DECARBONISING PATHWAYS FOR TASHKENT’S URBAN MOBILITY

METHODOLOGY REPORT FOR TASHKENT’S URBAN MOBILITY MODEL

November 2023

Supported by:

Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection

based on a decision of the German Bundestag

IKI INTERNATIONAL CLIMATE INITIATIVE

OECD

MINISTRY OF TRANSPORT REPUBLIC OF UZBEKISTAN

ABOUT THIS DOCUMENT

As part of SIPA, the Sustainable Infrastructure Programme in Asia, a national roadmap study was conducted in Uzbekistan. It focused on decarbonising urban passenger transport in Tashkent, emphasising the role of public transport. The main deliverables of this study are the Public Transport Improvement Plan for Tashkent and the Tashkent Urban Mobility Model.

This methodology report provides an explanation of the model components, underlying assumptions, modelling steps and result interpretation. It is a reference document for any user of the tool wishing to understand the model in detail and the relationships between different variables.

Access more information and project deliverables:

https://www.itf-oecd.org/decarbonising-pathways-urban-mobility-uzbekistan

DISCLAIMER

The results presented in the model should be regarded as an estimation derived from the best available data and information collected during the project. Its primary value lies in facilitating scenario comparisons rather than providing precise future values for certain indicators.

The ITF warrants the outputs of the default scenarios in the model: Baseline, Current Policy and Climate Ambition. These scenarios are validated by the technical team and the Ministry of Transport of the Republic of Uzbekistan. The model allows to manually create alternative scenarios by adjusting input, however, the ITF does not endorse the outcomes of this exercise and should not be quoted as the source of any manual scenario results.

The use of the model, its default scenarios and any other elements is free.

Please cite this work as: ITF (2023), “Tashkent’s Urban Mobility Model: Methodology Report”, *Sustainable Infrastructure Programme in Asia – Transport*, OECD Publishing, Paris.

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TASHKENT'S URBAN MOBILITY MODEL

Objectives

The objective of the model is to provide policymakers with a user-friendly tool to identify and assess possible pathways towards the decarbonisation of the urban passenger transport sector in Tashkent until 2050. Users of the tool are free to test different policy packages through scenario building.

The spreadsheet-based model is a ready-to-use tool for urban transport planners and policymakers to determine the urban mobility impacts of alternative policies and programs, in terms of mode shares, mobility levels, carbon emissions (well-to-wheel) and local pollutants.

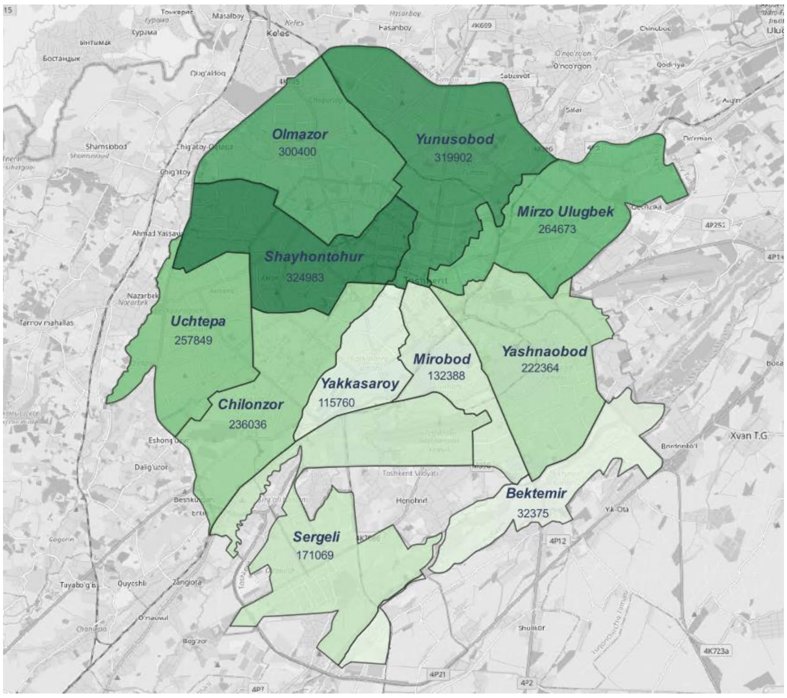
The tool is developed based on the ITF Global Urban Passenger Transport Model (Chen, Kauppila, 2017) which was first presented in 2017 and enhanced in the context of the Horizon 2020 project "Decarbonising Transport in Europe" (ITF, 2020), followed by annual updates in the context of the "ITF Transport Outlook 2021" (ITF, 2021) and the "ITF Transport Outlook 2023" (ITF, 2023).

The model is handed over to the Ministry of Transport of the Republic of Uzbekistan. The model is developed in the context of the OECD's "Sustainable Infrastructure Programme in Asia" (SIPA), of which ITF leads transport sector activities, funded by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU).

Model scope

The model represents urban mobility of Tashkent in Uzbekistan. The study area corresponds to the City of Tashkent that consists of 11 districts (see Figure 1).

Figure 1: Map of Tashkent city and its 2022 population by districts



Source: ITF analysis based on OpenStreetMap, Statistics Agency under the President of the Republic of Uzbekistan

The model analyses 14 modes, covering all the existing modes and potential future modes. These modes are listed and described in Table .

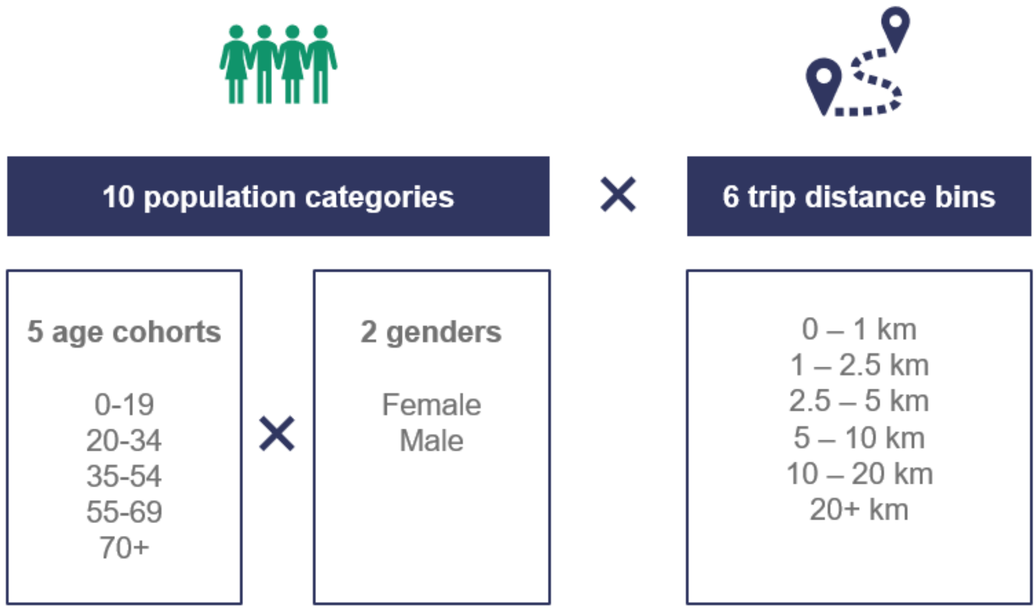
Table 1: List of transport modes included in the model

Active modes	
Walk	Walk
Bike	Private bicycle
Bike and scooter sharing	Shared electric kick scooter system and shared bike and electric bike system
Private vehicles	
Motorcycle	Private motorcycle
Car	Private car
Public transport	
PT-Rail	Heavy rail system for long distances (suburban travel)
PT-Metro	Heavy rail system for short to medium distances
PT-Bus	Conventional bus system
PT-BRT	Bus Rapid Transit system
PT-Minibus	Paratransit system not managed by the public administration
PT-On-demand Transport	Ride sharing system based on high-capacity vehicles. Also referred to as Taxi-bus
Shared mobility	
Taxi	Taxi system
Ride-sharing	Private ride hailing system
Car-sharing	Shared car system

To enhance the representation of urban mobility for different market segments, the model further breaks down travel demand by gender (male and female), 5 different age categories and 6 travel distance categories, as shown in Figure 2. For example, male and female travellers can have different preferences towards transport modes and depending on the trip distance, some modes are more attractive or applicable than others.

In terms of the forecast timeframe, the model produces projections of future travel demand and related emissions with a step of 5 years between 2015 and 2050.

Figure 2: Population and trip distance categories in the model

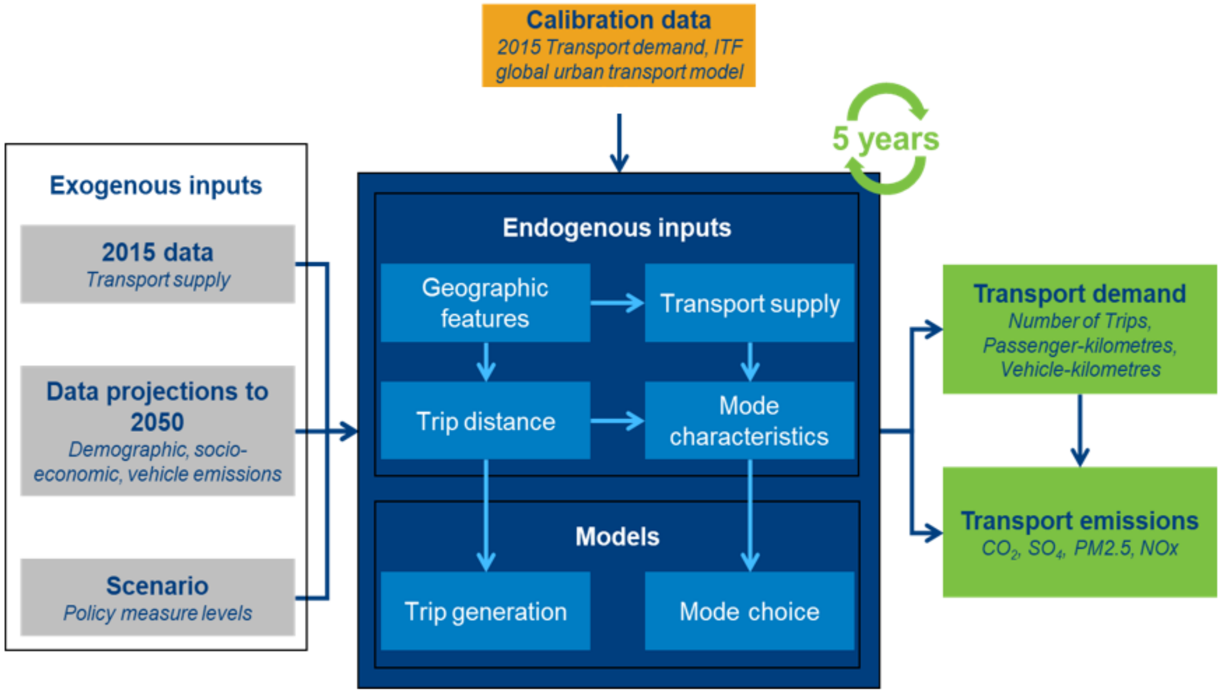


Modelling approach

Overall modelling steps

The core of the model is inspired by a traditional 4-step transport modelling approach to determine travel demand, with an additional step to calculate CO_2 emissions and local pollutants resulting from travel demand. The outputs of each step feed into the next step as inputs, as illustrated in Figure 3.

Figure 3: Overall modelling framework



First, the model is initialised with different data inputs, which include 1) base year data for 2015, 2) external/exogenous projections that depict the evolution of the urban area (e.g. demographics, socio-economic developments, vehicle technology pathways) until 2050, and 3) different scenario inputs - a set of policy measures and assumptions either predefined in the model or set by the user.

Second, the model updates the geographic features (e.g., urban area size, density) of the study area based on the socio-economic inputs, as well as the scenario measure inputs. Based on this information, transport supply (i.e., available transport infrastructure and transport services) and average trip distances for each trip distance bin (category) are computed. This enables the next step, which is the adjustment of mode availability and mode characteristics for each distance and gender category.

Third, the core of the transport model runs. The model generates a total number of trips based on the geographic and socio-economic data. Then, the mode choice model, accounting for different mode characteristics, yields trip mode shares.

Lastly, main model outputs are produced. Passenger travel demand results from a combination of the generated trips, average trip distances, and mode shares. The passenger demand is then converted into vehicle travel demand using assumptions on vehicle load factors. Finally, technology assumptions, such as fuel mix, fuel economy and emission factors, allow estimating CO_2 and local pollutant emissions resulting from the vehicle demand.

