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Spatially Informed Light Rail Transit Planning for the Colombo Fort - Malabe Corridor in Sri Lanka

Abstract

Globally Light Rail Transit (LRT) is recognized as a long-term sustainable solution to address transportation-related problems such as traffic congestion, greenhouse gas emissions, rising fuel costs, and limited public transit accessibility. This article highlights how geospatial technologies, specifically GIS and remote sensing, are shaping a new era of LRT planning. Using the proposed Fort-Malabe LRT project in the Colombo Metropolitan Area (CMA), this study demonstrates how Analytic Hierarchy Process (AHP) based Multi-Criteria Decision Analysis (MCDA) can be used to optimise the LRT lines. By incorporating and systematically weighting various factors from different criteria including engineering, environmental, socio-economic, urban structure and accessibility, this approach minimizes the environmental and social disruption while maximizing the accessibility and efficiency, thereby laying the foundation for a future-ready urban transport system.

Introduction

Rapid development, poorly planned public transport system and an increasing population pose severe challenges to the Transportation sector in developing countries like Sri Lanka. Colombo Metropolitan Area (CMA) is the main economic and administrative centre of Sri Lanka, which mainly relies on road-based transportation. This has led to increased travel time, severe traffic jams and high emissions which pollute the environment. To solve this, the Light Rail Transit (LRT) system has been proposed.

Many countries have used LRT system as a viable solution to address the transportation issues. Globally, many case studies proved that LRT is an environmentally friendly, long-term sustainable transport solution. However, identifying where and how to build these LRT lines remains a critical challenge. Geographic Information Systems (GIS) coupled with Multi-Criteria Decision Analysis (MCDA) and decision-making tools like Analytic Hierarchy Process (AHP) gives a powerful framework to identify and optimise the LRT lines and stations. This will improve accessibility, increase ridership and economic efficiency and minimize the disturbance to social and environmental systems.

Role of GIS & Remote Sensing in LRT Planning

Modern LRT planning relies on advanced geospatial technologies to map terrain, assess urban development, and analyze access patterns. GIS allows terrain, land use, and demographic data to be layered, whereas remote sensing can produce real-time data on spatial variation. In the case of LRT, such technologies allow planners to optimise the routes, conduct impact analysis, and long-term planning by combining engineering, environmental, and social data. By transforming these various datasets into standardized spatial layers, decision makers can evaluate multiple scenarios and optimise alignments based on empirical evidence rather than assumptions [1] [2].
Global Case Studies

Globally, most of the Successful projects utilize GIS and MCDA for LRT or metro route selection. Cartographic modeling and the AHP were employed in Istanbul to find the suitability zones of new metro line construction to ensure that corridors had minimum ecological impact and maximized connectivity [1]. Similarly, the Abuja metro project in Nigeria utilized a GIS-based MCDA framework to determine the most cost-effective alignments by integrating remote sensing, stakeholder feedback, and optimising that balanced cost, accessibility, and priorities in urban development [2]. The case studies demonstrate how GIS-MCDA structures are flexible and applicable in various planning processes. Lessons from such efforts are directly relevant to Sri Lanka's infrastructure ambitions.

Proposed LRT Project in Sri Lanka

The Colombo Metropolitan Area (CMA), located in the Western Province, consists of 20 Divisional Secretariat Divisions (DSDs) and 1,043 Grama Niladhari (GN) divisions. It had a population of 3,682,481 in 2012 and covers an area of 995.5 sq. Km [3]. The CMA encompasses the areas which are already urbanized and expected to be urbanized in 2035. The Urban Transport System Development Project has prioritized seven major corridors which faces severe traffic jams mostly [3]. Among them, the Malabe corridor has been identified as the top priority, as it is located in the central region of the CMA. It also supports Transit-Oriented Development (TOD) and multimodal transport, and passes through key areas including Colombo Fort, Rajagiriya, Battaramulla, and Malabe [3].

