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SUMP TÜRKİYE



NEAR/ANK/2021/EA-RP/0115
EU SUPPORT FOR PROMOTING SUSTAINABLE URBAN MOBILITY IN TURKISH CITIES

HANDBOOK FOR MOBILITY DATA MANAGEMENT FOR SUSTAINABLE POLICY DEVELOPMENT

REPUBLIC OF TÜRKİYE
MINISTRY OF TRANSPORT
AND INFRASTRUCTURE

SECTORAL
OPERATIONAL
PROGRAMME FOR
TRANSPORT

SUMP
TÜRKİYE

TBB

IMPRINT

Title: Handbook for Mobility Data Management for Sustainable Policy Development

About: This Handbook was prepared within the framework of "EU Support for Promoting Sustainable Urban Mobility in Turkish Cities" Project, jointly funded by the European Union and the Republic of Türkiye. The project was implemented by a consortium led by **Rupprecht Consult,** in cooperation with **BNN Consulting and Engineering, POLIS Network and MuConsult-Panteia**.

Project Stakeholders

End Recipient of Assistance: Union of Municipalities of Türkiye

Contracting Authority: Ministry of Transport and Infrastructure,
Directorate General for EU Affairs and Foreign Relations,
EU Investments Department

Co-Financier: Delegation of the European Union to Türkiye

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List of Acronyms

BAU	Business-As-Usual
BLoS	Bicycle Level of Service
CBA	Cost-Benefit Analysis
EC	European Commission
EU	European Union
EMW	European Mobility Week
EUR	Euro
GIS	Geographic Information System
GPS	Global Positioning System
HH	Household
IFI	International Financial Institutions
IoT	Internet of Things
IPA	Instrument for Pre-accession Assistance
KPIs	Key Performance Indicators
LoS	Level of Service
MCA	Multi-Criteria Analysis
MoENR	Ministry of Energy and Natural Resources
MoEUCC	Ministry of Environment, Urbanisation and Climate Change
MoH	Ministry of Health
MoI	Ministry of Interior
MoTF	Ministry of Treasury and Finance
MoTI	Ministry of Transport and Infrastructure
NGOs	Non-Governmental Organisations
PLoS	Pedestrian Level of Service
PTA	Public Transport Authorities
PTO	Public Transport Operators
SBO	Strategy and Budget Office
SCBA	Social Cost-Benefit Analysis
SSMS	Sustainable and Smart Mobility Strategy
SUMP	Sustainable Urban Mobility Plan
TurkStat	Turkish Statistical Institute
UITP	The International Association of Public Transport
UMT	Union of Municipalities of Türkiye

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Urban Mobility Data Management for Türkiye

Currently, urban mobility planning in Türkiye reflects a mix of established practices and emerging needs. Many cities continue to rely on the traditional "predict and provide" approach, extrapolating past data and trends into the future often leading to infrastructure projects like new highways and bridges that may not align with sustainable transport goals. Recent SUMP developments in Turkish cities are in favour of the “decide and provide" approach that aligns with modern objectives such as sustainability, climate change mitigation and adaptation, and urban quality of life which is based on comprehensive and continuous data analysis to ensure that transport planning is adaptive, evidence-based, and future-focused.

One of the major obstacles to more modern and effective mobility planning in Turkish cities is the availability and quality of data. Reliable and up-to-date data on mobility behaviour and transportation infrastructure is often scarce, inconsistent, or outdated. This lack of high-quality data hinders planners' ability to conduct thorough transport modelling and evaluate alternative strategies effectively. Additionally, the absence of standardised methodologies across different cities leads to disjointed and sometimes contradictory plans, further complicating efforts to develop cohesive and sustainable urban mobility policies[1].

The challenges extend to benchmarking urban mobility against national targets. Many Turkish cities struggle to efficiently collect, process, and apply data in their planning processes. As a result, policy decisions are often made using business-as-usual (BAU) practices rather than insights derived from data. This approach tends to prioritise short-term solutions over long-term sustainability, resulting in infrastructure investments that may not support the broader goals of the mobility transition. Additionally, the lack of comprehensive data poses significant challenges in identifying and setting national targets for urban mobility, further complicating efforts to drive cohesive, future-oriented planning across the country.

[1] The White Policy Paper and Green Policy Paper of the SUMP Türkiye project emphasize the critical role of data-driven, evidence-based decision-making ensuring that urban mobility policies are both effective and sustainable.

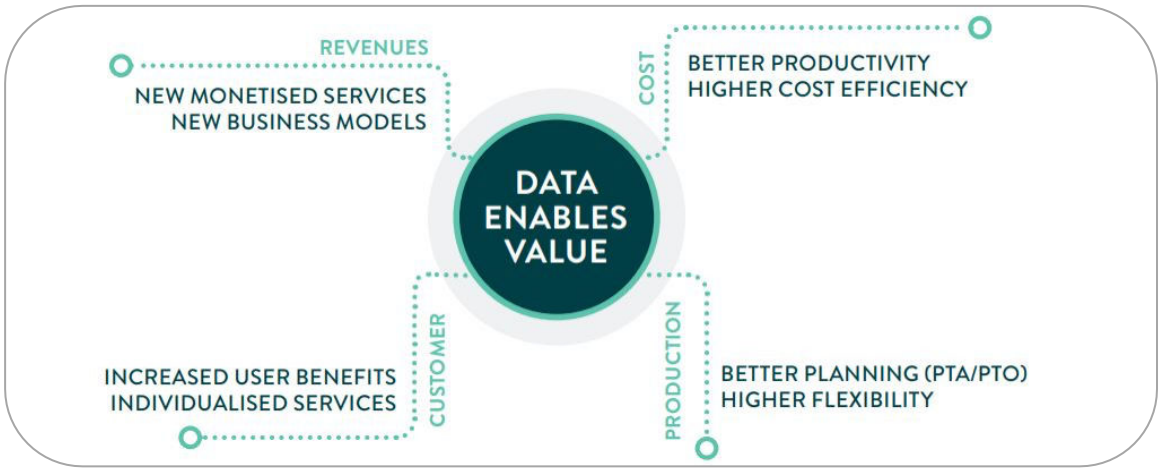


Figure 1 Value of Data in Mobility Planning for PTA (Public Transport Authorities) and PTO (Public Transport Operators). Source: UITP 2018

The need for a shift towards a strategic and data-driven approach in urban mobility planning in Türkiye is clear. By addressing these challenges and through improved data management practices, cities can better align their mobility strategies with national sustainability goals and respond more effectively to the specific needs of their urban environments.

This handbook[2] offers a thorough overview of the information, techniques, and expertise required for evidence-based planning and policy development within the framework of Sustainable Urban Mobility Plans (SUMPs). It focuses on the crucial mobility planning procedures that call for solid data, guiding the kinds of data that are required, how to get and handle this data, and how to utilise it to influence decisions. This handbook aims to facilitate a paradigm change away from the conventional "predict and provide" methodology and toward the more calculated "aim and manage" approach. Setting specific goals and key performance indicators (KPIs), and SMART targets for urban mobility, creating a baseline, and regularly tracking advancement through methodical data gathering are all part of this change. This strategy ensures that urban mobility policies are proactive in influencing the future of transportation in Turkish cities as well as responsive to the requirements of the present.

This handbook is specifically designed for transport planners, urban planners, local administrations, and legislators working in the field of transportation, data analysis, and urban development and/or are involved in the development and implementation of SUMPs in Türkiye. The primary goal is to equip these stakeholders with the knowledge and tools needed to transition from traditional planning methods to a more integrated, data-driven approach.

[2] This handbook is one of many tools within the SUMP Türkiye project that are intended to assist with many facets of urban mobility planning. In particular, it tackles the horizontal issue of "data," which touches on the five primary pillars of urban mobility—public transport, shared mobility, active mobility, road space & access, and freight & logistics. The other horizontal topics in the SUMP Türkiye White and Green Policy Papers, such as governance, funding and financing, digitization, decarbonization and energy efficiency, and resilience, are also strengthened by sustainable data management practices.

- Chapter 1 aims to provide a foundational understanding of urban mobility data management, outlining its scope, the diverse types of data involved, relevance and importance to Sustainable Urban Mobility Planning practices[3].

- Chapter 2 explores effective methods for collecting and managing urban mobility data, from traditional techniques like surveys to advanced technologies like sensors and remote sensing. It highlights the importance of proper data formatting for analysis and the role of data visualization in extracting actionable insights, ensuring that urban mobility planning is based on accurate and meaningful data.

- Chapter 3 explores how to utilise data management to understand and analyse the mobility situation in a Turkish city. It focuses on two main activities: identifying the necessary data for collection and analysing this data to highlight the strengths and weaknesses of the existing urban mobility system.

- Chapter 4 focuses on using sustainable data management practices to project future scenarios, employing both forecasting and backcasting methods utilising computational and manual techniques. This chapter also discusses how data management can help set realistic goals and targets for urban mobility planning.

- Chapter 5 focuses on setting urban mobility policy goals for the five mobility pillars Road Space & Access, Shared Mobility, Active Mobility, Freight & Logistics, and Public Transport highlighted in the Green and White Paper. It outlines the process for setting specific indicators and targets.

- Chapter 6 addresses the measurement of progress through monitoring and evaluation. It highlights the methodology of setting KPIs and smart targets utilizing data measures.

- Chapter 7 concludes the handbook by discussing comprehensive data governance for Turkish cities, including roles and responsibilities across different governance levels, data policies, standards, and legal compliances, as well as building a culture of data-driven decision-making.

Each chapter includes examples of how data can be utilised in various aspects of urban mobility planning. While this handbook presents the approach and methodology, the exact data needed should be chosen based on the priorities and specific context of each city. To support this, we conclude each chapter with a comprehensive summary-example table as well as an activity-based checklist, making it easier for cities to adapt and implement the strategies outlined.

[3] The data management practices outlined in this handbook are inspired by the SUMP Guidelines, aiming to help Turkish cities enhance their data management practices throughout the relevant activities and phases of the SUMP cycle.

1. Employing Data for Effective Sustainable Urban Mobility Planning

In urban mobility planning, such as the development of a SUMP, data serves as the essential foundation upon which every decision and strategy should be built. Data plays a critical role, not only in forecasting but also in scenario modelling, evaluating interventions, and monitoring progress toward goals. By harnessing data, planning becomes more dynamic and adaptive, enabling systems to respond effectively to changing needs.

The importance of data in planning processes like SUMP is undeniable. It is integral to every phase, requiring a comprehensive approach that goes beyond simply gathering raw data. This approach involves meticulously collecting, securely storing, efficiently visualising, thoroughly analysing, and thoughtfully interpreting a wide range of information. Such a comprehensive data management strategy ensures that the information is relevant, actionable, and capable of driving informed decision-making at every stage of urban mobility planning.



Figure 2 The Sustainable Urban Mobility Plan (SUMP) Process. Rupprecht Consult 2019

Understanding Data Management

Data management encompasses a comprehensive approach that involves **determining what data** is necessary, **how** to effectively manage and make use of this data, and **who** should be responsible for these activities. Effective data management involves multiple stakeholders across different sectors whether private or public, and different levels of governance–from local authorities' units to national agencies–each playing a critical role in ensuring that data is accurate, standardised, accessible, and actionable. This holistic view of data management is crucial for supporting informed decision-making and fostering sustainable urban mobility planning.

Scope and Dimensions of Urban Mobility Data Management

Urban Mobility Data Management is the structured process of handling data related to urban mobility systems to understand and analyse the current mobility systems, to better optimise the planning, implementation, and monitoring of mobility strategies. This process involves **collecting**, **prioritising**, formatting, **visualising**, **storing**, **sharing**, preprocessing, **analysing**, and **interpreting** various types of data to support sustainable urban mobility. The scope of urban mobility data management is comprehensive, encompassing not just quantitative data like traffic counts and travel times, but also qualitative data such as user satisfaction and public feedback. Each aspect of this data management cycle is interconnected, creating a dynamic

system where data flows between different units, levels of government, and stakeholders in the public and private sectors, ensuring that the entire urban mobility ecosystem is well-informed and responsive to current and future needs.

Introducing the Urban Mobility Data Landscape

Urban mobility data is a multifaceted resource that provides the foundation for understanding and enhancing transportation systems in cities. The data collected spans various types, each contributing uniquely to a holistic view of urban mobility.

- **Quantitative Data** forms the backbone of most mobility analyses, offering concrete, measurable facts that allow for precise evaluations of system performance. This data includes metrics such as traffic volumes, vehicle speeds, public transit ridership, travel times, and accident rates. Quantitative data is indispensable for identifying trends, forecasting demand, and optimising the efficiency of transportation networks.

- **Qualitative Data** complements quantitative insights by capturing the subjective experiences and opinions of the people who use and are affected by urban mobility systems. This data encompasses user experiences, stakeholder opinions, and community feedback, which provide a deeper understanding of the social and behavioural aspects of mobility. By listening to the voices of residents, commuters, and other stakeholders, planners can address issues that might not be apparent through numbers alone, such as accessibility concerns, satisfaction levels, and perceptions of safety.

Together, these types of data–quantitative and qualitative–create a comprehensive picture that informs strategic decision-making. This integrated approach ensures that urban mobility strategies are well-rounded, addressing both the technical efficiency of the system and the quality of services for its users and operators.

2. Methods for Collecting Vital Mobility Data

Building on the understanding of data management practices and the different landscapes of data, the next step is to explore how to effectively gather this data. The success of any urban mobility strategy hinges on the quality and relevance of the data collected, which in turn depends on the methods employed for its collection. Given the diverse nature of urban mobility data, a variety of collection methods must be employed to ensure comprehensive coverage. Different types of data require different approaches–some may be best captured through direct interaction with the public, while others may rely on advanced technological solutions or the utilisation of existing data systems.

The methods used to collect data include both traditional techniques, such as surveys and manual counts, and more advanced technologies, like sensor networks and satellite imagery. Each method has its strengths and limitations, and the choice of method often depends on the specific data needs, available resources, and the urban context in which the data is being collected.

By combining these methods, cities can build a robust data foundation that supports thorough analysis and informed decision-making. Common collection methods include:

- **Manual Counts and Observations** involve physically recording traffic and pedestrian movements, providing valuable data on volumes and behaviours that may not be captured through automated systems. This method is particularly useful for specific studies or in areas lacking advanced sensor infrastructure. While it allows for detailed, context-specific data collection, it is labour-intensive, time-consuming, and susceptible to human error. Additionally, its scale is typically more limited compared to automated methods.

- **Surveys and questionnaires**, including Household Travel Surveys, are commonly used to gather qualitative and quantitative data directly from individuals. Household Travel Surveys typically sample 1%-3% of the population and collect detailed demographic information about households, including vehicle ownership and specifics on trips made by household members. This data encompasses trip details such as time, start and end points, transfers, modes of transport, cost/fare, and purpose. These tools allow planners to capture a wide range of information, from travel behaviours and preferences to satisfaction with existing

transport services. However, the accuracy of the data depends heavily on the design of the questions, the sample size, and careful interpretation to account for potential biases.

- **Sensor and Tracking Technologies** such as traffic cameras, GPS trackers, and smart sensors, are employed to monitor real-time transportation system performance. These technologies offer continuous, high-resolution data on traffic flows, public transport usage, and active mobility patterns. The real-time nature of the data provides valuable insights into system performance as it happens. However, these technologies can be expensive to implement and maintain, and the data they produce often requires significant processing and analysis to extract actionable insights.

- **Remote Sensing and Satellite Imagery** involve using high-resolution images from satellites and drones for large-scale analysis of land use, infrastructure conditions, and environmental impacts on mobility. This method is particularly valuable for covering large areas or locations that are difficult to access. However, it is often expensive and may require specialised expertise to interpret the data accurately. Additionally, the resolution and accuracy of the data can vary depending on the technology used.

- **Existing System Data** refers to leveraging data from current urban systems and databases, such as transit ridership records and traffic management systems. This approach provides a wealth of historical and real-time information without the need for additional data collection efforts. However, the data may be outdated, inconsistent, or incomplete, which can complicate its use in analysis. Significant effort may be required to clean and standardise this data to ensure it is suitable for use.

Box 1: Strategies for Managing Data Gaps

When faced with data gaps, transport planners can utilise the following strategies to ensure planning processes continue effectively:

- **Leverage National Data**: Use relevant national-level datasets as a proxy for local data. While not as specific, national data can provide valuable insights and help maintain progress in planning efforts.
- **Incorporate Expert Assumptions**: Engage industry experts to provide informed estimates where data is missing. Expert assumptions can offer a credible basis for decision-making in the absence of hard data.
- **Apply Default Values**: Use established default values from similar projects or recognized guidelines to fill in missing information. This approach allows for consistency across planning activities and ensures that all variables are accounted for.

While these strategies enable planning to proceed with incomplete data, it is essential to validate and refine these assumptions as more accurate and localized data becomes available. Continuous data updates and adjustments are crucial to maintaining the accuracy and relevance of the planning process.

Formatting Data for Analysis

Data collection is only the first step in the data management process. Once data has been collected, it must be properly formatted to ensure it is ready for analysis. Proper data formatting is essential for maintaining the integrity of the data and ensuring that it can be used effectively in subsequent stages of planning. This process involves several critical tasks, including standardisation, data cleaning, and organising the data into a structure that is compatible with analysis and visualisation tools.

Without proper formatting, even the most accurate data can lead to misleading conclusions or become difficult to work with. Formatting data is about more than just ensuring consistency–it is about preparing the data to be as useful and actionable as possible. By taking the time to format data correctly, planners can avoid common pitfalls and ensure that their analysis is based on reliable, well-organised information. This step acts as a bridge between raw data collection and the creation of meaningful insights through visualisation.

Proper data formatting is the bridge between data collection and visualisation, ensuring that the information is accurate, consistent, and ready for use:

- **Standardisation**: Consistently apply units of measurement, date formats, and categories across all data sources to avoid discrepancies.
- **Data Cleaning**: Identify and correct inaccuracies, inconsistencies, and errors within the dataset to maintain data integrity.
- **Organising Data**: Structure data logically, such as sorting and categorising it, to facilitate smooth analysis.
- **Ensuring Compatibility**: Adjust data formats to ensure they are compatible with the software tools and platforms used for analysis and visualisation.

Visualising Data for Insightful Analysis

Once the data has been collected and properly formatted, the next step is to visualise it in a way that allows for insightful analysis. Data visualisation is a powerful tool that can transform complex datasets into clear, understandable visual formats that reveal trends, patterns, and relationships. Effective visualisation is crucial for communicating insights not only to planners and decision-makers but also to stakeholders and the public.

Different types of data are best represented through different visual formats. For instance, geographic data might be most effectively communicated through maps, while trends over time could be best illustrated through charts and graphs. The choice of visualisation method should align with the nature of the data and the specific insights that need to be conveyed. By selecting the right visualisation techniques, planners can ensure that their data is not only accurate but also accessible and actionable, meaning it can directly inform decisions and lead to tangible, real-world outcomes.

Key methods of data representation include:

- **Charts and Graphs** are useful for displaying trends, comparisons, and distributions due to their ease of interpretation. However, they can become cluttered or misleading if too much data is presented, scales are not carefully chosen, or if spurious correlations between unrelated trends are mistakenly highlighted. It is essential to ensure that the relationships being presented are meaningful and not coincidental, as misleading visuals can result in incorrect conclusions or policy decisions.

- **Maps and Spatial Representations** effectively highlight geographic patterns and relationships, making them ideal for visualising data with a spatial component, although they may require specialised software and expertise, and their effectiveness depends on the quality of the geographic data.

- **Diagrams and Models** are excellent for illustrating complex systems and processes, allowing for a clear breakdown of relationships within these systems, but they can be difficult to interpret if overly complicated and may need additional context or explanation.

- **Tables and Matrices** are advantageous for organising detailed information in a structured format, making it easier to compare data, but they can be overwhelming and less effective for quickly conveying trends or patterns.

- **Dashboards and Interactive Visualisations** offer dynamic ways to explore and interact with data, providing real-time insights, yet they can be complex and costly to develop, requiring regular updates and maintenance to stay relevant and useful.

3. Setting the Baseline: Identify the Mobility Situation

3.1. Data to understand the urban mobility system

To effectively plan and manage sustainable urban mobility, it is crucial to be able to understand and assess the current system and situation. This is only possible if we understand the system and collect and analyse a variety of data types. Data is crucial for understanding and evaluating the mobility system, as it provides insights into both the supply and demand aspects of the transport system, as well as the broader context of the city. By systematically organising and interpreting this data, cities can develop strategies that improve transportation system efficiency, safety, sustainability, and user satisfaction.

