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ANALYSIS OF THE STATE OF PUBLIC TRANSPORT IN ALMATY

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Abstract: Public transport today is again gaining relevance as a means of transportation in connection with the personal cars that have flooded urban spaces. The city of Almaty is no exception and since the beginning of the last decade has taken a course to organize pilot projects to create a priority for the movement of public transport. The difficulty of implementing such innovations is the public, accustomed to crossing long distances by private vehicles, and in most cases city streets are loaded from nearby agglomerations. The emergence of such a trend is directly related to the expansion of the city in breadth, i.e. from east to west, because the natural uniqueness of the urban area in the south is limited by the mountain ranges of the Trans-Ili Alatau. This paper is presented taking into account the existing initial data for the study of public transport issues through the introduction of the GTFS scientific methodology, which can give a new angle of view on the current situation with the organization of bus and trolleybus routes. This paper focuses on studying the potential of public transport in Almaty for consistent growth, because with the help of the restructuring of route networks and the creation of a priority traffic network, there is a chance to achieve an increase in capacity and an increase in the number of users. The aim of this article is to provide information about the current state of the public transport network and to discuss the potential of geographic information systems (GIS) within the urban space, which are guided by spatial analysis approaches related to the processing of General Transit Feed Specification data (GTFS), since statistical data are based on providing a complete picture of the existing transport network, and afterwards can become the basis for subsequent optimization of public transport traffic. This paper creates new perspectives for future development of public transport and restructuring of the understanding how to create public network according to necessity in Almaty city.

Key words: General Transit Feed Specification (GTFS), public transport, bus network, transit development, urban area, bus stops and routes, subway

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INTRODUCTION

Although transport research has traditionally focused on the movement of goods and people to solve mobility issues, researchers, planners, and policy-makers are increasingly interested in the integration of land use and transport systems in an effort to increase accessibility, thereby contributing to the well-being of individuals. Public transport plays a key role in providing access to opportunities, especially for vulnerable populations (Boisjoly and El-Geneidy, 2021). Accessibility is at the core of the economic and social development of cities. Investments in urban transport systems are thus paramount in achieving accessibility. Many cities are suffering from inadequate central government funding and reduction of finance, particularly in times of austerity and now in the presence of the new global pandemic (Cocconcelli and Medda, 2021).

Cities are constituted of several objects related within an urban form, which is a concept that is used to describe the physical and nonphysical characteristics of a city. Cities provide different services to fulfill citizens' needs, in which transport is demanded (Lee and Bencekri, 2021). The sheer number of vehicles carrying only one person to work every day is huge, and if you add to them trucks and delivery vans, company cars, buses and taxis that travel every day, it can lead to massive congestion (Aliyeva et al., 2019). Also, along with the above, it is possible to correlate the economic factor of the industry that depends on government subsidies that are insufficient to cover existing costs, as well as reducing investment attractiveness.

Due to the prevailing conditions, the factor of wear of public transport and the inability of bus fleets to replace diesel buses with electric ones is clearly manifested due to the high cost of the latter, which are also produced on the territory of the Republic of Kazakhstan. The cost of spare parts and fuel and lubricants over the past 20 years has led to an increase of 15-20 times, while the fare has received an increase of only 5 times, which actually leaves it impossible to modernize and update the parks. Various qualities of transit services, including travel time, frequency, and the presence of alternative paths, affect

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accessibility—how easily passengers can reach their destinations by transit (Kim and Lee, 2019). The General Transit Feed Specification (GTFS), with standard open-source data in both static and real-time formats, is being widely used in public transport planning and operation management (Wu et al., 2022). The analysis and metrics produced can support transport systems planners in major cities of low-income countries (Falchetta et al., 2021). System-wide maps of station locations, routes, fares, schedules, operating calendars, and other key information are simply not available to the public for the majority of paratransit routes around the world. Lack of data makes it hard for users to know how to navigate these systems and creates limitations for transit planners when developing transit models (Williams et al., 2015). In recent years the increasing availability of more detailed and disaggregated data has aligned with a growing concern for considering time-space constraints in accessibility to provide new methods and measures for accessibility analysis (Stępniak et al., 2019). The bus system in particular has the potential of providing transport services to larger proportions of urban commuters, hence, plays a significant role in reducing the number of vehicles on urban roads and consequently reducing traffic chaos in cities (Akintayo and Adibeli, 2022). Concern for the urban environment has raised the profile of urban design and streetscape. Recent trends in urban design and traffic engineering are reviewed and the implications for city logistics are outlined (Bell, 2021).

Questions regarding the sustainability of dispersed car dependent urban forms have led to a renewed interest in public transportation (Murray et al., 1998). Many studies have tried to quantify the impact of urban form on travel behavior by studying the influence of spatial characteristics such as density, land use mixing, and accessibility of the residential neighborhood (Van Acker, 2021). Placemaking refers to incremental and small-scale interventions in cities that aim to improve the quality, equity, and ecological sustainability of urban places (Babb, 2021). Transit-oriented development is known to be a key important policy to decrease car travel. It places public transport as the main transport mode to fulfill urban mobility travel needs. However, public transport trip necessarily starts and/or ends with an active travel trip, either walking or cycling from and to the specific origin and destination. In turn, this particularity places active accessibility as an important tool that needs to go alongside transit-oriented development to achieve the desired travel pattern (Vale, 2021). A key goal of urban transportation planning is to provide people with access to a greater number of opportunities for interaction with people and places. Measures of accessibility are gaining attention globally for use in planning, yet few studies measure accessibility in cities in low-income countries (Campbell et al., 2019). Network science offers powerful concepts and methods for studying complex systems, such as public transport networks. However, many existing studies on complex network analysis of public transport networks were primarily motivated to test network science concepts using real-life networks (Luo et al., 2019).

