

Geospatial Framework for Locating Optimal LRT Stations in the Colombo Metropolitan Area, Sri Lanka

Keerthi T, *Dissanayake DMDOK, and Chaminda SP

Department of Earth Resources Engineering, University of Moratuwa, Sri Lanka.

*Corresponding author – dmdok@uom.lk

Abstract

Developing countries like Sri Lanka face severe transportation challenges that arise due to increased demand driven by rapid urbanization and population growth. This highlights the necessity of long-term efficient, environmentally friendly, and viable transport solutions like Light Rail Transit (LRT). Thus, this study proposes an integrated Remote-Sensing and Geographic Information Systems (GIS) with Analytical Hierarchy Process (AHP)-based Multi-Criteria Decision Analysis (MCDA) approach to identify optimal LRT station locations within the Colombo Metropolitan Area (CMA). Eight important factors such as slope, land use, proximity to buildings, environmentally sensitive areas, socially sensitive locations, existing transportation nodes, main roads, population density were systematically weighted, analysed, and used to produce suitability maps. Station locations were carefully selected based on suitability values across 31 zones and validated through Google imagery to assess land feasibility and availability. The demand estimation and accessibility analysis were done within the 1 km buffer zones surrounding each proposed station. This confirms that the majority of selected stations have better ridership potential and good road accessibility. Despite certain limitations in datasets, this structure can be used to design sustainable urban transport planning and long-term mobility policies applicable to Colombo, especially with the integration of precise field measurements and high-resolution imagery.

Keywords: AHP, GIS, MCDA, Site Suitability analysis, Urban Transit

1 Introduction

Urban areas worldwide are experiencing increasing challenges in meeting the demand for efficient, sustainable public transport due to rapid urbanisation, population growth, and rising vehicle ownership [1][2]. The Colombo Metropolitan Area (CMA), as the primary administrative and economic centre of Sri Lanka, is facing severe transport-related problems, including massive congestion and environmental issues arising from poor and inefficient transport planning. The growing dependency on private vehicles further exacerbates traffic congestion and contributes to air quality deterioration, affecting both public health and economic productivity. This highlights the need for modern, environmentally friendly, and sustainable transport solutions [3][4].

The Light Rail Transit (LRT) system has been proposed as a solution to address these transport

challenges, as it has proven globally to be a sustainable option by providing a high-capacity, reliable, and environmentally friendly mode of urban transport [5]. In addition to reducing congestion, LRT systems have been shown to stimulate economic growth and support urban regeneration by improving access to key commercial and residential areas. Effective planning of such systems requires the careful selection of routes and station locations to maximise accessibility, minimise environmental and social impacts, and ensure cost efficiency [6][7].

Multi-Criteria Decision-Making Analysis (MCDA) using the Analytic Hierarchy Process (AHP) has proven valuable in urban transport decision-making, as it integrates multiple factors from different criteria, such as spatial, environmental, and socio-economic, in a systematic and replicable manner [8][9][10].

This study applies a GIS-MCDA-AHP framework to the Colombo Metropolitan Area as a case study to illustrate its practical application in identifying optimal LRT station locations. While this research focuses on a specific local context, the proposed framework is designed to be adaptable and replicable for similar urban transport planning efforts elsewhere, providing both methodological insights and practical outcomes.