To design and manage an effective urban mobility system, planners need to capture a comprehensive range of data types that reveal the complexities of transportation networks. This landscape of data encompasses:

General City Data includes essential information about demographics, the environment, and the economy, which provides the context necessary for informed mobility planning. Demographic data should capture the diversity of the population, including age distribution, gender, employment rates, household income levels, and the specific needs of various social groups such as the elderly, children, and people with disabilities. Environmental data includes metrics like air quality, carbon emissions, and noise levels, which are critical for assessing the environmental impact of transportation systems. Economic data informs investment decisions, with insights into transport budgets, cost-benefit analyses, and funding and financing sources. Additionally, geospatial data provides a spatial understanding of land use, infrastructure distribution, and geographic patterns that influence mobility.

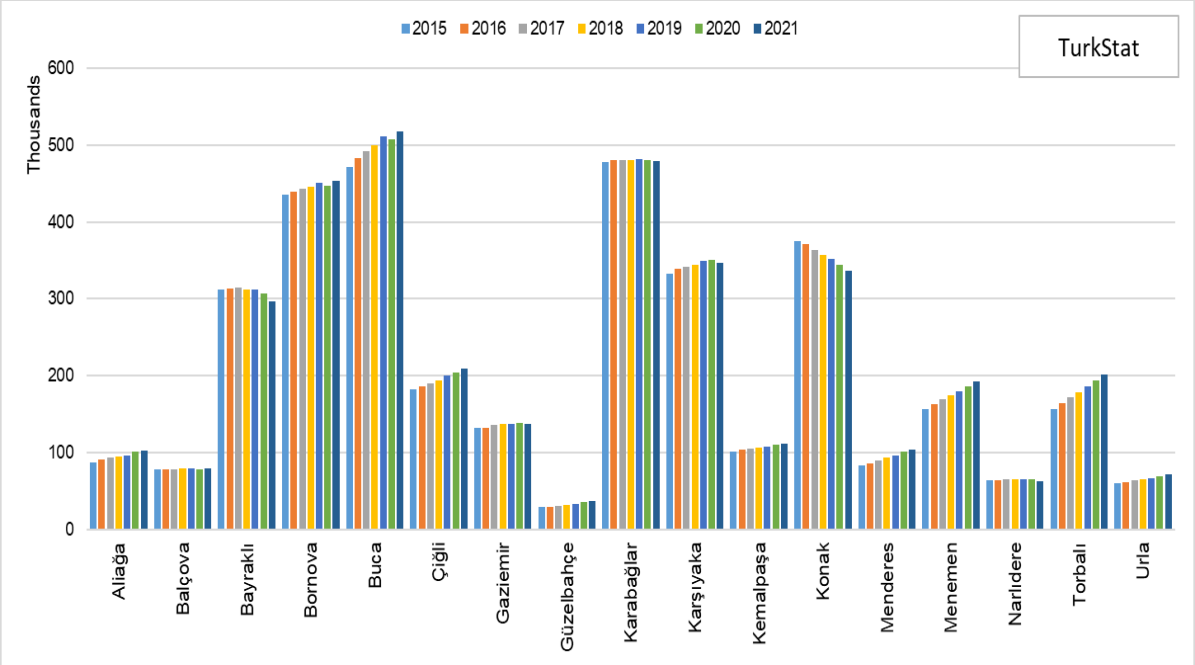


Figure 3 Example of Population Data representation. Population Change of some Districts in İzmir Province 2015-2021, TurkStat

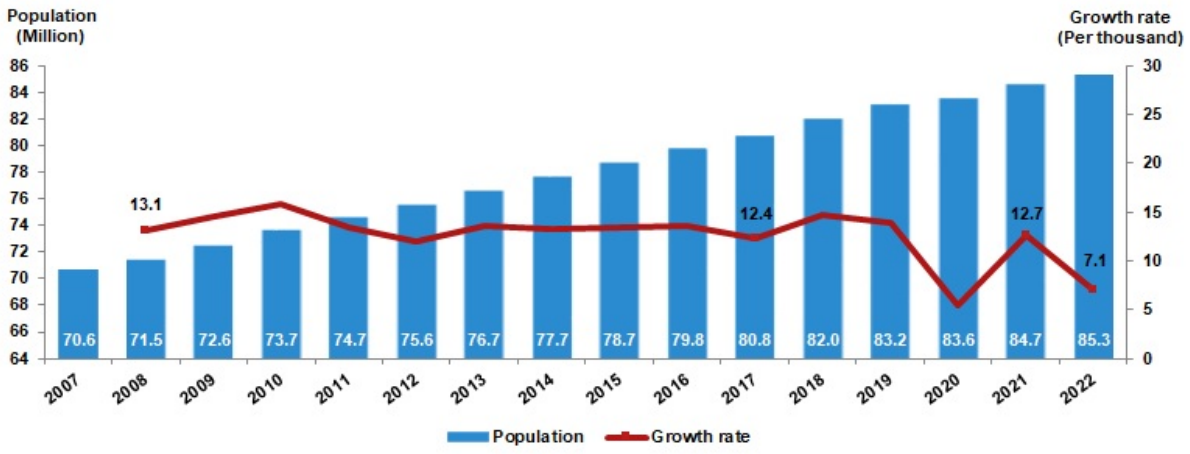


Figure 4 Population and annual population growth rate in Türkiye, 2007-2022 (Source: Turkstat)

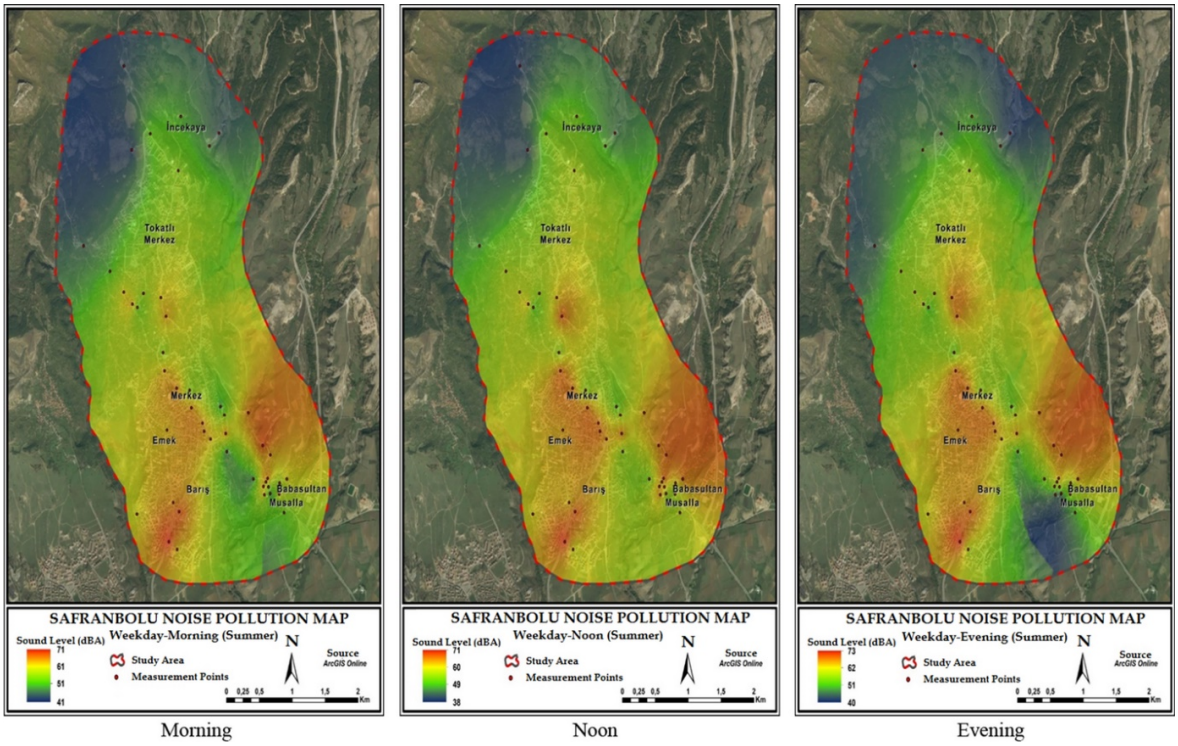


Figure 5 Example of noise mapping representation. Summer season (2017), weekdays morning–noon–evening noise measurement maps in Safranbolu, Karabük, Türkiye[4].

Supply-Side Data pertains to the infrastructure, services, and facilities that make up the transportation system. This includes data on public transport, such as bus and train routes, schedules, service frequency, fleet sizes, and water transport where applicable. Road infrastructure data covers road networks, traffic flow counts, parking facilities, and vehicle speeds. Additionally, data on active mobility includes information on bike lanes, pedestrian paths, bike-sharing stations, and pedestrian crossings, which are vital for promoting non-motorized transport options. It also encompasses micromobility services such as e-scooters and e-bikes, which play a vital role in supporting sustainable transport by complementing walking and cycling infrastructure. The sharing services like vehicles-sharing, ride-hailing and taxi services also plays a significant role in urban transport dynamics and should be captured within this category. Operational data, such as condition data of infrastructure, maintenance records, operational costs, and incident reports, is crucial for assessing the reliability and safety of transport systems. Lastly, any current or upcoming transport projects should be included to provide a comprehensive picture of the evolving mobility supply-side landscape.

[4] Source: Esmeray, E., Eren, S. GIS-based mapping and assessment of noise pollution in Safranbolu, Karabük, Türkiye. Environ Dev Sustain 23, 15413–15431 (2021). https://doi.org/10.1007/s10668-021-01303-5

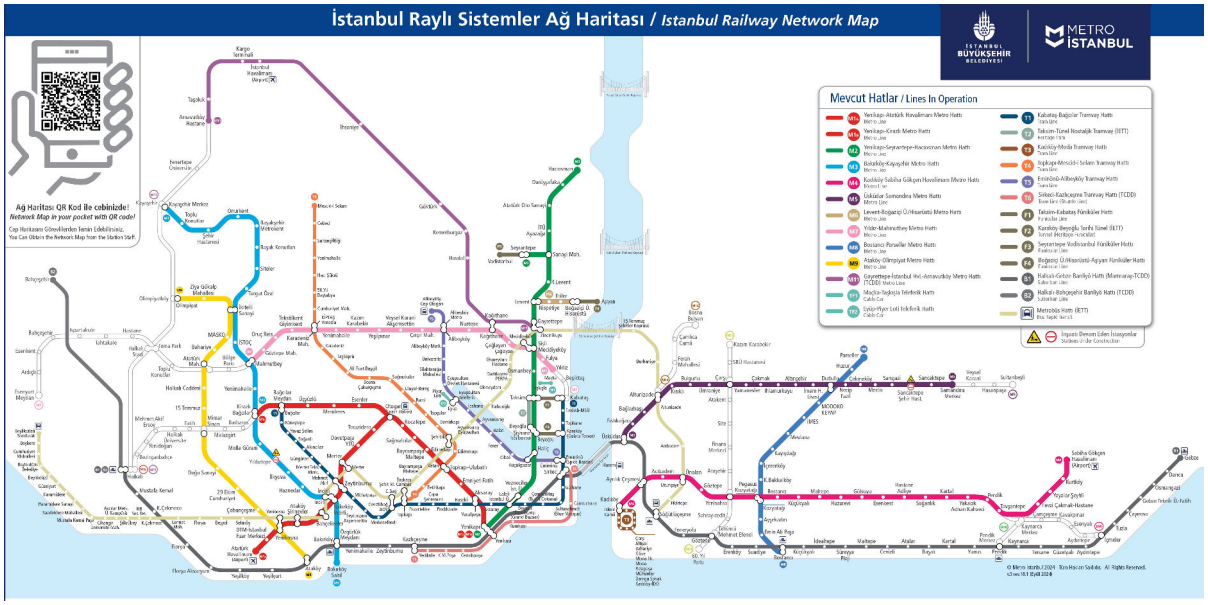


Figure 6 Example of Supply-side Data Representation. Metro infrastructure network map, Istanbul, Türkiye[5]

Demand-Side Data focuses on how the population uses various transportation modes and services. Data on public transport usage includes ridership statistics, vehicle occupancy rates, boarding and alighting locations, and user demographics. Private car usage data should include information on traffic congestion levels, average travel times, parking occupancy, and user demographics. Active mobility data captures pedestrian and bicycle counts, bike-sharing ridership, and user demographics. Additionally, data on the use of micromobility services (e-scooters, e-bikes), ride-hailing services, taxi services, and other shared mobility options is essential for understanding their role in the urban transport ecosystem. Moreover, freight transportation demand can also be included in this category, as it plays a significant role in urban traffic flow and impacts overall transport demand. Data on freight movements, delivery patterns, and vehicle types used in freight transport provides important insights into commercial transport needs and its impact on urban congestion. Lastly, travel behaviour data, gathered through surveys and questionnaires, provides qualitative insights into travel habits, user satisfaction, and the reasons behind mode choice, which are essential for tailoring services to meet user needs.

[5] https://www.metro.istanbul/YolcuHizmetleri/AgHaritalari

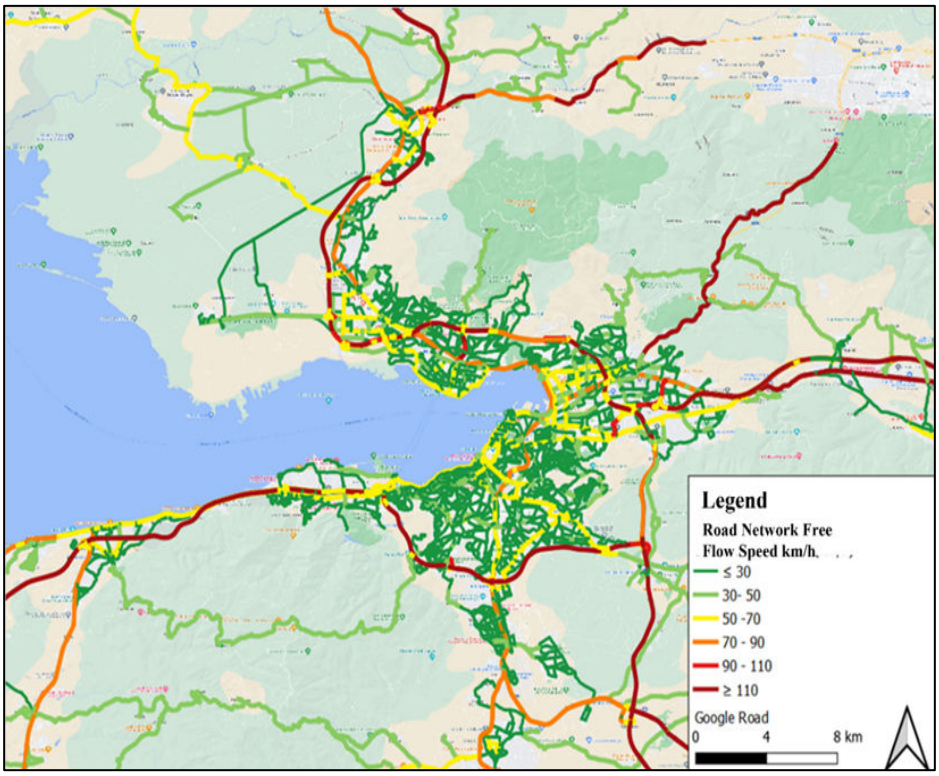


Figure 7 Free Flow Speed and traffic congestion overview in İzmir [6]

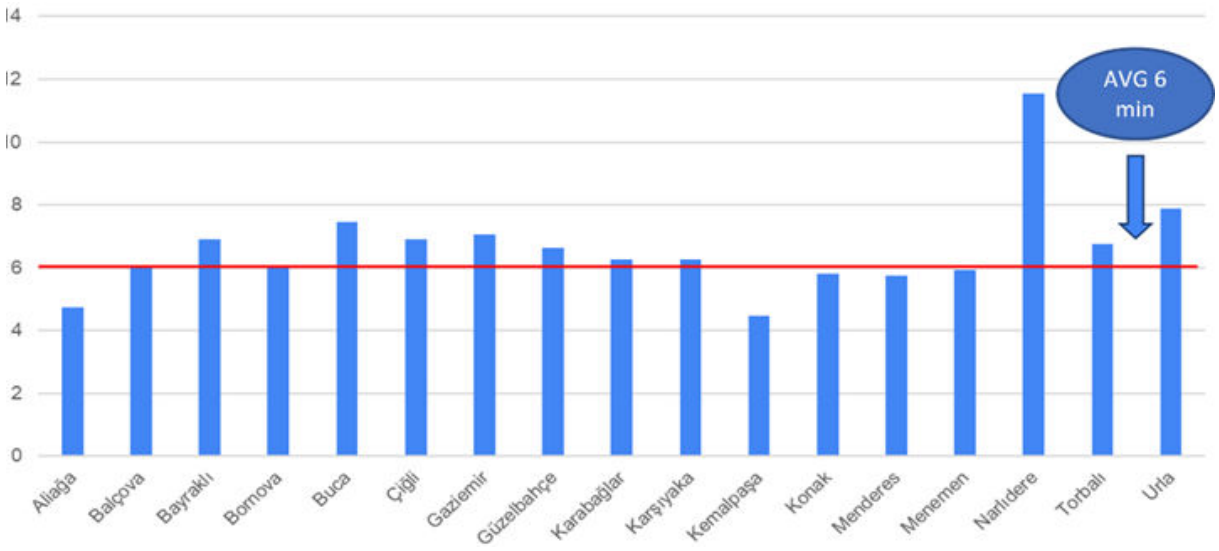


Figure 8 Example of Travel Behaviour Data Representation. Average Waiting Time for Public Transport by District in İzmir (Source: SUMP İzmir HH Survey)

[6] Data Collection Results and Current Mobility Assessment Report, EU Support to İzmir Sustainable Urban Mobility Plan, SUMP İzmir

Comprehensive Table of Data Types, Collection Methods, and Representations

To support the planning process, the following table categorises the different types of data relevant to mobility planning into three main categories: General City Data, Supply-Side Data, and Demand-Side Data. For each category, examples and potential visual representations are provided to illustrate the type of data that should be collected and further analysed.