The city of Almaty is the center of economic activity of the Republic of Kazakhstan and annually creates a large number of new jobs, which entails the interest of residents of the country to move to a large metropolis. The current trend leads to an accelerated expansion of urban boundaries, which regularly includes nearby settlements formed in its composition, which leads to the need to increase the level of coverage by public transport. In view of the prevailing conditions, the above-mentioned growth of urban areas to the west and east is predicted, since the largest settlements with well-established basic infrastructure are located on both sides of the city (for example, the administrative center of the Karasai district of the Almaty region, the city of Kaskelen to the west and the administrative center of the Talgar district of the Almaty region, the city of Talgar). The high density of development with the lack of the necessary number of land plots, the high cost of real estate in the city, as well as the environmental situation deteriorating from year to year, force many citizens to live outside the city of Almaty, but remain tied to the city due to the presence of a large number of high-paying jobs. Traffic and traffic infrastructure related technogenic pollution of heavy metal (HM) can be: depreciation of car parts; incomplete combustion of fuel; engine oil leakage; vehicular exhaust catalysts; heavy metal additives in the fuel; depreciation of the road infrastructure and road maintenance. The amount of heavy metal in the roadside oil is influenced by road design, type of fuel use, traffic density (vehicles per day), driving speed, driving behavior, etc. (Muzychenko et al., 2017). Every day (with the exception of weekends and holidays) the city is filled with a huge traffic flow arriving from nearby suburban areas and settlements of the Almaty region. The streets of the city are not able to accept such a number of cars during rush hours, even despite the number of wide 6-lane avenues and the Eastern Bypass highway flowing from east to west into Al-Farabi Avenue and then into Sain Street, as well as from west to east into the Kuldzhinsky tract. The pendulum migration observed on a daily basis plunges city streets into a slow-moving stream of cars unable to meet the demand of residents traveling by individual transport. The determinants of transit ridership within macro-level analyses are typically categorized as either internal or external factors, where internal factors relate entirely to decisions, policies and conditions determined by the transit agency or the municipalities providing subsidies. Whilst external factors typically equate to wider economic influences affecting society at large, such as unemployment rates and gas prices, which subsequently impact gas prices in the region (Boisjoly et al., 2018).

Public transport has historically had the goal of increasing the mobility of residents, but due to the lack of priority lanes on most streets, it is forced to be in the flow with individual transport, therefore the attractiveness of this type of transport decreases, which provokes a large number of residents to look for ways to purchase more comfortable, as it seems, individual transport, because the travel time is identical. The possibility of purchasing individual transport directly depends on economic well-being, but most residents are unable to provide themselves with this type of transport and use public transport based on need. The city of Almaty in the transport infrastructure directive is closer to the rest of the regions of the Republic to innovations, which is manifested in the presence of variable forms of traffic organization in the city, which include projects for the introduction of individual lanes for public transport. The main examples are the dedicated lanes on Abay and Rayimbek Avenues, as well as the BRT project along Timiryazev Street, which has a difference in traffic along the center of the street and has an infrastructure adjusted for the set goal of increasing the comfort of movement. The selected lanes demonstrate their effectiveness, because they allow bus drivers to maintain the interval, which contributes to the transportation of more people in less time, but the main problem is the lack of a common network of dedicated lanes

connecting most of the city's districts, as well as residential areas with the business center. The concept of accessibility binds together the key components of an urban structure: people, mobility and social activities, and makes it possible to have a functional view of urban structures and processes (Järv et al., 2018). Aside from personal characteristics, aspects of land use and characteristics of the public transport system play a role in explaining mode share. Many researchers have found that even when self-selection is accounted for, density, diversity, and design of the urban milieu influence ridership (Cui et al., 2020).

Almaty city consists of 8 districts with the following population (for 1 July, 2022): Alatau (326676 people), Almaly (225298 people), Auezov (312345 people), Bostandyk (368043 people), Zhetysu (174582 people), Medeu (226948 people, Nauryzbay (171249 people) and Turksib (248713 people) (Bureau of National Statistics, 2022). For greater awareness, it is necessary to add to the above data the population density (per square kilometer, for 2022), which is equal to the districts of the city: Alatau - 3141 people per square meter, Almaly – 12244, Auezov – 13291, Bostandyk – 3702, Zhetysu – 4408, Medeu – 897, Nauryzbay – 2456 and Turksib – 3281. The above data indicate that areas with a lower density are territories with a large amount of private development, which as a consequence leads to the expected expansion of the urban area, and therefore to a decrease in transport accessibility of residents of Almaty.

