18.27	21.38	24.46	28.50	25.30
DECEMBER	19.30	23.12	26.61	28.53	30.35
	2020	**2021**	**2022**	**2023**	**2024**
JANUARY	29.70	26.94	33.73	29.51	37.03
FEBRUARY	27.16	26.15	29.81	26.94	34.78
MARCH	29.75	29.44	34.37	32.16	36.15
APRIL	22.26	29.84	32.82	32.02	34.62

MAY	24.16	27.55	27.93	35.10	33.69
JUNE	26.82	30.02	31.80	36.09	34.02
JULY	30.80	29.55	30.33	34.27	32.21
AUGUST	31.75	29.25	31.30	34.14	33.58
SEPTEMBER	31.31	28.02	30.41	30.54	34.04
OCTOBER	29.66	30.61	29.49	28.10	35.33
NOVEMBER	23.42	28.73	28.28	26.01	34.45
DECEMBER	26.26	31.00	30.72	33.93	34.99

(Author developed)

4. CONCLUSION

Therefore, research able to conclude that, promoting transshipping more in global scale and executing capacity enlargements to attract more transshipping volumes to Sri Lanka is ideal as it further increase the service export income of Sri Lanka in future. Research has also found that there is an increasing linear trend in service export income generated through transshipping in the past ten years and number of transshipping containers handled has also increased from 2015 – 2024. Also, SLPA has increased the transshipping terminal handling charges from 2022 and which has also impact on observed increasing linear trend in service export income generated through transshipping. Research limitations of this research includes the use of two mean transshipping terminal handling charges while computing the service export income generated through transshipping as three types of transshipping container handling charges are charging by SLPA. Also, air transshipping data is not covered in the study due to the challenging nature of computing air transshipping income.

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PREDICTIVE MODELLING OF HOUSEHOLD E-WASTE RETURN BEHAVIOR: A QUANTITATIVE STUDY OF E-WASTE COLLECTION SYSTEMS IN URBAN SRI LANKA

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ABSTRACT - The growing use of electronic products has led to a steady increase in e-waste generation among households in urban Sri Lanka. However, the current reverse logistics systems are not well developed to support effective collection and recovery from the household sector. This study uses a data-driven approach to explore the main factors that influence e-waste return behavior among urban households. A structured survey was carried out with 385 households across Colombo, Kandy, and Galle. The responses were analyzed using multiple linear regression to understand the relationship between household characteristics and the volume of e-waste returned. The results show that education level, number of electronic devices owned, household size and environmental awareness are significant predictors, with the model achieving an adjusted R^2 of 0.72. These findings provide useful insights for designing household-focused green logistics systems. As a future step, the study proposes to include route optimization and carbon emission analysis to support more efficient and sustainable e-waste collection strategies.

Keywords: Behavioral analysis; E-waste; Predictive modeling; Reverse logistics; Urban Sri Lanka.

1. INTRODUCTION

E-waste is a growing environmental concern, particularly in urban regions of developing countries like Sri Lanka [1]. The rapid increase in the consumption of electronic devices, coupled with their short product lifecycles, has led to a substantial rise in the generation of e-waste. In Sri Lanka, urban areas like Colombo, Kandy, and Galle are witnessing higher rates of electronic waste due to population growth, increasing technological adoption, and rapid urbanization [2]. While global literature emphasizes the benefits of smart, sustainable reverse logistics systems in managing e-waste, many developing countries, including Sri Lanka, still lack robust, data-driven frameworks for effectively managing the return and recovery of e-waste [3], [4].

Studies from countries such as India and Indonesia have shown the effectiveness of predictive modeling in understanding disposal behavior and improving e-waste management systems. In these contexts, predictive models have been used to identify the socio-economic and behavioral factors that influence the return of electronic waste, allowing for the design of more efficient reverse logistics systems [4]. These models often include factors like education level, environmental awareness, income, and the number of electronic devices owned, which have been shown to significantly impact e-waste return behaviors.

However, in Sri Lanka, research on e-waste management is still in its early stages, and there is a lack of comprehensive studies that address both behavioral and logistical aspects of e-waste disposal [5], [6]. Existing systems for e-waste collection in Sri Lanka are generally underdeveloped, and there are significant gaps in public awareness and infrastructure. Many households and small businesses still lack proper channels for the return of electronic waste, leading to improper disposal methods such as dumping or incineration, which can have detrimental environmental and health effects.
This study seeks to address this gap by applying predictive modeling techniques to understand the behavioral and socio-economic predictors of e-waste return volumes in urban Sri Lanka. By identifying

the key factors that drive e-waste disposal behavior, the research aims to inform the development of more efficient and sustainable reverse logistics systems. The insights generated will be invaluable in designing targeted interventions, such as awareness campaigns and incentive-based programs, that could increase the volume of e-waste returned for proper recycling and disposal. Furthermore, the findings will contribute to the global body of knowledge on e-waste management and its integration with sustainable logistics practices in developing countries.

2. MATERIALS AND METHODS

2.1 Study Area and Sampling Strategy

The study was carried out in three key urban areas of Sri Lanka: Colombo, Kandy, and Galle. These cities were selected based on their high population density, increased usage of electronic products, and growing concerns related to household electronic waste. The research focused exclusively on households in these urban areas to understand their e-waste disposal behavior. A stratified random sampling method was used to ensure balanced representation across various household types, considering factors such as income levels, education backgrounds, and residential environments. A total of 385 households were selected for the study, with an approximately equal number of respondents from each city. Data collection was conducted using a structured questionnaire, which included sections on household demographics, electronic device ownership, disposal practices, and awareness of e-waste issues.

2.2 Questionnaire Design and Operationalization

A structured questionnaire was designed to gather data on household demographics, electronic device ownership, e-waste disposal practices, and environmental awareness. The questionnaire comprised four sections: (i) demographic information such as age, gender, education level, household income, and household size; (ii) the number and types of electronic devices owned by the household; (iii) frequency and methods of e-waste disposal, including preferred collection channels; and (iv) environmental awareness, measured through a 5-point Likert scale (1 = Not aware, 5 = Highly aware) assessing knowledge of e-waste hazards and recycling practices. A pilot test with 20 households was conducted to ensure clarity and reliability of the questions. Based on this, minor adjustments were made to wording and scale ranges before final data collection.

Table 8: Operationalization Table

Variable	Type	Measurement/Scale
E-waste Returned (kg)	Dependent	Continuous (monthly volume of e-waste returned)
Education Level	Independent	Ordinal scale: 1 = Primary, 2 = Secondary, 3 = Diploma, 4 = Graduate+
Household Income	Independent	Continuous (monthly income in LKR)
Device Ownership	Independent	Continuous (number of electronic devices owned)
Environmental Awareness	Independent	Mean score of 5-point Likert scale (1 = Low, 5 = High)
Household Size	Independent	Continuous (number of household members)

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2.3 Predictive Modeling

A multiple linear regression model was employed to identify the key predictors influencing monthly e-waste return volumes. The dependent variable was the quantity of e-waste returned, while the independent variables included education level, income, environmental awareness, device ownership, and household size. Regression was chosen as the predictive modeling technique because it effectively quantifies the relationship between multiple socio-economic factors and the continuous outcome

variable (e-waste returned), allowing us to assess the relative contribution of each predictor and generate accurate behavioral forecasts. This method is particularly suited for understanding and predicting patterns of household e-waste returns, which depend on a combination of demographic and behavioral variables. These variables were selected based on prior research and their relevance to consumer behavior in the Sri Lankan context. Before analysis, the data were cleaned and normalized to ensure consistency, and checks for multicollinearity were conducted to maintain model validity. The model's performance was evaluated using Adjusted R^2 to measure explanatory power and Root Mean Square Error (RMSE) to assess prediction accuracy. The analysis provided valuable insights into the socioeconomic and behavioral drivers of e-waste return behavior, forming a basis for developing targeted reverse logistics interventions in urban Sri Lanka.

3 RESULTS AND DISCUSSION

The multiple linear regression analysis was performed to determine the influence of selected household factors on the volume of e-waste returned monthly. The model included five independent variables: education level, household income, environmental awareness, device ownership, and household size. The analysis revealed a very strong model fit, with an Adjusted R^2 value of 0.996, indicating that 99.6% of the variation in e-waste return volumes could be explained by the model.

Among the predictors, household income ($p < 0.001$), device ownership ($p < 0.001$), and household size ($p < 0.001$) were found to be statistically significant. Income and device ownership had a positive impact, meaning that households with higher income and more electronic devices tended to return more e-waste. Interestingly, household size showed a negative relationship, suggesting that larger households may return less e-waste per capita, potentially due to shared usage or delayed disposal practices. In contrast, education level ($p = 0.579$) and environmental awareness ($p = 0.082$) were not statistically significant predictors in this model. This implies that while awareness and education are important factors in shaping attitudes, they may not directly translate into increased e-waste return behavior in the absence of infrastructure or incentives.

These findings provide evidence-based insights that can guide the design of more targeted reverse logistics programs, such as incentivizing households with high device ownership or focusing awareness efforts on larger households. In the future, the model will be extended to include route optimization and carbon emission calculations to enhance operational efficiency and environmental sustainability.

Table 2: Result of Multiple Linear Regression

SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.8634							
R Square	0.7455							
Adjusted R Square	0.7219							
Standard Error	2.5477							
Observations	385							
ANOVA								
	df	*SS*	*MS*	*F*	*Significa -nce F*			
Regression	5	1026.7187	205.3437	31.6363	0.0000			
Residual	384	350.5009	6.4908					
Total	389	1377.2196						
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-9.8930	1.5279	-6.4748	0.0000	-12.9563	-6.8297	-12.9563	-6.8297
Education Level	0.2034	0.3440	0.5913	0.0006	-0.4863	0.8931	-0.4863	0.8931
Household Income	0.0000	0.0000	5.0096	0.4528	0.0000	0.0000	0.0000	0.0000
Environmental Awareness	2.1074	0.2761	7.6337	0.0000	1.5539	2.6608	1.5539	2.6608
Device Ownership	0.2367	0.0383	6.1758	0.0000	0.1598	0.3135	0.1598	0.3135
Household Size	0.5269	0.2043	2.5790	0.0012	0.1173	0.9366	0.1173	0.9366

4. CONCLUSION

This study examined the behavioral and socio-economic factors influencing household e-waste return behavior in urban Sri Lanka using predictive modeling. The multiple linear regression model achieved a robust adjusted R^2 of 0.721, indicating that approximately 72% of the variation in e-waste return volumes can be explained by the selected predictors. The analysis revealed that education level, device ownership, household size, and environmental awareness are significant contributors to e-waste return behavior, while household income also plays an important role in influencing disposal patterns. The findings highlight that households with higher education levels and greater environmental awareness are more likely to participate in proper e-waste return programs. Similarly, an increase in the number of electronic devices owned directly correlates with larger volumes of returned e-waste. Interestingly, household size emerged as a critical factor, suggesting that larger households may adopt more structured disposal behaviors due to collective decision-making or the higher cumulative volume of outdated electronics.

The significance of this study lies in its ability to provide evidence-based insights for optimizing reverse logistics systems in Sri Lanka. By understanding the key behavioral drivers of e-waste returns, policymakers and waste management authorities can design targeted awareness campaigns, incentive schemes, and collection infrastructures that encourage household participation. Moreover, the predictive approach used in this research sets a strong foundation for future studies integrating route optimization and carbon emission analyses to create more sustainable and efficient e-waste collection strategies. Overall, this research contributes to bridging the knowledge gap in e-waste management in developing countries by linking behavioral factors with logistical planning. The findings can inform both policy interventions and private sector initiatives, ultimately leading to improved recycling rates and reduced environmental impacts.

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ANALYZING THE FACTORS AFFECTING THE CUSTOMER SATISFACTION OF REVERSE LOGISTICS PRACTICES IN APPAREL E COMMERCE MARKET IN COLOMBO DISTRICT, SRI LANKA

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ABSTRACT - This study primarily focuses on analyzing a pre-determined set of factors to see how these factors influence the customer satisfaction in reverse logistics within the apparel e commerce sector in Colombo District, Sri Lanka. With the significant growth in E commerce sector, efficient reverse logistics processes are crucial for maintaining customer satisfaction. This study employs a quantitative approach, collecting primary data from over 200 respondents in Colombo District. The pre-determined factors are backed by a thorough literature review and these factors include, Service Responsiveness, Technology Integration, Quality Control, and Company return policies. The validity of the study is supported by a Cronbach's value of over 0.7 and an R squared value of 0.764. Demographic Analysis shows a predominant age group of 18-24, a balanced gender distribution and a significant proportion of full time employed respondents. It further shows that the Customer Service Responsiveness is the most influential factor. All in all, the study highlights the importance of being responsive, having tight quality control and being flexible with the customers to be main policies that will foster customer loyalty and customer satisfaction. The study also underscores the need for further research to explore these dynamics in different regions and industries to improve the overall optimization of Reverse Logistics.
Keywords: Reverse Logistics; Customer Satisfaction; Optimization; Apparel; E Commerce.

