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Assessment of Safe Access to Pedestrian Infrastructure Facilities in the City of Almaty, Kazakhstan

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Abstract Currently, in all large and small cities in Kazakhstan, residential and public buildings are being actively built. It should be noted that the quantitative indicators of the construction of residential facilities prevail. The method applied to building residential facilities at the point and quarter increases the population density in urban areas. Increasing the number of residents requires assessing the levels of comfort for pedestrians at different speeds, the safety of sidewalks, and ensuring the accessibility of infrastructure facilities to people. The purpose of the study is to evaluate the quality of comfortable and safe conditions of pedestrian roads as a part of a district of Almaty. The assessment is based on the study of the presence and quality of elements and objects in the structures of transport roads and pedestrian sidewalks, and the determining level of pedestrian comfort is also applied (PCL). As a result of the study, the most problematic streets, the quality of pedestrian accessibility of extensive infrastructure facilities in each residential sector, and the main shortcomings and proposals for their elimination will be identified. The data obtained because of the study can be used in reconstruction, and urban area spatial planning concepts, allowing people to walk to most daily services and institutions, creating maximum opportunities to walk, reducing dependence on road transport, and contributing to the daily life of the community.

Keywords Pedestrian Roads, Security, Safe Accessibility, Urban Development, Infrastructure Facilities

1. Introduction

About 1,200,000 people live permanently in the revised area (part of the Bostandyk district of Almaty). However, due to the functioning of several extensive infrastructure facilities in the area, the number of people increases daily by 20-25 thousand people. Another important factor contributing to the increase in the number of pedestrians in the area at different times of the day is the excellent improvement of the embankment of the Bolshaya Almatinka River. In the last ten years, the Bolshaya Almatinka embankment has been a favorite place for walking, playing sports, and running for residents of the study area and citizens from other parts of the city. Although the arrival of 15-20 thousand people is temporary, they impact the formation of safety criteria on pedestrian roads. This aspect leads to an increase in the flow of traffic, an increase in the number of cars parked along the roads, an increase in the number of cyclists, people using scooters, pedestrians, parents with prams, etc.

According to the desired goal, a full-scale study of the selected square of the streets of Almaty city will be made. The task is to identify the shortcomings and favorable

conditions for the comfortable movement of people in the selected area of the city. The results of the study will be reflected in the illustrative scheme of each street and proposed to local executive bodies of the city government to improve the quality of life of Almaty city people. Research devoted to improving comfortable, safe conditions in cities makes an invaluable contribution to the urbanization process and the growth of cities worldwide.

As noted already, infrastructure facilities operating in this area can also be divided into "large" and "small" [1,2]. In this case, it should be noted that extensive infrastructure facilities include standalone buildings within their territory. Small infrastructure facilities include mini supermarkets, stores, children's centers, pharmacies, medical centers, and other facilities for daily public services. As a rule, small infrastructure facilities are located on the first floors of residential and public buildings. Small infrastructure facilities divide the territory of residential buildings, and the quality of pedestrian accessibility is not separately related to the general improvement of the residential yard. Within the framework of this study, primary attention is paid to assessing the comfort and safety of pedestrian accessibility to extensive infrastructure facilities in this area. The large infrastructure facilities are represented by four educational institutions, the Kazakh Leading Academy of Architecture and Civil Engineering (KazGASA), the Kazakh-American Academy (KAU), and the Kazakh National Academy. T. Zhurgenov (2nd building) (KazNAI), Academy of Economics and Statistics, two supermarkets, one extensive shopping and entertainment center, one office buildings (banks), two medical centers, four preschool institutions, five schools (1 of which are private, four states), and one arboretum with a total area of 53.8554 hectares. The area chosen for the study has the limits of Saina-Kablukov and Al-Farabi-Ryskulbekov streets, inside which there are several means of transport, one bicycle, and one main road. At the same time, it should be noted that all pedestrian roads are located along transport roads.

2. Literature Review

Safety is a significant factor influencing cyclist behavior, and understanding how road users perceive safety can help drive urban design that attracts more active travelers. Based on the stated preferences of motorists, cyclists, and pedestrians for safe transportation infrastructures , as well as analyzing street design elements including main streets, lanes, and sidewalks, conclusions described the importance of wide bike lanes and separating cyclists from vehicular and pedestrian traffic. Removing parking next to bike lanes also significantly improves perceptions of safety [3].

This study addresses the traffic light scheduling problem for pedestrian-vehicle mixed-flow networks. A macroscopic model, which strikes an appropriate balance between the needs of pedestrians and vehicle drivers, describes the problem of scheduling traffic lights in a scheduling framework [4-7]. More convenient and safer pedestrian conditions were created by expanding the scope of conventional button control methods [8-11]. Many transportation authorities have responded to traffic flow concerns in recent decades by building "footbridges" on significant roads and lower-velocity streets. This article argues for increasing attention to pedestrian-rights activism in infrastructure studies, offering insightful proposals for traffic control and sustainable transportation alternatives. The negative opinion of using pedestrian bridges and the need to find alternatives are becoming urgent issues in creating a safe environment for pedestrians [12,13].

Pedestrian safety in a city depends on many factors, such as crossing habits (road behavior, traffic culture), infrastructure elements, and general traffic conditions [1,14]. The case study analysis confirmed some of the existing results in the literature and laid the foundation for further research, such as surveying pedestrians and analyzing other urban crossings in high-density areas such as offices, banks, and schools [15,16]. To eliminate obstacles on city sidewalks that endanger the lives of citizens, self-centered applications are proposed. Immediate detection and removal of obstructions are essential to maintain clean and safe access to urban infrastructure. The authors of this paper developed methods to detect barriers and other dangerous obstacles pedestrians encounter on city sidewalks. For this purpose, a unique image dataset is created and used to analyze the performance of different methods for detecting and recognizing different types of obstacles using three different architectures of deep learning algorithms[17]. The high precision of the experimental results shows that the development of egocentric applications can successfully contribute to maintaining the safety and cleanliness of sidewalks while reducing the accident rate of pedestrians [18].

Creating comfortable conditions for pedestrians requires the study of various factors. A qualitative study of pedestrian streets, the walking experience of pedestrians, street traffic, needs of local pedestrians, etc. [19,20]. Comfortable accessibility of the target for pedestrians also requires considering a person's thermal comfort in the open air, especially in dry regions [21-23]. Various guidelines have been developed to implement data for all involved in the planning of city streets. These may include local government officials, elected members, consultants who evaluate the impact of a development proposal, developers, and designers. They represent the quality requirements for the construction of footpaths and crossings. These requirements apply when evaluating a new design or an existing footpath [24-26]. Pedestrian routes, in most situations, run along the buildings, allowing you to look at the facades' details and the lower level's filling. “The

border between inside and outside, private and public, is a natural part of urban life, as it is a convenient place to spend time"[10-12]. Visual contact in both directions enhances the visual experience. Plastically expressive architecture with a sufficient degree of permeability invites people to interact, creates a sense of harmony, and subsequently provides security. Attention to the medium scale, objects, and spaces between the building and the street and the formation of an environmental component becomes vital for people living in these areas [27].

3. Materials and Methods

The studied square of streets is indicated in aerial photographs of the area. Along the axes of transport/pedestrian roads, the entire area is divided into separate sectors, which are designated Sector 1 (from now on referred to as "C") C2, C3, C4, C4, C5, C6, C7, C8, C9, C10. The map highlights extensive infrastructure facilities and pedestrian and transport roads. Observation and photographic recording of the movement of pedestrians from each designated sector to a specific large infrastructure facility are carried out. The quality of the surface condition, the width of pedestrian roads, street lighting, and pedestrian traffic density are analyzed, and pedestrian streets' negative and positive qualities are revealed.

