Green Growth Knowledge Platform (GGKP)
Fourth Annual Conference on
Transforming Development Through Inclusive Green Growth
6-7 September 2016
Jeju International Convention Center, Republic of Korea

GREEN TRANSPORT ASSESSMENT METHODOLOGY: A TWO-STAGE FRAMEWORK FOR INDICATOR-BASED ASSESSMENT AND POLICY MAPPING

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ABSTRACT

Transport in developing countries is often a major obstacle to their transition to green development because the current transport system relies heavily on fossil fuel, lacks adequate public transport, and limits access to employment or education opportunities. Thus many developing countries place it among their top agenda to transform the transport system into green transport, aiming to reduce greenhouse gas emissions, mitigate traffic congestion, enhance road safety, and improve accessibility to services in an inclusive way without constraining urban development or economic growth. A wide range of transport policies towards green transport have been implemented around the world with different levels of sophistication and financial and technical resources requirement. To aid in the identification of most suitable and effective green transport policies to the local context in developing countries, this paper proposes a green transport assessment methodology, a two-stage framework that first diagnoses “weaknesses” of a city’s transport system and then identifies transport policies that can best address those weaknesses. In the first stage of the methodology, an indicator-based assessment of a city’s transport system from a green transport perspective is conducted using a set of 24 indicators which are categorized into six themes: transport intensity, infrastructure provision, transport emissions, energy consumption, traffic safety, and accessibility. Once the indicator-based assessment is completed, the methodology maps green transport policies to low scoring themes. The application of the methodology to Phnom Penh reveals the city’s strong dependence on private motorization and lack of sufficient infrastructure to host alternative transport modes, compared to peer cities like Bangkok, Dhaka, Hanoi, and Vientiane. Accordingly bus-rapid transit, non-motorized transport, and better land-use planning are recommended as suitable green transport policies for Phnom Penh.

Keyword: *green transport, assessment, indicators, policy mapping*

1. INTRODUCTION

Transport plays a key role in urban development and economic growth by providing mobility and accessibility for people and goods. While transport offers various opportunities economically and socially, it causes major challenges as well. According to the Intergovernmental Panel on Climate Change (IPCC), 23% of total energy-related carbon dioxide (CO_2) emissions originate from the transport sector and road transport is responsible for over 70% of these emissions (Sims et al., 2014). Traffic congestion leads to significant loss of productivity and air pollution from vehicles causes a serious health issue in many cities around the world. Estimated by the World Health Organization (WHO, 2015), 1.25 million people die every year due to road accidents and the large majority of road fatalities occurs in low income countries. In order to overcome these issues arising from conventional or business-as-usual transport, the current transport system has to be transformed into a more sustainable and “greener” transport system. The need for such a transformation is especially high in countries that experience a rapid urbanization.

Green transport as a paradigm of green growth has been introduced in GGGI (2011), UNEP (2011), and World Bank (2012) as well as in Banister et al. (2015) and Perkins (2011). GGGI (2011) defines green transport as transport following the principles of green growth and reducing negative effects by the current transport system through road diets, parking regulation, green vehicles, rail transport, promotion of cycling, and other policy measures. UNEP (2011) calls green transport a transport system “that supports environmental sustainability through e.g. the protection of the global climate, ecosystems, public health, and natural resources. It also supports the other pillars of sustainable development, namely economic (affordable, fair and efficient transport that supports a sustainable competitive economy as well as balanced regional development and the creation of decent jobs) and social (e.g. allowing the basic access and development needs of individuals, companies, and society to be met safely and in a manner consistent with human and ecosystem health, and promoting poverty reduction and equity within and between successive generations).” Despite different narratives of green transport, it can be interpreted as transport systems that enable sustainable transport by reducing greenhouse gas (GHG) emissions, reducing traffic congestion, providing better access and mobility, improving economic productivity and competitiveness, and improving traffic safety.

