SUSTAINABLE TRANSPORT INDEX ASSESSMENT OF RAJSHAHI – KUSHTIA HIGHWAY IN BANGLADESH

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ABSTRACT

Uncontrolled urbanization and motorization contribute to unsustainable urban land use and transportation systems on a social, economic, and environmental level. The first step was to create a conceptual framework based on the literature on sustainable development and transportation and the relevant Sustainable Development Goals (SDGs) for urban transportation planning. The purpose of this study is to review studies on sustainable transportation systems to better understand the notion of sustainable development and transportation. The research presents the sustainability indicators for transportation roads and their implementation in highway roads for investigation and evaluation of performance measures progress toward sustainable roads. It aims to evaluate the potentiality of sustainable urban transport on the Rajshahi – Kushtia Highway. The level of service of any roadway is a significant indicator in determining transportation performance. As flow and speed are important factors in evaluating any roadway's service level, manual volume count survey and moving observer methods are performed for volume count and journey speed analyses, respectively. Considering the level of service of the roadway, it lies between LOS 'E' to LOS 'F' almost all the roadway sections of the Rajshahi-Kushtia highway. The report assesses the current transportation and infrastructure system, as well as various sustainable transportation indicators, in order to determine whether the Rajshahi – Kushtia highway is sustainable. This included deciding how the index's elements should be normalised, weighed, and calculated. The Analytical Hierarchy Process (AHP) method ensures pair-wise ranking of the selected indicators based on the expert opinion. The ranking depicts the priority of affordability- travel cost as a share of income mostly among all other indicators. Other indicators like the traffic fatalities issue, public vehicle quality and services, the increasing rate of operational costs for the highway, the convenient access to the public transport services and the greenhouse gas emission issue from vehicles must be prioritized accordingly. Finally, certain recommendations are made that, if implemented, could result in a more sustainable urban transportation system on the Rajshahi–Kushtia highway. The assessment findings helped policymakers identify policy gaps and prioritise additional measures and investment options to improve urban transportation systems.

Keywords: Transport, Sustainable, Level of Service, SUTI.

1. INTRODUCTION

Transportation ensures that people goods and services in an economy can arrive from one location to another. It is indeed an integral process that is necessary for the development and stability of a nation, Sustainable transportation systems are intended to improve service quality, reduce pollution, limit government subsidies to urban transportation, improve the efficiency of transportation networks and land use, increase the mobility of people with disabilities, and avoid conflicts of interest among public transportation stakeholders (Cohen-Blankshtain, G. and Rotem-Mindali, O., 2016). Sustainable transportation systems are intended to improve service quality, reduce pollution, limit government subsidies to urban transportation, improve the efficiency of transportation networks and land use, improve the mobility of people with disabilities, and avoid conflicts of interest among public transportation stakeholders (Jeon et al. 2005; ASCE 2005). A sustainable transportation system should enable ecologically responsible, socially acceptable, and economically feasible access to people, places, commodities, and services. In the absence of comprehensive standard frameworks and instruments to assess the state of urban transportation systems in Asia, the United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP) has established the Sustainable Urban Transport Index (SUTI) (UNESCAP, 2016). SUTI is based on urban transportation indicators that describe the transportation system, as well as the environmental, social, and economic aspects of sustainability. The new paradigm for sustainable urban transportation requires a people-centred strategy to manage travel demand and promote accessibility over mobility. The promotion of energy-efficient transportation modes, focusing on non-motorized and public transportation systems, is at the centre of the strategy, along with pricing mechanisms that ensure private vehicle usage covers the full cost of externalities (ADB, 2009).

Bangladesh is a densely populated country. Bangladeshi traffic management suffers from a lack of enforcement. Traffic congestion consumes fuel and time, and makes travel difficult, given the country's population and infrastructure. It also makes existing public transportation inefficient, increasing noise and pollution levels to dangerous levels. Noise and pollution are stressful, and they can contribute to physical problems including heart disease and hypertension.

