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PRINCIPLES OF APPLYING GREEN AND DIGITAL TRANSPORT TECHNOLOGIES (ECO-HUBS) “PARK AND RIDE” IN SAMARKAND

Abstract: This study evaluates the “Park and Ride” network based on the Eco-Hub located on the periphery of Samarkand city through the digital modeling, with the aim of addressing the problems of traffic congestion and air pollution. In a study based on empirical observations, the SUMO (Simulation of Urban Mobility) platform was used for mathematical modelling of transport flows, and the isochrone methodology for time and distance factors was used to determine the optimal locations for P+R car parks. In addition, the impact of the “green roof” concept for an environmentally friendly alternative city centre on urban air quality, including a reduction in PM2.5 concentrations, was assessed. The results of the study show that a network of Eco Hub P+R car parks on the outskirts of the city could reduce traffic flows in the central area by approximately 30% and reduce PM2.5 levels by up to 37%.

Keywords*:* Green infrastructure, Peripheral urban areas, Traffic congestion, Urban revitalization, Eco Hub.

INTRODUCTION:

In rapidly developing cities, including Samarkand, transport systems are increasingly facing serious problems due to the growing number of privatecars. This situation leads to congestion in the city centre, increased air pollution and a decline in the efficiency of public transport. The growning dependence of urban

residents private cars further intensifies environmental stress and contributies to higher concentrations of PM2.5 in the atmosphere. According to the city transport department, during peak hours the average speed is only 8–12 km/h, while the average journey time in the central and surrounding areas has increased by 25% over the past five years [1]. Moreover, the high concentration of private cars significantly contributes to air pollution. During rush hours, PM2.5 (particlate matter smaller than 2.5 micrometers, mainly formed from fuel combustion and road dust) levels reach up to 45–50 μg/m³, which is three times higher than the standardscestablished by World Health Organization standards [2]. *The purpose of this study* is to develop a digital simulation model of the Park and Ride (P+R) parking facility within the Eco Hub framework as part of the radial ring transport conceptual scheme of Samarqand city. *This research focuses on the following key aspects:*

- Determining the optimal locations for P+R car parks based on travel time and distance using Isochrone graph analysis;
- Mathematical modelling of traffic flow using SUMO (Simulation of Urban Mobility) platform;
- Reduction of air pollution through the implementation of green infrastructure, particularly green roof systems.

The expected outcomes of the study include an approximately 30% reduction in the city centre congestion and a 37% decrease in PM2.5 concentrations levels.

METHODS and MATERIALS.

An isochrone-based method was applied to determine optimal locations for Park and Ride facilities within the radial-ring structure of Samarkand. The analysis is based on the principle of travel time should be equal to the travel time by private car or the P+R option should br faster than usining a private car[3,4].

$$T_{veh} \geq T_{P+R} \qquad (1)$$

T_{veh}- is the time spent by the car owner to move using personal vehicles.

T_{P+R} - is the amount of time spent by the owner of the car to drive using

“park and ride” and public transport. Let’s take a closer look at what each indicator consists of. The time spent by the owner of the car to move using light vehicles[5,6].

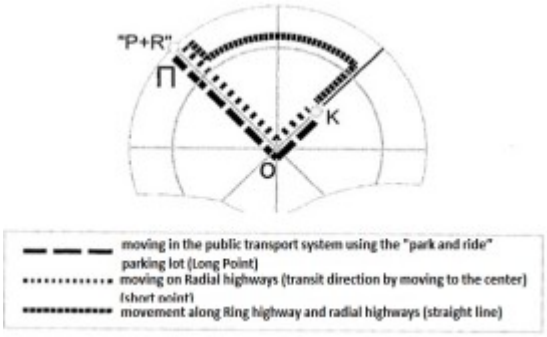

Figure 1. *Possible mobility transport options according to the single-ring scheme.*

This graph-analytical isochrone approach for transport analysis in cities with a radial ring structure, as illustrated in the scheme. The method is used to the concept of Park and Ride facilities, aiming to reduce private vehicle traffic in the city centre by combining travel time by private car $T_{veh}$with combined travel time using car and public transport. The isochrone diagram represents zones of accessibility from transport nodes within fixed time interval. It allows the evaluation of how far a person can travel within equal time periods using different transport modes[7,8].

At the second stage, a microscopic transport model of Samarkand was developed using the SUMO platform and the OSM Web Wizard module.

