

METHODOLOGICAL NOTE

A Sustainable Asset Valuation (SAVi) Assessment of Bus Fleet Electrification in Ulaanbaatar, Mongolia

Methodological note for the Ministry of Road and
Transport in Mongolia

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Overview

The International Institute for Sustainable Development carried out a Sustainable Asset Valuation (SAVi) assessment of the full electrification of the bus fleet in Ulaanbaatar, Mongolia. The SAVi assessment also included scenarios of modal shift from private vehicles to bus transport in the city. The electrification of the bus fleet is expected to lead to significant savings in bus fuel and maintenance costs, reduced CO₂ emissions, and lower air and noise pollution, among other impacts.

We used the SAVi methodology to develop an integrated assessment aimed at raising awareness of the impact of sustainable infrastructure by demonstrating the wide range of economic, social and environmental impacts that the bus fleet electrification in Ulaanbaatar will bring.

This document serves as a methodological background note for engagement with the Ministry of Road and Transport in Mongolia. It provides definitions of sustainable transport, indicators to consider, the modelling approach proposed, and the resulting analysis.



Introduction

Definition of Sustainable Transport

Sustainable transport can be defined using three pillars: efficiency, equity, and environment (Transformative Urban Mobility Initiative, 2018). In this formulation, “efficiency” refers to the improvement of sustainable technologies and services, “equity” refers to supporting the mobility of users, and “environment” refers to reducing the negative impacts of mobility. One of the most comprehensive definitions is proposed by the High-Level Advisory Group on Sustainable Transport for the United Nations (2016, p. 10):

Sustainable transport is the provision of services and infrastructure for the mobility of people and goods—advancing economic and social development to benefit today’s and future generations—in a manner that is safe, affordable, accessible, efficient, and resilient while minimizing carbon and other emissions and environmental impacts.

Indicators

To assess the sustainability of transport projects, indicators from the three dimensions of sustainability are crucial. In this context, the United Nations Economic Commission for Europe (UNECE) (2020) offers a list of indicators for this purpose, as shown in Table 1. Several of these indicators have been used to design the SAVi assessment for sustainable transport, in which indicators are divided into the following categories: economic, poverty and social, environmental, and risk to sustainability (Bassi et al., 2017). It is worth noting that the list of indicators can be expanded or reduced depending on the project’s requirements.

Table 1. Environmental and socio-economic indicators suggested by UNECE to evaluate the sustainability of transport projects

	Theme	Indicator
Environmental indicators	Global climate change	<ul style="list-style-type: none"> Greenhouse gas (GHG) emissions from transport
	Air pollution	<ul style="list-style-type: none"> Acidifying gases from transport Volatile organic compounds from transport
	Consumption of natural resources	<ul style="list-style-type: none"> Consumption of mineral and oil products for transport Land coverage Need for additional new construction



	Theme	Indicator
Social indicators	Health	<ul style="list-style-type: none"> • Exposure to particulate matter from transport in the living environment • Exposure to nitrogen dioxide from transport in the living environment • Exposure to traffic noise • Traffic deaths • Traffic injuries
	Equity	<ul style="list-style-type: none"> • Justice of distribution of economic benefits • Justice of exposure to particulate matter • Justice of exposure to nitrogen dioxide • Justice of exposure to noise • Segregation
	Opportunities	<ul style="list-style-type: none"> • Housing standards • Vitality of city centre • Vitality of surrounding region • Productivity gain from land use
	Accessibility and traffic	<ul style="list-style-type: none"> • Total time spent in traffic • Level of service of public transport and slow modes • Accessibility to city centre • Accessibility of services • Accessibility to open spaces
Economic indicators	Total net benefit from transport	<ul style="list-style-type: none"> • Transport investment cost • Transport user benefits • Transport operator benefits • Government benefits from transport • External accident costs • External emission costs • External greenhouse gas costs • External noise costs

Source: UNECE, 2020.