1. INTRODUCTION

Sri Lanka's e-commerce market is a rapidly growing sector, with the apparel sector accounting for a significant proportion of online sales and product returns. Therefore, the emphasis on reverse logistics is a timely priority. Reverse Logistics, the process of returning products from customers back to sellers, has become increasingly important [2], especially in apparel e-commerce, where size mismatches, quality issues, and incorrect deliveries are quite common. Despite this importance, reverse logistics is often overlooked by retailers, impacting customer satisfaction. Addressing the primary objectives, the study focuses on issues such as lack of tracking facilities, poor communication channels and strategies [3], the relationship between the identified factors and customer satisfaction and the most influential factor that impacts customer satisfaction. The study focuses on Colombo District, mainly because it is the most urbanized and one of the most populated districts in Sri Lanka [4]

2. MATERIALS AND METHODS

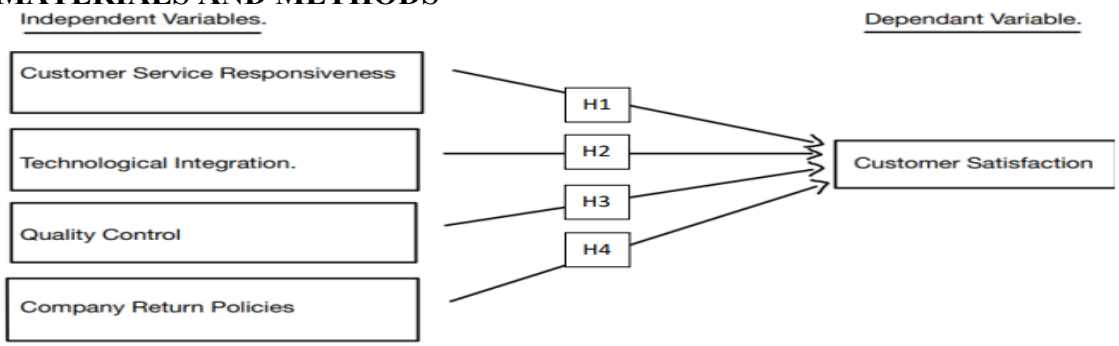

Figure 1. Conceptual Framework

The study focuses on the connection between Customer Satisfaction of reverse logistics practices in Apparel E commerce market in Colombo District, Sri Lanka, which is the dependent variable and key factors, Customer service responsiveness, Technological Integration, Quality Control and Company return policies, were treated as Independent variables. Each independent variable was measured using multiple positive indicators. For an example, Customer Service Responsiveness was measured using positive indicators such as speed of response and real time availability of responses etc. All items were phrased positively and rated on a 5-point scale, with higher scores indicating greater satisfaction. Customer Satisfaction is measured via Likelihood to Recommend to others, Likelihood to continue the service etc. SPSS analysis on a 5-point Likert scale covers both descriptive and inferential components. The study collected data from 219 respondents via a self-administered questionnaire and analyzed through SPSS. A non-probability convenience sampling method was used to collect data and prior to full distribution, a pilot test was done to get feedback on the clarity of the questions. Majority of the questionnaires were filled through online means and the consent was obtained and participants were clearly informed about the anonymity and confidentiality as their emails were collected for the study.

3. RESULTS AND DISCUSSION

3.1 Correlation Analysis

Table 1. Correlations Table

Correlations		Customer Satisfaction
Customer Service Responsiveness	Pearson Correlation	.811**
	Sig. (2-tailed)	.000
Technological Integration	Pearson Correlation	.722**
	Sig. (2-tailed)	.000
Quality Control	Pearson Correlation	.794**
	Sig. (2-tailed)	.000
Company Return Policies	Pearson Correlation	.668**
	Sig. (2-tailed)	.000

****. Correlation is significant at the 0.01 level (2-tailed).** Reference: Research Data

It can be concluded that all four variables have a positive relationship with the dependent variable.

3.2 Regression Analysis

Table 2. Regression Coefficients Table

Coefficients[a]							
Model			Unstd. Coefficients		Std. Coefficients	t	Sig.
			B	Std. Err.	Beta		
1	(Constant)	β_0	0.801	0.116		6.888	0.000
	Customer Service Responsiveness	β_1	0.644	0.074	0.784	8.671	0.000
	Technological Integration	β_2	0.200	0.076	0.257	2.626	0.009
	Quality Control	β_3	0.664	0.092	0.765	7.232	0.000
	Company return policies	β_4	0.756	0.086	0.994	8.819	0.000

Reference: Research Data

Table 3. Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.874[a]	.764	.760	.40485

Reference: Research Data

The multiple linear regression model for the subject study can be developed as below.

$Y = 0.801 + 0.644CSR + 0.2TI + 0.664QC + 0.756CRP$

Reliability was confirmed with Cronbach's alpha values exceeding 0.7, and regression analysis revealed an R squared of 0.764, indicating that 76.4% of the variation in customer satisfaction can be explained by the four independent factors. To address the second primary objective, identifying the most influential factor among the 4 independent variables, Pearson correlation analysis was conducted. The results indicated that Customer service responsiveness had the most significant relation with customer satisfaction. This finding is consistent with the work of Lysenko et al. (2017) [1], who emphasized the critical role of responsive communication in fostering customer loyalty. Quality control came in second, a result that is consistent with the findings of Samyukthaa and Ramya (2023) [2], who highlighted the importance of quality control in minimizing returns and enhancing satisfaction. The remaining factors also showed significant positive relationships with customer satisfaction. It is also important to note that, while customer service responsiveness showed the strongest individual correlation with the satisfaction, the multiple linear regression model revealed that Company return policies had the highest Influence, when the whole model is considered. This suggests that although responsiveness is closely associated with satisfaction, return policies play the a dominant role when accounting for the combined effects of all variables.

4. CONCLUSION

In conclusion, the study covers three primary objectives, as a part of the first objective, it identified four factors affecting the customer satisfaction when it comes to reverse logistics practices in the apparel e commerce market in Colombo District and the study addressed the second objective by identifying that there is a positive relationship between these factors and Customer satisfaction. And finally the customer service responsiveness has been identified as the most influential factor, covering all three objectives of the study. Recommendations such as enhancing real time communication, improving product quality, adopting technologically advanced ideas like virtual try on and tracking facilities for returned products were also highlighted in this study. These improvements will significantly improve the overall clarity of the return process and will drive long term customer satisfaction in Sri Lanka's growing online apparel market. While the study explicitly focused on the customer perspective to measure the satisfaction, it should be acknowledged that sellers and logistics providers play a key role as well. Future studies are encouraged to incorporate a multi-stakeholder approach, specifically with a more qualitative approach to gain a more holistic understanding of the whole process and also geographical expansion can also be done by using this study which primarily focused on Colombo District as a starting point.

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EVALUATING THE IMPACT OF ORGANIZATIONAL CM ON THE EXTERNAL PROCUREMENT PROCESS PERFORMANCE IN THE APPAREL INDUSTRY

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ABSTRACT: This study examines the various organizational communication methods (CM) employed in the procurement process to interact with suppliers in the apparel sector of Sri Lanka. The data were collected through a literature review and a questionnaire survey distributed to procurement professionals in the apparel sector, yielding 85 valid responses. The multiple regression analysis in SPSS was used to analyze the impact of each categorized method, such as Traditional Communication Method (TCM), Electronic Communication Method (ECM), Social & Informal Communication Method (SICM), and Automated Communication Method (ACM), on procurement performance (PP), considering the organization's size. The findings showed that small organizations still rely on TCM, whereas large organizations focus on ECM and ACM. The final model, which primarily focused on large organizations, indicated that over-reliance on TCM may reduce PP while ECM may enhance it. The ACM and SICM were not statistically significant in this sample. However, the study offers insights into the current importance of CM across apparel organizations and how organizations adopt suitable CM to improve their PP while revealing limitations and suggesting areas for future research in procurement communication with suppliers.

Keywords: *Communication Methods, Procurement performance, Sri Lankan apparel industry, Supplier Relationship*

1. INTRODUCTION

The apparel industry is a global market leader, with many countries participating due to its labor-intensive nature and low fixed costs. By helping the people in terms of job opportunities and poverty reduction, this sector is important for developing countries [1], [2] . Sri Lanka's apparel sector makes up approximately 43% of all exports [3]. To maintain competitiveness in the apparel sector, it has been identified that external procurement has become a key element, and it impacts the company's performance in the apparel industry [4]. Procurement performance (PP) is significantly influenced by communication since it promotes good supplier relationships [5]. Recent studies mostly focus on procurement's communication methods (CM), especially in the automotive sector[6], indicating that further investigation is required in other sectors. Therefore, the research aims to identify the different organizational CMs in the apparel sector, categorize them, and evaluate the impact of categorized CM on PP, providing both theoretical and practical insights into procurement communication.

2. MATERIALS AND METHODS

The different organizational CMs in the apparel sector were identified through literature and categorized. It was validated by experts with over ten years of experience in the apparel sector's procurement field. To evaluate the impact of CMs on PP, a questionnaire survey was conducted among procurement professionals. The major responses are from executives of large companies with 5-8 years of experience. PP is considered the dependent variable (DV), and the importance of each categorized CMs to the PP was taken as the independent variable (IV), and organization size, which was defined in terms of the number of employees, was taken as a control variable and coded as a categorical variable in the regression analysis. The 5-point Likert scale was used to measure the importance of each CM on PP, and the averaged value was taken for each categorized method. Similarly, under the PP, cost, quality, time, compliance, innovation, and sustainability were considered [7]. The data were analyzed using MLR analysis in SPSS to evaluate the individual effect of each categorized CM and the overall contribution of CMs to the PP, as one of the previous studies that has used MLR to quantify the effect

of procurement quality controls on PP[8]. A pilot survey was conducted among a small sample of experts to ensure clarity and validity, resulting in minor adjustments to the questionnaire. A total of eighty-five valid responses were obtained, which were then cleaned by eliminating outliers and addressing missing values. The regression assumption test was performed to ensure the trustworthiness of the results before the final analysis.

3. RESULTS AND DISCUSSION

3.1 Objective 1: Identify the different CMs in the apparel sector and categorize them

CMs used in the procurement process were identified from the literature, and CMs used in the external procurement of the apparel sector in Sri Lanka were filtered and ensured through pilot surveys.

- **Traditional CM (TCM)** - CMs that rely on human intervention and manual work are often required [15]. E.g., Face to face, Telephone, Written document/ hard document, fax [9]
- **Electronic CM (ECM)** - Web-based communication [11] and related to e-procurement [9] E.g., Cloud-Based Procurement Software, E-mail, Supplier portals, Video Conferencing[10], [11]
- **Social & Informal CM (SICM)** - Social-based relationship through informal methods [12] E.g., Social events, workshops, off-site meetings, communication guidelines, joint improvement projects, casual meals at a local restaurant, social media [12], [13]
- **Automated CM (ACM)** - without manual intervention, real-time information sharing, [5], [15] E.g., Automated Email Notifications, Order processing and Management, Automated data entry and sharing, Notifications and alerts [14]

The survey emphasized that small organizations rely on TCM while large organizations prioritize ECM, and medium-sized organizations appear to value both TCM and ECM. The importance placed on SICM does not significantly vary across organizations. Additionally, literature supports the survey's results.

3.2 Objective 2: Evaluate the impact of categorized CM on PP

Most variables met reliability standards, and almost all regression assumptions (normality, linearity, homoscedasticity, multicollinearity) were satisfied. Therefore, MLR was conducted with confidence.

The model was statistically significant ($F=3.008$, $P=0.015$), indicating that the model explains only 16 % of the variance ($R2=0.16$) in PP [8] highlighting limitations and future studies to identify the additional predictors to improve the model fit. The coefficient for TCM ($B = -0.279$, $p = 0.017$) indicates that a one unit increase in TCM leads to a decrease of 0.279 units in PP, holding other IVs constant, and is significant at 5% level. This aligns with previous studies that identify issues related to the TCM [15].Thus, heavy reliance on TCM will reduce the PP, particularly in large companies. The coefficient ($B = 0.412$, $p = 0.034$) indicates that a one unit increase in ECM increases PP by 0.412 units and is significant at 5% level, suggesting that adopting ECM may improve PP as it improves cost savings and accuracy[9]. Even though the results of this study revealed no statistically significant effect of SICM ($p = 0.743$) and ACM ($p = 0.073$) on PP, SICM builds trust and improves the relationship with suppliers[12] and ACMs are considered critical for enhancing procurement processes in the future. Recent studies highlight that developing countries lack the infrastructure and readiness to deploy automation tools fully [14]. These variables may show a significant impact in the future as automation adoption increases and explores the diverse range of datasets. Therefore, retaining this variable allows researchers to explore the impact of this in the future.

4. CONCLUSION

The study reveals that the over-reliance on TCM decreases the PP while ECM adoption enhances it, suggesting the importance of prioritizing the ECM in large organizations. There are limitations in this study in terms of the diversity of the importance of SICM and the lack of adoption of ACM in the

apparel sector in Sri Lanka. Future research might reveal a significant impact of ACM and SICM on PP as their adoption and data diversity increase.

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IMPACT OF LINER SHIPPING CONNECTIVITY ON THE COUNTRY'S ECONOMY:THE CASE OF THE PORT OF COLOMBO

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ABSTRACT - This study aims at analyzing the relation between the Liner Shipping Connectivity Index (LSCI) with the Sri Lankan economy in terms of GDP and the Port of Colombo's container throughput. The LSCI is a crucial indicator of a country's integration into global maritime networks, reflecting the efficiency and capacity of a port to handle international trade. Using data spanning from 2004 to 2021, this research analyzes the effect of LSCI growth on Sri Lanka's economy by applying descriptive statistics, correlation analysis, and simple linear regression. The analysis shows a very strong positive correlation with the growth of LSCI to GDP (r = 0.821) and a very strong correlation with container throughput (r = 0.953). The regression models show that a one-unit increase in LSCI will result in an increase of 2.61 billion USD in GDP and a 1.78 million TEU increase in container throughput. Forecasts, using the ARIMA (1,1,1) model, suggest that improved LSCI growth_diff is associated with consistent growth in both GDP growth_diff and container throughput growth_diff. This study underscores the significant role of enhanced shipping connectivity in driving Sri Lanka's economic growth and port performance. It emphasizes that improved port infrastructure and shipping services are crucial for sustaining the country's economic development.

Keywords: LSCI, GDP, container throughput, Port of Colombo, Sri Lanka

1. INTRODUCTION

Liner shipping connectivity (LSCI) is key in the world's logistics, and it is particularly vital for places like Sri Lanka, as most of their trade involves sending goods by maritime transport. Due to it is located along major international trade lanes, the Port of Colombo is a major transit hub for South Asia (*International-Trade-in-Sri-Lanka*, 2024). According to the United Nations Conference on Trade and Development (UNCTAD), the LSCI reflects a port's integration into international shipping. It depends on factors such as how many ships arrive at the port, how often services are provided, the size of the ships and the total capacity for shipping. An increase in the LSCI indicates improved access to global trade which should have a positive influence on the economy (Subhawickrama, 2019). This study focuses on GDP and container throughput because these two variables are direct indicators of a country's economic performance and port efficiency. GDP represents the overall economic health, while container throughput serves as a proxy for trade volume and port efficiency. Both are crucial in assessing the impact of improved maritime connectivity on national growth and port performance (Subhawickrama, 2019).
Key research questions include:

1. What is the impact of LSCI growth on GDP growth in Sri Lanka?
2. What is the impact of LSCI growth on container throughput growth in the Port of Colombo?
3. How can LSCI growth be used to forecast future trends in GDP growth and container throughput growth?

2. MATERIALS AND METHODS

The research employs a quantitative approach using secondary data from UNCTAD for LSCI, data from the Sri Lanka Port Authority for container throughput, and information from the World Bank for GDP analysis. The data covers both the sea and economic performance of Sri Lanka from 2004 until 2021, which corresponds to the period during which the Liner Shipping Connectivity Index (LSCI) has been published by UNCTAD. This time frame includes significant developments in maritime infrastructure

and global trade, making it crucial for understanding the impact of LSCI on economic performance.