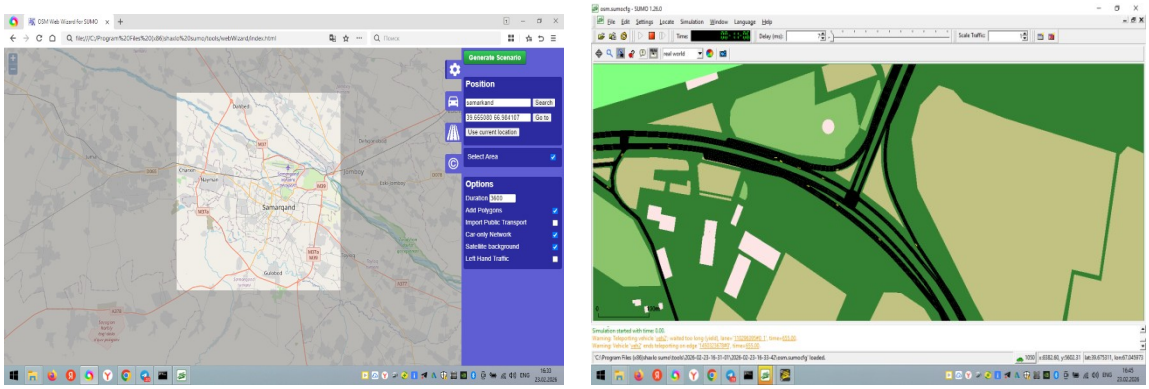

Figure 2, 3. *The street network of the Samarkand scenario in SUMO's WebWizard and Microsimulation - based traffic flow estimation for the Cho’pon ota section(M37) in Samarkand city.*

The model was created based on OpenStreetMap data and include:

✓ 🕐Road network geometry;

- ✓ 🕐Number of lanes and speed limits;
- ✓ 🕐Intersections and traffic signal control;

Traffic demand was simulated under peak-hour conditions, with light vehicles representing the dominant traffic flow. Particular attention was given to the Cho'pon ota section of the M37 highways, where the highest traffic intensity 4023 vehicle/day was observed. A scenario assuming a 50% modal shift to the P+R system was tested. Travel time was calculated using: $T = \frac{L}{V}$

The results show that the total travel time using the P+R system(26 min) is comparable to private vehicle travel time(29 min), confirming the feasibility of modal shift while reducing congestion[9,10].

At the final stage, the environmental impact, reflecting the proportion of pollutants such as PM2.5 and CO_2 that can be absorbed by a green roof on a parking hub. The literature shows that green roofs can absorb between five and fifteen percent of pollutants, depending on the area and density of plantings, which allows this indicator to be used for a conceptual assessment of the environmental impact[11]. Based on these data, a formula was proposed for calculating the predicted pollution concentration:

$$C = Co(1-N_{P+R}/N_{total})\cdot(1-\gamma)$$

Where Co- is the initial concentration of pollutants in the central part of the city, μg/m³ ; N_{P+R} -is the number of cars redistributed to P&R, N_{total} - is the total number of cars, and γ - is the proportion of pollution absorbed by green roofs. The formula allows for the simultaneous consideration of the effect of traffic flow redistribution and the additional reduction in pollution due to green spaces, which makes the assessment more comprehensive even without actual measurements[12,13].

RESULTS.

The transport model was developed using OpenStreetMap data and included road network geometry, speed limits, intersections and traffic signal control. Traffic demand was simulated under peak-hour conditions, with light vehicles

representing the dominant traffic flow. The analysis was focused on the Cho'pon ota section of the M37 highways, where the highest traffic intensity of approximately 4023 vehicle per day was observed. The results shows that the total travel time for P+R system is nearly equal to private car travel time, demonstrating the practical viability of the modal shift while reducing congestion in the city centre. In addition, environmental assessment shows that the integrigation of green roofs in Eco-Hub parking facilities contributes to reduction in air pollution. According to literature data, green roofs can absorb between 5% and 15% of pollutants, including PM2.5 and CO_2. The combined effect of traffic redistribution and green infrastructure leads to overall decrease in urban pollution levels, even without direct on-site measurements.

CONCLUSION.

The findings indicate that the Eco-Hub based Park and Ride system contributes to improved transport efficiency and reduced pressure on the central road network of Samarkand. The results confirm that a significant share of users can switch to the travel time, making it a practical alternative to private vehicle use. In addition, the integration of green infrastructure enhances the environmental performance of the urban air pollution. Overall, the proposed approach demonstrates the potential of combining transport planning and environmental solutions to support sustainable urban development and improve the quality of life.

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