I. Methodology

For the MCDA analysis, ten of the most relevant input factors were selected under various criteria for LRT line determination [4]. Table 01 illustrates the input layers used for the analysis. All spatial layers were projected and reclassified into five suitability classes, ranging from Class 1 (highly suitable) to Class 5 (not suitable). The AHP was used to find out their relative importance. This was through organized pair-wise comparison of the factors in order to obtain their influence on LRT line selection. The Consistency Ratio (C.R.) was 3.3%, indicating acceptable analytical consistency of the judgments. Using the resulting weights, a cumulative raster referred as the suitability raster was generated [5]. Figure 01 shows the input layers used for the MCDA, and Figure 02 presents the final MCDA output. (Suitability raster for line determination)

Table 01: MCDA factors and their weightages derived from AHP

Criteria	Factor	Weightage (%)
Engineering Suitability	Slope	20.84
	Surface Curvature	12.60
	Soil	16.20
Land use and Environment	Land use	25.79
	Flood Frequency	9.40
	Proximity to Environmentally Sensitive Area	6.17
Accessibility and Transport	Proximity to Main Roads	1.69
Socioeconomic Considerations	Population Density	2.35
	Proximity to Socially Sensitive Locations	1.68
Urban Structure	Proximity to Buildings	3.29

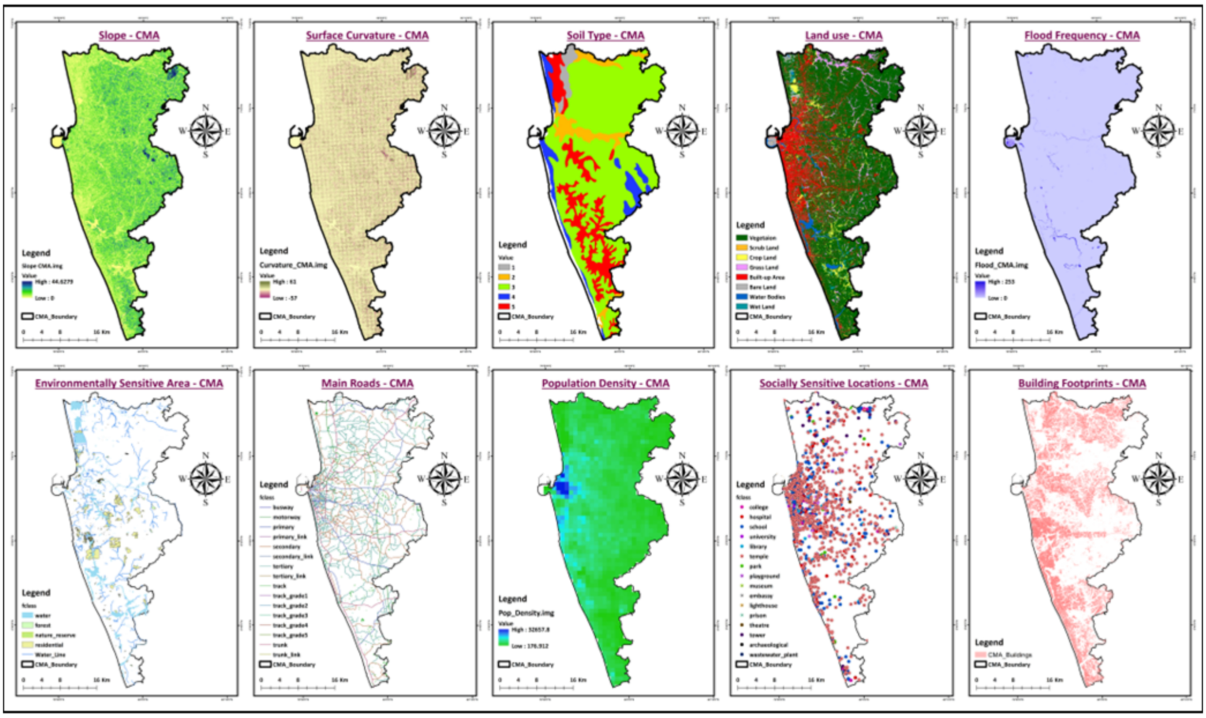

Figure 1: Input layers (10 factors) for MCDA Analysis

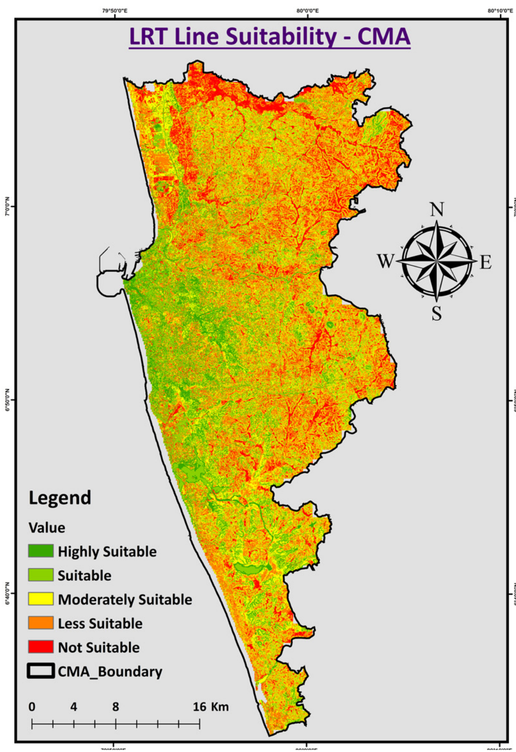

Figure 2: MCDA output - LRT Line Suitability

A Least Cost Path (LCP) was then calculated between the predetermined Fort and Malabe stations based on the suitability raster as cost surface. The LCP tool analyzed the cumulative "cost" of moving through each cell, resulting in an optimised route that avoids steep terrain, high-density zones, and environmentally sensitive areas while following accessible corridors. The derived route was cross-checked with Google Earth to assess the actual land use. Figure 03 illustrates the optimised LRT route between Colombo and Malabe through predetermined stations.

II. Results & Discussion