The figure does not describe exhaustively regression models linking the exogenous and endogenous input variables, which allow building future projections. The figure does not differentiate either between the inputs which are fixed in the model, and those which may alter due to different (policy) scenario settings. Both relationships are described more in-depth in the following sections.

Model calibration

This current model is essentially an extraction of the ITF Global Urban Passenger Transport Model (2023 version), which was designed and updated for producing the "ITF Transport Outlook 2023" (ITF, 2023). It is calibrated for each world region rather than at the national level, aiming at keeping consistent results across the regions.

The model coefficients presented in the following sections are taken directly from the ITF Global Model and applied for the City of Tashkent. Further, where data were available, the coefficients were adapted to the local context of Tashkent to reproduce observed travel demand and behavioural characteristics for the base year, e.g. mode shares, trip rates, etc.

It is worth noting that not all the calibration parameters might be exactly optimal for Tashkent due to the data availability constraints. Nevertheless, the parameter values can be seen as relevant starting points for calibrating the model. Once good quality data are available for different sub-models in the future, it will be possible to recalibrate some of the parameters and incorporate them in the model. This methodology report presents the corresponding formulas.

Model validation

Some of the model results for historical and projection years were validated against the existing information for Tashkent provided by the Ministry of Transport. This information comes from presidential decrees (e.g. №ПП-111 from 02.02.2022), annual reports of public transport operators (Toshshahartransxizmat), and existing studies carried out by international partners (Kalyon Ulastirma, MOEF – South Korea). Table 2 presents validated values. As the table shows, most of the values are very close to the ones observed in the reported documents.

Table 2: Model validation, key transport characteristics

Transport characteristics	ITF model		MoT information	
	Year	Value	Year	Value
Total population	2030	2.9 million	2030	3 million
Trips by metro per day	2021	515 thousand	2021	500 thousand
Trips by bus per year	2021	121 million	2021	138 million
Trips by public transport per day	2021	1.24 million	2021	1.32 million
Modal share of public transport	2021	19%	2021	21%

Model caveat

Despite the model's capacity in capturing most of the dynamics of the urban transport system, there are some limitations in the model due to data, technical and time constraints. However, the model framework is designed in a way that is flexible to incorporate additional modules and dynamics, once good quality data are available in the future.

MODEL INPUTS: EXOGENOUS

This chapter presents inputs needed to initialise the model, which are base year data in 2015, exogenous variables, socio-economic input, and user/scenario inputs. Exogenous variable is one whose value is determined outside the model and is imposed on the model.

Base year inputs and exogenous projections

Socio-economic data

Area size, GRP, population, age and gender shares are calculated based on the data provided by the Statistics Agency under the President of the Republic of Uzbekistan. Based on these data, growth rates for future years are estimated using a linear regression approach and applied for every five years from 2015 to 2050. The corresponding model sheet (*Socio-economic Input*) highlights the future projections.

Table displays the characteristics of the study area for selected years.

Table 3: Characteristics of the study area

Year	Urban Area, sq. km	Population	Population density (inh. per sq. km)	GRP per Capita, USD
2015	334.8	2 371 300	7 083	6 740
2020	334.8	2 571 700	7 681	7 820
2030	411.6	2 953 400	7 175	12 104
2050	411.6	3 749 500	9 109	19 103

Source: ITF Tashkent Urban Mobility Model

Transport supply data

The base year of the model is 2015. The transport infrastructure supply data of 2015, including network lengths, fleet size, modal characteristics and costs, were mostly provided by the Ministry of Transport. Remaining data gaps were closed using open sources (e.g. OpenStreetMap, Numbeo, local media) and proxy data from other countries in the region, which were eventually validated by the Ministry.

Transport demand data

The 2015 transport demand database contains a mix of available travel survey data or statistics on travel behaviour (i.e. mode choice, travel distances) and, where the required is not available, expert judgement. This database is then used for model calibration: a process of using various regression and optimisation techniques to identify coefficients of the sub-models so that the modelled results match the observed data or expert judgement. To ensure that the data from different sources are compatible, a thorough data cleaning and disaggregation/compilation process was undertaken.

Vehicle emissions data

Data on vehicle technology pathways come from two main sources. For each mode, vehicle fleet composition (by fuel type), respective CO_2 emission factors (tank-to-wheel (TTW) and well-to-tank (WTT)), and vehicle load factors between 2015 and 2050 come from the Mobility Model (MoMo) of the International Energy Agency (IEA) (IEA, 2020). Here, two trajectories of vehicle technology and emission from the MoMo model are integrated into the model. These are the trajectories of the IEA's New Policy Scenario (NPS) reflecting the baseline trajectory and the Sustainable Development Scenario (SDS) representing a more ambitious greening of vehicle fleets until 2050. The emission factors of local pollutants (e.g. SO_4, NO_x, and PM2.5) by mode and fuel type come from the ICCT Transport Roadmap Model (ICCT, 2019).

The IEA's NPS, now renamed into the Stated Policies Scenario (STEPS), is a key component of the World Energy Outlook. This scenario reflects the impact of existing policy frameworks and stated policy plans. It includes only those policy initiatives that have already been announced, focusing on their impact rather than speculating on future policy developments. The scenario covers a wide range of policies, including those related to fossil fuel consumption subsidies, fuel efficiency standards, support for electric vehicles, and clean energy deployment.

The IEA's SDS outlines a major transformation of the global energy system, showing how the world can change course to deliver on the three main energy-related Sustainable Development Goals simultaneously. The SDS holds the temperature rise limited to 1.65 °C with a 50% probability and presents strong support for electric mobility, alternative fuels and energy efficiency. In the SDS scenario, the energy efficiency of all technologies improves much more significantly than in the NPS scenario.

Scenario/User inputs

To allow users to freely design and test different policy scenarios, the tool contains 30 measures, as listed in Table 1. These measures can be direct policy measures, such as road pricing levels, or they can rather refer to desired outcomes, such as vehicle fuel technology development and uptake.

In the "Scenario Setting" sheet, users can set target levels of each measure for 2050 and also for one of the intermediary years (2025, 2030, 2035, 2040, 2045) when the policy implementation level is known to the user. These targets are translated into intermediate parameters in the "Scenario Parameters" sheet for each 5-year step between 2015 and 2050. A steady linear growth is applied from the present year to the intermediate reported milestone, and from the milestone to the final 2050 target. The detailed information on how each measure impacts the model is provided in the "Scenario Parameters" sheet and the respective section of this report.

Table 1: List of measures in the model

Measure name	Measure description
Infrastructure expansion	
Metro network	Total network length (km)
BRT network	Total network length (km)
Suburban rail network	Total number of stops
Conventional bus network	Total network length (km)
Bike network	Total network length (km)
Pedestrian network	Additional network length increase (%)
Public transport promotion	
Service improvement for mass transit	Increase in the operating speed from optimised stop positioning and service improvement, including ICT (%)

Measure name	Measure description
Service improvement for conventional bus	Increase in the operating speed from optimised stop positioning and service improvement, including ICT (%)
Public transport priority	Share of the bus network that has priority over other road modes (%)
Public transport fare integration	Average cost reduction of a public transport trip (%)
Launch of on-demand services	Total size of the on-demand fleet (number of vehicles)
Mobility as a Service	Share of the population with a MaaS subscription (%)
Shared transport promotion	
Incentives for taxi	Total size of the taxi fleet (number of vehicles)
Incentives for car sharing	Total size of the car sharing fleet (number of vehicles)
Incentives for ride sharing	Total size of the ride sharing fleet (number of vehicles)
Incentives for bike and scooter sharing	Total size of the bike and scooter sharing fleet (number of vehicles)
Taxi market reform	Share of legally operated vehicles in the total taxi fleet (%)
Carpooling incentives	Change in the load factor for private vehicles (%)
Restrictive measures	
Parking restrictions	Share of the city that is under (strong) parking restrictions
Vehicle access restrictions	Percentage of cars that will be restricted from circulating within the city
Speed limitations	Speed limit reductions (%)
Pricing measures	
Road pricing (congestion charging)	Average fare for city entry (USD)
Parking pricing	Average parking fare (USD/h)
Fuel tax	Increase in vehicle usage costs (per km) due to increase of fossil fuel cost (%)
Vehicle ownership and purchase tax	Increase in vehicle ownership and purchase cost (%)
Vehicle technology development	
Vehicle fuel technology development and uptake - pre-defined scenarios	Trigger of two possible technology and vehicle efficiency scenarios: 0 - IEA NPS, 1 - IEA SDS
Technology stock targets for car fleet	Share of different vehicle technologies in the private car fleet (overwriting the IEA scenarios)
Technology stock targets for bus fleet	Percentage share of different vehicle technologies in the bus fleet (overwriting the IEA scenarios)
Other measures	
Teleworking promotion	Share of the active population that regularly teleworks (%)
Transit Oriented Development and improved urban planning	Increase in diversity of land-use functions and density around public transport network (%)

MODEL INPUTS: ENDOGENOUS

This section describes endogenous data inputs used to run the core sub-models, and how their future values are estimated up to 2050. An endogenous variable is a variable in a statistical model that is changed or determined by its relationship with other variables within the model. In almost all cases, data from the base year come from the ITF Global Urban Passenger Model, which has compiled various sources at the city level. The remainder of this section describes various relationships between the variables and the way these relationships are used in the model.

Trip distance

This module computes an average distance assigned to each trip distance bin and determines the proportion of trips that occur in each distance bin (i.e., x% of trips in Tashkent are <= 1 km).

It can be found in the "Sub-models Calibration" sheet, and the resulting calculations can be found in the "Trip Rates & Distances" sheet.

Average trip distance

Assumed average trip distance:

1) For the first distance bin, "0-1 km": set $\mathrm{distance}$ = 0.75 km.

2) For all other distance bins:

- If the average distance of the previous distance bin is null: set $\mathrm{distance}$ = NA.
- If $\mathrm{bound}_{\mathrm{lower}}$ is greater than 3 times the city's radius $(3 \times \sqrt{\frac{\mathrm{urbanArea}}{\pi}})$, set $\mathrm{distance}$ = NA; otherwise,
  - For the category "> 20 km", additional constraints are applied, so that this distance category does not have an average trip distance over 50 km or under 25 km:

    $$\text{Set distance} = \min\left(50, \max\left(1.25 \times \mathrm{bound}_{\mathrm{lower}}, 1.25 \times \sqrt{\frac{\mathrm{urbanArea}}{\pi}}\right)\right)$$

  - For the remaining categories,
    - If $\mathrm{bound}_{\mathrm{upper}}$ > 3 x radius, then $\mathrm{distance}$ = 1.25 x $\mathrm{bound}_{\mathrm{lower}}$
    - Otherwise, set $\mathrm{distance}$ = 0.4 × $\mathrm{bound}_{\mathrm{lower}}$ + 0.6 × $\mathrm{bound}_{\mathrm{upper}}$

Where $\mathrm{distance}$ is the average distance of trips in the distance bin (km), the $\mathrm{bound}_{\mathrm{lower}}$ and $\mathrm{bound}_{\mathrm{upper}}$ are the lower and upper bounds of the distance bin, radius is the average city radius (km), $\mathrm{urbanArea}$ is the size of the urban area (sq km).

Share of trips by distance bin

The share of trips by distance bin is explained by the urban area size, urban population density, and land-use mix coefficient. It is calibrated using a discrete choice model with a multinomial logit format. The utility function of each distance bin $\mathrm{U}_{\mathrm{dist}}$ is formulated as follows:

Coefficients of the multinomial logit model used to compute the utility functions of each distance bin d: $\text{Utility}^{d} = \mu * (\sum_i \text{Parameter}^{d}{}_i * \text{variable}^{d}{}_i)$

The variables are slightly transformed to include threshold effects and the impact of the “Pedestrian network”, “Bike network” and “Teleworking promotion” measures. Bike and pedestrian infrastructures increase the share of trips in the two lowest distance categories and teleworking increases the share of trips in the three lowest distance categories.

$$U_{dist} = \mu \times \Big(ASC_{dist} + \text{parameter}_{dist}^{\text{Area}_{coeff}} \times \text{Area} + \text{parameter}_{dist}^{\text{Density}_{coeff}} \times \text{Density} + \text{parameter}_{dist}^{\text{LandUseMix}} \times \text{LandUseMix}\Big)$$

Where μ is a standard coefficient, ASC_{dist} is the alternative specific constant of the distance bin, and $\text{parameter}_{dist}^{variable}$ is a model parameter related to the variable for the distance bin dist.

