

Review

People-Oriented Mobility and Urban Air Quality: The Case of Almaty's Transport Reforms Towards an Eco-City Model

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Abstract

Urban transport systems are major contributors to air pollution in rapidly growing post-Soviet metropolitan areas. Almaty, Kazakhstan's largest city, has experienced a sharp rise in private vehicle ownership, accompanied by persistent exceedance of guideline values, particularly for particulate matter (PM₁₀ and PM_{2.5}). In response, successive municipal administrations have introduced transport and mobility reforms aimed at mitigating traffic-related emissions and improving urban environmental sustainability. This study applies a descriptive longitudinal policy analysis to review and systematize major transport policy interventions implemented in Almaty between 2005 and 2019, including metro expansion, Bus Rapid Transit (BRT) corridors, pedestrianization programs, cycling infrastructure development, and public transport fleet modernization. A brief comparative reference to Bishkek (Kyrgyz Republic) is included as a contextual benchmark rather than as a full comparative case, situating Almaty's experience within the Central Asian urban context. Using aggregated time-series air-quality data from RSE Kazhydromet, transport infrastructure statistics, and demographic indicators, the study examines how successive reform phases align with long-term particulate matter dynamics. The analysis suggests that people-oriented mobility restructuring and investments in high-capacity public transport tend to coincide with downward trends in particulate matter concentrations, whereas road-expansion-oriented measures demonstrate limited long-term environmental benefits. The study applies a descriptive longitudinal policy framework, focusing on system-level patterns and indicative alignment between transport policy phases and air-quality dynamics rather than causal attribution. The findings provide policy-relevant insights into other rapidly motorizing post-Soviet cities, subject to data and methodological limitations.

Keywords: urban transport reform; air quality management; sustainable mobility; people-oriented city; public transport modernization; pedestrianization; post-Soviet cities; Almaty; Central Asia

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1. Introduction

Environmental research, although younger than many classical academic disciplines, has rapidly moved to the forefront of sustainability scholarship as the consequences of human-induced environmental change have become increasingly visible. Over recent decades, concerns over climate change, air pollution, and urban environmental degradation have shaped global development agendas and policy frameworks. This shift has been

formalized through international agreements such as the Kyoto Protocol adopted under the United Nations Framework Convention on Climate Change [1] and the introduction of the United Nations Sustainable Development Goals (SDGs) in 2015 [2]. Together, these initiatives define environmental protection, climate mitigation, and sustainable urban development as key global priorities. In line with these commitments, Kazakhstan has incorporated the SDGs into its national development strategies, including the Strategy-2050 agenda, positioning environmental modernization and sustainability as central policy objectives [3].

Within urban environmental studies, fine particulate matter (PM_{2.5}) and inhalable particles (PM₁₀) are considered among the most critical indicators of air quality due to their strong association with respiratory and cardiovascular diseases and increased risks of premature mortality [4]. In rapidly growing post-Soviet cities, the expansion of private vehicle ownership, combined with low-density urban development and limited demand-management mechanisms, has made road transport one of the dominant sources of particulate pollution. This trend has intensified pressure on urban environments and public health systems across the region [5].

A key debate in contemporary urban sustainability research concerns the environmental effectiveness of transport policy choices. Conventional planning approaches have long relied on expanding road infrastructure and constructing grade-separated intersections to address congestion. However, a growing body of empirical research suggests that such measures often generate induced traffic demand and provide only short-term congestion relief, while failing to deliver sustained improvements in air quality [6]. In contrast, people-oriented mobility strategies, such as the prioritization of public transport, pedestrian-friendly urban design, and the development of cycling infrastructure, are increasingly associated with long-term reductions in particulate matter concentrations and broader improvements in urban environmental performance [7–9].

Almaty, Kazakhstan's largest metropolitan area, provides a particularly illustrative example of these policy tensions. National environmental monitoring reports consistently identify Almaty as one of the country's most polluted cities [10], while academic studies emphasize vehicular traffic as a principal contributor to its deteriorating air quality [11]. Earlier post-Soviet research primarily focused on technical dimensions of air pollution, transport safety, and emission measurements [12–15], whereas more recent studies have examined infrastructure-based mitigation initiatives and selected transport reforms [16]. Nevertheless, comprehensive longitudinal analyses of municipal transport governance, examining how successive city administrations have structured mobility policy priorities and how these policy trajectories align with long-term environmental outcomes, remain limited, particularly in the context of post-Soviet urban systems.

This study seeks to address this research gap by providing a descriptive longitudinal review of transport and urban mobility reforms implemented in Almaty between 2005 and 2019. Rather than establishing direct causal relationships between specific interventions and pollution outcomes, the analysis focuses on identifying policy sequences, institutional priorities, and temporal alignments between major transport reforms and observed trends in particulate matter concentrations. The study examines how successive municipal administrations responded to urban air-quality challenges, how transport policy priorities evolved over time, and which approaches proved more consistent with long-term environmental improvement. Key reform domains include metro development, Bus Rapid Transit (BRT) corridors, pedestrianization initiatives, cycling infrastructure expansion, and public transport fleet modernization.

To situate Almaty's experience within a broader regional context, the study incorporates a brief comparative reference to Bishkek (Kyrgyz Republic). Bishkek is not treated as a full comparative case but serves as a contextual benchmark illustrating alternative

mobility trajectories within Central Asia. The reference highlights how differing governance choices, policy coherence, and institutional capacity can influence environmental outcomes in cities sharing similar post-Soviet legacies and geographical conditions.

The study pursues three main objectives:

1. to systematize major transport and mobility reforms implemented in Almaty across successive municipal administrations;
2. to examine how distinct policy phases align with long-term trends in particulate matter concentrations; and
3. to derive transferable, policy-relevant insights for other rapidly motorizing post-Soviet cities facing comparable environmental and institutional constraints.

The remainder of the article is structured as follows. Section 2 describes the data sources and research methodology. Section 3 presents the results through a diachronic analysis of transport reforms and air-quality trends. Section 4 discusses the findings in terms of policy implications and regional transferability, and Section 5 concludes the study by summarizing key insights and outlining directions for future research.

2. Materials and Methods

2.1. Research Design

This study employs a descriptive longitudinal policy analysis to examine the evolution of transport and urban mobility reforms in Almaty and their alignment with long-term air-quality dynamics. The analytical focus is placed on identifying policy sequences, institutional priorities, and temporal co-movements between major transport interventions and particulate matter trends, rather than establishing direct causal relationships. Such an approach is particularly suited to post-Soviet urban contexts, where data limitations and overlapping environmental drivers constrain the application of causal modeling techniques.

A brief comparative reference to Bishkek (Kyrgyz Republic) is incorporated as a contextual benchmark. Bishkek is not examined as a full comparative case but is used to illustrate alternative mobility trajectories within Central Asia, given shared post-Soviet urban legacies, similar geographical settings, and comparable stages of motorization.

The empirical period of analysis spans from 2005 to 2019, corresponding to four successive municipal administrations in Almaty. Background information on the late-1990s/early-2000s governance period is briefly included to provide a pre-reform baseline for subsequent 2005–2019 policy phases.

2.2. Data Sources

Air-quality data were obtained from official environmental monitoring bulletins published by RSE Kazhydromet (Astana, Kazakhstan), the national hydrometeorological service of Kazakhstan. The analysis relies on aggregated annual and seasonal concentrations of particulate matter (PM₁₀ and PM_{2.5}, where available), which represent the most consistently reported air-quality indicators across the study period.

