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Detailed transport analysis and modelling focused on the key network of streets in Satpayev city

A.M. Saiynov*, S.K. Tashenov, M.V. Kartashov, A.M. Bulgynova, B.M. Yeszhanov

LLP «Universal Tech Decisions», Astana, Kazakhstan

E mail: science@utd.kz

Abstract. The range of research of this paper is the central area of Satpayev city with a radius of around 150 hectares. The first problem was to define the possible effect of expanding Satpayev Avenue via Miners Square on the current transport network of the city. Based on the established traffic simulation software, researchers were able to model two different urban planning scenarios. These were then benchmarked against real traffic data that was recorded in the 80 intersections referred to as the key intersections in the city to measure the changes in the traffic performance. It was found that traffic in the evenings was extremely more delayed compared to the morning traffic; an average of about 20 percent more congestions. The avenue extension under consideration had a favorable influence on the state of the total traffic, providing significantly better travel times. In addition, the findings indicate that the extension would aid in relieving transit traffic out of residential areas, thereby enhancing the living conditions in those places. The analysis has affirmed that the suggested extension is likely to boost mobility, reduce congestions, and improve accessibility of emergency and municipal services.

Keywords: road network, transport modelling, motorization growth, pedestrian square, through traffic, courtyard road

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*the corresponding author

Introduction

City of Satpaev is one of the major industrial cities of the region, which is located in Ulytau Region. The number of the city population has not changed much in the past years, estimated at around 70,000 people [1]. This negligible growth of the population is evidence of the demographic equilibrium and lack of drastic changes. Simultaneously with this demographic stability, the level of motorization in Kazakhstan has increased at an accelerated pace. From 2020 to 2025, the number of passenger cars in the country increased from 3.87 million to 6.37 million (approximately 11% per year) [2].

As long as this trend persists, the number of passenger vehicles in the country can rise to above 6.4 million by early 2026. It is reported on the official basis of the Ulytau Regional Police Department that 3,537 additional vehicles were registered in the region from 2023 to 2025. By the end of March 2025, the total number of registered vehicles in Satpaev reached almost 16,000 vehicles. This equates to a motorization rate of about 200-230 cars per 1000 residents.

One of the major transport problems of the city of Satpaev is the discontinuity of the through passage along Satpaev Avenue in the central part of the city due to a break in the road at Gorniakov Square. The interruption of through connectivity on this important arterial road causes much hassle to the residents and jeopardises the efficiency of the city's transport system. The main negative consequences include:

- An increase in transit traffic through nearby residential neighbourhoods, with residents' complaints about increased levels of noise, aggravated environmental conditions, and lowered safety of courtyard areas.
- Reduced levels of efficiency of emergency services – especially the ambulances and fire services – because of the lack of direct and continuous access along the route selected.

Such issues become severe at the peak hours, because of the high traffic load and decreased speed of the vehicles. Restoring, through connectivity, is crucial to enhancing the flow of transport as well as response to emergencies and safety.

Figure 1. Load distribution scheme for courtyard driveways

The methodology

This research is based on the detailed analysis of traffic streams, using modern methods of data collection and data processing, and computer modelling. To be accurate and objective, traditional field research and the use of innovative devices were employed. The model was developed utilizing the open source mapping services such as OpenStreetMap, Yandex. Maps and Google Earth services. The collection of traffic load data was made using the following methods:

- Direct observation – manual observing of vehicles at chosen road segments.
- Aerial photography (with the help of unmanned aerial vehicles (UAVs) which was utilized to acquire fine-grained facts on traffic density, connection, and conflict points.
- Video recording process followed by automatic processing with the use of specialized software.

In order to achieve complete control over the most important directions, there was designed a network of 80 observation points. Recording was made in peak hours (8:00–9:00 and 18:15–19:15) on weekdays to ensure representativeness of data.