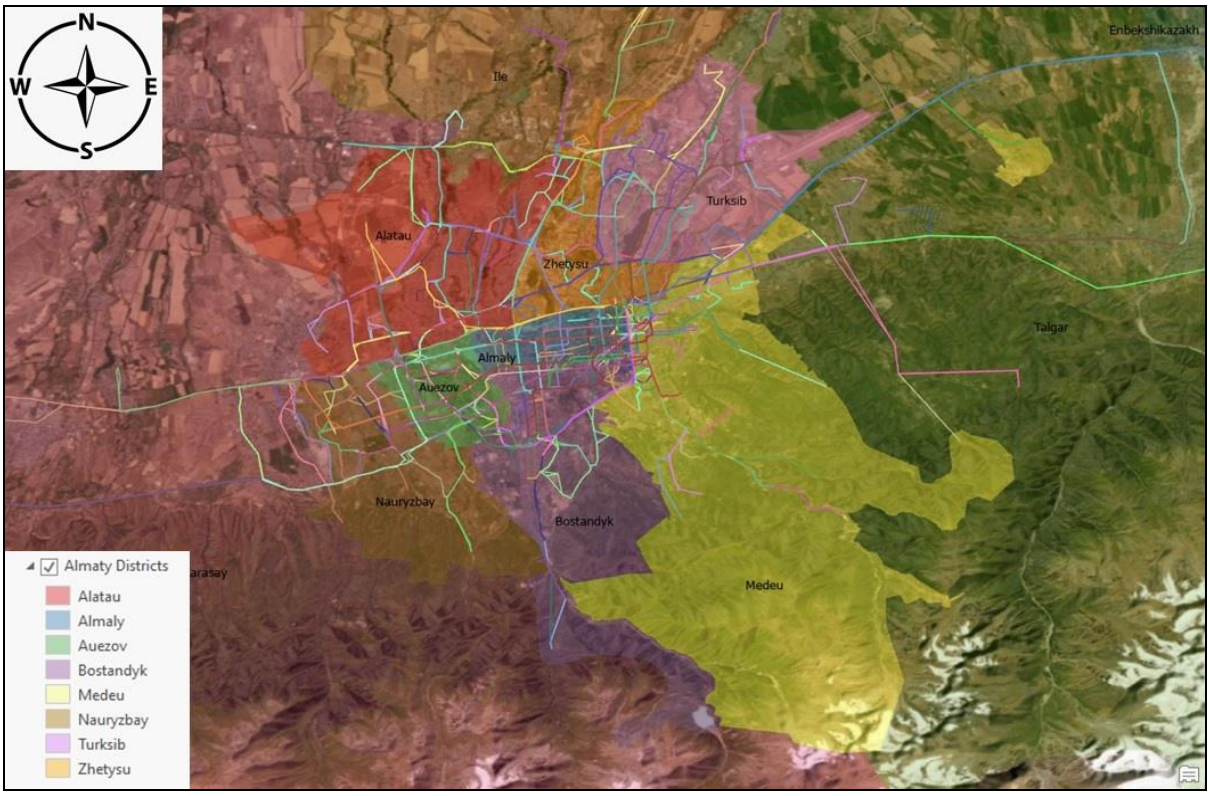

Figure 1. Bus routes of Almaty city (Source: Transport holding of Almaty - citybus.tha.kz)

The number of routes given for further analysis of the service area provided is 154 (Figure 1). The total length of routes in both directions is about 6805 kilometers (6805439 meters) per flight. Taking into account the total length of routes, on average, each route accounts for 44 kilometers, and 22 kilometers in one direction when performing one trip. On average, about 1557 buses (diesel and electric), trolleybuses, school buses and minibuses go to the line daily. The value of the average number varies depending on the number of public transport units that meet the maintenance standards, the time of day (route No. 3 is a night route), school buses (run in certain areas and have a short coverage distance) and the day of the week (there are weekend routes No. 88, No. 209, No. 210, No. 211 in the bus depot). The above-mentioned 154 routes make passengers loading and unloading at 2891 stops, which are located both within the city limits and outside it when performing suburban routes. Transit agencies and planners must adapt to changing demand and amend their transit networks and services to provide appropriate transit services. The role of public transport systems is becoming increasingly complex, and the size of areas to be served by public transport is increasing (Hama Salih and Lee, 2022). Public transit brings many social and economic benefits to our society, such as lower traffic congestion, reduced air pollution, and improved accessibility. While different people may emphasize different aspects of these benefits, the COVID-19 pandemic has shown that the most essential function of public transit is to connect low-wage earners to their jobs or potential employment opportunities (Yan et al., 2022). The purpose of the study was to analyze the current situation with public transport in Almaty on the basis of open data, which were gradually structured according to the bus and trolleybus routes available on the balance sheet of companies.

MATERIAL AND METHODS

Compact city and transit-oriented development aims of integrating public transport networks with high density mixed-use development around stations and urban centers have been prominent policies for improving urban transport sustainability in many cities around the world for several decades (Smith and Barros, 2021). The urban mobility landscape is

currently undergoing a period of major uncertainties, largely driven by a multitude of emerging technologies (Mladenović and Stead, 2021). The form of a city has a major impact on the lifestyles of its residents. As urban centers grow, careful strategies are required to ensure that the regional quality of life is not adversely affected by this growth. An important strategic consideration is transportation planning. The methods that have been applied are based on ESRI technologies and are presented in the Transit Feed (GTFS) toolset (ESRI). The primary task was to collect data from open sources (Yandex Maps (Yandex, 2004), OpenStreetMap (OpenStreetMap Foundation, 2004), 2GIS, the official Internet resource "Public Transport of Almaty" (Transport holding of Almaty - citybus.tha.kz), etc.) for subsequent classification by text files (in the format.txt) on the Visual Studio Code platform (Figure 2). Data on the route network were compiled into 4 main files – stops.txt , which contains data on stopping points indicating numbering (stop_id), latitude (stop_lat), longitude (stop_lon), stop type (location_type), type name (type_name) and stop name (stop_name); routes.txt , carrying in get information about the route paths, namely the numbering of the route (route_id) and the type of route (route_type); shapes.txt responsible for the visual representation of stops indicating the route number (shape_id), latitude (shape_pt_lat), longitude (shape_pt_lon) and the order of stopping points of each route (shape_sequence), as well as trips.txt , built on the subsequent integration of the above-mentioned files indicating the trip number (trip_id), the visual form of the trip (shape_id) and route numbers (route_id). Next stage of processing input data into a text file is capable of carrying a large array of information, which subsequently led to the proper form of interpretation and visual representation during conversion. The final stage of transferring the geographic information system of ArcGIS Pro to the working project is the use of a toolset of transit feed, namely, converting a text file from a stop (GTFS Stops to Features) and a text file with forms using tools (GTFS Shapes to Features).