Transport infrastructure, vehicle ownership, population, and mobility-related indicators were collected from the Bureau of National Statistics of Kazakhstan (Astana, Kazakhstan), municipal open-data portals of the Almaty Akimat, and official transport development programs. Policy documents, strategic plans, and archival materials were retrieved from the Central State Archive of Almaty (Almaty, Kazakhstan).

Contextual information for Bishkek was drawn from publicly available reports and datasets published by international organizations, including the Japan International Cooperation Agency (JICA, Tokyo, Japan), the European Bank for Reconstruction and Development (EBRD, London, UK), the United Nations Economic Commission for Europe

(UNECE, Geneva, Switzerland), and national statistical agencies of the Kyrgyz Republic. All data sources used in this study are publicly accessible.

2.3. Analytical Procedure

The analysis was conducted in three sequential stages:

1. chronological reconstruction of major transport and mobility reforms in Almaty, grouped by municipal administration and major policy sector;
2. descriptive alignment of reform milestones with observed trends in aggregated particulate matter concentrations; and
3. comparative contextual interpretation using Bishkek as a reference city to highlight governance-related differences in mobility policy trajectories.

No statistical causal modeling or micro-scale air-quality analysis was applied. The results are interpreted as indicative policy-aligned trends rather than direct causal effects.

2.4. Methodological Limitations

Several limitations should be acknowledged. First, the analysis relies on aggregated city-level air-quality data, which do not capture localized pollution variations near specific transport corridors or individual interventions. Second, key confounding factors, such as industrial emissions, meteorological variability, and changes in fuel quality, are not controlled for statistically and may influence observed air-quality dynamics. These constraints are explicitly recognized and are addressed through cautious interpretation of the findings.

Ethical Considerations

This study relies exclusively on publicly available secondary data and does not involve human or animal subjects; therefore, ethical approval was not required.

3. Results

Transport-related emissions are among the major contributors to urban air pollution in Almaty, alongside heat-and-power generation and other sources. Figure 1 illustrates the dynamics of vehicle growth in the metropolitan area, showing a steady increase over time.

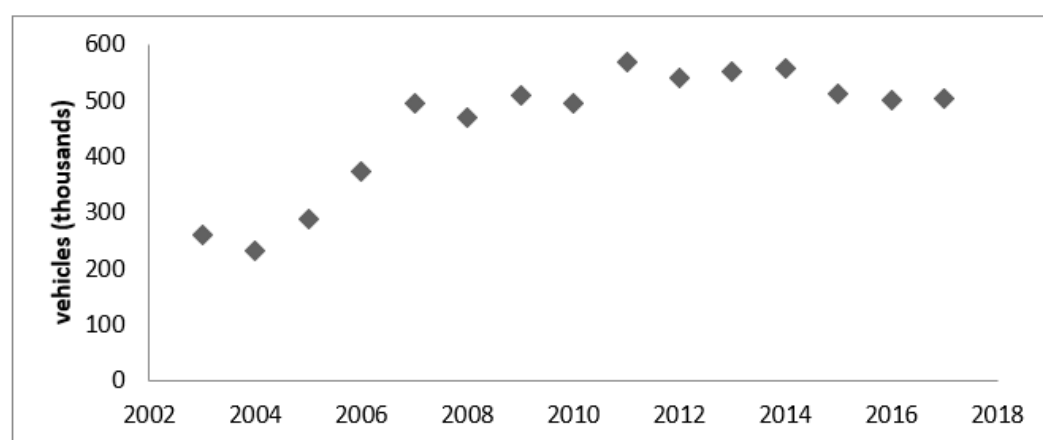


Figure 1. Almaty city vehicle fleet growth [17].

According to national statistical data as of 1 January 2018, Kazakhstan had 3,851,600 registered vehicles, of which approximately one-seventh operated in Almaty [10].

Continued growth of private motorization is expected to intensify parking shortages and pressure on urban road infrastructure [17].

Several underlying factors have contributed to the current environmental situation. Following the dissolution of the Soviet Union, Kazakhstan's national priorities largely focused on political stabilization and economic restructuring, while environmental governance and protection were not treated as central policy priorities during the early transition period, as reflected in international environmental assessments of Kazakhstan's policy framework and institutional capacity [18]. Over time, additional factors further aggravated urban environmental conditions. One of the most significant has been poorly regulated real estate development. Intensive construction of multi-storey residential buildings aimed at maximizing mountain views has partially obstructed natural ventilation corridors, limiting air circulation and increasing pollutant accumulation in central districts, with potential adverse health consequences for the urban population [16]. These factors form an important contextual background for interpreting city-level air-quality trends and for understanding the institutional and spatial constraints under which transport policy interventions were formulated and implemented.

In this context, the study summarizes transport and mobility countermeasures implemented by the Almaty city Akimat (municipal administration) during 2005–2019. Table 1 presents the sequence of municipal administrations corresponding to the analyzed policy periods.

Table 1. Sequence of municipal administrations in Almaty (1991–2019) [18].

№	Municipal Administration	Years
1	First post-independence administration	1991–1994
2	Transitional administration	1994–1997
3	Reform-oriented administration	1997–2004
4	Infrastructure expansion phase	2004–2008
5	Public transport reform phase	2008–2015
6	People-oriented mobility phase	2015–2019

The year 2000 marked a turning point in Almaty's urban development for several reasons. First, following changes in municipal governance, the volume of fiscal transfers from the city, one of the largest donors to the central government budget decreased, enabling the local administration to allocate a larger share of financial resources to municipal development needs. Second, the economic environment became more favorable for large-scale infrastructure investment (Table 2). Third, foreign investors with a long-term cooperation orientation became more visible in the city's development agenda [18]. For these reasons, this study takes the 1997–2004 municipal administration as the starting point and examines transport-related environmental measures implemented under four consecutive city administrations.

Note on air-quality data availability. Before 2014, systematic annual monitoring of PM₁₀ and PM_{2.5} in Almaty was limited. Most pre-2010 observations refer to total suspended particles (TSP) or sporadic measurements that are not directly comparable across years due to methodological inconsistencies and incomplete temporal coverage. More consistent PM_{2.5} and PM₁₀ monitoring suitable for multi-year trend interpretation became available only from the mid-2010s, as documented in independent methodological assessments of air-quality data in Almaty [19].

Using these more consistent datasets, subsequent empirical analyses demonstrate that particulate pollution levels in Almaty substantially exceeded World Health Organization annual guideline values during the 2013–2018 period. In particular, Kerimray (2020) report that annual mean PM_{2.5} concentrations were on average approximately 5.3

times higher than WHO guidelines, while PM₁₀ concentrations exceeded guideline levels by about 3.9 times [20]. Strong seasonal variability was observed, with pronounced winter peaks and summer minima, reflecting the combined influence of heating-related emissions, transport activity, and meteorological conditions limiting pollutant dispersion. This data constraint is explicitly considered in the interpretation of results, which focuses on descriptive alignment rather than causal attribution.

Table 2. Expenses of city administration (unit–million tenge) [21].

	1998	1999	2000	Change in Expenditure from 1998 to 2000
B. Expenses and loan services by deducting of-ficial transfers to the Central Government budget	13,999	13,590	19,010	+5011
1. Expenses by deducting official transfers	13,949	13,411	18,850	+4901
1.4. Education	4015	4210	4337	+322
1.5. Health care	2233	3769	4093	+1860
1.6. Social security and social aid	4369	1624	1571	−2798
1.11. Transport and communications		529	1994	+1994

Notes: only one part is given for comparison.