All growth rates for LSCI, GDP, and container throughput are calculated relative to the constant base year of 2004, allowing for standardized measurement of growth over time and facilitating consistent comparison of performance trends throughout the study period.

Correlation analysis and simple linear regression models are employed to explore the relationship between LSCI growth, GDP growth, and container throughput growth at the Port of Colombo. The regression models were selected due to their ability to quantify the relationship between variables, while the ARIMA model was used to forecast future trends based on the time-series data available. The ARIMA model was chosen because it is well-suited for predicting future values in a series with established patterns, such as GDP and container throughput growth. The effect of LSCI growth on GDP and container throughput is calculated using regression, while the ARIMA model is used to predict future trends. All statistical analyses were performed using SPSS, and forecasting was conducted using EViews.

3. RESULTS AND DISCUSSION

3.1 Correlation Analyss -

Based on the results of the correlation, there is a high and positive connection between LSCI growth and GDP growth (r = 0.821, p-value = 0.000). Figure 2 shows the scatter plot of LSCI growth vs. GDP growth. The data points are aligned along an upward-sloping trend, confirming the strong positive correlation between LSCI growth and GDP growth. In addition, the container throughput growth at the Port of Colombo is highly correlated with the growth of the LSCI (r = 0.953, p-value = 0.000). Figure 3 illustrates the scatter plot of LSCI growth vs. container throughput growth. The close grouping of data points along a steep positive trend line indicates a very strong positive relationship between LSCI growth and container throughput growth.

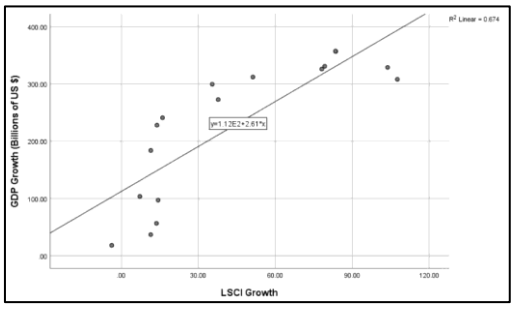

Figure 1 Scatter Plot of LSCI growth vs. GDP growth

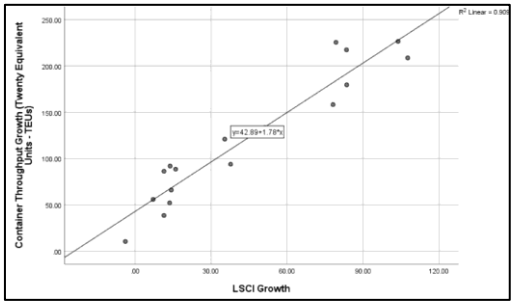

Figure 2 Scatter Plot of LSCI growth vs. con_thr_growth

3.2 Simple Liner Regression Analyss -

The relationship between LSCI growth and GDP growth is captured by the following regression equation:

$$\boldsymbol{GDP\ Growth} = \mathbf{112.4188} + \mathbf{2.614}(\boldsymbol{LSCI\ Growth})$$

The intercept (β_0) is 112.4188, representing the GDP growth when LSCI growth is zero. The coefficient for LSCI growth (β_1) is 2.614, meaning that for every one-unit increase in LSCI growth, GDP growth increases by 2.614 billion USD. This highlights the positive impact of LSCI on Sri Lanka's economic performance.

The relationship between LSCI growth and container throughput growth is represented by the following regression equation:

$$\boldsymbol{Container\ Throughput\ Growth} = \mathbf{42.89279} + \mathbf{1.781}(\boldsymbol{LSCI\ Growth})$$

The intercept (β_0) is 42.89279, representing the container throughput growth when LSCI growth is zero. The coefficient for LSCI growth (β_1) is 1.781, indicating that for every one-unit increase in LSCI

growth, container throughput at the Port of Colombo increases by 1.781 million TEUs. This demonstrates how improvements in maritime connectivity directly enhance port performance.

3.3 Forecasting Future Trends Using LSCI Growth -

This section forecasts future trends in GDP growth and container throughput growth in Sri Lanka, based on LSCI growth, using simple linear regression and ARIMA models for the period 2022–2031.
All variables in the model, including GDP growth, container throughput growth, and LSCI growth, are non-stationary. Therefore, to achieve stationarity, the analysis applies first-order differencing to each of these variables. The ARIMA (1, 1, 1) model was selected as the most appropriate model for forecasting the differenced data, yielding the best results in predicting GDP growth_diff and container throughput growth_diff. The forecast suggests continued growth in both GDP growth_diff and container throughput growth_diff, assuming LSCI growth_diff maintains its current trend. Figures 3 and 4 illustrate the forecasted trends for GDP growth_diff and container throughput growth_diff, with upper and lower bounds showing the potential variability in growth estimates.

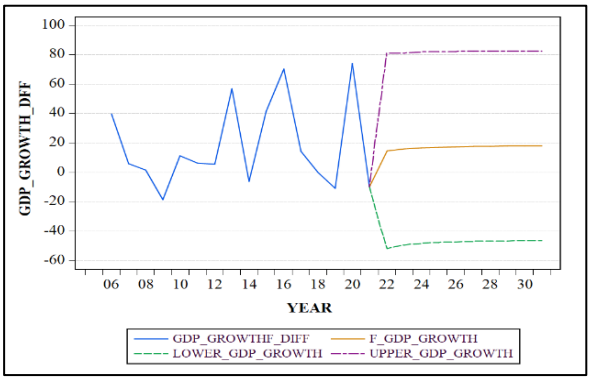

Figure 7 Forecasting results of gdp_growth_diff

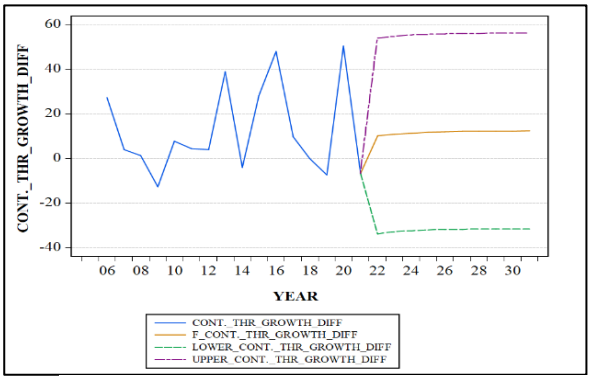

Figure 4 Forecasting results of con_thr _growth_diff

4. CONCLUSION

The study concludes that LSCI growth plays a significant role in Sri Lanka's economic performance. An increased positive correlation proves that boosting LSCI helps to increase trade, reduce shipping and encourage higher foreign investment. According to the regression, LSCI growth is directly linked to economic growth, as one extra unit of LSCI increases GDP by $2.61 billion and container shipment at the Port of Colombo by 1.78 million TEU. Based on forecasting models, GDP growth_diff and container throughput growth_diff will continue to grow, underscoring the significance of sustained investment in maritime infrastructure and connectivity.
According to the findings, improving the efficiency of Sri Lanka's ports should be done by focusing on ship services, making room for larger vessels and streamlining the procedures at the ports to shorten the processing time.

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Smart Mobility

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AUTOMATIC NUMBER PLATE RECOGNITION SYSTEM FOR SRI LANKAN VEHICLES USING DEEP LEARNING TECHNIQUES

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ABSTRACT - Today, with the massive growth in the number of vehicles in use, the importance of accurate Automatic Number Plate Recognition (ANPR) systems has become more popular. The objective of this study is to apply the developing model for Sri Lankan Vehicles to identify the accuracy-increasing points of NP detection and recognition. This study focuses on developing an ANPR system using a Deep Learning (DL) algorithm. The ANPR model is developed using the latest DL technique for object detection, You Only Look Once (YOLO), which is a type of Convolutional Neural Network (CNN) and uses Tesseract OCR for recognition of Number Plate (NP) characters.

Keywords: Automatic Number Plate Recognition (ANPR); Deep Learning (DL); Convolutional Neural Network (CNN); You Only Look Once (YOLO); Optical Character Recognition (OCR)

1. INTRODUCTION

Transportation is crucial for economic development and globalization, with population growth increasing demand and high vehicle counts. Vehicle identification is essential for parking, traffic demand analysis, and security purposes. Vehicle number plates are unique notations for individual vehicle identification, but manual identification is time-consuming and less accurate as vehicle count increases[1]. Thus, Automatic Number Plate Recognition Systems (ANPR) significantly impact tasks like traffic management, law enforcement applications, and electronic toll collection[2]. In the Sri Lankan context, several studies have proposed ANPR systems using traditional image processing methods[3]. They are facing challenges due to real-world conditions, such as varying camera angles, lighting, and motion blur. In comparison to the prior studies in Sri Lanka which primarily focus on traditional image processing methods[3], this paper focus is on the basis of deep learning algorithms (YOLOv11) for the detection process and combination with OCR to recognize characters to improve accuracy across varied camera angles.

2. MATERIALS AND METHODS

Traditional ML methods like Support Vector Machine (SVM)[4], Connected Component Analysis (CCA)[5], and K-nearest Neighbour (KNN)[5] have limitations in accuracy and speed when applied to large-scale ANPR systems. Due to growing data volumes, ML techniques are less suitable. In present studies, deep learning has come into the picture. The majority of the present studies of ANPR are done using Convolutional Neural Network (CNN) techniques. Also, there are several types of CNN. Namely, You Only Look Once (YOLO), Region-Based Convolutional Neural Networks (R –CNN), Fast R, CNN and Faster R – CNN. CNN specializes in image processing and object detection[1], [6]. The ANPR model is developed mainly under two phases.

I. Develop the number plate detection model. YOLO (You Only Look Once) is the object detection technique used in this study.
II. Recognize the characters of the detected Number Plates. - Optical Character Recognition (OCR) engines can be used.

2.1 Data Collection

The required data types can be categorized in two ways.

I. A dataset to train and validate the model - The dataset required for training and validating the model should include with high number of images for a more accurate model [2]. The datasets were obtained through https://universe.roboflow.com/, which can be accessed for free. The dataset used in this study included around 7000 test images & 1200 validation dataset.

II. A sample Sri Lankan dataset to test the model for Sri Lankan Vehicles - The dataset was collected using surveillance footage from a pedestrian flyover (which is around 6 meters high from the ground) and ground level/the side of the road (The Camera is standing at about 1 meter height from the ground).

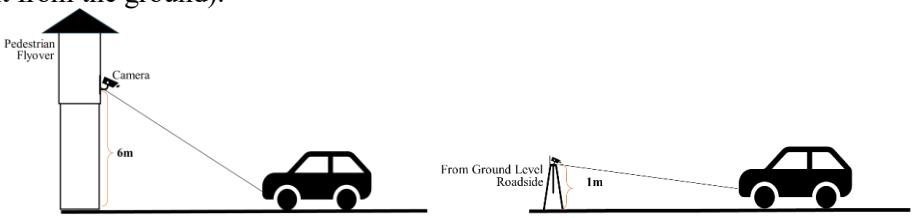

Figure 8: Side view of Camera position and Angle from pedestrian Flyover & Ground Level

2.2 Model Development

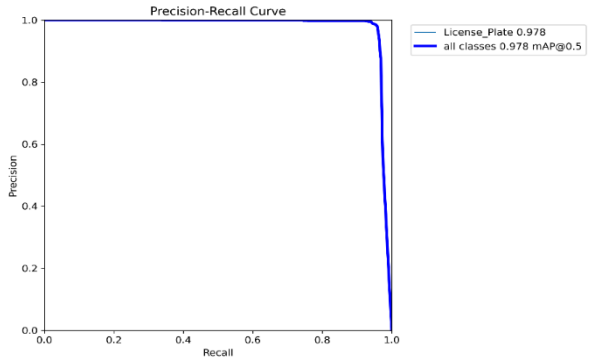

Figure 9: mAP of the Trained Model

Phase I of the model development focuses on training the YOLOv11 object detection model and evaluating the accuracy of the model. YOLO is a real-time object detection model performed in a single network pass, achieving accuracy exceeding 97% in studies[7]. YOLO uses a single convolutional network that simultaneously predicts multiple bounding boxes and class probabilities for those boxes.[8] The accuracy of the model is calculated using mAP (Mean Average Precision). It is the parameter used to check the accuracy and model fitness in DL models. mAP is checked after 150 epochs to check the model stability and accuracy, and a mAP of 97.8% is achieved as the best mAP for the model.

Phase II is for recognizing the characters of vehicle NPs using the detected NPs from the early phases. An Optical Character Recognition (OCR) engine is used for identifying characters of numbers and letters where Tesseract-OCR is used in this study. After the model was built tested it with Sri Lankan vehicle videos and images.

Figure 10: Output of NP Detection & recognition from Pedestrian Flyover and Ground Level, respectively

3. RESULTS AND DISCUSSION

In this study, video data were gathered from two different perspectives to view the performance of the vehicle number plate (NP) detection and recognition system.

Both angles were examined for their effectiveness in NP recognition with the help of the YOLOv11 model; further, they were recognized through Tesseract OCR.

3.1 Number Plate Detection Performance

The YOLOv11 detection model demonstrated strong performance across various camera heights and angles, demonstrating its ability to accurately identify vehicle number plates in congested Sri Lankan Road environments.

3.2 Character Recognition Performance

Although the detection was reliable, there was a wide range of differences in OCR-based character recognition accuracy between the two perspectives.
Ground-Level Footage: Character recognition accuracy was improved with an average of 70%.
Pedestrian Flyover Footage: Character recognition precision was compared with ground-level videos and notably low. The increased distance, camera angle and resolution limitation had unexpectedly negative effects on OCR performance.

3.3 Factors affecting OCR Accuracy

The performance of OCR in Sri Lankan vehicles is limited by font size, style, proximity to the camera, low contrast of images, occlusion and vehicle queues, and damaged number plates and obstacles. Province letters printed smaller than numeric parts make them difficult to read, while low contrast can deceive OCR engines. Damaged number plates in vehicles like buses and three-wheelers contribute to inaccuracies.

4. CONCLUSION

In conclusion, this study indicates that the best way to have higher accuracy in ANPR models is to set up the camera in a ground-level position.
For future work, it is suggested to combine this ANPR model with vehicle classification before this model. So, it will be beneficial for traffic management purposes. And suggested developing the model for real-time ANPR systems, which will be beneficial for transportation.