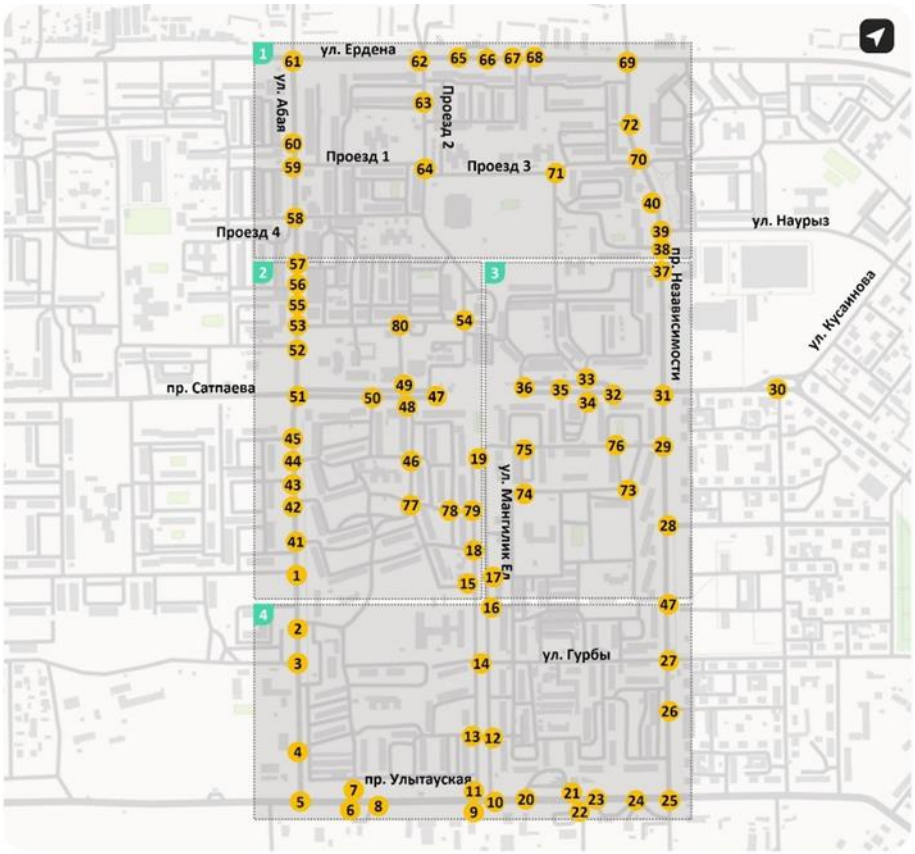

Figure 2. Control sections of the study

The collected materials were systematized by the following: the direction of travel, the kind of vehicles used, and the time passed. Using video footage with graphic schemes, it was concluded that the following were: volume of traffic, average speed, and delay duration. For the traffic situation analysis, the Aimsun software package was implemented with the capabilities of micro- and mesoscopic analysis of the traffic flows. Its functionality allowed for:

— Reconstruction of the existing situation of roads;
— Testing of potential modernization scenarios;
— Imagining congestion and flow patterns.
— Comparison of simulated and real traffic parameters.

The result of the study led to the development of proposals to achieve the best traffic conditions. The used methodology has shown extremely high effectiveness in the analysis of transport systems and the provision of scientifically justified solutions.

Findings/Discussion

The urban area of 1.5 km^2 (150 hectares), including main city roads (Yerden Street, Abay Street, Mangilik El Street, Ulytau Street, etc.) as well as Satpaev Avenue and Independence Avenue, was covered by the study. A central urban hub is Gorniakov Square, which divides Satpaev Avenue into two parts. During morning and evening peak times, traffic movement is slowed by an increased concentration of both pedestrian and vehicular flows in the city center [3].

