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Justification of the Effectiveness of Developing and Using a Mobile Overpass

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Abstract. The article discusses the development and research of a mobile overpass as an engineering solution in the field of mechanical engineering and transport technology. It describes the design features of the overpass: the load-bearing span integrated into a two-axle wheeled chassis, the tensioning mechanism, and the suspension system, which ensure reliability and stability under dynamic loads. The technological advantages of the design are shown: mobility, quick installation without major construction, modularity, and the possibility of repeated use in various operating conditions. Based on preliminary engineering calculations and analysis of transport loads, the strength and operational reliability of the structure when moving passenger cars and light-duty vehicles is justified. The use of reinforced guide elements and a spatial truss scheme minimizes deformation and evenly distributes loads. The economic analysis confirms the efficiency of the proposed overpass's installation and operation, demonstrating a total annual saving exceeding 18 million tenge, primarily through reduced fuel consumption and minimized vehicle idling time. The results of the study confirm the feasibility of introducing mobile overpasses as an effective engineering solution that ensures the maintenance of transport links during major repairs and reconstruction of roads. The design combines manufacturability, mobility, and operational reliability, which opens up prospects for its widespread use in Kazakhstan's transport infrastructure.

Keywords: mobile overpass design; mobile overpass installation technology; utility network repair; traffic capacity of mobile overpass; mobile overpass installation efficiency.

Introduction.

Modern cities face complex transport problems associated with the growth in the number of cars, congestion on the road network, and environmental degradation. In Kazakhstan, urbanization and the increase in the number of cars are leading to regular traffic jams, fuel overconsumption, and longer travel times. In Karaganda, for example, the average travel time is about 32 minutes, which is close to the national average of 34.7 minutes. Such values indicate a high load on the urban road network, since an interval of 30–45 minutes in transport statistics is considered an indicator of severe congestion and traffic jams [1]. As a result, this negatively affects the efficiency of the transport system, increases socio-economic costs, and exacerbates the environmental situation [2].

The problem becomes particularly acute during periods of repair and road works on utility networks and road surfaces. Such work is often accompanied by lane closures, speed restrictions, and the redistribution of traffic flows. As a result, traffic capacity is reduced several times over [3]. Practice shows that during major repairs, the intensity of traffic jams increases sharply. Drivers are forced to use detour routes that are not designed for high traffic, which leads to congestion on secondary streets. This increases travel time, reduces the average speed of traffic flow, contributes to an increase in road accidents, and leads to additional emissions of harmful substances into the atmosphere [4,5].

When repairing urban underground utilities (heating networks, water pipes, communication cables, and power lines), traffic is also disrupted and diverted to other roads [6]. In this case, the mileage of cars increases, the intensity of traffic on detour routes increases, which leads to additional fuel consumption and greater air pollution [7]. Air pollution from nitrogen oxides, carbon monoxide, soot, and fine particulate matter (PM2.5 and PM10) causes an increase in the number of respiratory and cardiovascular diseases, including asthma, bronchitis, chronic obstructive pulmonary disease, ischemic heart disease, and stroke [8,9]. Children, the elderly, and people with chronic diseases, whose lung function deteriorates and whose immunity weakens, are particularly vulnerable to these effects [10,11].

Thus, traffic congestion caused not only by the growth in the number of vehicles but also by repair works is becoming one of the key transport problems. The overload of the urban road network during major repairs requires not only organizational measures but also the development of mobile engineering structures that ensure the continuity of traffic flow.

The development and application of a mobile overpass is proposed, designed to maintain uninterrupted traffic movement in areas where repair works and reconstruction of utility networks are carried out without complete closure of the roadway [12,13].

The mobile overpass considered in this study is part of a comprehensive research program conducted at the Department of Transport Equipment and Logistics Systems aimed at reducing the overall environmental load of the urban transport system. In addition to the development of mobile overpasses, this research also addresses methods of exhaust gas purification [14] through the introduction of innovative technologies for cleaning exhaust gases in car mufflers [15] and provides practical recommendations for improving air quality in urban environments. The combined application of these approaches — ensuring continuity of traffic flows and reducing vehicle emissions by — is expected to produce a significant integrated environmental and transport effect.

