AI-DRIVEN PEDESTRIAN SIMULATION FOR SUSTAINABLE URBAN PLANNING: AN AGENT-BASED SPACE SYNTAX FRAMEWORK FOR THE KANDY CITY, SRI LANKA

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Abstract

Urban planning in developing contexts prioritizes physical infrastructure, with limited attention to predicting pedestrian behavior. This study presents an AI-driven framework for analyzing pedestrian dynamics in Kandy, Sri Lanka, integrating urban morphology, Space Syntax theory, and Agent-Based Modeling (ABM). The framework uses OpenStreetMap-derived data, GIS-based land-use analysis, weighted spatial decisions, temporal profiling, algorithmic routing, and dynamic network recalculation. The agent-based simulation was custom developed in JavaScript as a rule-based AI system, with agent behavior guided by Hillier's Space Syntax principles: street-network integration values provide configurational attraction, while functional land-use categories provide activity attraction. The model integrates a road network layer and a functional land-use layer. A theoretically informed weighting of 55% for road configuration and 45% for land-use attraction was adopted, giving slightly greater influence to spatial configuration in accordance with the Space Syntax natural-movement proposition. Twenty-four-hour temporal profiles capture changing urban rhythms associated with educational, religious, commercial, and nighttime activities. Individual pedestrian agents are generated across the network, preferentially distributed along highly integrated street segments, and routed using a breadth-first search algorithm, with movement influenced by street configuration and time-dependent land-use activity. The behavioral logic is grounded in Space Syntax natural-movement theory, where street-network configuration influences movement distribution while land uses function as pedestrian attractors. Interactive intervention testing enables comparative evaluation of planning scenarios before implementation. The results showed spatially and temporally differentiated pedestrian-flow patterns, while the introduction of new road connections altered network accessibility and dynamically redistributed pedestrian movement. The simulation reproduced temporal variations associated with religious activity peaks, school-hour concentrations, midday commercial activity, and reduced nighttime movement, while network interventions resulted in the redistribution of pedestrian routes across the modified network. The study helps planners understand and predict pedestrian movement in Sri Lankan urban areas to guide decisions on street layouts, walking routes and public spaces.

Keywords: AI-Driven Decision Support, Pedestrian Dynamics, Agent-Based Modeling, Sustainable Urban Planning, Space Syntax