The analysis carried out in this article with input data was carried out using a set of Network Analyst tools with an indication of the database of streets of Almaty available in the GIS system for visualizing the service area of stopping points of urban and suburban routes. In addition to the above, the process of enriching the input data using the Enrich tool was carried out in order to give the received data an additional information load (open data on the number of population, settlement density, purchasing power, number of households and the number of representatives of certain age categories) and to find cause-and-effect relationships affecting the complexity of organizing public transport in the city of Almaty.

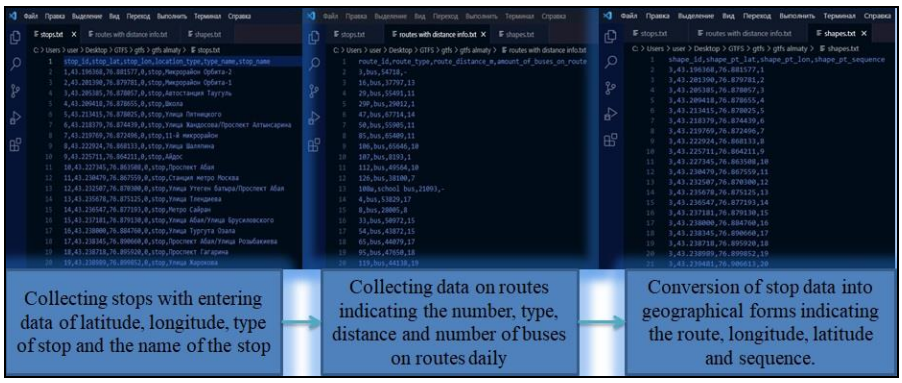

Figure 2. A flowchart of the methodology steps when collecting data on public transport (Source: Transport holding of Almaty - citybus.tha.kz)

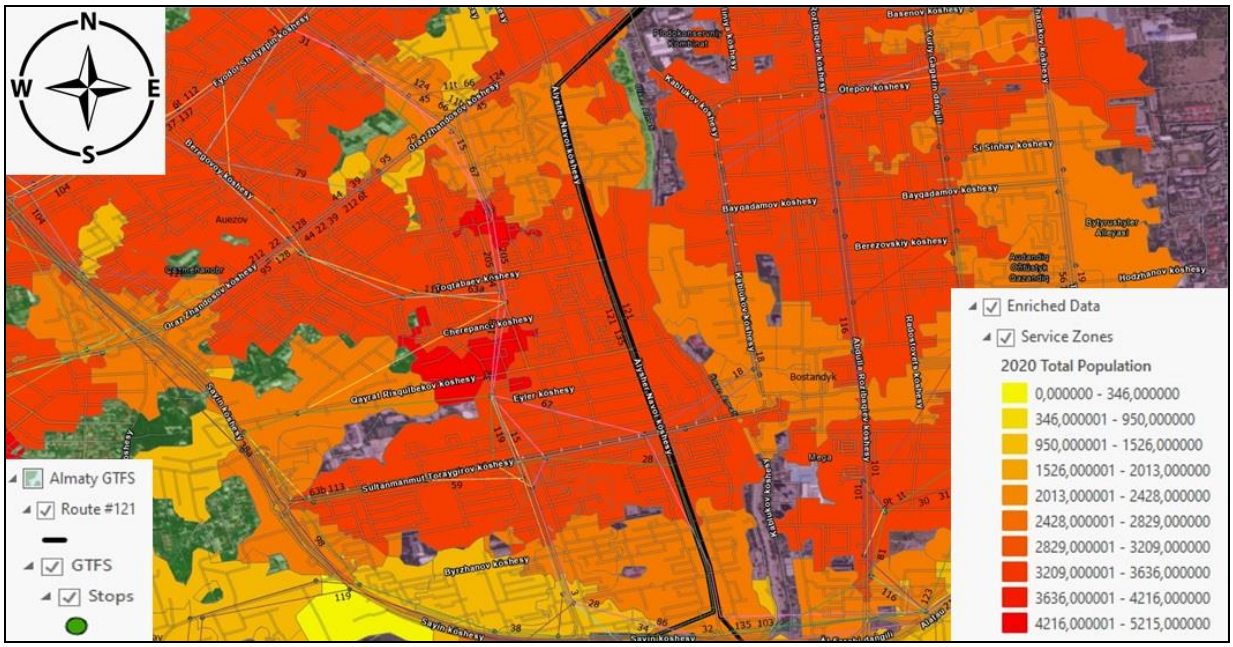

Figure 3. An example of insufficient coverage by public transport along Navoi Street in the north direction (Source: Transport holding of Almaty - citybus.tha.kz)

RESULTS AND DISCUSSION

One of the criteria for selecting the level of accessibility of public transport is a quantitative indicator of the existing infrastructure, or rather the number of routes that serve certain streets. Some streets, including streets with dedicated lanes, are

oversaturated with public transport and, based on this, the accessibility and increase in standardized intervals are deteriorating due to the fact of loading and unloading of passengers on adjacent and intersecting buses at a certain stopping point. In this scenario, there are a number of streets in the city that are served by only one route, although there is a need to increase the number associated with the number of population and outgoing density, as well as to redistribute routes for more efficient organization and expansion of coverage of city streets. The first in the list of routes that are served by only one bus route is Navoi street in the north direction from Toraygirov street to Zhandosov street at a distance of 1.85 kilometers (Figure 3).

