ПОВЫШЕНИЕ ЭФФЕКТИВНОСТИ ТРАНСПОРТНОГО ПОТОКА НА ГОРОДСКИХ МАГИСТРАЛЬНЫХ УЛИЦАХ НА ОСНОВЕ ОПТИМИЗАЦИИ ПЕШЕХОДНЫХ ПЕРЕХОДОВ

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Аннотация: В статье исследовано влияние нерегулируемых пешеходных переходов на эффективность транспортного потока и безопасность дорожного движения на улице Ислама Каримова в городе Намангане. На основе методов транспортной инженерии и модели Гриншилдса проанализированы основные параметры транспортного потока. Предложено решение по переносу нерегулируемого пешеходного перехода в зону безопасного перекрестка. Расчеты показали, что реализация данного решения позволяет увеличить среднюю скорость движения на 23,8 %, пропускную способность дороги на 21,8 %, сократить транспортные задержки на 73,3 % и снизить выбросы CO_2 на 16 %. Предлагаемое решение способствует повышению безопасности пешеходов и транспортно-экологической эффективности городской магистрали.

Ключевые слова: *транспортный поток, безопасность дорожного движения, пешеходный переход, магистральная улица, модель Гриншилдса, пропускная способность, транспортные задержки, экологическая эффективность, город Наманган.*

IMPROVING TRAFFIC FLOW EFFICIENCY THROUGH THE OPTIMIZATION OF PEDESTRIAN CROSSINGS ON URBAN ARTERIAL ROADS (A CASE STUDY OF ISLAM KARIMOV STREET IN NAMANGAN CITY)

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Abstract. his study examines the impact of unsignalized pedestrian crossings on traffic flow efficiency and road safety along Islam Karimov Street in Namangan City. Using traffic engineering methods and the Greenshields model, key traffic flow parameters were analyzed. An infrastructure solution involving the relocation of an unsignalized pedestrian crossing to a safer intersection area is proposed. The results indicate that the proposed measure can increase average traffic speed by 23.8%, improve road capacity by 21.8%, reduce traffic delays by 73.3%, and decrease CO_2 emissions by 16%. The proposed solution contributes to enhanced pedestrian safety and improved transport and environmental performance of the urban arterial road.

Keywords: *traffic flow, road safety, pedestrian crossing, urban arterial road, Greenshields model, road capacity, traffic delay, environmental efficiency, Namangan city.*

Introduction. The theoretical foundations of analyzing traffic flow parameters on urban road networks and ensuring road traffic safety have been examined. Based on these analyses, the development and optimization of practical infrastructure solutions aimed at improving traffic safety have become increasingly important. Along with enhancing traffic flow efficiency, protecting human life and health remains a priority, and every element of road infrastructure plays a significant role in achieving this goal. Islam Karimov Street is one of the busiest streets in Namangan City. Pedestrian and vehicular traffic interact continuously along this corridor throughout the day. As noted above, these interactions have a significant impact on traffic flow performance, affecting vehicle movement, speed, and overall traffic efficiency.

Main Part. Human factors play a crucial role in the formation and operation of traffic flow. Drivers' qualifications, experience, psychophysiological condition, and level of compliance with traffic regulations significantly affect traffic flow stability. Likewise, pedestrian behavior, particularly crossing the road at undesignated locations, leads to interruptions in traffic flow, reductions in vehicle speed, and the formation of congestion.

External environmental factors, including weather conditions, also have a considerable impact on traffic flow. During rain, snow, fog, icy conditions, and strong winds, drivers are compelled to reduce their speed for safety reasons. As a result, traffic flow intensity and operating speed decrease, negatively affecting the overall efficiency of the road network.