Figure 3. Study Area

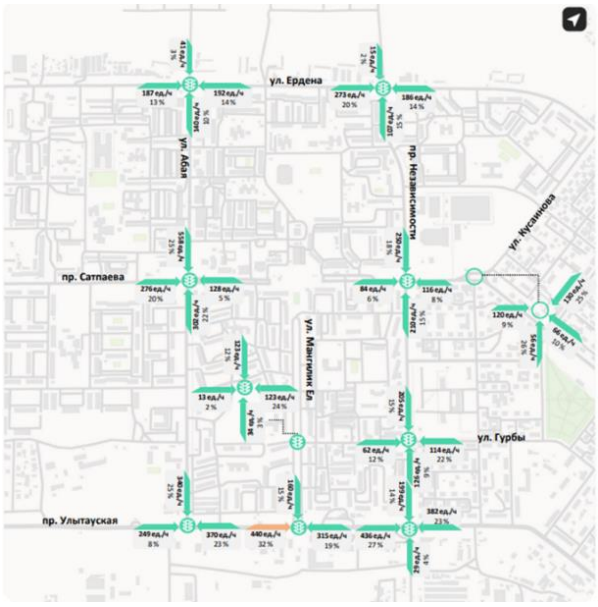

Figure 4. Reserve Capacity during Evening Peak Hour

It was found out through the analysis of the current traffic load that the evening peak hour is 20% more severe than the morning one in relation to the time of delay. Thus, modelling was performed based on the data for the evening peak period. Two major development scenarios were established based on the conducted study:

1. Baseline Scenario – There are no changes in the existing road infrastructure.
2. Optimized Scenario – carrying out the recommended traffic organization improvements.

This approach made it possible to make a direct comparison of the efficacy of potential solutions. One of the most important in the transport system analysis of Satpaev was the reconstruction of Abay Street, a major urban road that was scheduled for 2015. The consideration of this planned upgrade was made in all calculations of the traffic modeling undertaking.