3.1. Municipal Administration (1997–2004) (City Districts: 6, Population: 1,175,208 in 2004) – Reform-Oriented Administration

To identify policy priorities during the 1997–2004 municipal administration, municipal expenditure trends for the period 1998–2000 were examined. As shown in Table 2, expenditures in the category “Transport and communications” increased markedly from 529 million tenge in 1999 to 1994 million tenge in 2000, indicating a growing municipal focus on transport and logistics [21]. This shift suggests that transport infrastructure began to receive higher strategic priority as a component of urban development policy, reflecting a predominantly infrastructure-led approach to congestion management and environmental mitigation.

From a policy-structure perspective, transport interventions during this period were dominated by measures aimed at expanding road capacity and improving traffic flow, while people-oriented mobility instruments and demand-management tools remained limited or absent. The measures listed below illustrate how this infrastructure-oriented logic was translated into concrete planning and investment decisions.

The main transport-related measures aimed at improving urban environmental conditions during this administration included the following:

1. Expansion of city borders and ring road planning (2002).

In December 2002, a presidential decree approved the expansion of Almaty’s city borders by approximately 3.7 thousand hectares (Figure 2). As the construction of a ring road was still at the planning stage, territories were transferred from Almaty oblast to the city following coordination with the region akim. Approximately 1600–1800 hectares were allocated for future ring road development [22].

2. Electrified public transport development under the General Plan–2020.

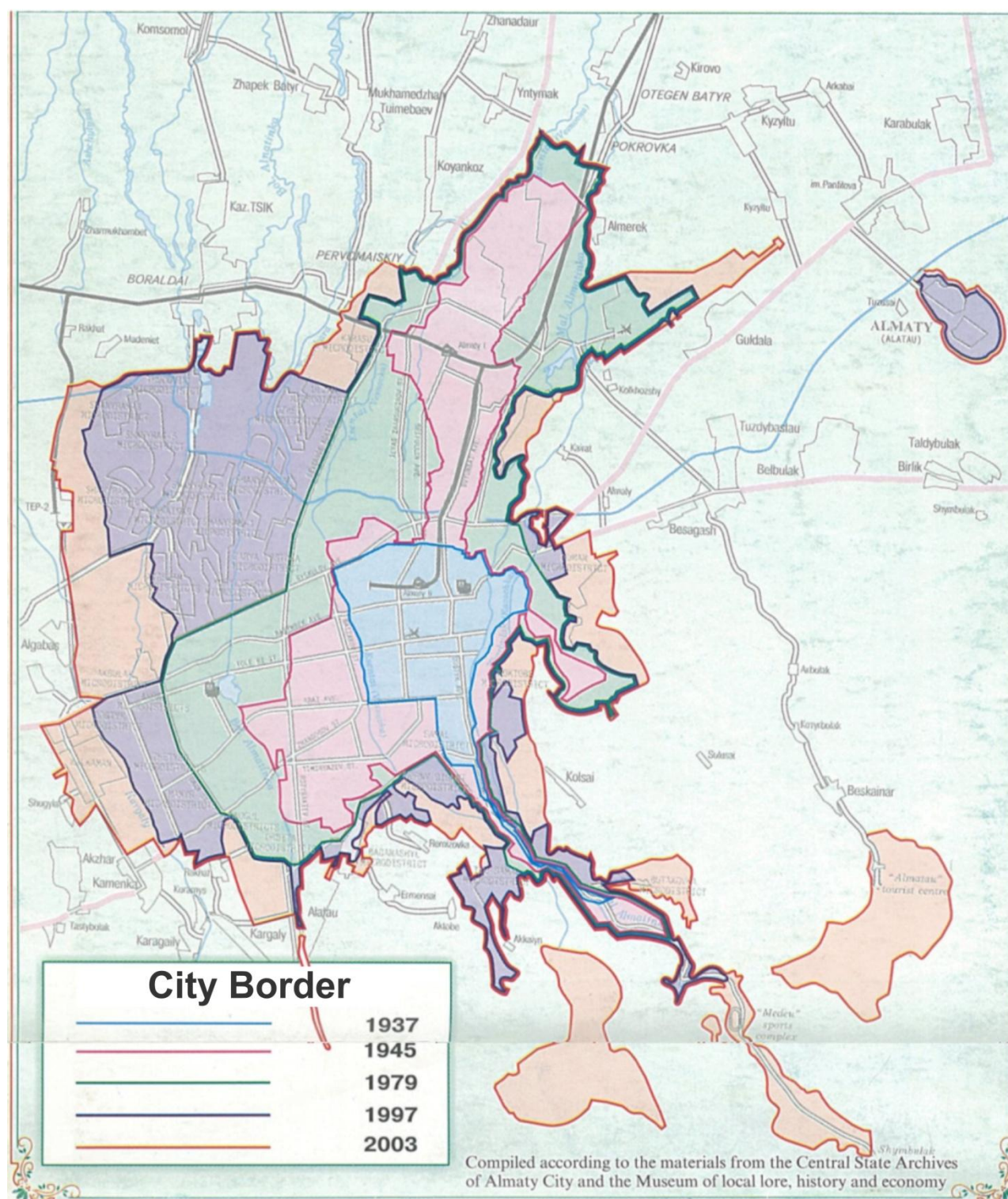


Figure 2. Almaty city map, scale 1:35,000 [22]. Note: RSPE "National Cartographical and Geodesic Foundation", 2006.

The General Plan for Almaty's socio-economic development up to 2020 proposed strengthening electrified public transport through:

- Completion of the first metro section (Furmanov Street–Raiymbek Avenue–Abai Avenue–Sain Street; total length 8.3 km);
- Expansion of trolleybus networks along major urban corridors (including Auezov–Satpaev–Sain, Sain–al-Farabi–Dostyk, Green Bazaar–Dostyk–Medeu, and other routes);

- Introduction of local electric rail services on the Almaty–Uzynagash and Almaty–Kapshagay corridors following railway electrification [23].

Although these measures indicated early recognition of the environmental benefits of electrified public transport, their implementation remained largely at the planning or preparatory stage during this period.

3. Metro financing strategy.

Metro construction, initiated during the Soviet period, had been suspended after independence due to financial constraints. Despite negotiations with several foreign companies, no private investors were secured by 2000. Consequently, in February 2003, a presidential decree authorized metro construction to be financed through the central government budget [24].

4. Monorail project proposal.

A Canadian company proposed a monorail system to be implemented following metro completion, based on its lower construction costs and successful international examples. However, as the metro project was not executed by this company, the monorail initiative was not realized [22].

5. Rolling stock renewal and electric transport expansion [25].

Under the Almaty City Action Program on Transportation to 1999, the administration planned:

- Renewal of at least 10% of rolling stock through joint ventures and procurement of buses (Renault, Ikarus, Mercedes, Daewoo);
- Establishment of the Skoda–Kazakhstan joint venture for trolleybus assembly;
- Procurement of 25 Skoda trolleybuses and 40 modern trams (KTD-4D);
- Expansion of trolleybus lines in the Aksay (16 km) and Orbita (8 km) microdistricts (Almaty City Action Program on Transportation to 1999, 1998).

These measures reflect an increased policy attention on electrified public transport as a means to improve environmental performance and operational efficiency.