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PREPROCESSING AND STRUCTURING RAW GPS DATA FOR TRAVEL TIME AND DWELL TIME ANALYSIS OF PUBLIC TRANSIT BUSES

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ABSTRACT - Sri Lanka's public bus system faces significant reliability issues due to variable travel times, complex traffic patterns, and weather impacts. These challenges reduce passenger confidence and increase congestion from private vehicle use. To address this, the present study develops a machine learning-based framework to predict short-distance bus travel times along the Kandy–Kadugannawa route. Raw GPS logs from public buses including latitude, longitude, timestamp, speed, and device ID were collected and preprocessed in Python. Noise was removed by eliminating entries with missing coordinates, duplicate records, and unrealistic speeds (<0 km/h or >100 km/h). A ±10 m spatial corridor was created using GeoPandas and Shapely to ensure route adherence, retaining over 90% of records for analysis. Processed data was used to compute segment travel times and dwell times, which, along with rainfall data, formed the feature set for three predictive models: KNN, ANN, and LSTM. Among these, the LSTM model achieved the highest accuracy (MAE = 55.3 s, RMSE = 81.8 s), effectively capturing sequential traffic patterns. The study demonstrates that integrating GPS and weather data can provide reliable, real-time bus travel time predictions, supporting the development of intelligent public transportation systems in Sri Lanka.
Keywords: GPS data preprocessing; geopandas; spatial corridor; shapely

1. INTRODUCTION

Accurate estimation of travel and dwell times is essential for improving the efficiency of public transport systems. GPS technology has made it easier to track vehicle movements with high spatial and temporal detail. However, raw GPS data, containing only location coordinates and timestamps, has limited use unless processed to extract meaningful operational insights. Challenges such as device calibration errors, signal drift, missing data due to network issues, and spatial inaccuracies complicate this process. These issues are even more significant in developing countries like Sri Lanka, where diverse traffic patterns, frequent unscheduled stops, and limited infrastructure create an unpredictable transport environment. Unlike structured systems in developed countries, Sri Lanka's public transport demands more flexible and robust data handling. This study presents a structured framework that first cleans the raw GPS data by addressing noise, missing values, and spatial errors. More importantly, it focuses on extracting key operational features such as travel times between stops and dwell durations at bus stops. The resulting datasets support accurate system evaluations and provide a foundation for real-time monitoring, predictive modeling, and data-driven transport planning.

2. METHOD

The dataset used in this study consisted of raw GPS logs from public buses operating along the Kandy–Kadugannawa route in Sri Lanka, an area characterized by varied terrain and complex traffic conditions. Each record included latitude, longitude, timestamp, speed, and device ID, structured using pandas. Initial preprocessing removed entries with zero coordinates caused by signal loss and standardized timestamps, discarding missing or corrupt values. Duplicate records, often resulting from

retransmissions, were also eliminated to maintain data quality. Speed outliers were filtered by discarding points with speeds below 0 km/h or above 100 km/h (since negative speeds are physically impossible and speeds above 100 km/h are unrealistic for urban buses), applying logical thresholds through pandas. Spatial refinement was conducted using geopandas and shapely by creating a ±10-meter bounding corridor along the route centerline modeled as a LineString. GPS points outside this corridor were classified as spatial outliers and removed, ensuring adherence to the actual bus path. This spatial cleaning process is illustrated in Figure 1.

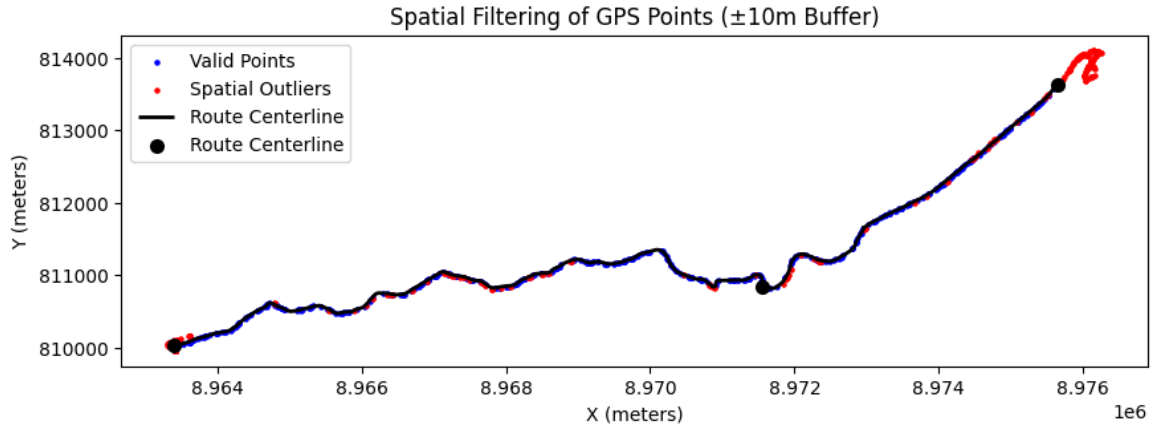

Figure 1. Spatial filtering showing bounding corridor and valid GPS points inside the route buffer.

Following the data cleaning and spatial refinement process, bus stop locations were imported from a verified external dataset and cross-validated through targeted field observations along the Kandy–Kadugannawa corridor. Around each bus stop, a 30-meter dynamic buffer was virtually generated using spatial analysis tools, taking into account typical GPS device positional accuracy in urban environments. This approach is similar to techniques described by Shiveswarran & Thayasivam (2023). in Kandy route GPS cleaning Dwell events were identified by detecting sequences of GPS points with recorded speeds of zero within these buffers, with entry times corresponding to the first detected zero-speed point and exit times to the last. To estimate segment travel times between bus stops, only GPS points located outside the stop buffers but within the defined in-corridor boundary were considered, ensuring that travel time calculations accurately reflected true vehicle movement between stops rather than stationary periods. This systematic approach enabled the reliable extraction of both dwell times and segment travel times from the cleaned GPS dataset, forming a robust foundation for subsequent transit performance evaluations, travel time reliability analysis, and predictive modeling of public transport operations in complex and heterogeneous urban traffic conditions like those found in Sri Lanka.

3. RESULTS AND DISCUSSION

3.1 Spatial Filtering and Dataset Structuring

The raw GPS data from public buses were processed into two structured datasets: dwell times at bus stops and segment-based travel times. Cleaning was performed using pandas, geopandas, and shapely. Faulty entries with zero coordinates, missing or invalid timestamps, and duplicates were removed. Unrealistic speed records were filtered using thresholding in pandas. Spatial refinement involved creating a ±10meter bounding corridor around the bus route centerline, modeled as a LineString through known stops. Points outside the corridor were treated as spatial outliers and discarded. Figure 2 shows the comparison of Raw GPS data vs the Cleaned GPS data. Figure 1 illustrates the spatial filtering step using a bounding corridor, whereas Figure 2 compares the entire GPS dataset before and after all preprocessing stages including timestamp validation, speed filtering, and spatial refinement

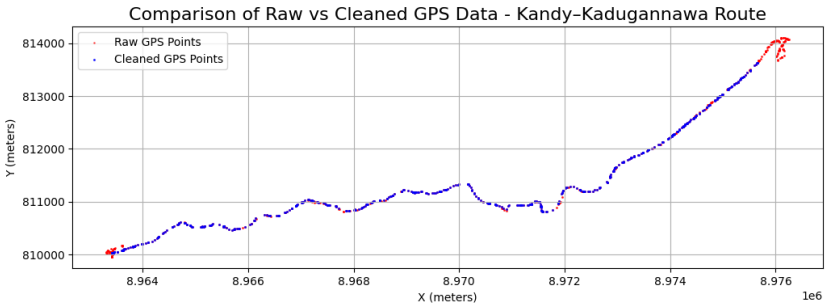

Figure 2. Comparison of Raw vs Cleaned GPS Data.

3.2 Dwell Time and Segment Travel Time Analysis

To evaluate operational performance, dwell times and segment travel times were calculated from the cleaned GPS dataset. Dwell time for each stop was determined by aggregating all zero-speed events detected within the 30 m stop buffers. Average dwell times were computed for each stop across the dataset using Pandas group-by functions and visualized using bar plots to compare terminal and intermediate stops. Segment travel times were calculated as the elapsed time between exiting one stop buffer and entering the next. Average travel times for each segment were then aggregated and compared across the route. These were further analyzed by location type (urban vs. semi-rural) and plotted to identify congestion-prone sections. The analysis showed that dwell times were longest at terminal hubs such as Kandy Railway Station, Good Shed Bus Stop, and Kadugannawa Town Centre, where trips typically begin or end due to scheduled dispatching, boarding delays, and operational turnaround activities. In contrast, peripheral stops exhibited much shorter dwell durations. Segment travel times were longest in urbanized sections within central Kandy due to congestion and frequent stop–go traffic, while segments closer to Kadugannawa displayed smoother flow and shorter travel times. These findings confirm that stop-level demand and traffic density significantly influence both dwell behavior and running times, consistent with observations in similar studies (Farzin & Sajjadi, 2018).

4. CONCLUSION

This study presented a systematic approach to clean and structure raw GPS data for accurate travel time and dwell time analysis along the Kandy–Kadugannawa corridor. The findings revealed that dwell times were longest at terminal hubs such as Kandy Railway Station, Good Shed Bus Stop, and Kadugannawa Town Centre due to scheduled dispatching and boarding delays. Segment travel times were highest in urban sections of central Kandy due to congestion, while peripheral segments toward Kadugannawa showed smoother flow and reduced travel times.

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We sincerely thank the Department of Civil Engineering, University of Peradeniya, for their continuous support and encouragement throughout this research. Special appreciation is extended to the Kandy Multimodal Transport Terminal (KMTT) office for providing access to the GPS datasets, which were fundamental to the success of this study. Their cooperation and assistance are deeply acknowledged

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GEO – AI ENHANCED TOD ASSESSMNET: A NODE PLACE ANALYSIS OF RAILWAY AND BUS STATIONS IN THE WESTERN PROVINCE, SRI LANKA

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ABSTRACT - Effective assessment of Transit-Oriented Development (TOD) potential remains a key gap in transport planning, particularly in developing countries. In many cities, the transit-oriented development (TOD) strategy is considered a practical solution for dealing with the challenges embedded in transit system construction by improving the interaction between transit and surrounding land use. In Sri Lanka, many urban and regional plans propose TOD without systematically evaluating actual potential. Existing methods focus largely on rail systems, overlooking bus networks and using limited indicators. This study addresses these gaps by applying a Geo-AI enhanced Node-Place Model to assess TOD potential at 92 railway stations and 25 bus stands in the Western Province. The model evaluates the balance between transport connectivity (Node) and surrounding development (Place), using the Entropy Weight Method to derive indicator weights. The TOD potential was further analyzed using K-Means clustering for typology classification and XGBoost to identify key influencing indicators. Results show substantial variation in TOD readiness, with many nodes lacking a balance between transport and development attributes. Most influential factors identified. This research offers a scalable, data-driven framework, integrating AI techniques to support planners and policymakers in prioritizing TOD strategies more effectively.

Keywords: Transit Oriented Development, TOD – ness, Node Place Model, Transport Planning, Geo AI, Sustainable Mobility Planning, Strategic Planning and Decision Making

1. INTRODUCTION

With urbanization expected to reach 70% by 2050, Transit-Oriented Development (TOD) has emerged as a strategic approach to enhance sustainable urban mobility [1]. While TOD focuses on compact, mixed-use development around transit hubs to reduce car dependency and improve livability, many Sri Lankan urban plans like WRMPP (2016) and CoMTrans (2014) propose TOD initiatives without data-driven assessments. This results in mismatches between transport connectivity (Node) and land development (Place). Existing TOD studies predominantly focus on railway stations, overlooking the vital role of bus stands. Furthermore, current methods often rely on simplistic indicators, lacking comprehensive, AI-integrated frameworks. There is a significant gap in applying advanced models such as the entropy-weighted Node-Place Model and machine learning to assess TOD systematically in developing regions like Sri Lanka.

2. MATERIALS AND METHODS

This study assessed the TOD potential of 92 railway stations and 25 bus stands in Sri Lanka's Western Province using a Geo-AI-enhanced Node-Place model. A total of 39 indicators, aligned with TOD principles, were used to evaluate Transport (T), Oriented (O), and Development(D) attributes.

2.1. Study Area & Data Sources

The Western Province was selected as the case study. Data were obtained from the Sri Lanka Railway Department, JICA CoMTrans GIS layers, web scrapings, OpenStreetMap, field surveys, and web platforms (e.g., Routemaster.lk, Google Maps).

2.2. TOD Index and Classification

TOD Index values were calculated by summing the weighted T, O, and D scores. Nodes were classified using the Node-Place typology (e.g., Stress, Accessibility, Un - sustained Node/Place, Dependency).

Data Type	Source
Passenger Flow Data	Railway Department of Sri Lanka, JICA ComTrans GIS layers
Land use and Population Data, FAR	Web Scraping, JICA ComTrans GIS layers,
Willingness Inquiries	People Interviews
SGI, CCI, Entropy of the Land Properties	Used Standard Formulas

K-Means Clustering was used to group nodes.

2.3. AI Modeling

Decision Tree and XGBoost models were applied to identify which indicators most influence passenger volume, helping determine critical TOD success factors.
Decision Trees and XGBoost were selected for their interpretability and effectiveness in identifying key influencing variables in structured datasets. XGBoost, in particular, offers high predictive performance and handles multicollinearity well, making it ideal for TOD-related decision-making tasks where multiple indicators interact.

3. RESULTS AND DISCUSSION

3.1. TOD Index Calculation & Node Place Model Development

The TOD Index was calculated using 39 normalized and entropy-weighted indicators under the T (Transport), O (Opportunity), and D (Development) attributes. Based on these scores, the Node-Place Model classified transit nodes into five typologies,

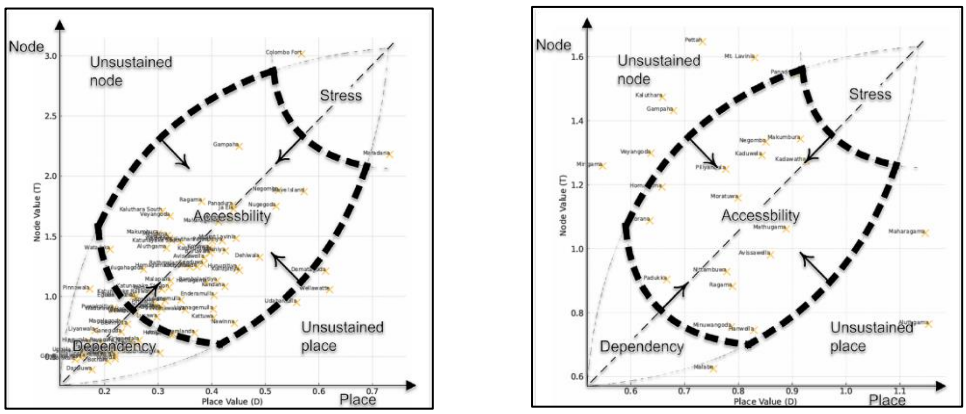

Figure 11: Developed Node Place Model for Bus Stands & Railway Stations

3.2. K - Means Clustering

K-Means clustering (K=3 via Elbow Method) further grouped nodes by TOD readiness.