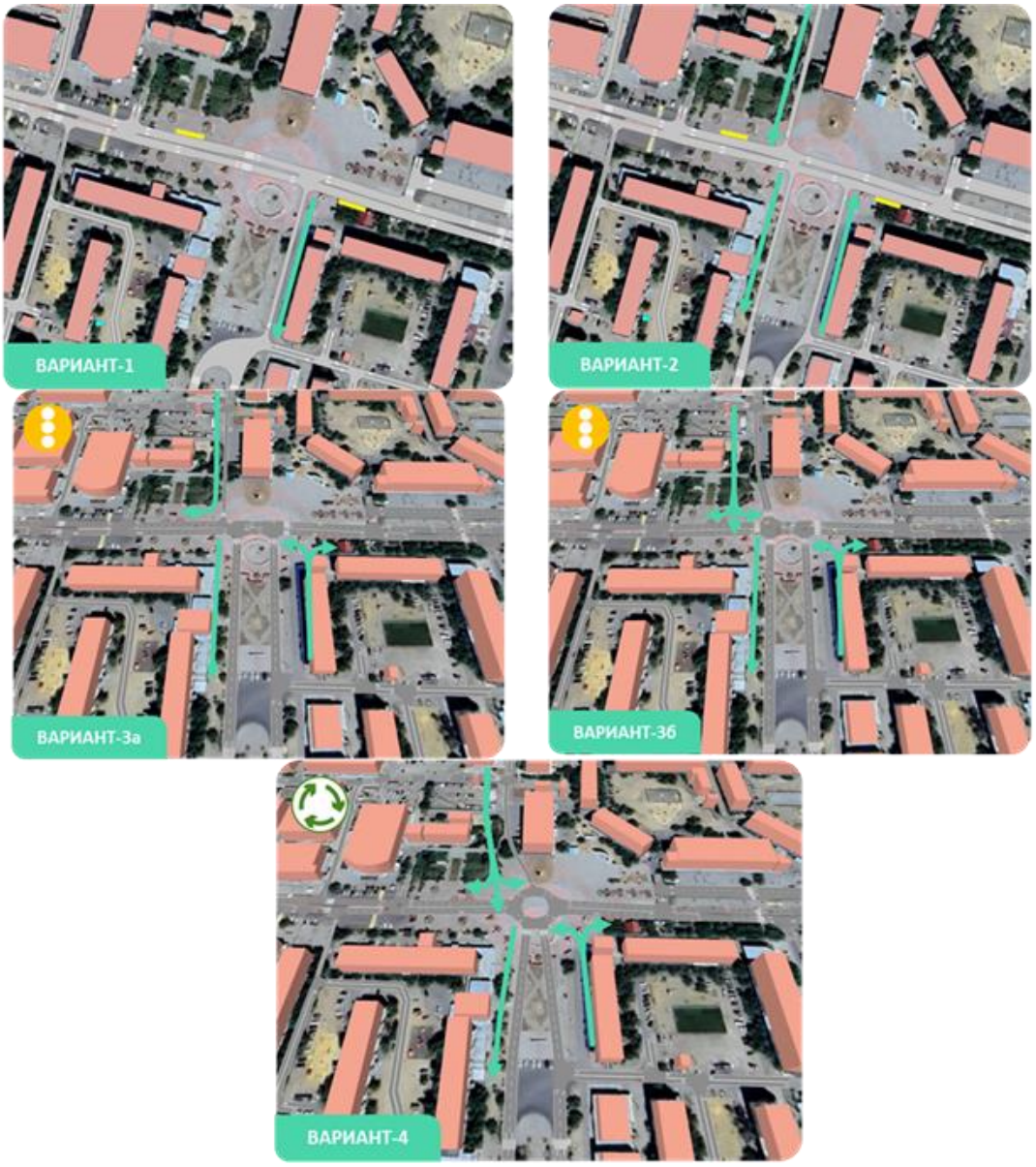

Figure 5. Traffic Flow Simulation Results

For optimizing traffic on Satpaev Avenue, four alternative options of development scenarios were developed. The first option, which was associated with relatively small changes to the square, showed a serious drawback: increased pressure on intra-block routes. This led to the creation of additional solutions (Scenarios 2, 3a, 3b, and 4), which suggested different schemes of traffic, both signalized and unsignalized intersections, and possible utilization of roundabouts. These steps intend to minimise transit traffic in areas with residential buildings and courtyard roads.

Suggested Measures to Decrease the Load on Interblock Networks:

1. One-Way Traffic Mangilik El Street, along with an exit towards Satpaev Avenue. This alternative is for rerouting clustered traffic away from the south and the east inner-yard roads; however, it keeps the possibility of overloading the other segments.

2. Unsignalized Exit – Boulevard Connection between Mangilik El Street and Satpaev Avenue without a traffic light. Allows entry as well as exit into the area around the Akimat.

Signalized Intersections:

3a. The T-Crossing has a one-way traffic towards Akimat and a return route to the rear end of Ulytau mall. A new left-hand lane towards Mangilik El Street.

3b. An X-shaped intersection having an extra lane and signalling control.

4. Roundabout at the junction of Satpaev Avenue and Street Mangilik El.

Provides free-flow traffic comprising U-turns for large vehicles with no signal delays.

The key parameters of the traffic flow were the basis of the effectiveness criteria. speed, density, delay time, and length of trip. The comparison of the five scenarios of Aimsun clearly revealed how the four sets of developed alternatives were better at optimizing the interblock traffic than the baseline scenarios.

Key indicators when analyzing the efficiency of different traffic management scenarios varied considerably. The best for the trip duration was realized in Scenario 4, and a decrease in travel time by 9.8%, which considerably exceeded the number in Scenario 1 (8.1%). The biggest decrease in vehicle delay time (12.1%) was achieved in Scenario 2. A thorough assessment of Scenario 4 proved its outstanding superiority over key parameters: the density of traffic went down to 17.8%, but the average speed went up by 7.8%. On the other hand, the respective numbers corresponding to Scenario 1 were much lower — 8.4% and 6.1% respectively (Table 1 – Results of Comparative Analysis).

Table 1. Results of Comparative Analysis

Indicator	Baseline	S-1	Change (%)	S-2	Change (%)	S-3a	Change (%)
Travel Time	126,88	116,75	8,1 ▲	114,89	9,6 ▲	114,72	9,7 ▲
Delay Time	32,72	30,47	10,1 ▲	29,83	12,1 ▲	30,36	10,4 ▲
Density	4,14	3,78	8,4 ▲	3,46	16 ▲	3,43	16,7 ▲
Speed (km/h)	31,65	33,63	-6,1 ▼	34,05	-7,4 ▼	34,13	-7,7 ▼

Indicator	Baseline	S-3b	Change (%)	S-4	Change (%)
Travel Time	126,88	115,75	8,9 ▲	114,66	9,8 ▲
Delay Time	32,72	31,4	7,2 ▲	30,12	11,2 ▲
Density	4,14	3,52	14,5 ▲	3,38	17,8 ▲
Speed (km/h)	31,65	-6,8	-6,8 ▼	34,16	-7,8 ▼

To calculate travel time across the route, having the intersection of Independence Avenue and Satpaev Ave (Point A) and the intersection of Abay Street and Satpaev Ave (Point B), the modeling was performed in 3D for two scenarios. The timeline of the current traffic scheme (yellow route) will take about four minutes, and the proposed resolution with the new formation of the passage

(green route) will reduce the time to only one minute.