The total trip share of the distance bin dist, Dist_{share}, is then computed with the multinomial logit formula:

$$\text{Dist}_{share} = \frac{e^{U_{dist}}}{\sum_{i=1}^{6} e^{U_i}}$$

Transport supply

This module projects the future transport supply of the urban area considered in the model. The transport supply indicators are updated by taking into consideration the future geographic and socio-economic characteristics of the urban area, as well as the assumptions of the related measures defined in the “Scenario Setting” sheet.

It can be found in the “Sub-models Calibration” sheet and the resulting calculation can be found in the “Urban Area Descriptors” sheet.

Transport infrastructure supply

Road infrastructure supply

The base year data on road infrastructure supply are provided by the Ministry of Transport and then validated using the OpenStreetMap database. This yields the total length of roads per road type for the urban area. There are five road types, from road type 1 (trunk roads) to road type 5 (residential roads).

The network length of each road type 1-5 in 2015 is a user input value, which can be found in the “Transport Indicators” sheet.

The formula to compute the total road network length from 2020 onwards is presented below:

$$\text{length}_i = \max\Big(\text{length}_{i-1};\ 0.5 \times \text{length}_{i-1} \times \frac{\text{urbanArea}_i}{\text{urbanArea}_{i-1}} + 0.5 \times \big(\text{length}_{i-1} + \text{Pop coefficient} \times (\text{Population}_i - \text{Population}_{i-1}) + \text{Area coefficient} \times (\text{urbanArea}_i - \text{urbanArea}_{i-1}) + \text{GRP coefficient} \times (\ln(\text{GRP per capita}_i) - \ln(\text{GRP per capita}_{i-1}))\big)\Big)$$

Where length_i is the total road length (km), urbanArea_i is the urban area size (sq km), Population_i is the total population size, GRP per capita_i is the GRP per capita (USD), all for the selected year; Pop coefficient, Area coefficient and GRP coefficient are calibrated coefficients of this regression model, which can be found in the “Sub-models Calibration” sheet.

A constraint is introduced to limit the growth of the road network so that the surface area of all roads in the city does not surpass 30% of the total urban area size.

After computing the total road network length, it is distributed among the road types based on the constant shares stemming from the base year 2015:

$$\text{Share}_{\text{type}_i} = \frac{\text{length}_{\text{type}_i}}{\sum_{i=1}^{5} \text{length}_{\text{type}_i}}$$

Pedestrian infrastructure supply

The total pedestrian network length is the sum of road type 4 (tertiary) and road type 5 (residential) presented in the section above.

The effect of the “Pedestrian network” measure is included by increasing the network length according to the scenario input.

Cycling infrastructure supply

The cycling network length in 2015 and 2050 are user input values. Users can also select an intermediary implementation year and enter the corresponding value. These values can be found in the “Transport Indicators” (2015) and “Scenario Setting” (intermediary year and 2050) sheets.

For the other years, the values are derived using a linear regression method from 2015 to the selected intermediary year and then from that intermediary year to 2050.

Public transport infrastructure supply

Public transport includes metro, BRT, suburban rail, bus and minibus. The infrastructure supply for metro, BRT, bus and minibus is quantified in kilometres, whereas the supply for suburban rail is quantified in the number of stops.

The supply data for all years between 2015 and 2050 are user input values, which can be found in the “Transport Indicators” (2015) and “Scenario Setting” (2020-2050) sheets.

Vehicle fleets

Private vehicle ownership

Private vehicle ownership represents the number of vehicles per 1000 inhabitants, namely car and motorcycle. The private vehicle fleet data in 2015 are user input values, which can be found in the “Transport Indicators” sheet. This submodule can be found in the “Sub-models Calibration” sheet and the resulting calculation in the “Urban Area Descriptors” sheet.

The growth of vehicle ownership is largely influenced by GRP. Additionally, several policy measures targeting private vehicle use limit ownership growth: “Vehicle access restrictions” (VAR), “Speed limitations” (SL), “Parking restrictions” (PR), “Road pricing” (RP), “Parking pricing” (PP), “Fuel tax” (FT), “Vehicle ownership and purchase tax” (VT) and “Transit-oriented development” (TOD).

For both modes, the calculation follows the standard formula:

- If year > 2015:

$$\text{ownership}_m = \text{Threshold}_m \text{ x } \left(\frac{1}{1+\exp(-\text{Parameter2}_m \text{ x GRP})}\right)^{\text{Parameter1}_m}$$
$$\text{x min(Maximum impact}, (1 - \text{VAR coeff x VAR}) \text{ x } (1 - \text{SL coeff x SL}) \text{ x } (1 - \text{PR coeff x PR}) \text{ x } (1 - \text{FT coeff x FT x } (1 - \text{ShareSustainableFleet})) \text{ x } (1 - \text{PP coeff x PP}) \text{ x } (1 - \text{TOD coeff x } (\text{TOD} - 1)) \text{ x } (1 - \text{RP coeff x RP}) \text{ x } (1 - \text{VT coef x VT}))$$

Where Threshold_m is a fleet saturation value for the selected mode, Parameter1_m and Parameter2_m are calibrated coefficients, $\text{measure}_{\text{coeff}}$ is an estimated coefficient for each of the applicable scenario measures (VAR, SL, PR, RP, PP, FR, VT and TOD), ShareSustainableFleet is the share of sustainable vehicles in the overall fleet, Maximum impact is the limit for the combined impact of all measures in place on vehicle ownership.

Car ownership is also affected by the evolution of car sharing services. Therefore, an additional reduction parameter is applied to the standard formula above:

$$\text{Car sharing impact} = \left(1 - \min\left(0.25,\ 0.05 \text{ x } \frac{\text{car sharing}}{0.01}\right)\right)$$

Where car sharing is the car sharing fleet size.

Table 5: Calibrated coefficients for the vehicle ownership model

Coefficient	Value
Threshold car	800
Threshold motorcycle	120
Parameter1 car	3.40
Parameter1 motorcycle	3.50
Parameter2 car	0.00010
Parameter2 motorcycle	0.00003
VAR coeff	0.20
SL coeff	0.20
PR coeff	0.10
FT coeff	10.00
PP coeff	0.20
TOD coeff	0.10
RP coeff	0.007
VT coeff	0.60
Maximum impact	0.40

Source: ITF Tashkent Urban Mobility Model

Shared transport service supply

Shared transport service includes taxi, ride sharing, bike and scooter sharing, car sharing and on-demand transport, which are all quantified in the number of vehicles per 1000 inhabitants. The shared fleet size data for 2015 and 2050 data are user input values. Users can also select an (intermediary) implementation year and enter the corresponding value. These values can be found in the “Transport Indicators” (2015) and “Scenario Setting” (intermediary year and 2050) sheets.

For the other years, the values are derived using a linear regression method from 2015 to the selected (intermediary) implementation year and then from that (intermediary) implementation year to 2050, taking into account whether the service has already been introduced or will appear only in the future.

Mode characteristics

This section can be found in the “Sub-models Calibration” sheet and the resulting calculations can be found in the “Modal Attributes” and “Urban Area Descriptors” sheets.

Once the average trip distances by distance bin and transport supply are computed, it is possible to determine the characteristics of each transport mode. These elements are key inputs for the mode choice model. The mode characteristics module estimates the features of each mode during a trip, including access time, waiting time, infrastructure connectivity, speed, travel time, travel cost and parking cost. These mode characteristics are calculated for each trip distance category.

Prior to that, an applicability matrix is set to determine whether a mode alternative is included in the mode choice or not.

Mode availability and applicability

The submodule for mode availability and applicability limits the number of mode alternatives considered in the mode choice. The availability and applicability are respectively determined by:

- **Transport supply in the urban area**. While some modes are available by default, such as walk, bicycle and private car, a few other might only appear in the future. In order to account for this, a mode alternative is only considered in the mode choice if there is a (future) transport supply for this mode (vehicle fleet or infrastructure). The availability of future modes varies depending on the scenario input. Tables 6 and 7 demonstrate the corresponding availability of four potential modes that do not appear in the Baseline scenario. The value "1" indicates that the mode is available in the selected year.

Table 6: Mode availability under the Current Policy scenario

	PT-BRT	Bike and scooter sharing	Car-Sharing	PT-On-demand Transport
2015	-	-	-	-
2020	-	-	-	-
2025	1	1	-	-
2030	1	1	-	-
2035	1	1	-	-
2040	1	1	-	-
2045	1	1	-	-
2050	1	1	-	-

Source: ITF Tashkent Urban Mobility Model

Table 7: Mode availability under the Climate Ambition scenario

	PT-BRT	Bike and scooter sharing	Car-Sharing	PT-On-demand Transport
2015	-	-	-	-
2020	-	-	-	-
2025	1	1	1	1
2030	1	1	1	1
2035	1	1	1	1
2040	1	1	1	1
2045	1	1	1	1
2050	1	1	1	1

Source: ITF Tashkent Urban Mobility Model

- **Distance bin**. Certain modes are usually used on limited distances only. For instance, walking and biking are often considered for short-distance trips, hence they are excluded from the mode choice for the highest trip distance categories in the model. The applicability of each mode for each distance bin can be manually defined in the "Sub-models Calibration" sheet. This applicability is represented as a matrix, with "1" indicating that the mode is applicable for the related distance bin and "0" otherwise. An extract of the applicability matrix for Tashkent is provided in Table .

Combining the availability and applicability elements allows to determine the final set of mode alternatives for the mode choice model.

Table 8: Mode applicability matrix for Tashkent

Mode	Mode ID	Distance bin					
		bin 0	bin 1	bin 2	bin 3	bin 4	bin 5
		< 1km	1 - 2.5 km	2.5 km - 5 km	5 km - 10 km	10 - 20 km	20 km
Walk	M_1	1	1	1	-	-	-
Bicycle	M_2	1	1	1	1	-	-
Motorcycle	M_3	1	1	1	1	1	1
Car	M_4	1	1	1	1	1	1
Taxi	M_5	1	1	1	1	1	1
PT-Rail	M_6	-	-	1	1	1	1
PT-Metro	M_7	-	1	1	1	1	1
PT-Bus	M_8	1	1	1	1	1	1
PT-BRT	M_9	-	1	1	1	1	1
PT-Minibus	M_10	1	1	1	1	1	1
Bike and scooter sharing	M_11	1	1	1	1	-	-
Ride-sharing	M_12	1	1	1	1	1	1
Car-sharing	M_13	-	1	1	1	1	1
On-demand Transport	M_14	1	1	1	1	1	1

Source: ITF Tashkent Urban Mobility Model

Speed

The speed attribute refers to the average speed of a mode in kilometres per hour. The initial values are provided for the base year 2015, which are then updated automatically for future years. Additional constraints are also introduced to avoid unrealistic values. The 2015 values can be found in the "Transport Indicators" sheet.

Several user-defined measures can have an impact on the access time for certain modes: "Infrastructure expansion for bike network" (BN), "Infrastructure expansion for pedestrian network" (PN), "Service improvement for mass transit" (MTS), "Service improvement for conventional bus" (PTS) and "Public transport priority" (PTP).

The speed formulas from 2020 onwards are presented below:

Walk:

$$= \min\left(\text{MaximalValue}, \text{speed}_{\text{old}}^{1+\text{PNcoeffxPN}}\left(\frac{\text{road 4 length} + \text{road 5 length}}{\text{road density} \times \text{urbanArea}}\right)\right)$$

Bike, Bike and scooter sharing:

$$= \min(\text{MaximalValue}, \text{speed}_{\text{old}}{}^{1+\text{ BN coeff} \times \text{BN}})$$

Car, Motorcycle, Car sharing, Ride sharing:

$$= \min(\text{MaximalValue}, \max(\text{MinimumValue}, \text{speed}_{\text{old}}{}^{1-(\text{ PN coeff} \times \text{PN} \times \left(\frac{\text{road 4 length+road 5 length}}{\text{road density x urbanArea}}\right) + \text{BN coeff} \times \text{BN} + \text{PTP coeff x PTP})}))$$

Taxi:

$$=\min(\text{MaximalValue}, \max(\text{MinimumValue}, \text{speed}_{\text{old}}{}^{1-\text{PTP coeff x PTP}}))$$

Rail, Metro, BRT:

$$= \min(\text{MaximalValue}, \max(\text{MinimumValue}, \text{speed}_{\text{old}}{}^{1+\text{MTS coeff} \times \text{MTS}}))$$

Bus, Minibus:

$$= \min(\text{MaximalValue}, \max(\text{MinimumValue}, \text{speed}_{\text{old}}{}^{1 + \text{PTScoeff} \times \text{PTS} + \text{PTPcoeff} \times \text{PTP}}))$$

Where MaximalValue and MinimumValue are respectively the upper limit and the lower limit of the speed value, $\text{road 4 length and road 5 length}$ are the network lengths for road type 4 and 5, road density is the overall road network density (km per sq km), $\text{measure}_{\text{coeff}}$ is an estimated coefficient for each of the applicable scenario measures (PN, BN, MTS, PTS and PTP).