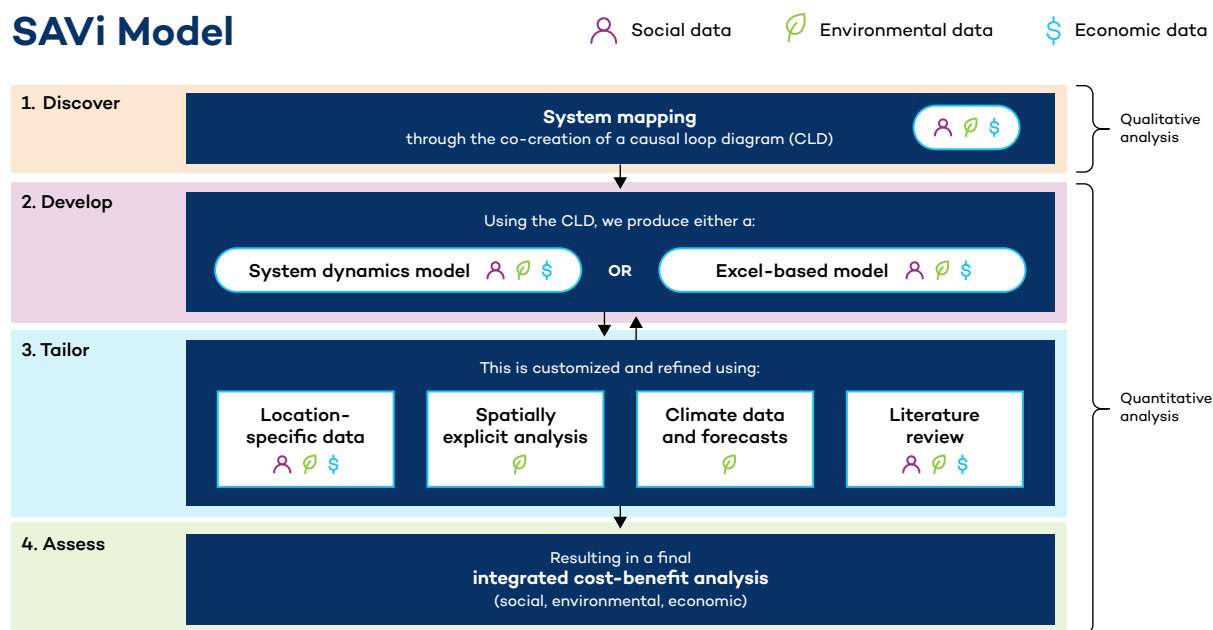
Sustainable Asset Valuation

The SAVi methodology allows the assessment of infrastructure projects considering risks usually overlooked in traditional valuations, making it possible to identify the monetary value of the environmental and socio-economic added benefits and avoided costs. SAVi is based on systems thinking (Bassi & Pallaske, n.d.) and combines a set of different modelling tools: system dynamics modelling, multi-criteria analysis, spatial models, and project finance modelling. SAVi also provides scenario analysis and compares how the financial performance of an infrastructure project changes in relation to climate change and other drivers over time. SAVi thus considers different types of indicators (environmental, social, and economic) with a



high level of customization, with additional financial indicators, informing decision-makers on the costs, avoided costs, and benefits of their projects. The SAVi methodology is designed to provide evidence of the risks, benefits, and climate impacts of infrastructure projects (Bassi et al., 2021). SAVi has been applied to various infrastructure projects and across sectors in more than 25 countries around the world. A summarized version of the different steps of the SAVi model is presented in Figure 1.

Figure 1. Steps of the SAVi model



Source: Authors.

The first step in the SAVi assessment is to identify the impacts and underlying dynamics of the transport project, including driving forces and key indicators, summarizing them in causal loop diagrams (CLDs). CLDs show the interconnections of social, economic, and environmental components of the system, highlighting key dynamics and potential trade-offs emerging from the different scenarios considered in a SAVi assessment. The CLD is the starting point for the development of the mathematical stock and flow model that will simulate the bus electrification and modal shift scenarios. The CLD was validated through engagement with the OECD, the Asian Infrastructure Research Institute (AIRI) and numerous ministries and agencies in Mongolia.¹