2 Methodology

2.1 Study Area

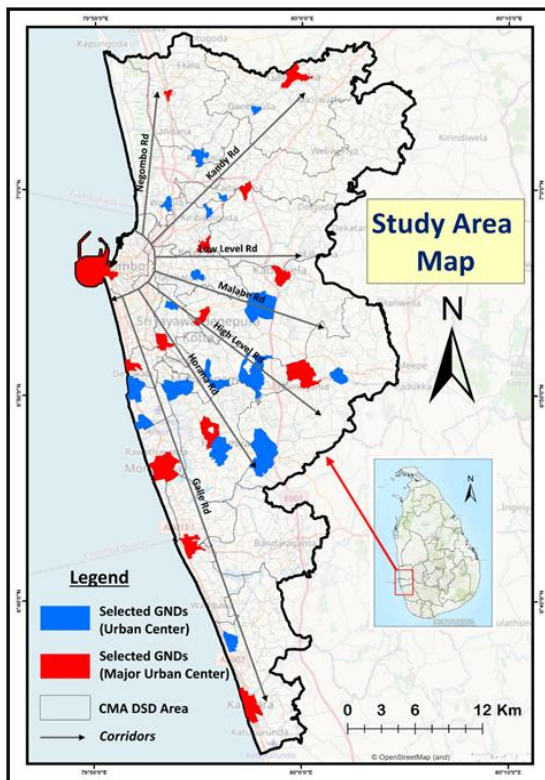


Figure 1: Study area map (CMA) with proposed LRT corridors and station zones, adopted from [3]

Figure 1 shows the study area, which is Colombo Metropolitan Area (CMA), located in the Western Province of Sri Lanka. It is recognized as the country's administrative and main economic core. According to the Urban Transport System Development Project, CMA boundaries are defined by existing population, population growth, and population densities roughly more than 20 people per hectare throughout the day and night. It covers both areas which already have been urbanized and those predicted to be urbanized by 2035, and areas that are socioeconomically dependent on Colombo [3]. The CMA spans over 20

Divisional Secretariats Divisions (DSDs) and 1,043 Grama Niladhari Divisions (GNDs) across three districts. Among that, Colombo District representing 49.2% of the total area and 69.2% of the total population, followed by Gampaha District amounting to 32.7% of the area and 19.5% of the population and Kalutara District having 18.1% of the area and 12.2% of the population of the CMA [3].

According to Urban Transport System Development Project, seven major corridors have identified, which serves as key links between Colombo and the surrounding urban and suburban zones, experiencing high demand and huge traffic congestion daily [3]. The seven major corridors are listed in Table 1 and respective stations for the corridors are summarized in Table 2. Two types of urban zones have been proposed along every corridor [3].

- Major Urban Centres: Areas with high population density, economic activity and transport connectivity.
- Urban Centres: Areas with fast-growing prosperous residential and commercial hubs.

Table 1: Corridor reference

Corridor ID	Corridor Name
C1	Negombo
C2	Kandy Road
C3	Low Level Road
C4	Malabe
C5	High Level Road
C6	Horana
C7	Galle Road

Table 2: Station reference

Station ID	Respective Corridor	Station Name	Type
S01	C1 to C7	Colombo Fort	1
S02	C1, C2	Kelaniya	1
S03	C1	Watala	2
S04	C1	Ragama	2
S05	C1	Ja Ela	1
S06	C2	Kiribathgoda	2
S07	C2	Mahara	2
S08	C2	Kadawatha	1
S09	C2	Ganemula	2
S10	C2	Gampaha	1
S11	C3	Kottikawatte	2
S12	C3	Kaduwela	1

S13	C4	Rajakiriya	2
S14	C4	Battaramulla	1
S15	C4	Malabe	2
S16	C5, C6	Nugegoda	1
S17	C5	Maharagama	2
S18	C5	Kottawa	2
S19	C5	Homagama	1
S20	C5	Godagama	2
S21	C6	Boralesgamuwa	2
S22	C6	Piliyandala	1
S23	C6	Kesbewa	2
S24	C6	Kahathuduwa	2
S25	C7	Dehiwala	1
S26	C7	Mount Lavana	2
S27	C7	Ratmalana	2
S28	C7	Moratuwa	1
S29	C7	Panadura	1
S30	C7	Wadduwa	2
S31	C7	Kalutara	1

(Type: 1 -Major Urban Centre, 2 -Urban Centre)

2.2 Factor Identification & Data Collection

Eight key factors were selected (under four different criteria) based on literature, and data availability to create the suitability surface for LRT station placement using MCDA approach [4] [9]. Factors and respective criteria are listed in Table 3.