Access time

Access time, as the name indicates, measures the average time in minutes needed to access a certain mode. For private vehicles, it is the average time to reach the place where the vehicle is parked. For public transport, it is the average time to reach the nearest stop/station. The initial values are given for the base year 2015, which are then updated automatically for future years. The 2015 values can be found in the "Transport Indicators" sheet.

Several user-defined measures can have an impact on the access time for public transport modes, such as infrastructure expansion (MN, BRTN, SRN, CBN), fleet expansion (CSI, BSI, ODS), "Vehicle access restrictions" (VAR), "Transit-oriented Development" (TOD) and "Mobility as a Service" (MAAS). Additional constraints are also introduced to avoid unrealistic values.

The access time formulas for each mode from 2020 onwards are shown below:

Bicycle:

$$= \max\left(\text{MinimumValue}, \text{AccessTime}_{\text{old}}\left(1 - \left(\text{PNcoeff} \times \text{PN} \times \left(\frac{\text{road 4 l ength} + \text{road 5 length}}{\text{road density x urbanArea}}\right)\right)\right)\right.$$

Motorcycle, Car:

$$= \max\left(\text{MinimumValue}, \text{AccessTime}_{\text{old}}\left(1 - \left(\text{PNcoeff} \times \text{PN} \times \left(\frac{\text{road 4 l ength} + \text{road 5 length}}{\text{road density x urbanArea}}\right)\right)\right.\right. \\ (1 - \text{VARcoeff} \times \text{VAR})(1 - \text{PRcoeff} \times \text{PR})\Bigg)$$

Rail, Metro, BRT:

$$= \max\left(\text{MinimumValue}, \text{AccessTime}_{\text{old}}\left(1 - \left(\text{PN coeff} \times \text{PN} \times \left(\frac{\text{road 4 l ength} + \text{road 5 length}}{\text{road density x urbanArea}}\right)\right)\right.\right.$$

$$\big(1 - (\text{SRN(MN, BRTN)coeff} \times \text{SRN(MN, BRTN)})\big)\big(1 - (\text{MAAS coeff} \times \text{MAAS})\big)\big(1 - (\text{TODcoeff} \times \text{TOD})\big)$$

Bus, Minibus:

$$= \max\left(\text{MinimumValue}, \text{AccessTime}_{\text{old}}\left(1 - \left(\text{PN coeff} \times \text{PN} \times \left(\frac{\text{road 4 l ength} + \text{road 5 length}}{\text{road density x urbanArea}}\right)\right)\right.\right.$$

$$(1 - (\text{PTS coeff} \times \text{PTS}))(1 - (\text{CBN coeff} \times \text{CBN}))(1 - (\text{MAAS coeff} \times \text{MAAS}))$$

$$\big(1 - (\text{TODcoeff} \times \text{TOD})\big)$$

On-demand transport, Shared modes:

$$= \max\left(\text{MinimumValue}, \text{AccessTime}_{\text{old}}\big(\text{FLEETcoeff} * \text{Sqrt(PI/fleet expansion)}\big)\right.$$

$$\left(1 - \left(\text{PNcoeff} \times \text{PN} \times \left(\frac{\text{road 4 l ength} + \text{road 5 length}}{\text{road density x urbanArea}}\right)\right)\right)$$

Where MinimumValue is the lower limit of access time, road 4 length and road 5 length are the network lengths for road type 4 and 5, road density is the overall road network density (km per sq km), fleet expansion represents one of the policy measure parameters (CSI, BSI and ODS) and $\text{measure}_{\text{coeff}}$ is an estimated coefficient for each of the applicable scenario measures (MN, BRTN, SRN, CBN, CSI, BSI, OD, VAR, TOD and MAAS).

Waiting time

Waiting time is the average time in minutes spent waiting to access or board a vehicle at a public transport stop or shared mobility station. It is set to zero for active modes and private vehicles. The initial values are given for the base year 2015, which are then updated automatically for future years.

Several user-defined measures can have an impact on the waiting time: "Service improvement for mass transit" (MTS), "Service improvement for conventional bus" (PTS), "Launch of on-demand services" (ODS), "Taxi incentives" (TI) and "Ride sharing incentives" (RSI).

The waiting time formulas for each mode from 2020 onwards are shown below:

Rail, Metro, BRT, Bus, Minibus:

$$= \max(\mathrm{MinimumValue}, \mathrm{WaitingTime_{old}}^{1+\mathrm{PTS(MTS)coeff} \times \mathrm{PTS(MTS)}})$$

On-demand transport:

$$= \mathrm{if}(\mathrm{ODS} = 0, \max(\mathrm{MinimumValue}, \mathrm{InitialValue} * \mathrm{Sqrt}(\frac{\mathrm{PI}}{\mathrm{ODS}})), \max(\mathrm{MinimumValue}, \mathrm{WaitingTime_{old}}^{1-\mathrm{FLEETcoeff}\times((\mathrm{ODS\ new}-\mathrm{ODS\ old})/\mathrm{ODS\ old})})$$

Taxi and Ride sharing:

$$= \max\left(\mathrm{Minimum\ value}, \mathrm{WaitingTime_{old}}^{1-\mathrm{FLEET\ coeff}\times\frac{\mathrm{TI(RSI)\ new}-\mathrm{TI(RSI)\ old}}{\mathrm{TI(RSI)\ old}}}\right)$$

Where $\mathrm{MinimumValue}$ is the lower limit of waiting time, $\mathrm{InitialValue}$ is the starting point value for waiting time and $\mathrm{measure_{coeff}}$ is an estimated coefficient for each of the applicable scenario measures (MTS, PTS, ODS, TI and RSI).

Infrastructure connectivity

The infrastructure connectivity indicator represents the advantage of extended and connected infrastructure for making more efficient trips. It is considered for all modes and explained by the following attributes:

- Car and Motorcycle: vehicle ownership;
- Rail: stop density;
- Walk, Bicycle, Metro, Bus and BRT: network density;
- Minibus: road density;
- Shared modes and on-demand transport: fleet size per 1000 inhabitants.

Travel distance and time

Travel time is traditionally and intuitively one of the most important factors in mode choice. In order to compute travel time, it is necessary to define the real travel distance and the average speed of each mode.

First, it is important to distinguish the trip distance from the real travel distance. The trip distance is considered "as the crow flies", while there are some additional detours for the real travel distance caused by the network density, shape and directionality. Additional elements, such as searching for parking with private modes or picking up passengers with on-demand transport, also have an impact on the resulting travel distance. The degree of indirectness heavily depends on the selected mode and distance bin, and it is generally much lower on longer distances.

In order to convert the trip distance into the travel distance, a mode-specific distance detour coefficient is applied:

$$\text{travel distance} = \text{coefficient}_{\text{detour}} \times \text{trip distance}$$

This coefficient is always above 1. The initial matrix providing all distance detours per mode and distance bin is presented in Table . The distance detour matrix is based on expert judgement and can be edited in the "Sub-models Calibration" sheet.

Table 9: Initial distance detour matrix

Code_mode	Mode	Distance bin					
		bin 0: < 1 km	bin 1: 1 - 2.5 km	bin 2: 2.5 - 5 km	bin 3: 5 - 10 km	bin 4: 10 - 20 km	bin 5: > 20 km
0	Walk	1.20	1.10	1.05	1.02	1.02	1.02
1	Bicycle	1.22	1.15	1.10	1.05	1.02	1.02
2	Motorcycle	1.60	1.50	1.25	1.20	1.10	1.05
3	Car	1.75	1.50	1.25	1.20	1.10	1.05
4	Taxi	1.75	1.50	1.25	1.20	1.10	1.05
5	PT-Rail	1.20	1.15	1.10	1.08	1.05	1.03
6	PT-Metro	1.20	1.15	1.10	1.08	1.05	1.03
7	PT-Bus	1.40	1.33	1.25	1.20	1.15	1.08
8	PT-BRT	1.30	1.20	1.10	1.08	1.05	1.03
9	PT-Minibus	1.40	1.33	1.25	1.20	1.15	1.08
10	Bike and scooter shar	1.40	1.32	1.27	1.10	1.02	1.02
11	Ride-sharing	1.75	1.50	1.25	1.20	1.10	1.05
12	Car-sharing	1.84	1.58	1.31	1.23	1.10	1.05
13	On-demand Transport	2.05	1.76	1.46	1.41	1.29	1.23

Source: ITF Tashkent Urban Mobility Model

The travel time for each distance bin and mode is obtained through the travel distance divided by the corresponding speed.

Travel costs

Overview of travel costs

The last modal attribute, probably as important in mode choice as travel time, is travel costs (in USD). The travel costs consist of several components, which are distance-based (e.g. fuel costs, taxi fares), trip-based (e.g. public transport fare, parking fare) and long-term (vehicle ownership and maintenance). These cost components significantly vary by mode.

The model incorporates three distinct categories of costs: transport fares, which can be found in the "Urban Area Descriptors" sheet, along with the average trip cost and parking cost, both of which are located in the "Modal Attributes" sheet.

Transport fares

The initial values for 2015 are user input values, which can be found in the "Transport Indicators" sheet. From 2020 onwards, the estimation of transport fares follows the formula:

$$\text{TF} = \text{TF}_{\text{old}} \times \frac{\text{GRP per capita new}}{\text{GRP per capita old}}^{\text{Elasticity coeff}} \times \text{PTF}$$

Where Elasticity coeff refers to the responsiveness, or elasticity, of different fare types to GRP per capita; PTF is the measure "Public transport fare integration", which applies to public transport modes only.

The elasticity coefficients can be found and further updated in the "Sub-models Calibration" sheet.

Table 10: Transport fare elasticity by mode

Elasticity to GDP per capita	Value
Elasticity of taxi fixed	0.70
Elasticity of taxi var km	0.80
Elasticity of taxi var hour	0.70
Elasticity of PT fare	0.60
Elasticity of minibus fare	0.70
Elasticity of PT subscription	0.60
Elasticity of Ride Sharing fixed	0.60
Elasticity of Ride Sharing var km	1.00
Elasticity of Ride Sharing var hour	0.60

Source: ITF Tashkent Urban Mobility Model

Average trip cost

The average trip cost provides a comprehensive cost estimation that includes various economic, operational, and behavioural factors that affect the price of travel using different transportation modes.

Several user-defined measures can have an impact on the average trip cost, such as “Road pricing” (RP), “Fuel tax” (FT) and “Vehicle ownership and purchase tax” (VT). It is assumed that electric vehicles are charged lower parking costs as an incentive for their adoption.

The estimation of average trip costs follows the formula:

Motorcycle, Car:

$$= \left\langle \begin{array}{c} \text{GRPcoeff} \times \text{GRPperCapita}^{\text{GRPpower}} \times \\ \left\{1 + \text{VT} \times \begin{bmatrix} \text{ELEC coeff} \times \text{Share of Electric VKM} + \\ \text{(1-Share of Electric VKM)} \end{bmatrix}\right\} + \\ \{\text{Average cost per VKM} \times [1 + (1 - \text{Share of Electric VKM}) \times \text{FT}]\} \times \text{Distance} \\ + \text{RP coeff} \times \text{RP} \end{array} \right\rangle \Big/ \text{Load Factor}$$

Bike and scooter sharing:

$$= (\text{Taxi fixed start cost} \times \text{Ratio coeff} + \text{Taxi variable per km cost} \times \text{Ratio coeff} \times \text{Distance}) \times (1 - \text{Fleet coeff} \times \text{BSI})$$

Car sharing:

$$= \left(\begin{array}{c} \text{Taxi fixed start cost} \times \text{Ratio coeff} + \\ \text{Taxi variable per km cost} \times \text{Ratio coeff} \times \text{Distance} \end{array} \right) \times (1 - \text{Fleet coeff} \times \text{CSI}) \Big/ \text{Load Factor}$$

Taxi and Ride sharing:

$$= \frac{\text{Taxi fixed start cost} + \text{Distance} \times \text{Taxi variable per km cost} + \text{Share Stop} \times \text{Taxi variable per hour}}{\text{Load Factor}}$$

Where GRPcoeff and GRPpower are calibrated model coefficients, ELECcoeff – discount rate applied to taxes for electric vehicles, Share of Electric VKM refers to the share of vehicle-kilometers traveled by electric vehicles, Average cost per VKM – cost of driving a vehicle per kilometer (mostly based on fuel cost), Load Factor – average number of persons per vehicle, Taxi fixed start/variable per km/variable per hour cost – various components of the composite taxi tariff, Ratio coeff – conversion factor across different shared mobility services.