This article focuses on the development and justification of a mobile overpass [16] as an engineering transport solution that combines mobility, manufacturability, and operational reliability.

The purpose of the study is to justify the need to develop and use a mobile overpass and to prepare specific proposals for its operation to reduce traffic congestion and optimize traffic flow.

To achieve this goal, the following tasks were set:

– analysis of the effectiveness of existing infrastructure solutions (traffic light control, detour routes, public transport priority, intelligent transport systems);

– justification of the need to develop and use a mobile overpass, with a description of its design and installation technology;

– assessment of the economic and environmental efficiency of the proposed solution;

– preparation of practical recommendations for the operation of a mobile overpass using the example of a selected street section in the city of Karaganda.

The scientific novelty of the research lies in the development of a methodology for assessing the effectiveness of the proposed solution in the urban transport system. In particular, it presents a system of criteria that allows assessing the economic feasibility, environmental sustainability, and logistical efficiency of the proposed solution in conditions of road network congestion.

The practical significance of the work lies in the fact that the proposed solution will reduce traffic congestion, reduce average delays, and ensure annual savings in time and fuel for motor vehicles on the road. The methodology and results of the study can be applied in the planning of transport projects by local authorities, as well as in the design of temporary and mobile infrastructure facilities.

1. Materials and methods

In global practice, a wide range of solutions are used to reduce traffic congestion and optimize traffic flow, each of which has its own advantages and limitations (Table 1).

Table 1. Key solutions for reducing traffic congestion and optimizing traffic flow

Solutions	Advantages	Disadvantages	Implementation time	Financial costs	Countries where it is used
Special lanes for public transport	Increases the speed of public transport and reduces delays	Infrastructure is not suitable on some streets	6–12 months	200–400 million tenge	Colombia (Bogotá), Turkey (Istanbul), China (Beijing)
Smart traffic light system	Regulates traffic in real time, prevents congestion	Expensive system, requires sensors and database	6–9 months	150–300 million tenge	Netherlands (Amsterdam), Russia (Moscow), Singapore
Limits parking time at stops	Public transport runs according to schedule	Constant monitoring of driver compliance is required	3 months	20–50 million tenge	Finland (Helsinki), Singapore, Japan
Introduction of one-way traffic or detour systems	Redistributes traffic flows at intersections, reduces congestion	For some directions, the length of the route increases	3–6 months	50–100 million tenge	Czech Republic (Prague), Spain (Barcelona), USA (New York)

According to Table 1, dedicated lanes for public transport increase its speed and reduce delays, but their implementation may not be possible on all streets due to the need to adapt the infrastructure. Intelligent traffic light systems allow real-time traffic control and prevent traffic jams, but require expensive sensors and a developed database. Limiting parking time at stops helps buses run on schedule, but it needs to be strictly enforced. Setting up one-way traffic or detour routes helps redistribute traffic flows, but it can make some trips take longer.

Analysis of these examples shows that in many countries, solving the problem of traffic jams requires a comprehensive approach that combines the development of public transport, the introduction of digital technologies, and changes in traffic management schemes. Such practices are also of interest to Kazakhstan, but their high cost and the need for constant monitoring and maintenance limit their widespread implementation.

Therefore, the solution requires a comprehensive approach that takes into account the characteristics of infrastructure and public transport and the introduction of mobile solutions. One such solution is the use of temporary mobile overpasses, which allow traffic to continue uninterrupted and reduce socio-economic losses during road works.

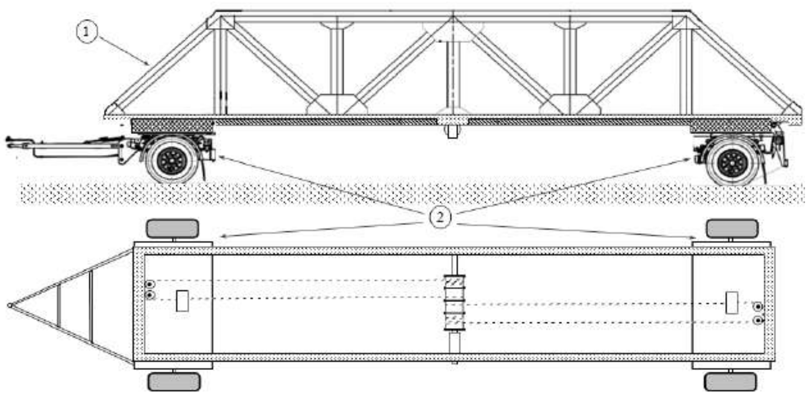
A mobile overpass is a temporary, quickly erected engineering structure designed to organize traffic over congested or repaired sections of road [17,18]. Unlike the organizational measures listed above, the developed mobile overpass is a mechanical structure with a focus on strength, reliability, and the ability to be used repeatedly under various loads .