It is often argued that transport in developing countries, in particular, is a major obstacle to their transition to green development because the current transport system relies heavily on fossil fuel, lacks adequate public transport, and limits access to employment or education opportunities. Thus many developing countries place it among their top agenda to transform the transport system into green transport, aiming to reduce greenhouse gas emissions, mitigate traffic congestion, enhance road safety, and improve accessibility to services in an inclusive way without constraining urban development or economic growth. A wide range of transport policies towards green transport have been implemented around the world with different levels of sophistication and financial and technical resources requirement. However identifying most suitable and effective green transport policies for a city of a developing country is not always straightforward due to the local context. To aid in the identification of such green transport policies in developing countries, this paper proposes a green transport assessment methodology, a two-stage framework that first diagnoses "weaknesses" of a city's transport system through an indicator-based assessment and then identifies transport policies that can best address those weaknesses. The salient feature of the methodology is that it combines indicator-based assessment with policy mapping in a standardized and systematic way.

A review of literature in the field of sustainable transport shows that several indicator-based assessment tools exist but there is rarely a standardized approach to connect the assessment results to policy making. The Sustainable Transportation Performance Indicators (Gilbert et al., 2002), the Transport Environment Reporting Mechanism (EEA, 2014), the Index of Sustainable Urban Mobility (Silva et al., 2010), the Future of Urban Mobility (Van Audenhove et al., 2014), and OECD's Environmentally Sustainable Transport project (OECD, 1999; Wiederkehr et al., 2004) use indicators to measure and compare transport systems on the national and local level. However none of them attempt to use the results for the appraisal of policies. A possible exception might be the Sustainable Mobility Project (SMP) 2.0 (WBCSD, 2016). This tool requires an intensive consultation process and qualitative information as seven of its nineteen indicators are based on surveys. The connection between the assessment and the policy appraisal is made through decisions of stakeholders, not by predetermined criteria. These characteristics could limit the applicability and usefulness of the tool.

The remainder of the paper is organized as follows. In Section 2, the green transport assessment methodology is described in detail, including a set of indicators used and the process for policy mapping. The methodology is applied to the city of Phnom Penh in Section 3. Lastly concluding remarks are given in Section 4.

2. METHODOLOGY

The green transport assessment methodology consists of two stages. In the first stage, the methodology assesses the current situation of a city's transport by scoring against a set of indicators chosen to reflect those considerations for green transport described in Section 1. Two scoring approaches are employed: one is to compare with the desired target values and the other is to compare with peer cities. Based on the scoring results, areas (or themes) that need improvement are identified. From a constellation of green transport policies, the second stage selects suitable policies that are expected to bring about such improvements.

2.1 Assessment of a Transport System

The first stage of the methodology requires the formation of the indicator structure, the selection of indicators, and the development of weighting and scoring mechanisms. The indicator structure is established by first determining categories and then themes under each category. The three pillars of sustainable development, economic, environmental, and social dimensions, constitute the categories. Under each category are chosen two themes that are supposedly most relevant to transport from the lens of the category. Transport intensity and infrastructure provision are chosen as the themes for the economic category. The environmental category includes transport emissions and energy consumption as its themes. And the social category considers traffic safety and accessibility themes.

Having the indicator structure in place, the indicator selection process begins by compiling a long list of potential indicators for each theme. They are then evaluated according to the OECD selection criteria for environmental indicators: relevance, analytical soundness, and measurability (OECD, 1999; 2011). In simultaneous consideration of a manageable number of total indicators and potential unavailability of some indicators in developing countries, the number of indicators per theme is set to four. Table 1 shows a set of 24 indicators selected through this process.