Parking cost

This attribute represents costs associated with parking a vehicle at a paid location. It mostly concerns private vehicles (car and motorcycle) and depends on the vehicle engine type. It is assumed that electric vehicles are charged lower parking costs as an incentive for their adoption. The evolution of the parking cost stems from the user-defined measure "Parking pricing" (PP). Then, it is estimated with the following formula:

$$\text{parking cost} = \text{parking cost}_{\text{old}} \times \ (1 - \text{ELECcoeff} \times \text{ShareofElectricVKM})$$

Where ELECcoeff – discount rate applied to parking fares for electric vehicles.

Vehicle technology adjustment

The share of green technologies (hydrogen, hydrogen-hybrid and electric) per mode can vary. For instance, it is common to observe modern vehicles in taxi and car sharing fleets, which would then have a better average performance than private vehicles. The opposite applies to paratransit services (minibus) that usually have less strict performance requirements compared to public buses.

However, the user is requested to provide input only for the technology stock targets for Car (CTECH) and Bus (BTECH), as presented in Figure 4 (for more information, see description in the "Scenario Measures" chapter).

Figure 4: Measures CTECH and BTECH

Measure code	Measure name	Description of value to be provided		Implementation year	Anticipated values in implementation year	Anticipated values in 2050
CTECH	Technology stock targets for car fleet	Shares of different vehicle technologies in private car fleet (%). **Please note that if you specify the shares, they will substitute the default shares of the IEA scenario. Please make sure the sum of the shares is 100%, otherwise the default IEA shares will be used.**	Gasoline	2025	60%	35%
			Gasoline-hybrid		0%	0%
			Diesel		0%	0%
			Diesel-hybrid		0%	0%
			LPG/CNG		30%	15%
			Hydrogen		0%	0%
			Hydrogen-hybrid		0%	0%
			Electric		10%	50%
			Total		**100%**	**100%**
BTECH	Technology stock targets for bus fleet	Shares of different vehicle technologies in bus fleet (%). **Please note that if you specify the shares, they will substitute the default shares of the IEA scenario. Please make sure the sum of the shares is 100%, otherwise the default IEA shares will be used.**	Gasoline	2025	0%	0%
			Gasoline-hybrid		0%	0%
			Diesel		60%	0%
			Diesel-hybrid		0%	0%
			LPG/CNG		15%	0%
			Hydrogen		0%	0%
			Hydrogen-hybrid		0%	0%
			Electric		25%	100%
			Total		**100%**	**100%**

Source: ITF Tashkent Urban Mobility Model

Additional adjustment factors are applied to the input shares to reflect the technology composition for other modes, which are expected to have higher or lower performance targets. The values are presented in Table 11 and can be found in the "Sub-models Calibration" sheet. This is a product of the initial calibration based on expert judgement; the factors can be further adapted to the local context.

Table 11: Vehicle technology adjustment factors

Mode	Value
Taxi	10%
PT-Minibus	-20%
Car-sharing	10%
Ride-sharing	-20%
PT-BRT	20%

Source: ITF Tashkent Urban Mobility Model

TRIP GENERATION AND MODE CHOICE MODELS

This chapter describes the key steps of generating trips and splitting this overall travel demand across the available modes.

Trip generation model

This submodule can be found in the "Sub-models Calibration" sheet and the resulting calculation can be found in the "Trip Rate & Distances" sheet.

The trip generation submodule estimates the trip rate (average daily number of trips per inhabitant) for the urban area and each population group. The population groups are determined by two gender categories and five age categories, as shown in Table 12. The trip rate evolution is, primarily, a function of GRP per capita. The trip rate is estimated with the formula below:

$$\text{Trip rate} = \log(\text{GRP}_{\text{coeff}} * \text{GRP per capita}) * \exp\left(\text{Constant} + \text{Gender} + \text{Age}_{\text{group}}\right)$$

Where $\text{GRP}_{\text{coeff}}$ and Constant are fixed parameters of the trip generation function calibrated for the urban area, Gender and $\text{Age}_{\text{group}}$ are parameters with fixed values depending on the respective gender and age population groups, and GRP per capita is the actual value of GRP for the selected year. All of the calibrated parameters are extracted from the ITF Global Urban Passenger Transport Model and can be further adjusted in the "Sub-models Calibration" sheet.

Table 12: Trip rate model coefficients

Variable	Category	Value
Constant	All	0.200
GRPcap	All	0.005
Gender	M	-0.050
Gender	F	0.106
Age_group	0-19	0.136
Age_group	20-34	0.240
Age_group	35-54	0.310
Age_group	55-69	0.184
Age_group	70+	0.000

Source: ITF Tashkent Urban Mobility Model

Mode choice model

This submodule can be found in the "Sub-models Calibration" sheet and the resulting calculations can be found in the "Mode Share Utilities" sheet.

The mode choice model is a logit model with 14 alternative modes presented in the previous chapter. Although there are 14 modes in the default settings, the availability of each mode is activated according to the existence of this mode over time and its applicability for certain travel distances.

This model uses a standard discrete choice approach, explaining aggregate mode shares with the attributes of each transport mode (e.g. travel time, travel cost, access time, infrastructure connectivity, etc.).

The following equation describes the probability, P, of choosing mode m, over K modes:

$$\mathrm{P_m} = \frac{\mathrm{e}^{\mathrm{u_m}}}{\sum_{\mathrm{k=1}}^{\mathrm{K}} \mathrm{e}^{\mathrm{u_k}}}$$

The utility, U_m, of each mode m is computed using the generic utility function below. The utility function varies across different modes. For example, the parking cost is only applied to motorised private modes.

$$\mathrm{U_m} = \mathrm{Gender_{coeff}} * \log\left(\mathrm{ASC_m} + \beta_{\text{travel time}} * \text{travel time}_\mathrm{m} + \beta_{\text{cost}} * \text{travel cost}_\mathrm{m} + \beta_{\text{access time}} * \text{access time}_\mathrm{m} + \beta_{\text{waiting time}} * \text{waiting time}_\mathrm{m} + \beta_{\text{parking cost}} * \text{parking cost}_\mathrm{m} + \beta_{\text{infrastructure}} * \text{infrastructure}_\mathrm{m} + \beta_{\text{measure}} * \text{measure}_\mathrm{m}\right) * \text{availability}_{\mathrm{m,year}}$$

ASC is the alternative specific constant for each mode, accounting for any of the other decision-making criteria that are not reflected in the included modal attributes; β is the estimated coefficient for each of the modal attributes, including travel time, travel cost, access and waiting time, parking cost, and infrastructure, as well as for applicable scenario measures; $\mathrm{Gender_{coeff}}$ is the gender coefficient.

To incorporate gender-specific modal preferences, an additional dummy variable is included in the mode choice utility function. According to the global practice, female travellers tend to use private vehicles (bike, motorcycle and car) less often, opting instead for public transport and shared mobility services. The initial mode choice model is calibrated for female users, which then gets adjusted to male travellers through the gender coefficient.

Several user-defined measures can increase the utility of shared modes and public transport, such as “Service improvement for mass transit” (MTS), “Service improvement for conventional bus” (PTS), “Public transport fare integration” (PTF), “Mobility as a Service” (MAAS), “Launch of on-demand services” (ODS) and “Transit-oriented development” (TOD).

The parameters and ASCs for each mode, as obtained by the discrete choice model, are presented in Table .

Table 13: Calibrated coefficients of the mode choice model

Mode	Mode ID	Gender	ASC	Access time	Waiting time	Cost	Parking cost	Infrastructure	Travel time
Walk	M_1	1.00	0.0					0.040	-2.30
Bicycle	M_2	1.30	-2.5					1.000	-2.30
Motorcycle	M_3	1.60	-2.8			-0.20	-0.20	0.030	-2.30
Car	M_4	1.40	0.0			-0.20	-0.20	0.003	-2.30
Taxi	M_5	0.90	-1.3	-0.045	-0.05	-0.20		0.600	-2.30
PT-Rail	M_6	0.60	-0.3	-0.045	-0.05	-0.20		21.000	-2.30
PT-Metro	M_7	0.60	0.0	-0.045	-0.05	-0.20		1.800	-2.30
PT-Bus	M_8	0.50	-0.5	-0.045	-0.05	-0.20		0.080	-2.30
PT-BRT	M_9	0.60	0.0	-0.045	-0.05	-0.20		1.500	-2.30
PT-Minibus	M_10	0.50	-0.7	-0.045	-0.05	-0.20		0.040	-2.30
Bike and scooter sharing	M_11	1.30	-1.6	-0.045	-0.05	-0.20		0.600	-2.30
Ride-sharing	M_12	0.90	-1.3	-0.045	-0.05	-0.20		0.300	-2.30
Car-sharing	M_13	1.30	-0.5	-0.045	-0.05	-0.20		1.250	-2.30
PT-On-demand Transport	M_14	0.50	-1.0	-0.045	-0.05	-0.20		7.000	-2.30

Mode	Mode ID	MTS Coeff	PTS Coeff	PTF Coeff	MAAS Coeff	ODS Coeff	TOD Coeff
Walk	M_1						
Bicycle	M_2						
Motorcycle	M_3						
Car	M_4						
Taxi	M_5				0.4		
PT-Rail	M_6	0.2		0.3	0.4	0.0003	1.00
PT-Metro	M_7	0.2		0.3	0.4	0.0003	1.00
PT-Bus	M_8		0.2	0.3	0.4		1.00
PT-BRT	M_9	0.2		0.3	0.4	0.0003	1.00
PT-Minibus	M_10		0.2	0.3	0.4		1.00
Bike and scooter sharing	M_11				0.4		
Ride-sharing	M_12				0.4		
Car-sharing	M_13				0.4		
PT-On-demand Transport	M_14			0.3	0.4		1.00

Source: ITF Tashkent Urban Mobility Model

OUTPUTS

This chapter describes the final steps transforming travel demand into vehicle activity, and eventually into related emissions. The main outputs of the model include mode shares, passenger-kilometres, vehicle-kilometres, CO_2 emissions, and local pollutant emissions. Each output item is presented by mode, gender and distance bin.

Passenger-kilometres

The total number of trips is first computed by multiplying the total population by the average trip rate (number of trips per day per inhabitant). This demand is then allocated to different modes through the application of the estimated mode shares stemming from the mode choice model (as presented in the previous chapter). A multiplication by the average trip distance by mode gives the total number of passenger-kilometres.

$$\text{PKM}_{\text{year,gender,dist,mode}} = \left(\sum \text{population}_{\text{year, gender}} \times \text{trip rate}_{\text{year, gender}}\right)$$

$$\times \text{share of trips}_{\text{dist}} \times \text{mode share}_{\text{dist}} \times 365 \div 1000 \times \text{trip distance}_{\text{dist}}$$

Where $\text{population}_{\text{year, gender}}$ is the total population by gender for a selected year, $\text{trip rate}_{\text{year, gender}}$ is the average daily number of trips per inhabitant, $\text{share of trips}_{\text{dist}}$ refers to the proportion of total trips within a specific distance range, $\text{mode share}_{\text{dist}}$ is the mode share within each distance range, $\text{trip distance}_{\text{dist}}$ is the average trip distance for each distance range.

Vehicle-kilometres

Vehicle-kilometres directly result from the application of the average load factor per mode (number of persons per vehicle) to passenger-kilometres. Load factors of the Baseline scenario correspond to the assumptions of the IEA'S NPS Scenario (IEA, 2020). Load factors of the alternative scenarios can either take the assumptions of the IEA'S SPS Scenario (IEA, 2020) or can be directly adjusted by the user. Values for the base year are summarised in Table below. Load factors for individual modes tend to remain stable in projections, to the contrary of those growing for public transport.