6. Street extensions and ventilation corridor improvement.

Plans were developed to extend Zheltoksan, Nauryzbay Batyr, and Seifullin streets toward al-Farabi Avenue, and Tole Bi Street toward the Qalqaman microdistrict. These extensions were intended both to reduce congestion at critical intersections and to improve natural ventilation flows from the mountainous areas, with expected benefits for urban air quality [22].

7. Construction of grade-separated intersections.

The first grade-separated interchange was completed in 2001 at the Mailin–Bekmahanov–Lavrenev intersection. This project was part of a broader plan to construct 18 interchanges aimed at reducing accident risk and improving traffic flow through uninterrupted movement. A second major interchange at Raiymbek–Sain was planned for completion by 2005 [26].

These projects were primarily intended to reduce congestion and accident risks; however, their long-term environmental effectiveness remained uncertain due to induced traffic effects and continued growth in private vehicle ownership.

Overall, the 1997–2004 period was characterized by a clear dominance of infrastructure-led transport policy, with environmental considerations addressed primarily through traffic flow optimization rather than through integrated people-oriented mobility or demand-management strategies.

3.2. Municipal Administration (2004–2008) (City Districts: 6; Population: 1,324,739 in 2008)—Infrastructure Expansion Phase

The 2004–2008 municipal administration continued several initiatives initiated under the previous leadership and introduced new measures aimed at mitigating traffic congestion and improving environmental conditions, largely reinforcing an infrastructure-expansion-oriented policy trajectory.

From a policy-domain perspective, this phase was characterized by the dominance of road-capacity expansion and traffic redistribution measures, complemented by selected regulatory and planning instruments addressing urban form and environmental constraints. The interventions listed below illustrate how this infrastructure-led logic was further operationalized during the 2004–2008 period.

1. Polycentric urban development strategy.

A key planning objective was to promote a polycentric urban structure by developing residential and recreational infrastructure across multiple urban centers. This approach aimed to reduce traffic concentration in the historical city core, where high volumes of vehicles and dense building patterns contributed to smog formation. In practice, this strategy functioned primarily as a spatial traffic redistribution tool rather than as a comprehensive demand-management or mobility-reduction instrument.

2. Construction height restrictions.

In 2005, the local authorities introduced restrictions on the construction of high-rise buildings exceeding six storeys on the mountainous side of al-Farabi Avenue. This measure was intended to limit further obstruction of natural ventilation corridors and mitigate the accumulation of polluted air in central districts.

3. Metro commissioning target.

Municipal communications in 2006 indicated that the first section of the Almaty metro (8.3 km) was scheduled to be commissioned in 2008 following directives from the President and the central government [27].

4. Development of parking infrastructure.

To alleviate congestion in high-demand zones, particularly around Old Square, where educational institutions, administrative offices, and shopping facilities are concentrated, the administration proposed the construction of parking facilities at five strategic locations. A three-year plan included the development of 189 parking facilities with a total capacity of 46,400 vehicles, including 59 detached parking structures for 20,300 vehicles and 49 parking facilities within public service buildings for 8300 vehicles [26,27].

The relocation of parked vehicles to designated facilities was expected to free street space for green areas and urban landscaping, thereby contributing to local air pollutant absorption. However, the environmental relevance of parking expansion remained ambiguous, as increased parking supply may also facilitate continued private vehicle use in central areas.

5. Expansion of grade-separated intersections.

Building on the results of the initial interchanges, the Akimat planned the construction of additional road junctions. Under the Master Plan for urban development up to 2020, 24 new grade-separated intersections were scheduled (Table 3), aiming to improve traffic flow and reduce congestion-related emissions [28,29]. As in the previous phase, these measures prioritized traffic flow optimization, with limited evidence of sustained long-term air-quality improvement.

Table 3. Planned intersections (Almaty city) [29].

No.	Crossings, Where Intersections Were Built	No.	Crossings, Where Intersections Were Built
1	Rysqulov–Seifullin	13	Raiymbek–Otegen batyr
2	Rysqulov–Zhansugurov	14	Raiymbek–Rozybaqiev
3	Rysqulov–Bokeikhanov	15	al-Farabi–Rozybaqiev
4	Raiymbek–Sain	16	Tole bi–Sain
5	Raiymbek–Auezov	17	Rysqulov–North half ring
6	al-Farabi–Furmanov	18	Timiryazev–Seifullin
7	Abay–Sain	19	Furmanov–railways north from Raiymbek
8	Abay–Otegen batyr	20	North ring road–Bokeikhanov
9	Abai–Zhandosov	21	North ring road–road till the petroleum base
10	Zhandosov–Sain	22	Talgar highway–road till the airport
11	Zhandosov–Rozybaqiev	23	Qulzha highway–road till the airport
12	Zhandosov–Satpayev	24	Boraldai highway–road till the petroleum base

6. Preparation and construction of the Big Almaty Ring Road (BAKAD).

In accordance with national land legislation and government decrees, the city administration prepared the documentation for the Big Almaty Ring Road (BAKAD). Construction began in autumn 2007 and was completed in 2010. The project was intended to support interregional economic connectivity and redirect transit traffic.

7. Vehicle age restrictions.

The administration proposed limiting access for vehicles older than seven years as an economic measure to reduce greenhouse gas emissions from older, less efficient vehicles [28]. Although this proposal reflected growing awareness of emission-related risks, it remained a narrowly targeted regulatory measure rather than part of an integrated demand-management framework.

8. Development of the East Belt Road (VOAD).

Construction of the East Belt Road (VOAD) was initiated to form a ring-road system surrounding the city, defined by al-Farabi Avenue (south), Sain Street (west), Rysqulov Avenue (north), and the VOAD corridor (east) [30].

Overall, the 2004–2008 period reinforced an infrastructure-expansion-oriented transport policy model. While selected regulatory and planning measures addressed environmental and spatial constraints, people-oriented mobility instruments and comprehensive demand-management approaches remained secondary.

3.3. Municipal Administration (2008–2015) (City Districts: 8; Population: 1,641,444 in 2015)—Public Transport Reform Phase

This administrative period marked a transition toward more systematic sustainable transport policies aimed at improving urban environmental conditions, while still coexisting with earlier infrastructure-oriented traffic management approaches.

From a policy-domain perspective, the 2008–2015 period represents a transitional phase in which high-capacity public transport and people-oriented mobility instruments gained institutional support, while road-capacity expansion measures continued to be implemented in parallel. The interventions listed below illustrate how this mixed policy configuration evolved over time.

1. UNDP–GEF “City of Almaty Sustainable Transport” project.

In 2011, the five-year UNDP–GEF project “City of Almaty Sustainable Transport” (CAST) was launched to support the city in addressing transport-related emissions through the promotion of sustainable mobility options and the implementation of pilot projects. The CAST initiative was implemented in partnership with the Almaty city administration, the European Bank for Reconstruction and Development, and international organizations such as UITP, ITDP, and GIZ. In 2013, the City of Almaty Sustainable Transport Strategy for 2013–2023 was elaborated and adopted. In May 2014, projects for building a BRT corridor and a new bicycle lane were presented and approved by the city administration [31].

The CAST project played a key role in introducing integrated planning principles and external expertise, thereby strengthening the strategic coherence of subsequent transport reforms.