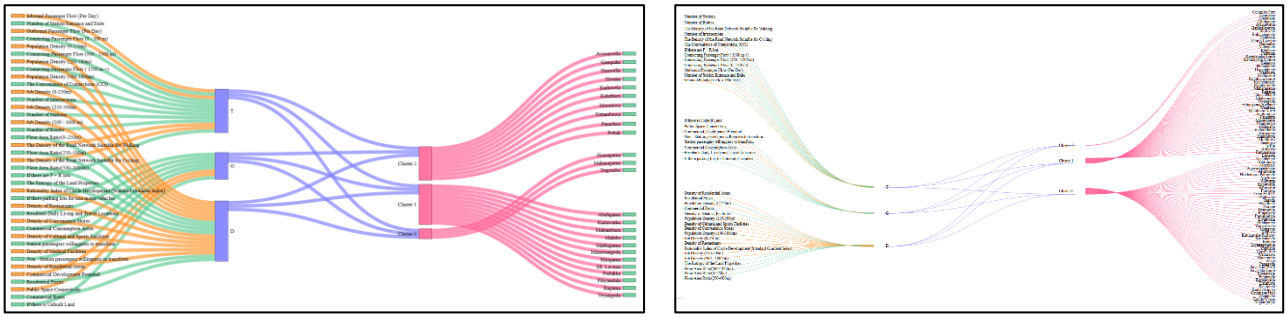

Figure 12: Sankey Diagrams for Clustering Results

XGBoost Model

To identify key influencing factors, an XGBoost model was developed. The model performed well (R^2 = 0.815), supporting data-driven planning. These insights provide a robust foundation for targeted TOD strategies and infrastructure investment.

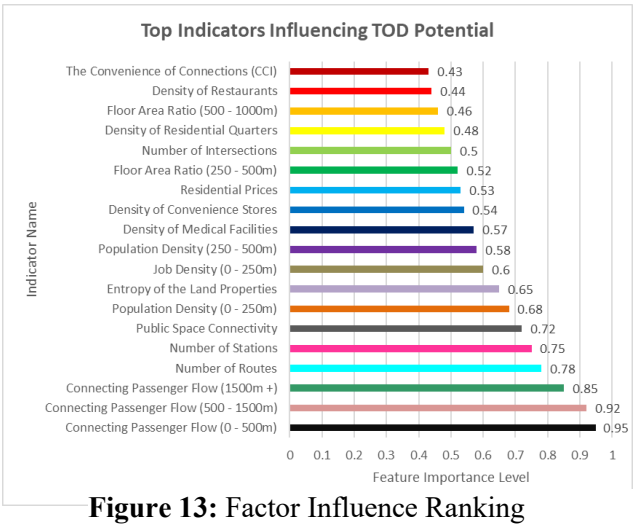

Figure 13: Factor Influence Ranking

4. CONCLUSION

This study assessed TOD potential across 117 transit nodes in Sri Lanka's Western Province using a Node-Place Model, K-Means clustering, and XGBoost analysis. The results revealed major differences in TOD readiness and highlighted key factors.The approach provides a practical, data-driven tool to guide future TOD planning and investment.

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PASSENGER COUNTING USING THE YOLO ALGORITHM FOR TRANSPORT INFRASTRUCTURE OPTIMIZATION

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ABSTRACT - In urban areas, transport systems face numerous challenges regarding efficiency and resource allocation due to a lack of accuracy in estimating the number of passengers and vehicle occupancy. The importance of the YOLOv11 (You Only Look Once) algorithm is in detecting passenger flow (number of people in and out). YOLO's accurate and high-speed object detection leads to finding simultaneous objects and seamless passenger tracking. The method employed in this study involves recording a video with a CCTV camera and saving it as an MP4 file. Calculations were performed using recorded video and written code in Python and its libraries. Currently, systems use image processing to detect objects based on information in one frame. This research aims to provide transport authorities with information to optimize scheduling, reduce congestion, and increase overall pedestrian operation efficiency. Owing to the maximization of Artificial Intelligence (AI), modern systems can be used in the transportation engineering field to enhance sustainable development and build smart cities.

Keywords: YOLO (You Only Look Once), AI (Artificial Intelligence), detection, tracking, Passenger Counting

1. INTRODUCTION

In modern society, transportation systems play a major role with the increase in the number of vehicles and passengers in cities. An efficient transportation system is crucial for mitigating traffic congestion, reducing fuel consumption, and reduction air pollution in cities. Rapid urbanization and population increase create challenges to transportation systems. In these circumstances, modern technologies, such as Artificial Intelligence (AI), can be used to mitigate the problems that occur in city transportation. AI can be used for object detection to analyze traffic patterns and passenger dynamics. YOLO, which stands for "You Only Look Once," is a state-of-the-art real-time object detection algorithm introduced in 2015 by Joseph Redmon. The algorithm divides an input image into a grid of S×S cells, with each cell responsible for predicting the bounding boxes and class probabilities of objects within that cell. The bounding box predictions include the center coordinates (x,y) and dimensions (w,h), whereas the confidence score reflects the likelihood of an object's presence. YOLO uses a convolutional neural network (CNN) to extract features from an image and combines features from multiple scales to enhance the detection of objects of varying sizes. In this research, the latest YOLOv11 algorithm, YOLOv11-S (Small) model, is utilized to enhance passenger counting and detection tasks. This model ensures comprehensive object detection and object tracking capabilities to enhance real-world transportation scenarios. By using the YOLO algorithm, this study aims to develop a system for real-time data collection and analysis. The main objective of this research is to accurately count passengers to utilize in assessing public transportation efficiency, to identify ways to improve passenger comfort, and to optimize transportation infrastructures.

2. LITERATURE REVIEW

In one of the latest study widely recognized its effectiveness of, the YOLO algorithm for passenger counting and transportation infrastructure optimization. This study proposes a real-time automatic passenger counting system for public buses using YOLOv8. This study used the CCTV camera or smartphone video footage to detect and count passengers. The YOLOv8 has demonstrated detection accuracies typically ranging from 69% to 80% across real-world scenarios, making it suitable for

live monitoring applications. The study also proposed mitigation of, challenges such as sensitivity to camera angles, lighting conditions, and blockage camera position by an optimal camera positioning.[1] The other research proposes a robust counting system using CCTV camera footage and YOLO based deep learning models. It combines image processing and real-time object detection to enhance transport infrastructure using accurate, scalable, and privacy-conscious passenger monitoring under variant conditions.[2] The next research presents a robust and practical approach for real-time object counting using YOLOv5 detection with the velocity-based frame-down sampling algorithm, which adjusts frame processing frequently based on the motion speed of objects.[3] When compared to other YOLO versions, YOLOv11 is more accurate, speed, resource efficient and has real-time capability (resource-constrained environments).

3. APPROACH METHODOLOGY

The methodology used in this study is capturing videos from several locations, which are processed to convert the videos into individual frames. A custom-trained YOLOv11 object detection model was developed to identify passengers. The model was trained using diversified labeled datasets to detect and count passengers accurately, and used 600 images collected from different places. The dataset was divided into 70% for training, 20% for validation, and 10% for testing, and annotation was done with the LabelImg tool. For this dataset, training hyperparameters are batch size 8, image size 640px, and epochs 100. For the training process computational minimum requirement of 8GB RAM and an NVIDIA GPU with 4GB of VRAM and CUDA 12.1 Toolkit is required to accelerate the GPU from NVIDIA. Python (version 3.11) and OpenCV were utilized for video processing, frame extraction, and model implementation. The outputs of the YOLOv11 model, including the detected passenger counts, were validated against manually collected data. The comparative analysis provided insights into the model's accuracy and performance in real-world scenarios.

4. RESULTS AND ANALYSIS

This research used data from several locations and carefully selected field locations to analyze passenger and traffic flow. Passenger counting was conducted in four high-passenger traffic locations: Maradana, Makubura, Pettah, and Kandy Hospital. These locations were in urban areas with significant passenger activity. To validate the accuracy of the AI model for passenger counting, a 5-minute CCTV MP4 video footage was used. The collected video footage was initially manually counted at each data collection location. The developed AI model with YOLO again applied video footage to detect and count the passengers. Results of manually collected counts for passengers and AI model-developed count outputs were compared to determine the accuracy of the model.

4.1. AI Model Counted Passenger Locations

In each location, MP4 5-minute video footage was imported to the developed AI model with YOLO, which detects and counts the in- and out-passengers.

Figure 1. Using an AI Model Counting the Entry and Exit Passengers

4.2. Analysis with Manual and AI Model Passenger Count

A comparative analysis was conducted between manually counted and AI model counted for accuracy and efficiency. Results indicated that this AI model achieved high accuracy levels closely matching the manual counts, while significantly reducing the time and human effort required. Minor differences were observed during peak crowd situations due to obstruction, but overall, the AI

model demonstrated strong reliability and scalability for passenger monitoring applications. The linear regression of the AI model was 0.9999. In this research accuracy of the AI model is evaluated with the total number of passengers.

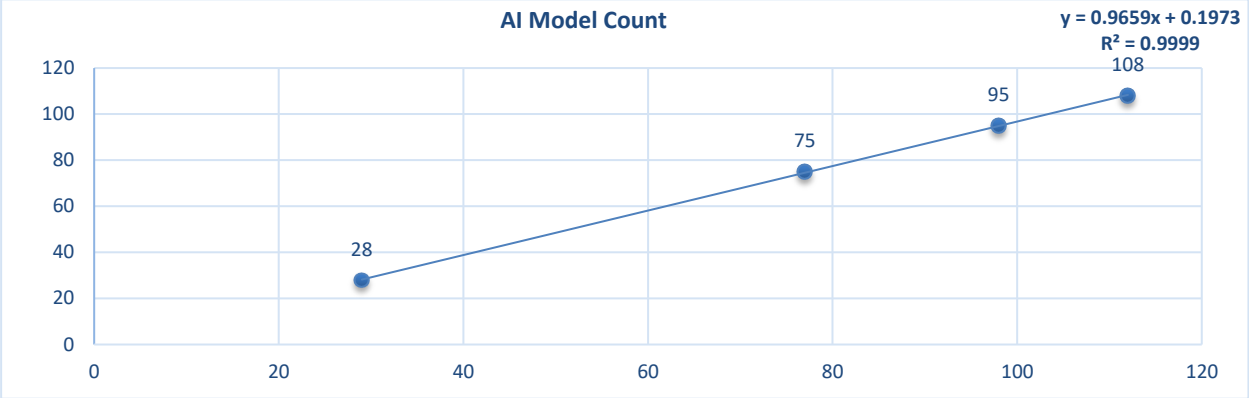

Figure 2. Graphical representations of comparative results and detection outputs

Table 1. The Accuracy of The AI Model Passenger Counts at Each Location

Location	Manual Count	AI Model Count	Accuracy
Makubura	29	28	97%
Maradana	77	75	98%
Pettah	112	108	96%
Kandy Hospital	98	95	97%

5. RECOMMENDATION

Future research should address challenges such as passenger blockage by using the multi-camera system and depth sensing technique. Enhancing YOLO performance in low-light and crowded environments through image processing is vital. Integrating YOLO with IoT and sensor fusion can enable real-time analytics and boost detection accuracy. For the future real-time detector implementation, we need to consider the cost of the material. Additionally, these ensure a secure passenger transportation infrastructure and passenger monitoring in public environments.

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IMPACT OF RIDE-HAILING APPS ON THE THREE-WHEELER TAXI MARKET IN SRI LANKA

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ABSTRACT
This study investigates the impact of ride-hailing apps on traditional three-wheeler taxi market in Sri Lanaka, focusing on adoption patterns, market dynamics, and stakeholder perspectives. Using a mixed-methods approach data was collected from 107 drivers and 158 passengers across Colombo (urban), Kegalle (semi-urban) and Monaragala(rural) districts. The analysis integrates survey data, government and industry report, and statistical testing. Results highlights a strong urban-rural and generational divide in ride-hailing adoption. Smartphone ownership, age, and geographic area significantly influence ride-hailing usage. Youngers, urban drivers and passengers exhibit higher adoption due to greater digital literacy. Ride-hailing drivers complete more trips per hour, due to technological advantages. However, adoption is limited in rural regions due to technological, infrastructural, and awareness gaps. From passengers' perspective, price, convenience, safety are key motivators for ride-hailing preference. Despite ride-hailing growth, traditional three-wheelers remain dominant in rural areas, showing the continued reliance on conventional, non-digital transportation services. To ensure inclusive development, the study recommend targeted policy interventions, smartphone and data subsidies and hybrid service models. This research contributes to transport planning by illuminating regional and demographic disparities in digital mobility adoption.

Keywords: Ride-hailing, Three-wheelers, Sri Lanka, Driver adoption, Passenger preference

1. INTRODUCTION

Three-wheeler taxis have been integral to Sri Lanka's transport network since the 1980s, offering flexible, affordable service. With the advent of ride-hailing platforms like Pick Me (2015) and Uber (2016), the traditional three-wheeler model has been disrupted by app-based mobility solutions offering GPS navigation, digital payment and price transparency.

While ride-hailing has gained traction in urban centers, especially Colombo, adoption in rural areas remains low due to smartphone penetration and connectivity gaps (Thilakarathnea1 & Jayaratneb, 2019a)). Existing studies have primarily focused on passenger satisfaction and urban mobility benefits of ride-hailing services (Rathnayaka, 2024), and a few have examined operational and income effects on three-wheeler drivers (Kumarage et al., 2010). However, the combined and comparative analysis of both driver and passenger perspectives, especially across different geographical regions in Sri Lanka, remains limited.

This study differentiates itself by capturing insights about understanding ride-hailing's socioeconomic impact on three-wheeler drivers, regional disparities in ride0hailing adoption, and shifting passenger behavior.

The objectives of the study are:

- To analyze the development and adoption of ride-hailing vs three-wheeler services in Sri Lanka.
- To examine the effect of ride-hailing on driver livelihoods, customer preferences, and operational dynamics.
- To offer policy-relevant insights into balancing traditional and digital mobility modes

2. MATERIALS AND METHODS

A mixed-method research design was employed.