To date, this section is served by route No. 121, which has a direction from the Orbita-2 microdistrict to the Zhuldyz-1 and Zhuldyz-2 microdistricts (in the south-east direction in one direction and in the north-west in the opposite direction). The main objective of this route is to connect the above-mentioned residential areas with the city center through Zhandosov and Satpayev streets and Dostyk avenue. Every day, the route is served by about 15 buses with an interval of 10 minutes and a total distance in both directions of 53 kilometers (53479 meters). The number of stops is 102, which indicates an average distance between stops of about 500 meters, the number of population determined by the service zone is 16357, which is an average of 3271 people per service zone, and together the service zones include residents of private arrays, Tau Samal residential complex, Nauai residential complex, Shakhristan residential complex, the Sesame residential complex and border on the densely populated Orbita-1 microdistrict. The settlement density in this area is on average 8897 people per square kilometer, which is 3.7 times higher than the average density in the Bostandyk district and exceeds the average in the Auezovsky district, equal to 8378 people per square kilometer. This segment represents residential areas and needs to increase the number of routes to improve transport accessibility, because a street with four lanes of two in each direction is not able to withstand traffic during peak hours. Next in the list is Shevchenko street in the western direction from Dostyk avenue to Seifullin street with an interval of 1.81 kilometers, served by one route No. 112. No. 112 has a direction from Gorky Park of culture and recreation to the Barlyk market. The main objective of this route is to connect two food outlets of the city – the market "Zeleniy Bazar" and the market "Barlyk" with intermediate coverage of residents of the horizontal streets Shevchenko, Satpayev and Rayimbek avenue, as well as vertical Dostyk avenue and Momyshuly street with the neighborhoods Mamyr-4, Zhetysu-3, Aksai, etc. Every day this route is served by an average of 11 buses with an interval of 15 minutes. The number of the population located in the service area is 18048 people (ESRI, 2020), which is also confirmed by the high density that is typical for the central part of the city. Additionally, it is worth noting that this route on the section of Shevchenko street from Kunaev to Mukanov goes in the same direction with traffic and subsequently has to be rebuilt from the extreme left lane to the extreme right lane. Shevchenko street has prospects for restructuring the allocated lane, which will run against the movement of the main bus flow, as it is implemented on Kabanbai Batyr street, which will be discussed further. This form of dedicated lane will allow buses to run, focusing only on adjacent bus routes without reference to the existing traffic on Shevchenko street. The solution can also be the exchange of routes of Shevchenko and Kurmangazy streets, since they are organized with one-way traffic to improve throughput.

Turgut Ozal, Brusilovsky and Tlendiev streets are parallel and on these streets it is also worth paying attention to the revision of public transport traffic patterns, since residential areas in this area are densely populated and pass through the Tastak microdistrict. Turgut Ozala Street is a two-lane road with southbound traffic. The service of this street in the segment from Rayymbek Avenue to Tole Bi Street is carried out by 6 routes (№4, №70, №85, №99, №106 and No. 120a), and after that 4 routes (No. 4, No. 65, No. 70 and No. 120a) move in the south direction, which in general, they cover the basic needs for the number of permissible routes, depending on the number of lanes. Given that the Turgut Ozala is one-way in the south direction, it makes sense to move part of the routes to parallel streets. Bus route No. 4 corresponds to the transport request of the area, because it uses one-way traffic along Turgut Ozala Street, but without a dedicated lane and, in addition, without a dedicated lane opposite to traffic, and when heading back, it moves along Brusilovsky Street with two lanes of traffic in each direction. The difficulty in ensuring transport accessibility for residents of the Tastak microdistrict along Brusilovsky Street can be the presence of only one bus route for the entire street from Satpayev Street to Rayymbek Avenue in the north direction, and there are no routes at all in the south direction, which once again encourages residents of stretched due to the presence of a large private array of territories to resort to the use of private vehicles and thereby increasing the load on this and adjacent streets. Bus No. 65 connects the bus station at the intersection of Tole bi and Yassaui streets with the Magnum supermarket near the former village of Besagash in Talgar district, now part of Medeu district. This route mainly moves along Abay and Tole bi streets, moving along Turgut Ozala Street, crossing the section from Tole bi to Abay with 3 adjacent routes, which increases the length of intervals under traffic conditions. An alternative when driving from the bus station at the intersection of Tole bi and Yassaui streets to the Magnum supermarket can be a turn along Tole bi Street not to the two-lane Turgut Ozala Street with 3 other routes (No. 4, No. 70 and No. 120a), but to Brusilovsky Street with further movement towards Abaya Street. The advantage in this case may be the absence of other routes in the south direction and providing residents in the service area of this street with a route that will subsequently follow the central street of Abai with a dedicated lane. This aspect is not as critical as the reverse movement from the Magnum supermarket, when route No. 65, moving along Abaya Street, turns onto Rozybakieva Street, where in addition to automobile traffic, there are 7 more adjacent routes (№70, №77, №81, №101, №116, №120 and no.135) in the north direction from Abaya Street to Tole bi Street. An alternative to this movement may be a turn from Abai Street on the next two streets – Brusilovsky and Tlendiev.

Turning onto Brusilovsky Street will lead to movement in the north direction and intersection only with route No. 4, and Tlendiev Street in the section from Abai Avenue to Tole Bi Street is not serviced by public transport, which again increases the demand for personal vehicles. Route No. 120a is a ring and moves along Brusilovsky Street from Rayymbek Avenue to Abai Avenue in a northerly direction, duplicating route No. 70 in this segment, going from the Kokzhiyok microdistrict to the Gorny Giant microdistrict. Perhaps one of these routes would increase the efficiency of coverage of the Tastak microdistrict if, instead of turning to Rayymbek Avenue to Turgut Ozala Street, he would make a turn to Brusilovsky

Street, because on the segment from Rayymbek Avenue to Abai Avenue, this street is not covered by any route in the south direction. There is a high probability that this change would reduce the intervals between buses, since in both cases buses No. 70 and No. 120a leave for Abai Avenue, where there is a dedicated lane for public transport. Comparing the value of these changes for each of the routes, it is worth noting that in the case of the ring route, this would increase coverage, since this route has a long length (No. 120a – 45 kilometers, and No. 70 – 24 kilometers). It is also worth taking into account the average number of buses on each of the routes – there are 13 buses on route No. 120a daily, which on average at this distance means 1 bus for 3.5 kilometers, and 10 buses go to route No. 70 daily, which on average at this distance means 1 bus for 2.4 kilometers. Three stops along Turgut Ozala Street in the interval between Tole Bi Street and Abai Avenue have a service area with a population of 12434 people, which also results in a high population density in these service sectors (9500 people per square kilometer) with a total population density of 8475 people per square kilometer in Almaly district.