The Pedestrian Comfort Level (PCL) method estimates the density level of foot traffic on a sidewalk. It is based on the density of pedestrian flow observed on a given street [2,28]. "To assess it, it is necessary to divide the street into several sections, highlighting the most characteristic sections of the street (pickets). These pickets must contain objects that impede traffic or be located where the sidewalk widens or narrows. Therefore, objectively assessing the quality of pedestrian movement along the sidewalk is possible. The PCL index, people/(m·min), is calculated using the formula (1) for each picket. This allows you to analyze the quality of pedestrian movement at individual points and throughout the sidewalk.

$$PCL = \frac{F_{m(p)}}{60 \cdot W_{cp}} \quad (1)$$

Where Wcp is the clear width of the passage, m; Fm(p) - average or peak intensity (density) of the pedestrian flow, people / s, the value of Wcp is usually determined separately for each picket experimentally. The following formula determines the density $F_{m(p)}$:

$$F_{m(p)} = \frac{3600 \cdot N_{total(p)}}{T_s \cdot n_{s(p)}} \quad (2)$$

where N_{total} is the total number of pedestrians who passed through the "virtual gate" for the total time of all measurements (or for rush hour), people; Ts is the time of one measurement, s; ns is the total number of measurements (or during rush hour).

Depending on the PCL value, the conditions for pedestrian traffic in the section of this picket belong to one of the categories: A-, A, A + - these categories provide the maximum level of comfort for pedestrian traffic, regardless of the type of territory. B-, B, B+ - these categories provide minimum comfort for pedestrian traffic on most streets. Type B- is considered uncomfortable for main streets or tourist routes. C-, C, C+ - these categories provide minimum comfort for pedestrian traffic in business districts and transport interchange zones. Such conditions are uncomfortable for residential areas, and the main streets are unacceptable. D, E - these categories do not provide comfortable conditions for pedestrian traffic. There is no freedom of maneuver. Pedestrians should look for detours, as traffic conditions can become uncomfortable and dangerous.

Based on the studied material, an assessment of compliance with the following criteria will be made:
the needs of pedestrians and cyclists?

- Are there any bus stops?
- Are the bus stops easily accessible for pedestrians?
- The presence of additional passageways to get to public transport stops or public facilities?
- Have particular actions been taken that are necessary for special groups of citizens - for example, young people, the elderly, the sick, the disabled, the deaf, or the blind?
- The availability of lighting and the correctness of its planning?
- is the view obstructed - for example, by barriers, road equipment, parking lots, road signs, landscaping, plants, bridge piers, or buildings?
- Are cycle paths well marked near public transport stops?
- Are the flows of vulnerable road users and motor vehicles separated?
- Are pedestrian crossings marked?
- Are the transitions convenient and safe?
- Is there any risk that pedestrians will not use underground and overground passages?
- Are the safety islands wide and large enough for waiting pedestrians and cyclists?

4. Results

4.1. Al-Farabi Avenue-Saina Street

Al-Farabi is the main avenue of the city of Almaty and, from the south side, connects to the mountains "Zaili Alatau". Many modern multifunctional complexes, theaters, shopping and entertainment complexes, residential buildings, etc. are concentrated on Al-Farabi Avenue. This avenue has a semicircular shape on the city's plane and flows from the east and north into other streets that connect the city with suburban areas. This street on the east side, the so-called eastern bypass road,

intersects Saina Street on the west side, as shown in **Figure 1**.

In this study, a part of Al-Farabi Avenue is considered, which includes a section that starts from Kekilbayuly Street and ends with Saina Street. There are many interchanges and elevated pedestrian roads on Al-Farabi and Saina Avenue. In this study, Al-Farabi Avenue connects the considered residential area with the arboretum, as shown in **Figure 2**. The opportunity for residents to visit the dendropark (president's park) is conducted with the help of one aboveground and one aboveground pedestrian road.

Saina Street is also the main road. In recent decades, many road forks have been built on Saina Street, over which pedestrian crossings pass. Several road means of transport have increased in Almaty, prompting the call for this measure. In the part of the street where there are no underground passages for cars, elevated pedestrian bridges were built, as shown in **Figure 3**. The pedestrian roads also operate on both sides of the Al-Farabi and Saina streets throughout their length.

4.2. A. Kekilbayuly Street

Kekilbayuly is a two-lane street for vehicular traffic, as shown in **Figure 4**. On one side of the road is a pedestrian sidewalk; on the other, there is a green stripe and a bicycle road. The bicycle road was organized instead of the former tram line. In the early 2000s, all tram lines were dismantled in Almaty, and instead, bicycle roads were built. This event was organized as part of the city for the people program. The main goal was the development of pedestrian and bicycle roads; the embankment of the territory, in general, propaganda to reduce the number of cars in the city.

This bike path is trendy among the residents of the area and the city. In addition to cyclists, this road is actively used by people on scooters, roller skates, and pedestrians. Kekilbayuly Street is the eastern boundary of the study area. Infrastructure facilities like the Kazakh Academy of Arts, named after T. Zhurgenov (2nd building), the Mega shopping and entertainment center, and the Big Almaty Canal are on this street.