Table 1. Overview of Indicators

Category	Theme	Indicator	Unit
Economic	Transport Intensity	Motorization Rate	vehicles per 1,000 people
		Modal Share of Private Transport	%
		Public Transport Mode Diversity	number of public transport modes
		Share of On-Street Parking	cars per 100 m
	Infrastructure Provision	Population Density	people/km^2
		Density of Road Network	km/km^2
		Bicycle Network Length	km per 10,000 people
		Share of Budget for Green Transport	%
Environ-mental	Transport Emissions	CO_2 Emissions by Transport	ton CO_2 (eq) per capita
		PM_{10} and $PM_{2.5}$ Emissions	µg/m^3
		NO_2 Emissions	µg/m^3
		People Affected by Traffic Noise	%
	Energy Consumption	Energy Consumption in Transport	MJ per capita
		Energy Efficiency of Private Transport	MJ per vehicle-km
		Vehicle Occupancy Rate	persons per car
		Amount of Daily Trips	number of trips
Social	Traffic Safety	Road Traffic Injuries	non-fatal injuries per 100,000 people
		Road Traffic Fatalities	fatalities per 100,000 people
		Share of Motorcyclists and Non-Motorized Casualties	%
		Traffic Education Program Participation	%
	Accessibility	Urban Connectivity	intersections/km^2
		Average Journey Time	min
		Household Expenses for Transport	%
		Public Transport Coverage	%

The level of importance of indicators may be different from each other and this is captured by the weight of each indicator, i.e. relative importance. A widely used approach to determine the weights of indicators is the analytic hierarchy process (AHP) that relies on the judgements of experts to derive priority scales. If AHP is applied to the set of indicators in Table 1, a total of 42 pairwise comparisons along the three levels (category, theme, and indicator) are needed. A simple alternative is to assume that each indicator is of equal importance.

Two scoring approaches are employed in the methodology: proximity-to-target and peer-comparison. The proximity-to-target method evaluates the value of an indicator against a predetermined desired target. The result is captured by how close in percentage the indicator is towards the target. Let T_i denote the desired target for indicator *i*. For instance, the target for the *modal share of private transport* indicator is set to 20%. Let L_i be the "lower" (or worst allowable) limit of indicator *i*. For the same indicator, L_i is set to 90%. The purpose of the lower limit is to make the range of the indicator bounded, which is necessary to scale the indicator score between 0 and 100%. Let V_i denote the value of indicator *i*. Then the score of indicator *i*, denoted by IS_i, is calculated as

$$IS_i = \frac{(R_i - D_i)}{R_i} \times 100 \qquad (1)$$

where $R_i = |T_i - L_i|$ is the range of indicator *i* and $D_i = |T_i - V_i|$ is the distance between the value of indicator *i* and its target. As can be surmised from the equation, the closer the indicator value to its target, the bigger the indicator score. The targets and lower limits of all indicators used in this paper are listed in Table A.1 in Appendix.

Once the indicator scores are calculated, they are weighted to yield the score of the theme where those indicators belong. Let TS_j denote the score of theme *j*. Then

$$TS_j = \sum_{\forall i \in j} W_i \times IS_i \qquad (2)$$

where W_i is the weight of indicator *i*. The scores of the themes can be visualized through a radar chart (see Figure 2, for example).

The peer-comparison method, as its name suggests, compares the value of an indicator with the average value of the indicator among a peer group of cities. To this end, the indicator value is first standardized:

$$Z_i = \frac{V_i - E[V]}{s_V} \qquad (3)$$

where $E[V]$ and s_V are the sample mean and sample standard deviation of indicators belonging to the same theme. The score of indicator *i* in a 100-point scale is then obtained by the following T-score transformation: If a higher value of the indicator is preferable,

$$IS_i = Z_i \times 10 + 50 \qquad (4)$$

Otherwise,

$$IS_i = -Z_i \times 10 + 50 \qquad (5)$$

Note that the transformation shifts and scales the mean and standard deviation of the indicator score to 50 and 10, respectively. Once the indicator scores are determined by Equation (4) or (5), the score of a theme is calculated as before through Equation (2). If the score of the theme is above 50, it implies that the city's performance on the theme is better compared to peer cities on average. If it is below 50, the opposite is the case. In addition to this delineation along the line of 50, a higher score of the theme is obviously preferred. Figure 1 summarizes key characteristics of the two scoring methods.