Then we move on to Bukhar Zhyrau Boulevard, located in the Bostandyk district. This boulevard with a length of almost 2.243 kilometers from west to east covers a number of social facilities (Children's City Clinical Infectious Diseases Hospital, School No. 10, School No. 81, Russian Medical School, Gymnasium No. 51, Gymnasium No. 138, etc.), but it is served only by one route No. 18, following from the Orbita-3 microdistrict to the Magnum supermarket through the Almaty railway station-1. At the same time, it should be borne in mind that the route serves the boulevard only in the direction from west to east from Baizakov Street to Baitursynov Street, and in the opposite direction the route moves from Zhandosov Street along Manas Street to Timiryazev Street. Bukhar Zhyrau Boulevard has great potential in the continuation of the BRT (Bus Rapid Transit) line running along Timiryazev Street and limited to the interval from Zhandosova Street to Zheltoksan Street. Located in the middle of the boulevard and dividing it into two opposite directions, the pedestrian array is suitable for placing oversized bus stops that will not require reorientation of the entire street space. This measure is also necessary due to the presence of the Koktem microdistrict to increase the variability of movement and shorten the way to stopping points, and will also avoid transport collapse due to the planned construction of the square of the Khamit Ergaliev embankment, Satpayev and Baitursynov streets, as well as Bukhar Zhyrau Boulevard. Already piled up due to point development, this zone will increase its density upon completion of the construction of residential complexes "Riverside" and "Urban Park". According to the analysis of the available three stops of bus route No. 18 along Bukhar Zhyrau Boulevard, the number of people in the service zone is 9715 people with a population density of 8077 per square kilometer, while the average population density in the Bostandyk district is 2375 people per square kilometer. Thus, this boulevard needs to increase the number of running routes with the introduction of a dedicated lane, which in the future could be part of the BRT project operating along Timiryazev Street.

Gagarin Avenue has a length of 5.976 kilometers from south to north and has two-way traffic oriented in the north-south direction and vice versa. This avenue crosses two districts of the city of Almaty – Bostandyksky and Almalinsky and is intermittent, because in the gap between Zhandosov and Timiryazev streets there is a residential area of about 40 hectares on the way of the avenue, which makes it difficult to move along this street. The section of the avenue located above Timiryazev Street is served by 5 to 8 public transport routes (one of them trolleybus to Kozhabekov Street) to Al-Farabi Avenue with a length of 3 kilometers. The emphasis in the analysis of this avenue should be placed on the section from Zhandosova Street to Tole bi Street with a length of about 2.3 kilometers, since this section is served by only one route No. 212 in both directions with further movement towards the village of Shamalgan, Karasai district, Almaty region. The main objective of this route is to provide transport services for residents of the villages of Shamalgan, Zhandosov, Kairat, Maly Dolan, Kyrgyzauyldy and others in order to deliver them to the central streets of the city – Zhandosov Street, Abai Avenue and Tole Bi Street. However, the public bus network of this section, whose service area in the Rozybakiev-Tole bi-Zharokov-Zhandosov square is about 172 hectares, needs to increase the number of routes. The number of residents in the service area at bus stops within the boundaries of the avenue is 20052 with a density of 9526 per square kilometer, with an average density in Almaly and Bostandyk districts of 8475 and 2375 people per square kilometer, respectively. One of the options for improving transport accessibility can be a revision of the movement of route No. 22 moving along Auezov Street, which is served by an average of 5-7 routes. Route No. 22 aims to connect urban areas in the Gorky Park of Culture and Recreation with the Barlyk market. Movement towards Barlyk is carried out along Shevchenko Street to Auezov Street with further rebuilding to Zhandosov Street. An alternative is to continue following Shevchenko Street to Gagarin Avenue and further rebuilding to Zhandosov Street. This change will not greatly affect the distance of the route, but it will allow integrating Gagarin Avenue with an additional route into the public transport network. In the direction of the Gorky Park of Culture and Recreation from the Barlyk market, route No. 22 moves along Auezov Street, followed by a turn to Karasai Batyr Street. Karasai Batyr Street with a length of 3.3 kilometers from Rozybakiev Street to Masanchi Street is also served by only one public route (the above-mentioned No. 22) in the interval from Auezov Street to Mukanov Street.