In the early 1990s, the notion of sustainability was initially applied to the transportation sector in developed countries. A sustainable transportation system should enable ecologically responsible, socially acceptable, and economically feasible access to people, places, commodities, and services. In the absence of comprehensive standard frameworks and instruments to assess the state of urban transportation systems in Asia, the United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP) has established the Sustainable Urban Transport Index (SUTI) (UNESCAP, 2016). Sustainable urban transportation is one of the most important aspects of a city's socioeconomic and physical structure. Through its accessibility to land, a well-planned and built transportation infrastructure facilitates people's movement. It determines the city's growth pattern and degree of economic activity (Arasan, T.V. and Vedagiri, P. r, 2008). When services and facilities are confirmed with transportation, in particular, a sustainable transportation system is regarded as properly planned. In order to achieve sustainable transportation, government policy is crucial. Economic criteria are factors that influence an economy's performance and have long-term consequences for transportation sustainability. Sustainable transportation is influenced positively by social dimensions, green technology, and environmental elements (Amekudzi et al., 2009).

2. METHODOLOGY

2.1 Study Area Profile

Rajshahi – Kushtia highway is the most important highway. The study area is located between 24°068′ and 24°113′ north latitudes and between 89°039′ and 89°119′ east longitudes. The total length of the National Highway is 3,544.06 Km in Bangladesh. It is the only highway to connect North Bengal to South Bengal of Bangladesh. The major bridge of Bangladesh Lalon Shah (Paksey) bridge is connected by this road.

Too much traffic is flowing on this highway. About 27,000 vehicles pass daily on the Rajshahi – Kushtia Highway. The national highway number is N704. The Support Nuclear Power Plant is situated beside the east side of the road. The physical area surrounding the Rajshahi – Kushtia highway has been changed dramatically creating a potential pressure of additional attraction and production of daily trips. A congested commercial area is considered a major attraction for trips. A residential area is also a part of the region surrounding Rajshahi – Kushtia highway. All these factors as well as the increasing number of motor vehicles produce problematic issues with traffic congestion during the morning and evening peak periods.

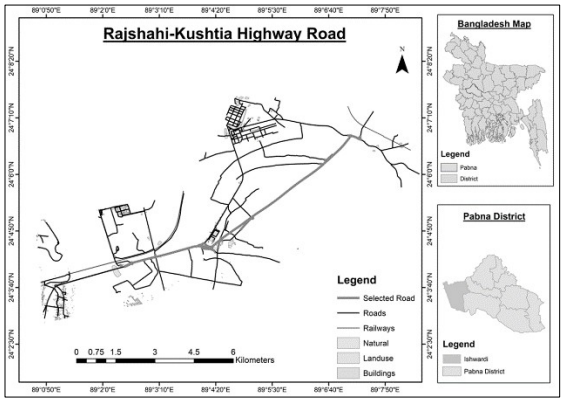


Figure 1: Study area

2.2 Data Acquisition

To analyze the present situation of the road, the study needs some data. For conducting the study, information has been collected from both primary and secondary sources. A user opinion survey is conducted to collect socio-economic data regarding the users' opinions of the roadway. The purpose of travel, travel modes, various public transport facilities, services consumed by the users, and socio-economic data like income, cost, and level of satisfaction concerning various roadway facilities, services and issues are collected through the survey. A questionnaire survey sheet is prepared concerning the factors. Around 70 respondents are randomly selected and the opinions of the respondents are collected using the questionnaire. The speed of the roadway is measured by performing the moving observer survey. 3 suitable times the days were selected for the study. They are- 8-9 am, 12-1 pm and 5-6 pm. Journey time, delay, vehicles overtaking and overtaking vehicles met in the opposite direction etc. data are collected using a moving vehicle. With the collected data, the speed and flow of the roadway are measured.

Secondary data were collected to make the present study more valuable. The secondary sources of information including various reports, journals, papers, books, etc. are reviewed to collect various information which was helpful in reaching this research objective.

2.3 Data Analysis & Result

Analysis of the research has been conducted by Microsoft Excel, SPSS, and Arc GIS software. Some data has been filtered for the convenience of the analysis. Besides, the volume, speed, parking data, level of services, etc. are visualized using bar charts, pie charts, or tabular format.