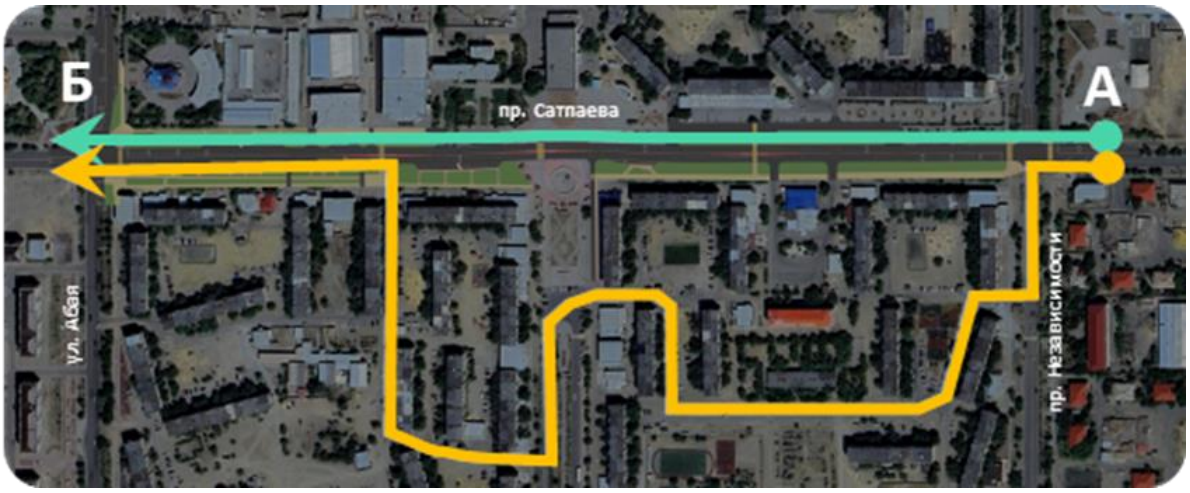

Figure 4. Travel Time Assessment from Point A to Point B

The project of getting rid of Gorniakov Square and extension of Satpaev Avenue envisages a holistic approach to the solution of the city's transportation problems involving improvement of connectivity of the road network, removal of local bottlenecks, and capacity improvement of road structures. The international experience of implementing similar projects demonstrates that, along with the obvious advantages of enhanced traffic performance, such transformations can also produce adverse impacts. The study of global case-studies allows objective evaluation of the balance between potential risks and benefits, which is of particular significance for the project's adaptation to local urban conditions and flow characteristics of transport.

Flexible use of transport space is becoming a common practice in modern cities: its functions are alternated by the city where it is needed. Global practice shows success stories of how the traffic areas can temporarily be made pedestrian for public events. For example, the Austrian town of Vöcklabruck shuts its main Stadtplatz to cars every week to allow it to hold a farmers' market for 15,000 – 20,000 people [4]. Similar measures can be seen during Christmas markets in Vienna, Prague, and Strasbourg, where central squares become pedestrian-only zones for weeks. Such an approach enables cities to preserve the accessibility of traffic during working days and promote the comfortable environment of an urban space for the crowds and happenings.

In the post-Soviet cities, the tradition of closing the main streets and squares during public events has become a successful case as well. In Moscow, during city celebrations, Tverskaya Street and Red Square turn into pedestrian zones. on the same note, in Astana, the central square is made devoid of traffic to accommodate celebrations [5]. These examples reflect an innovative strategy of urban space management, switching transportation hubs to temporary public space. A confirmation of the possibility of multipurpose use of city squares with the effective combination of transport functions and social and cultural activities.

The use of mobile elements of infrastructure – temporary fences, modular structures, bollards – allows adapting the space for more rapid functional use [6]. That approach provides the most appropriate balance between the requirements of the transport system and the demand for the arrangement of comfortable settings for urban activities.