Primary Data Collection - Structured surveys were conducted with 107 drivers (both ride-hailing and traditional) and 158 passengers across urban (Colombo), semi-urban (Kegalle), and rural (Monaragala) context. Survey questions addressed demographics, smartphone ownership, service preferences.

Questions and Criteria Design- Questionnaires were developed based on literature and pilot testing. Key variables included:

- Age, Area, Gender
- Smartphone ownership and Ride-hailing awareness
- Usage frequency and Service type
- Perceived benefits: Safety, Convenience, Price

Secondary Data - Sourced from government publications, academic papers, and transport industry reports.

Analysis Tools-

- Descriptive statistics (Excel, SPSS)
- Inferential tests: Chi-square, ANOVA
- Thematic analysis for open responses

3. RESULTS AND DISCUSSION

3.1 Urban-Rural Divide

Ride-hailing adoption was 27.6% among drivers in Colombo vs approximately no in Monaragala (X^2 =11.10, p=0.04). Passengers mirrored trend 78% in Colombo vs 6.7% in Monaragala preferred ride-hailing.

The urban-rural gap reflects unequal smartphone penetration (65.2% o tradition drivers owned smartphones) and infrastructure limitations in rural areas (Nimeshika & Pradeepa, 2019).

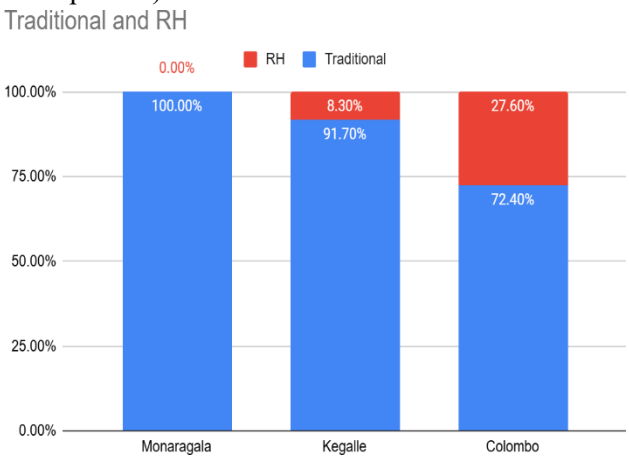

Figure 14. Traditional vs. ride-hailing – Urban Rural divide (Drivers)

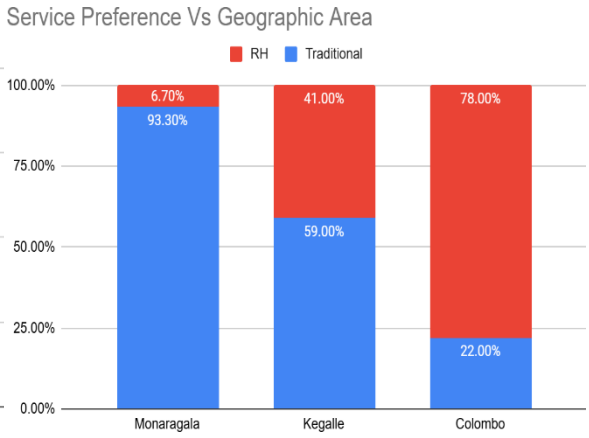

Figure 15. Traditional vs. ride-hailing – Urban Rural divide (Passengers)

3.2 Age and Technology Adoption

Younger drivers (25-35) adopted ride-hailing at 26.7%, while only 3.3% of drivers aged 55+ used these platforms (X^2=26.494, p<0.001). Younger passengers (18-35) prefer ride-hailing services 2x more than older groups (45+)

The generational divide highlights digital literacy barriers for older drivers, who often lack smartphone proficiency. Younger users, more comfortable with apps, drive ride-hailing growth in cities.

3.3 Operational Efficiency and Driver Livelihoods

Ride-hailing drivers completed 4.2 trips/hour vs, 1.9 trips/hour for traditional drivers (ANOVA F=116.203, p<0.001). Ride-hailing efficiency comes from automated dispatch and cashless payments, reducing idle time, commission fees may offset income gains, echoing concerns in Kumarage et al. 2020.

3.4 Passenger Preferences

Pricing and safety are top reasons for ride-hailing preference in Colombo and no significant difference in ride-hailing usage between male and female passengers (X^2=0.000, p=0.983).
Ride-hailing fixed fares and tracking features appeal to urban passengers, while rural users rely on trust-based negotiations with drivers.

4. CONCLUSION

This study reveals ride-hailing's urban dominance in Sri Lanka, driven by smartphone access and generational divides. To ensure equitable mobility, hybrid models (e.g., SMS bookings) (Divall et al., 2021) and targeted digital inclusion (Thilakarathnea1 & Jayaratneb, 2019b) are critical. Future research should track long-term income effects and evaluate rural pilot interventions.

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DEVELOP A BUSINESS STRATEGY FOR MATTALA INTERNATIONAL AIRPORT

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ABSTRACT: Airports function not only as transportation hubs but also play a significant role in national economic development by generating diverse business opportunities. The Sri Lankan government also developed Mattala Rajapaksa International Airport (MRIA) to enhance Sri Lanka's aviation sector and the country's overall economy. Still, it remains underutilised due to low passenger traffic, environmental issues, limited airline partnerships, poor Marketing, and financial losses. This research aims to develop comprehensive business strategies for MRIA in Sri Lanka, addressing the challenging situation by analyzing successful models from similar airports in developed countries. A comparative analysis was conducted through a literature review to identify key revenue-generating strategies, and three potential business models were proposed. Promoting MRIA as a Tourist Hub, Promoting MRIA as a Freight Forwarding Hub, and Promoting MRIA as an Aviation Training School. To evaluate the above strategies, an expert opinion survey was conducted among 20 aviation industry experts, and the data was analysed using the Analytic Hierarchy Process (AHP). Due to MRIA's geographic advantage and Sri Lanka's solid tourist sector, the result suggests that **promoting MRIA as a tourism hub is the most practical business strategy for MRIA**. This study emphasizes the necessity for a deliberate, data-driven approach to develop and enhance the operations of MRIA as a profitable airport. Policymakers and aviation stakeholders may use this data to help propel MRIA's development into a prosperous international airport.

Keywords: Airports, Mattala Rajapaksa International Airport (MRIA); Airport Business Strategy; Revenue Generation in Aviation; Underutilized Airports

1. INTRODUCTION AND OBJECTIVES

1.1. INTRODUCTION

An airport is an important part of the national economy of a country, but not all can get the maximum benefit from it. This research focuses on developing revenue-generating strategies for underutlized airport. MRIA is the same case in Sri Lanka. MRIA, also known as Hambantota International Airport (HIA), was built in March 2013 as an alternative international airport to Bandaranaike International Airport (BIA). MRIA is situated in the southern province inside the 'Mattala' region of the 'Hambantota' district, recognized as one of Sri Lanka's districts with the lowest per capita income. The construction of the MRIA commenced in 2009 with the assistance of a concessional loan program offered by the Chinese government. MRIA is expected to serve as a marine and air interchange operations centre in conjunction with the expansion of Hambantota port, with the additional purpose of attracting travellers from the Middle East to the region. However, MRIA has not yet achieved its targets. The future of MRIA is doubtful due to the significant sunk costs and ongoing losses, which harm the Sri Lankan economy. In order to improve MRIA utilisation, a viable and practical business strategy should be established. This research focuses on a realistic business model that should be identified to increase usage, leveraging MRIA's infrastructure. [1][2][3]

2. METHODOLOGIES

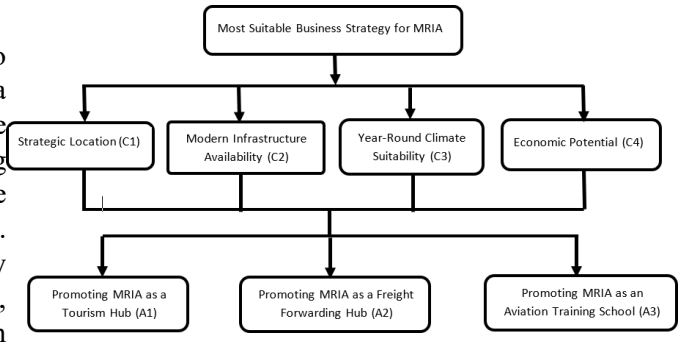
2.1. DATA COLLECTION

The data collection process for this research is done through a structured survey to ensure a comprehensive evaluation of business strategies for MRIA. Initially, a comprehensive literature review was conducted to understand the MRIA's current situation, global airport business models, and best practices in revenue generation. Following this, a comparative analysis was conducted using three airports (Norwich Airport in the UK, Chubu Centrair in Japan, and Bellingham Intl in the USA) with similar characteristics from developed countries to identify the strategies they employed for revenue generation.
Norwich Airport (NWI) in the United Kingdom, despite its small size and limited traffic, generates significant profit by focusing on cargo operations and freight transport, which supplement passenger-related revenue. This strategy demonstrates how efficient use of low congestion and non-aeronautical services can ensure financial sustainability. Similarly, Chubu Centrair International Airport's secondary terminal (NGO) in Japan benefits from proximity to a major tourist hub, generating notable profit through tourism-driven demand and effective regional integration. In contrast, Bellingham International Airport (BLI) in the USA has diversified its revenue streams by forming strategic partnerships, particularly with aviation training services like Bellingham Aviation Services, proving the value of non-traditional aviation activities. Compared to these airports, Mattala Rajapaksa International Airport (MRIA) has greater infrastructure capacity but remains underutilized. By adopting strategies such as cargo logistics (as in NWI), tourism collaboration (as in NGO), and aviation education (as in BLI), MRIA can optimize its operations and improve financial performance.[4], [5], [6]

Through this analysis, three potential business strategies were identified for MRIA: (1) promoting MRIA as a tourism hub, (2) promoting MRIA as a freight forwarding center, and (3) establishing an aviation training school. Developing as a Freight Forwarding Hub strategy was selected because MRIA has modern infrastructure, a large available area, and low air traffic, making it ideal for handling cargo operations. Its proximity to Hambantota Port and major sea routes adds to its strategic advantage in developing as a regional freight hub. Development as a strategy was chosen because MRIA's underutilized space and low traffic volume provide a safe and cost-effective environment for training. It also has the infrastructure to support facilities for pilot training, aircraft maintenance, and air traffic control, which could attract both local and international students, creating a skilled workforce and generating revenue. Developing as a tourist hub was selected due to MRIA's location near major tourist attractions such as Yala National Park, Arugam Bay, and Kataragama. By enhancing services and facilities, MRIA can become a gateway for international tourists, boosting both passenger traffic and local tourism-related economic activity.[7], [8], [9], [10]

A structured expert opinion survey was designed and distributed online to select the most suitable strategy. The survey targeted aviation professionals, policymakers, and industry stakeholders. The purpose of this survey is to determine which of the three business strategies is the best and most feasible. To gather information for the survey, a structured questionnaire containing eight sections. Regarding decision-making procedures, this survey has been designed for seasoned professionals in the aviation industry. Gathered information from 20% of all replies with less than 5 years of experience, 48% with 5 to 10 years, and 32% with 11 to 20 years.

Figure 1: AHP Hierarchy Tree



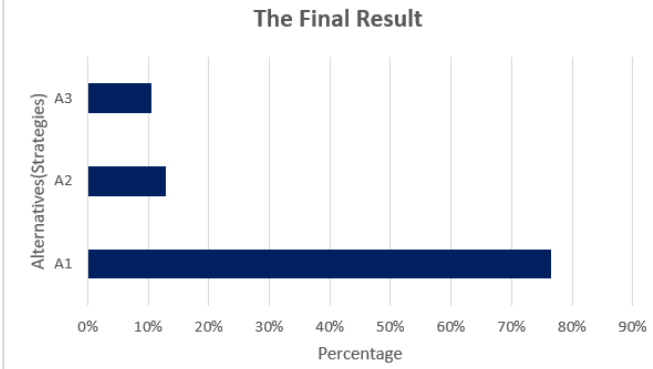
2.2. DATA ANALYSIS

An Excel-based AHP model was created to analyse the collected data. When survey data is provided, the model does pairwise comparisons and determines the final ranking of the three suggested techniques. Three crucial stages are followed in the analysis. First, evaluation criteria are used to identify the best strategy among the three options, including strategic location, modern infrastructure availability, climate stability, and economic potential, classify expert replies. The relative relevance of each element is then ascertained through pairwise comparisons. Lastly, the Excel model ranks the three strategies. [11]

Figure 2: Final Result

3. RESULTS

Based on the expert opinion, the utilisation of MRIA may be significantly increased by utilising proximity to key tourist destinations, strengthening airline partnerships, and implementing targeted marketing initiatives. The decision-making process involves professional opinions. After conducting an AHP analysis, the final results highlight that promoting as a tourist hub (A1) is the most feasible strategy, given the country's strong tourism industry, which is primarily based in the southern province. Because the Sri Lankan government can promote MRIA as the best international gateway to global tourists.



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IDENTIFY THE POTENTIAL TO DEVELOP BANDARANAIKE INTERNATIONAL AIRPORT AS A LOGISTICS HUB

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ABSTRACT
This research evaluates the potential for BIA to emerge as a competitive logistics hub in the South Asian region. Against the backdrop of evolving BIA's role beyond passenger operations, the study contemplates its strategic implications in global trade facilitation. Adopting a mixed methods design, data was collected through semi structured questionnaires and interviews with stakeholders, targeting the key players in the aviation and logistics sectors. The AHP was employed to prioritize significant logistics hub attributes, including strategic location, multimodal connectivity, infrastructure, regulatory efficiency, value added services, IT integration, and operational efficiency. Findings indicate that BIA's greatest strength lies in its proximity to major maritime trade routes; however, it suffers from limited multimodal connectivity, inadequate infrastructure, and weak stakeholder coordination. Though it has the required basic infrastructure, BIA's performance is hindered by the absence of multimodal integrated transport and high-end logistics technology. The research emphasizes the need for targeted investments, regulatory reforms, and collaborative governance to achieve BIA's logistics hub status. The research contributes new knowledge through the incorporation of AHP and expert judgment, highlighting urgent priorities for policy reform and industry action. Despite data constraints, the findings are a foundation for the development strategies ahead to boost BIA's role in regional economic integration and global supply chains.