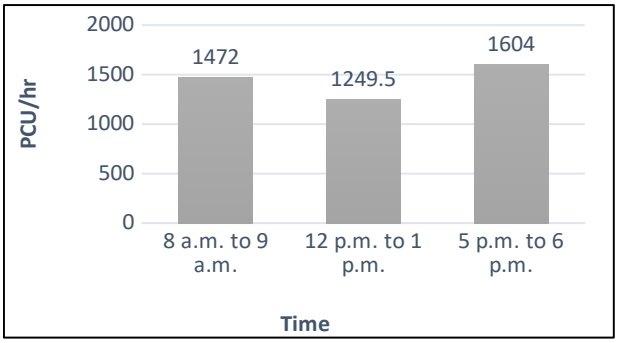
3. EXISTING ROADWAY ROAD CONDITION OF RAJSHAHI – KUSHTIA HIGHWAY

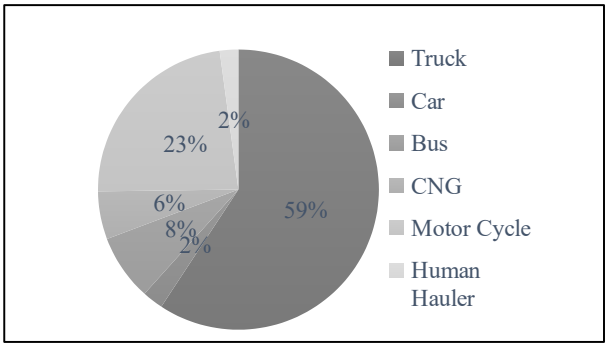
The existing Rajshahi-Kushtia highway is eight meters in width. The highway has 2 lanes. But there exists no median, divider, shoulder, etc. which are major components of any highway. There are bus stoppages along the roadway. Moreover, police boxes and check posts are also seen along the highway. Vegetation or greeneries are attractive features that exist along the highway. Traffic signs are also available. To facilitate the vehicles, auto-filling stations and gas stations are also available.

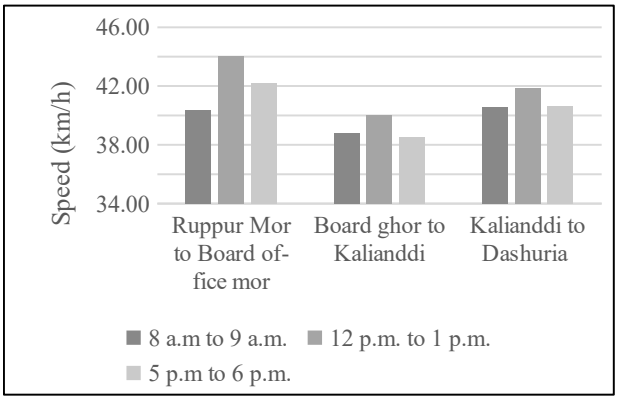
But some common features of the roadway like a zebra crossing, footpath or pedestrian facilities, speed breaker etc. are absent. Again, drainage facilities, street light facilities, and emergency lanes are also not available. These are the mandatory features required for roadways to facilitate the users. However, the absence of the roadway facilities degrades the performance of the roadway.

3.1 Outcome of The Volume and Speed Survey

The manual volume count study is performed to figure out the existing volume of vehicles on the Rajshahi-Kushtia highway. Graph 5.1 shows the different hours of the day taken to conduct the survey. 8 to 9 am, 12 to 1 pm and 5 to 6 pm are selected for volume count at the road section.