Table 14: Vehicle load factors by mode in 2015

Mode	Load factor (pers. / veh.)
Motorcycle	1.1
Car	1.5
Taxi	2.1
PT-Rail	205.1
PT-Metro	205.1
PT-Bus	23.6
PT-BRT	47.1
PT-Minibus	6.3
Bike and scooter sharing	1.0
Ride-sharing	2.1
Car-sharing	1.9
PT-On-demand Transport	6.3

Source: IEA's Mobility Model, 2020

CO_2 and local pollutant emissions

Tank-to-Wheel CO2 emissions

Tank-to-Wheel (TTW) CO_2 emissions are calculated as a result of transport demand by mode and vehicle types. First, the total number of vehicle-kilometres by mode is assigned to different vehicle technologies. Then, fuel consumption by fuel type is calculated by applying the average fuel economy for each mode, vehicle technology and fuel type to vehicle-kilometres travelled. CO_2 emissions for each fuel type then result from the application of CO_2 emission factors by fuel type.

$$\text{TTW CO}_2\text{ emissions} = \text{VKM}_{\text{mode}} \times \text{share of VKM}_{\text{fuel type, mode}} \times \text{fuel econ}_{\text{fuel type, mode}} \times \text{TTW CO2 emission factor}_{\text{fuel type, mode}}$$

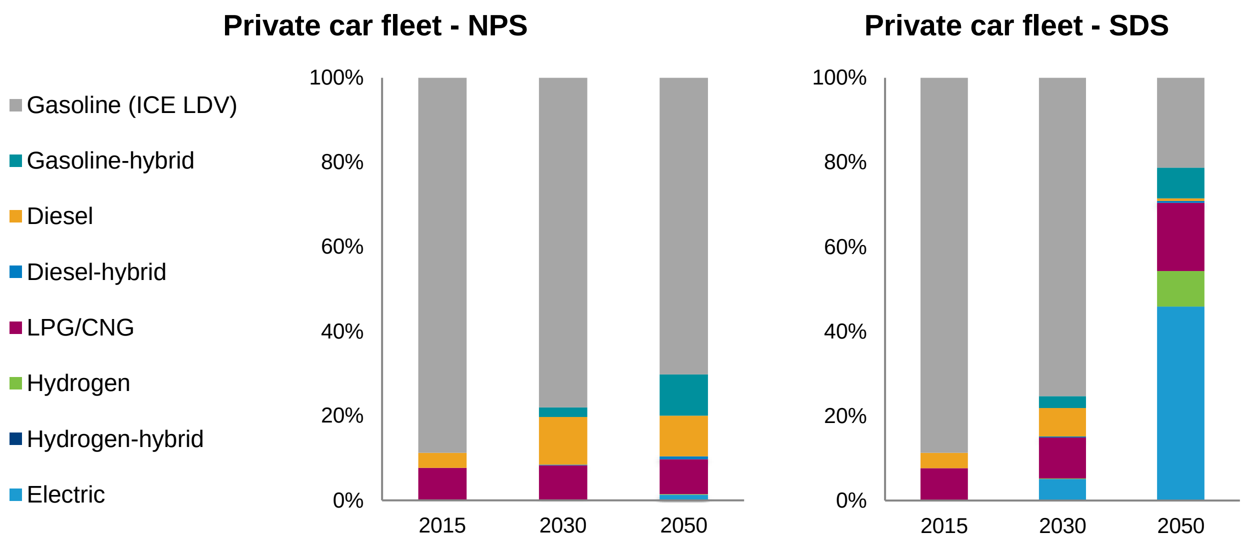
Alternative scenarios can test higher penetration rates of alternative-fuelled vehicles. The alternative vehicle technology scenario used in this study comes from the IEA's SDS scenario (IEA, 2020). Figure display respectively the private car fleet and bus fleet composition by fuel type for the base year and projected years for both IEA scenarios.

The model user can also overwrite the technology settings of the IEA scenarios for the private car fleet and the bus fleet by applying the respective measures CTECH and BTECH (see description in the "Scenario Measures" chapter).

Well-to-Tank CO2 emissions

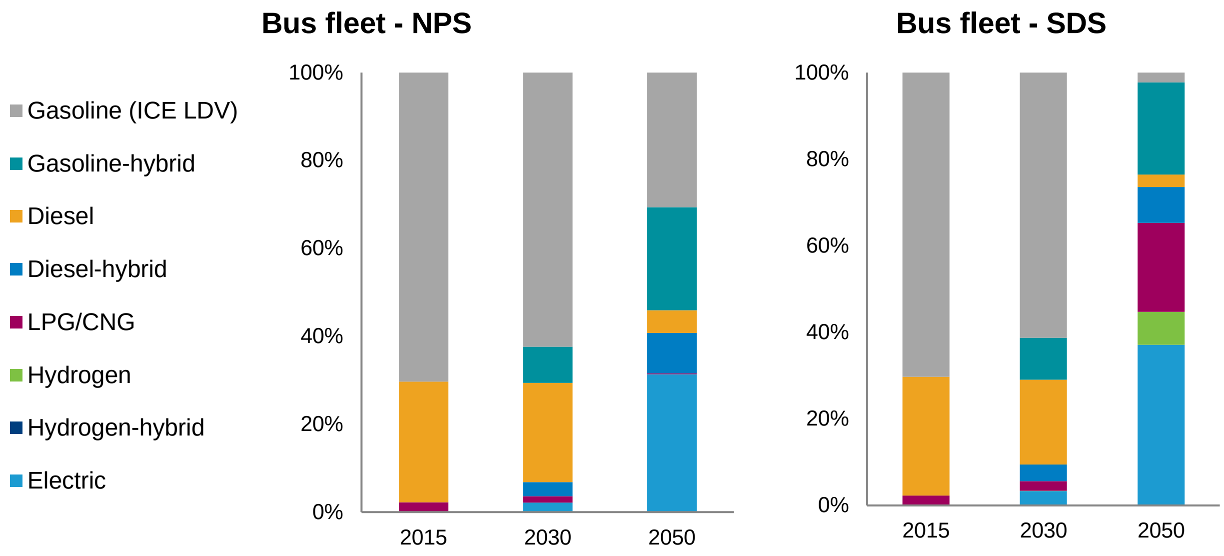
In this model, the outputs also include Well-to-Tank (WTT) CO_2 emissions in order to reflect the full scope of the emissions associated with urban mobility. The WTT emissions consider the emissions from fuel production and distribution. Two WTT emission factors are possible, coming from the IEA NPS and SDS scenarios respectively (IEA, 2020). The two scenarios diverge on possible sources of electricity for the coming decades. In the SDS scenario, there is almost a 100% shift to renewable energy by 2050. This has a significant impact on the overall emissions of urban rail (e.g. metro, commuter rail), or any other mode where electric vehicles largely penetrate the market.

Figure 5: Private car fleet by fuel type under different IEA scenarios



Source: IEA's Mobility Model, 2020

Figure 6: Bus fleet by fuel type under different IEA scenarios



Source: IEA's Mobility Model, 2020

Local pollutants

Urban transport is a significant contributor to local air pollution, principally through the emission of oxides of nitrogen (NOx), sulphates (SO4) and particulate matter measuring 2.5 microns or less (PM2.5). CO_2 emission is strictly proportional to the fuel consumption of vehicles, while the quantity of local pollutants per unit of fuel in exhaust fumes can vary greatly. This model uses emission factors from the Roadmap model of the International Council on Clean Transportation (ICCT, 2019). The ICCT Roadmap includes expected improvements in vehicle efficiency standards and their probable penetration in vehicle fleets until 2050.

SCENARIO MEASURES

This chapter details the definition of each measure that feeds the “Scenario Setting” sheet and how it affects different model components and parameters (e.g. urban area growth, transport supply, mode share, travel demand, etc.).

Measures overview

The model contains a total of 30 measures from seven categories: Infrastructure expansion, Public transport promotion, Shared transport promotion, Restrictive measures, Pricing measures, Vehicle technology development and Other measures. Other measures are a group of exogenous scenario variables, of which, it is assumed that the decision-making authority does not have full control.

These measures cover a wide range of policy and technology alternatives, affecting the built environment, transport supply, transport demand and average vehicle emissions. This variety of measures enables testing the combined impact of several measures together within a scenario, on the final urban transport demand and related CO_2 emissions (including TTW and WTT emissions) as well as other pollutants such as NOx, PM2,5 and SO4.

For most of the measures, an anticipated value in the implementation year and a target value by 2050 are assigned by the user. The model automatically converts these two values into a set of parameters for each five-year temporal step of the model, which are used in the model iterations. These parameter values can be further edited in the “Scenario Parameters” sheet if non-regular/non-linear measure implementations are desired.

Figure 7: Scenario setting in the model

Selected scenario	Baseline		Insert your values into these columns			Suggested value range	
Measure code	Measure name	Description of value to be provided	Implementation year	Anticipated values in implementation year	Anticipated values in 2050	MIN	MAX
		Infrastructure Expansion					
MN	Metro network	Total network length (km)	2015		36.2	35	300
			2020		59.5	35	300
			2025		59.5	35	300
			2030		59.5	35	300
			2035		59.5	35	300
			2040		59.5	35	300
			2045		59.5	35	300
			2050		59.5	35	300
BRTN	BRT network	Total network length (km)	2015		0.0	0	300
			2020		0.0	0	300
			2025		0.0	0	300
			2030		0.0	0	300
			2035		0.0	0	300
			2040		0.0	0	300
			2045		0.0	0	300
			2050		0.0	0	300
SRN	Suburban rail network	Total number of stops	2015		8	8	30
			2020		8	8	30
			2025		8	8	30
			2030		8	8	30
			2035		8	8	30
			2040		8	8	30
			2045		8	8	30
			2050		8	8	30
CBN	Conventional bus network	Total network length (km)	2015		3800.0	2500	10000
			2020		3800.0	2500	10000
			2025		3800.0	2500	10000
			2030		3800.0	2500	10000
			2035		3800.0	2500	10000
			2040		3800.0	2500	10000

Source: ITF Tashkent Urban Mobility Model

In the following sections, information on each measure that the model user can apply to define scenarios is provided. A description of the measure is followed by a description of how the measure is implemented in the model. In the last section on each policy direction, the impact of the measures on CO_2 emissions is provided. The impact assessment for each policy direction is done by comparing two scenarios with each other that only differ in the settings of the specific policy direction that is being discussed.

Infrastructure expansion

Public transport infrastructure improvement [MN], [BRTN], [CBN]

Reinforcing the supply of public transport infrastructures increases their network length. It leads to improving the overall PT area coverage, connectivity, presence of sustainable mobility and transport safety.

The user sets a target for the total network length of metro, BRT and conventional bus between 2015 and 2050. The model also converts these values into:

- Total network length for metro, BRT and conventional bus.
- Decrease in the access time for metro, BRT and conventional bus.

Suburban rail network improvement [SRN]

Similar to the previous measure, the number and location of stations on the existing railway lines influence the access time, transport connectivity and overall sustainability and safety of urban mobility.

The user sets a value for the total number of stops between 2015 and 2050. The model converts this value into:

- Total number of rail stops.
- Decrease in the access time for suburban rail.

Enhancement of the bike network [BN]

Enhancing the supply and network design of cycling infrastructure in a city encourages more people to cycle. This measure allows for faster and safer travel by bike thanks to dedicated infrastructure. However, most of the motorised modes experience additional impedance as cyclists receive priority at intersections and other crossing points.

The bike network already exists in the city. The user sets a target for the total network length (km) for a future expansion year and 2050. The model converts this value into:

- Increase in the bike network length.
- Increase in the share of trips in the two lowest distance categories.
- Increase in the speed for bike and scooter sharing.
- Decrease in the speed for motorised modes (except for prioritised PT and taxi).

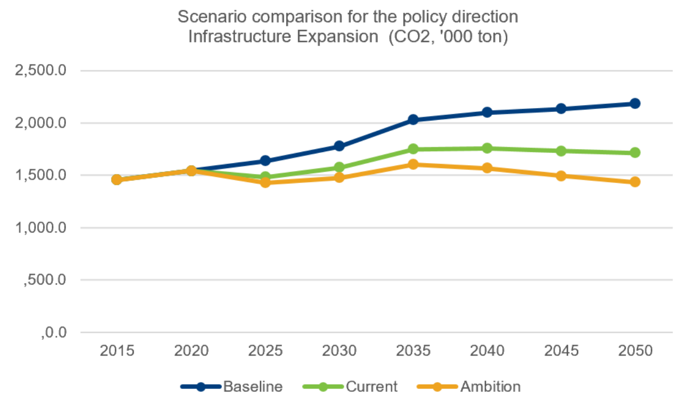
Enhancement of the pedestrian network [PN]

Enhancing the supply and network design of walking infrastructure in a city encourages more people to walk. More users with various physical abilities and needs can move freely in the city, being able to access a larger variety of destinations as well as the locations of other modes (including public transport). However, most of the motorised modes experience additional impedance as pedestrians receive priority at intersections and other crossing points.