From an engineering and design point of view, the mobile overpass is a metal load-bearing system for the roadway, mounted on a two-axle wheeled chassis that acts as a running gea [19]. This design solution simultaneously ensures the transport of the module to the place of operation and its stable position during operation [20]. (Figure 1).

The load-bearing part of the overpass is designed for motor vehicle traffic and is made as a single-span structure without connecting elements. The span configuration allows it to cross trenches and obstacles up to 8 meters wide. The width of the roadway is 2.5 m, with a design load on the pavement of up to 3 t/m² . The design load of 3 t/m² corresponds to the passage of passenger cars and the majority of light-duty commercial vehicles with a gross vehicle weight up to 3.5 tons (category N1 according to UNECE classification). Thus, the overpass ensures safe operation for the entire spectrum of urban light transport without weight restrictions for this vehicle category.

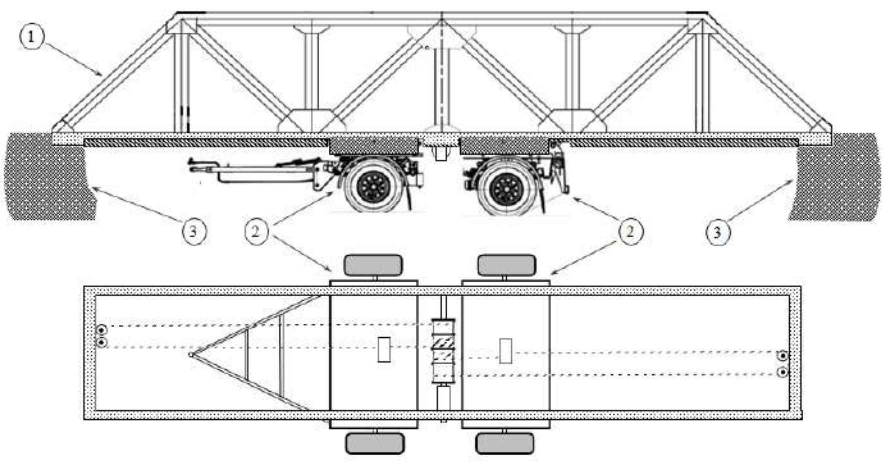
Fig. 1 – Three-dimensional model of a modular overpass

Its key feature is high mobility: the overpass is transported on a special chassis or trailer and can be quickly delivered to the place of operation (Figure 2). Installation is carried out directly at the site of work by deploying the structure, which does not require capital construction and reduces installation time to a few hours (Figure 3).



1 – supporting structure (platform) of the mobile overpass; 2 – movable suspension of the overpass.

Fig. 2 - Single-span modular overpass structure - transport position



1 – supporting structure (platform) of the mobile overpass; 2 – movable suspension of the overpass; 3 – trench side.

Fig. 3 - Single-span modular overpass structure - in operational position above the trench

The presented structural diagram of the overpass ensures high operational reliability: the use of a spatial truss and reinforced guide elements allows for even load distribution and minimizes deformation.

The undercarriage of the overpass is equipped with a system of running wheels that can be in two positions: raised and lowered. In the transport position, the wheels are lowered, which allows the overpass to be moved to the installation site. After the structure is moved over the trench, the suspensions are moved using a special mechanism, transferring the overpass to bridge mode.