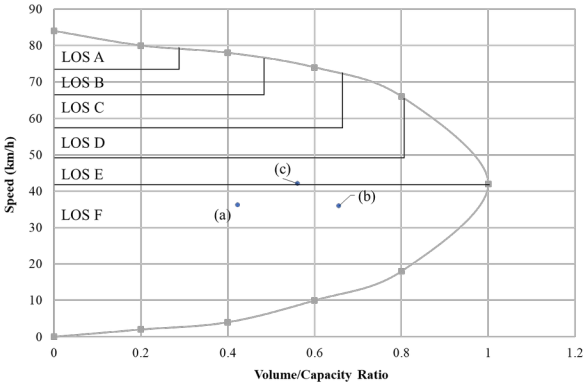


Figure 2: (a) Volume of vehicles on Rajshahi-Kushtia highway. (b) Mode of vehicles used by people (c) Average speed at the various links of the Rajshahi-Kushtia roadway (d) Level of service at various points of Rajshahi-Kushtia roadway

The manual volume count survey outcome shows the volume is higher during peak hours (5 to 6 pm) which is around 1600 PCU/hr. Most of the vehicles (59%) found in higher volume in the Rajshahi-Kushtia are trucks. The moving observer survey shows that the average speed is higher at Ruppur Mor to Board Office Road section which is around 44 km/hr. during the off-peak hour. But during peak hours, the speed is lower than at other times of the day and from Board Office Mor to Kalianddi Mor, the speed is only 38 km/hr. Considering the level of service of the roadway, it lies between LOS 'E' to LOS 'F' almost at all the roadway sections of the Rajshahi-Kushtia highway.

4. SUSTAINABILITY ANALYSIS OF THE EXISTING ROAD OF RAJSHAHI – KUSHTIA HIGHWAY

The sustainability indicators are selected to measure the sustainability of the Rajshahi-Kushtia highway. The data regarding the indicators is collected through a field survey. The survey is conducted at the bus stops and the roadways. People using public transport regularly are asked about various factors. Around 70 respondents were randomly selected to have their review the factors. After the collection of data, they are analyzed. The total number of responses in each factor was calculated and later, a weighted average of all the aspects along with the percentage of satisfaction was calculated. Frequency of services, level of comfort and cleanliness, the safety of vehicles, availability of information, fare level, etc. are some of the variables taken for measuring sustainability.

4.1 Public Transport Quality and Reliability

Considering the quality and reliability of public transport on the roadway, table 1 shows that around 54% of the respondents are satisfied with the frequency of public transport services. But 68% of the respondents are dissatisfied with the punctuality provided by the public transport services. Again, the services are not comfortable enough to facilitate people, moreover, they lack cleanliness to a great extent. Around 28% of the users are satisfied with the comfort and cleanliness of the services. Furthermore, 28% of the respondents are satisfied with the safety measures taken or provided by the vehicles. Even 60% of the respondents are satisfied with the fare taken from them.

Table 1: Calculation of several factors representing transport quality and reliability

Dimensions	Dissatisfied			Neutral	Satisfied			Average Score	% of Satisfaction
	Very		Partly		Partly		Very		
	1	2	3	4	5	6	7		
Frequency of Service	10	9	8	5	26	7	5	3.986	54.286
Punctuality	5	11	16	15	14	6	3	3.743	32.857
Comfort and Cleanliness	11	7	19	13	14	5	1	3.443	28.571
Safety of Vehicles	9	13	10	18	15	4	1	3.471	28.571
Convenience of Bus Stops or Stations	6	7	12	11	17	10	7	4.200	48.571

Availability of Information	5	6	17	20	16	6	0	3.771	31.429
Personal courtesy	4	6	12	13	21	8	6	4.271	50
Fare Level	2	5	9	12	17	15	10	4.743	60
Total	52	64	103	107	140	61	33	3.954	41.786

4.2 Affordability – Travel Costs as Part of The Income

Transport cost is a significant factor in people's daily lives. It is one of the mandatory expenditures which has no alternatives. Generally, the lower-income class and lower-middle-income class people rely on public transport facilities like buses, three-wheeled vehicles, rickshaws, CNG autorickshaws, etc.