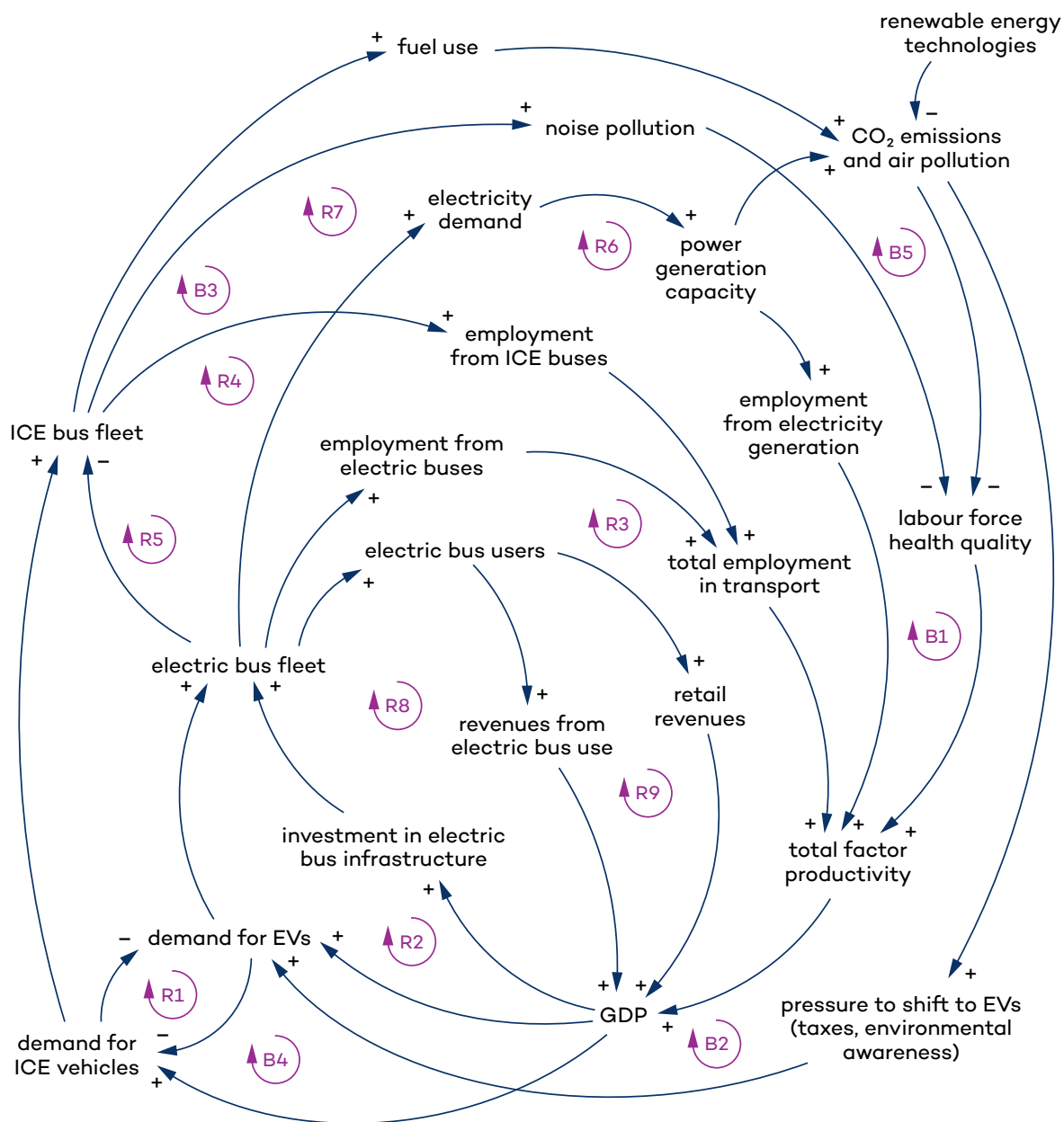
Figure 2 presents the CLD that was developed for the bus fleet electrification in Ulaanbaatar, Mongolia. The impacts of the electrification strategy and its feedback mechanisms are

¹ Ministry of Economy and Development of Mongolia, Ministry of Energy of Mongolia, Ministry of Finance of Mongolia, Ministry of Environment and Climate Change of Mongolia, Ministry of Road and Transport Development of Mongolia, Ministry of Urban Development, Construction and Housing of Mongolia, Water Agency of Mongolia, Financial Stability Council of Mongolia, Mongolian National Audit Office



represented in the CLD. The relationships are diverse and involve interconnected social, environmental, and economic variables.

Figure 2. CLD representing the dynamics of the bus fleet electrification in Ulaanbaatar



Source: Authors.