Table 1 Comprehensive Table of Data Types, Collection Methods, and Representations

Category	Type of Data	Description	Data Sets' Examples	Türkiye Data Source		Recommended Data Collection Method	Recommended Data Format	Recommended Data Representation
				Level of Collection	Organisation			
General City Data	Demographic Data	Population data that affects transport planning and demand.	Population density	Neighbourhood	TurkStat, Municipalities	Surveys, Existing System Data	Tabular (CSV, Excel), GIS formats	Comparative Charts, Graphs, GIS Maps
			Age distribution	Neighbourhood	TurkStat			
			Employment rates	Neighbourhood	Social Security Institution, Turkish Employment Agency			
			Household income levels	Neighbourhood	Municipalities, Private Companies, Mobile Network Operators			
			Private Car ownership	Neighbourhood	TurkStat			
	Environmental Data	Data related to environmental impacts of transport systems.	Air quality measurements	Province, Station based	Municipalities, MoEUCC, Google	Sensor Technologies, Remote Sensing	Tabular (CSV, Excel), Time-series data	Charts, Graphs, Heatmaps
			Carbon emissions	Province	Municipalities, MoEUCC, Google			
			Energy consumption	Household	Municipalities, MoEUCC			
			Noise levels	Province, Station Based	Municipalities, MoEUCC			
	Economic Data	Economic factors that influence mobility planning and infrastructure investment.	Transport budgets	Transportation Mode Based	Municipalities, Municipal Enterprises	Existing System Data, Surveys	Tabular (CSV, Excel), Financial Reports	Charts, Graphs, Tables
			Funding sources	Transportation Mode	Municipalities, Municipal Enterprises			
	Geospatial Data	Geographic information related to transport networks and land use.	GIS maps	Local	Municipalities	Remote Sensing, GIS Mapping	GIS formats (Shapefiles, GeoJSON)	Maps, Spatial Representation
			Infrastructure distribution	Local	Municipalities			
			Land use patterns.	Local	Municipalities, MoEUCC			
	Policy and Regulation Data	Information on current policies, regulations, and legislative framework affecting mobility.	Transport policies	National, Province	MoTI, Municipalities	Existing System Data, Document Analysis	Document Formats (PDF, Word), Tabular data	Tables, Diagrams
			Zoning laws	National	Municipalities			
			Safety regulations	National, Local	General Directorate of Security, Municipalities			
			Environmental standards	National	MoEUCC			

Category	Type of Data	Description	Data Sets' Examples	Türkiye Data Source		Recommended Data Collection Method	Recommended Data Format	Recommended Data Representation
Supply Side Data	Public Transport	Information on public transport infrastructure and services.	Bus/Train routes	PT Line based	Municipalities, Municipal Enterprises	Existing System Data, Manual Counts	Tabular (CSV, Excel), Schedule files	Charts, Tables, GIS Maps
			Bus/Train schedules	PT Line based	Municipalities, Municipal Enterprises			
			Service frequency.	PT Line based	Municipalities, Municipal Enterprises			
			Fleet Sizes	Institution	Municipalities, Municipal Enterprises			
	Roads / Private Cars	Data on road infrastructure and private vehicle usage.	Road networks	Street level	Municipalities	Sensor Technologies, Manual Counts, Remote Sensing	Tabular (CSV, Excel), GIS formats	Charts, Graphs, GIS Maps
			Traffic flow counts	Street level	Municipalities, General Directorate of Highways, General Directorate of Security			
			Parking facilities	Institution Based	Municipalities, Municipal Enterprises			
			Vehicle speeds.	Network Based	Private Company (navigation firm), Municipalities			
	Active Mobility	Information on infrastructure supporting walking and cycling.	Bike lanes	Network Based	Municipalities, Municipal Enterprises, Private Company	Manual Counts, Surveys, Existing System Data	Tabular (CSV, Excel), GIS formats	Charts, Graphs, GIS Maps
			Bike-sharing stations	Coordinate Based	Municipalities, Municipal Enterprises, Private Company			
			Pedestrian paths	Network Based	Municipalities			
			Pedestrian crossings	Coordinate Based, Polygons, Lines	Municipalities			
	Sharing Services	Data on services like vehicles-sharing, ride-hailing and taxi services.	Service availability	Coordinate Based	Municipalities, Municipal Enterprises, Private Company	System Data, Surveys	Tabular (CSV, Excel), Time-series data, GIS formats	Tables, Graphs, Maps
			Fleet sizes	Institution Based	Municipalities, Municipal Enterprises, Private Company			
			Operation areas	Network Based	Municipalities, Municipal Enterprises, Private Company			
	Operational Data	Data on the maintenance and performance of transport systems.	Maintenance records	Institutions	Municipalities	Existing System Data, Manual Counts	Tabular (CSV, Excel), Time-series data	Tables, Graphs
			Operational costs	Institutions	Municipalities			
			Incident & accident reports	Local, Coordinate Based	General Directorate of Security, Gendarmerie General Command			
Demand Side Data	Public Transport Usage	Data on how public transport services are utilised by the public.	Ridership statistics	PT Stop or PT Line Based	Municipalities, Municipal Enterprises	Sensor Technologies, Surveys, Existing System Data	Tabular (CSV, Excel), Time-series data	Charts, Graphs, Tables
			Vehicle occupancy rates	PT Line Based	Municipalities, Municipal Enterprises			
			On/off Boarding Locations	Line based	Municipalities, Municipal Enterprises			
			PT Users Demographics	Neighbourhood	Municipalities, Municipal Enterprises			

Category	Type of Data	Description	Data Sets' Examples	Türkiye Data Source		Recommended Data Collection Method	Recommended Data Format	Recommended Data Representation
Demand Side Data	Private Car Usage	Data on private vehicle usage patterns.	Traffic congestion levels	Network Based	Municipalities, Municipal Enterprises	Sensor Technologies, Manual Counts	Tabular (CSV, Excel), Time-series data	Charts, Graphs, GIS Maps
			Average travel times	Network Based	Municipalities, Municipal Enterprises			
			Parking occupancy	Coordinate Based	Municipalities, Municipal Enterprises			
			Users Demographics & Vehicles ownership	Household	Municipalities, Municipal Enterprises			
	Active Mobility (AM) Usage	Data on how active mobility options are utilised.	Pedestrian & bicycle counts	Household	Municipalities, Municipal Enterprises	Sensor Technologies, Surveys, Manual Counts	Tabular (CSV, Excel), GIS formats	Charts, Graphs, GIS Maps
			Bike Sharing ridership	Line based	Municipalities, Municipal Enterprises			
			AM Users Demographics	Coordinate Based	Municipalities, Municipal Enterprises			
			Bike Sharing Users Demographics	Coordinate Based	Municipalities, Municipal Enterprises			
	Shared Services Usage	Data on usage and ridership for vehicles-sharing, ride-hailing, taxi services, and other shared mobility options	User demographics	Household	Municipalities, Municipal Enterprises, Private Company	System Data, Surveys	Tabular (CSV, Excel), GIS formats	Charts, Graphs, GIS Maps
			Taxi service usage	Local	Municipalities			
			Ride-hailing trips	Coordinate Based	Private Company			
	Travel Behaviour Data	Qualitative data collected from users to understand travel habits and satisfaction.	Travel behaviour analysis	Neighbourhood	Municipalities, Mobile Network Operators	Surveys, Questionnaires	Document Formats (PDF, Word), Tabular data	Charts, Diagrams, Tables
			User satisfaction surveys	Neighbourhood, District or City	Municipalities, Municipal Enterprises			
			Public Consultations					

Checklist for Data needed to evaluate the current Mobility System

By following the outlined steps for data collection and understanding the different types and representations of data, urban mobility planners can effectively evaluate and improve transportation systems. This comprehensive approach ensures that all relevant data is collected, accurately represented, and readily available for analysis and decision-making, paving the way for sustainable and efficient urban mobility solutions.

Box 2: Activities Checklist for Data needed to understand and evaluate the current Mobility System

1. **Identify Data Needs & Priorities**
- Determine required general city data, supply-side data, and demand-side data.
- Identify must-have data and nice-to-have data sets.
2. **Integrate Collection Methods & Data sources:**
- Identify, and standardise, if possible, the collection methods for different data sets: surveys, sensors, manual counts.
- Identify existing databases.
- Identify a suitable data collection period.
3. **Prepare Tools, Resources and Storage Platforms:**
- Gather necessary expertise: data collection specialists, field personnel.
- Secure survey platforms, GIS software, traffic sensors, and mobile apps.
4. **Collect Data:**
- Implement chosen methods to gather data.
- Use expert assumptions or national data if specific data is unavailable.
5. **Format, Validate and Review Data:**
- Check data for accuracy and completeness.
- Validate with experts and stakeholders.
6. **Visualise Data:**
- Utilise (and standardise whenever possible) recommended data visualisation tools to represent data findings.
7. **Document and Store Data:**
- Organise data in databases or cloud storage.
- Ensure data is accessible for further analysis.

3.2 Data analysis to describe strengths and weaknesses of the urban mobility system

In the previous sections, we explored the critical role of urban mobility data management and how effectively managing this data helps establish a baseline understanding of the current mobility situation. Building on that foundation, this section delves into the analysis of mobility data to identify and assess the strengths and weaknesses of the urban mobility system. By focusing on key indicators, cities can conduct both quantitative and qualitative evaluations of their mobility systems. These evaluations are essential for guiding targeted improvements, informing strategic planning, and ensuring that urban mobility policies align with national sustainability goals.

The following categories of indicators[7] have been defined and explained to provide a structured approach to analysing various aspects of urban mobility. These indicators encompass infrastructure performance, user experience, usage patterns, environmental and safety impacts, and operational efficiency. For each category, the necessary data inputs, expected outcomes, and recommended analytical tools are detailed later in the comprehensive table. This structured approach not only facilitates a thorough analysis of current systems but also supports the development of data-driven strategies that address the specific needs and challenges faced by cities in Türkiye.

Infrastructure Performance, Accessibility, and Equity

Infrastructure performance is crucial for identifying and addressing inefficiencies within the urban transport network. Analysing infrastructure performance, accessibility, and equity helps ensure that all population groups have fair access to transportation services and that the infrastructure supports efficient mobility. The key analyses indicators for this category are the following:

a. **Level of Service (LoS):** LoS measures the quality of service across various transportation modes, including roads, public transport, and active mobility. This analysis helps identify bottlenecks and inefficiencies, guiding infrastructure improvements.
b. **Accessibility**: Accessibility analysis evaluates how easily different population groups can access transportation. This includes general accessibility across regions and equity of accessibility among different demographic groups. The results guide interventions to improve access and ensure equitable service distribution.

[7] Detailed indicators' definitions can be found in the Glossary chapter.

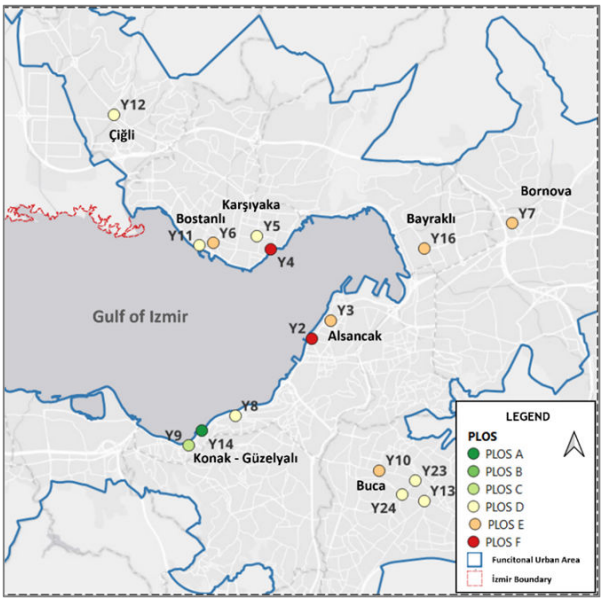


Figure 9 Weekday (PLOS) Results in Izmir[8]

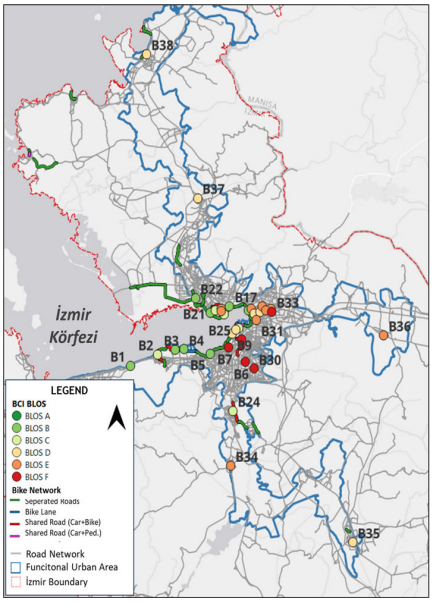


Figure 10 BLOS at Bicycle Counting Points in Izmir[9]

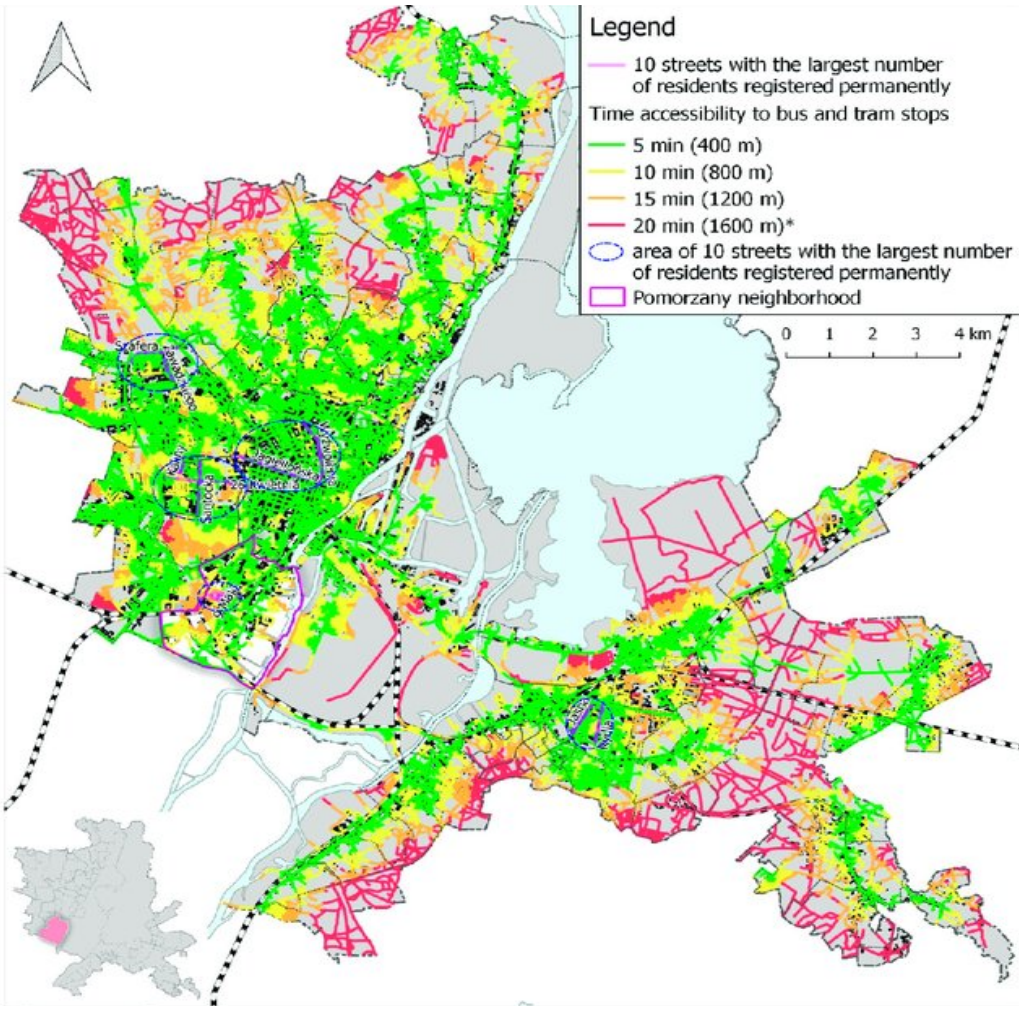


Figure 11 Public transport walk accessibility for the City of Szczecin residents within different thresholds of walk duration[10] (2019)

User Experience

Understanding user experience is critical for improving satisfaction with urban mobility systems. Analysing user satisfaction and travel time provides insights into how well the transport system meets user needs and where improvements are necessary. The key analyses indicators for this category are the following:

c. **User Satisfaction**: Analysing user satisfaction involves gathering feedback on various aspects of the transport experience, such as reliability, comfort, affordability and safety. This qualitative measure informs targeted improvements to enhance overall satisfaction.
d. **Travel Time**: Travel time analysis is essential for identifying inefficiencies and delays within the transport network. By benchmarking average travel times, in minutes/hours, and analysing variability, cities can make informed decisions to improve network efficiency.

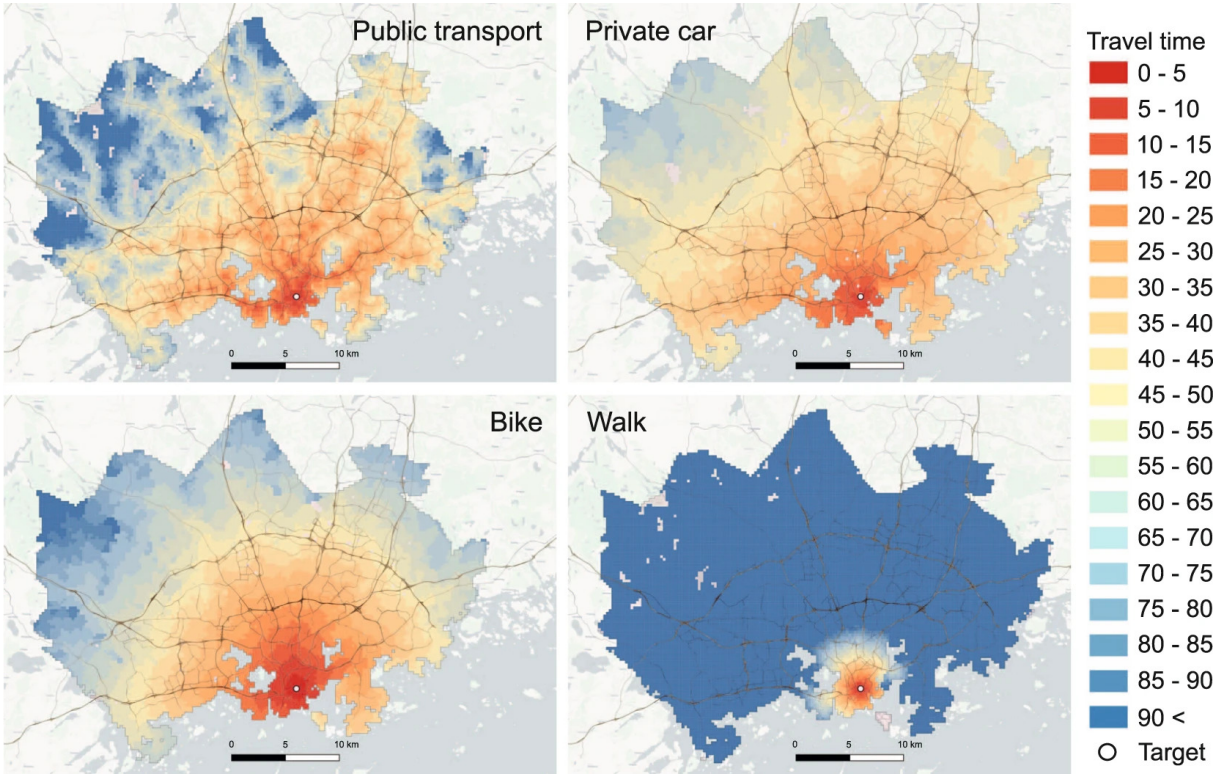


Figure 12 Travel time visualisation from origin point - visualisation from study in Helsinki, Finland[11]

[8] Source: DATA COLLECTION RESULTS AND CURRENT MOBILITY ASSESSMENT REPORT, *'EU Support to SUMP Izmir'* Project.
[9] Source: DATA COLLECTION RESULTS AND CURRENT MOBILITY ASSESSMENT REPORT, *'EU Support to SUMP Izmir'* Project
[10] Source:https://www.researchgate.net/publication/334371219_Walking_Access_to_Public_Transportation_Stops_for_City_Residents_A_Comparison_of_Methods
[11] Source: Tenkanen, H., Toivonen, T. Longitudinal spatial dataset on travel times and distances by different travel modes in Helsinki Region. Sci Data 7, 77 (2020). https://doi.org/10.1038/s41597-020-0413-y

Usage Patterns

Analysing usage patterns helps cities understand how residents interact with different transportation modes, guiding strategies to promote sustainable mobility options. The key analysis indicators for this category are the following:

e. **Modal Split**: Modal split analysis examines the proportion of trips made by different transportation modes. Understanding these patterns supports the development of strategies to encourage the use of more sustainable modes, such as public transport and active mobility.

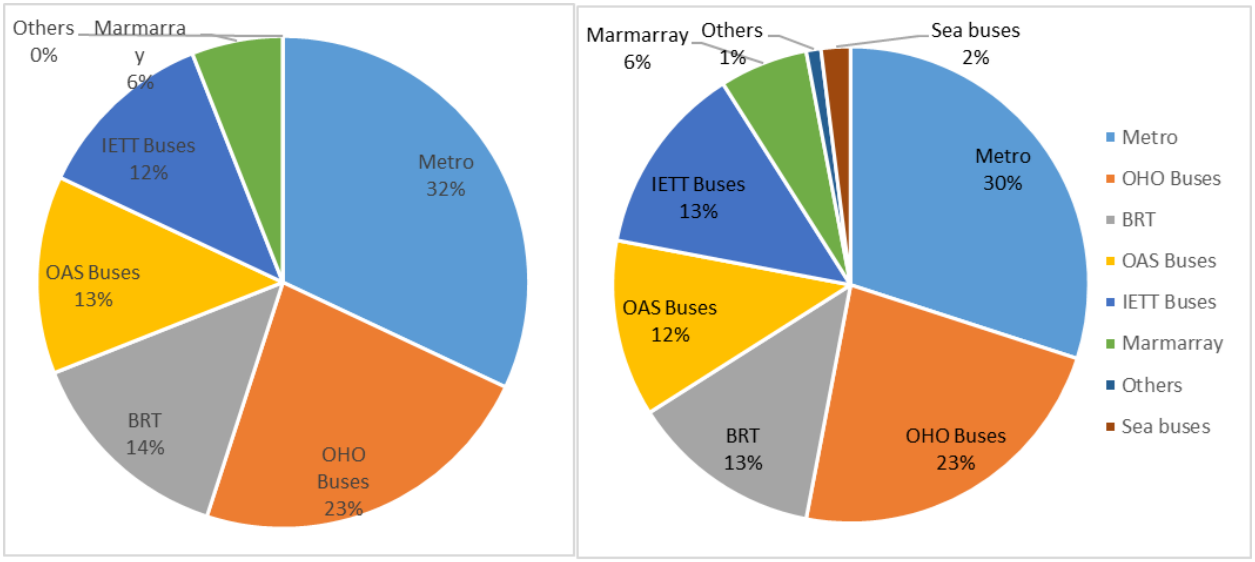


Figure 13 Journey distribution by modes of public transportation in Istanbul for 2019 (left) and 2020 (right) own illustration based on source[12]

f. **Parking Utilisation**: Assessing parking utilisation helps optimise the management of on-street and off-street parking facilities. This analysis identifies underutilised areas and informs decisions to reduce illegal parking and improve overall parking management.