The position of the axle is adjusted by rotating a special drum that transmits force to the cable. When the tension of the cable is changed, the axle moves to the required position. The process of pulling or loosening the cable can be performed either manually or using an electric drive, which ensures high positioning accuracy. The electrical equipment of the mobile overpass is designed according to a single-wire DC power supply system with a nominal voltage of 24 V. Power is supplied either from the onboard electrical network of the towing vehicle or from an автономоus аккумулятор battery mounted on the overpass frame. A separate independent circuit is provided for powering the electric motor of the axle movement drive (24 V). Such a power supply scheme allows the overpass to be installed and operated in locations without stationary electrical infrastructure while ensuring reliable operation of the tensioning and positioning mechanisms.

The running gear also includes cargo tie rods designed to connect to the towing vehicle, as well as suspension movement mechanisms. The latter ensure the correct installation of the structure on the supports, allowing this process to be carried out smoothly and safely.

To increase rigidity and operational reliability, a system of additional links connecting the front and rear axles is provided. This spatial arrangement prevents deformation and ensures the stability of the structure when subjected to dynamic loads during transportation.

An essential element of the structure is reinforced metal guide skids, which evenly distribute the load from the wheels to the supporting surface. This reduces the impact on the ground, allowing the overpass to be used even in areas with reduced bearing capacity without the risk of damage.

Thus, the running gear of the mobile overpass is a complex system that includes mechanisms for transportation, maneuvering, and installation. Design solutions aimed at increasing its strength and functionality ensure reliable operation of the overpass in various road and soil conditions.

The structure is designed to overcome trenches, repaired utilities, and temporarily closed road sections, ensuring the continuity of traffic flow even during large-scale reconstruction. During the operation of the mobile overpass, pedestrian movement across the repair zone is organized along temporary side walkways installed parallel to the overpass. This ensures complete separation of pedestrian and vehicle flows and increases overall safety during repair works.

An analysis of strength characteristics has shown that the mobile overpass is capable of functioning reliably under loads created by the movement of light and small-tonnage vehicles. The structure maintains the required level of rigidity and stability when exposed to dynamic factors. The spatial truss scheme ensures stability and uniform load distribution, while the presence of side barriers increases safety by eliminating the risk of vehicles veering off the road.

The economic efficiency of the mobile overpass is evident in the reduction of traffic jams, fuel consumption, and transport downtime. This achieves a significant socio-economic effect, especially in cities with heavy traffic. After the repair work is done, the overpass can be taken down and quickly moved to another spot, making it a flexible and versatile tool for temporarily organizing traffic and effectively managing traffic flows.

The study examines the main factors affecting the efficiency of traffic flows. The condition of Kazakhstan's road network remains one of the main factors contributing to transport problems: more than 40% of roads are in poor condition, and the lack of interchanges and bridges creates problem areas on the roads. Traffic management is also far from optimal: only about 15% of traffic lights are integrated into intelligent control systems, which limits the ability to regulate traffic flows and increases delays. The growth of the vehicle fleet further exacerbates the problem: by 2023, the number of registered vehicles exceeded 5 million, with about 60% of them being more than ten years old.

Urban development is also lagging behind the growth in car ownership: the density of the street and road network limits the possibilities for expansion, and the shortage of parking spaces is evident; for example, in Almaty, there are three cars for every parking space. The use of intelligent transport systems is still limited: only in Astana and Almaty do they cover about 30% of the territory, while in other cities such solutions are practically non-existent. The environmental component is also significant: the old, fuel-inefficient vehicle fleet accounts for up to 25% of the country's total pollutant emissions.

All these factors together create a systemic effect: worn-out roads, ineffective regulation, growth of the vehicle fleet, and weak integration of digital technologies lead to increased traffic jams, higher socio-economic costs, and a worsening environmental situation.

The above factors have an impact on key road sections in Karaganda. In particular, an analysis of the transport infrastructure and traffic at the intersection of Komissarova Street and Voinov-Internatsionalistov Street in Karaganda (Figure 4) revealed a number of key problems. Its strategic importance is due to the fact that this transport hub provides a direct connection to the railway station along Komissarova Street, provides access to the central district of the city (Mikhailovka) and the business center of Karaganda, and also serves the heavy traffic flows heading to large shopping and entertainment complexes, in particular City Mall. In addition, this intersection plays an important role in the transport accessibility of cultural and leisure facilities, such as the city circus, as well as related infrastructure, including hotels, administrative buildings, and social institutions.