The pedestrian network already exists in the city. The user sets a target for a future expansion year and 2050. The model converts this value into:

- Increase in the pedestrian network length (road category 4 and 5).
- Increase in the share of trips in the two lowest distance categories.
- Decrease in the access time for all modes.
- Increase in the speed for walking.
- Decrease in the speed for motorised modes (except for prioritised PT and taxi).

Figure 8: Impact on CO_2 emissions from Infrastructure expansion

<table>
<tr><td>CO_2 emissions in the study period</td><td>Impact</td></tr>
<tr><td colspan="2">Evolution 2015-2050</td></tr>
<tr><td>
</td><td>Reduction in transport-related CO_2 emissions attributed to the policy direction compared to Baseline in the same year

By 2030 / By 2050
Current Policy: -12% / -22%
Climate Ambition: -17% / -34%</td></tr>
</table>

Public transport promotion

Service improvement for mass transit [MTS]

Improved service for mass transit modes implies better planning by enhancing future network route design, network frequency and timetable development, and by optimising vehicle and staff scheduling. This makes the service more convenient for existing and potential passengers.

The user sets a target for the increase in operating speed from service improvement, including ICT (%) for the anticipated implementation year and 2050. The model converts this value into:

- Decrease in the waiting time for metro, BRT and suburban rail.
- Increase in the speed for metro, BRT and suburban rail.
- Increase in the utility for metro, BRT and suburban rail.

Service improvement for conventional bus [PTS]

This measure is similar to the previous one, however, the flexibility of conventional bus networks allows to reallocate bus stops, revise the entire route structure and apply modern technologies for real-time operations optimisation.

The user sets a target for the increase in operating speed from optimised stop positioning and service improvement, including ICT (%) for the anticipated implementation year and 2050. The model converts this value into:

- Decrease in the access time for bus and minibus.
- Decrease in the waiting time for bus and minibus.
- Increase in the speed for bus and minibus.
- Increase in the utility for bus and minibus.

Public transport priority [PTP]

Delays induced by public transport operations in mixed traffic account for a significant share of the total travel time of buses. This has an impact on the quality of service for users, may lead to lower public transport ridership and has an impact on fuel consumption and related emissions of public transit services. The creation of dedicated bus lanes and the implementation of transit signal priority for buses can enhance their efficiency and travel times. This infrastructure can also be used by legal taxi and ride sharing vehicles.

The user sets a target for the share of bus network that has priority over other road modes for the anticipated implementation year and 2050. The model converts this value into:

- Decrease in the speed of private motorised modes and car sharing.
- Increase in the speed of motorised PT modes, taxi and ride sharing.

Public transport fare integration [PTF]

Integration can take the form of a common payment mechanism, a single ticket on different operator services, a single ticket across different modes, or combinations of these elements. In most cases, an integrated ticketing system will also involve integrated tariffs, where common pricing structures exist across different modes and operators. Benefits to users include ease of access, time savings and greater flexibility, which can encourage public transit ridership.

The user sets a target for the average cost reduction of a public transport trip for the anticipated implementation year and 2050. The model converts this value into:

- Decrease in the growth of the PT fare and monthly subscription costs.
- Increase in the utility of all PT modes.
- Application of the standard PT fare to minibus.

Launch of on-demand services [ODS]

An on-demand transport service, such as a taxi-bus, offers a flexible and efficient way for passengers to request shared rides, combining the convenience of a taxi with cost-effective group transportation. Passengers can easily book these services through apps or platforms, optimising travel options for short distances or larger groups. Ideally, the on-demand service should be integrated into the public transport system, including its fare structure.

The user sets a target for the total size of the on-demand fleet (number of vehicles) for the anticipated implementation year and 2050. The model converts this value into:

- Evolution of the on-demand fleet.

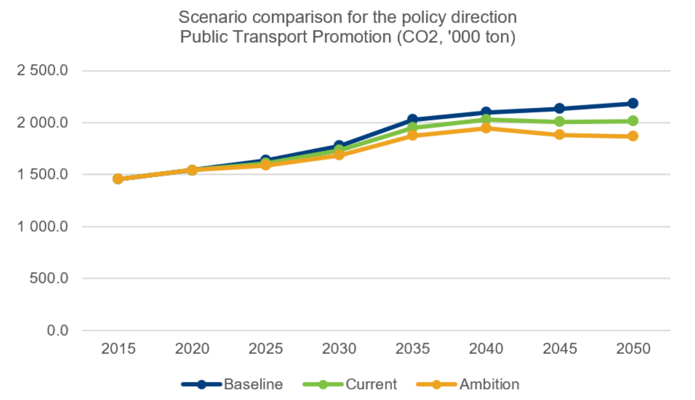
Mobility as a Service [MAAS]

MaaS is envisaged as an (app-based) transport service model. It integrates transport networks and services from all operators, such that all possible means of completing a journey (public and private) can be presented to, and completed by, travellers using a single interface or point of contact. Users would complete the whole journey (point-to-point) planning, purchasing of public transport tickets and booking of on-demand services, shared modes and micromobility through this platform.

The user sets a target for the expected share of the population with a MaaS subscription for the anticipated implementation year and 2050. The model converts this value into:

- Increase in the number of PT subscriptions.
- Decrease in the access time of all PT modes.
- Increase in the utility for PT and shared modes.

Figure 9: Impact on CO_2 emission from Public transport promotion

<table>
<tr><th>CO_2 emissions in the study period</th><th>Impact</th></tr>
<tr><td colspan="2">Evolution 2015-2050</td></tr>
<tr><td>
</td><td>Reduction in transport-related CO_2 emissions attributed to the policy direction compared to Baseline in the same year

| | By 2030 | By 2050 |
Current Policy: -3% (By 2030), -8% (By 2050)
Climate Ambition: -5% (By 2030), -15% (By 2050)</td></tr>
</table>

Shared transport promotion

Incentives for taxi [TI]

This measure focuses only on conventional taxi services. Taxis are typically owned and operated by individuals or taxi companies. These vehicles are dedicated for use as taxis and are subject to various regulations, including licensing, safety inspections, and fare structures. Taxis can be hailed on the street, called via phone, or found at designated taxi stands, although some companies have adopted app-based systems. Local or municipal authorities can control the total size of the taxi fleet by issuing or recalling operating licences. A larger taxi fleet can provide a convenient travel alternative to private vehicle users, and therefore increase the utilisation of private vehicles through higher load factors and reduce car ownership. However, it can also compete with public transport if the respective costs are set at comparable levels.

Taxi services are already present in the city. The user sets a target for the total size of the taxi fleet (number of vehicles) for an expected adjustment year and 2050. The model also converts these values into:

- Adjustment of the taxi fleet.
- Adjustment of the waiting time for taxi.

Incentives for ride sharing [RSI]

This measure focuses only on ride sharing services, including legally and illegally operated vehicles (see the next measure TMR). Such services do not own the vehicles used for transportation. Instead, they connect passengers with drivers who use their own personal vehicles. The legal services are primarily accessed through smartphone apps. The requirements on driver qualifications and vehicle characteristics are usually less stringent. In case of illegal operations, passengers request rides by street hailing. A larger ride sharing fleet can provide a convenient travel alternative to private vehicle users, and therefore increase the utilisation of private vehicles through higher load factors and reduce car ownership. However, it can also compete with public transport if the respective fares are set at comparable levels. The access of ride sharing services to the market is controlled by the relevant authority, but the exact number of vehicles and their operation might not be fully regulated, which creates a potential avenue for additional policies.

Ride sharing services are already present in the city. The user sets a target for the total size of the ride sharing fleet (number of vehicles) for an expected adjustment year and 2050. The model also converts these values into:

- Adjustment of the ride sharing fleet.
- Adjustment of the waiting time for ride sharing.

Taxi market reform [TMR]

Illegal taxi operations have been a persistent source of concern for Tashkent, giving rise to significant challenges that extend beyond the taxi and ride sharing industry itself. These challenges include the adverse impact on public transportation demand, compromised safety, comfort, and reliability, as well as substantial losses in municipal revenues due to untaxed taxi operations. To address these issues, a comprehensive reform of the taxi market has been introduced, seeking to foster a more conducive environment for legally operated vehicles. By doing so, the authorities can make sure that a larger share of vehicles operate on ride sharing platforms, and therefore their fares, driver qualifications and vehicle characteristics become possible to regulate.

The taxi market reform was introduced in 2020. The user sets a target for the share of legally operated vehicles in the total ride sharing fleet for the expected expansion year and 2050. The model also converts these values into:

- Increase in the ride sharing cost.
- Assignment of the privileges of official taxis (e.g. access to priority lanes).
- Improvement in the ride sharing emission performance.

Incentives for car sharing [CSI]

Car sharing is a type of car rental where users can rent vehicles for short periods of time (e.g. by the hour). Depending on the design of the service, it can operate with fixed locations/stations or as a free-flow scheme with any available parking locations in the city. Typically, users can localise vehicles or stations through web and/or mobile phone applications. Car sharing is usually attractive to individuals who make only occasional car trips, which can help to reduce private vehicle ownership. It can also be used in conjunction with public transport as an access and egress mode. Moreover, car sharing fleets are usually modern and regularly upgraded, so their average emission levels are lower than those of the private fleet.

The user sets a target for the total size of the car sharing fleet (number of vehicles) for the anticipated implementation year and 2050. The model also converts these values into:

- Evolution of the car sharing fleet.
- Decrease in the access time for car sharing.

Incentives for bike and scooter sharing [BSI]

Bike and scooter sharing programs provide convenient and sustainable transportation options in urban areas. These services offer access to (electric) bicycles and scooters as independent modes or for first- and last-mile connections, reducing the reliance on private modes on short distances. The shared micromobility model not only decreases traffic congestion and carbon emissions but also promotes a healthier and more active lifestyle.

The user sets a target for the total size of bike and scooter sharing fleet (number of units) for the expected implementation year and 2050. The model also converts these values into:

- Evolution of the bike and scooter sharing fleet.
- Decrease in the access time for bike and scooter sharing.

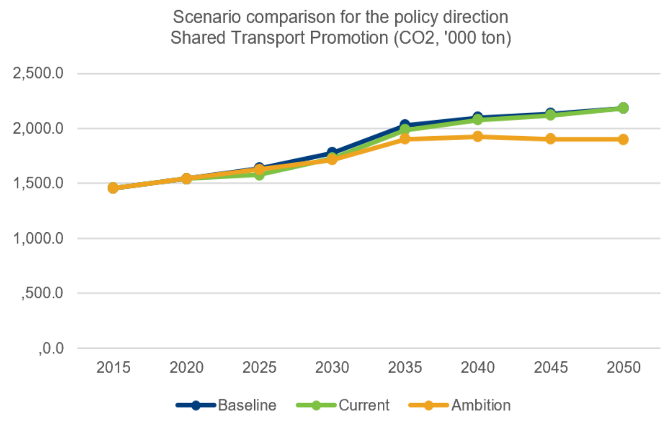
Carpooling incentives [CPI]

Carpooling policies favour the adoption of high occupancy car use. They aim at increasing the average car load factor, which is generally low and close to one, to reduce the traffic and the emissions per car user. Carpooling policies can promote the development of carpooling companies, provide advantages for high occupancy cars such as dedicated High Occupancy Vehicle (HOV) lanes or access to restricted zones or lanes, or reward carpooling with tokens or subsidies.

The user sets a target for the change in the load factor for private vehicles (%) for the anticipated implementation year and 2050. The model converts these values into:

- Increase in the load factor for motorcycle, car and car sharing.

Figure 10: Impact on CO_2 emission from Shared transport promotion

<table>
<tr><th>CO_2 emissions in the study period</th><th>Impact</th></tr>
<tr><td colspan="2">Evolution 2015-2050</td></tr>
<tr><td>
</td><td>Reduction in transport-related CO_2 emissions attributed to the policy direction compared to Baseline in the same year

<table>
<tr><th></th><th>By 2030</th><th>By 2050</th></tr>
<tr><td>Current Policy</td><td>-3%</td><td>-0.2%</td></tr>
<tr><td>Climate Ambition</td><td>-3%</td><td>-9%</td></tr>
</table></td></tr>
</table>

Restrictive measures

Parking restrictions [PR]

Parking restrictions are measures that affect the availability of parking space for private vehicles.. They can be applied to specific streets, areas, zones or the whole city. With implemented parking restriction measures, the accessibility level of private vehicles is decreased, which in turn disincentivises vehicle ownership. Policymakers must pay attention to avoid deteriorating the parking restricted zone's attraction by ensuring other modal alternatives' availability before implementing such measures.