Table 3: Factors & respective criteria

Criteria	Factor
Engineering	Slope
Suitability	Proximity to Buildings
Land Use and Environment	Land use
	Proximity to Environmentally Sensitive Area
Accessibility and Transport	Proximity to Existing Transportation Nodes
	Proximity to Main Roads
Socioeconomic Considerations	Population Density
	Proximity to Socially Sensitive Locations

The slope was calculated from Digital Elevation Model (DEM) (30m resolution) to show the level of terrain steepness. Areas with less slope or less steep were preferred due to construction viability, cost effectiveness and safety of rail operations. Distance from buildings was considered to indicate the land availability for new station construction. Keeping a distance

with buildings also allowed to minimize the cost of land acquisition, demolition, and minimize the impact to existing settlements.

Land use, obtained from a 10 m Sentinel-based raster, was used to represent different land use classes such as forest, buildup area, water bodies, bare, and croplands. This assisted in locating the area where the land can be occupied by the stations or not. Bare, crop, grass, and sparse vegetation lands were mostly considered as suitable. Proximity to environmentally sensitive regions including forests, water bodies, natural reserves, and residential areas was taken into account that might adversely impact biodiversity and land-use policy. Location of the stations in less sensitive areas was favoured to minimize ecological disturbance.

Proximity to primary, secondary, and residential roads was assessed to ensure accessibility to stations. Areas close to roads were favoured for multimodal integration and easier user access. Close proximity to areas of public transport like bus stations, railway stops, airports, and ferry terminals had been assessed to enable multimodal transport connectivity. Stations near existing transport hubs were found to be suitable so as not to require further infrastructure.

Population density was obtained from 1km resolution raster, was used to show the concentration of population per square kilometre. The regions with high population density were considered as higher demand areas and having the stations closer to these regions were expected to increase potential ridership. Proximity to socially sensitive areas such as schools, hospitals, temples, prisons, and archaeological sites was also analysed, as these may trigger public opposition or legal constraints. The purpose of maintaining distance was to reduce conflict and social risk.

Data for environmentally sensitive areas, building footprints, socially sensitive locations, public transport nodes, roads were obtained from Open Street Map (OSM). It provides updated, and freely accessible data for many Geo-spatial analyses.

2.3 Data Preprocessing & Reclassification

All criterion maps were projected to the same coordinate reference system and resampled to a consistent spatial resolution. Then based on thresholds they were reclassified into five classes according to the suitability for proposing new station. The scale adopted to reclassify the map is presented in Table 4.

Table 4: Common scale adopted for ranking the suitability of factors

Class	Suitability Level
Class 1	Not Suitable
Class 2	Less Suitable
Class 3	Moderately Suitable
Class 4	Suitable
Class 5	Highly Suitable

2.4 Analytical Hierarchy Process (AHP)

AHP was used to identify the significance of each factor in establishing the suitable location of LRT stations. In this approach, pairwise comparison is applied to determine the weightage according to its relative importance on the choice of appropriate LRT station sites through the systematic decision-making process. A pairwise comparison matrix was created with respect to Saaty's 1 to 9 scale, with the larger number demonstrating the stronger importance of one criterion over another. Consistency Ratio (CR) was also determined to ensure that the judgments made are accurate, whereby a CR of < 0.1 indicates an acceptable level of consistency [9]. The sum of all the weightage values must be equal to 100. Table 5 shows the respective weightage derived from AHP with the CR ratio.

Table 5: Weightage of all factors (from AHP table)

Factor	Weightage
Land use	28.34%
Population Density	22.28%
Proximity to Existing Transportation Nodes	16.50%
Proximity to Socially Sensitive Locations	11.99%
Proximity to Main Roads	8.73%
Proximity to Environmentally Sensitive Area	6.57%
Proximity to Buildings	3.44%
Slope	2.15%

2.5 Suitability Mapping

The final suitability surface was produced by multiplying the reclassified raster of each factor with an appropriate weight derived during the AHP process. The weighted layers were then added to form a continuous raster of overall suitability using the weighted overlay method. The outcome raster is the merged influence of all

factors in which higher values indicating greater suitability.