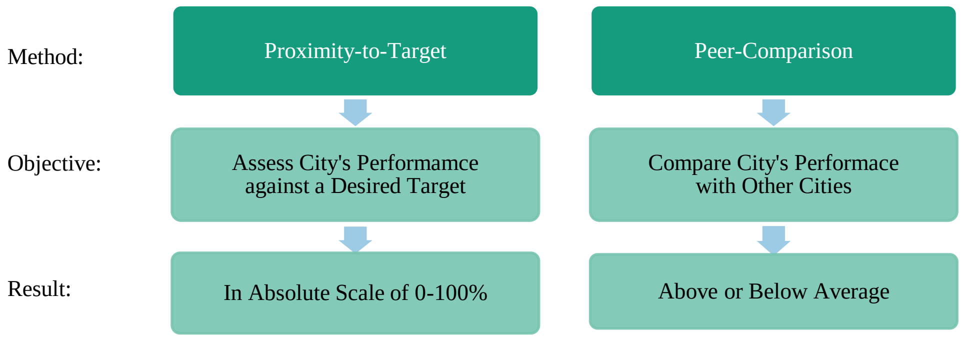

Figure 1. Comparison of Scoring Methods

Each scoring method has advantages and drawbacks. The advantage of the proximity-to-target method is that it is based on absolute targets. Therefore the result is stand-alone and can be easily understood. And different assessments can be compared with each other. On the other hand, it is subject to the criticism that setting the targets (and lower limits) is somewhat arbitrary. The peer-comparison method has the advantage that it is based on actual circumstances not on arbitrarily defined goals, making it free from the criticism for the proximity-to-target method. Comparing with peer cities may also provide additional insights from the context under consideration. The main drawback of this method is the burden of data collection. Gathering indicators requires substantially more efforts as a group of peer cities gets larger. This poses a big challenge particularly for cities in developing countries, where lack of data is a prevalent issue. Caution needs to be taken when interpreting the scoring result. The fact that the score of some theme is above the average does not necessarily mean that the city performs well on the theme. It merely indicates that the city’s situation is comparatively better than peer cities, but all of them collectively can be subpar in an absolute sense.

2.2 Policy Mapping

The second stage of the methodology maps green transport policies to the results of indicator-based assessment above. Specifically, this stage of policy mapping identifies green transport policies that can improve the themes with low scores. There can be a large number of transport policies claiming to promote green transport. For a practical reason, we focus on policies that can be employed at the urban level with a connection to the Avoid-Shift-Improve (A-S-I) framework (Dalkmann et al., 2014). Table 2 shows the universe of green transport policies considered in this stage.

The perceived effect of each policy on the six themes is measured on an interval scale ranging from -1 (very strong negative impact) to 1 (very strong positive impact). This ex-ante policy impact assessment is assisted by various literature on transport policies, best practices, and other policy libraries (e.g. Dalkmann et al., 2014; University of Leeds, 2016; VTPI, 2014; WBCSD, 2016). Table 3 is an excerpt of the assessment results.

With the results of policy impact assessment, the policy mapping is carried out for three low scoring themes, in the sequence of the theme with the lowest score, the one with the second lowest score, and the one with the third lowest score. The following rules are applied in the mapping process:

1. A policy can only be selected once in the whole process.
2. The selected policy must have the highest impact for the theme.
3. If more than one policy have the same impact on the theme, the policy with the highest aggregated impact for all three themes is selected.
4. If a tie still occurs, the policy with the highest aggregated impact for all six themes is selected.