Fig. 4 – General view of the intersection of Komissarova and Voinov-Internatsionalistov streets

An analysis of the current traffic situation at the intersection of Komissarova Street showed that during rush hour, the load on the intersection reaches critical levels. In the morning (7:30–9:30 a.m.), there is heavy traffic, mainly from residential areas, including Mikhailovka, towards the railway station and the city center. The evening period (17:00–19:00) is characterized by the opposite direction of traffic: the main flow goes from the station and the center to the residential areas. During both time periods, the traffic intensity consistently exceeds the standard capacity of the intersection. This leads to the formation of long traffic jams several hundred meters long.

Measurements for the section under consideration were taken between August 18 and 24, 2024, over a full 24-hour period with one-hour intervals. Particular attention was paid to the morning and evening peak periods. To record the data, vehicles were counted manually by direction of travel: straight ahead, right, and left, at each of the approaches to the intersection.

The recorded value was 1,067 vehicles/hour, which exceeds the reference capacity of 1,000 vehicles/hour. The reference capacity value of 1000 vehicles/hour corresponds to the typical calculated capacity of a signalized urban intersection according to traffic engineering practice and methodologies presented in the Highway Capacity Manual (HCM). The distribution of traffic flows showed that the straight direction is predominant — up to 75% ($q_{straight}$= 800 vehicles/hour). The share of right-turn and left-turn flows was 13% ($q_{(right)}$ = 134 cars/hour) and 12% ($q^{(left)}$= 133 cars/hour), respectively. The total flow at the turns reached 267 cars per hour.

If the total traffic flow q_c exceeds the standard capacity of intersection C, traffic jams and congestion are inevitable on the road section. In this case, the recorded value was 1,067 vehicles/hour, which exceeds the established standard of 1,000 vehicles/hour. Thus, the intersection of Komissarova Street and Voinov-Internatsionalistov Street is operating at overload, which confirms the presence of persistent traffic jams and highlights the need to implement additional engineering solutions to increase its capacity.

In addition, large-scale repair work is currently being carried out on the section under study, involving the replacement of underground utilities. These measures have significantly complicated the traffic situation: part of the roadway was completely blocked, which led to a reduction in the already limited number of lanes and a significant decrease in the capacity of the intersection (Figure 5).

Fig. 5 – Situation at the intersection of Komissarova Street and Voinov-Internatsionalistov Street during the overhaul of utilities

A telling example was the situation recorded in Karaganda from September 5 to 7, 2024, when traffic through the intersection of Komissarova Street and Voinov-Internatsionalistov Street was completely closed (Figure 6).

Fig. 6 – Fig. 6 – Traffic closure plan developed based on official municipal repair scheme

During this period, it was impossible to drive through the intersection, which exacerbated traffic jams and forced motorists to use detours.

In addition to organizational restrictions, the construction work itself was a complicating factor: pipelines were being replaced at the intersection, requiring significant intervention in the road structure (Figure 7).

Fig. 7 – Work on replacing utilities (pipelines)

The situation on site showed that the actual capacity of the intersection had decreased by more than half, which led to a forced redistribution of traffic flows to neighboring streets. However, the street network of the adjacent area is not designed for such high loads, which caused a chain reaction of traffic jams, increased transportation costs, and reduced overall traffic efficiency in the central part of the city. As a result, traffic restrictions in this area inevitably have a negative impact on the functioning of the entire urban transportation system.

In such conditions, the use of a mobile overpass appears to be the most rational engineering solution. Its installation will ensure continuity of traffic, redistribute transit traffic over the section under repair, and reduce the load on the intersection, while maintaining the stability of the city's transport links.

Unlike traditional traffic management methods (temporary detour schemes, installation of additional traffic light phases, widening of lanes at the expense of road shoulders), a mobile overpass provides physical separation of traffic flows and guarantees the preservation of traffic capacity on a critically important route.

A distinctive feature of this technology is its modularity and mobility. The structure can be erected in a very short time, without the need for large-scale earthworks or prolonged traffic closures. At the same time, standard low-frame chassis and prefabricated span structures can be used, which makes the project economically viable and technically realistic for urban conditions.