Keywords: Bandaranaike International Airport (BIA); Logistics Hub; Analytic Hierarchy Process (AHP); Key Factors; Strategic Location

1. Introduction

Bandaranaike International Airport (BIA) is the primary international gateway to Sri Lanka and a key driver of Sri Lanka's economic growth and international economic integration. The airport, which began operations in 1968, has undergone various phases of expansion to cater to increased demand for air travel. During the last decade, BIA put more emphasis on enhancing passenger satisfaction with better service quality to compete in the global air transport business across the world. Meanwhile, airport operations have gone beyond the conventional passenger services and progressively positioned airports at the center of logistic centers that act to facilitate the smooth transportation of cargo and integration into global supply chains. The research investigates the potential of BIA as a premier logistic hub of South Asia by identifying its current capabilities and infrastructure and by identifying strategic interventions required to enhance its logistic function further.

1.1 Purpose

The primary purpose of this research is to evaluate the potential of BIA to operate as a logistics hub in South Asia. Specifically, the research seeks to identify the most important characteristics of an airport logistics hub that is successful, compares BIA's present performance with these characteristics, and produces strategic implications for its future development. By way of such exploration, this research intends to add to general knowledge regarding airports' development into rival logistics hubs, and in so doing, add to their role of increasing global trade and economic development.

2. METHODOLOGY

The present research employs mixed methods design by using quantitative as well as qualitative approaches to analyze BIA as a possible logistics hub in a complete manner. Quantitative information is collected via electronically sent semi-structured questionnaires from a specified sample of logistics and aviation specialists, comprising freight forwarders, airport managers, and government officials. The questionnaire is pilot tested with the stakeholders to ascertain reliability and validity, and subjected to the AHP, ranking criteria by relative importance. Qualitative data obtained by semi-structured interviews with the stakeholders to identify strategic themes, issues, and opportunities. Thematic analysis is employed to seek repetition of patterns in the views of stakeholders. This methodological triangulation adds depth and authenticity to the findings, enabling an in-depth comprehension of BIA's modern-day capabilities and the strategic moves necessary for its emergence as an international logistics hub. The simultaneous approach provides an in-depth analysis of BIA's potential and readiness.

3. FINDINGS

This research evaluates the feasibility of BIA to develop as a key logistics center for South Asia. The study identifies key determinants like strategic location, multimodal connectivity, infrastructure, regulatory efficiency, value-added services, IT integration, and operational efficiency. Through the AHP, the study identifies BIA's geographical location as its main strength due to its proximity to major maritime trade routes. But imbalances such as limited multimodal connectivity primarily a lack of a railway link and negligible road connections affect the efficiency of logistics. Strategic Location has the highest weight (0.1932) with a 19% contribution to the decision model. Stakeholder opinions identify the need to enhance infrastructure, real-time information networks, and efficient customs. Additional provision of value-added services such as warehousing and distribution is recommended. Ineffective operations caused by the weak coordination of stakeholders also must be remedied. The contribution of other factors to the decision model is limited, accounting for less than 19%. In conclusion, while BIA has locational advantages, improvement in connectivity, technology, infrastructure, and inter-institutional cooperation is essential to establish it as a large regional logistics center.

4. RESEARCH LIMITATIONS / IMPLICATIONS

The research is rich in insight into the potential of BIA as a logistics hub but is limited in that it is predicated on expert opinion. Future research needs to expand the sample size and include a wider range of stakeholders to provide an enriched understanding of the opportunities and challenges. As the logistics sector continues to evolve, continued assessment of BIA's strategic appropriateness and performance is important. Despite collecting insights from 30 key stakeholders, the study acknowledges limitations due to the absence of real-time logistics performance data.

4.1 Practical Implications

The study gives strategic guidance to policymakers and stakeholders to foster BIA's contribution to foreign investment, international trade, and regional economic development through policy, technological improvement, and infrastructure.

4.2 Social Implications

Transformation of BIA into a logistics hub can provide employment opportunities in cargo, transport, and customs industries, contributing to poverty alleviation and improved standards of living. Additionally, easier access to goods and services could contribute to economic stability and improved community welfare.

5. ORIGINALITY / VALUE

The paper contributes to the airport logistics hub literature by its in-depth analysis of how BIA can be developed into a competitive logistics hub. Compared to Dubai’s logistics hub model, BIA lags in integrated transport systems and high-end warehousing, but shares advantages in strategic maritime location. The research is novel in the sense that it undertakes a systematic evaluation of BIA's current

performance based on established benchmarks of successful airport logistics hubs. The application of the AHP to prioritize strategic interventions is another aspect that makes this research stand out. Findings and recommendations presented offer valuable input to decision makers involved in optimizing the potential of BIA to enhance global supply chains as well as Sri Lanka's economic development.

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DETERMINANTS OF PASSENGER PERCEPTION TOWARDS "SELF-SERVICE CHECK IN" AS A TECHNOLOGICAL IMPROVEMENT FOR AIR TRAVELLING (SPECIAL REFERENCE TO BANDARANAIKE INTERNATIONAL AIRPORT)

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ABSTRACT - In today's world, technological improvements play a key role, leading to the adoption of "self-service check-in" in many airports to streamline passenger processing operations, and as a result, most of the countries consider "self-service check-in" as a viable passenger check-in method where there is an immense benefit for the passengers. The study investigates determinants of passenger perception towards self-service check-in as a technological improvement for air travel with special reference to Bandaranaike International Airport (BIA). Moreover, analyzing the depths of relationship and the impact that identified determinants; perceived ease of use, perceived usefulness, attitude and behavioral intentions, hold for the dependent variable; passenger perception towards self-service check-in is considered as the secondary objective of the study. The data is collected through a self-administrative questionnaire that is distributed among passengers comprised of 334 respondents and was undertaken using convenience sampling. The statistical data was processed with SPSS software and analyzed using reliability analysis, descriptive analysis, correlation and regression analysis. The researcher has identified that perceived ease of use, perceived usefulness, attitude and behavioral intentions are the factors that have a strong positive influence towards the dependent variable passenger perception. The research findings reveal that perceived usefulness has the strongest correlation within the study. Moreover, the research findings conclude that self-service check-in helps to reduce time and streamlines passenger processing experience within the airport, while within the study the researcher has also identified the main reasons for this technology remain a less embraced concept among the passengers.

Keywords: Passenger Perception, Self-service check-in, Technological Improvement

1. INTRODUCTION

The world is advancing in technology applications in airports, with Sri Lanka yet to achieve it. Self-service check-in processes, introduced in many airports worldwide, allow passengers to independently check in, reducing queues and streamlining movements. This innovative concept significantly impacts passenger processing operations and reduces queues within airports [1]. Bandaranaike international airport (BIA) being the main international gateway in Sri Lanka experiences multiples challenges in its quality of services due to its increased capacity. Originally designed to handle six million passengers per year, it now handles 10.5 million, causing congestion and difficulties in passenger processing. As a service industry, airlines need to improve service quality in traditional operations to enhance passenger satisfaction. Technological improvements, such as Self-Service Check-in, can help reduce processing times [4]. However, many passengers are unaware of this service. Passengers' evaluations on websites like SKYTRAX and airline ratings indicate that BIA's service quality is not up to standard, leading to gaps in services and dissatisfaction among passengers. This negative impact on the airport and passengers is a significant concern. This study aims to identify determinants of passenger perception towards Self- service Check in as a technological improvement for air travelling as the primary objective, while secondary objectives involve identifying the relationship and the impacts of the determinants of passenger perception towards "Self-service check in" as a technological improvement for air travelling. The Technology Adoption Model (TAM) is commonly used to study consumers' adoption of technology, with an emphasis on two important factors: perceived utility and perceived ease of use. It provides a structural framework for studying technology adoption, such as self-service technologies in air travel. Studies demonstrate that these parameters have a significant impact on user satisfaction and propensity to use [2].

2. MATERIALS AND METHODS

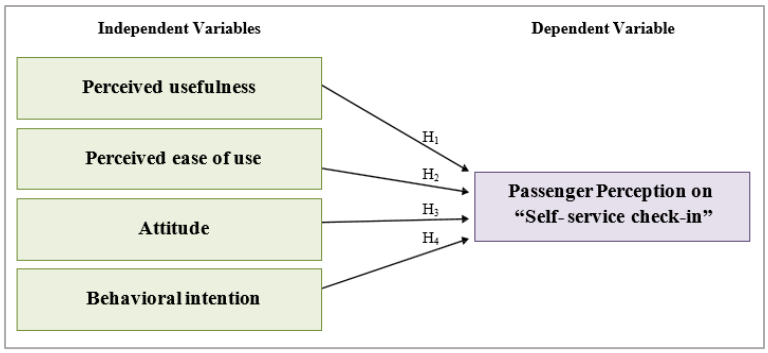

Figure 1. Conceptual Framework

This study delves into the connection between passenger perception on self-service check-in and key determinants of perceived ease of use, perceived usefulness, attitude and behavioral intention of passengers. This study uses a quantitative design and a deductive research approach, with passengers being given a self-structured online questionnaire through Google Forms. Convenience sampling technique is applied, and the SPSS will be used to analyze the data on a 5-point Likert scale. The target population consists of all passengers, with 5,502,539 movements reported at Bandaranaike International Airport in the year 2022. According to the Morgan's table, since the population is exceeding 1,000,000, a sample size of 384 will be used to conduct the research with in a 95% confidence level and a 5% margin of error [3].

3. RESULTS AND DISCUSSION

3.1 Correlation Analysis

Table 1. Correlations Table

Correlations		Passenger Perception on Self-service Check-in
Perceived Ease of Use	Pearson Correlation	**0. 795**
	Sig. (2-tailed)	< 0.001
Perceived Usefulness	Pearson Correlation	**0.847**
	Sig. (2-tailed)	< 0.001
Attitude	Pearson Correlation	**0.829**
	Sig. (2-tailed)	< 0.001
Behavioral Intention	Pearson Correlation	**0. 834**
	Sig. (2-tailed)	< 0.001

Reference: Research Data

According to the correlation analysis, it can be concluded that perceived ease of use, perceived usefulness, attitude and behavioral intention are having a strong positive relationship with the dependent variable, Passenger Perception on Self-service Check-in.

3.2 Regression Analysis

Table 2. Regression Analysis

Model Summary					
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson

1	.861[a]	.742	.739	.33917	1.982	
Coefficients						
Model		Unstd. Coefficients		Std. Coefficients	t.	Sig.
			B	Std. Err.	Beta		
t1	(Constant)	β_0	.666	.146		4.557	.000
	Perceived Ease of Use	β_1	.164	.069	.159	2.391	.017
	Perceived Usefulness	β_2	.487	.133	.565	3.659	.000
	Attitude	β_3	-.169	.136	-.182	-1.246	.214
	Behavioral Intention	β_4	.339	.071	.344	4.753	.000
a. Dependent Variable: Passenger Perception on Self-service Check-in							

Reference: Research Data

The multiple linear regression model for the study is developed as follows.
Passenger Perception on Self-service Check-in = 0.666 + 0.164 PE+ 0.487 PU + 0.339 BI

MLR model for the study is jointly significant, leading to rejecting the null hypothesis and accepting the alternative hypothesis of all independent variables except for attitude indicating that perceived ease of use, perceived usefulness and behavioral intention of passengers are jointly affecting Passenger Perception on Self-service Check-in. The β values for all the independent variables are positive except for Attitude. It indicates that perceived ease of use, perceived usefulness and passenger behavioral intention variables have a positive impact whereas the attitude indicates a negative impact on the passenger perception on self-service check-in due to the lack of awareness on this discipline among the passengers. The study aimed to determine the factors influencing passenger perception towards self-service check-in as a technological improvement in air travel. The research found that passenger movements have increased due to the Covid-19 pandemic, leading to an increase in airport capacity and dissatisfaction with the service provided. The study found a strong positive relationship between the four independent variables and passenger perception, with a positive impact on perceived ease of use, perceived usefulness, and behavioral intentions. The demographic factors revealed that 53.09% of respondents were male, with the age group under 25, 25-36 traveling more than the elderly, and the majority being full-time employers earning above 90000. Self-check-in was mainly within the scope of younger generations and male-dominated. Around 37.7% of respondents had only experienced this service, while 43.1% were unaware of it and 32.3% had no knowledge of it. The results indicated that passengers are not knowledgeable about the check-in process. The researcher recommends that perceived usefulness is the major influencing factor for passengers, and self-service check-in should be promoted more among passengers to make them aware of this service. Further implementation of self-service check-in within airports is recommended for the benefit of passengers, and government intervention is highly recommended. In conclusion, the study highlights the need for increased promotion and awareness of self-service check-in as a technological improvement for air travel. Government intervention and promoting the service to passengers will help improve the overall experience and satisfaction with self-service check-in.

4. CONCLUSION

The research found that passenger perception of self-service check-in as a technological improvement for air travel is moderate. However, there are several aspects that need improvement to enhance the passenger experience. Most respondents believe that self-service check-in reduces time and is convenient for passenger processing, as well as allowing for personalized seat selections and streamlines the airport experience. However, most passengers are unaware of this service, and proper government and relevant authorities should collaborate to improve passenger experience. Factors such as perceived ease of use, perceived usefulness, and behavioral intentions have positive impacts on passenger perception of self-service check-in, with perceived usefulness having the highest significance among the four independent variables. The study suggests that proper awareness and collaboration

between the government and relevant authorities can improve the use of advanced technologies like self-service check-in kiosks.

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CONNECTIVITY OF SOUTH ASIAN AIRPORTS: REVELATIONS FROM A COMPARATIVE EXAMINATION OF VIABLE CONNECTIONS AND GLOBAL WEIGHTS

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ABSTRACT

The aviation sector in South Asia is crucial for regional and global economic growth and integration into the global network. This study focusses on identifying the relative connectivity level of major South Asian airports by analyzing their connectivity efficiency and global rankings within the Asian and global aviation network, Secondary data from the SRS Analyzer (September 2024) and annual passenger traffic for 2024 were used to calculate the Quantitative Viable Connections (QVC) and Global Weights for 22 major airports across Asia, including key airports from each South Asian country. The results revealed that while India's Indira Gandhi International Airport (DEL) leads with the highest level of connectivity within the region, Kempegowda International Airport (BLR) and Chhatrapati Shivaji Maharaj International Airport (BOM) also indicated having moderate connectivity levels, but being focused mostly on handling domestic passenger traffic. Other South Asian airports, such as Bandaranaike International Airport (CMB), Jinnah International Airport (KHI), and Tribhuvan International Airport (KTM) yielded lower QVC and Global Weight ranks due to limited infrastructure and long-haul route connections; geopolitical constraints being a possible cause behind. MLE and KBL airports have the lowest performance connectivity in the Asian region and globally. In general, the connectivity levels of South Asian airports collectively lag behind leading Asian hubs like Singapore (SIN), Dubai (DXB), and Hong Kong (HKG). To enhance connectivity, South Asian countries must expand their long-haul routes network, improve airport infrastructure, possibly through strategies such as new technology advancements, capitalizing on strategic geographic advantages, boosting tourism, and adopting open sky agreements. These strategies will strengthen their connectivity and Global Weighting within the aviation network.