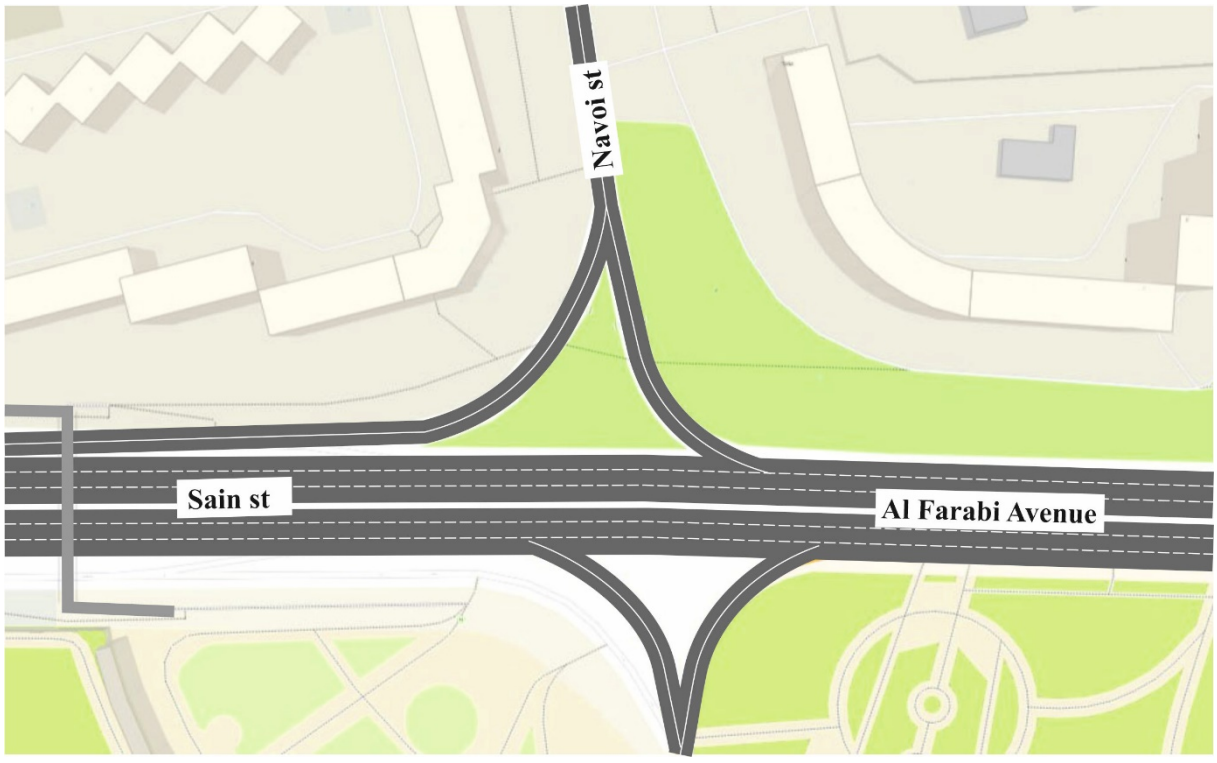

Figure 1. Al-Farabi Street crossing points to Saina Street

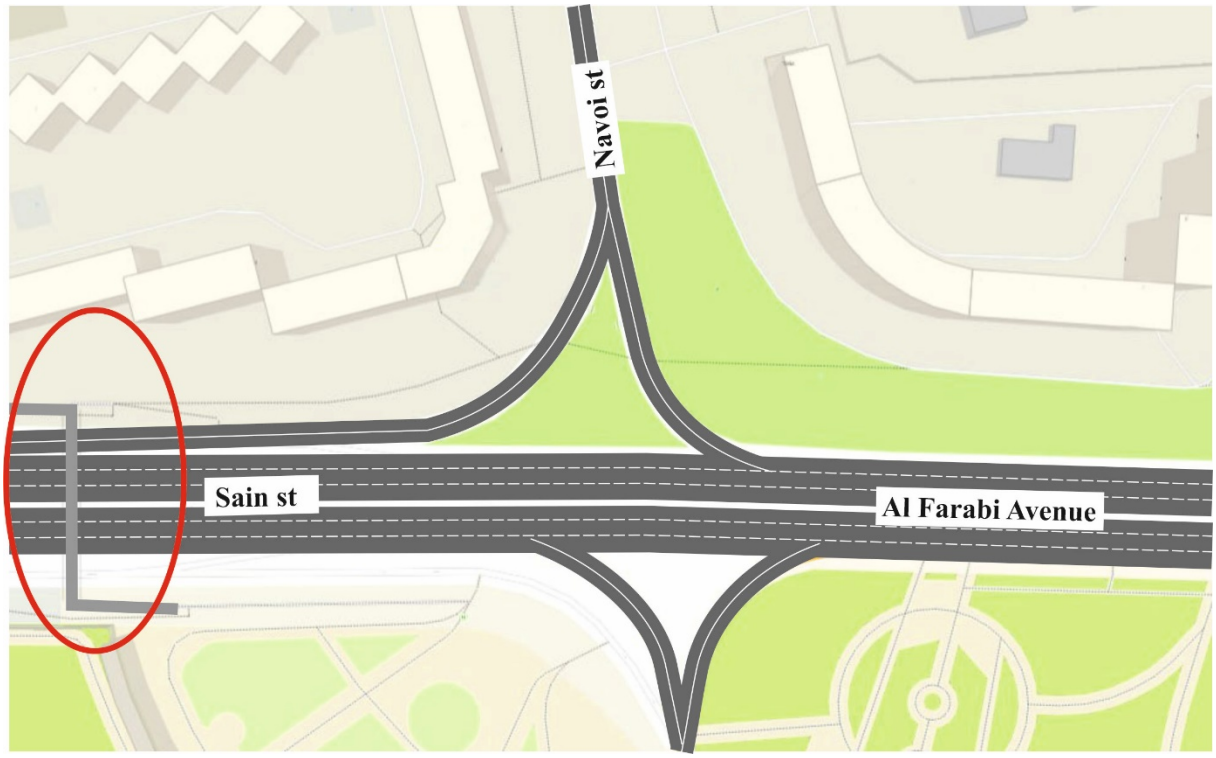

Figure 2. Al-Farabi Avenue, pedestrian bridge

Figure 3. Saina Street, an example of a footbridge

Figure 4. Kekilbayuly Street (bike path)

4.3. Big Almaty Canal

The vertical continuation of Kekilbayuly Street above Toraigyrov Street to Al-Farabi Avenue passes to the Bolshaya Almatinka Embankment and is only a pedestrian road. In this study, the Bolshoy Almatinka embankment is presented as an element of an infrastructure facility, as well as a space for pedestrian movement. “Bolshaya Almatinka is in three landscape zones: mountainous, foothill, and flat. In 1971, according to the project of Soviet engineers, a water cascade was created along the channel of the Malaya Almatinka River, consisting of 28 reinforced concrete water basins 8x12 in size, with a total length of 600 m. necessary dampers of the speed of the flow of water, protecting the city from flooding and floods. The task and purpose of the cascading water basins of the river are to protect the city from floods and improve the microclimate by cooling the city's air in the summer heat. In 1971, along the river embankment, under the Alma-Ata Green Belt project, a protective green zone was established on both sides of the riverbed, where protective green spaces were planted [29].

From 2012 to now, various landscape and transformation works have been carried out to create a

comfortable public space for citizens to relax. Children's playgrounds, sports equipment with inclusion, small architectural forms, and good lighting are organized along the embankment. Some river sections have restored small forms of artistic value [30-32]. Currently, the Bolshaya Almatinka embankment is a well-maintained area, which citizens actively use at different times of the day and day [33]. I would especially like to note the reconstruction of the space under the bridge, which was previously the negative section of the embankment. There are about 20 bridge structures along the Bolshoy Almatinka embankment located within the city, as shown in **Figure 5**.

4.4. Toraigyrov Street (as the new name is called)

Kekilbayuly Street flows into Toraigyrov Street with a smooth bend to the west and is a continuation of the automobile and bicycle roads. The pedestrian road along Kekilbayuly street also flows and connects with the bicycle road, thus combining the second function of the pedestrian road. When connecting Kekilbaev and Toraigyrov streets, the road is located on the southern side of Toraigyrov, and the cycling and pedestrian road is in its northern part. On Toraigyrov Street, there are such extensive infrastructure facilities of the district as the city polyclinic No. 4, the building of the Kazakh-American University (KAU), and schools at the Kazakh Leading Academy of Architecture and Civil Engineering. Thus, the functional feature of Toraigyrov Street is that there are three types of roads in parallel - automobile, bicycle, and pedestrian. Pedestrian roads are on one side of the motor road and the side of the bicycle road. Trees grow on both sides of pedestrian roads and provide good shade during the hot season, as shown in **Figure 6**.

4.5. Ryskulbekov Street

Ryskulbekov street is the northern, final boundary of the study area, which is parallel to the streets of Toraigyrov, Birzhan, and AlFarabi-Sain. KazGASA Academy of Economics and Statistics buildings are located on Ryskulbekov Street. This street has a high level of congestion during the day and the school period. About seven thousand students are studying at KazGASA, the Academy of Economics and Statistics. The increase in the daytime flow of people in cars is the main reason for blocking pedestrian roads, creating an obstacle to the comfortable movement of people, especially on the section of Ryskulbekov Street from Sain and Mustafin. The pedestrian road is located on both sides of the transport network.

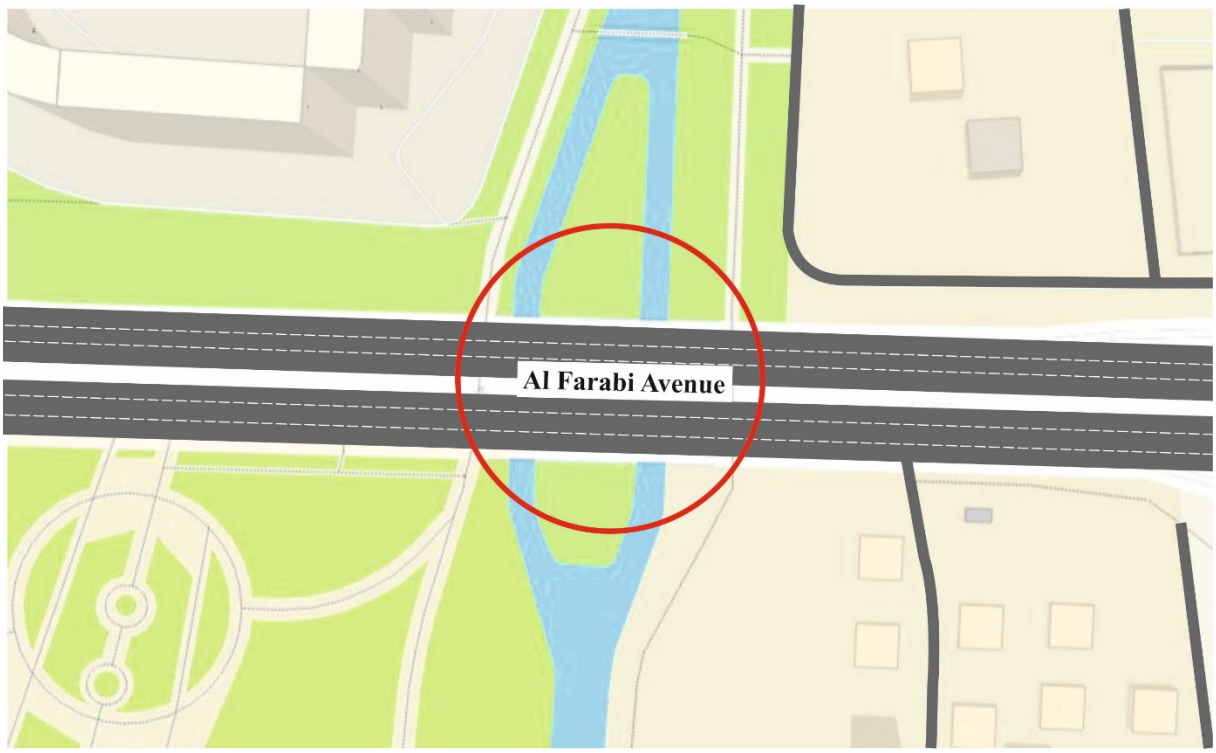

Figure 5. Embankment of the Bolshaya Almatinka River, Almaty

Figure 6. Toraigyrov Street

Figure 7. Mustafina Street

4.6. Mustafina Street

Mustafin, Navoi, and Kekilbayuly streets are perpendicular to Al-Farabi Street and parallel to Sain. On Mustafina Street, there are such infrastructure facilities as Secondary schools No. 40 and 45, grocery supermarkets "Magnum", "Orbita", a children's clinic, and a bank building. Pedestrian roads are located on both sides of the highway. The upper part of Mustafina Street above the perpendicular Toraigyrov Street has a complex structure. The car street widens and has four lanes for transport, and in the middle has a wide lane with green spaces, primarily coniferous trees, street flowers, and lawns. Pedestrian roads are located on both sides of the highway. The upper part of Mustafina Street is landscaped with comfortable benches, lanterns, and green spaces, as shown in **Figure 7**