The socio-economic effect of the introduction of a temporary mobile overpass is evident in several key areas:

- reduction of transport costs by reducing travel time and fuel consumption;
- maintaining the stability of the city's transport system by redistributing traffic flows and eliminating congestion on the street and road network in residential areas;
- minimization of environmental damage by reducing emissions from cars stuck in traffic jams;
- increased safety for both drivers and pedestrians by eliminating intersections between traffic flows and repair work zones.

Thus, the introduction of a temporary mobile overpass at the intersection of Komissarova street and Voinov-Internatsionalistov street can be considered an innovative and strategically important solution capable of significantly improving the efficiency of Karaganda's transport system under restrictive conditions. Moreover, the mobile overpass can be reused in other parts of the city where similar capacity problems arise, ensuring its reusable value and quick return on investment.

2. Results and discussion

It is estimated that after the installation of the overpass, 90% of straight traffic will be redirected to the overpass, with only 10% remaining at the intersection (Figure 8).

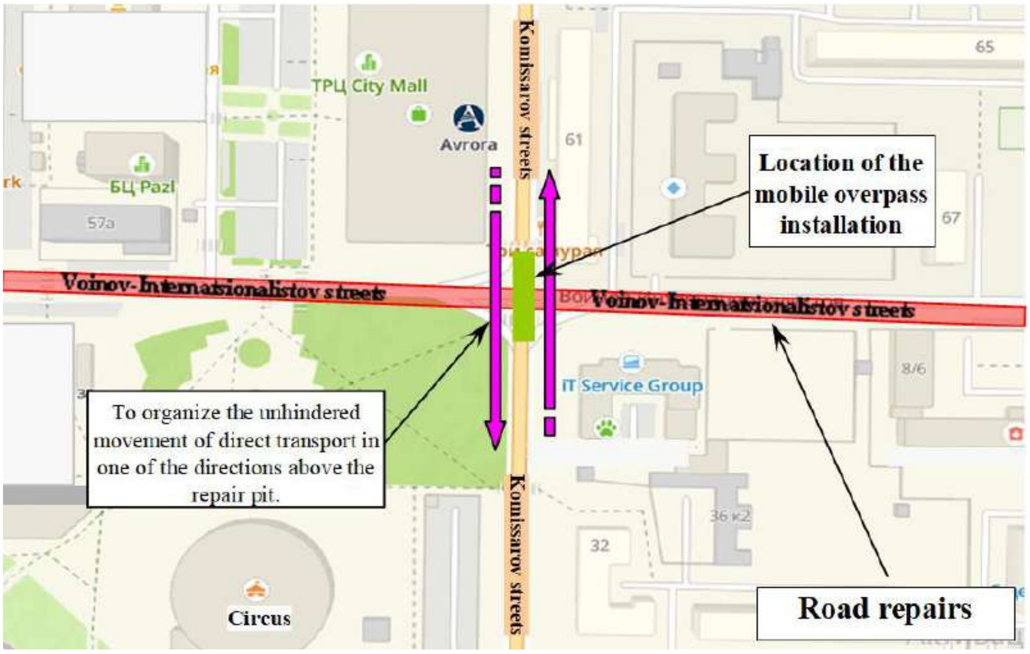


Fig. 8 – Proposed scheme for installing a mobile overpass to ensure continuity of traffic at the intersection in question

Then, if the straight flow initially was q_t =800 cars/hour, then the traffic flow ascending the overpass and remaining at the intersection will be:

$$q_{asen} = q_t \cdot n, car/hour \quad (1)$$

where q_t- the straight flow;

n - % of straight traffic, which will be redirected to the overpass or will be remained at the intersection.

$$q_{asen} = 800 \cdot 0{,}9 = 720 \ car/hour$$

$$q_{rem} = 800 \cdot 0{,}1 = 80\ car/hour$$

And the total traffic flow after the overpass is installed will be:

$$q_{total} = q_{rem} + q_{on\ turns},\quad car/hour \tag{2}$$

where $q_{on\ turns}$ - The share of right-turn and left-turn flows

$$q_{total} = 80 + (133{,}5 + 133{,}5) = 347\ \ car/hour$$

As a result of the redistribution of traffic flows, the total load on the intersection will decrease from 1,067 to 347 vehicles/hour, which is significantly lower than the standard capacity. This will eliminate the conditions for traffic jams. Consequently, after the installation of the mobile overpass, traffic will flow without congestion at the intersection of Komissarova Street and Voinov-Internatsionalistov Street during the calculated time intervals.

