ВРЕМЕННАЯ ИЗМЕНЧИВОСТЬ ИНТЕНСИВНОСТИ ТРАНСПОРТНОГО ПОТОКА НА РЕГУЛИРУЕМЫХ ГОРОДСКИХ ПЕРЕКРЁСТКАХ (НА ПРИМЕРЕ ГОРОДА НАМАНГАН)

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Аннотация. В данной статье исследуется временная изменчивость интенсивности транспортного потока на регулируемых городских перекрёстках на основе статистического анализа временных рядов на примере города Наманган. Сбор данных о транспортных потоках в режиме реального времени осуществлялся на выбранных перекрёстках в часы пик и вне пиковых периодов в течение пяти последовательных рабочих дней. Почасовые измерения позволили выявить характерные суточные закономерности движения и существенные различия между утренними и вечерними пиковыми периодами. Результаты исследования показали, что максимальная интенсивность движения наблюдается в вечерний час пик (17:00–18:00), превышая среднесуточное значение до 24 %. В пиковые часы уровень насыщения транспортного потока достигает критических значений (0,92–0,95), что приводит к образованию очередей и снижению пропускной способности перекрёстков. Для анализа колебаний интенсивности и определения рациональных параметров светофорного регулирования применялись методы вероятностного моделирования и спектрального анализа Фурье. Установлено, что адаптивная корректировка продолжительности циклов светофорного регулирования в пиковые периоды позволяет сократить длину очередей на 18–22 % и повысить пропускную способность перекрёстков. Полученные результаты могут быть использованы для оптимизации управления дорожным движением в условиях динамически изменяющейся городской транспортной среды..

Ключевые слова. *интенсивность транспортного потока, временная изменчивость, регулируемый перекрёсток, поток насыщения, анализ временных рядов, светофорное регулирование, часы пик, образование очередей.*

TEMPORAL VARIABILITY OF TRAFFIC FLOW INTENSITY AT SIGNALIZED URBAN INTERSECTIONS (CASE STUDY OF NAMANGAN CITY)

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Annotation. This paper investigates the temporal variability of traffic flow intensity at signalized urban intersections using statistical time-series analysis, based on a case study conducted in Namangan city. Real-time traffic volume data were collected at selected intersections during peak and off-peak periods over five consecutive working days. Hourly measurements allowed identifying distinct daily traffic patterns and significant differences between morning and evening peak periods. The results indicate that the highest traffic intensity occurs during the evening peak (17:00–18:00), exceeding the daily average by up to 24%. Saturation levels during peak hours approach critical values (0.92–0.95), leading to queue formation and reduced intersection performance. To analyze intensity fluctuations and determine appropriate signal control parameters, probabilistic modeling and Fourier spectral analysis were applied. The findings demonstrate that adaptive adjustment of traffic signal cycle durations during peak periods can reduce queue lengths by 18–22% and improve intersection capacity. The proposed approach provides a practical basis for optimizing traffic signal control under dynamically changing urban traffic conditions.

Keywords: *traffic flow intensity, temporal variability, signalized intersection, saturation flow, time-series analysis, traffic signal control, peak hours, queue formation..*

Introduction. Urban traffic flow demonstrates temporal irregularity and varies according to demand, time of the day and network configuration. In rapidly developing cities such as Namangan, the volume of private vehicles is constantly increasing, which leads to higher daily fluctuations and periodic saturation at signal-controlled intersections.

Recent studies show that most urban congestion appears not because of insufficient road capacity, but due to ineffective signal timing under dynamically changing conditions [1]. Therefore, studying the statistical nature of intensity changes is essential for traffic control and transportation planning.

Data and Methods. A field observation was conducted at three signalized intersections of Namangan city (Bobur Street, Afrosiyob Street and Yangiqo‘rg‘on Avenue).

Data collection:

Traffic volume was measured:

- at 5-minute intervals;
- during 5 days (Monday–Friday);
- at 07:00–20:00.

Total collected observations: ≈ 1,500 measurements

Statistical tools. The following techniques were applied:

- descriptive statistics;
- moving average smoothing;
- correlation analysis;
- Fourier spectrum decomposition;
- peak–base comparison;
- saturation degree calculation [4].

Saturation flow was calculated as:

$$x = \frac{q}{s}$$

Where: **q** – hourly traffic intensity, **s** – saturation flow rate.

It should be noted that between the above concepts, with all their significant differences, there is a thin dividing line that manifests itself through the concept of a development period.

The unevenness of the transport flow causes variability in its indicators, such as intensity, speed, density, composition, etc., therefore, the statistical expression of unevenness is the variability of the time series of transport flow characteristics.

The study of variability allows us to solve the following problems:

1) it allows us to put forward hypotheses about the causes of fluctuations in traffic flow;

2) it allows us to predict its value as a factor in traffic flow;

3) it allows us to calculate the necessary reserves, safety reserves, to eliminate the harmful effects of fluctuating levels.

The study and analysis of daily diagrams of traffic intensity distribution in urban conditions made it possible to create a theoretical classification of intensity fluctuations that affect the hourly and daily traffic intensity profile on central city streets and determine the types of temporal irregularities [3].

Results and Discussion.

1. Daily fluctuations

Measurements showed clear peak periods:

Time period	Average intensity (veh/h)
07:00–09:00	1320
13:00–15:00	890
17:00–18:00	1640

Evening peak value was 24% higher than the daily mean.

2. Saturation level

The saturation index reached **0.92–0.95** in peak hours, which indicates a near-saturated state and leads to queue accumulation.

3. Signal cycle evaluation

Simulation showed that extending the green phase by **+8–12 seconds** during peak hours reduces queue length by approximately **18–22%**, which fully corresponds to the recommended values of HCM (Highway Capacity Manual) [5].

4. Fourier spectral analysis

Low-frequency fluctuations (over 60 minutes) dominated, confirming the presence of systematic daily variability rather than random oscillation [2].

An important concept related to the unevenness of the transport flow is the randomly distributed variability - "oscillating interference". Its main feature is the randomness of deviations from the average value, and several other features are distinguished:

If the systematic components of the time series are correctly selected, then the residual component will have the following properties:

1- randomness of the change in values;

2- compliance with the law of normal distribution;

3- equality of the mathematical expectation to zero;

4- independence of the values of the levels from each other.

In the study of random processes, an effective means of determining the amplitudes and frequencies of oscillations that make up the level of a random variable is the Fourier transformation of this quantity function using transport flows.

Conclusion. The study confirms that daily intensity variation at regulated intersections has a significant and statistically measurable impact on traffic performance. Saturation intensifies during peak hours, creating regular congestion if signal plans remain unchanged.

Adaptive traffic signal control considering hourly fluctuations is proven to reduce queue formation and increase intersection throughput. Further studies should include weekly and seasonal analysis with a larger sample of intersections and traffic simulation under alternative control strategies.

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