4.7. Navoi Street

Secondary schools No. 60.68 on Navoi Street and a supermarket "Magnum" (the second store) are secondary schools. The largest multifunctional residential complex, "Shahristan," is located on this site. This residential complex has a well-developed infrastructure and occupies the square of the streets: Kekilbaev-Navoi, Toraigyrov-Ryskulbekov. Inside this multifunctional complex are a private school for primary school children, a kindergarten, several mini markets, offices, and educational centers.

This map shows aerial photographs of Sain-Kablukov streets, Al-Farabi-Ryskulbekov streets, ten residential areas, and extensive infrastructure facilities for monitoring their territory. Each street provides information about pedestrians' open and dangerous facilities [33-35]; the figures show the analysis of Al-Farabi street as follows: **Figure 8**, **Figure 9**, **Figure 10**, and **Figure 11**. The figures show the analysis of Kekilbayuly Street as follows: **Figure 12** and **Figure 13**. Moreover, the figures show the analysis of Toraighyrov Street, as follows: **Figure 14** and **Figure 15**. Furthermore, the figures show the analysis of Ryskulbekov street, as follows: **Figure 16** and **Figure 17**. The figures show the analysis of Mustafin Street: **Figure 18** and **Figure 19**. Moreover, the figures show the analysis of Navoi Street as follows: **Figure 20** and **Figure 21**.

The results of the assessment of the density of pedestrian streets are shown in **Table 1**. Furthermore, **Table 2** shows the assessment of safe accessibility of infrastructural facilities for pedestrians.