The average delay time for one vehicle at the intersection before and after the installation of the overpass was also considered:

$$d = \frac{0{,}5 \times c \times \left(1 - \frac{g}{c}\right)}{1 - X \times \frac{g}{c}},\ seconds. \tag{3}$$

where c - the traffic light cycle (84 s);

g - the duration of the green traffic light signal (35 s);

X - the load level

The load level is determined by the following equation:

$$x = \frac{g}{c}\ , \tag{4}$$

$$d_{before} = \frac{0{,}5 \cdot 84 \cdot \left(1 - \frac{35}{84}\right)}{1 - 1{,}067 \cdot \frac{35}{84}} = 25{,}74\ c.$$

Vehicle delay time at the intersection after the overpass installation:

$$d_{after} = \frac{0{,}5 \cdot 84 \cdot \left(1 - \frac{35}{84}\right)^2}{1 - \frac{347}{1000} \cdot \frac{35}{84}} = 16{,}71\ \ c$$

It is assumed that after the installation of the overpass, the average delay time for one vehicle at the intersection will be 16.71 s.

After the overpass is installed, the delay time for vehicles is reduced:

$$\Delta d = \ \ d_{before} - \ d_{before}\ \ hour \tag{5}$$

where d_{before} – vehicle delay time at the intersection before the overpass installation;

d_{after} – vehicle delay time at the intersection before the overpass installation.

$$\Delta d = 25.74 - 16.71 - 9.03\ c = 0.0025\ hour$$

Therefore, after the installation of the overpass, the average delay time for a single vehicle at the intersection will be reduced to **16.71 seconds**. Thus, compared to the initial value of **25.74 seconds**, the delay will be reduced by **9.03 seconds**, which is equivalent to approximately **0.0025 hours**.

Based on the calculations, a graph was drawn up describing the traffic flow at the intersection in question before and after the installation of the overpass (Figure 9).

The graph clearly demonstrates that redistributing traffic flow using an overpass reduces the load on the intersection and significantly reduces vehicle waiting times. This confirms the effectiveness of the proposed engineering solution in terms of both throughput capacity and reduction of socio-economic costs.

The effectiveness of installing the overpass was also assessed according to the following criteria:

- load reduction coefficient (traffic flow) per vehicle:

$$K_{lr} = \frac{q_{total(before)} - q_{total(after)}}{q_{total(before)}}$$

$$K_{lr} = \frac{1067 - 347}{1067} \cdot 100\% = 67{,}4\%$$

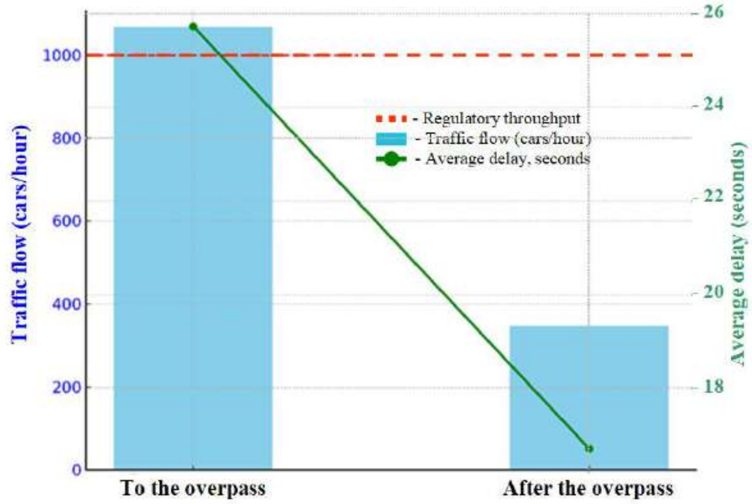


Fig. 9 - Graph describing the traffic flow at the intersection in question before and after the installation of the overpass