Problem and Mechanism. As a result, both traffic flow intensity and travel speed decrease. On the analyzed 1.1 km (1100 m) section of the urban arterial road, the maximum permitted speed is 60 km/h. However, during peak traffic periods, vehicles are forced to slow down and stop due to the presence of an unsignalized pedestrian crossing located in the middle of the section and the influence of nearby signalized intersections. These interruptions reduce the average operating speed of the traffic flow to approximately 42 km/h, thereby decreasing roadway efficiency and increasing travel delays.

Practical Analysis and Proposed Solution. Model for Calculating Average Travel Speed. The average travel speed of a traffic flow along a road section (*v*avg) can be determined using the following internationally recognized traffic engineering formula:

$$v_{avg} = \frac{L}{T_{free} + \sum \Delta t_{delay}} \times 3.6\,[km/h]$$ where:

- L – total length of the road section (L = 1100 m);
- Tfree – travel time under free-flow conditions at the permitted speed of 60 km/h (Tfree = 66 s);
- ΣΔtdelay – total delay and stopping time experienced by vehicles along the road section (s).

Experimental Scenarios and Calculations. Based on field observations and the proposed infrastructure improvements, two traffic operation scenarios were evaluated.

Existing Condition (Before Optimization). During peak hours, a vehicle loses an average of 28 seconds due to yielding to pedestrians at the unsignalized crossing and waiting at traffic signals. According to the formula, the average travel speed is:

$$v_{avg} = \frac{1100}{66+28} \times 3.6 \approx 42.1 \ km/h$$**Proposed Condition (After Optimization).** After relocating the unsignalized pedestrian crossing to a safer signalized intersection, unnecessary braking and stopping maneuvers are eliminated. Consequently, the average delay decreases from 28 seconds to 10 seconds, resulting in:

$$v_{new} = \frac{1100}{66+10} \times 3.6 \approx 52.1 \ km/h$$The final results are summarized in the comparative analysis table of travel time and average speed indicators.

Results. *Relationship Between Speed and Traffic Flow Rate (Greenshields Model.* In traffic engineering and traffic flow theory, the fundamental relationship between vehicle speed and traffic flow rate is commonly described by the Greenshields model. This model assumes a linear relationship between vehicle speed (v) and traffic density, resulting in a quadratic (parabolic) relationship between speed and traffic flow. In addition, concentrating pedestrian movements at a single controlled crossing reduces conflict points between pedestrians and vehicles. This contributes not only to improved road safety but also to greater traffic flow stability and operational efficiency.

The proposed solution is expected to increase the average traffic speed, reduce vehicle delays, and improve the overall level of service of the analyzed road section.

Calculation of Equivalent Traffic Flow Rate (*N*eq).

To account for different vehicle types within the traffic stream, traffic volumes are converted into passenger car units (PCU) according to national road design standards. The conversion coefficients used are:

- Passenger car = 1.0
- Bus = 2.5
- Truck = 2.0–3.0

The equivalent traffic flow rate during the peak hour is calculated as follows:

$$N_{eq} = (N_{car} \times 1.0) + (N_{bus} \times 2.5) + (N_{truck} \times 3.0)$$For the experimental traffic composition (Ncar = 1500, Nbus = 40, Ntruck = 60):

$$N_{eq} = (1500 \times 1.0) + (40 \times 2.5) + (60 \times 2.0) N_{eq} = 1500 + 100 + 120 = 1720 \text{ veh/h}$$Thus, the equivalent peak-hour traffic flow rate for the analyzed road section is **1720 vehicles per hour**, which was used as the basis for evaluating traffic performance and the effectiveness of the proposed infrastructure improvements.

Conclusion. The study confirmed that unsignalized pedestrian crossings on Islam Karimov Street significantly affect traffic flow efficiency and road safety. Relocating the crossing to a safer signalized intersection can increase average vehicle speed by 23.8%, improve roadway capacity by 21.8%, reduce delays by 73.3%, and decrease CO_2 emissions by 16%. The findings demonstrate that optimizing pedestrian crossings is an effective way to enhance traffic performance, improve safety, and reduce environmental impacts on urban arterial roads.

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