From the suitability map, 7.2% of the area was identified as highly suitable, 20.14% as suitable, 27.43% as moderately suitable, 28.12% as less suitable, 12.08% as not suitable, and 5.03% as not computed due to the edge effect in raster processing. The length of derived LRT line is 14.53 km. The obtained route closely follows major transportation axes while avoiding flood-prone and high-density residential zones wherever possible. Most of the alignment passes through barren land, paddy fields, park areas, and crosses a few built-up zones and wetlands including a notable crossing over Diyawanna Lake.

Despite the strengths of this integrated GIS-AHP framework, certain limitations exist. Data quality and spatial resolution may affect the precision of the results. Additionally, field validation is necessary to confirm the outcomes. Nevertheless,

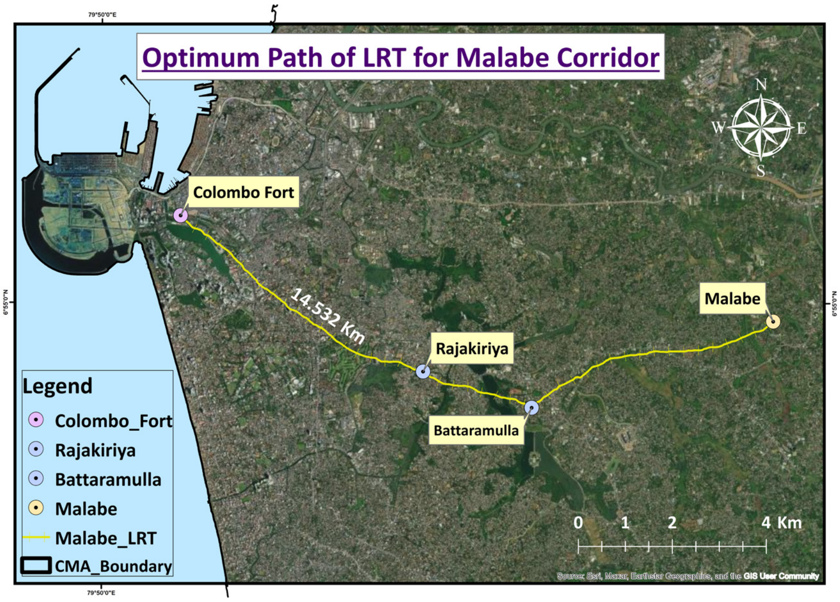

Figure 3: Optimised LRT route between Colombo Fort and Malabe

this approach not only enhances connectivity but also provides a transparent and data-driven basis for informed planning decisions.

III. Conclusion

The workflow developed in this study using GIS, remote sensing, and MCDA extends beyond academic research, offering practical guidance for policymakers and planners in Sri Lanka. By enabling transparent, data-driven decision-making, it helps to prioritize transport investments, reduce unnecessary costs, and avoid conflicts with sensitive environments or densely populated areas. As Sri Lanka advances major infrastructure projects, applying this spatial analysis will support for more equitable, efficient, and sustainable urban development. To enhance future accuracy, real-time data such as traffic congestion and construction risks should be integrated into the GIS model. Machine learning algorithms can further refine weightings dynamically based on the past project outcomes, while also predicting congestion, identifying high-demand zones, and supporting predictive maintenance through sensor data. Ultimately, this integrated approach lays the foundation for transport policies that are both scientifically sound and responsive to the needs of Colombo and similar urban areas.

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