Environmental and Safety Impact

Monitoring environmental and safety impacts is vital for creating safer and more sustainable urban environments. Analysing pollution levels and accident data helps cities implement effective mitigation strategies. The key analyses indicators for this category are the following:

[12] Aydın, Nezir & Kusakci, Ali & Deveci, Muhammet. (2022). The impacts of COVID-19 on travel behavior and initial perception of public transport measures in Istanbul. Decision Analytics Journal. 2. 10.1016/j.dajour.2022.100029

g. **Pollution Hotspots**: Analysing pollution data allows cities to identify areas with high levels of air and noise pollution. These insights guide the implementation of policies such as Low-Emission Zones and other environmental protections.
h. **Accident Data**: Accident analysis is essential for improving safety. By identifying accident hotspots and understanding the causes, cities can design and implement safety measures to reduce accidents and enhance infrastructure for vulnerable road users.

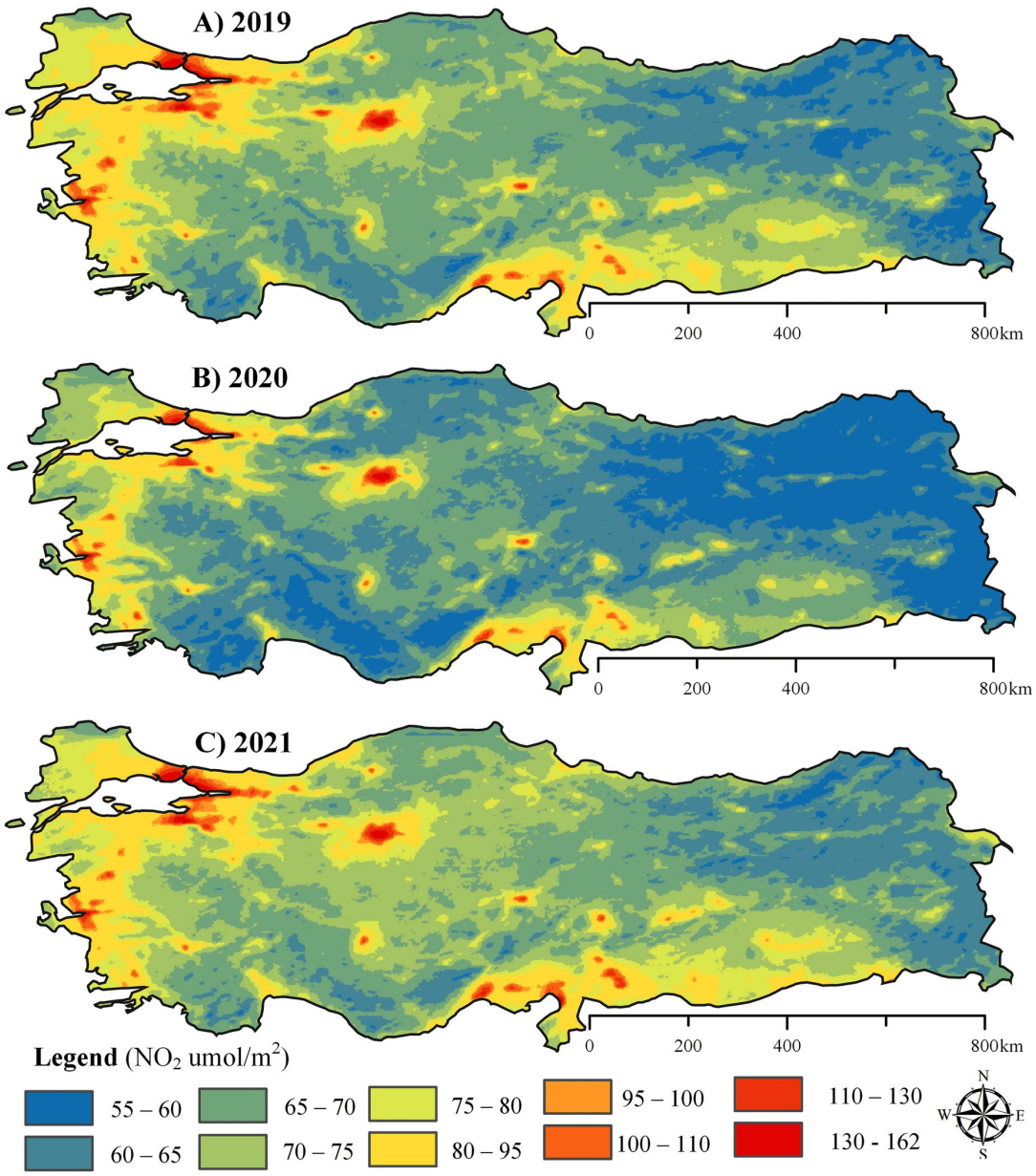


Figure 14 Mean NO_2 values over Türkiye for A 2019; B 2020; C 2021[13]

[13] Dilek, Küçük, Matci., Gordana, Kaplan., Uğur, Avdan. (2022). Changes in air quality over different land covers associated with COVID-19 in Türkiye aided by GEE. Environmental Monitoring and Assessment, 194(10) doi: 10.1007/s10661-022-10444-7



Figure 15 Traffic accident statistics in Türkiye[14] (2004–2017)

[14] Erdoğan, S., Dereli, M.A. & Şenol, H.İ. A GIS-based assessment of long-term traffic accidents using spatiotemporal and empirical Bayes analysis in Türkiye. Appl Geomat 14, 147–162 (2022). https://doi.org/10.1007/s12518-022-00419-1

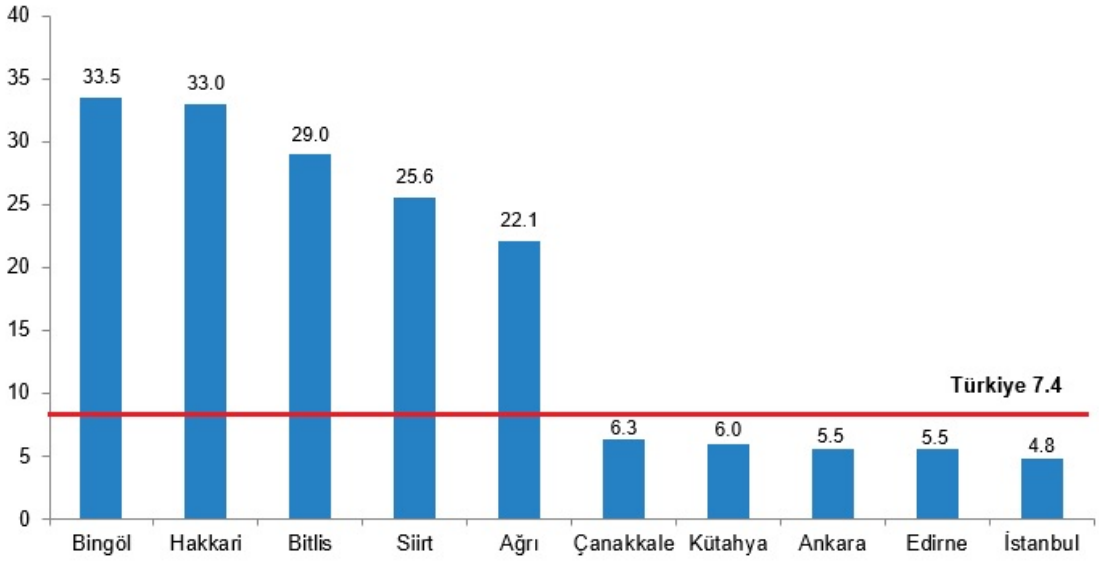


Figure 16 First and last 5 provinces in Türkiye by number of traffic accidents involving death or injury per thousand vehicles, 2021 (Source: Turkstat[15])

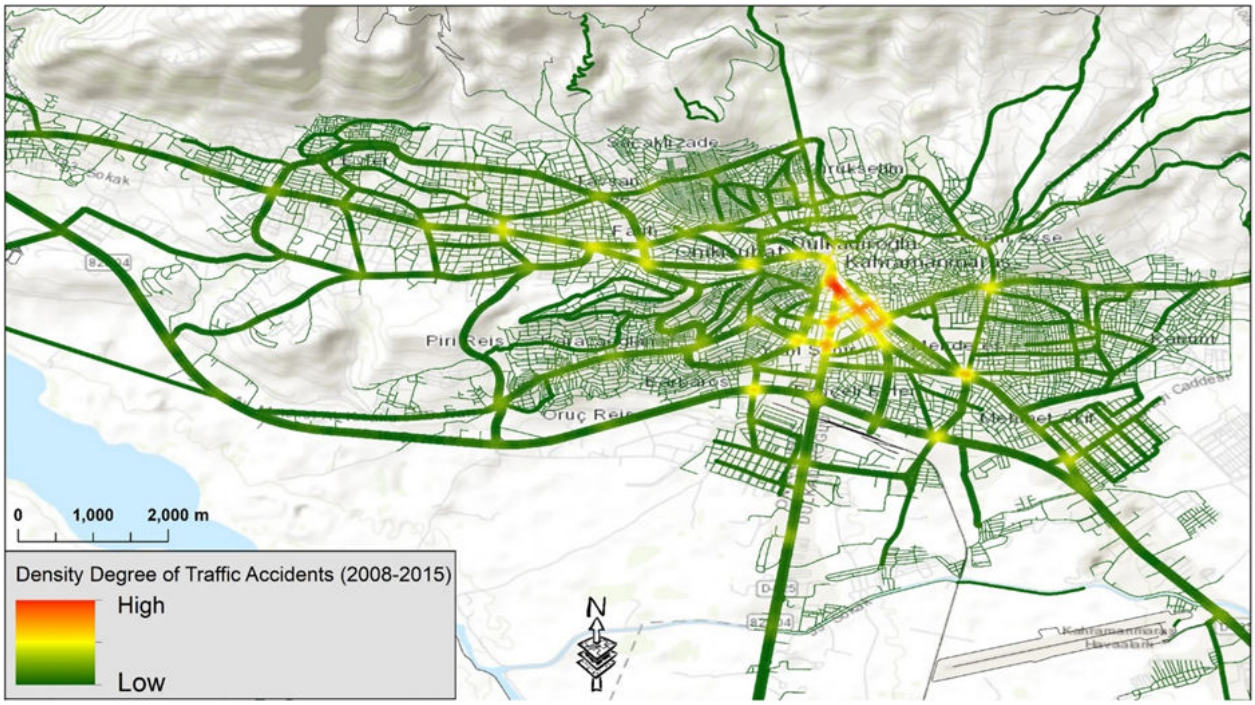


Figure 17 Spatial density of traffic accidents in Kahramanmaraş, Türkiye for the years 2008 – 2015[16]

[15] **Turkstat accident statistics**, 2021, available at https://data.tuik.gov.tr/Bulten/Index?p=Road-Traffic-Accident-Statistics-2021-45658&dil=2

[16] Mehmet, Özcan., Muhterem, Küçükönder. (2020). Investigation of Spatiotemporal Changes in the Incidence of Traffic Accidents in Kahramanmaraş, Türkiye, Using GIS-Based Density Analysis. Journal of The Indian Society of Remote Sensing, 48(7):1045-1056. doi: 10.1007/S12524-020-01137-0

Freight Operational Efficiency

Efficient freight operations are critical for reducing congestion and ensuring timely deliveries. Analysing freight movement and last-mile delivery efficiency helps optimise logistics and improve urban freight services. The key analysis indicators for this category are the following:

i. **Urban Freight Movement**: Analysing freight movement patterns helps cities optimise logistics, reduce congestion, and improve delivery efficiency.
j. **Last-mile Delivery**: Understanding last-mile delivery patterns and challenges helps enhance service efficiency, reduce delays, and minimise the impact of freight operations on urban traffic

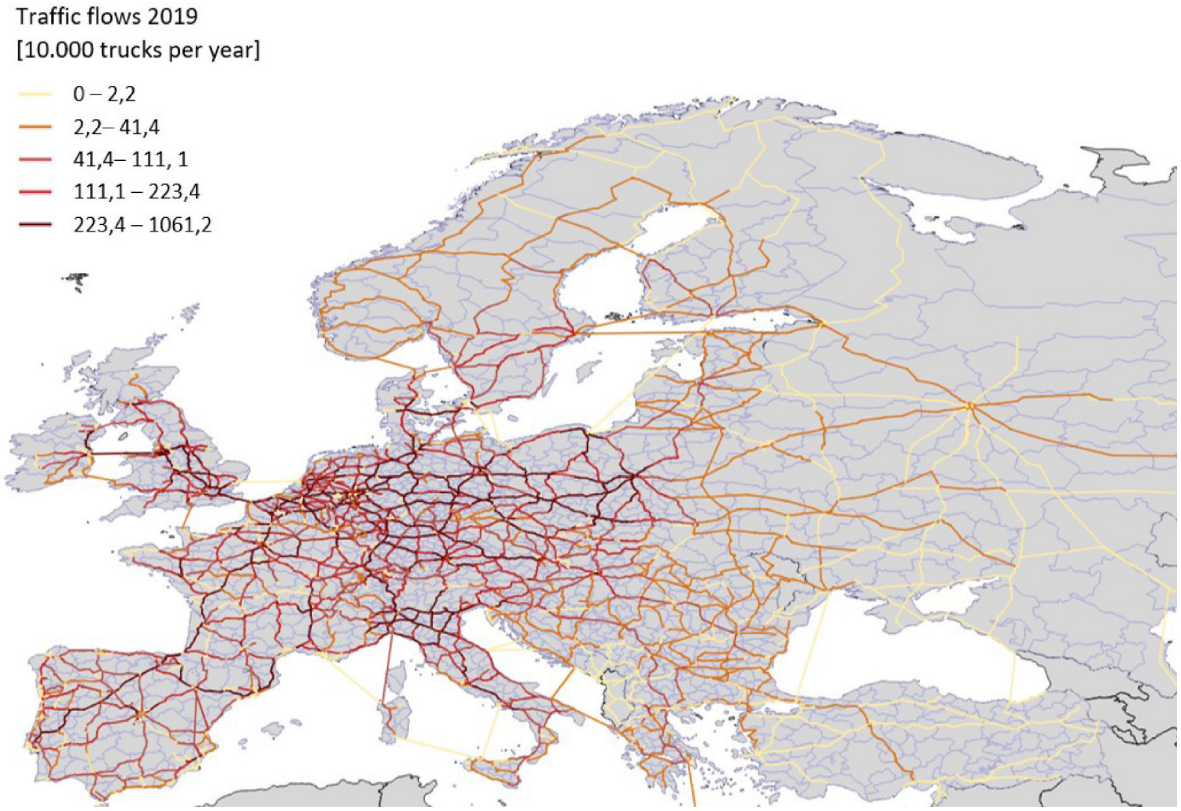


Figure 18 Visualisation of Truck traffic flow patterns in Europe (2019[17])

[17] Speth, D., Sauter, V., Plötz, P., & Signer, T. (2022). **Synthetic European Road freight transport flow data. Data in Brief**, 41, 108158. https://doi.org/10.1016/j.dib.2022.108158

Concluding Overview: Comprehensive Table of Key Analysis Indicators

As we conclude this chapter on analysing urban mobility systems, we present a comprehensive table that serves as a practical guide for urban planners and decision-makers. This table synthesises the various key indicators discussed, providing a structured framework to support a thorough and data-driven assessment of urban mobility systems in Türkiye.

The table is designed to be a user-friendly reference that brings together all the essential components needed for effective analysis. Each field within the table has been carefully defined to offer clear guidance on how to approach the evaluation process:

- **Key Analyses / Indicators:** This field identifies the core areas of analysis, such as infrastructure performance, user experience, and environmental impact. These indicators are the foundation for understanding the strengths and weaknesses of the urban mobility system.

- **Subcategories:** Each key analysis is further broken down into subcategories, offering more granular insight into specific aspects of urban mobility. This allows for a focused examination of particular elements, such as the level of service for different transport modes or the distribution of modal split across various trip purposes.

- **Definition:** For each indicator and subcategory, a brief definition is provided to clarify the scope and intent of the analysis. These definitions ensure a consistent understanding of what each indicator represents and how it contributes to the overall evaluation.

- **Input Data Needed:** This section details the specific types of input data required to perform the analysis effectively. Whether it's demographic data, traffic volumes, or user satisfaction surveys, having the right input data is critical for generating accurate and meaningful insights.

- **Analysis Goals / Expected Outcomes:** Here, the table outlines the primary objectives of each analysis, along with the expected outcomes. This includes identifying bottlenecks, assessing user satisfaction, or evaluating environmental impacts. Understanding these goals helps planners focus their efforts on achieving tangible improvements in urban mobility.

- **Examples of Tools:** To support the analysis, the table also provides examples of tools that can be utilised. These include GIS software, traffic simulation tools, statistical analysis programs, and other specialised applications that enhance the accuracy and depth of the analysis. By leveraging these tools, planners can efficiently process and interpret complex data, leading to more informed decision-making.

This comprehensive table is not just a summary; it is a strategic resource that encapsulates the analytical approach needed to drive meaningful change in urban mobility. By systematically working through each indicator and utilising the recommended tools, cities can develop actionable insights that lead to more efficient, equitable, and sustainable transportation systems. Whether you are assessing infrastructure performance or exploring user satisfaction, this table provides the roadmap needed to translate data into effective urban mobility strategies.