One of the main dynamics of the system is the shift from demand for internal combustion engine (ICE) vehicles to demand for electric vehicles (EVs) and vice versa, which is represented by a reinforcing loop (R1) that is strengthened or weakened by the rest of the loops. As the city of Ulaanbaatar continues to develop and the population grows, the need for public transport infrastructure increases. Until today, ICE road transport has been leading the



mobility solutions in Ulaanbaatar, resulting in traffic congestion, air pollution, CO₂ emissions, and noise pollution, among other negative impacts. These outcomes impact ICE bus fleet and electric bus fleet demand in different ways by either reinforcing or limiting their use.

The feedback loops that can positively or negatively impact investment in electric bus infrastructure are demand for EVs driven by GDP (R2), employment from electric buses and ICE buses (R3 & R4), fuel use from the ICE bus fleet that leads to CO₂ emissions and air pollution (R5), employment from electricity generation as a result of the electric bus fleet (R6), noise pollution from the ICE bus fleet (R7), increased revenues from electric bus use (R8) and increased retail revenues (R9) around bus stations from increased electric bus users.

Several balancing loops can counteract the effects of the reinforcing loops in electric bus systems use, specifically the ones representing the impact of CO₂ emissions and air pollution on EVs demand (B2), and the impact of CO₂ emissions from power generation on EVs demand (B5). However, in Ulaanbaatar, the latter effect is weakened because the electric grid is primarily coal-based. In the case of the ICE bus fleet, impacts that offset its growth include CO₂ emissions and air pollution (B1) and noise pollution (B3). The effect of GDP on demand for ICE vehicles is included in B4.

In general, the CLD exercise demonstrates that electric bus systems can enhance positive social outcomes (employment), can mitigate negative environmental impacts (reducing fuel use, CO₂ emissions, air pollution and noise pollution) and can improve economic outcomes (increasing bus revenues and retail revenues).

A SAVi assessment provides an integrated cost-benefit analysis, along with financial performance indicators, to compare costs and benefits, including externalities, selected according to the characteristics of the infrastructure project and the objectives of the assessment.

Sustainable infrastructure investments must have environmental and social cohesion at their core, given the current challenges posed by climate change and population growth. The “what-if” simulations based on the SAVi methodology are designed to inform decision-makers while considering those challenges.

The what-if scenarios are run to understand the socio-economic benefits that can be realized when public spending (also from sustainable recovery packages) is targeted at sustainable infrastructure. To do so, simulations are based on authoritative data and scientific analysis, incorporating different methods and models.

The SAVi assessment can also include climate data to understand how different climate change scenarios will affect the costs and benefits of the project, as well as spatial data retrieved from spatial models (such as InVEST). SAVi models use integrated world-class data on climate from the [Copernicus Climate Change Service](#), which provides a single entry point for continuously updated climate data and products on the past, present, and future (International Institute for Sustainable Development, n.d.).

The results of the SAVi assessment of the bus fleet electrification in Ulaanbaatar, Mongolia, are presented and discussed in the summary of results published jointly with this methodological note.



Key Assumptions and Data Sources

The SAVi assessment of the bus fleet electrification in Ulaanbaatar drew on data from several available studies and data sets, as listed in the data source column of Table 2. The data was primarily provided by AIRI. Cooperation with AIRI was successful, and their support and contributions are gratefully acknowledged.

Table 2. Assumptions and data sources used in the SAVi assessment of the bus fleet electrification in Ulaanbaatar

Indicator	Value	Data source
Capital investment costs		
Number of buses for public transport in Ulaanbaatar (ICE and electric buses)	1,303 buses (1,213 ICE buses and 90 electric buses)	Eldev-Ochir et al., 2024
Cost of EV charging infrastructure	MNT 83,500,000	Eldev-Ochir et al., 2024
Current number of EV charging stations	13	Eldev-Ochir et al., 2024
Price per electric bus	USD 300,000	Eldev-Ochir et al., 2024
Time of implementation	10 years	Assumption
Average annual cost reduction due to EV technological improvement	7%	Assumption
Operation and maintenance (O&M) costs		
Operating costs of the ICE light bus at 10 km/h	USD 0.48/km	2024 Updated Feasibility Study: Ulaanbaatar City Urban Transportation Project, personal communication with author
Average length of bus route	17.70 km	2024 Updated Feasibility Study: Ulaanbaatar City Urban Transportation Project, personal communication with author
Average number of daily bus routes per day	8	Assumption
Reduction in maintenance costs: Electric bus vs ICE bus	40%	Karsan, 2025
Cost of electricity	280 MNT/kWh	Energy Regulatory Commission, 2024
Total potential consumption of electricity from buses	1.5 kWh/km	Sustainable Bus, 2023