The user sets a target for the share of the city core that is under (strong) parking restrictions for the anticipated implementation year and 2050. The model converts these values into:

- Increase in the private vehicle access time.
- Decrease in the growth of private vehicle ownership.

Vehicle access restriction [VAR]

Vehicle access restriction policies refer to setting a "cordon" in an urban area, i.e. block an area for a subset of the urban vehicle fleet for specific periods, to reduce congestion and emissions. Vehicle restriction policies may apply only during peak traffic periods or during the entire working day (e.g. a specific day or specific days during a week). In a more ambitious form, such policies imply a complete closure of a street or an area for traffic to create car-free zones.

The user sets a target for the share of private vehicles that will be restricted from circulating within the city for the implementation year and 2050. The model converts these values into:

- Decrease in the growth of private vehicle ownership.
- Increase in the access time for private vehicles.
- Increase in the private vehicle distance detour.

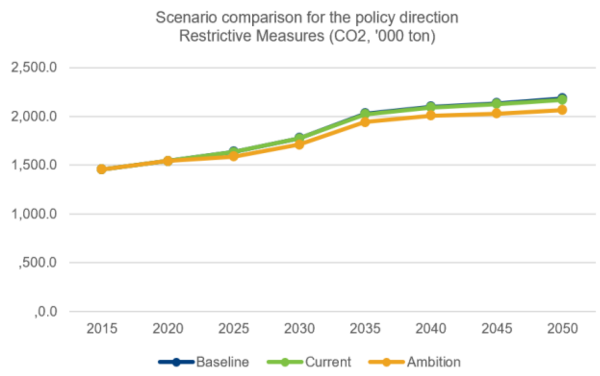
Speed limitation [SL]

Speed limitation aims to reduce the dominance of motorised vehicles, improving safety and environmental quality in urban areas. Normally, speed limitation should be applied as an area-wide technique. If applied only to a particular street, it runs the risk of pushing accidents, pollution and cut-through driving to areas with higher speed limits. Calming street infrastructure, with speed bumps, stop signs, and traffic circles, can further enhance the policy effectiveness.

The user sets a target for the speed limit reduction in percentage for the anticipated implementation year and 2050. The model converts these values into:

- Decrease in the reference road speed.
- Decrease in the growth of private vehicle ownership.

Figure 11: Impact on CO_2 emission from Restrictive Measures

CO_2 emissions in the study period	Impact
Evolution 2015-2050	
	Reduction in transport-related CO_2 emissions attributed to the policy direction compared to Baseline in the same year By 2030 / By 2050 Current Policy: -0.2% / -4% Climate Ambition: -0.5% / -5%

Pricing measures

Road pricing (congestion charging) [RP]

Congestion charging is a system where drivers are required to pay fees for entering high-traffic zones during a particular time period. This approach helps reduce traffic congestion, lower carbon emissions, and encourage shift to sustainable transport modes.

The user sets a target for the average fare for city entry (USD) for the anticipated implementation year and 2050. The model converts these values into:

- Increase in the cost of private motorised modes.
- Decrease in the growth of private vehicle ownership.

Parking pricing [PP]

Introducing parking pricing typically means to start charging motorists for the use of parking facilities. It can apply to commuter, non-commuter and residential parking. Parking pricing can have a significant impact on the cost of car ownership and use. As it does not vary with travel distances, its impact is more relevant for relatively shorter trips. In recent years, an increasing number of cities have adopted pricing that varies with vehicle environmental performance.

The user sets a target for the average parking fare (USD/h) for the anticipated implementation year and 2050. The model converts these values into:

- Increase in the private vehicle parking cost (electric vehicles receive discount).
- Decrease in the growth of private vehicle ownership.

Fuel tax [FT]

Fuel tax, when implemented as a carbon tax, involves levying a tax on the carbon content of fuels, aiming to reduce greenhouse gas emissions. This tax incentivises individuals and businesses to transition towards cleaner, more efficient transportation options and technologies.

The user sets a target for the increase in the vehicle usage costs (per km) for the anticipated implementation year and 2050. The model converts these values into:

- Increase in the cost of private emitting modes.
- Decrease in the growth of private emitting vehicle ownership.

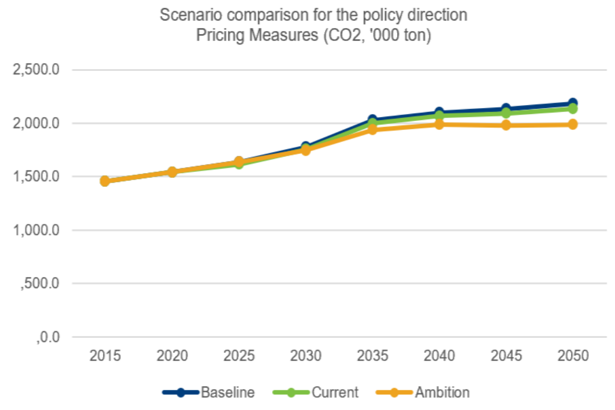
Vehicle ownership and purchase tax [VT]

Vehicle ownership tax is an annual tax that vehicle owners must pay to the government. This tax is typically calculated based on factors such as the vehicle's weight, engine size, emissions, or other factors related to its potential impact on the road and the environment. Vehicle purchase tax is levied at the time of purchasing a vehicle, often based on the vehicle's value, type, and sometimes its emissions or fuel efficiency. The tax can be a fixed amount or a percentage of the vehicle's purchase price. It's intended to generate revenue for the government and, in some cases, to discourage excessive consumption or to promote the adoption of more environmentally friendly vehicles.

The user sets a target for the increase in the vehicle ownership and purchase cost for the anticipated implementation year and 2050. The model converts this value into:

- Increase in the cost of private motorised modes (electric vehicles receive discount).
- Decrease in the growth of private vehicle ownership.

Figure 12: Impact on CO_2 emission from Pricing measures

<table>
<tr><td>CO_2 emissions in the study period</td><td>Impact</td></tr>
<tr><td colspan="2">Evolution 2015-2050</td></tr>
<tr><td>
</td><td>Reduction in transport-related CO_2 emissions attributed to the policy direction compared to Baseline in the same year

| | By 2030 | By 2050 |
Current Policy: -1% (by 2030), -2% (by 2050)
Climate Ambition: -2% (by 2030), -9% (by 2050)</td></tr>
</table>

Vehicle technology development

Vehicle fuel technology development and uptake - predefined scenarios [TECH]

The user can activate one of the IEA's technology scenarios. It can be 1) the IEA NPS corresponding to a baseline approach, or 2) the IEA SDS corresponding to a high ambition approach. For the description of each scenario, see the "Model Inputs: Exogenous" chapter of this document. For the scenario impact on CO_2 emissions, see the "Outputs" chapter.

The user chooses the IEA scenario: 0 triggers the IEA NPS scenario, while 1 triggers the IEA SDS scenario. This choice affects the way the emissions are calculated.

Technology stock targets for car fleet [CTECH]

Policies for greening private car fleets encompass a range of measures designed to incentivise and accelerate the adoption of environmentally friendly vehicles. These policies can include tax incentives, rebates, and subsidies to make electric and hybrid cars more affordable. Regulatory measures may also include stricter fuel efficiency standards and emissions limits. Additionally, the development of charging infrastructure and public awareness campaigns can complement these policies, making it more attractive for individuals to opt for greener car options.

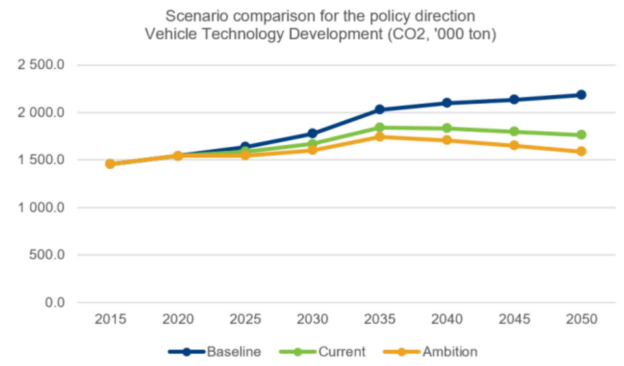
The user sets the expected shares of different vehicle technologies in the private car fleet in a target year and 2050. The model then recalculates the average emissions based on the fleet composition at a given year (which is backcasted from the target values) within the vehicle stock model.

Technology stock targets for bus fleet [BTECH]

Policies for greening bus fleets aim to reduce the environmental impact of public transportation by promoting the adoption of cleaner and more fuel-efficient buses. This typically involves transitioning from traditional diesel buses to electric, hybrid, or alternative fuel options, which result in lower greenhouse gas emissions and improved air quality. Government incentives, regulations, and investments in sustainable technology play a crucial role in achieving these goals.

The user sets the shares of different vehicle technologies in the bus fleet for the anticipated target year and 2050. The model then recalculates the average emissions based on the fleet composition at a given year (which is backcasted from the target values) within the vehicle stock model.

Figure 13: Impact on CO_2 emission from Vehicle technology development

<table>
<tr><td>CO_2 emissions in the study period</td><td>Impact</td></tr>
<tr><td colspan="2">Evolution 2015-2050</td></tr>
<tr><td>
</td><td>Reduction in transport-related CO_2 emissions attributed to the policy direction compared to Baseline in the same year

| | By 2030 | By 2050 |
Current Policy: -6% (By 2030), -19% (By 2050)
Climate Ambition: -10% (By 2030), -27% (By 2050)</td></tr>
</table>

Other measures

Teleworking promotion [TW]

Teleworking is broadly defined as carrying out work at a location that is remote from the employer's site while staying connected to the office via network technologies. Telework helps to reduce the number of commuting work trips, which tend to happen during peak hours and be longer than the average urban trip length. Encouraging teleworking can create an additional demand for short-distance trips, however, sustainable modes (especially active mobility) are more competitive on this range. Teleworking promotion has a potential role in travel demand management strategies that aim to decarbonise transport.

The user sets the share of active population that regularly teleworks in a target year and 2050, starting from an estimation of 1% for 2015. The model converts these values into:

- Increase in the share of trips in the three lowest distance categories.

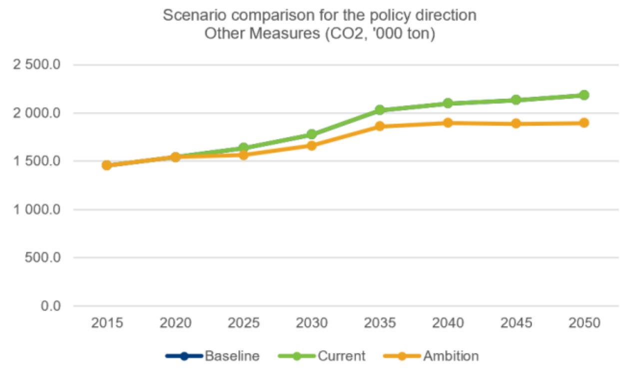
Transit Oriented Development and improved urban planning [TOD]

Transit-Oriented Development (TOD) targets the creation of compact, walkable, mixed-use communities centred around high-quality public transport systems. It integrates transport and land-use development practices. TOD leads to additional densification and public transport efficiency, reducing the need to travel on longer distances and with private modes.

The user sets a target for the increase of land-use mixture for the anticipated implementation year and 2050. The model converts these values into:

- Decrease in the growth of private vehicle ownership.
- Decrease in the public transport access time.
- Decrease in the share of trips in the three highest distance categories.
- Increase in the utility for public transport.

Figure 14: Impact on CO_2 emission from Other measures

<table>
<tr><td>CO_2 emissions in the study period</td><td>Impact</td></tr>
<tr><td colspan="2">Evolution 2015-2050</td></tr>
<tr><td>
</td><td>Reduction in transport-related CO_2 emissions attributed to the policy direction compared to Baseline in the same year
<table>
<tr><td></td><td>By 2030</td><td>By 2050</td></tr>
<tr><td>Current Policy</td><td>0%</td><td>0%</td></tr>
<tr><td>Climate Ambition</td><td>-7%</td><td>-13%</td></tr>
</table></td></tr>
</table>

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