Table 2 Comprehensive Table of Key Analysis Indicators

	Key Analyses / Indicators	Subcategories Examples	Definition	Examples of Input-Data Needed	Analysis Goals/outputs	Example of Utilised Tools
Infrastructure Performance, Accessibility and Equity	**Level of Service (LoS)**	**Roads**	Measures the quality and efficiency of road traffic flow, providing insights into congestion, capacity, and road performance.	• Mean speed *(km/h)* • Travel time *(minutes or hours)* • Delay *(minutes or hours)* • Queue length *(meters or number of vehicles)* • ...	• Identify congestion hotspots and bottlenecks • Performance comparison • Monitor progress • ...	• GIS tools (e.g., ArcGIS) • Traffic simulation software (e.g., VISSIM) • Data analysis tools (e.g., Python)
		Public Transport	Evaluate the quality and reliability of public transport services, focusing on operational efficiency, capacity, and user experience.	• Schedule adherence vs delays *(minutes or percentage of on-time trips)* • Occupancy rates *(%)* • ...	• Identify delays • Diagnose capacity issues • Assess service quality • ...	• Public transport simulation tools (e.g., AnyLogic) • GIS tools (e.g., ArcGIS) • Schedule analysis (e.g., GTFS)
		Active Mobility (Cycling/ Walking)	Assesses the safety and usability of infrastructure for non-motorised modes like cycling and walking.	• Traffic volume *(vehicles per hour)* • Pedestrianised Streets Length *(meters or kilometers)* • Lane width *(meters)* • Safety incidents *(count, per year or month)* • On-street Cycle Network length *(meters or kilometers)* • Walking Path Network *(meters or kilometers)*	• Identify safety issues • Assess infrastructure gaps • Diagnose comfort problems • ...	• GIS tools (e.g., ArcGIS) • Mobility pattern analysis (e.g., StreetLight Data) • Visualisation tools (e.g., Power BI)

	Key Analyses / Indicators	Subcategories Examples	Definition	Examples of Input-Data Needed	Analysis Goals/outputs	Example of Utilised Tools
	Accessibility	**General Accessibility**	Examines how easily different population groups can access transport networks and key services.	• Network data analysis • Temporal Analysis • Demographic data *(age, gender, income, etc.)* • Travel time data *(minutes or hours)* • Coverage and Network gaps	• Identify access gaps • Diagnose network connectivity issues • Assess spatial disparities • …	• Network data (e.g:OpenStreetMap) • Mapping tools (e.g., Mapbox) • Statistical analysis tools (e.g., R) • GIS tools (e.g., QGIS) • Demographic analysis tools (e.g., SPSS)
		Equity of Accessibility	Focuses on whether transport accessibility is equitable across demographics, such as income groups or disabled individuals.	• Accessibility data by demographics *(percentage or number)* • Affordability of Public Transport *Cost of transport relative to income (%)*	• Diagnose equity gaps • Identify underserved areas • ..	
User Experience	**User Satisfaction**	**Overall Satisfaction**	Measures users' perceptions of transport services, covering reliability, safety, comfort, and affordability.	• Users' Surveys & Public Consultation on • Reliability • Accessibility • Comfort • Safety • Affordability • Passenger information • …	• Identify dissatisfaction areas • Diagnose service gaps • Assess user complaints • …	• Survey collection tools (e.g., Qualtrics) • Qualitative data analysis (e.g., NVivo) • Visualisation tools (e.g., Power BI) • Statistical analysis (e.g., SPSS)
		Mode-specific Satisfaction	Tracks user satisfaction specific to a transportation mode, such as bus, rail, or cycling.	• Mode-specific surveys	• Identify mode-specific issues • Diagnose service-specific problems	
	Travel Time	**General Travel Time**	Measures the time taken to travel across various routes and regions, identifying delays and inefficiencies	• Average travel time *(minutes)* • Time based Variability *(standard deviation, minutes)* • Delay *(minutes-hours)* • Travel Speed *(km/h)*	• Identify travel time variability • Diagnose delays • Assess inefficiencies • …	• Travel time data (e.g., Google Maps API) • Statistical analysis (e.g., R) • GIS tools (e.g., ArcGIS) • Data analysis tools (e.g., Python)

	Key Analyses / Indicators	Subcategories Examples	Definition	Examples of Input-Data Needed	Analysis Goals/outputs	Example of Utilised Tools
		Mode-specific Travel Time	Examines travel time for specific modes (car, public transport, bike) , helping to compare efficiencies and delays between them	• Mode-specific travel times *(minutes-hours)*	• Compare mode efficiencies • Diagnose delays per mode	
Usage Patterns	**Modal Split**	**Overall Modal Split**	Analyses the proportion of trips by different transportation modes, helping to understand travel behaviour	• Household surveys • Demographic data • Geospatial data • ..	• Identify mode use patterns • Diagnose shifts in modal preferences • Assess geographic distribution	• Statistical analysis tools (e.g., SAS) • GIS tools (e.g., ArcGIS) • Visualisation tools (e.g., Power BI)
		Purpose-based Modal Split	Focuses on modal split by trip purpose (commuting, leisure, etc.), giving insights into travel motivations.	• Purpose-specific travel data	• Diagnose purpose-specific travel issues • ...	• Statistical analysis tools (e.g., SAS) • GIS tools (e.g., ArcGIS) • Visualisation tools (e.g., Power BI)
	Parking Utilisation	**On-street Parking**	Tracks the availability and occupancy of on-street parking, highlighting underutilisation or misuse.	• Parking occupancy rates *(%)* • Turnover rates *(vehicles/hour)* • Geographic distribution	• Identify underutilised parking areas • Diagnose illegal parking issues • Assess parking management gaps	• Occupancy data tools (e.g., ParkMobile) • Parking management tools (e.g., Parkalot) • GIS tools (e.g., ArcGIS)
		Off-street Parking	Monitors the usage of off-street parking facilities such as garages, providing data on capacity issues.	• Occupancy rates *(%)* • Geographic distribution	• Identify underutilised garages • Diagnose capacity issues	
Environmental and Safety Impact	**Pollution Hotspots**	**Air Pollution**	Identifies areas with high pollution levels, providing insights into environmental impacts.	• Air Quality Levels Data *($\mu g/m^3$ for specific pollutants)* • Air Quality Spatial Data • ...	• Identify pollution hotspots • Diagnose temporal pollution patterns • Assess sources of pollution	• Air quality data tools (e.g., AirVisual) • GIS tools (e.g., ArcGIS) • Temporal analysis tools (e.g., Tableau)
		Noise Pollution	Assesses noise pollution levels in different urban areas, especially near transport hubs.	• Noise level data *(dB)* • Noise Spatial data	• Identify high-noise areas • Diagnose noise sources	• Noise mapping tools (e.g., SoundPLAN) • GIS tools (e.g., QGIS)

	Key Analyses / Indicators	Subcategories Examples	Definition	Examples of Input-Data Needed	Analysis Goals/outputs	Example of Utilised Tools
	Accident Data	**Road Traffic Accidents**	Evaluates road traffic accidents, identifying causes and preventing future incidents.	• Accident rate *(accidents/year)* • Severity Rate • Accident types • Time Patterns *(percentage, count)* • Location Patterns • Weather-Related Accidents *(percentage, count)* • Road Condition-Related Accidents *(percentage, count)* • Human Factor-Related Accidents *(percentage, count)*	• Identify accident hotspots • Diagnose accident causes • Evaluating Safety Measures • Comparing Accident Rates	• Accident data tools (e.g., CRASH) GIS tools (e.g., ArcGIS) • Visualisation tools (e.g., Tableau) • Safety analysis tools (e.g., Vision Zero Suite) • GIS tools (e.g., ArcGIS)
		Pedestrian and Cyclist Accidents	Tracks accidents involving pedestrians and cyclists, focusing on improving their safety. | - Accident data for pedestrians/cyclists Location and time data	• Accident data specific to pedestrians and cyclists *(percentage, count)*	• Identify pedestrian/cyclist accident hotspots • Diagnose accident causes • Evaluating Safety Measures • Comparing Accident Rates	
Freight Operational Efficiency	**Freight and Delivery Services**	**Urban Freight Movement**	Assesses the efficiency of urban freight and delivery services, particularly regarding route efficiency and congestion impact.	• Freight traffic data • Delivery times *(minutes, hours)* • Delivery vehicle types, • Delivery vehicle routes	• Identify inefficiencies in freight routes • Diagnose congestion impacts • Assess delivery delays • …	• Freight data tools (e.g., FleetComplete) • GIS tools (e.g., ArcGIS) • Visualisation tools (e.g., Tableau)
		Last-mile Delivery	Measures the effectiveness and efficiency of last-mile delivery services in urban areas.	• Delivery times *(minutes, hours)* • Delivery routes • Delivery vehicle types	• Identify last-mile delivery issues • Diagnose delays • …	

4. Looking into the Future with Data: Projections, Trends and Scenario Building

Building on the analysis of the current mobility situation from the previous chapter, we now move into the strategy development phase of the SUMP cycle. Effective forecasting plays a crucial role in this phase, serving as the bridge between understanding the present and shaping the future.

Forecasting via Sustainable Data Management practices is not merely about predicting future demand; it should represent a paradigm shift from the traditional "predict and provide" approach to a more dynamic strategy of "aiming and managing." This shift is enabled by sustainable data management practices, which allow for more informed and flexible data-driven decision-making.

In setting a city's vision, mission, and targets, forecasting must be grounded in the current mobility analysis and baseline scenario. This involves assessing how urban mobility will evolve under a BAU scenario. However, it's equally important to explore alternative scenarios, which can reveal the most suitable and tailored strategies for the city's future. These alternative scenarios help prioritise and address identified weaknesses while leveraging strengths and opportunities highlighted in the earlier analysis.

To effectively forecast the future, various tools and methods are available. These range from trend analysis and scenario planning to advanced techniques like predictive modelling and simulation, all of which will be discussed in the following sections.

4.1. Integrating Data-Driven Quantitative and Qualitative Insights for Future Mobility Planning

Future mobility planning requires a balanced integration of both quantitative and qualitative insights. While traditional transport modelling has its strengths, it is not sufficient on its own to address the complexities of modern urban mobility. Sustainable data management practices

with the support of emerging technologies such as Internet of Things (IoT), AI, and Big Data[18] have transformed how cities approach mobility planning, enabling more accurate, real-time, and holistic strategies. These advancements allow cities to blend model-based and expert-informed approaches, each offering unique strengths and addressing different aspects of the planning process.

In this section, we explore two key approaches to future mobility planning: Model-Based Planning and Expert-Informed Planning. Rather than being mutually exclusive, these approaches complement each other, with each bringing its advantages and limitations. Together, they provide a robust framework for making informed, data-driven decisions that are both comprehensive and adaptable to the needs of modern cities.

Enhancing Accuracy with Quantitative, Data-Driven Insights: Model-Based Planning

Model-based planning relies on quantitative methods, enriched by sustainable data management practices, to project future urban mobility patterns. This approach can incorporate vast amounts of data from IoT devices, allowing for real-time updates and adjustments. Predictive modelling, a key technique within this approach, uses historical data combined with real-time inputs to forecast trends in mobility. Additionally, simulation tools, powered by AI, enable the exploration of various scenarios, offering a detailed view of how different policies or infrastructure changes might impact future mobility.

The integration of Big Data analytics further strengthens these models, allowing cities to process and analyse large datasets that can include sensor data, GPS data, social media inputs, and mobile app usage, as needed. This comprehensive data collection and analysis provide more accurate and detailed insights, which are crucial for strategic and urban-events planning.

The inputs required for model-based planning include historical mobility data, policy plans, and economic forecasts and can also include real-time sensor data. The outputs are detailed, data-driven projections that can be adjusted in real time based on new data, providing cities with precise insights to guide their mobility strategies.

While model-based planning offers high accuracy and detail, it requires substantial data infrastructure and technical expertise. Additionally, there may be sensitivity and considerations around data privacy and security, given the vast amounts of personal and public data involved.

[18] **Big Data** refers to extremely large and complex datasets that are beyond the capability of traditional data processing tools to manage and analyse. It involves the collection, storage, and analysis of diverse data types from various sources, often in real-time, to uncover patterns, trends, and associations that inform decision-making processes. Detailed examples of Big Data types, including their advantages, disadvantages, data requirements, and relevant planning stages, are provided in a comprehensive table in the annex.

Leveraging Qualitative Human Insight with Data Support: Expert-Informed Planning

Expert-informed planning combines qualitative insights with data-driven support, providing a comprehensive approach to urban mobility strategy development. This method is particularly valuable in dealing with complex, uncertain issues that require human judgment, or with topics with scarce or no available data sets. Techniques such as the Delphi Method involve iterative surveys with experts, refining projections with each round, while scenario workshops bring together stakeholders to evaluate different future scenarios.

Incorporating data from IoT devices and Big Data analytics into these expert-driven processes adds a layer of empirical support, enhancing the credibility and robustness of the planning. Data visualisation tools, including GIS and interactive dashboards, play a crucial role in this approach, making complex data more accessible and actionable for experts and stakeholders.

The inputs for expert-informed planning include expert knowledge, qualitative data from consultations, and empirical data from IoT and Big Data sources. The outputs are qualitative projections enriched with data-driven insights, providing a nuanced understanding of potential risks, opportunities, and strategies that may not be captured by purely quantitative models.

Although expert-informed planning is flexible and incorporates a wide range of insights, it can be subjective, depending heavily on the quality and diversity of the experts involved. It also may require more time and resources to achieve consensus, particularly when dealing with complex scenarios.

Table 3 Summary of Future Mobility Planning Approaches Utilising Qualitative & Quantitative approaches

Aspect	Input Data	Expected Output	Strengths	Limitations
Model-Based Planning	• Historical data • Real-time sensor data • Big Data analytics	• Detailed, data-driven projections • Scenario-specific insights • Real-time adjustments using AI	• High accuracy and detail • Handles large datasets • Real-time responsiveness to changes • Enhanced precision with AI and machine learning	• Data-intensive and complex • Requires substantial data infrastructure and technical expertise • Potential privacy and security concerns due to extensive data usage

Aspect	Input Data	Expected Output	Strengths	Limitations
Manual / Expert-Informed Planning	• Expert knowledge • Qualitative data from consultations • IoT and Big Data sources	• Qualitative projections enriched with data-driven insights • Comprehensive scenarios informed by expert judgment	• Leverages expert insights for complex or uncertain issues • Incorporates qualitative aspects not captured by models • Enhanced by data visualisation and scenario analysis tools	• Potentially subjective • Depends on the quality and diversity of experts involved • May require more time and resources to reach consensus • Influenced by the availability and quality of supporting data

4.2 Data Requirements for Scenario Development

Effective urban mobility planning requires the exploration of various scenarios that can help cities anticipate future challenges and opportunities. Scenario development is not just about projecting current trends into the future; it is about envisioning different pathways and understanding the potential impacts of various choices. However, the effectiveness of these scenarios' hinges on the quality and sustainability of the data that underpins them. Sustainable data management practices ensure that the data used in scenario development is accurate, comprehensive, and adaptable to changing conditions. This section introduces four key scenarios: the "Do Nothing" scenario, the BAU scenario, Alternative scenarios, and the Back casting scenario. Each scenario is built upon specific input data and offers distinct insights that inform strategic planning highlighting how sustainable data management is integral to each approach.

Do Nothing Scenario: Preserving Historical Data Integrity

The "Do Nothing" scenario serves as a baseline by assuming no new policies or projects are introduced, continuing current trends. It highlights the risks of maintaining the status quo, such as worsening congestion, environmental degradation, and declining public transportation usage.

To develop this scenario, cities must rely on historical mobility data, including traffic volumes, public transit ridership, and non-motorized transport usage. Environmental data, such as air quality metrics and greenhouse gas emissions, also play a crucial role in understanding the broader impacts of doing nothing. Socioeconomic data, including population growth, economic activity, and land use patterns, help to contextualise these trends within the broader urban

landscape. Effective data archiving and preservation are essential to maintain the integrity of this historical data, allowing it to be reliably used for future projections. Additionally, sustainable data practices include regular updates and audits of data sources to ensure ongoing accuracy and relevance.

The expected output of the "Do Nothing" scenario is a projection of future conditions where no interventions are made. This provides a clear picture of the areas that will likely deteriorate without action, thereby highlighting potential areas of decline, and providing a clear picture of the risks associated with inaction, identifying the most critical points of intervention for future planning.

BAU Scenario: Integrating Current Data and Future Projections

The BAU scenario builds on the "Do Nothing" approach by incorporating planned policies and projects. It provides a realistic forecast of future mobility conditions based on the assumption that existing initiatives will be implemented as planned.

Developing the BAU scenario requires detailed input data from multiple sources, including planned infrastructure projects such as new transit lines, road expansions, and bike lanes. Policy initiatives, including congestion pricing, parking regulations, and emission reduction targets, are also key inputs. Economic forecasts, covering aspects like employment growth, income levels, and fuel prices, further shape the scenario by providing context for the expected demand for mobility.

The output of the BAU scenario is a realistic projection of future mobility trends under the assumption that existing plans and policies proceed as expected. This scenario is crucial for assessing whether the current strategies will be sufficient to meet future mobility needs or if additional interventions will be necessary. This scenario highlights the importance of continuously updating and validating data sources to ensure that forecasts remain accurate and aligned with ongoing developments.

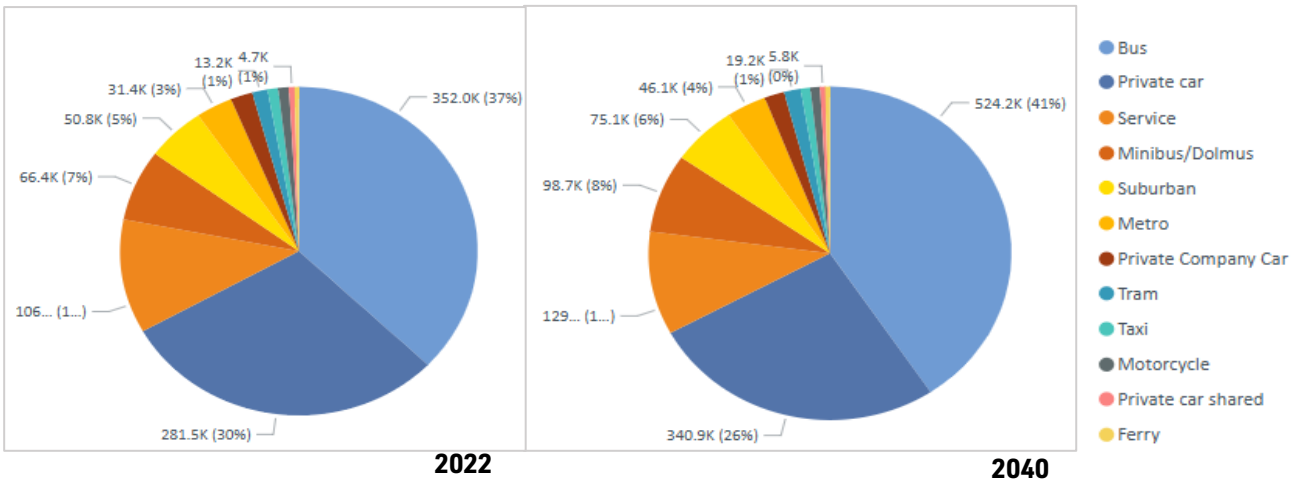


Figure 19 Number of motorised person trips by mode in 2022 (left) and 2040 BAU (right) in SUMP Izmir[19]

Alternative Scenarios: Leveraging Emerging Data Sources for Innovation

Alternative scenarios explore different futures by varying assumptions about technology, policy, and social behaviour. These scenarios allow cities to test innovative strategies, such as investment in public transportation or the adoption of smart city technologies, to identify the most effective paths to achieving long-term goals.

Developing alternative scenarios involves input data such as demographic projections, including anticipated changes in population size, age distribution, and migration patterns. Technological advancements, such as the deployment of autonomous vehicles, mobility-as-a-service platforms, and the IoT, are critical factors that can significantly alter mobility patterns. Environmental considerations, including climate change impacts and sustainability goals, must also be integrated into these scenarios to ensure they align with broader urban and environmental objectives.

The output of alternative scenarios is a set of projections that offer a range of possible futures. These scenarios provide cities with the flexibility to explore different strategic options and to prioritise actions that address the specific weaknesses identified in the previous analysis while leveraging existing strengths and opportunities. By comparing the outcomes of these scenarios, cities can develop more resilient and adaptable mobility strategies that are tailored to their unique contexts.

[19] Source: "**DATA COLLECTION RESULTS AND CURRENT MOBILITY ASSESSMENT REPORT**", 'EU Support to SUMP Izmir' Project

Backcasting Scenario: Strategic Data Planning for Long-Term Goals

The backcasting scenario starts with a vision of a desired future, such as a carbon-neutral city, and works backward to determine the necessary steps to achieve that vision. This approach is particularly useful for planning strategies aimed at meeting long-term sustainability goals.

In developing a backcasting scenario, cities must first define visionary goals and objectives. These might include long-term sustainability targets or mobility integration objectives that are essential for the city's future. The scenario also requires input on long-term environmental, economic, and social goals, which serve as benchmarks for what the city aims to achieve. Technological possibilities, such as the adoption of autonomous vehicles, the expansion of renewable energy sources, and the integration of advanced public transportation systems, also play a critical role in shaping this scenario.

The output of a backcasting scenario is a detailed roadmap of actions and interventions necessary to realise the desired future state. This roadmap includes identifying key milestones, such as the introduction of new policies or the completion of major infrastructure projects and outlines the policy changes required to stay on course. Backcasting helps planners identify potential challenges and opportunities, ensuring they are prepared to address obstacles and capitalise on opportunities as they arise. Sustainable data management practices ensure that this roadmap is not only accurate at the outset but remains relevant and actionable as new data becomes available and circumstances evolve.

Comparative Analysis and Visual Summary

To conclude this chapter, we will present a comparative table that summarizes the different types of scenarios, forecasting techniques, and emerging technologies discussed. This table will help visualise the key aspects of each method and scenario, highlighting their inputs, outputs, strengths, and limitations.