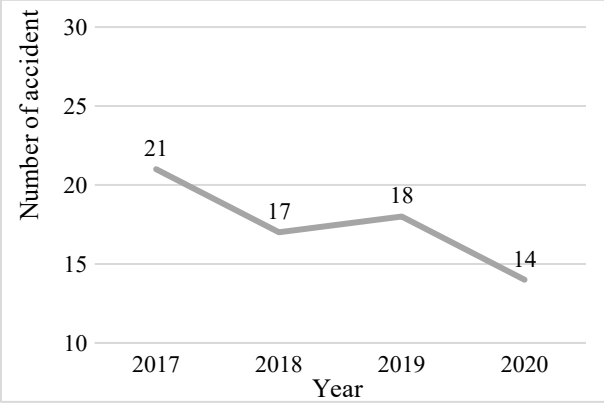
Table 2: Average wage and transport cost

Factors	Quantity (BDT)
Average Wage of People (According to Survey Result)	21320
Average Transport Cost	2190

For sustainable urban transport, Affordability – travel costs as part of income are 3.5% to 4%. But table 2 shows that the average income of the selected users of the highway is more than BDT. 21000. Again, the average transport cost of the users is around BDT. 2200. Almost 10.27% of the income is expended on day-to-day travel and this represents a huge pressure on the lower-income group. The cost of transport is more than two times higher for the people using the roadway.

4.3 Traffic Fatalities Per 10000 Vehicles

Road accident is a common phenomenon in developing countries like Bangladesh. Road accident is a constant thing, especially on highways, the condition is terrible. While ensuring the sustainability of the roads, road accident is also a considerable factor.



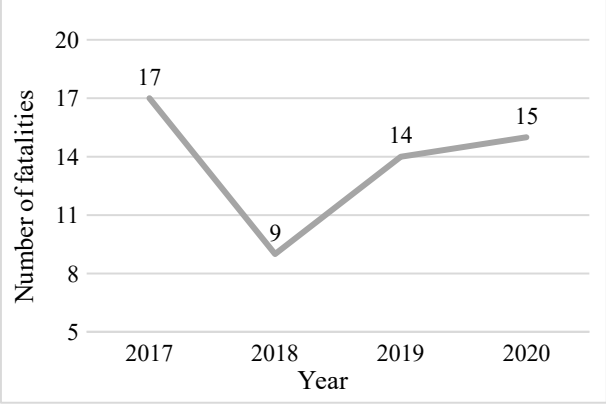


Figure 3: (a) Total accidents occurred in several years at the Rajshahi-Kushtia highway (b) Total fatalities due to road accidents in several years at Rajshahi-Kushtia highway

The traffic fatalities per 10000 vehicles on Rajshahi – Kushtia Highway is 5.185. According to the sustainable urban transport criteria, the traffic fatalities per 10000 vehicles are 3.6. That means the rate is higher for the Rajshahi-Kushtia highway.

4.4 Operational Costs of The Public Transport System

The running cost of vehicles (fuel cost, wage of driver and support staff), maintenance cost, and fixed cost (rent of garage, insurance, road permit, etc.) are the three major operating costs considered in the transportation sector. Transport companies generally depend on revenues collected through fares or other ways like advertisements or other promotional activities to cover the operation costs of vehicles. The required revenues are received by the sale of tickets, passes, and concessions to the passengers (i.e., the payment received from passengers for the journey performed). This indicator is defined by the percentage of operational cost recovered by fares and is usually termed as farebox ratio.

Table 3: Operating cost and revenue

Factors	Amount
Operating Revenues	562302
Operating Cost	603930

This indicator is a critical economic variable as it represents the financial stability of the operator. Table 3 shows that the amount of operation cost is higher than the revenue earned from the highway. The recovery rate is almost 91.1 per cent which indicates that government subsidies are needed to recover the revenue and reduce the operation costs.

4.5 Convenient access to public transport service

The availability of public transport is an important factor in ensuring sustainability on highways. But the most important thing is whether the facilities are accessible to the population or not. If the population gets proper access to public transport services, it indicates the sustainability of the transportation system. According to the Sustainable Urban Transport Index (2017), the indicator is defined by the rate of the population within a 500-meter radius of bus stoppage with 20 minutes frequency of buses. However, according to the survey, people come to visit or use this roadway a maximum of 3 km away from the Rajshahi-Kushtia highway. Using ArcGIS, the convenient access of people to public transport is visualized.