In this case, an alternative is to transfer the movement of this route from traffic on Zhandosova Street to Timiryazev Street to traffic on Zhandosova Street to Gagarin Avenue with a further turn on Karasai Batyr Street. This change can increase the number of routes that serve Gagarin Avenue, and also increase the integration section of Karasai Batyr Street by two blocks than it was earlier when driving along Auezov Street to Karasai Batyr Street. Additionally, it makes sense to pay attention to route No. 101, following from the car park in the Alatau district to the Esentai Mall shopping center, following mainly along Momyshuly, Tole bi and Rozybakiev Streets. Rozybakieva Street is prone to a high level of traffic during peak hours, which is why the intervals (+ travel time) of public transport also increase. Accordingly, in order to unload traffic, there is an option to transfer the turn from Tole Bi Street not to Rozybakiev Street, but to Gagarin Street next to it, followed by rebuilding to Abai Avenue. A turn to Abai Avenue implies movement along a dedicated lane with a turn to the neighboring Zharokova Street, which from Abai Avenue to Al-Farabi Avenue is served by two routes (No. 19 and No. 113), unlike Rozybakiev Street, which from Abai Avenue to Al-Farabi Avenue is served by 5-6 routes, depending on the direction of movement (in south or north direction). The transfer of traffic from Rozybakieva Street to Gagarin Avenue with a further transition to Gagarin Street,

because in both cases route No. 101 makes entry into and exit from the Kazakhfilm microdistrict along part of Zharokov Street, which subsequently leads to movement according to the standard route through the Baganashyl and Ermensai microdistricts, the horticultural association "Resort", etc. The above option will lead to the leveling of the need to make U-turns on Zharokova Street when driving in the north direction and on Rozybakiev Street in the south direction.

There is also the potential of introducing a dedicated lane for bus routes, since the avenue is divided in both directions by a pedestrian zone similar to the one on Bukhar Zhyrau Boulevard, which was described earlier. If, in the case of an increase in the number of routes on Kabanbai Batyr Street, the attractiveness factor of the pedestrian Panfilov Street, which is a point of attraction, can be cited, then in the case of Gagarin Avenue, the Mahatma Gandhi Park, covering an area of about 8.4 hectares, can be cited. Zharokov and Rozybakiev Streets run parallel to Gagarin Avenue, which are served on a similar section from Tole Bi Street to Zhandosov Street by an average of 2 and 8 routes, respectively. The section of Zharokova Street from Tole bi Street to Shevchenko, as well as Gagarin Avenue, is served by only one route (No. 19). This route connects the Kazakhfilm microdistricts (Bostandyk district) and Nurkent (Alatau district), but the difference from the only route on Gagarin Avenue is that this route follows continuously from the beginning of the street on Tole bi to its end on Al-Farabi Avenue. The total number of routes on Zharokova Street with a length of 5.6 kilometers with the above boundaries varies from 1 to 3, which also reduces the attractiveness of bus routes in this section, increasing the demand for personal vehicles.

Then we move on to another street that is served by one route – Askarova Street, located in the Bostandyk district and served by bus route No. 119. This route connects the Sayakhat bus station and the territory above the Kargaly microdistrict, moving along the section of Askarov Street that interests us. Moving in a southerly direction along Mustafina Street, the route exits onto Sain Street and later makes a U-turn on the ring section at Toraighyrov Street for further exit to Askarov Street through the Daryn microdistrict. 9979 people live in the service area of the stopping points from the beginning of Askarov Street to the final (initial) stop of route No. 119, and the population density is 4509 people per square kilometer with the previously indicated population density in the Bostandyk district equal to 2375 people per square kilometer. The population density index exceeds the average for the district by two times, and this is despite the fact that this area is located in the foothills and is mainly built up with private houses, which significantly reduces the population density. Route No. 119 runs a distance in both directions of 44 kilometers (44138 meters) and is served by an average of 15 buses every day with an interval of 10 minutes. There is no traffic on dedicated lanes on the entire route, which increases the possibility of disruption of the intervals between buses. A potential increase in the number of routes in this zone may lead to partial unloading of Al-Farabi Avenue in the eastern direction during the morning rush hour. It is also worth adding the need to introduce Sadykov Street into the route No. 119 map. To date, he performs traffic on Askarov Street in both directions and skips Sadykov Street. A potential turn to Sadykova Street when driving from the Sayakhat bus station could save this route from traffic on Sain Street at a distance of 1.6 kilometers and provide direct traffic from Mustafina Street through the ring section on Sain Street to Sadykova Street, which will also increase mobility during the evening rush hour. When considering an alternative option related to traffic from the Kargaly microdistrict and turning onto Sadykov Street with further exit to Mustafina Street through the ring section on Saina Street, it will reduce the route by 900 meters. The inclusion of Sadykov Street may be due to the active development of this territory – the commissioning of residential complexes "President's Park" and "Nef Uptown", as well as club houses "Capital Club", "Rich" and "Embassy" is planned.

Factors that influence passenger activity at the stop level can be categorized as those related to the built environment and sociodemographic characteristics of areas adjacent to stops, and transit supply, expressed as the level of transit service offered at the stop (Cui et al., 2022). In order to quantify the bus delay changes, the biggest challenge is to correctly and timely estimate the bus arrival times at various bus stops in the network. The information of bus arrival time is currently unavailable, as the bus stations are not interconnected or monitored digitally. However, the real-time positioning of each bus across the network is available via real-time transmitted GPS (Global Positioning System) location points (Ou et al., 2022). Transit's attractiveness generally stems from the spatial extent of routes, their frequency, and fare prices. However, features such as clear signage, places to sit, shelters to provide shade and protection from inclement weather, ease in boarding and exiting vehicles (e.g. unobstructed curbs), and screens providing real-time arrival estimates are also influential (Moran, 2022). Transit service can be aligned and scheduled to allow passengers to transfer between routes that arrive together and provide the opportunity to connect. Recovery time to accommodate variable traffic levels and transit speeds can be added as needed. Routes with lower ridership can be scheduled with lower frequency of service. Portions of the same route can be served with different frequencies. A central grid of routes can branch as radial suburban routes (Etgen, 2022). Transport inequality analyses are often informed by accessibility estimates based solely on travel time impedance, ignoring other elements that might hinder access to activities, such as the monetary cost of a trip (Herszenhut et al., 2022). The 1990s were a period of creating Kazakhstani material and technical and scientific base for metro construction. Despite the minimal financing, the penetration of the distillation and escalator stations, of the approach workings to the deep-seated stations continued, and, most importantly, the experienced cadres of engineers and workers were retained. During all this time, metro was built and on 1 December 2011 the first stage of the subway with a total length of 8.6 km was put into operation. It included seven stations. After four years, in 2015 were opened two stations and the length of the subway tunnel increased by 2.74 km (Bazarbekova et al., 2018). Metro data processing was carried out in a similar way – by creating points with coordinates with further conversion of points into shapes indicating the sequence. Upon completion of the transfer process, it became necessary to demonstrate the availability of metro stations, taking into account the impedance factor, since the service area differs from the buffer zone in that it is aimed at demonstrating accessibility, taking into account standard restrictions on the way to metro stations. The subsequent development of bus routes in the future should correlate with another type of transportation – the city subway. The year 2022 was marked by the opening of two new metro stations in the Auezovsky district – "Bauyrzhan Momyshuly" and "Saryarka" (Figure 4).