Conclusion

The examination of the traffic situation on Satpaev Avenue and the surrounding streets represents the present state of the roads based on climatic and seasonal factors. Conducted in compliance with the standards of regulatory documentation of the Republic of Kazakhstan, the study has covered a territory of 150 hectares with a macro-level analysis of the road network, an intense assessment of 15 signalized intersections, 80 points of measurement of traffic intensity, and 7 lines of public transport.

The most important result is that the proposed scenarios (2–4) overnight remove all transit traffic through courtyard areas. Though the 11% increase in motorization may bring slight deterioration in the traffic situation, the construction of Abay Street needs adjustments to avoid overloading local streets.

Recommendations:

— Place a four-lane arrangement in Satpaev Avenue with parking bays, a reduction of speed, and safe pedestrian crossing.

— Optimize the public transport network according to the data of passenger flow (mainly, for Cases 1–3).

— Alter Abay Street reconstruction plan such that it lessens its impact on neighboring streets.

— Reconfigure movement of traffic signals (at Gurban street – Mangilik El street, the palace of schoolchildren) to allow for priority movement of high volumes of traffic directions.

— Effectiveness of the proposed solutions:

— Extension of the Satpaev Avenue cuts travel time four times between Independence Avenue and Abay Street.

— Enhanced relationship with Mangilik El Street (roundabout or signalized intersection) will remove pressure from interblock streets.

— Temporal street closures for public occasions will necessitate the planning of alternative routes.

The contribution of the authors

Saiynov A.M. - concept, methodology, drafting;

Tashenov S.K. - modeling, analysis;

Kartashov M.V. - data collection, visualization, interpretation;

Bulgynova A.M. - data collection, writing;

Yeszhanov B.M. - resources, supervision, funding acquisition;

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А.М. Сайынов*, С.К. Ташенов, М.В. Карташов,
А.М. Булгынова, Б.М. Есжанов

[1]ТОО «Universal Tech Decisions», Астана, Казахстан

Детальный транспортный анализ и моделирование, сосредоточенные на ключевой уличной сети города Сатпаев

Аннотация. Объектом изучения в данной работе является центральная часть города Сатпаев площадью около 150 гектаров. Главной задачей исследования являлось определение возможного влияния расширения проспекта Сатпаева через Площадь Горняков на существующую транспортную сеть города. С помощью специализированной программы моделирования дорожного движения было смоделировано два различных сценария планирования. Эти сценарии были сопоставлены с реальными данными о движении, зафиксированными на 80 ключевых перекрёстках города, чтобы оценить изменения в транспортной нагрузке. Выяснилось, что в вечерние часы движение значительно более загружено по сравнению с утренним трафиком — в среднем на 20% больше заторов. Будущее соединение проспекта оказало положительное влияние на общую ситуацию с транспортным потоком, обеспечив заметно лучшее время в пути. Кроме того, результаты показывают, что проект может способствовать выводу транзитного транспорта из жилых районов, тем самым улучшая условия жизни в этих зонах. Проведённый анализ подтвердил, что предложенное расширение, скорее всего, повысит мобильность, снизит заторы и улучшит доступ к экстренным и муниципальным службам.

Ключевые слова: дорожная сеть, транспортное моделирование, рост автомобилизации, пешеходная площадь, сквозное движение, внутридворовая дорога.

А.М. Сайынов*, С.К. Ташенов, М.В. Карташов,
А.М. Булгынова, Б.М. Есжанов

ЖШС «Universal Tech Decisions», Астана, Қазақстан

Сәтпаев қаласының негізгі көше желісіне бағытталған кешенді көлік талдауы мен модельдеуі

Аңдатпа. Бұл зерттеудің нысаны – Сәтпаев қаласының шамамен 150 гектарды құрайтын орталық аумағы. Зерттеудің басты мақсаты – Сәтпаев даңғылын Горняк алаңы арқылы ұзарту қаланың қазіргі көлік желісіне қалай әсер ететінін анықтау болды. Жол қозғалысын модельдеуге арналған сенімді бағдарламалық жасақтама негізінде зерттеушілер екі түрлі қалалық жоспарлау сценарийін жасады. Бұл сценарийлер қаланың 80 негізгі жол айрығынан алынған нақты қозғалыс деректерімен салыстырылды, сол арқылы көлік қозғалысының тиімділігін бағалау жүзеге асырылды. Зерттеу нәтижесінде