Keywords: Connectivity; Asian Aviation; South Asian Airports; Global strength

1. INTRODUCTION

Aviation has emerged, and is growing, as a vital sector contributing to the South Asian region's economic growth and its global integration. In South Asia, Bangladesh, Bhutan, India, Sri Lanka, the Maldives, Nepal, and Pakistan are positioned on vital crossroads between Asia, the Middle East, and other global aviation networks. Owing to this strategic location and the growing passenger demands, the connectivity level of the South Asian airports has become a topic of interest and scrutiny. While major airports in the region, such as Indira Gandhi International Airport in Delhi and Bandaranaike International Airport in Colombo, have witnessed increased air traffic, their connectivity level positioning within the Asian aviation landscape faces challenges from well-established hubs like Dubai, Singapore, and Hong Kong.

Connectivity can be defined as the degree to which nodes in a network are interconnected. (Burghouwt.G,2013). Literature reveals research conducted that has focused on the changes in connectivity levels, based on connectivity analysis results; Singapore, Suvarnabhumi, and Kuala Lumpur airports hold a leading position among major Asian airports (Chang & Kung, 2023). Many studies have focused on the connectivity level of major airports in the Asian region. This research uniquely applies standardized connectivity metrics across Asian airports, primarily those in South Asia, providing a comprehensive benchmark to guide strategic planning and policy for enhancing South

Asia's aviation competitiveness. Mainly, the study seeks to answer the question of how major South Asian airports position themselves within the Asian and global aviation networks in terms of connectivity.

2. MATERIALS AND METHODS

This study adopted a quantitative research approach to evaluate and analyse the connectivity of South Asian airports in comparison to other major hub airports of Asia. A stratified sampling method was employed to ensure balanced representation across various regions of Asia. The sample allocation was initially based on the 2023 population data from the World Bank. A total of 20 countries were chosen, with the sample distribution adjusted according to population across regions. East Asia, though initially allocated 8 positions due to its higher population share, its allocation was subsequently adjusted because it doesn't have 8 countries with major airports. The elements in the sample were distributed to other regions with significant airport hubs to ensure a balanced examination. All South Asian countries were included in the sample, and the major airports in each country were chosen based on passenger traffic. Only 3 airports were selected from India, as they appeared the most prominent in the South Asian region. 22 airports across Asia were thereby selected as the sample for analysis, namely CAN (China), HND (Japan), ICN (South Korea), KBL (Afghanistan), DAC (Bangladesh), DEL (India), BOM (India), BLR (India), KTM (Nepal), KHI (Pakistan), CMB (Sri Lanka), MLE (Maldives), ALA (Kazakhstan), CGK (Indonesia), KUL (Malaysia), BKK (Thailand), SGN (Vietnam), SIN (Singapore), DXB (UAE), JED (Saudi Arabia), IST (Turkey) and DOH (Qatar)

The secondary data were collected from the SRS analyzer. Airport schedule data for September 2024 was used because September is the non-peak demand period in the aviation sector. To comparatively examine the connectivity strength of individual airports, the Quantitative Viable Connections (QVC) and Global Weight of Airport were used as indicators.

The QVC takes into account the viable flight connections of airports and their efficiency. Viable connections refer to the connecting flights that meet the set criteria for the connection time, and is estimated using the following formula:

$$QVC = \sum_{\text{inbound flight } 1}^{n} \text{connection (n)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (01)$$

The present study followed the research conducted by of Chang, Y., Lee, W., & Hsu, C. (2020), Chang & Kung (2023) and set the Minimum Connection Time (MCT) to 90 minutes and the Maximum Connection Time (MACT) to 300 minutes. The QVC was thereby calculated as the total number of connections within the time period. Each arrival flight time was compared against each departure flight time from each hub airport.

On the other hand, the Global Weight of Airport is a ratio reflecting the destination airport's size in terms of passengers handled annually, relative to the largest global airport, which was the Los Angeles International Airport in 2024, according to the SRS analyzer available data. The global rank of each airport was thus calculated based on the passengers handled by each airport in 2024, using the following equation:

$$Global\ Weight = \frac{Sample\ Airport\ passenger\ Traffic}{\text{Los Angeles International Airport Passenger traffic 2024}} \ldots\ldots\ldots\ldots\ldots (02)$$

3. RESULTS AND DISCUSSION

The QVC values of the selected 22 Asian airports for September 2024, estimated in the present research, are depicted in Figure 1.

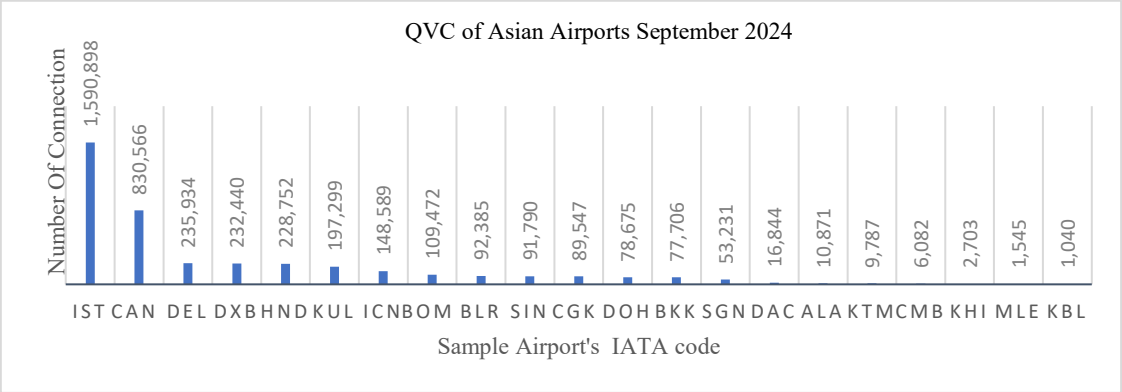

Figure 16.QVC of Sample Asian Airports

The above results indicate that QVC estimates for IST and CAN are much higher than all other airports examined in this research.

Table 1 (below) summarizes the Global Weight and "Rank" of the airports subject to examination.

Table 9. Global Weight and Rank of the Sample Airports

IATA CODE	HND	CAN	DEL	ICN	SIN	BKK	DXB	CGK	BOM	KUL	JED
Global Rank	2	3	4	6	12	14	15	18	21	26	37
Global Weight	0.997302	0.979753	0.968231	0.944878	0.806055	0.780826	0.772552	0.749508	0.709758	0.681935	0.61849
IATA CODE	BLR	IST	SGN	DOH	DAC	ALA	KTM	CMB	KHI	MLE	KBL
Global Rank	46	50	53	146	185	232	245	259	298	312	800
Global Weight	0.556886	0.530143	0.505688	0.233042	0.187405	0.142162	0.132973	0.119539	0.099537	0.095216	0.020542

Source: Author Compilation based on the SRS analysis data 2024

The results indicate that the connectivity of South Asian airports lags behind that of major global and Asian airports. Among the South Asian airports, Indira Gandhi International Airport (DEL) appeared to have the highest connectivity level globally. However, BOM, BLR have a lower weight in terms of Global Weight rank because of these airports primarily handle domestic passengers. These airports also showed moderate QVC values. For instance, Hazrat Shahjalal International Airport (DAC) and Tribhuvan International Airport (KTM**)** appeared to have limited connectivity with lower global weights. Bandaranaike International Airport (CMB) and Jinnah International Airport (KHI) ranked even lower, reflecting their restricted linkages to regional and global networks.

The outcomes of the research, therefore, demonstrate that the connectivity levels of airports in the South Asian region lag behind those of global hubs, as well as several Asian airports.

4. Conclusion

In the South Asian region, except for India's DEL airport, all other airports lag behind the global and Asian connectivity rankings. Airports of KTM, KHI, CMB, MLE, and KBL appear to perform poorly, possibly because of their geopolitical restrictions. findings highlight the need for policy reforms, infrastructure upgrades, and strategic planning to enhance connectivity. Improved connectivity can drive economic growth, regional cooperation, tourism, and trade. This study offers a quantitative benchmark for airport authorities and policymakers.

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AN ANALYSIS OF THE POSSIBLE TURNAROUND STRATEGIES FOR SRI LANKAN AIRLINES

Perera, Shihara; Nayanalochana, Chathula

ABSTRACT

The COVID-19 pandemic highlighted the pre-existing inefficiency of Sri Lankan Airlines operations and highlighted the company was vulnerable to the inefficiency of governing bodies and financial management, its financial capabilities, and the weak nature of operational limits. This paper examines the underlying cause of the disruptions that affected the airline and evaluates possible recovery strategies using the case of Air India that recorded a remarkable turnaround after being privatized in 2022. As a qualitative study case study, data on the internal stakeholder was obtained through semi-structured interviews and complemented using secondary performance indicators. The results bring forward some of the unresolved problems of the Sri Lankan Airlines that include outdated fleet, overstaffing, and political intervention, the latter being an obstacle to reform. On the contrary, the restructuring process at Air India consisted of better governance, consistent rationalization of routes, and manpower optimization- which resulted in efficiency and financial recovery. Full privatization might not be the next best possible option in the case of Sri Lanka but strategic takeaways like reshaping to partnership-based operation, changes in magnum opus, and autonomy in decision making can be drawn and adapted. The research adds literature in the study of reforming state-owned airlines through providing a policy recommendation for the case of Sri Lankan Airlines, which focuses on how airlines might achieve sustainable competitiveness amid internal or external pressures.

Keywords: Sri Lankan Airlines; Governance Reform; Operational Efficiency; Financial Sustainability; Privatization

1. INTRODUCTION

The COVID-19 crisis led to disruption that had never been experienced in the aviation industry and it created operational, financial, and labor distress in the industry. In the case of state owned-carriers within the developing economies, the crisis revealed structural misalignments and inefficiencies that had been on the card. The Sri Lankan airlines have become an example of a commercial instability intersecting with national identity as the company faces the challenges of constant debt, political influence, and archaic operating systems (International Air Transport Association [IATA], 2022). Conversely, Air India whose situation was not different recorded an impressive turnaround after its privatization under the Tata Group in 2022. It is a research into the deep-rooted causes of the disturbances in the Sri Lankan Airlines scenario and it assesses the efficacy of the comparative recovery models in coming up with strategic, situation-suitable reforms.

Research objectives

1. Identify the root causes of financial and operational disruptions at Sri Lankan Airlines.
2. Examine the impact of governance on operational efficiency and strategic execution.
3. Compare Sri Lankan Airlines' recovery attempts with Air India and other leading global carriers.
4. Evaluate context-sensitive turnaround strategies for sustainable recovery.
5. Contribute to the discourse on state-owned airline transformation in developing nations.

Research Questions

1. What are the core disruptions faced by Sri Lankan Airlines during and after the COVID-19 crisis?

2. How do Sri Lankan Airlines' recovery strategies compare with those implemented by Air India and other global carriers?
3. What strategic lessons can be extracted and adapted from Air India's post-privatization recovery, considering the political and economic environment of Sri Lanka?
4. How can Sri Lankan Airlines balance internal reforms and external market pressures to achieve long-term competitiveness and sustainability?

2. MATERIALS AND METHODS

This qualitative case study used a mixed-methods approach combining primary and secondary sources.

Primary Data Collection
Nine semi-structured interviews were conducted with senior managers, pilots, cabin crew, HR staff, and a government official. Interviews lasted 10–15 minutes via video conferencing and followed ethical guidelines with informed consent and confidentiality protocols. An open-ended guide explored themes such as debt, governance, route strategy, and fleet management.

Secondary Data Collection
Comparative data were gathered from official reports and literature on Air India, Singapore Airlines, Emirates, and Qantas. Key indicators included fleet age, load factors, workforce-to-aircraft ratios, and cost per available seat kilometer (CASK).

Data Analysis
Transcripts were analyzed using thematic coding in NVivo. Themes were triangulated across interviews and secondary sources to validate insights and reduce bias (Borenstein & Rose, 2014).

3. RESULTS AND DISCUSSION

Root Disruptions at Sri Lankan Airlines

- Governance Dysfunction - Government interference in route selection, hiring, and leadership changes significantly undermined strategic continuity (Sri Lankan Airlines, 2023).
- Operational Inefficiencies - An aging fleet (average 15.2 years) and overstaffing (350:1 ratio) contributed to rising CASK and poor load factors.
- Financial Mismanagement - Between 2015–2023, Sri Lankan Airlines accumulated over USD 500M in net losses, compounded by reliance on unsustainable government bailouts (Daily FT, 2024)

Comparative Insights - Air India

Post-privatization, Air India achieved substantial improvements.

Indicator	Sri Lankan Airlines	Air India (2023)	Industry Benchmark
Fleet Utilization (hrs/day)	7	10	12
Revenue per Passenger (USD)	90	110	130

Indicator	Sri Lankan Airlines	Air India (2023)	Industry Benchmark
Load Factor (%)	75%	85%	87%

Key strategic differences included workforce rationalization, modernized fleet procurement, and autonomy in route design (Air India, 2022).

Triangulation of Findings

Stakeholder interviews confirmed secondary data. For instance, a First Officer noted, "We spend more on repairs than fuel-it's killing our margins", reinforcing the quantitative fleet data.

Contextual Challenges for Strategy Transfer

Direct adoption of Air India's model in Sri Lanka faces obstacles - weaker private capital markets, labor union resistance, and political volatility. This necessitates phased public-private partnerships rather than full privatization.

4. CONCLUSION

Sri Lankan Airlines' recovery is hindered by internal inefficiencies, weak governance, and structural inertia. While Air India offers a compelling blueprint for reform, Sri Lanka must contextualize its strategy. A combination of governance reform, fleet renewal, route rationalization, and revenue diversification (particularly in cargo) is essential.

To secure long-term viability, Sri Lankan Airlines should:

- Transition to a **hybrid governance model (e**.g., PPP with independent board oversight)
- Implement **tenure-based executive appointments** with performance KPIs
- Use **cost-benefit frameworks** to assess fleet renewal and partnership strategies
- Establish a **national aviation competitiveness policy** addressing regulatory barriers

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