Indicator	Value	Data source
Average O&M costs per EV charging station	USD 400 per station	Qmerit, 2023
Avoided costs of air pollution		
Cost of PM 2.5	USD 401.6/kg	Ministry of Land, Infrastructure and Transport, 2022, personal communication with author
Average length of bus route	17.70 km	2024 Updated Feasibility Study: Ulaanbaatar City Urban Transportation Project, personal communication with author
Average number of daily bus routes per day per day	8	Assumption
Number of ICE buses for public transport	1,213	Eldev-Ochir et al., 2024
Emissions of PM 2.5 emitted by bus at 10km/h	0.04	Ministry of Land, Infrastructure and Transport, 2022, personal communication with author
Bus travel speed	10 km/h	2024 Updated Feasibility Study: Ulaanbaatar City Urban Transportation Project, personal communication with author
Population of Ulaanbaatar	1,690,000 people	2024 Updated Feasibility Study: Ulaanbaatar City Urban Transportation Project, personal communication with author
Number of households owning a car	57.4%	2024 Updated Feasibility Study: Ulaanbaatar City Urban Transportation Project, personal communication with author
Number of registered private vehicles	600,000	2024 Updated Feasibility Study: Ulaanbaatar City Urban Transportation Project, personal communication with author
Total number of trips per day	3,830,000 passenger trips/day	2024 Updated Feasibility Study: Ulaanbaatar City Urban Transportation Project, personal communication with author
Modal share of cars in Ulaanbaatar	44%	2024 Updated Feasibility Study: Ulaanbaatar City Urban Transportation Project, personal communication with author
Average car travel distance	11 km	Numbeo, n.d



Indicator	Value	Data source
Emissions of PM 2.5 emitted by car at 10km/h	0.02	Ministry of Land, Infrastructure and Transport, 2022, personal communication with author
Avoided cost of CO₂ emissions		
Cost of CO ₂	USD 0.04/kg	Ministry of Land, Infrastructure and Transport, 2022,, personal communication with author
Average length of bus route	17.70 km	2024 Updated Feasibility Study: Ulaanbaatar City Urban Transportation Project, personal communication with author
Average number of daily bus routes per day per day	8	Assumption
Number of ICE buses for public transport	1,213	Eldev-Ochir et al. 2024
Bus travel speed	10 km/h	2024 Updated Feasibility Study: Ulaanbaatar City Urban Transportation Project, personal communication with author
Emissions of CO ₂ emitted by light cargo bus at 10 km/h	831 g/km	Ministry of Land, Infrastructure and Transport, 2022, personal communication with author
Population of Ulaanbaatar	1,690,000 people	2024 Updated Feasibility Study: Ulaanbaatar City Urban Transportation Project, personal communication with author
Number of households owning a car	57.4%	2024 Updated Feasibility Study: Ulaanbaatar City Urban Transportation Project, personal communication with author
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Indicator	Value	Data source
Average car travel distance	11 km	Numbeo, n.d.
Emissions of CO ₂ emitted by cars at 10 km/h	380.8 g/km	Ministry of Land, Infrastructure and Transport, 2022, personal communication with author
Avoided cost of noise pollution		
Average noise pollution from traffic: peak traffic hours, lowest load traffic hours	70.8 dB, 58.1 dB	2024 Updated Feasibility Study: Ulaanbaatar City Urban Transportation Project, personal communication with author
Average size per apartment in Ulaanbaatar: Public investment social housing, private investment market housing	37 m ² , 69 m ²	Asian Development Bank, 2018
Average apartment price per m ² in Ulaanbaatar	MNT 4,500,000 per m ²	2024 Updated Feasibility Study: Ulaanbaatar City Urban Transportation Project, personal communication with author
Average number of households in Ulaanbaatar	462,276 households	International Organization of Migration, 2022
Reduction in traffic noise pollution as a result of electric buses	4.4 dB	Tsoi et al., 2023
Property price reduction as a result of increases in noise pollution	0.23%	Brandt & Maennig, 2011
Avoided cost of fuel use		
Fuel consumption: Light bus, heavy bus, car	0.2 litre/km, 0.49 litre/km, 0.15 litre/km	2024 Updated Feasibility Study: Ulaanbaatar City Urban Transportation Project, personal communication with author
Cost of gasoline	USD 1.16/litre	2024 Updated Feasibility Study: Ulaanbaatar City Urban Transportation Project, personal communication with author
Average length of bus route	17.70 km	2024 Updated Feasibility Study: Ulaanbaatar City Urban Transportation Project, personal communication with author
Average number of daily bus routes per day per day	8	Assumption