Table 2. Green Transport Policies

Link to A-S-I Framework	No.	Policy
Planning Instruments	1	Land Use Planning
	2	Road Maintenance
	3	Physical Restrictions
	4	Para-Transit and Public Bus System
	5	Bus Rapid Transit
	6	Light Rail Transit
	7	Metro System
	8	Non-Motorized Transport
	9	Electric and other Low-Emission Vehicles
	10	Car-Sharing
	11	Bike-Sharing
Regulatory Instruments	12	Road Safety Improvements
	13	Traffic Calming
	14	Low Emission Zones
	15	Car-Free Areas
	16	Parking Management
	17	Traffic Management
	18	Improvement of Transit Service
Economic Instruments	19	Road Pricing
	20	Incentives for Green Transport
Information Instruments	21	Awareness Campaigns and Marketing
	22	Driver Behavior and Eco-Driving
	23	Guidance Systems
Technological Instruments	24	Intelligent Transport Systems
	25	Teleworking

Table 3. Excerpt of Policy Impact Assessment Results

Policy	Transport Intensity	Infrastructure Provision	Transport Emissions	Energy Consumption	Traffic Safety	Accessibility
Land Use Planning	0.75	0.5	0.75	0.75	0.50	0.75
Road Maintenance	0.25	0	-0.25	0.25	0.25	0
Para-Transit and Public Bus System	0.5	0.25	0	0	0.25	0.5
Bus Rapid Transit	1	0.5	0.5	0.5	0.5	0.75
Light Rail Transit	0.75	0.75	1	0.5	0.5	0.5
Metro System	1	0.25	0.75	0.75	0.25	0.5
Non-Motorized Transport	0.5	0.75	1	1	0.75	1

3. CASE STUDY

In this section the methodology is applied to Cambodia's capital Phnom Penh. As a group of peer cities, Bangkok, Dhaka, Hanoi, and Vientiane are considered. Data are collected from various sources, but the availability of data for these cities is generally poor. Some indicators have to be estimated from other statistics or proxy data should be used instead. For instance, the annual amount of CO_2 emissions in Phnom Penh is not available. It is thus estimated from the national figure. The average journey time in Vientiane is not possible to retrieve. From a travel survey for Vientiane showing that 90% of the travel time is under 10 minutes, the average journey time is assumed to be 10 minutes. For this case study, we manage to retrieve 17 indicators out of 24. Besides missing data, the reliability of data is also an issue. Road accidents in Dhaka and Hanoi are greatly underreported. This issue is impossible to overcome because no alternative road accident estimates exist. Therefore indicators related to road accidents have to be taken with caution. It is assumed that all indicators have the equal weight, i.e. they are of equal importance.

3.1 Results from the Proximity-to-Target Method

Figure 2 illustrates the theme scores from the proximity-to-target method. Cambodia's capital scores well on energy consumption, transport emissions, and traffic safety. Infrastructure provision is the biggest challenge towards green transport.

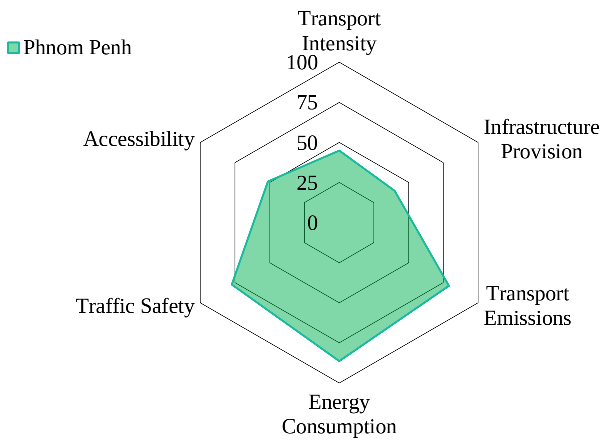

Figure 2. Theme Scores from Proximity-to-Target Method

Upon analyzing the results, it seems that the low population density and lack of infrastructure for non-motorized transport accelerate the use of private vehicles. Phnom Penh is still being developed, not a mature city yet. This could explain low scores on infrastructure provision and accessibility, but it could also be the reason for good performance in energy consumption and transport emissions as mobility of the city is still at a low level.