The load on the intersection after the installation of the overpass is reduced to 67.4%
- Intersection capacity (K_{ic}):

$$K_{ic} = \frac{C_{before}}{C_{after}} \tag{6}$$

$$K_{ic} = \frac{1067}{347} = 3{,}07$$

The capacity of the intersection will increase threefold after the installation of the overpass.
The economic efficiency of installing the overpass was assessed according to the following criteria:
- time savings at the intersection:

$$T_Y = \Delta d \cdot N_к \cdot C \tag{7}$$

where Δd – Is the reduction in vehicle delay time;
$N_к$ – number of cars, 1000 units;
C – price per hour of 1 driver's time 1500 tenge/hour.

Per day:

$$T_Y = 0.025 \cdot 1.000\ cars \cdot 1.500\ tenge/year = 3.750\ tenge$$

Per year:

$$T_Y = 3750 \cdot 365 = 1\,368\,750\ tenge/year$$

- Fuel savings:

$$\Delta Q = \Delta L \cdot R \cdot N \tag{8}$$

where $\Delta L = 2$ km (reduction in traffic congestion)
$R = 10$ l/100 km = 0.1 l/km (fuel consumption)
$N = 230$ tg/l (fuel price)

The value $\Delta L = 2$ km is based on field observations conducted during the closure of the intersection (September 5–7, 2024), where the average length of traffic congestion on detour routes recorded by visual measurements and GPS tracking exceeded 1.8–2.2 km.

Per day:

$$\Delta Q = 2 \cdot 0.1 \cdot 1000 = 200 \quad l/day$$

Per year:

$$\Delta Q = 200 \cdot 230 \cdot 365 = 16\,790\,000 \; tenge/year$$

Total savings:

$$E_{year} = T_Y + \Delta Q$$

$$E_{year} = 1\,368\,750 + 16\,790\,000 = 18\,158\,750 \quad tenge/year$$

Thus, the calculations show that the installation of a mobile overpass at the intersection of Komissarova Street and Voinov-Internatsionalistov Street provides significant transport and economic benefits. The total load on the intersection is reduced by more than two-thirds – by 67.4 percent, which eliminates the conditions for traffic jams. At the same time, the effective throughput capacity increases 3.07 times thanks to the diversion of the main part of the direct traffic flow to the overpass. The average delay time for one car is reduced from 25.74 to 16.71 seconds, which corresponds to a reduction of almost nine seconds. In economic terms, this provides a tangible benefit: the annual time savings for drivers is estimated at 1.37 million tenge, and the reduction in fuel consumption due to the reduction of traffic jams by two kilometers allows for additional savings of about 16.8 million tenge per year. The total annual effect of installing the overpass is approximately 18.2 million tenge, which confirms the practical significance of implementing the proposed engineering solution.

Conclusion

The study confirmed the engineering and operational efficiency of the developed mobile overpass as an element of transport technology. The design, based on a metal support system integrated into a two-axle wheeled chassis, provides high mobility, strength, and stability under operational loads. The developed solutions for the suspension system, cable tensioning mechanism, and spatial truss scheme of the span section ensure reliability and durability of operation with short-term installation and dismantling.

Preliminary studies have confirmed that the overpass is capable of withstanding loads corresponding to the movement of light and small-tonnage vehicles, while maintaining structural rigidity and stability under dynamic loads. The use of reinforced guide rails and connecting elements minimizes deformation and allows the structure to be used in various road and soil conditions.

From an engineering point of view, the mobile overpass is an example of a high-tech mechanical engineering solution that not only allows traffic flows to be maintained during major repairs, but also allows the product to be reused multiple times at different sites. Its modularity, collapsible elements, and standardized components simplify production, transportation, and operation, which is especially important in the urban infrastructure of Kazakhstan.

Thus, the results of the study confirm the promising prospects for the development of mobile overpasses in the context of mechanical engineering and transport technology. The design combines mobility and technological efficiency with operational reliability, which makes it in demand both for temporary transport connections and for further improvement of engineering solutions in the field of road and construction technology.

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