2. Establishment of municipal public transport assets.

Prior to 2008, public transport services were predominantly privately operated and characterized by aging vehicle fleets. To improve service quality and environmental performance, municipal transport assets were established. In 2013, the tram and trolleybus bureau was reorganized into the municipal limited liability company “Almatyelectrotrans.” According to 2015 statistics, the municipal fleet included 600 gas-powered buses and 400 gas-powered taxis, as well as 232 trolleybuses and trams (together with metro assets), indicating a shift toward cleaner public transport modes [32].

This institutional shift reduced reliance on fragmented private operators and enhanced municipal capacity to pursue environmentally oriented transport policies.

3. Development of cycling infrastructure.

From 2010 onward, bicycle lanes were introduced for citizen use in Almaty, beginning with the establishment of a dedicated transport bicycle lane along Abai Avenue connecting Dostyk Avenue and the Central Stadium. In subsequent years, cycling infrastructure continued to expand, with additional lanes and route projects developed across major streets such as Timiryazev Street and extensions toward Baytursynov and Abai, reflecting growing consideration of cycling infrastructure in road design and reconstruction [33].

4. LRT feasibility and international cooperation.

Solving environmental problems through the development of more sustainable transport requires considerable investment; therefore, local authorities actively cooperated with international financial institutions and experts. In particular, preparatory work on the Light Rail Transit (LRT) project was conducted with the involvement of international partners and feasibility studies were prepared during 2009–2011; however, no final decision on implementation was adopted during this period [34].

The absence of a final implementation decision during this phase underscores the financial and institutional constraints that limited the pace of large-scale public transport transformation.

5. Expansion of grade-separated intersections.

Between 2008 and 2015, 16 grade-separated road junctions were constructed, increasing the total number of such facilities in the city to 28 [29]. The continued construction of grade-separated intersections reflects the persistence of legacy traffic-engineering approaches alongside emerging sustainable mobility policies.

6. People-oriented urban design and metro commissioning.

Elements of the “people-first” urban design approach associated with Jan Gehl’s concept began to be implemented, emphasizing urban space for pedestrians rather than cars. A major milestone was the opening of the first section of the Almaty metro on 1 December

2011 (seven stations: “Raiymbek Batyr,” “Zhibek Zholy,” “Almaly,” “Abay,” “Baikonur,” “Auezov Theatre,” and “Alatau”), followed by the opening of two additional stations (“Sayran” and “Moskva”) on 18 April 2015 [23].

For the later years of the 2008–2015 period, monitoring-based evidence suggests persistently elevated particulate matter concentrations. Annual PM_{10} and $PM_{2.5}$ levels exceeded WHO guidelines by multiple folds, with significant seasonal variation, highlighting that while transport reforms were underway, overall urban air quality remained strongly influenced by multiple emissions sources and climatic conditions [20]. This pattern indicates that while transport reforms were gaining momentum, their potential air-quality benefits were moderated by non-transport emission sources and climatic factors.

Overall, the 2008–2015 period represents a transitional stage in Almaty’s transport policy evolution, characterized by the gradual institutionalization of public transport reform and people-oriented mobility, coexisting with inherited infrastructure-expansion strategies.

3.4. Municipal Administration (2015–2019) (City Districts: 8, Population: 1,854,656 in 2019)—People-Oriented Mobility Phase

At the 8th Ljubljana Forum, the City of Almaty received the 2018 Future of Cities Award for the urban mobility reform project “From a Car-Oriented to a People-Oriented City”. The award committee emphasized the city administration’s strategy of improving environmental conditions through public transport reform and the expansion of pedestrian-oriented public spaces [35,36]. As a result, Almaty’s transport and logistics transformations attracted nationwide public attention. This recognition reflects the consolidation of people-oriented mobility as an explicit policy framework rather than a set of isolated projects.

From a policy-domain perspective, the 2015–2019 period represents the consolidation phase of people-oriented mobility in Almaty. High-capacity public transport, pedestrianization, demand-management instruments, and active mobility measures were increasingly implemented as an integrated policy package rather than as stand-alone interventions.

1. Light Rail Transit (LRT) project (PPP framework).

Since 2013, a new phase of the LRT project has been implemented with the support of the UNDP–GEF “City of Almaty Sustainable Transport” program and the European Bank for Reconstruction and Development. Three consultant groups (IDOM, Norton Rose, and Ernst & Young) prepared tender documentation under a public–private partnership framework. The project envisages a 22.9 km LRT line with a forecast capacity of 77,000–106,000 passengers per day. The preliminary route and rolling stock parameters are presented in Figure 3 [31]. Although the LRT project did not reach the operational stage during this period, its advanced preparation signaled a strategic commitment to high-capacity public transport within a people-oriented mobility paradigm.

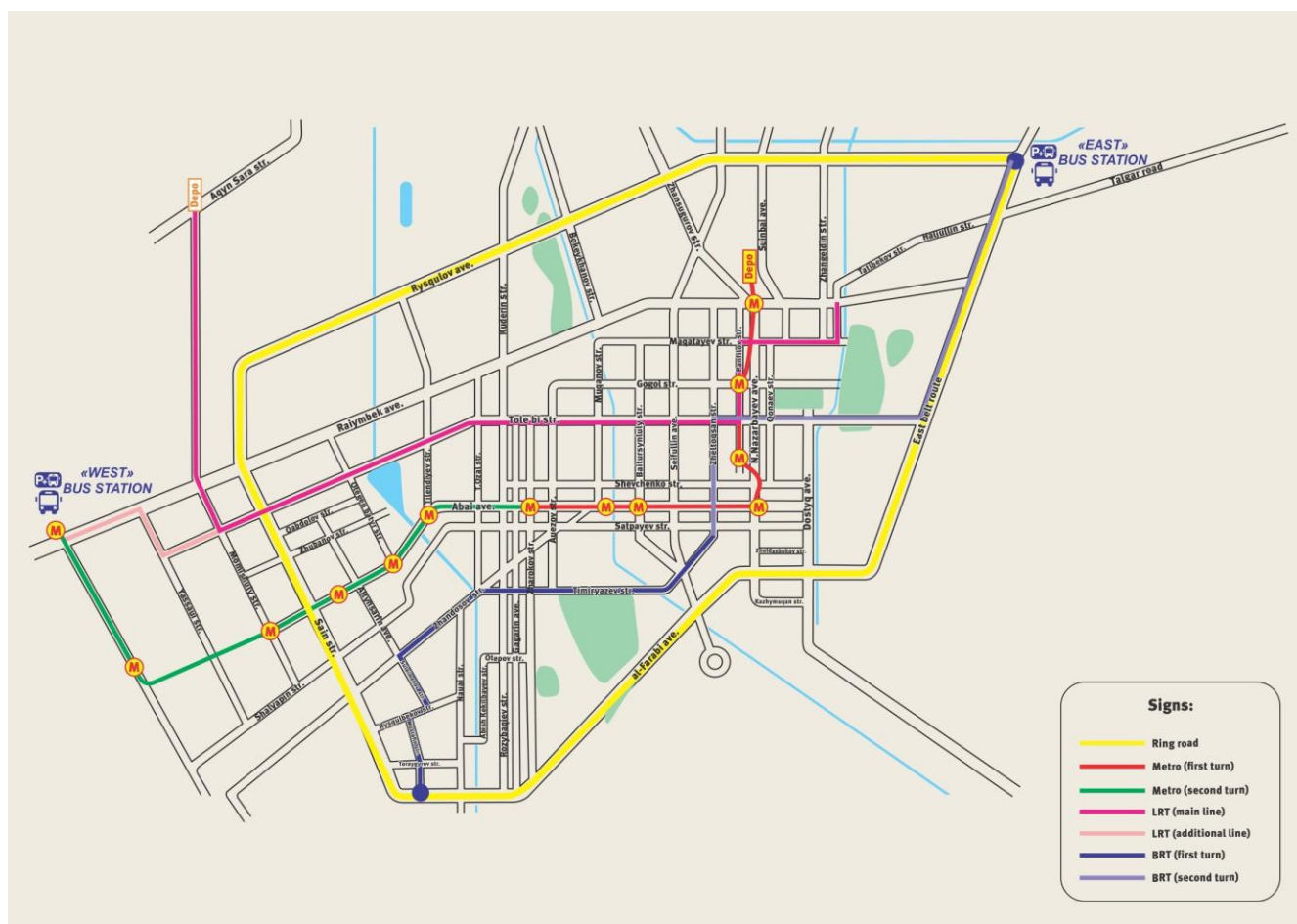


Figure 3. Almaty city's transport network map. Note: Map is drawn according to the official web-sites' information of LRT, BRT and Metro.