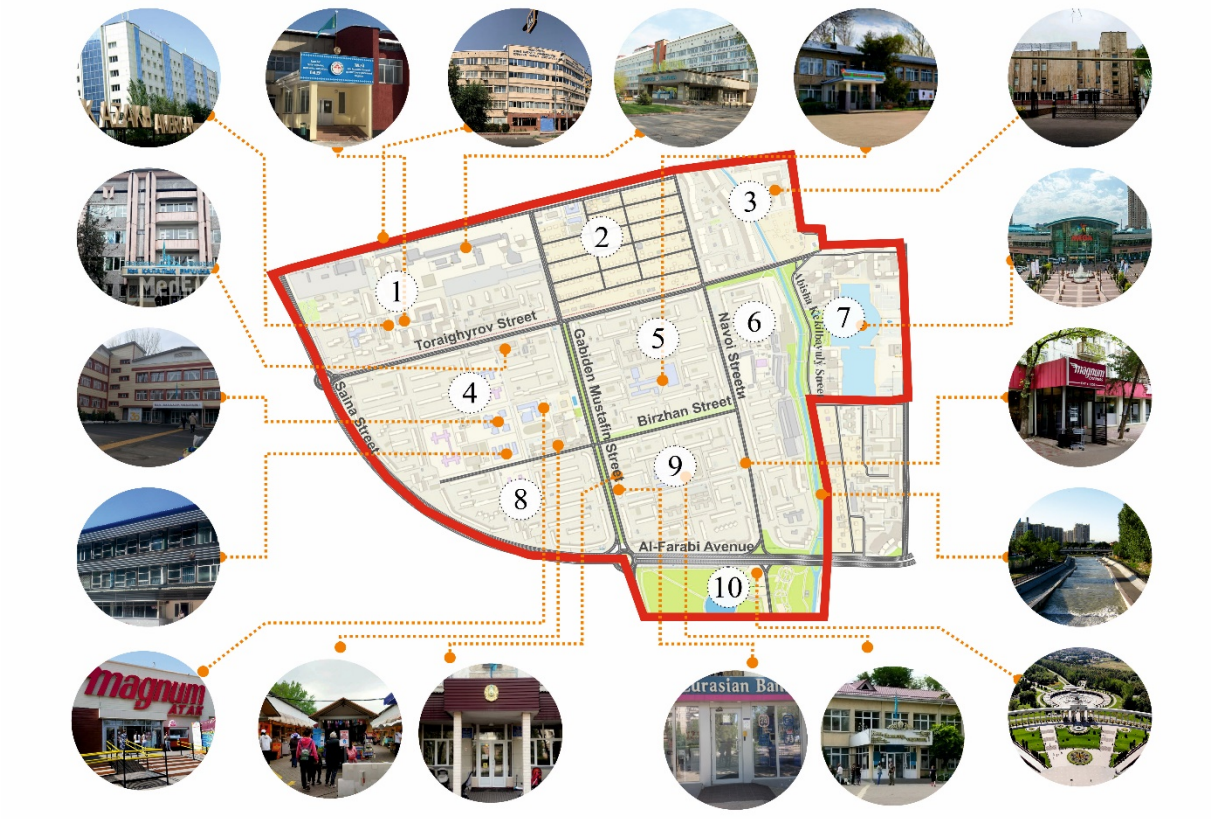

Figure 8. Map of Saina- Kekilbayuly, Al-Farabi-Ryskulbekova street

Figure 9. Al-Farabi streets

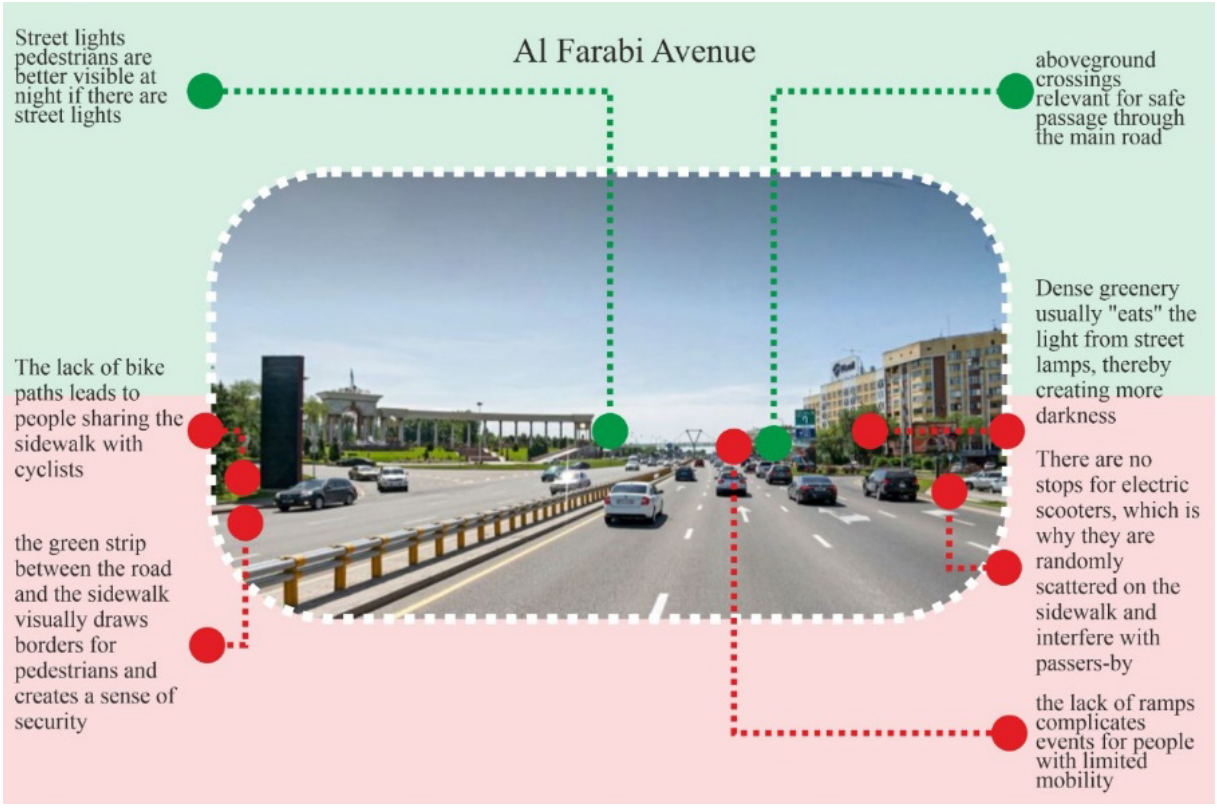

Figure 10. Accessibility assessment of the arboretum through Al-Farabi street

Figure 11. Al-Farabi Avenue-Saina Street

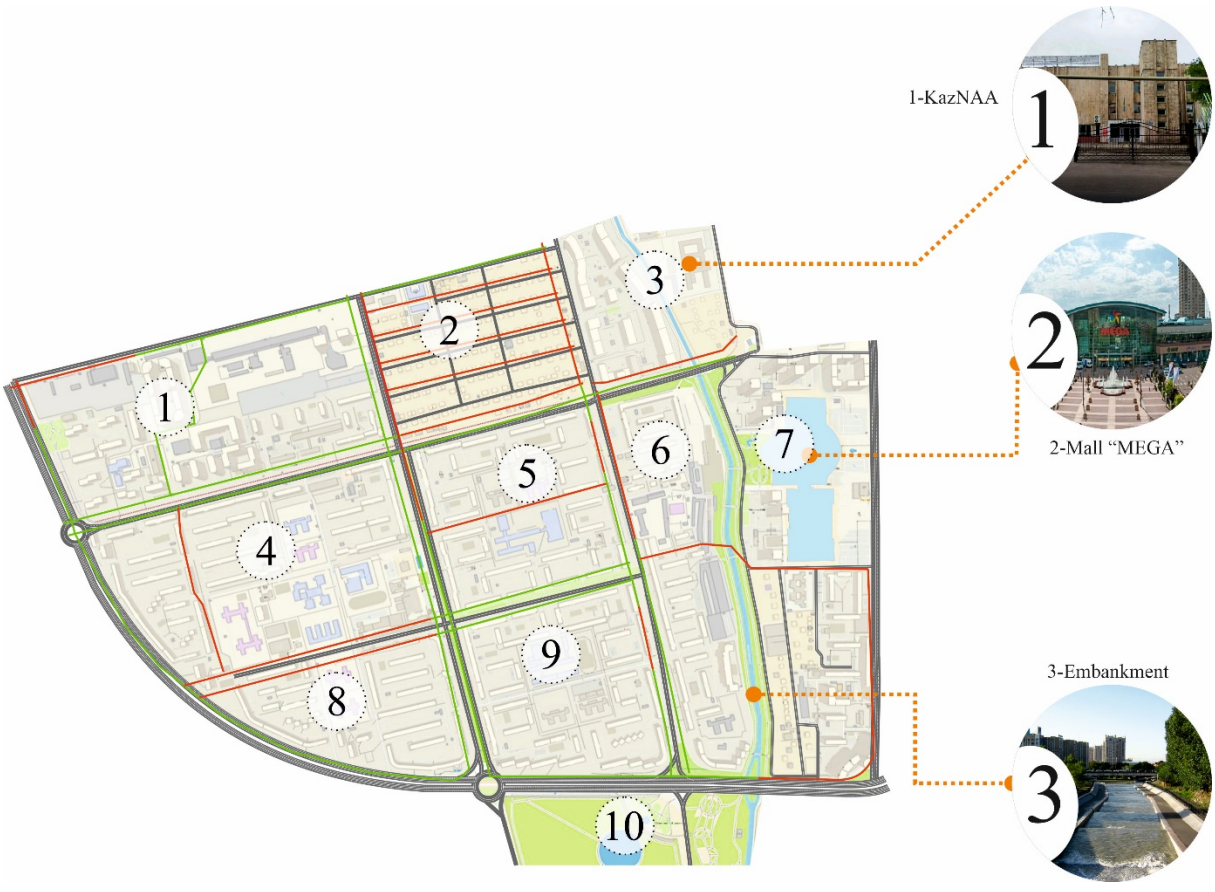