2.6 Station Selection

As shown in Figure 1, a set of GNDs were selected to identify the suitable station locations from each major urban centre and urban centre along the proposed LRT corridors. These GND sets were chosen based on zones defined by Urban Transport System Development Project [3]. The generated suitability raster from weighted overlay analysis, was clipped to the area chosen GND set extend. Then output raster cells were converted to point features and then location with highest suitability value was identified. This location is proposed as a suitable location for constructing new stations. Coordinates (X, Y) of each station were determined. Then, the layer was exported to KML format and viewed from Google Earth to confirm the actual conditions of land cover and its availability.

2.7 Demand Estimation and Accessibility Analysis

The demand was estimated by multiplying total population within a 1 km buffer around each proposed station, with the average capture rates (30% for major urban centres, 20% for urban centres). The accessibility was analysed based on the total length of main and minor roads, as well as the transport nodes like bus stops, railway stations, ferry terminals and airport terminals, all of which fell within a 1 km buffer area of the proposed station.

3 Results

3.1 Suitability map

Suitability map (Figure 2) resulted from weighted overlay analysis, demonstrates the spatial distribution of potential to locating the LRT stations. It was classified into five classes based on the suitability scores. Most of the CMA (672.98 Sq km) falls under the not suitable (37.5%) and less suitable (30.1%) categories. 17.8% of CMA (177.4 Sq km) represent the moderately suitable locations. A relatively very small area approximately 2.8% (28.29 sq km) was identified as highly suitable, while 8.7% (86.21 sq km) was classified as suitable area. Suitability value of the remaining portion, accounting for 3.08% (30.62 Sq km) of the CMA was not computed.