2. Pedestrianization and public space reform.

Due to sustained population growth, the municipality launched the “Comfortable City for Pedestrians” program as part of its people-oriented urban transformation strategy. Demographic dynamics indicate a steady increase in Almaty's population, accompanied by a parallel rise in private vehicle ownership (Figure 4) [37]. While this trend partially reflects improved living standards, it has also intensified traffic congestion and contributed to the deterioration of urban environmental conditions. In response, municipal planning priorities were gradually reoriented toward a spatial division in which the historic city center is adapted primarily for pedestrian use, whereas peripheral zones accommodate transit traffic and grade-separated road infrastructure.

Since 2017, Arbat (Zhibek Zholy Street between Konayev and Zheltoksan Streets), Panfilov Street (from Qabanbay Batyr Street to Zhibek Zholy Street), and Astana Square have been fully pedestrianized [38]. In parallel, Gogol, Qabanbay Batyr, and Baitursynov Streets were transformed into semi-pedestrian corridors, with further pedestrianization projects initiated across other central streets of the city [39]. These interventions marked a qualitative shift from traffic accommodation toward human-scale urban design as a core element of mobility policy.

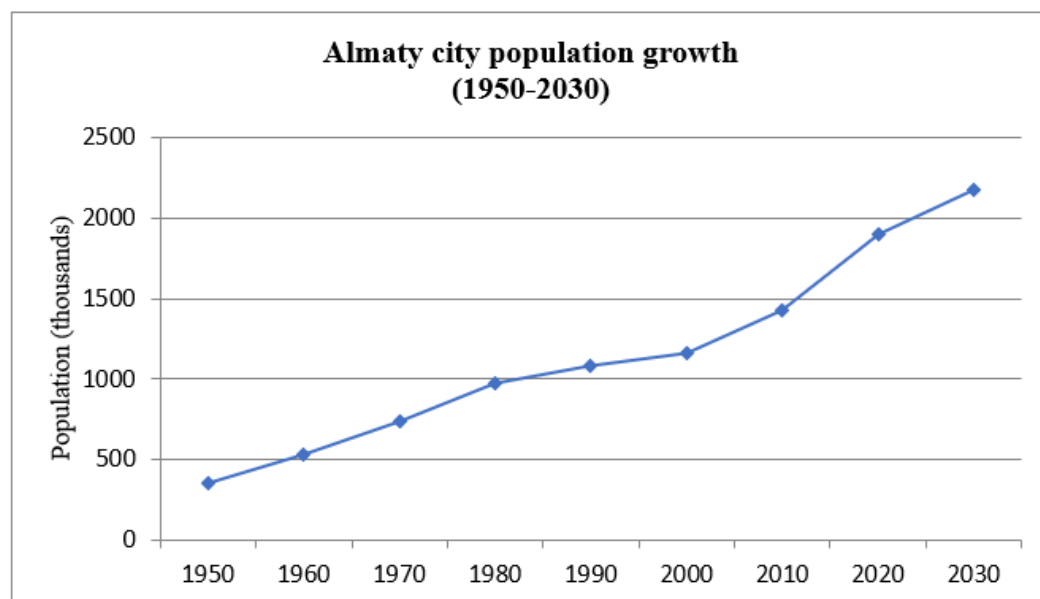


Figure 4. Almaty city population [37].

3. Dedicated public transport lanes (“A” lanes).

The first dedicated public transport lanes were introduced in Almaty in June 2015 as part of the Comprehensive Traffic Scheme implemented through 2023. These so-called “A” lanes currently operate along major arterial corridors, including Abay Avenue, the North Ring Road, Nauryzbay Batyr Street, Zheltoksan Street, Otegen Batyr Street, Tole Bi Street, Qabdolov Street, Altynsarin Street, and Raiymbek Batyr Avenue. Municipal planning documents envisage the expansion of the dedicated-lane network to a total length of approximately 150 km. According to the Almaty city development master plan, “A” lanes were scheduled for implementation on 40 major streets by 2020 [40]. Dedicated lanes functioned as a key demand-management instrument by prioritizing public transport over private vehicle use along major corridors.

4. Trolleybus network modernization.

In 2017, 5.5 billion tenge were invested in trolleybus network modernization, which was reported to be three times more cost-effective than tram reconstruction [41].

5. Metro expansion.

Metro construction continued, and two new stations: “Dostyq” and “Saryarqa”, were scheduled for opening in 2020. Passenger flows reportedly increased by 25%, contributing to cost recovery [41].

6. Peripheral park-and-ride facilities and emission control.

In early 2016, the city administration announced plans for the construction of two large park-and-ride facilities with a combined capacity of approximately 5000 suburban vehicles at the main city entry points (“East” and “West” terminals; Figure 4). These facilities were designed to accommodate vehicles subject to environmental penalty charges, thereby restricting their access to central districts and reducing traffic-related emissions [42]. In parallel, emission control measures were strengthened in 2016. As a result, administrative fines totaling 136 million tenge were imposed for violations of exhaust gas emission standards. Municipal reporting further indicated that approximately 67% of registered atmospheric pollutants originated from suburban vehicles, underscoring the significance of peripheral traffic management for improving urban air quality [31]. Together, these measures illustrate the integration of spatial planning, regulatory enforcement, and environmental objectives within a unified mobility strategy.

7. Bus Rapid Transit (BRT).

The Bus Rapid Transit (BRT) high-speed bus corridor was first launched in Almaty in August 2018. The initial 8.7 km route operates along Mustafin, Suleimenov, Zhandosov, and Timiryazev streets up to Zheltoksan Street, while an additional 13.2 km corridor runs along Zheltoksan Street, Tole Bi Street, the East Belt Road (VOAD), and the Qulzha Highway toward the Zhetysu Market (Figure 4). According to the project feasibility documentation, the BRT system includes a dedicated depot designed for up to 200 articulated 18 m buses, 67 compressed natural gas buses, specialized passenger platforms, and intelligent transport systems (ITS), including adaptive traffic light control. Following implementation, municipal statistics indicate a measurable increase in passenger flows on the corridor, reflecting the growing role of high-capacity public transport in Almaty's mobility structure [43].

8. Bicycle-sharing program ("Almaty Bike").

An environmentally friendly urban mobility initiative was launched in Almaty in 2016 with the support of the Sovereign Wealth Fund "Samruk-Kazyna" JSC. The city administration initiated the development of the Almaty Bike bicycle-sharing system as part of a broader strategy to promote active mobility and reduce dependence on private vehicles.