кешкі уақыттағы қозғалыстың таңғы уақытқа қарағанда шамамен 20%-ға көбірек кідірістерге ұшырайтыны анықталды. Ұсынылып отырған даңғылды ұзарту жалпы көлік ағынына оң әсер етіп, жүру уақытын едәуір қысқартатыны байқалды. Сонымен қатар, нәтижелер бұл жобаның транзиттік көлікті тұрғын аймақтардан тыс шығарып, сол аумақтардағы өмір сапасын жақсартуға көмектесетінін көрсетеді. Жүргізілген талдау ұсынылған кеңейтудің қозғалуды жақсартуға, кептелісті азайтуға және шұғыл және коммуналдық қызметтердің қолжетімділігін арттыруға ықпал ететінін растады.

Түйін сөздер: жол желісі, көлік моделдеу, автомобилизацияның өсуі, жаяу жүргіншілер алаңы, транзиттік қозғалыс, аулалық жол.

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Information about the authors:

Sayinov A.M. – corresponding author, Director of LLP “Universal Tech Decisions”, 53/42 Kabanbay Batyr Ave., Z05H0P9, Astana, Kazakhstan

Tashenov S.K. – Transport Modelling Specialist, LLP “Universal Tech Decisions”, 53/42 Kabanbay Batyr Ave., Z05H0P9, Astana, Kazakhstan

Kartashov M.V. – MSc in Information Systems, MSc in Economics, Senior Researcher, LLP “Universal Tech Decisions”, 53/42 Kabanbay Batyr Ave., Z05H0P9, Astana, Kazakhstan

Bulgunova A.M. – MSc in Business, Transport Planning Specialist, LLP “Universal Tech Decisions”, 53/42 Kabanbay Batyr Ave., Z05H0P9, Astana, Kazakhstan

Yeszhanov B.M. – Director of Development, LLP “Universal Tech Decisions”, 53/42 Kabanbay Batyr Ave., Z05H0P9, Astana, Kazakhstan

Сайынов А.М. – хат-хабар авторы, ТОО «Universal Tech Decisions» директоры, Қабанбай батыр даңғылы, 53/42, Z05H0P9, Астана, Қазақстан

Ташенов С.К. – көлік моделдеу маманы, ТОО «Universal Tech Decisions», Қабанбай батыр даңғылы, 53/42, Z05H0P9, Астана, Қазақстан

Карташов М.В. – ақпараттық жүйелер магистрі, экономика магистрі, ТОО «Universal Tech Decisions» аға ғылыми қызметкері, Қабанбай батыр даңғылы, 53/42, Z05H0P9, Астана

Булгынова А.М. – бизнес магистрі, көлік жоспарлау маманы, ТОО «Universal Tech Decisions», Қабанбай батыр даңғылы, 53/42, Z05H0P9, Астана, Қазақстан
Есжанов Б.М. – даму жөніндегі директор, ТОО «Universal Tech Decisions», Қабанбай батыр даңғылы, 53/42, Z05H0P9, Астана, Қазақстан

Сайынов А.М. - автор для корреспонденции, директор ТОО «Universal Tech Decisions», пр. Кабанбай батыра, 53/42, Z05H0P9, Астана, Казахстан
Ташенов С.К. - специалист транспортного моделирования ТОО «Universal Tech Decisions», пр. Кабанбай батыра, 53/42, Z05H0P9, Астана, Казахстан
Карташов М.В. – магистр информационных систем, магистр экономики, старший научный работник ТОО «Universal Tech Decisions», пр. Кабанбай батыра, 53/42, Z05H0P9, Астана, Казахстан
Булгынова А.М. – магистр бизнеса, специалист транспортного планирования ТОО «Universal Tech Decisions», пр. Кабанбай батыра, 53/42, Z05H0P9, Астана, Казахстан
Есжанов Б.М. – директор по развитию ТОО «Universal Tech Decisions», пр. Кабанбай батыра, 53/42, Z05H0P9, Астана, Казахстан