Table 6: Proposed LRT stations with suitability value, and current land use

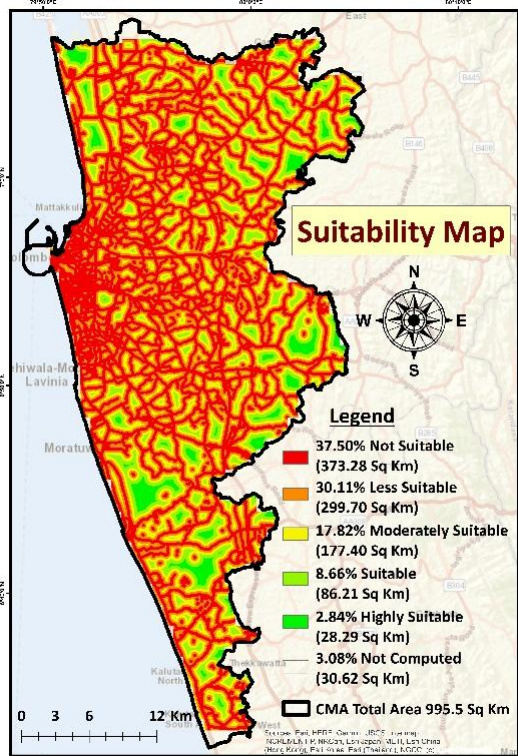


Figure 2: LRT station placement suitability map

3.2 Proposed Station Location

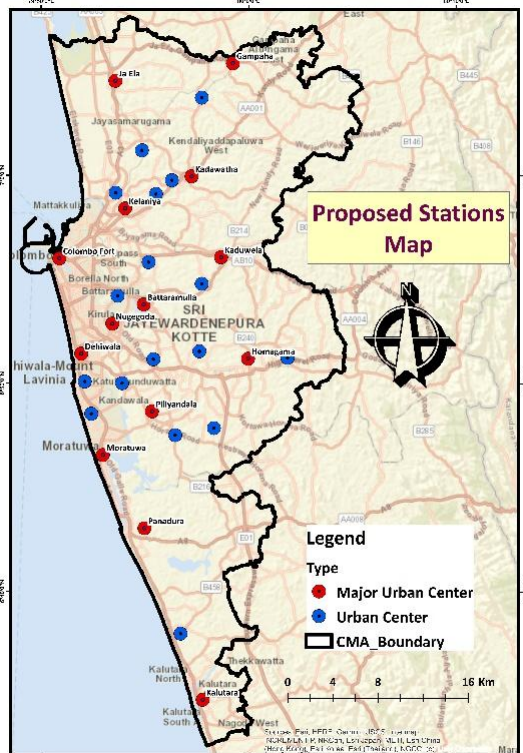


Figure 3: Proposed LRT stations location map

Station ID	Suitability Value	Current Land use
S01	5.420	Railway Station
S02	60.911	Sparse Vegetation
S03	27.815	House
S04	34.675	Sparse Vegetation
S05	37.457	Bare Land
S06	44.420	House
S07	42.053	Sparse Vegetation
S08	34.991	Coconut Land
S09	20.338	Paddy Land
S10	18.099	Sparse Vegetation
S11	48.057	Playground
S12	24.208	Park
S13	31.807	Garden
S14	34.151	Bare Land
S15	50.475	Paddy Land
S16	25.221	Park
S17	18.029	Garden
S18	22.759	Crop Land
S19	21.179	Paddy Land
S20	21.703	Paddy Land
S21	36.616	Wet Land
S22	44.289	Garden
S23	16.736	Coconut Land
S24	76.450	Barren Land
S25	11.608	Barren Land
S26	38.481	Playground
S27	29.326	Playground
S28	23.497	House
S29	46.504	House
S30	7.560	Grass Land
S31	27.191	Sparse Vegetation

(Refer Table 02 for station ID)

Figure 3 shows the locations of proposed stations, which were derived from suitability raster (Figure 2) and Table 6 displays the stations with suitability scores, and current land use observed from Google Earth. The proposed station sites fall into the land use categories including croplands (including paddy and coconut lands), sparse vegetation, gardens, but few sites are under land uses like playgrounds, residential areas, wetlands, and park

3.3 Demand Estimation and Accessibility Analysis

Table 7: Demand estimation and Accessibility analysis of proposed LRT stations

Station ID	Station Name	Estimated No. of Users (per Sq. Km)	No. of Existing Transport Nodes	Primary Roads (Km)	Secondary Roads (Km)	Residential Roads (Km)
S01	Colombo Fort	7034.07	27	14.47	10.2	11.85
S02	Kelaniya	7554.81	4	6.74	1.02	16.82
S03	Watala	3712.06	2	7.14	4.86	23.76
S04	Ragama	2589.04	2	0	5.57	14.9
S05	Jaela	4262.43	1	4.56	5.1	44.67
S06	Kiribathgoda	3029.40	3	3.56	4.17	22.89
S07	Mahara	3886.80	0	4.08	3.72	20.45
S08	Kadawatha	5392.32	1	7.83	9.12	21.12
S09	Ganemula	2269.56	1	0	7.53	39.18
S10	Gampaha	2353.78	1	4.65	5.87	19.87
S11	Kottikawatte	5229.30	3	1.64	4.94	27.89
S12	Kaduwela	3773.19	8	18.05	3.5	18.05
S13	Rajakiriya	3651.50	9	6.84	7.14	28.89
S14	Battaramulla	3547.17	10	20.59	7.58	20.59
S15	Malabe	3003.08	14	2.11	4.4	28.78
S16	Nugegoda	5388.03	19	0	9.84	35.18
S17	Maharagama	4850.98	12	3.06	5.71	30.22
S18	Kottawa	3033.40	3	0	5.27	16.31
S19	Homagama	4098.75	1	0	4.13	18.43
S20	Godagama	1951.92	1	3.15	0.88	18.92
S21	Boralesgamuwa	4544.42	5	3.11	3.33	20.33
S22	Piliyandala	5037.30	0	5.35	4.39	28.4
S23	Kesbewa	2377.08	0	4.76	2.15	21.28
S24	Kahathuduwa	2239.56	0	1.72	0.96	22.46
S25	Dehiwala	13129.95	12	3.67	12.17	42.75
S26	Mount Lavinia	5518.98	13	3.8	4.82	43.82
S27	Ratmalana	5090.60	9	3.57	7.23	30.02
S28	Moratuwa	7568.67	14	5.91	3.8	22.44
S29	Panadura	7248.09	0	0.96	1.05	33.27
S30	Wadduwa	2385.96	3	3.19	2.37	23.36
S31	Kalutara	4201.53	4	2.75	3.38	17.52
Total		139953.73	182	147.26	156.2	784.42