At the initial stage, 50 bicycle stations equipped with 270 bicycles were introduced into operation. By 2017, municipal plans envisaged an expansion of the system to approximately 2500 bicycles. Taking into account Almaty's climatic conditions, the bicycle-sharing system was designed to operate on a year-round basis, thereby enhancing its potential contribution to sustainable urban transport and emission reduction [44].

9. One-way street schemes.

To improve traffic flow and reduce accident risks, the direction of movement on several central streets in Almaty was revised. The first streets converted to one-way operation were Shevchenko Street and Qurmangazy Street. Tram rails on Shevchenko Street (from Dostyq Avenue to Zharokov Street) were dismantled, and traffic was reorganized into a westbound one-way scheme, while the adjacent Qurmangazy Street was assigned the opposite traffic direction. These measures were introduced to enhance travel safety, shorten travel time, and reduce traffic loads on major arterial roads [45].

Following the positive results of the initial phase, the city administration extended one-way traffic schemes to eight additional streets beginning in August 2018 as part of a broader traffic management reform aimed at congestion mitigation and emission reduction [46]. While primarily aimed at traffic optimization, these measures were implemented in parallel with people-oriented reforms and did not constitute the dominant policy logic of the period.

Municipal data indicate that average annual PM₁₀ concentrations declined by approximately 22% in the later part of the study period [41]. At the same time, independent monitoring-based analyses for the 2013–2018 period demonstrate that particulate pollution in Almaty substantially exceeded World Health Organization guideline values and exhibited pronounced seasonal variability, with strong winter peaks. These patterns reflect the combined influence of transport-related emissions and non-transport sources, including heating and meteorological conditions that limit pollutant dispersion. These trends are interpreted as indicative alignment rather than as evidence of direct causal effects of individual transport interventions.

To provide additional context for the particulate matter dynamics referenced above, Kerimray et al. (2020) report that wintertime PM_{2.5} concentrations in Almaty often exceeded 90–100 µg/m³ during the 2013–2018 period. A concise summary of key particulate

matter indicators and their relationship to WHO guideline levels is presented in Table 4 [20].

During this period, municipal planning priorities increasingly shifted toward pedestrian-oriented urban design and public transport use, alongside broader traffic management and mobility reforms.

Overall, the 2015–2019 period represents the most coherent phase of people-oriented mobility implementation in Almaty, characterized by the integration of public transport prioritization, pedestrianization, and demand-management measures within a consolidated policy framework.

Table 4. Summary of particulate matter indicators in Almaty based on monitoring studies (2013–2018) [20].

Pollutant	Period	Pattern vs. WHO
PM _{2.5}	2013–2018	~5.3× WHO guideline
PM ₁₀	2013–2018	~3.9× WHO guideline
Seasonal	Winter vs. Summer	Winter peaks, summer minima

3.5. Comparative Reference: Bishkek (Kyrgyz Republic)

Bishkek (Kyrgyz Republic) is introduced as a contextual comparative reference rather than a full analytical case. The city shares post-Soviet urban development legacies with Almaty, including rapid motorization, constrained municipal budgets, and inherited transport infrastructures, while demonstrating a markedly different institutional capacity and policy implementation trajectory. The Bishkek case is used to contextualize Almaty’s transport reforms and highlight alternative governance and mobility trajectories within Central Asia, rather than to provide a direct assessment of policy effectiveness.

The capital of Kyrgyz Republic faces environmental challenges similar to those observed in Almaty, primarily driven by transport-related emissions. Car density in Bishkek is among the highest in the region, reaching approximately 640 vehicles per 1000 inhabitants. The predominance of diesel-powered minibuses (marshrutkas), which partially substitute for a deficient municipal public transport system, has been linked in the literature to elevated respiratory and cardiovascular morbidity [47].

Public transport in Bishkek is composed mainly of trolleybuses, midibuses, and privately operated minibuses. Due to persistent budgetary constraints, the municipal authorities have relied extensively on international assistance to modernize the city’s transport fleet. In particular, China provided grant support for the procurement of midibuses in 2008, while the European Bank for Reconstruction and Development (EBRD) supported trolleybus modernization within the Bishkek Public Transportation Project [48]. Despite these initiatives, the absence of systematic traffic surveys and transport demand forecasting since the 1970s has hindered evidence-based planning and limited the prioritization of urban transport interventions.

To address these structural limitations, the Bishkek City Government initiated the Comprehensive Urban Transport Master Plan Study with technical cooperation from the Japan International Cooperation Agency (JICA). Conducted between 2011 and 2013, the study aimed to establish an integrated urban transport master plan and to identify priority “soft” and “hard” measures, including traffic flow optimization, modernization of public transport infrastructure, pedestrian zone development, and traffic control system improvements [49].

The first privately operated minibuses appeared in Bishkek in the early 1990s and initially accounted for a minor share of passenger transport. However, as internal migration to the capital increased, minibuses gradually became the dominant mode of urban transport [48]. Empirical studies confirm that marshrutkas remained the primary means

of passenger transportation throughout the 2000s and 2010s [50], forming the basis for comparative modal structure analyses presented in Table 5.

Table 5. Surveys’ results on the public transportation in Bishkek [49,51].

Gwilliam K., 2003 [51]		JICA, 2013 [49]	
% of Passengers Transported By		% of Transportation Made By	
Minibuses	74	Minibuses	42.1
Buses	7	Buses	1.2
Trolleybuses	19	Trolleybuses	3.4
		Walking	26.6
		Cars	26.2

Note: table was made by authors based on the information of Ryzhkov A’s article.

This modal dominance can be explained by several structural factors [51]. First, the municipal fleet of buses and trolleybuses has long been limited in size and characterized by aging rolling stock, which constrained service coverage and reliability. Second, intensive domestic migration contributed to the spatial expansion of Bishkek and the emergence of novostroyka (newly developed peripheral districts) where municipal transport services remain insufficient. As a result, municipal buses and trolleybuses primarily serve the central city areas, while privately operated minibuses have become the dominant transport mode in newly urbanized suburbs [48]. Third, the substantially higher number of minibuses compared to municipal vehicles ensures shorter headways and greater service frequency, making marshrutkas more attractive to passengers (Table 6).

Table 6. Public transportation performance in Bishkek [50].

	Minibus	Bus	Trolleybus
Routes number	119	15	9
Vehicles number	2800	455	171
Vehicles number in motion, units	2650	180	100
The share of the encompassed territory of the city covered by routes, %	70	44	22
Average peak route interval, min	6.2	13.1	10.4

Recent qualitative and quantitative improvements in Bishkek’s municipal public transport system have been achieved through the procurement of new gas-powered buses and the introduction of electronic ticketing systems, contributing to enhanced service reliability and passenger convenience [52]. These modernization measures are expected to increase public transport ridership, reflecting trends similar to those observed in Almaty.

At the governance level, the requirement to incorporate community engagement has gradually transformed transport policy implementation from a predominantly top-down administrative model toward a multi-stakeholder decision-making framework. Contemporary policy processes increasingly involve non-governmental organizations, academic researchers, municipal authorities, political actors, and citizen groups, indicating an emerging shift toward more participatory elements in urban mobility governance.