Figure 12. Location of infrastructure facilities on Kekilbayuly Street

Figure 13. A. Kekilbayuly Street

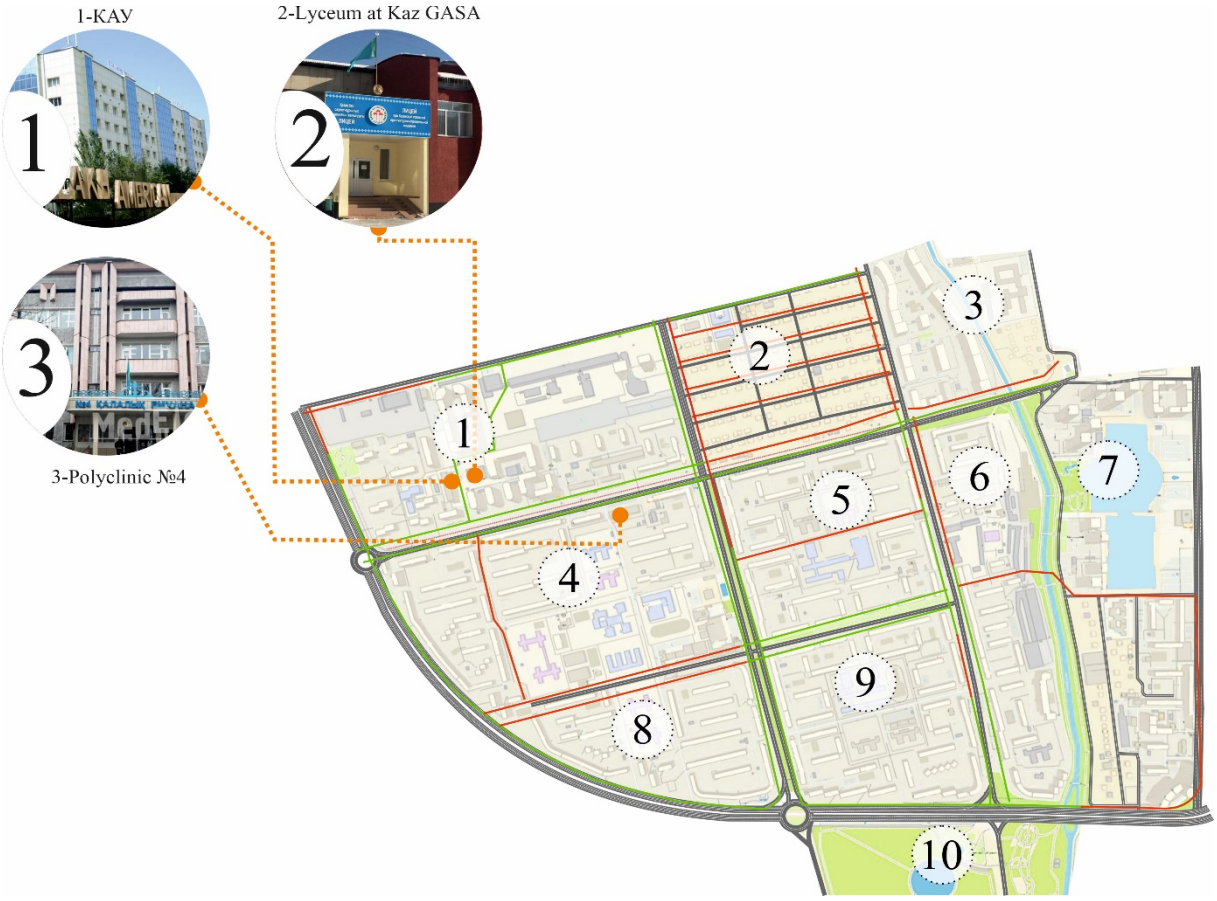

Figure 14. Location of infrastructure facilities on Toraighyrov Street

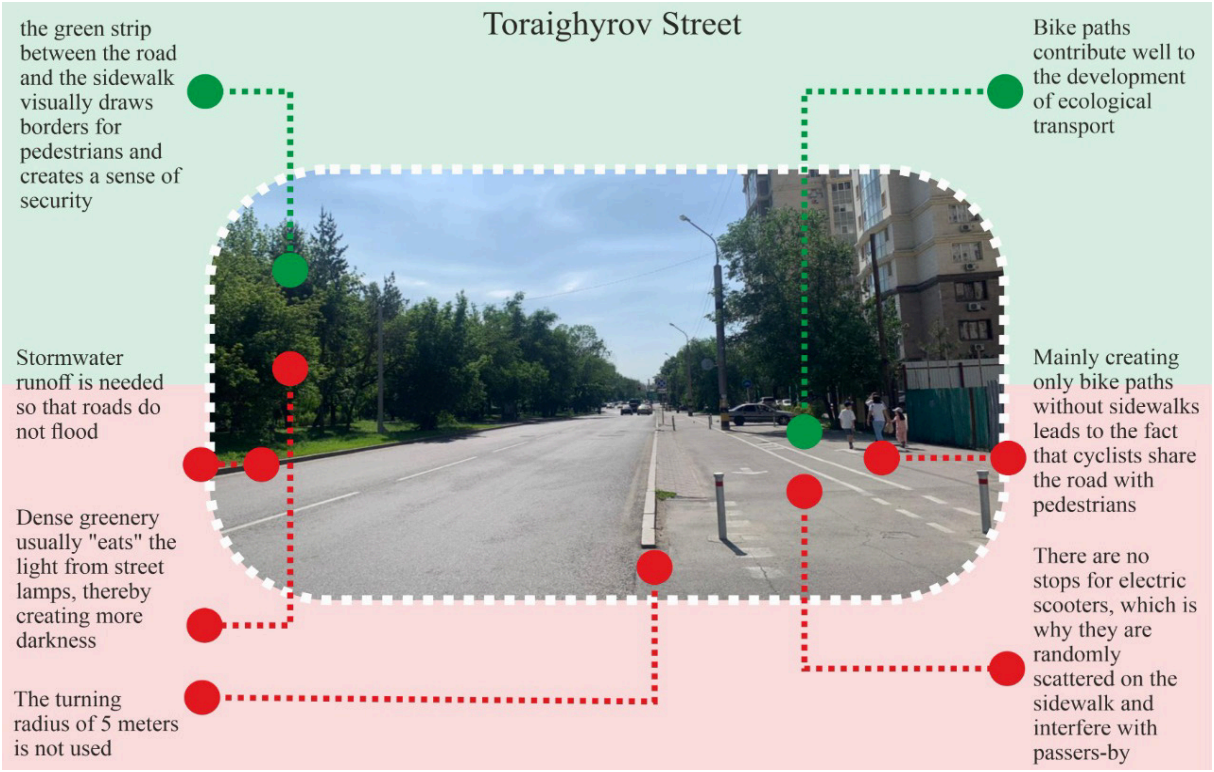

Figure 15. Toraigyrov Street (as the new name is called)