Table 4 Comparative Summary of Scenarios, Forecasting Techniques, and Emerging Technologies

Planning Scenarios	Input Data	Expected Output	Strengths	Limitations
Do Nothing	• Historical mobility and environmental data • Long-term trend analysis	• Projections of future conditions with no intervention	• Provides a baseline understanding • Identifies critical areas needing intervention	• Lacks proactive intervention • May highlight deteriorating trends without offering solutions
Business-As-Usual	• Planned policies • Infrastructure projects • Economic forecasts	• Realistic future trends reflecting current plans and policies	• Allows for assessment of policy impact • Realistic view of future trends based on current strategies	• Assumes continuity and that current plans will proceed as expected • May not account for significant disruptions
Alternative Scenarios	• Demographic projections • Technological advancements • Environmental factors	• Innovative strategies • Diverse potential future scenarios	• Flexibility and innovation • Exploration of a range of futures • Testing of bold strategies • üAdaptability to new technologies	• Requires more assumptions • Can be resource-intensive • Demands thorough analysis to avoid overly optimistic or pessimistic projections
Backcasting Scenario	• Visionary goals • Long-term objectives • Technological possibilities	• Roadmap of necessary actions and interventions • Milestones and policy changes • Identification of challenges and opportunities	• Encourages long-term strategic thinking • Aligns short-term actions with long-term goals • Facilitates transformative change	• Requires a clear vision of the future, which can be challenging to define • May involve significant changes in policy and infrastructure • Potential resistance to transformative changes

Checklist: Key Activities for Future Mobility Planning Utilizing Data Approaches

To ensure a comprehensive approach to future mobility planning, it is essential to integrate both data-driven methodologies and expert insights. The following checklist outlines key activities and best practices to guide the planning process. By systematically applying these steps, planners can effectively align qualitative and quantitative approaches, verify critical baseline data, and develop robust scenarios that inform strategic decision-making. This structured approach will also facilitate ongoing monitoring, adaptation of plans, and meaningful stakeholder engagement, ultimately leading to a more resilient and responsive urban mobility system.

Box 3: Key Activities for Future Mobility Planning Utilising Data Approaches

1. **Introduce and Align Qualitative and Quantitative Approaches**

- Establish clear guidelines for when to apply model-based (quantitative) approaches and when to leverage expert-informed (qualitative) insights.
- Ensure a balanced integration of both qualitative and quantitative methods in your planning process.

2. **Verify Baseline Data Collection**

- Focus on verifying baseline data related to historical traffic volumes, public transit usage, environmental metrics, and socioeconomic factors.
- This step follows the earlier analysis that identified current strengths and weaknesses in the urban mobility system.

3. **Scenario Development**

- **Do Nothing Scenario:** Use historical data to project future conditions without any new interventions.
- **BAU Scenario:** Integrate data from planned policies, infrastructure projects, and economic forecasts to forecast future mobility conditions.
- **Alternative Scenarios:** Explore different futures by incorporating demographic projections, technological advancements, and environmental considerations.
- **Backcasting Scenario:** Define long-term goals and work backward to identify the necessary actions to achieve the desired future state.

4. **Implement Data-Driven Planning Techniques**

- **Model-Based Planning:** Utilise real-time data collection, predictive modelling, and simulation tools to explore policy impacts and infrastructure changes.
- **Expert-Informed Planning:** Combine qualitative insights with empirical data, using tools like GIS and scenario workshops to enhance decision-making.

5. **Review and Adapt Strategic Plans**

- Monitor key mobility indicators regularly, using real-time data to assess the effectiveness of implemented strategies.
- Adapt and refine plans based on new data and scenario outcomes, ensuring flexibility to respond to emerging challenges and opportunities.

6. **Engage Stakeholders and the Public**

- Conduct stakeholder consultations to gather diverse input and feedback, ensuring that all perspectives are considered.
- Communicate strategic plans to the public effectively, using data-driven insights and visualisations to enhance understanding and buy-in.

5. Data-Driven Goal Setting for Urban Mobility Policy Creation

In this chapter, we delve into the critical components of urban mobility, structured around five key pillars: Road Space & Access, Shared Mobility, Active Mobility, Freight & Logistics, and Public Transport. Each pillar represents a fundamental aspect of the urban transportation system, influencing how people and goods move within cities. To effectively manage and improve these areas, specific indicators have been identified, providing measurable targets and insights.

The table below outlines these five mobility pillars, along with corresponding indicators, definitions, insights they offer, data required for analysis, and examples of targets. The indicators serve as tools to assess current conditions, identify areas for improvement, and track progress towards achieving the set objectives.

Each pillar is associated with specific indicators that allow transport and/or urban planners and policymakers to measure and evaluate performance. For example, in the Road Space & Access pillar, indicators such as Traffic Volume and Congestion Levels help in understanding road usage patterns and congestion hotspots. Similarly, the Shared Mobility pillar includes indicators like Ridership and Modal Share to gauge the effectiveness and appeal of shared transportation services.

By systematically tracking these indicators and analysing the required data, cities can set clear, achievable targets, such as reducing peak-hour traffic volume by 10% by 2025 or increasing public transport ridership by 20% by 2030. These targets not only guide policy and infrastructure development but also ensure that urban mobility systems evolve to meet the changing needs of the population.

Box 4: Indicators and Target Setting

Indicators are the backbone of any performance evaluation system in urban mobility. They serve as specific, measurable data variables that allow cities to assess the performance and progress of their objectives and goals. Indicators offer a tangible link between the status of a mobility system and its future aspirations, bridging the gap between status quo analysis and goal setting. Indicators not only provide a clear, objective basis for evaluating the effectiveness of implemented measures and strategies but also enhance transparency and accountability. They enable decision-makers to make informed choices based on performance monitoring, ultimately guiding the strategic direction of urban mobility policies. To effectively guide urban mobility planning, different types of indicators are used:

- **Performance indicators** measure the efficiency, effectiveness, and overall performance of a project or program.
- **Output indicators** measure the direct products or services produced by an activity or project.
- **Impact indicators** measure the long-term effects and significant changes resulting from a project, program, or policy.
- **Input indicators** measure the resources utilised to execute an activity or project.

Target setting translates strategic goals into measurable outcomes, providing a clear pathway for achieving a city's vision for its mobility system. The success of target setting hinges on robust data management practices, as the process of defining, monitoring, and achieving targets requires accurate, timely, and relevant data. In urban mobility planning, targets represent specific, measurable objectives that a city aims to achieve within a defined timeframe. They act as benchmarks against which the progress of various initiatives can be evaluated.

Targets can be classified into two types: qualitative and quantitative. Combining qualitative and quantitative targets ensures a well-rounded strategy.

- **Qualitative** Targets: These are descriptive, subjective, and based on perceptions or opinions. An example is 'Increasing public satisfaction with public transport.'
- **Quantitative** (SMART) Targets: SMART refers to Specific Measurable Achievable Relevant Time-bound targets. These are numerical, objective, and measurable. An example is 'Reducing CO_2 emissions by 20% by 2030'.

5.1. Key Analysis Indicators

The following table provides a comprehensive overview of the key indicators necessary for effectively monitoring and advancing the five mobility pillars outlined in the Green Paper of the SUMP Türkiye project. These pillars–Road Space & Access, Shared Mobility, Active Mobility, Freight & Logistics, and Public Transport–each require targeted indicators to guide progress. The table links each indicator to its definition, the insights it provides, the data required, appropriate analysis tools, and specific target examples. This structured approach ensures that each mobility pillar is both measurable and actionable, enabling cities to set clear, data-driven goals that align with broader sustainability objectives. Some of the indicator's example provided might be used interchangeably. This gives more flexibility for cities to collect the data for the indicator easiest for them.

Table 5 Mobility Pillars Proposed Key Analysis Indicators & Target Examples

Mobility Pillar	Indicator Example	Definition	Insights	Data Required	Analysis Tools	Target Example
Road Space & Access	Traffic Volume	Vehicles per unit time	Identify congestion hotspots, assess road capacity	Traffic counters, GPS data, floating car data	Traffic simulation software, GIS	Reduce peak-hour traffic volume by 10% by 2025
	Average Travel Speed	Average speed of vehicles on key corridors	Evaluate traffic flow efficiency, identify bottlenecks	GPS, ANPR data	Data analysis software	Increase average travel speed on key corridors by 15% by 2028
	Congestion Levels	Measured by LoS	Assess congestion, inform traffic management strategies	Traffic density, queue length data	Data analysis, GIS, real-time traffic data	Achieve LoS C or better on major roads by 2028
Shared Mobility	Ridership	Number of users of shared mobility services	Evaluate demand, identify underutilised routes	Usage data from shared mobility providers	Data analysis software	Increase shared mobility ridership by 30% by 2030
	Vehicle Turnover Rate	Frequency of shared vehicle use	Assess the efficiency of shared vehicle usage	Usage data, trip data	Statistical software	Improve vehicle turnover rate by 20% by 2025
	Modal Share	Proportion of trips made via shared mobility services	Evaluate the attractiveness of shared mobility	Travel surveys, usage data	Data analysis software	Increase modal share of shared mobility to 10% by 2030

Mobility Pillar	Indicator Example	Definition	Insights	Data Required	Analysis Tools	Target Example
Active Mobility	Bicycle Mode Share	The proportion of trips made by bicycle	Assess cycling popularity, identify infrastructure needs	Bike-sharing data, traffic counts	Data analysis software	Increase bicycle mode share to 15% by 2030
	Walking Mode Share	The proportion of trips made by walking	Identify pedestrian hotspots, inform infrastructure planning	Pedestrian counters, traffic video analysis	Data analysis and statistical software	Increase walking mode share to 25% by 2030
	Infrastructure Parameters	Quality and coverage of bike lanes, sidewalks	Evaluate infrastructure quality, guide investments	Data on infrastructure length, width, signage	AutoCAD, GIS	Expand bicycle lanes by 30% and improve sidewalk coverage by 2025
	Safety (Perceived and Actual)	Assesses safety for cyclists and pedestrians	Identify high-risk areas, inform safety measures	Accident data, surface conditions, survey data	AutoCAD, GIS, statistical software	Reduce pedestrian and cyclist accidents by 20% by 2025
Freight & Logistics	Freight Traffic Volume	Number of freight vehicles per unit of time	Assess road capacity, congestion impacts	Traffic counters, GPS data, logistics data	Traffic simulation software, GIS	Reduce freight traffic volume in city centres by 15% by 2025
	Delivery Efficiency	Time and reliability of freight deliveries	Evaluate logistics performance	Delivery time data, route data	Data analysis software	Improve delivery efficiency by 20% by 2025
	Urban Freight Share	The proportion of urban trips made by freight vehicles	Assess the impact of freight on urban traffic	Freight surveys, GPS data	Data analysis software	Decrease urban freight share in congested areas by 10% by 2030
Public Transport	Ridership	Number of passengers using public transport	Evaluate service demand, identify underutilised routes	Ticketing data, passenger counts	Data analysis software	Increase public transport ridership by 20% by 2030
	Headway Reliability	Scheduled vs. actual arrival times	Assess service reliability, identify delays	Vehicle tracking data, timetables	Statistical software	Improve headway reliability to 90% by 2025
	Modal Share	The proportion of trips made by public transport	Evaluate public transport attractiveness	Travel surveys, ticketing data	Data analysis software	Increase modal share of public transport to 50% by 2030
	Accessibility (spatial, temporal)	Ease of access to public transport services	Identify accessibility gaps, inform network planning	Stop spacing, travel time, fare structure	GIS, data analysis software	Ensure 75% of residents are within a 10-minute walk of transit by 2028

Checklist for Defining Indicators and Setting Targets

The following checklist provides a concise guide for defining indicators and setting targets in mobility planning. It outlines essential steps to ensure that indicators are aligned with strategic goals, involve key stakeholders, apply SMART criteria, and are supported by reliable data. This process is crucial for establishing clear, measurable, and achievable targets that drive progress and accountability in mobility planning.

Box 5: Checklist for Defining Indicators and Setting Targets

1. **Align with Objectives and Goals:**
   - Define clear objectives and goals, with clear scope (short, medium, long-term).
2. **Involve Stakeholders:**
   - Engage relevant stakeholders (government, experts, public).
   - Ensure inclusivity by addressing diverse population needs.
3. **Apply SMART Criteria:**
   - Specific: Ensure indicators and targets are focused and precise.
   - Measurable: Confirm they are quantifiable.
   - Achievable: Ensure they are realistic and attainable with available resources.
   - Relevant: Align them with strategic goals.
   - Time-bound: Set a specific timeframe for achievement.
4. **Determine Data Requirements:**
   - Choose appropriate data collection methods and assess data availability and quality.
5. **Set Baseline Values:**
   - Collect and analyse current baseline data.
   - Benchmark against similar cities or standards.
6. **Define Target Values:**
   - Establish both quantitative and qualitative targets, ensuring that targets are specific, measurable, and aligned with the broader goals and objectives of the mobility plan.
7. **Monitor and Adjust Targets:**
   - Regularly track progress against the established targets using up-to-date data.
   - Adjust targets as needed based on emerging trends, data analysis, and new challenges or opportunities.
8. **Ensure Accountability:**
   - Define clear roles and responsibilities for target monitoring and evaluating the progress toward targets.
   - Report regularly on progress and adjust strategies as needed.

6. Measuring Progress: Indicators as Enablers for Efficient Monitoring & Evaluation

In the previous chapter, we discussed the importance of setting goals, defining indicators, and establishing targets for a city's mobility system. Monitoring involves tracking these indicators over time to assess progress, while evaluation helps understand the effectiveness of strategies and informs future planning. The KPIs, along with their baseline values and target values, form the foundation of the monitoring and evaluation process. Monitoring and evaluation (M&E) are essential for understanding the performance of mobility systems and the impact of transportation policies. It provides data-driven insights to inform decision-making, identify successful strategies, measure progress, optimise resource allocation, and ensure that mobility goals are being met.

Box 6: Monitoring & Evaluation Definitions

Monitoring	**Evaluation**
Monitoring is the systematic collection of data on specific mobility indicators to provide authorities and stakeholders with an indication of the extent of the progress and the achievement of objectives.	Evaluation is the systematic and objective assessment of an ongoing or completed plan, policy or measure, its preparation, implementation and results. It helps to understand the reason behind performance variations, assess effectiveness of different approaches and learn from past experiences, i.e. evaluation reveals how well the plan, policy or measure has performed.

M&E can be broadly categorized into two Impact and Process M&E:

1. Impact M&E is concerned with assessing the long-term outcomes and effects of the project or policy intervention. It evaluates whether the desired goals were achieved and measures the broader impacts on the community or environment. The following methods are typically used for Impact M&E:

- **Financial Cost-Benefit Analysis (CBA):** Focuses primarily on quantifying the project's financial outcomes in monetary terms, considering direct costs and benefits such as investments, operational costs, and revenue generation.

- **Social Cost-Benefit Analysis (SCBA):** Expands on the traditional CBA by including social, environmental, and broader economic impacts, such as public health benefits, environmental sustainability, and social equity, alongside financial factors.

- **Multi-Criteria Analysis (MCA):** Evaluates projects and programs through indicators by assigning weights based on their relevance to overall goals.

2. Process M&E focuses on evaluating how the implementation of a project or policy was carried out. It assesses whether the planned activities were executed as intended and identifies any issues in the implementation process. The following methods are commonly used for Process M&E:

- **Program Reviews:** Assess project activities, timelines, budgets, and alignment with the original plan.

- **Stakeholder Workshops:** Gather insights from project staff and partners to evaluate the implementation process.

- **Audits:** Review project documents, reports, and financial records for accuracy and compliance.

- **Surveys:** Collect feedback from beneficiaries and stakeholders to understand on-ground implementation.

Box 7: Data Collection Frequency types

The data collection frequency for monitoring processes has two main data-set types:

- **Real-time or Continuous Datasets:** Information collected and processed immediately or with minimal delay to reflect the current state. Examples include traffic flow data and air quality measurements.
- **Periodic Datasets:** Data collected at regular intervals, such as daily, weekly, monthly, or annually. This provides a historical perspective on transportation trends and patterns. Examples include census data, household travel survey data, and modal share data.

6.1. Monitoring and Evaluation Indicators

The following table serves as a tool for monitoring and evaluating the progress of urban mobility initiatives across key mobility pillars. It organises essential indicators under each pillar, providing a structured approach to data collection frequency, target setting, and performance assessment. The table is designed to support cities in systematically tracking their mobility goals, highlighting both the progress made and areas requiring further attention. By incorporating a monitoring status and an evaluation focus, the table not only facilitates ongoing performance tracking but also provides insights into the effectiveness of implemented strategies. This structured approach ensures that urban mobility plans remain aligned with broader sustainability goals and can be adapted as needed based on real-time data and evolving conditions.

Table 6 Comprehensive Table of Monitoring and Evaluation Indicators

Mobility Pillar	Indicators Examples	Suggested Frequency of Data Collection	Aimed Target Examples	Current Value / Progress	Monitoring Status	Evaluation Focus
Road Space & Access	**Traffic Volume**	Hourly or daily	Reduce peak-hour traffic volume by 10% by 2025	6% reduction achieved	On Track	Assess annual reduction impact and congestion hotspot management
	Average Travel Speed	Hourly or daily	Increase average travel speed on key corridors by 15% by 2028	10% increase achieved	On Track	Evaluate traffic flow efficiency and identify bottlenecks
	Congestion Levels	Continuous monitoring, quarterly	Achieve LoS C or better on major roads by 2028	LoS C achieved	On Track	Yearly impact assessment on congestion management
Shared Mobility	**Ridership**	Daily or weekly	Increase shared mobility ridership by 30% by 2030	12% increase achieved	On Track	Annual growth analysis and user satisfaction surveys
	Vehicle Turnover Rate	Monthly	Improve vehicle turnover rate by 20% by 2025	15% improvement achieved	On Track	Bi-annual efficiency evaluation and performance review
	Modal Share	Annual	Increase modal share of shared mobility to 10% by 2030	10% share achieved	On Track	Review of modal shifts every two years, focusing on shared mobility impact

Mobility Pillar	Indicators Examples	Suggested Frequency of Data Collection	Aimed Target Examples	Current Value / Progress	Monitoring Status	Evaluation Focus
Active Mobility	**Bicycle Mode Share**	Annual or biannual	Increase bicycle mode share to 15% by 2030	7% achieved	On Track	Annual infrastructure use and mode shift report
	Walking Mode Share	Annual or biannual	Increase walking mode share to 25% by 2030	4% increase achieved	Needs Improvement	Bi-annual pedestrian activity and infrastructure adequacy review
	Infrastructure Parameters	Annual	Expand bicycle lanes by 30% and improve sidewalk coverage by 2025	20% expansion achieved	On Track	Infrastructure impact analysis every three years
	Safety (Perceived and Actual)	Monthly and quarterly	Reduce pedestrian and cyclist accidents by 20% by 2025	10% reduction achieved	On Track	Yearly safety improvement analysis and public feedback review
Freight & Logistics	**Freight Traffic Volume**	Hourly or daily	Reduce freight traffic volume in city centres by 15% by 2025	6% reduction achieved	On Track	Annual review of freight traffic reduction and road capacity improvements
	Delivery Efficiency	Real-time tracking	Improve delivery efficiency by 20% by 2025	15% improvement achieved	On Track	Quarterly efficiency analysis and yearly impact assessment
	Urban Freight Share	Quarterly	Decrease urban freight share in congested areas by 10% by 2030	5% reduction achieved	Needs Improvement	Bi-annual traffic impact analysis focusing on freight activity
Public Transport	**Ridership**	Daily or weekly	Increase public transport ridership by 20% by 2030	12% increase achieved	On Track	Annual ridership growth analysis and passenger feedback review
	Headway Reliability	Hourly or real-time	Improve headway reliability to 90% by 2025	85% reliability	Needs Improvement	Quarterly reliability reports and service improvement analysis
	Modal Share	Annual	Increase modal share of public transport to 50% by 2030	40% share achieved	On Track	Biennial modal share analysis focusing on public transport usage
	Accessibility (spatial, temporal)	Annual or biannual	Ensure 75% of residents are within a 10-minute walk of transit by 2028	35% of residents are within a 10-minute walk of transit	Needs Improvement	Comprehensive access and equity review every two years

Mobility Pillar	Indicators Examples	Suggested Frequency of Data Collection	Aimed Target Examples	Current Value / Progress	Monitoring Status	Evaluation Focus
	Opportunity Index	Periodic surveys, census data	Increase access to jobs within 30 minutes by 20% by 2028	8% increase in access has been achieved	On Track	Evaluate social equity and job accessibility improvements

Checklist for Monitoring and Evaluation Process

The following checklist outlines the essential steps for a comprehensive monitoring and evaluation (M&E) process in mobility planning. It guides practitioners through determining data resolution, identifying and addressing data gaps, setting monitoring frequency, and comparing baseline values with targets. Additionally, it provides strategies for analysing outcomes and selecting the appropriate evaluation methods to assess both the implementation process and the broader impact of interventions. This structured approach ensures that M&E efforts are thorough, data-driven, and aligned with strategic objectives.