The estimated demand and accessibility indicators for each proposed station are summarized in Table 7. Higher demand can be seen in areas such as Colombo Fort, Dehiwala, Moratuwa, Kelaniya, Kadawatha, Panadura, Mount Lavinia, Nugegoda, and Piliyandala. Looking at the demand in corridor-wise, the Galle Road corridor has the highest demand compared to all other routes. Comparatively, the Kandy Road and High-Level Road corridors

have a moderate level of demand, whereas the other corridors show average values of demand. In the context of accessibility, stations such as Colombo Fort, Nugegoda, Malabe, Moratuwa, Dehiwala, and Maharagama show a high number of transport nodes, indicating strong connectivity with existing transport networks. On the other hand, stations such as Kesbewa, Mahara, Kahathuduwa, and Panadura had fewer transport connections with their surroundings.

When looking at road coverage, the highest combined lengths of main and secondary roads were observed around stations such as Dehiwala, Ja-Ela, Battaramulla, Kaduwela, and Kadawatha. Conversely, the stations such as Kahathuduwa, Homagama, Wadduwa, and Kalutara were showing relatively lower accessibility. Moderate accessibility can be seen around some stations like Kiribathgoda, Gampaha, Mahara, and Wattala.

4 Discussion

The accuracy of determining station locations depends on the spatial resolution. Population density was derived from 1 km resolution raster. Although it is adequate to provide regional-level analysis but limits the analysis of highly populated or fast-growing urban areas, which may affect the demand estimation. Though the OSM data is freely available and provides updated data, its completeness and positional accuracy may vary across the area. Nevertheless, these datasets were suitable for preliminary analysis. The AHP method is successfully applied to give a structured and scientifically reasonable weighting system. The consistency ratio obtained in this study was 1.5% which indicates that there is logical consistency in the weight assignment and therefore can be accepted. The land use ranked first because of its direct implications on construction viability and environmental impact. Population density and proximity to existing transport nodes followed closely, reflecting their importance in ensuring demand and multimodal transport connectivity. Factors like proximity to social and environmentally sensitive locations, main roads, and buildings were carefully weighted to balance public acceptance, ecological preservation, buildability and accessibility.

The suitability map shows clearly the spatial variations, which mainly correspond to urbanization and transportation patterns. It can be observed that highly suitable areas are mostly clustered around existing major transport corridors. The majority of the areas were classified into less or unsuitable categories, which indicated the existence of dense built-up areas, environmentally sensitive regions, or steep land types. Some edge areas were not computed due to the edge effects in raster processing. The highest suitability value point in each GND set was selected as the proposed station location. Those points have been cross-checked with Google Earth to determine the practicality of having the station in that location.

Since most of the chosen locations fall into the land use categories such as croplands, sparse vegetation, and garden, this shows that there would be enough land to construct new stations without necessitating much resettlement and clearance of existing structures.

To maintain the analytical consistency, all station demands will be estimated using the uniform 1 km buffer zone. An average capture rate of 30% was assigned for stations in major urban centres and 20% for those in urban centres, based on general trends observed in similar case studies from South Asia, where exact values are often estimated due to the lack of consistent empirical data. Using this method, the daily potential user of all corridors in CMA, is estimated at about 195,000 (per Sq Km). Dense residential patterns and proximity to existing public transport infrastructure have led to increased demand in some localities such as Dehiwala, Moratuwa and Kelaniya.

The accessibility analysis further supported the strategic significance of connecting new stations to the road network and transport nodes to maximize usage and provide easy accessibility, which would boost the demand. Stations with dense road networks and multiple transport nodes, such as Nugegoda and Maharagama, displayed ideal conditions for effective multimodal integration. Overall, the buffer zones around all the proposed stations will have a total of 147.26 km of main roads, 156.2 km of secondary roads, and 784.42 km of residential streets, which proves that proposed stations have great accessibility and high demand capacity. This research serves as a preliminary framework for identifying and validating potential LRT station sites in the CMA. Further, optimum LRT line will be identified using these proposed stations.