3.2 Results from the Peer-Comparison Method

The results from the peer-comparison method are presented in Figure 3. This comparative analysis shows that Phnom Penh, compared to the group of Bangkok, Dhaka, Hanoi, and Vientiane, has below average performance in the themes of transport intensity, infrastructure provision, and energy consumption. Phnom Penh performs above average for accessibility and transport emissions.

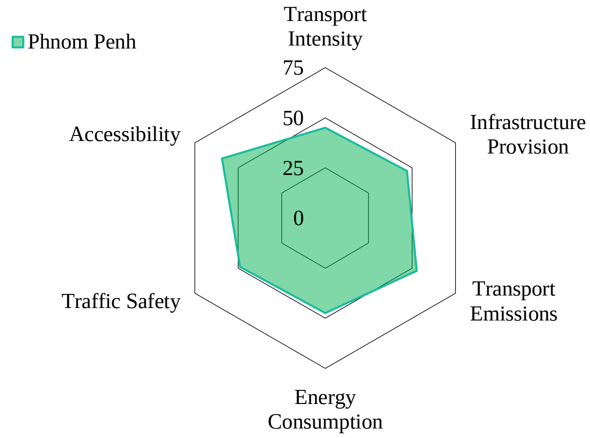

Figure 3. Theme Scores from Peer-Comparison Method

It should be noted that Phnom Penh's below average performance on a certain theme does not necessarily mean that the city's score on the theme is lower than those of all other cities. For instance, Phnom Penh's score on energy consumption is higher than that of Vientiane as appeared in Figure 4 where the theme scores are presented for each city.

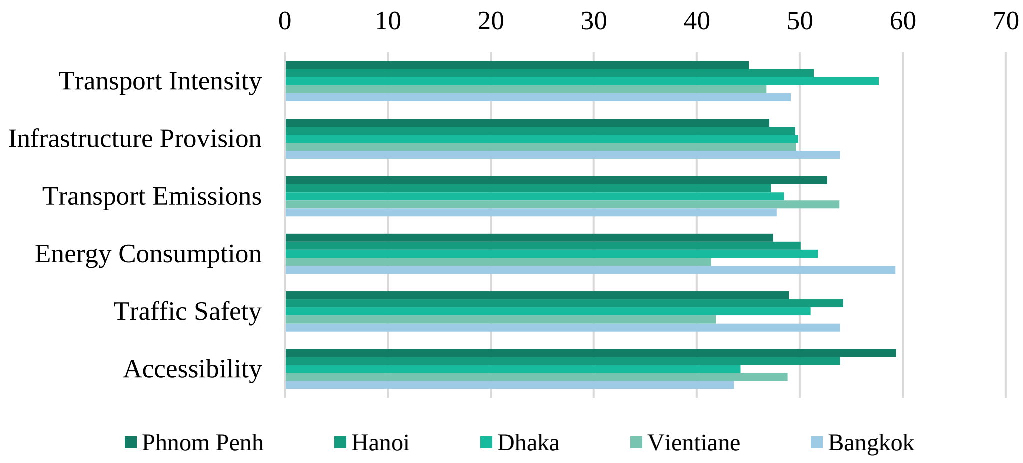

Figure 4. Theme Scores from Peer-Comparison Method for Each City

Among the peer cities, Dhaka scores the best for transport intensity due to the low volume of motorized transport. Bangkok's lead in energy consumption is attributed to a high rate of vehicle occupancy among other things. Had there not been the underreporting issue of traffic injuries in Hanoi, Bangkok could also have led in the traffic safety theme. Vientiane shares many characteristics with Phnom Penh as a city where the transport system has yet to develop.