Box 8: Checklist for Monitoring and Evaluation Process

The Integrated Process of Data Management Monitoring & Evaluation

1. **Determine Data Resolution/Granularity:**
   - Decide the level of detail for monitoring data. Example: Accident data categorised by pedestrian involvement, vehicle type, etc.
2. **Identify Existing Data Sources:**
   - Review available data from sources like traffic data, public transport data, accident data, etc.
3. **Address Data Gaps & Identify New Sources:**
   - Contrast existing data with required indicators and evaluation needs and identify new sources for data to support both monitoring and impact assessment.
4. **Determine Monitoring & Evaluation Frequency:**
   - Establish how often data should be collected (e.g., hourly, daily, annually) and when periodic evaluations will take place (e.g., quarterly, annually, after a major milestone).
5. **Compare Baseline Values with Target Values:**
   - Assess progress by comparing current data against target values. Use methods like percentage change, absolute change, or hypothesis testing[20].
6. **Understand & Analyse Monitoring Outcomes:**
   - Apply data analytics techniques like descriptive statistics, regression analysis, temporal or geospatial analysis to understand trends and relationships.
7. **Choose Suitable Evaluation Strategy; based on the monitoring outcomes:**
   - **Process Evaluation:** Focuses on evaluating how well the implementation was carried out. Use methods such as: Program reviews, stakeholder workshops, audits, surveys.
   - I**mpact Evaluation**: Evaluates the long-term outcomes and broader impacts of the intervention. Use methods such as: Cost-Benefit Analysis (CBA), Social Cost-Benefit Analysis (SCBA), Multi-Criteria Analysis (MCA).

[20] **Hypothesis testing** is a statistical method used to determine if there is enough evidence in a sample of data to infer that a certain condition is true for the entire population. It typically involves comparing data against a null hypothesis (e.g., "no change" or "no effect") to see if any observed differences are statistically significant.

7. Comprehensive Data Governance Strategies for Turkish Cities

Effective data governance is crucial for the successful implementation of sustainable urban mobility plans. It ensures that data is collected, managed, and utilised in a manner that supports informed decision-making and aligns with legal and ethical standards. In the context of Turkish cities, robust data governance practices are essential to navigate the complexities of urban mobility, involving a diverse range of stakeholders across various levels of government and society.

7.1. Roles and Responsibilities in Data Governance: A Turkish Perspective[21]

Developing and implementing sustainable mobility policies necessitates collaboration across various governance levels to facilitate data collection, sharing, and interpretation. Various stakeholders play crucial roles at different levels of governance, from national to regional and local levels, including the private sector and international organisations, in addition to public organisations.

At the national level, the key stakeholders include ministries such as the Ministry of Transport and Infrastructure (MoTI), Ministry of Environment, Urbanisation and Climate Change (MoEUCC), Ministry of Interior (MoI), Ministry of Treasury and Finance (MoTF), Ministry of Energy and Natural Resources (MoENR), and the Ministry of Health (MoH). These ministries are responsible for setting policies, ensuring alignment with national priorities, and integrating environmental and health considerations into urban mobility planning.

- One of the most important entities for data management is the Turkish Statistical Institute (TurkStat), the official body for producing national statistics. TurkStat plays a central role in the data governance framework by providing critical data for planning and policy evaluation.

- Other key national entities include the Presidency of Strategy and Budget (SBO), the General Directorate of Highways (KGM), the Turkish National Police, the Directorate of

[21] Detailed roles and responsibilities of Turkish Stakeholders can be found in the annex.

Climate Change (DCC), all of which contribute to the data governance framework by providing infrastructure, law enforcement, climate-related data, and more.

- Additionally, the TCDD Transport plays a crucial role in providing urban transport services in cooperation with municipalities in some cities.

At the municipal and local levels, stakeholders such as the Union of Municipalities of Türkiye (UMT) and local authorities (metropolitan municipalities, provincial municipalities, and district municipalities) play a crucial role in implementing data governance practices that adhere to national standards while addressing specific local needs. They also facilitate data sharing and collaboration among municipalities to ensure consistency and effectiveness in data management across municipalities.

In addition to these core stakeholders, **secondary stakeholders** also play a vital role in the ecosystem of sustainable mobility. These include the Information and Communication Technologies Authority (ICTA), which regulates technological infrastructure; İLBANK, which provides financial resources; and the Intelligent Transport Systems Association (AUSDER), which is an umbrella platform for stakeholders to work together in the field of Intelligent Transport Systems. International financial organisations (IFIs) offer critical funding, while advocacy groups such as My Rights in Traffic Association and the Road Traffic and Safety Association promote road safety and active mobility. Other secondary stakeholders include the Turkish Cycling Federation, the Turkish Federation of Drivers and Motorists (TŞOF), and the Cyclists Association of Türkiye, among others, who contribute expertise, promote sustainable transport options, and support road safety initiatives.

Box 9: Approaches to Data Governance in Urban Mobility: Centralised, Specialised, and Hybrid Models[22]

In managing urban mobility data, cities worldwide adopt different governance structures depending on their size, complexity, and specific needs. The choice of governance structure significantly impacts the effectiveness of data management, coordination among stakeholders, and the ability to respond to emerging challenges. This section explores three main approaches to data governance–centralised oversight, specialised agencies, and a hybrid model–each with its advantages and challenges.

- **Centralised Oversight by a Single Agency:** A centralised approach involves one agency responsible for overseeing all aspects of data governance in urban mobility.

  This model ensures consistency in data management practices across various mobility sectors, such as public transport, road infrastructure, and active mobility. For countries with smaller populations or those with limited administrative capacity,

[22] To further illustrate how different governance approaches can be applied across various mobility pillars, an exploratory table has been provided in the annex. This table outlines specific governance structures for key mobility areas in Türkiye, such as road spaces, shared mobility, active mobility, freight, and public transport, detailing the responsible agencies, central coordinating bodies, and the rationale behind the chosen governance model for each pillar. The annexed table serves as a practical example of how these approaches can be implemented in a complex urban environment.

a centralised model can be ideal. It allows efficient use of resources, with a single authority maintaining a unified approach. For example, in Singapore, the Land Transport Authority (LTA) acts as the central body responsible for all transport data, ensuring that policies and practices are uniformly applied across different sectors. This approach allows for streamlined coordination and clear accountability but may risk overburdening the central agency with a broad scope of responsibilities.

- **Specialised Agencies for Each Focus Area:** In contrast, some cities prefer to assign different agencies to oversee specific mobility areas, leveraging their expertise to manage data within their respective domains. For instance, in the United States, various departments handle different aspects of transport data: the Federal Highway Administration (FHWA) manages road infrastructure data, while the Federal Transit Administration (FTA) focuses on public transport. This approach might suit larger countries with advanced human capacity and complex mobility ecosystems, where sectoral expertise is critical. It allows agencies to tailor their data governance practices to the specific needs of their sector, fostering innovation and responsiveness. However, without robust coordination mechanisms, this model can lead to fragmented data governance, where silos hinder data sharing and integration.
- **Hybrid Approach: Central Coordination with Specialised Agencies**: The hybrid model combines the strengths of both centralised and specialised approaches. Here, a central agency or institution sets overarching policies and standards, while specialised agencies manage data within their focus areas. This model is exemplified by the European Union's transport data governance structure, where the European Commission sets high-level guidelines, and member states or specific agencies implement them within their national or sectoral contexts. This approach is suitable for countries or regions with a high level of governance maturity and the administrative capacity to coordinate across sectors. It ensures consistency and integration across sectors while allowing specialised agencies to maintain their focus on specific areas. It facilitates comprehensive data sharing and enables a flexible response to sector-specific challenges.

7.2 Establishing Data Policies, Standards, and Legal Compliance

Building on the roles and responsibilities outlined in the previous section, and drawing from the foundational principles of data management discussed in earlier chapters, this section delves into the critical elements that form the backbone of effective data governance. As Turkish cities continue to enhance their urban mobility systems, the need for robust data policies, standards, and legal frameworks becomes increasingly apparent. These elements are essential for ensuring that data collected across various mobility pillars–whether managed through centralised, specialised, or hybrid governance models–is accurate, secure, and legally compliant.

The effective implementation of data governance practices discussed in this chapter is closely tied to the roles defined in the earlier sections. Each stakeholder, whether part of a central government, a specialised department, or a local authority, plays a crucial role in upholding

these standards. Moreover, the sustainable data management practices emphasised in previous chapters underscore the importance of establishing clear protocols for data handling, sharing, and protection to ensure that the insights derived from data are both reliable and actionable.

Defining Data Policies

Data policies are the guiding principles that ensure data is managed consistently and effectively across all levels of governance. These policies, as discussed in the previous chapters, are not just about data collection but also about ensuring that data is accurate, secure, and useful. Building on the earlier discussions, this section focuses on formalizing these principles into actionable policies that address:

- **Data Quality:** The Twelfth Development Plan (2024-2028) emphasises the need for robust information collection and statistical data infrastructure. This aligns with the overarching goal of ensuring data accuracy, completeness, and timeliness, which is critical for urban mobility planning in Türkiye. For instance, the plan includes initiatives to enhance data collection for accident prevention and urban transport network management, reflecting a strong commitment to data quality across all levels of governance.

- **Data Accessibility:** To support the collaborative data-driven approaches discussed in earlier chapters, policies must define clear guidelines for data accessibility. The Transport and Logistics Master Plan 2053 advocates for the development of open data platforms and a National Transport Database, ensuring that data is available when needed for decision-making. This includes determining who can access what data, and under what conditions, and ensuring that data is available for comprehensive analysis and strategic planning.

- **Data Security:** With the increased emphasis on data sharing and collaboration discussed earlier, securing data against unauthorized access and breaches is critical. The Turkish Transport Policy Paper outlines the need for centralised data management and secure IT practices, particularly in managing Big Data and analytics efforts across local and central levels. This includes defining access controls and encryption standards, especially when data is shared across different agencies or with external partners.

- **Data Privacy:** The Accessible Transport Strategy and Action Plan (2021-2025) highlights the importance of maintaining a digital accessibility database while ensuring data privacy. The plan's focus on up-to-date digital mapping of accessible transport services underscores the need for strict privacy policies, ensuring that personal data is handled in compliance with regulations and that individuals' privacy rights are protected.

Developing Data Standards

The need for standardised data formats and protocols was emphasised in earlier sections to ensure interoperability between different systems and agencies. In Türkiye, several strategic documents and protocols provide a framework for these standards:

- **Standardised Data Formats**: Consistency in data formats, such as using common file types and structures, is essential for seamless data exchange and analysis, as discussed in the context of integrating data from various sources. The General Transit Feed Specification (GTFS) and National Transportation Communications for Intelligent Transportation System Protocol (NTCIP) are widely utilised in Turkish urban mobility projects to ensure consistency in data formats, such as those used in public transport and ITS applications. This ensures seamless data exchange and analysis across various transport modes, as discussed in the Transport and Logistics Master Plan 2053.

- **Metadata Standards**: Establishing clear metadata standards ensures that data is well-documented, making it easier to track its source, accuracy, and usage history. Turkish National Geographic Information System (TUCBS) ensures that data is well-documented. This system enhances the interoperability of geographic information systems (GIS) across the country, making it easier to track data sources, accuracy, and usage history–key aspects highlighted in the Twelfth Development Plan (2024-2028).

- **Interoperability Protocols**: To avoid data silos and enhance collaborative planning, as mentioned earlier, protocols must be in place to allow different systems to communicate effectively. The potential use of the Transport Operator to Mobility-as-a-Service Provider API (TOMP-API) in Turkish mobility projects exemplifies how interoperability can be achieved. This protocol fosters seamless integration of various transportation services, fostering an environment where data from various agencies can be efficiently integrated and used.

Encouraging Interagency Collaboration

Interagency collaboration is a recurring theme in urban mobility planning, as discussed in previous chapters. For data sharing to be effective:

- **Interagency Agreements**: Formal agreements ensure that data is shared efficiently and securely, with clear terms of responsibilities and usage rights, building on the collaborative roles outlined earlier. The Turkish Transport Policy Paper emphasises the importance of centralised data management and the development of data governance mechanisms. Formal agreements, such as those established under the Road Traffic Safety Strategy Document (2021-2030), ensure that data is shared efficiently and securely across agencies, with clear terms on responsibilities and usage rights.

- **Data Sharing Platforms**: Establishing centralised data hubs, as discussed in the earlier sections, facilitates real-time data sharing and integration across different sectors, supporting comprehensive analysis and decision-making. The Transport and Logistics

Master Plan 2053 advocates for the establishment of centralised data hubs and a National Transport Database. The creation of an open-access data portal, as part of this master plan, is crucial for enabling diverse stakeholders to access and utilise data effectively.

- **Open Data Initiatives**: Encouraging open data practices, as seen in the Twelfth Development Plan (2024-2028), aligns with the principles of transparency and public engagement discussed in earlier chapters. The plan's focus on open data platforms and statistical data infrastructure promotes public access to high-quality data, allowing external stakeholders to contribute to and benefit from urban mobility data.

Ensuring Comprehensive Data Protection and Legal Compliance

As Turkish cities advance in data sharing and integration within their urban mobility systems, safeguarding personal data and ensuring legal compliance are essential components of effective data governance. These aspects are crucial not only for maintaining the integrity and trustworthiness of the data but also for protecting individual privacy and adhering to legal standards. Cities must implement robust measures that address both personal data protection and compliance with national and international regulations. This integrated approach involves several key actions.

- **Anonymisation Techniques**: Implementing robust anonymisation practices is essential to protect individuals' privacy. The Accessible Transport Strategy and Action Plan (2021-2025) underlines the importance of anonymisation practices to protect individuals' privacy. These techniques allow cities to utilise data for analysis and decision-making without compromising personal information, ensuring that data can be shared and used ethically.

- **Data Usage Agreements**: To maintain data integrity and protect privacy, all parties involved in data sharing should adhere to strict data usage agreements. The Transport and Logistics Master Plan 2053 calls for the establishment of data usage agreements to maintain data integrity and protect privacy. These agreements clearly define how data can be used and ensure that it is handled in compliance with privacy laws and ethical standards.

- **Respecting Intellectual Property Rights**: When using third-party data, cities must respect intellectual property rights. The Ministry of Transport and Infrastructure's Strategic Plan (2024-2028) emphasises respecting intellectual property rights when using third-party data. Proper licensing and usage permissions prevent legal conflicts and uphold the integrity of the data governance framework.

- **Data Retention and Disposal Policies**: Establishing clear guidelines for data retention and secure disposal is crucial for legal compliance. The Twelfth Development Plan (2024-2028) includes provisions for managing the lifecycle of mobility data, ensuring that data is stored only as long as necessary and disposed of in a manner that meets legal and ethical requirements.

- **Regular Audits and Reviews**: Conducting regular audits of data practices, as mandated in the Road Traffic Safety Strategy Document (2021-2030), ensures ongoing compliance with

evolving legal standards. These audits help identify potential areas of non-compliance or emerging challenges, allowing cities to take corrective actions and maintain high standards of data governance.

By integrating personal data protection with broader legal compliance measures, Turkish cities can create a data governance environment that is both secure and legally sound. This approach ensures that data is used responsibly, protecting individual privacy while also supporting the effective and ethical use of data in urban mobility planning.

7.3 Building a Culture of Data-Driven Decision-Making

For Turkish cities to fully realise the potential of their urban mobility data, it is essential to cultivate a culture that prioritises and values data-driven decision-making. This culture is the cornerstone of sustainable urban mobility planning, enabling cities to make informed, transparent, and effective decisions that align with their strategic goals. Building such a culture requires both the implementation of the right technologies and processes as well as the nurturing of an organisational mindset that fully embraces data at every level.

Embedding Data-Driven Practices Across All Levels

The successful implementation of data-driven decision-making requires that data practices be embedded throughout all levels of governance and across all departments involved in urban mobility. This can be achieved by:

- **Leadership Commitment**: City leaders must champion data-driven decision-making, setting a clear vision and expectations for the use of data in planning and policymaking. Leadership commitment ensures that data governance and data-driven practices are prioritised across the organisation.

- **Continuous Improvement**: Data-driven decision-making should be seen as an ongoing process, with regular reviews and updates to data practices. Cities should establish feedback loops where the outcomes of decisions are evaluated based on data, and lessons learned are used to refine future strategies.

Capacity Building and Training

To sustain a data-driven culture, city officials and staff must be equipped with the necessary skills and knowledge to effectively use data in their work. This involves:

- **Regular Training Programs:** Offering continuous education and training opportunities ensure that staff at all levels remain up to date with the latest data management tools, techniques, and best practices. This training should encompass not only technical skills but also the interpretation of data insights and their application to decision-making. The Accessible Transport Strategy and Action Plan (2021-2025) includes initiatives to train staff

in maintaining and updating digital accessibility databases, ensuring ongoing competence in data management.

- **Developing Data Literacy:** Building a baseline level of data literacy across the organisation ensures that all employees, regardless of their role, understand the importance of data and how to engage with it. This fosters a more inclusive and effective data-driven environment.

- **Capacity Building Initiatives:** Beyond training, cities should invest in capacity-building initiatives that enhance the overall data management capabilities of their departments. This includes upgrading technical infrastructure, improving data quality, and expanding the range of data sources available for decision-making.

Encouraging Innovation Through Data

Fostering a culture of data-driven decision-making also means encouraging innovation. Cities should create an environment where data is not just used for current planning needs but also as a tool for exploring new possibilities:

- **Pilot Projects and Experiments**: The Transport and Logistics Master Plan 2053 encourages the use of data to pilot innovative solutions and test new approaches to urban mobility challenges. Data-driven experiments, such as the integration of new ITS applications, can provide valuable insights that lead to scalable solutions.

- **Partnerships with Academia and Industry**: Collaborating with universities, research institutions, and private sector companies can bring in fresh perspectives and cutting-edge technologies. These partnerships can help cities explore new ways to use data, driving continuous improvement and innovation.

Building a culture of data-driven decision-making is essential for the success of sustainable urban mobility planning in Turkish cities. By embedding data practices at all levels, investing in capacity building, and encouraging innovation, cities can ensure that their mobility strategies are both effective and resilient. This culture not only enhances the quality of decision-making but also strengthens the city's ability to adapt to future challenges and opportunities.

Activity-Based Checklist: Comprehensive Data Governance Strategies

To effectively implement the strategies discussed in this chapter, the following checklist outlines key activities that Turkish cities should undertake. This actionable checklist guides cities through establishing robust data governance practices, developing data policies and standards, protecting personal data, and fostering a culture of data-driven decision-making, all while considering existing plans and strategies.

Box 10: Activity-Based Checklist: Comprehensive Data Governance Strategies

1. **Define Roles and Responsibilities in Data Governance**
   - Identify the appropriate governance model (centralised, specialised, or hybrid) based on city needs.
   - Establish clear roles for stakeholders at all levels, ensuring alignment across governance and sectors.
   - Integrate data governance roles with current plans.
2. **Develop and Implement Data Policies**
   - Draft data policies covering quality, security, privacy, and accessibility, aligned with existing frameworks.
   - Ensure policies align with national regulations and best practices.
   - Communicate and enforce these policies across all stakeholders.
3. **Create Data Standards and Interoperability Protocols**
   - Develop standardised data formats and protocols for seamless sharing.
   - Establish interoperability protocols to ensure system compatibility.
   - Regularly update standards to reflect technological advancements.
4. **Ensure Legal Compliance and Data Protection**
   - Implement anonymisation techniques to protect personal data.
   - Establish data retention policies in line with legal standards.
   - Conduct regular audits to ensure ongoing legal compliance.
5. **Foster Data-Driven Decision-Making**
   - Encourage leadership to champion data-driven approaches.
   - Promote collaboration to enhance data sharing.
   - Establish feedback loops for continuous improvement based on data insights.
6. **Invest in Capacity Building and Training**
   - Offer regular training on data management tools and best practices.
   - Build data literacy across the organisation.
   - Enhance data management capabilities through capacity-building initiatives.
7. **Encourage Innovation Through Data**
   - Support pilot projects and experiments in urban mobility.
   - Foster partnerships with academia and industry for fresh perspectives.
   - Create an environment that promotes data use for planning and exploration.