5 Conclusion

This study effectively demonstrated that integrated Remote Sensing, GIS, and AHP techniques can identify optimal LRT station locations within complex urban environments like the Colombo Metropolitan Area. Suitability scores were derived using eight key factors, were systematically weighted and analysed, so that the selection of station sites was based on empirical information rather than assumptions. Although mid-resolution population data and open-access datasets were used, the consistency ratio confirmed the methodological reliability and Google Earth imagery supported the practicality of the chosen locations.

Considering rapid urbanization and heavy traffic congestion, there is an urgent need for sustainable transport solutions. Therefore, the LRT system has become highly favourable, eco-friendly, and long-term urban mobility option for the CMA. Future research needs to consider higher resolution satellite imagery, detailed surveys of soil and geology, real time data on traffic demand forecasts, household surveys, and proper land valuation models to increase implementation accuracy and reliability. Such additions would enable stations to be placed in demanded locations and enhance the accuracy of cost estimation. Ultimately, this foundational work contributes meaningfully toward actionable infrastructure development and supports national sustainable urban development goals.

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References

[1] Y. Sun and Y. Cui, "Evaluating the coordinated development of economic, social and environmental benefits of urban public transportation infrastructure: Case study of four Chinese autonomous municipalities," *Transport Policy*, vol. 66, pp. 116-126, Aug. 2018, doi: <https://doi.org/10.1016/j.tranpol.2018.02.006>.

[2] M. Ngoc, K. V. Hung, and V. A. Tuan, "Towards the Development of Quality Standards for Public Transport Service in Developing Countries: Analysis of Public Transport Users' Behavior," *Transportation Research Procedia*, vol. 25, pp. 4560-4579, 2017, doi: <https://doi.org/10.1016/j.trpro.2017.05.354>.

[3] CoMTrans Study Team, *Urban Transport System Development Project for Colombo Metropolitan Region and Suburbs: Urban Transport Master Plan, Final Report*. Colombo: Japan International Cooperation Agency (JICA) and Ministry of Transport, Sri Lanka, 2015.

[4] M. Ghorbanzadeh, M. Effati, M. Gilanifar, and E. Ozguven, "Subway Station Site Selection Using GIS-Based Multi-Criteria Decision-Making: A Case Study in a Developing Country," *Computational Research Progress in Applied Science & Engineering CRPASE*, vol. 06, no. 02, pp. 60-69, 2020.

[5] L. Zhao et al., "Location selection of intra-city distribution hubs in the metro-integrated logistics system," *Tunnelling and Underground Space Technology*, vol. 80, pp. 246-256, Oct. 2018, doi: <https://doi.org/10.1016/j.tust.2018.06.024>.

[6] Farkas, *Route/Site Selection of Urban Transportation Facilities: An Integrated GIS/MCDM Approach*, in *7th International Conference on Management, Enterprise and Benchmarking*, Budapest, Hungary (2009).

[7] S. Subasinghe, R. Wang, M. Simwanda, Y. Murayama, and L. L. Vitanova, "Neighborhood dynamics of urban expansion based on morphological spatial pattern analysis and geospatial techniques: a case study of the Colombo metropolitan area, Sri Lanka," *Asian Geographer*, pp. 1-21, Mar. 2021, doi: <https://doi.org/10.1080/10225706.2021.1903519>.

[8] M. D. McDonald and F. C. Kessler, "Least-Cost Path and Accessibility Analysis of a High Speed Railway Corridor: Victorville, CA to Las Vegas, NV," *Journal of Geographic Information System*, vol. 14, no. 01, pp. 40-60, 2022, doi: <https://doi.org/10.4236/jgis.2022.141003>.

[9] N. Mohajeri and G. R. Amin, "Railway station site selection using analytical hierarchy process and data envelopment analysis," *Computers & Industrial Engineering*, vol. 59, no. 1, pp. 107-114, Aug. 2010, doi: <https://doi.org/10.1016/j.cie.2010.03.006>.

[10] N. G. Ahmed and N. M. Asmael, "A GIS-Assisted Optimal Urban Route Selection Based on Multi Criteria Approach," *The Iraqi Journal for Mechanical and Material Engineering, Special Issue (D)*, pp. 556-567, 2015.