3.3 Results of Policy Mapping

Policy mapping is carried out based on the results from the peer-comparison method. Transport intensity, infrastructure provision, and energy consumption are the low scoring themes. The policy mapping rules explained in Section 2.2 are applied to these themes in that order. As a result, bus rapid transit (BRT), non-motorized transport, and land use planning are identified as green transport policies with significant potential to improve the city's transport in respect of the themes.

A BRT system is a high-efficiency bus service that can carry a large number of passengers without requiring high investment costs. Curitiba and Bogota are two famous examples of successful BRT systems. The non-motorized transport policy seeks the provision of bicycle lanes and pedestrian sidewalks. In addition, this policy promotes a transport culture that grants non-motorized travellers a safe and convenient traveling environment. Land use planning includes transit-oriented and high density development that would facilitate the implementation of the two other policies.

4. CONCLUSIONS

The green transport assessment methodology is a tool designed to assess a city's transport from a green and sustainable perspective and then identify transport policies with high potential of contributing towards green transport transformation. A total of 24 indicators are selected under six themes of transport intensity, infrastructure provision, transport emissions, energy consumption, traffic safety, and accessibility, which are designed to represent the aspects of green transport. The results of indicator-based assessment are then fed into the process of policy mapping from a list of 25 green transport policies. The salient feature of the methodology is that it combines indicator-based assessment with policy mapping in a standardized and systematic way.

The application of the methodology to Phnom Penh reveals that the city's transport needs improvement in transport intensity, infrastructure provision, and energy consumption when compared with peer cities. Consequently bus rapid transit, non-motorized transport, and land use planning are identified as priority policies to be implemented due to their positive impact on those theme. This is useful information that can guide the focus of government and allocate its limited resources optimally.

The methodology is of cause far from being perfect. During the case study, some indicators prove to be difficult to obtain especially for cities in developing countries. Although it is a technical issue, setting the targets and lower limits of indicators can be subject to disagreement. Despite these potential pitfalls, the methodology with further refinement and improvement is expected to remain a valuable contribution to the field of green and sustainable transport.

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APPENDIX

Table A.1. Targets and Lower Limits of Indicators

Indicator	Target	Lower Limit
Motorization Rate	20 vehicles per 1,000 people	500 vehicles per 1,000 people
Modal Share of Private Transport	20%	90%
Diversity of Transport Modes	4 public transport modes	0 public transport modes
Share of On-Street Parking	0 per 100 m	25 per 100 m
Population Density	8,000 people/km^2	800 people/km^2
Density of Road Network	2 km/km^2	30 km/km^2
Bicycle Network Length	5 km per 10,000 people	0 km per 10,000 people
Share of Budget for Green Transport	80%	10%
CO_2 Emissions by Transport	0.5 ton CO_2 (eq) per capita	2.5 ton CO_2 (eq) per capita
PM_{10} and $PM_{2.5}$ Emissions	$PM_{2.5}$: 10 µg/m^3	$PM_{2.5}$: 150 µg/m^3
	PM_{10}: 20 µg/m^3	PM_{10}: 100 µg/m^3
NO_2 Emissions	10 µg/m^3	70 µg/m^3
People Affected by Traffic Noise	0%	50%
Energy Consumption in Transport	15,000 MJ per capita	55,000 MJ per capita
Energy Efficiency of Private Transport	2 MJ per vehicle-km	8 MJ per vehicle-km
Vehicle Occupancy Rate	2.5 persons per car	1 person per car
Amount of Daily Trips	2	5
Road Traffic Injuries	40 non-fatal injuries per 100,000 people	500 non-fatal injuries per 100,000 people
Road Traffic Fatalities	5 fatalities per 100,000 people	30 fatalities per 100,000 people
Share of Motorcyclists and Non-Motorized Casualties	10%	50%
Traffic Education Program Participation	100%	0%
Urban Connectivity	150 intersections/km^2	20 intersections/km^2
Average Journey Time	10 minutes	60 minutes
Household Expenses for Transport	15%	80%
Public Transport Coverage	100%	20%