Appendices

Appendix 1: Big Data in Future Mobility Planning

Table 7 Examples of Utilising Big Data in Future Mobility Planning

Big Data	Advantages	Disadvantages	Required Algorithms	Model Stage
Bluetooth Data	• Bluetooth sensor data provides information on motor vehicle flows along the main arteries in the city. • Speed profiles and trip times can be extracted along the main arteries where the sensors are located. • OD matrix can be extracted based on the main arteries. • It is easy and cheap to install and operate.	• It does not contain vehicle class information. • The penetration rate is about 15%. • It only explains the mobility in the places where it is installed. • The distribution for random sampling should be well controlled.	• Trip and activity detection algorithm, • O-D algorithm • Trip time and speed algorithm	• Forecasting trip demand • Validation
Automatic Number Plate Recognition (ANPR) System Data	• Speed profiles and trip times between ANPR points can be found. • Artery-based OD matrix can be found. • It has a high accuracy rate. (It has a detection and accuracy rate of over 95%, in line with the type specifications.)	• It only explains the mobility in the places where it is installed. • Data needs to be anonymised and aggregated.	• Trip and activity detection algorithm, • O-D algorithm • Trip time and speed algorithm	• Forecasting trip demand • Validation
GPS Data	• Speed profiles and trip times can be found. • O-D matrices can be produced for commercial vehicles. • Trip route can be found. • It has a high penetration rate. (3% to 25%) • Data is collected every 6 seconds. • Location margin of error is very low and can be assigned to the road network (< 6 m)	• Impurities in the data need to be cleaned. • The data needs to be processed into the road network. • It involves high technical challenges for data processing. • Vehicle type classification is difficult. Random sample verification is difficult.	• Trip and activity detection algorithm, • O-D algorithm	• Forecasting trip demand • Validation

Big Data	Advantages	Disadvantages	Required Algorithms	Model Stage
Smart Card Data	• The demand for public transportation can be measured. • Travel information from station to station can be obtained. • Public transport level of service and performance analyses can be made. • O-D matrix can be produced by making an alighting forecast for regular trips. • Different passenger profiles and OD matrices can be produced according to the ticket type.	• There is no alighting information in the data. • Data needs to be processed to find alighting information. • Does not include door-to-door trips. • It is difficult to find the purpose of the trip. • O-D forecast of irregular trips cannot be made.	• Trip and activity detection algorithm, • O-D algorithm	• Forecasting trip demand • Validation
Floating Car Data	• Traffic information for the entire road network is generated. • Road network average speed and trip time information for the last three years is available. • In 1 minute, the average speed information for each 50-meter road section is produced. • Speed profiles can be found • Detailed levels of service such as delay, and queue can be found. • Dynamic queue formation can be removed. • Bottleneck points and congestion analysis can be done. • Event detection can be done. • Real-time traffic situation and forward (15, 30, 60 min) traffic estimation can be made. • It has a high penetration rate.	• It may not be able to produce detailed and reliable information for low-grade road classes. • Processing data is costly and involves technical difficulties.	• Trip time and speed algorithm	• Validation

Big Data	Advantages	Disadvantages	Required Algorithms	Model Stage
Mobile Network Operator Data	• CDR + DDR =XDR • Sociodemographic information can be produced. • The purpose of transportation can be inferred by using land use information. • Some modes of transport can be produced. • There is a high probability of sampling and representation: Activity information of more than 50% of the population can be extracted.	• Vehicle ownership information cannot be removed. • The trip route cannot be removed. • Since it is base station-based, the location resolution is low, and it is difficult to infer the mode selection.	• Trip and activity detection algorithm, • O-D algorithm	• Forecasting trip demand • Validation • Calibration

Appendix 2: Detailed Roles and Responsibilities of Turkish Stakeholders in Data Management

Table 8 Detailed Roles and Responsibilities of Turkish Stakeholders in Data Management

Governance Level	Stakeholder	Role	Coordination Partners	Key Responsibilities
National	**Ministry of Transport and Infrastructure (MoTI)**	Central authority for transport policies and data governance	MoEUCC, SBO, Local Authorities	Set national guidelines, coordinate with ministries and local authorities to align data governance with national mobility goals
National	**Ministry of Environment, Urbanisation and Climate Change (MoEUCC)**	Oversees environmental data related to urban mobility	MoTI, SBO, Local Authorities	Integrate environmental considerations into transport planning, ensure data governance supports climate change mitigation
National	**Presidency of Strategy and Budget (SBO)**	Aligns data governance initiatives with national strategic priorities	MoTI, MoEUCC	Ensure data-driven strategies are financially supported and strategically aligned
National	**General Directorate of Highways (KGM)**	Manages data related to road infrastructure	MoTI, Local Authorities	Integrate road data into broader transport planning, coordinate with MoTI and local authorities

Governance Level	Stakeholder	Role	Coordination Partners	Key Responsibilities
National	**Turkish Statistical Institute (TurkStat)**	Provides statistical data for urban mobility planning	MoTI, MoEUCC, Local Authorities	Standardise data collection methodologies, ensure data accessibility for all relevant stakeholders
National	**Information and Communication Technologies Authority (ICTA)**	Ensures the regulation and support of the relevant information technologies and communication infrastructure and services	MoTI, MoEUCC, Local Authorities, AUSDER	Ensure data systems are interoperable and secure, support the technological infrastructure for data management
Local	**Union of Municipalities of Türkiye (UMT)**	Facilitates data sharing and governance across municipalities	Local Authorities, MoTI, MoEUCC	Provide guidance and support to local governments, ensure consistency in data governance practices across the country
Local	**Local Authorities (Metropolitan Municipalities and Municipalities)**	Implement data governance practices at the local level	MoTI, MoEUCC, UMT, KGM	Align local data collection and management with national standards, collaborate with other municipalities and national ministries
Private Sector / International	**Intelligent Transport Systems Association (AUSDER)**	Promotes integration of intelligent transport systems (ITS)	ICTA, Local Authorities	Ensure effective use of ITS data for urban mobility planning, coordinate with ICTA and local authorities
Private Sector / International	**Private Sector & International Financial Organisations (IFIs)**	Provide funding, technology, and expertise for data governance projects	National Ministries, Local Authorities	Align investments in data infrastructure with urban mobility goals, provide financial and technological support for data governance initiatives
Local /National	**Civil Society Organisations**	Advocate for data-driven approaches to traffic safety, public health, and sustainable mobility	Local Authorities, National Ministries	Ensure public concerns and needs are reflected in data governance practices, coordinate with local authorities and national ministries to advocate for effective data use

Appendix 3: Example of a Mixed Data Governance Approach for Türkiye's Mobility Pillars

Table 9 Example of a Mixed Data Governance Approach for Türkiye's Mobility Pillars

Mobility Pillar	Key Responsibilities & Explanation	Responsible Agency	Central Coordinating Body
Road Spaces & Accessibility	**Centralised:** Ensures consistent data management and uniform standards nationwide for road infrastructure.	General Directorate of Highways (KGM)	Ministry of Transport and Infrastructure (MoTI)
Shared Mobility	**Hybrid:** Balances specialised management with centralised coordination, integrating shared mobility into the broader transport and ICT infrastructure.	Intelligent Transport Systems Association (AUSDER)	Information and Communication Technologies Authority (ICTA)
Active Mobility	**Specialised:** Focuses on active mobility, with tailored approaches to local contexts, supported by MoEUCC expertise in environmental and urban planning.	Ministry of Environment, Urbanisation and Climate Change (MoEUCC)	Union of Municipalities of Türkiye (UMT)
Freight & Logistics	**Hybrid:** Combines expertise from trade and transport ministries, coordinated by TurkStat for comprehensive logistics data management.	Ministry of Trade and Ministry of Transport and Infrastructure (MoTI)	Turkish Statistical Institute (TurkStat)
Public Transport	**Specialised:** Managed by local authorities, allowing for tailored public transport strategies with overarching guidelines from MoTI.	Local Authorities (Metropolitan Municipalities)	Ministry of Transport and Infrastructure (MoTI)

Appendix 4: Turkish Data Strategy and Policy Papers

Table 10 Extracts from Turkish Data-Related Strategy Documents and Policy Papers

Turkish Strategy and Policy Papers	Abstract Policy Description
Twelfth Development Plan (2024-2028)	609.3. The use of digital applications and systems in the transport sector will be made widespread, and their development and production using domestic resources, R&D studies, and the use of mobility data will be supported. 614.2. Information collection, evaluation, analysis, and data dissemination activities will be strengthened, and common databases will be used in accident prevention activities. 884.3. Legislation on the examination and evaluation of urban rail system projects and their takeover by the Ministry of Transport and Infrastructure will be prepared and statistical data infrastructure will be established. 885.4. To ensure more efficient use of the urban transport network, increase traffic safety, manage transport demand accurately, and plan more effectively, applications compatible with the national intelligent transport system (ITS) architecture will be made widespread, especially in metropolitan areas, and dynamic passenger, driver and pedestrian information systems and cooperative national intelligent transport system (C-ITS) installations will continue.
Turkish Transport Policy Paper	Legislation Development: Legislation will be established to produce and encourage the use of transport data in standards that facilitate its usage in studies. Centralised Data Management: Main focuses will be developed for the centralised management of Big Data/Analytics efforts carried out by different public authorities in the transport sector at both local and central levels. Data Governance Mechanisms: Data governance mechanisms will be developed to ensure consistent, reliable, and GDPR-compliant access, storage, and sharing of transport data, supporting transport system research, decision support systems, and the integration of automation and AI applications with other essential public services. Best IT Practices: Transport authorities will adopt innovative, accessible, and secure best IT practices. Open Data Platforms: Open data platforms will be developed to provide access to high-quality data, supporting data-driven technologies, processes, and decision-making.
Accessible Transport Strategy and Action Plan 2021-2025	Ensure availability of data on accessibility of transport services Creating a transport accessibility database and digital accessibility map by determining data norms and keeping them up to date
Road Traffic Safety Strategy Document (2021-2030)	Combination of existing traffic safety data, necessary but not yet systematically collected of uncollected data and common to collect them in a database establishing the necessary legal infrastructure
Transport and Logistics Master Plan 2053	Open data platforms should be developed with access to high-quality data to support data-driven technologies, operations, and decision-making. National Transport Database (NTD) infrastructure should be established to make fast and economic analysis in planning, monitoring, and evaluation processes. Suggestions should be made for making the data to be collected through communication and digitalization useful for other sectors and the use of this data by the stakeholders.

Turkish Strategy and Policy Papers	Abstract Policy Description
	Developing a national software that will enable communication and data sharing between centres established within the ITS, such as the Traffic Management Center (TMC), Public Transport Management Centre (PTMC), Emergency Management Centre (EMC) Establishing an open access data portal for ITS application stakeholders to benefit and make cost comparisons of ITS applications Creating new data systems for data collection, sharing, and security for ITS systems
Energy Efficiency 2030 Strategy and National Energy Efficiency Action Plan (2024 - 2030)	Establishing effective monitoring systems by digitizing transport sector data Integrated development of intelligent transport systems and digitalization for energy efficiency
Strategic Plan (2024-2028) of the Ministry of Transport and Infrastructure	Establishing mobility centres in local authorities Inclusion of district municipalities in the Mobility for All mobile application Determining the conditions for access, sharing, and management of data to be used in ITS applications, activities, and projects Establishment of the National ITS Data Management Centre (DMC) for the provision of the data needed, collection and processing of data and analysis, and preparation of legislation on open data and sharing.
Strategic Plan (2024-2028) of Ministry of Environment, Urbanization and Climate Change	Collecting up-to-date, effective, inclusive, reliable, easily accessible, and reportable data on local authorities that can be used both in the studies to be carried out by the central government (legislation preparation and/or policy determination processes) and in the decision-making processes of the municipality

Appendix 5: Data Standards Utilised in Turkish Cities

Table 11 Examples of Data Standards Utilised in Turkish Cities

Category	Standard	Description
Land Use and Geographic Information Systems	**TUCBS (Turkish National Geographic Information System)**	A project aimed at enhancing, managing, and standardizing geographic information infrastructure in Türkiye to improve GIS interoperability and data sharing among stakeholders.
	TAKBİS (Land Registry and Cadastre Information System)	A system developed to digitally store, manage, and share land registry and cadastre data across Türkiye, enhancing transparency and efficiency in property registration.
	WKT (Well-Known Text)	A text-based format used in GIS to represent geometric objects in a human-readable form is widely used for spatial data management.

Category	Standard	Description
	OSGeo (Open-Source Geospatial Foundation)	An international non-profit organisation promoting the development and use of open-source geospatial software, supporting GIS, remote sensing, and spatial data management.
	INSPIRE (Infrastructure for Spatial Information in the European Community)	An EU initiative to create a standardised spatial data infrastructure covering various thematic areas, including land use.
	ISO 19152 - Land Administration Domain Model (LADM)	An international standard providing a conceptual model for land administration, including land use, developed by ISO.
	OGC (Open Geospatial Consortium) Standards	Develops open standards for geospatial content and services, facilitating data sharing and processing in GIS.
Public Transport	**Transmodel**	An abstract model for public transport concepts and data structures, used in systems for timetabling, fares, operational management, and journey planning.
	GTFS (General Transit Feed Specification)	A standardised data format for representing public transportation services, enabling data sharing across platforms and applications.
	SIRI (Service Interface for Real-Time Information)	A European standard for exchanging real-time public transport operations data between systems, supporting various communication needs.
	NeTEx (Network Timetable Exchange)	A European standard for exchanging public transport schedules and related data, covering network topology, timetables, and fare information.
	TCIP (Transit Communication Interface Profiles)	A standard for automatic information exchange in transit applications, covering data exchange among transit systems, subsystems, and devices.
Road Network	**DATEX II**	A European standard for data exchange in road traffic management, supporting sustainable mobility through interoperable information sharing.
Active Mobility	**GBFS (General Bikeshare Feed Specification)**	A standardised data format for real-time information sharing by bike-sharing systems, enabling consistent data reporting and integration into applications.
	TOMP-API	An emerging standard for communication between Transport Operators and Mobility-as-a-Service (MaaS) providers, ensuring interoperability and integration across services.
Intelligent Transport Systems (ITS)	**CEN/TC 278**	European technical committee for developing standards in Intelligent Transport Systems, focusing on interoperability, safety, and efficiency.

Category	Standard	Description
	ISO/TC 204	ISO technical committee developing standards related to Intelligent Transport Systems, covering technologies and systems for improved traffic management and safety.
Road Safety	**CADAS (Common Accident Data Set)**	A European standard for the relational and schematic format of traffic accident data, enhancing the detail and usability of accident databases.

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Glossary

Metric	Description
Roads & Infrastructure	
Traffic flow	Number of vehicles passing per unit of time
Traffic density	Number of vehicles per unit length of road
Travel time	Time taken to cross the road section
Speed	The average mean or local speed in the section
Occupancy	Percentage of road space occupied by vehicles
Road Level of Service (LoS)[23]	
LoS A	Free flow: Maximum permissible speed possible
LoS B	Reasonably free flow: No traffic jam condition
LoS C	Stable flow: Occasional traffic, but moderate jams or congestion
LoS D	Approaching unstable flow: Stop-and-go traffic, with frequent jam conditions.
LoS E	Unstable flow: Stop-and-go traffic, with intense traffic jams.
LoS F	Forced flow: Stationary traffic. Queuing of vehicles.
Bicycle Level of Service (BLoS)[24] **Ratings**	
BLOS A	Extremely High: Exceptionally safe and comfortable; ideal for all cyclists.
BLOS B	Very High: Very safe and comfortable; minor challenges, suitable for most cyclists.
BLOS C	Moderately High: Generally safe with some challenges; comfortable for experienced cyclists.
BLOS D	Moderately Low: Less favourable, with safety concerns; better suited for experienced cyclists.
BLOS E	Very Low: Poor cycling conditions; high traffic stress, unsuitable for most cyclists.
Pedestrian Level of Service (PLoS)[25] **ratings**	
PLOS A	Extremely High: Ideal walking conditions with wide sidewalks, low congestion, minimal road crossing delays, and a safe, pleasant environment. Suitable for all pedestrians.
PLOS B	Very High: Very good conditions with minor challenges like slightly narrower sidewalks or occasional road crossings. Comfortable and safe for most pedestrians.
PLOS C	Moderately High: Reasonably good conditions with noticeable limitations such as narrower sidewalks or moderate pedestrian traffic. Safe but less comfortable.
PLOS D	Moderately Low: Less favourable conditions with significant challenges like narrow sidewalks, frequent crossings, and some safety concerns. Stressful for some pedestrians.
PLOS E	Very Low: Poor conditions with major issues like very narrow or absent sidewalks, high pedestrian traffic, long crossing delays, and potentially unsafe environments.

[23] https://www.smatstraffic.com/2021/07/26/level-of-service/

[24] The Bicycle Compatibility Index: A Level of Service Concept, Implementation Manual FHWA-RD-98-095, 1998

[25] https://www.smatstraffic.com/2021/07/26/level-of-service/

PLOS F	Extremely Low: Unacceptable conditions with severe hazards, no sidewalks, heavy traffic, and extremely uncomfortable or dangerous environments. Avoidance recommended.
Accessibility	
Network Analysis:	Evaluates network connectivity, shortest paths, and service coverage to assess how effectively the transportation network meets user needs.
Spatial Analysis:	Identifies accessibility hotspots and disparities across different areas to highlight regions with either high or low access to transportation services.
Temporal Analysis:	Examines how accessibility varies at different times of the day to understand peak and off-peak variations in transport availability.
Social Equity Analysis:	Assesses accessibility for various population groups, including different occupational and income groups, to ensure equitable access to transportation services.
Scenario Analysis:	Models the impact of potential infrastructure changes or policy interventions on accessibility to predict outcomes and guide decision-making.
Accessibility Indicators:	Develops quantitative measures of accessibility, such as the proportion of the population reached by transportation services or the number of points of interest (POIs) accessible.
Equity Analysis:	Identifies disparities in accessibility across different regions, communities, or income classes to address inequalities in transportation access.
Infrastructure Gaps:	Use of spatial analysis to detect gaps in the transportation infrastructure that may hinder accessibility and require targeted improvements.
Priority Areas:	Identifies areas within the city with low transport accessibility, both spatially and temporally, to prioritise enhancement and development.
Analysing accident data:	
Accident Rate	Number of accidents per unit distance or population
Severity Rate	Proportion of accidents resulting in fatalities or injuries
Accident Types	Classification of accidents (rear-end, side impact, pedestrian, cyclist)
Time Patterns	Accident distribution by time of day and day of week
Location Patterns	Accident hotspots or areas with high accident rates
Weather-Related Accidents	Number of accidents under specific weather conditions
Road Condition-Related Accidents	Number of accidents based on road surface conditions
Human Factor-Related Accidents	Number of accidents caused by driver or pedestrian error
User Satisfaction	
Reliability	Adherence to schedules, minimal disruptions
Accessibility	Ease of access to services
Comfort	Physical and psychological comfort during travel
Safety	Personal and vehicle safety
Affordability	Cost of travel
Information	Availability and clarity of information

Pollution Hotspots (according to the national AQI index[26] for Türkiye.)

Index	AQI	SO_2 (µg/m3) 1 hr Avg.	NO_2 (µg/m3) 1 hr Avg.	CO (µg/m3) 8 Sa. Avg.	O_3 (µg/m3) 8 Sa. Avg.	PM10 (µg/m3) 24 hrs Avg.
Good	0-50	0-100	0-100	0-5500	0-120	0-50
Middle	51-100	101-250	101-200	5501-10000	121-160	51-100
Sensitive	101-150	251-500	201-500	10001-16000	161-180	101-260
Unhealthy	151-200	501-850	501-1000	16001-24000	181-240	261-400
Bad	201-300	851-1100	1001-2000	24001-32000	241-700	401-520
Dangerous	301-500	>1101	>2001	>32001	>701	>521

[26] Ministry of Environment and Urbanization, Air Quality Index. https://egethm.csb.gov.tr/hava-kalitesi-indeksi-i-87403 https://egethm.csb.gov.tr/hava-kalitesi-indeksi-i-87403 Retrieved from: 14/08/2023

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