4. Discussion

Transportation systems exert both direct and indirect environmental impacts. Direct impacts include land take for new infrastructure, visual intrusion, landscape fragmentation, and noise and vibration generated during construction and operation, whereas indirect impacts encompass local air pollution, acidification, water contamination, and climate change effects [9]. The present study examined municipal transport and mobility reforms

implemented in Almaty across successive governance phases, with a particular focus on indirect environmental impacts, given that vehicular emissions represent a major source of urban air pollution alongside heat-and-power generation and other contributors.

The results indicate that, despite the consistent framing of environmental improvement as a policy priority, the early policy phase was dominated by infrastructure-oriented traffic management, including the expansion of grade-separated interchanges and ring-road planning. Consistent with international empirical evidence, road-capacity expansion can stimulate additional private vehicle use through induced demand, thereby limiting long-term congestion and air-quality benefits [53]. In Almaty, private vehicle ownership continued to rise during the period when these approaches were prioritized, suggesting that road investments alone were insufficient to offset motorization pressures. In line with this interpretation, subsequent assessments suggest that large-scale bypass and ring-road projects may not deliver sustained congestion mitigation in the absence of complementary demand-management measures. Recent spatial analyses of urban activity further indicate that pedestrianized and public-transport-oriented districts concentrate higher social and economic activity compared to car-oriented peripheral zones, reinforcing both the functional and environmental rationale for people-oriented urban restructuring [6,30,54].

A strategic shift became more evident during the mid-to-late reform phase, when urban development priorities increasingly emphasized people-oriented mobility. This transition is reflected in the expansion of high-capacity public transport systems (metro extensions and the introduction of BRT), the pedestrianization of central streets, and the gradual integration of cycling infrastructure. International sustainability research associates high-capacity public transport and pedestrian-oriented urban design with statistically significant reductions in particulate matter concentrations and improvements in urban air quality [6]. Although the present study does not establish causal effects, the observed alignment between the consolidation of people-oriented mobility measures and the reported decline in average annual PM₁₀ concentrations during the later period (Section 3.4) provides indicative support for the environmental relevance of this policy direction.

At the same time, the Almaty results underscore the importance of system-level constraints and confounding drivers. Independent monitoring-based studies show that particulate matter concentrations remained substantially above World Health Organization guideline values during 2013–2018 and were characterized by pronounced winter peaks (Table 4), reflecting the combined influence of transport emissions and non-transport sources such as heating, fuel quality, and meteorological conditions that limit pollutant dispersion. These interacting factors imply that transport reforms should be interpreted as one component of a broader air-quality system rather than as a standalone determinant of PM dynamics. Future work could strengthen inference by combining corridor-level exposure assessments, source-apportionment evidence, and meteorological controls with policy-timing analysis.

Several implementation gaps also remain relevant for policy interpretation. While municipal authorities increasingly encouraged active mobility, persistent deficiencies in supportive infrastructure (e.g., discontinuous cycling networks, limited bicycle parking, and seasonal maintenance constraints) may reduce the practical effectiveness and uptake of cycling policies. Similarly, the long-term air-quality relevance of public transport modernization depends on sustained operational performance, network integration, and continued investment in service reliability and fleet renewal. In this regard, the observed growth in public transport ridership and passenger flows during reform periods should be interpreted as an enabling condition but not as a guarantee of emissions reduction without complementary measures that discourage private vehicle use.

The study's transferable contribution lies in identifying a policy-relevant pattern that is not specific to Almaty alone: in rapidly motorizing post-Soviet metropolitan settings, people-oriented mobility restructuring (public transport investment, pedestrianization, and demand management) is more plausibly aligned with long-term environmental improvement than road-expansion-oriented congestion strategies, which are vulnerable to induced demand effects [53]. This generalization is offered as an indicative lesson rather than a causal claim and may be relevant for other cities with similar institutional and spatial legacies.

To contextualize these findings within the Central Asian region, Section 3.5 introduced Bishkek as a comparative reference rather than a parallel analytical case. The Bishkek evidence illustrates how constrained municipal capacity, reliance on private minibuses, and fragmented investment pathways can limit the scope and coherence of mobility modernization, even when external assistance programs are present [48,49]. Regional assessments further indicate that Kyrgyz Republic has made progress in strengthening legal and policy frameworks for environmental protection; however, challenges remain in translating strategic commitments into stable financing and infrastructural implementation [55]. In this sense, the Bishkek reference supports the interpretation that governance capacity, planning continuity, and investment mechanisms are critical mediators of mobility-policy feasibility in post-Soviet Central Asian cities.

More broadly, comparative international studies suggest that eco-city and sustainability agendas are often implemented through predominantly top-down governance arrangements in which local authorities coordinate multiple stakeholders [7,8]. While strong public leadership is frequently necessary to initiate large-scale urban transformation, limited citizen participation and weak NGO integration may constrain the inclusiveness and durability of urban sustainability governance. In Almaty, the gradual institutionalization of participatory elements (e.g., strategy and consultation mechanisms) may therefore be interpreted as a complementary governance development that can support policy legitimacy and implementation continuity, although further evidence would be required to assess its direct effectiveness.

Overall, the findings indicate that people-oriented mobility restructuring, rather than car-oriented road expansion, constitutes a more environmentally sustainable development pathway for rapidly motorizing post-Soviet metropolitan cities. Almaty's evolving transport policy framework demonstrates measurable alignment with internationally recognized sustainability principles and offers regionally relevant lessons for urban environmental governance in Central Asia, while remaining indicative in nature due to data and methodological constraints.

5. Conclusions

This study reviewed the evolution of transport and urban mobility policies implemented in Almaty between 2005 and 2019 and examined how successive municipal administrations responded to the city's growing air-quality challenges. By systematizing key reforms and descriptively aligning them with long-term particulate matter dynamics, the paper provides an integrated picture of how different governance approaches correspond to Almaty's environmental trajectory. A comparative reference to Bishkek was used to situate Almaty's experience within the broader Central Asian urban context rather than to provide a direct policy-effectiveness comparison.

The analysis indicates a transformation in the logic of municipal transport policy. Earlier governance phases relied predominantly on car-oriented congestion management, emphasizing road widening, grade-separated intersections, and ring-road construction. These measures were designed to improve traffic flow but appear to have provided limited long-term environmental benefits, as rising private car ownership continued to exert

pressure on air quality. Over time, policy priorities shifted toward people-oriented mobility restructuring, marked by metro development, the introduction of BRT corridors, pedestrianization of central streets, the expansion of dedicated public transport lanes, and the modernization of public transport fleets.

Descriptive alignment of reform phases with monitoring data indicates that people-centered and high-capacity public transport interventions are more consistently aligned with improvements in particulate matter dynamics than road-expansion strategies. This supports the strategic relevance of integrated public transport systems, pedestrian-friendly urban design, and active mobility infrastructure as core instruments of urban environmental governance in rapidly motorizing cities.

The comparative reference to Bishkek further highlights the role of institutional capacity, financing, and long-term planning frameworks in shaping sustainable transport transitions. While both cities face similar structural challenges related to rapid motorization and demographic growth, differences in implementation pace underline the importance of coordinated governance and stable investment mechanisms.

Overall, the findings suggest that long-term improvement of urban air quality in post-Soviet metropolitan areas is more closely associated with people-oriented mobility restructuring than with continued road expansion. The findings should be interpreted as system-level policy insights applicable to cities with comparable post-Soviet institutional and spatial conditions, rather than as universally transferable causal evidence. Almaty's experience illustrates that a transition toward public transport prioritization, pedestrianization, and active mobility can form a viable pathway for environmentally sustainable urban development in Central Asia and comparable regions.

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