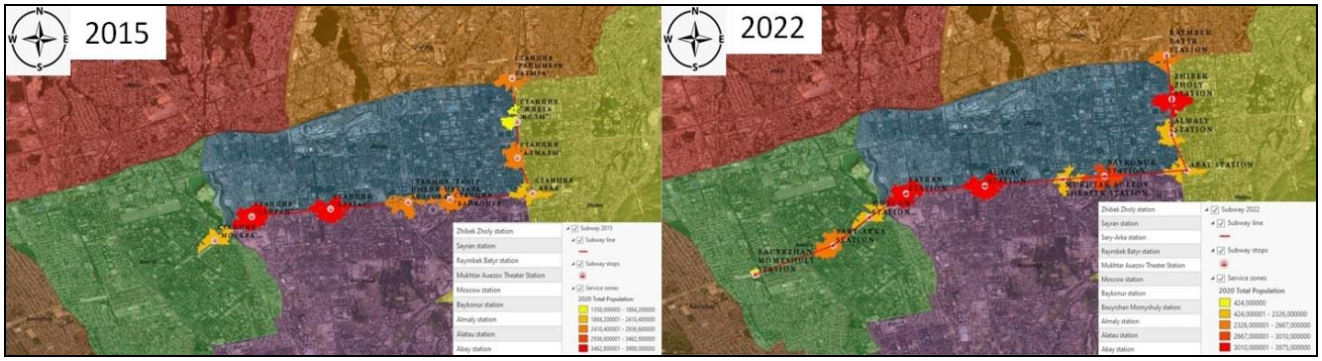

Figure 4. Comparison of the coverage areas of the city metro after the commissioning of new stations (Municipal State Enterprise "Metro")

The listed stations will be a continuation of the only branch line, which previously consisted of 9 stations, mainly located along Abai Avenue. The new stations of the Almaty metro are no exception and are located along the same avenue of Abai. A further directive for the development of the city metro is aimed at joining the Nauryzbay district to the existing metro line with a final stop in the area of the Altyn Orda and Barlyk markets on the border with the Karasay district of Almaty region, which will increase passenger traffic by providing an alternative to individual transport to residents of the above areas. Metro systems are part of the urban rail network that provide commuter services as part of the transit network in metropolitan areas. Metro systems are expensive infrastructure projects that require both capital investment and local capacity. Metro systems are characterized by rail-based vehicle technology, with scheduled services and fixed stations (underground, ground level and elevated infrastructure) (Vergel-Tovar, 2022). The metro as such is an expensive project and is implemented over a long time period, which does not always satisfy city residents. Thus, with the development of a network of urban routes, it makes sense to cooperate with representatives of the city metro, which in the short term reduces the need for it, because the issue of revising the movement of bus routes or the organization of dedicated lanes is not so capacious in technical terms, and more importantly does not require significant financial injections. Public transit ridership forecasts have long played a role in understanding the potential success of a policy or investment, but their limitations have led researchers and practitioners to identify other performance analysis approaches. Accessibility, or the ease of reaching opportunities, has become very popular and widely used for this purpose. But commonly used accessibility measures also embody weaknesses that are seldom acknowledged; these limit their utility for truly understanding the benefits of transit investments (Karner, 2022).

CONCLUSION

It is worth concluding the study with the conviction that a phased restructuring of bus and trolleybus routes is necessary with an increase in coverage area according to statistical indicators characterizing the number of population and settlement density according to service zones. Service zones formed on the basis of GTFS data are able to illustrate the ratio of residents of Almaty with the existing public transport network. The issue of creating a network of lines with dedicated lanes for the subsequent connection of all 8 districts of the city of Almaty, as well as bordering settlements of the Almaty region, needs more detailed elaboration and public discussions with representatives of the transport sector. The city of Almaty tends to consistently expand with the inclusion of border populated areas in the city boundaries, which automatically leads to an increase in the distances between various urban objects of economic activity of the city, but on the other hand there are technologies that are actively being introduced into the urban environment.

These technologies are able to reorganize the streets of Almaty in spite of the automobile lobby, and what is even more important – to lead the residents of the city to switch to public transport and means of micromobility. Summing up all the results of the existing transport network based on GTFS data, it is necessary to single out the above-described problematic streets in a separate row, since the restructuring of traffic along these streets will increase capacity, as well as increase the load on the existing dedicated lanes, which can be the starting point for a consistent increase in BRT lanes in Almaty. Summarizing the above, this study aims to increase interest in the introduction of scientific methods to improve the provision of public transport services, because this industry is still not attractive to investors and is subsidized by the state and local budgets. This study revealed the main characteristics of the existing public transport network and subsequent studies will also be aimed at analyzing the changes being made with a comparison of service zones, which will demonstrate the change in quantitative and qualitative indicators of the provision of public transport services in Almaty.

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