Figure 16. Location of infrastructure facilities on Ryskulbekov Street

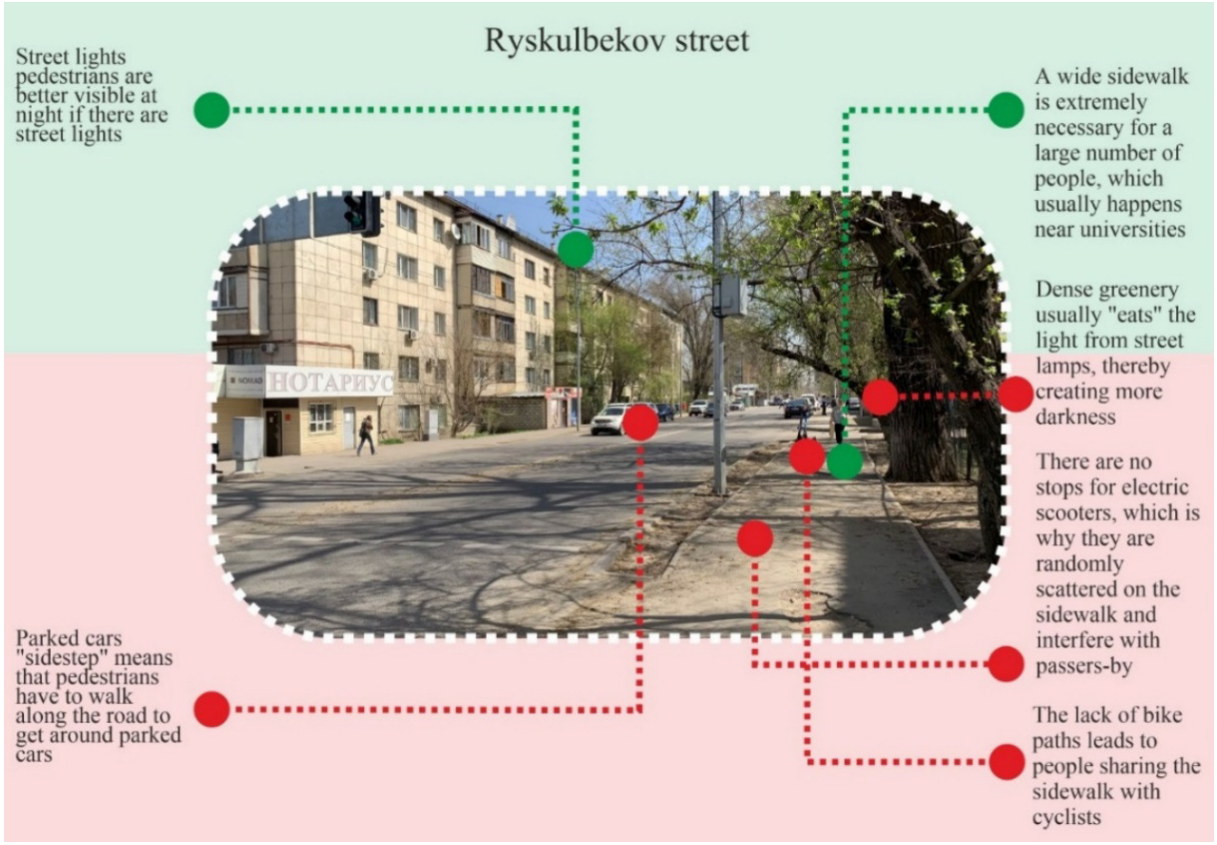

Figure 17. Ryskulbekov Street

Figure 18. Location of infrastructure facilities on Mustafin Street

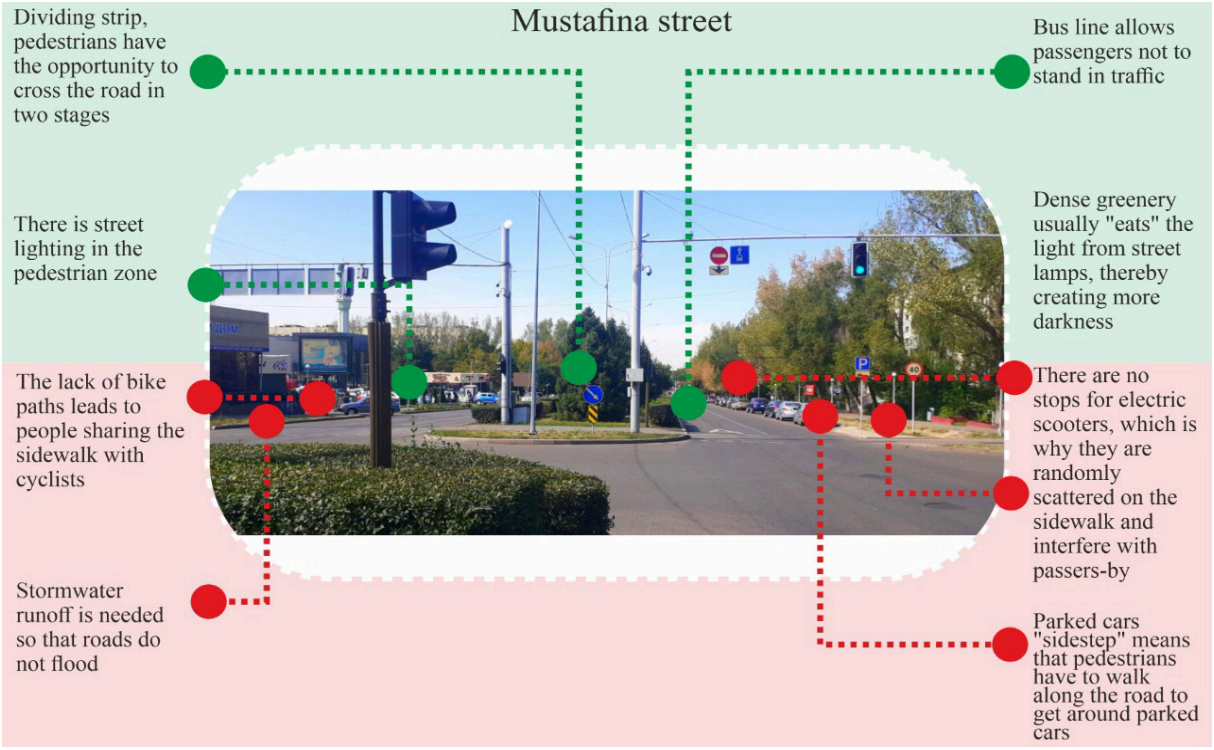

Figure 19. Mustafina Street

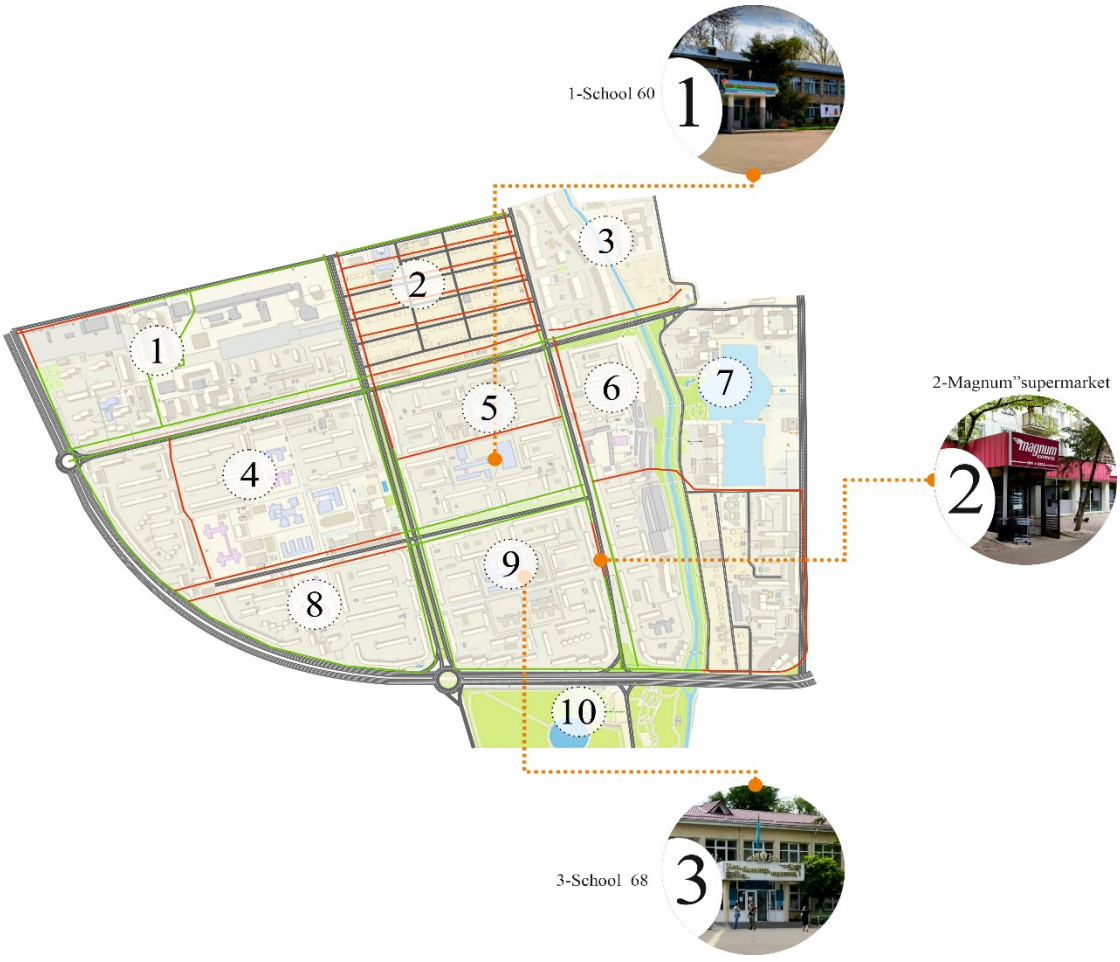

Figure 20. Location of infrastructure facilities on Navoi street

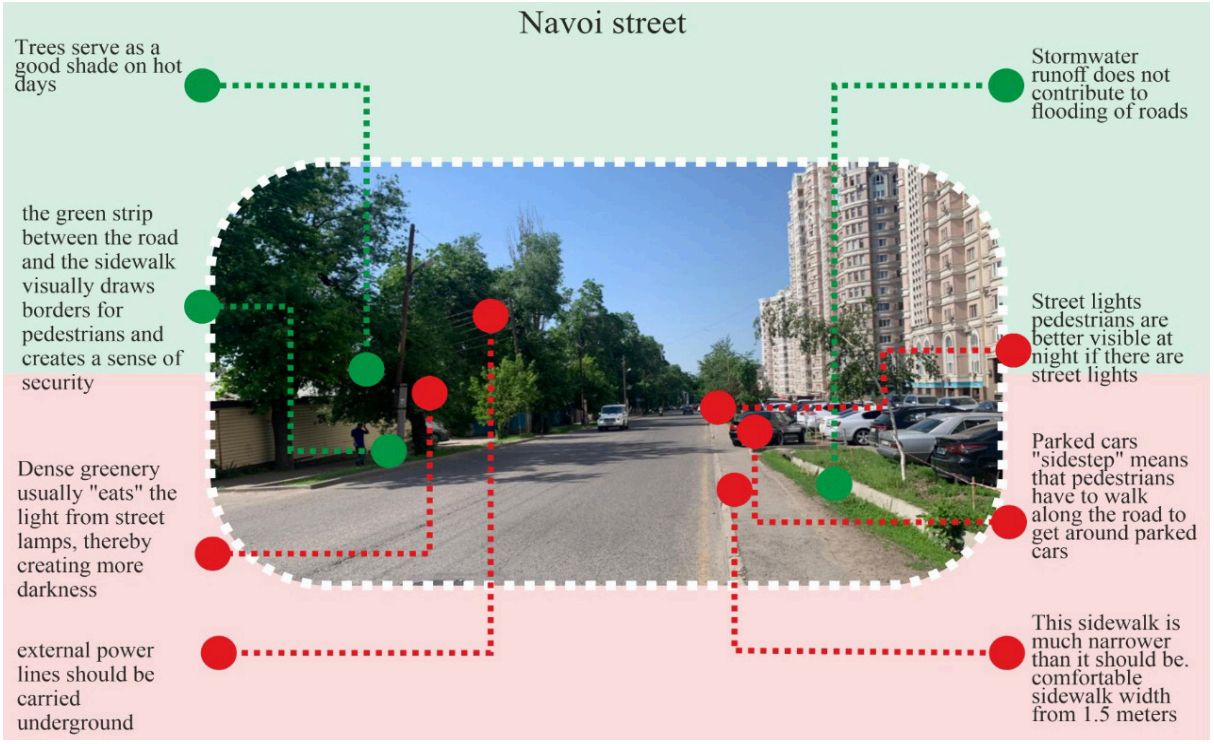

Figure 21. Navoi Street, Road Safety Assessment

Figure 22. Examples of road structure

Figure 23. Measures to improve safety in the urban environment

Table 1. The results of the assessment of the density of pedestrian streets

Street name	Meaning W_{cp}, m	Meaning $F_{m/p}$ Human/second	Meaning PCL, Human/(m-min)	Quality Category
Al-Farabi Avenue	1,5/2 (2nd type)	50	1,25/1,8	A
Toraigyrov	5/1,5 (2nd type)	30	10/3	A
Ryskulbekov	1,5	50	50	A
Mustafina	1,5	30	50	A
Navoi	1,5	20	50	A
Saina	2,0	20	6	A