Indicator	Value	Data source
Number of ICE buses for public transport	1,213	Eldev-Ochir et al., 2024
Total number of trips per day	3,830,000 passenger trips/day	2024 Updated Feasibility Study: Ulaanbaatar City Urban Transportation Project, personal communication with author
Modal share of cars in Ulaanbaatar	44%	2024 Updated Feasibility Study: Ulaanbaatar City Urban Transportation Project, personal communication with author
Average car travel distance	11 km	Numbeo, n.d.
Avoided cost of maintenance		
Operating costs for a light bus at 10 km/h	0.48 USD/km	2024 Updated Feasibility Study: Ulaanbaatar City Urban Transportation Project, personal communication with author
Average length of bus route	17.70 km	2024 Updated Feasibility Study: Ulaanbaatar City Urban Transportation Project, personal communication with author
Average number of daily bus routes per day per day	8	Assumption
Number of ICE buses for public transport	1,213	Eldev-Ochir et al., 2024
Added revenues from bus use		
Total number of trips per day	3,830,000 Passenger trips/day	2024 Updated Feasibility Study: Ulaanbaatar City Urban Transportation Project, personal communication with author
Modal share of cars in Ulaanbaatar	44%	2024 Updated Feasibility Study: Ulaanbaatar City Urban Transportation Project, personal communication with author
Population of Ulaanbaatar	1,690,000 people	2024 Updated Feasibility Study: Ulaanbaatar City Urban Transportation Project, personal communication with author



Indicator	Value	Data source
Number of households owning a car	57.4%	2024 Updated Feasibility Study: Ulaanbaatar City Urban Transportation Project, personal communication with author
Number of registered private vehicles	600,000	2024 Updated Feasibility Study: Ulaanbaatar City Urban Transportation Project, personal communication with author
Average number of trips per person per day	2.77 trips/person/day	2024 Updated Feasibility Study: Ulaanbaatar City Urban Transportation Project, personal communication with author
Bus fare	MNT 500 per trip	2024 Updated Feasibility Study: Ulaanbaatar City Urban Transportation Project, personal communication with author
Added value of domestically produced electricity		
Cost of electricity	280 MNT/kWh	Energy Regulatory Commission, 2024
Total potential consumption of electricity from buses	1.5 kWh/km	Sustainable Bus, 2023
Average length of bus route	17.70 km	2024 Updated Feasibility Study: Ulaanbaatar City Urban Transportation Project, personal communication with author
Average number of daily bus routes per day per day	8	Assumption
Number of ICE buses for public transport	1,213	Eldev-Ochir et al., 2024
Percentage of electricity cost that is value added	10%	Assumption
Added value of retail revenues		
Average minimum retail spending per day	40 INR/day/person	Kapetanakis et al., 2023
Population of Ulaanbaatar	1,690,000 people	2024 Updated Feasibility Study: Ulaanbaatar City Urban Transportation Project, personal communication with author



Indicator	Value	Data source
Number of households owning a car	57.4%	2024 Updated Feasibility Study: Ulaanbaatar City Urban Transportation Project, personal communication with author
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Modal share of cars in Ulaanbaatar	44%	2024 Updated Feasibility Study: Ulaanbaatar City Urban Transportation Project, personal communication with author
Average number of trips per person per day	2.77 trips/person/day	2024 Updated Feasibility Study: Ulaanbaatar City Urban Transportation Project, personal communication with author
Increase in retail revenue	42%	Rabl & Nazelle, 2012

Source: Authors.



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