Table 2. Assessment of Safe Accessibility of Infrastructural Facilities for Pedestrians

Infrastructure Facility	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
KazGASA										
КАУ										
KazNAA										
Eurasian Innovation Academy of Economics and Management										
Mall “MEGA”										
“Magnum” supermarket										
“Magnum” supermarket										
Polyclinic №4										
Eurasian Bank (near the children's polyclinic)										
Market (Orbita)										
Arboretum										
Embankment										
School 68										
School 60										
Lyceum at Kaz GASA										
School 40										
School 45										
Children's polyclinic										
Embankment										

safe, partially secure, not safe

5. Discussions

The road and transport network of the city of Almaty has a mesh shape. Pedestrian roads are located on both sides of each transport network. However, the city of Almaty has a unique town-planning feature. This is the presence of a ditch system that runs through the entire city parallel to transport and pedestrian roads. Thus, the network of the city of Almaty has a complex structure. It consists of a transport road on both sides, of which there are pedestrian roads, ditches, trees, shrubs, and a green lawn, as shown in **Figure 22**. Such a road structure is also typical for the area studied in this article.

The city's grid layout allows good access to all infrastructure facilities in each district. The disadvantage that needs to be addressed is the mixed use of the bicycle road by pedestrians, cyclists, and people on scooters. Another critical factor is the non-compliance of the slope of the ramps with the regulatory requirements, and this problem is especially aggravated during snowy and rainy periods. Poor pedestrian sidewalks' lighting causes citizens' displeasure and increases the danger at crossings.

All streets in Almaty have been reconstructed in the past few years, with a clear separation of lanes for public transport and private cars. Pedestrian crossings and stops were subject to reconstruction. This positive development increases pedestrians' safety and accelerates the achievement of infrastructure facilities by public transport within the city. Another positive solution to improve safety in the urban environment is the installation of video surveillance cameras at every street intersection and on the territory of almost all public and residential buildings, as shown in **Figure 23**.

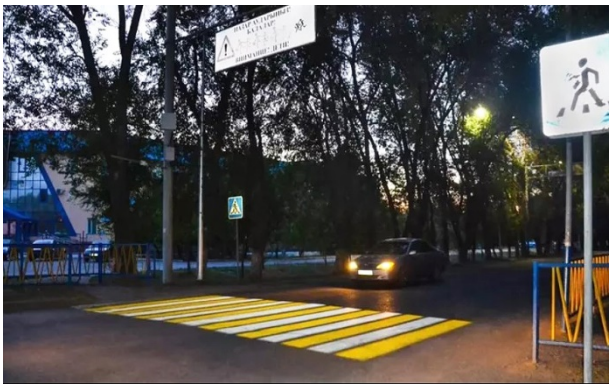

Figure 24. An example of using the "Smart Pedestrian Crossing" system

In the city of Almaty, the specialists of Transtelecom JSC launched the Smart Pedestrian Crossing system [36]. The project was implemented in a pilot mode in the Shanyrak micro-district. Its goal is to improve road safety. Thanks to sensors that automatically light up a section of the road, a "smart pedestrian crossing" makes it possible to safely cross the road at night [37] **Figure 24**. When a pedestrian is detected by one of the sensors, the signal is transmitted to the software, thereby activating the automatic activation of the light panels "Caution, pedestrian!" in both directions of movement. Thus, the system warns the driver that a pedestrian crossing is ahead of him and that there are people on it. The complex acquires relevance in those road sections where the pedestrian crossing is poorly visible due to the terrain. The system also has a video camera, an overview scanner, and excellent detail. Another advantage of the system is the projection of zebras. A vital feature of the technical novelty is to ensure the visibility of the crossing on a winter night and in conditions of fog, rain, and snowfall [38].

Directional light allows you to see the transition and the people on it. In addition, the bright light markings are not worn out by the wheels and attract attention from afar. The system is connected to the remote setting of operating modes [39]. This is remote monitoring of the state of each element of a pedestrian crossing and emergency notification in case of malfunctions and emergencies. The device operates via a wireless network using a "cloud" infrastructure via GSM (3G), LoRa, NB-IoT, and XNB channels. Management is automatically implemented. Transtelecom JSC plans to scale further, replicate this system, and develop similar projects in Almaty and Kazakhstan.

Another critical factor is the presence of video cameras at almost all intersections in the study area. In this case, the role of video cameras in improving security in the urban environment should be specially noted. With the help of fixing video cameras, various disputable situations in traffic accidents are revealed, and great help is provided in detecting crimes and other cases. One exciting example is a study conducted using video footage from CCTV cameras and surveys of pedestrians in places conducted in London.

With the help of information from video footage from CCTV cameras, more than 75 sections of the transport network of London roads were investigated. The main criteria for the study were:

- Detailed information about the pedestrian flow. This gave information about the level of pedestrian traffic during the day, how the direction of traffic changed during the day, and which peaks were experienced.
- Pedestrian speed was measured during and between peak hours to assess the impact of the number of people and the direction in which they were traveling.
- The number of people whose movement was restricted was recorded. Limited movement is when people have had to change their speed or route, experienced “shoulder brushing,” or bumped into other users.
- The distance people leave between themselves and outdoor furniture, “passing distance," was accurately measured using CCTV surveillance and detailed topographic surveys.
- A survey was conducted at many sites to assess people's perception of comfort and how this might affect their actions.

The results of these studies were used in a comprehensive assessment of comfort in different area types, the tolerance to different comfort levels, and the passing distances people leave between each other and street furniture. This was then used to determine the guidance in this paper. [28].

6. Conclusions

The study of the area based on aerial photography, field survey, photographic recording, and collection of information on the number of daily pedestrians led to the following conclusions. Depending on the location of the transport and road network, the district was divided into ten sectors, and 19 extensive infrastructure facilities were identified. In general, assessing the quality of the safe accessibility of infrastructure facilities for residents and pedestrians temporarily arriving in the area is satisfactory.

Based on daily observations of the movement of pedestrians, conducting a study following the goals set in

general, positive and negative qualities of pedestrian roads were identified. Positive qualities include: 1. Additional night lighting of the pedestrian crossing ensures the safety of people at night. This method is highly relevant near educational institutions. 2. Street lights. 3. The green strip between the road and the sidewalk visually draws borders for pedestrians and creates a sense of security. 4. Bike paths contribute generously to the development of ecological transport. 5. Stormwater runoff does not contribute to the flooding of roads. 6. Dividing the strip, pedestrians can cross the road in two stages. 7. Bus line allows passengers not to stand in traffic. 9. Above ground crossings relevant for safe passage through the main road.

Negative qualities include 1. Parked cars "sidestep" means that pedestrians have to walk along the road to get around parked cars. 2. Creating only bike paths without sidewalks leads to cyclists sharing the road with pedestrians. 3. No stops for electric scooters, which is why they are randomly scattered on the sidewalk and interfere with passers-by. 4. Dense greenery usually "eats" the light from streetlamps, creating more darkness. 5. The lack of ramps complicates events for people with limited mobility. 6. Narrow sidewalks, it is inconvenient for pedestrians to walk on a sidewalk less than 1.5 meters wide. 7. The absence of street sidewalk lights is very inconvenient for pedestrians at night.

The calculation of the movement density of pedestrians on all the streets studied showed a good result. In this regard, it should be noted that for a total population of 150,000 people (including temporarily arriving people) on the territory of 200 hectares of the urban area, it can provide good, comfortable conditions for the movement of pedestrians. The Pedestrian Comfort Level (PCL) method used is effective. The infrastructural security of the district in terms of the number of inhabitants is good. As noted at the beginning of the study, the safe accessibility for pedestrians of extensive infrastructure facilities was studied in this work. The buildings with their territory were classified as extensive infrastructure facilities. During the study, it was also determined that the number of small infrastructure facilities that provide the population is 10-15 times higher than the large types in this area. An analysis of the route of residents to infrastructure facilities determined the safe accessibility of each building for residents of different sectors.

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Conflicts of Interest

The authors declare that they have no conflict of interest.

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