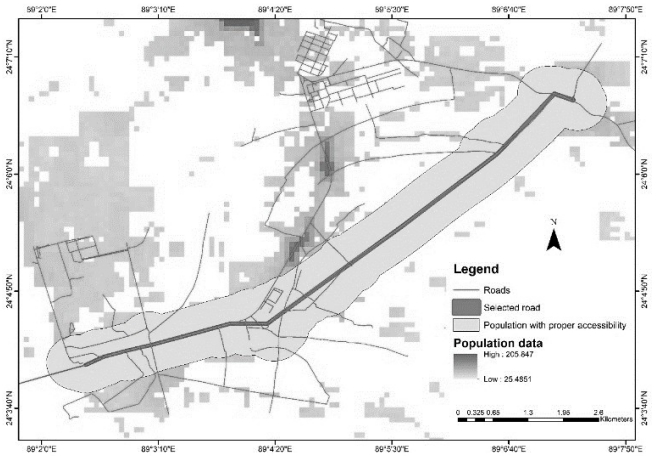


Figure 3: Convenient access of the public transport

Table 4: Accessibility data of population to public transport

Aspects	Quantity
Total Population	125000
Population with Accessibility to public transport	62154
Percentage	49.72%

Table 4 shows that the population of the Rajshahi-Kushtia road users is around 1.25 lakh. But only around sixty thousand people get access to the available public transport. So, the percentage is 49.72% which is less than 50%. More than a portion of the population lacks access to public transport services and facilities. This is a great obstacle to ensuring sustainability in transportation.

4.6 Greenhouse Gas Emissions

The emission of greenhouse gases is a concerning phenomenon. It determines the rate of environmental pollution at any place. Several Carbon, Sulphur and nitrogenous gases are emitted from vehicles which pollute the air to a great extent. But CO_2 is one of the most common greenhouse gases emitted from vehicles.

Table 5: CO_2 gas emission

Total CO_2 Emission	Population	Emission/capita
150797.6622 ton/year	125000	1.2064

For sustainable urban transport, greenhouse gas emissions from transport per capita are 13.2. But Table 5 shows that the emission per capita is around 49 which is larger in amount. Such emission deteriorates the environmental condition and degrades the condition of the air. So, most of the population along the roadway is at risk due to the harmful emissions by the vehicles.

4.7 Equal Weight Method

Indicators on different scales need to be normalized before comparison and aggregation are possible. The method applied uses linear rescaling which is a common approach in composite index design and is often used for sustainable transport indices (Zito and Salvo 2010). This allows for a simple transformation to a linear scale of 1-100 for each indicator. Formula 1 is used,

$$Z_i = \frac{(K_i) - (K_{min,i})}{(K_{max,i}) - (K_{min,i})} * 100 \quad (1)$$

Where, Z is the normalized indicator K for topic I and K_{min} is the lowest value of the indicator in actual units, whereas K_{max} is the highest value.

Table 6 shows that the several indicators selected for the study are normalization using the formula of normalization. Various indicators are normalized using their maximum, minimum and mean values. Instead, a formula is used that gives an equal weight of 0.10 to all of the six indicators regardless of domain. The normalization values are shown in the following table where the normalization value of the operational costs of the public transport system is the highest and the public transport quality and reliability have the lowest normalization value. There are different possible formulas to use to aggregate results from the indicators. Two basic options are to use either arithmetic mean or geometric mean.

$$SUTI = \sqrt[n]{i_1 * i_2 * i_3 \ldots * i_n} \quad (2)$$

Where, n = Number of indicators, i = indicators value

The most significant output of the study is the geometric mean of several indicators which is around 58%.

Table 6: Several indicators and their normalization value

No	Indicators	Units	Weights	Range		Value	Normalization
				Min	Max		
1	Public transport quality and reliability	% satisfied	1	30	95	41.786	18.13
2	Affordability – travel costs as share of income	% of income	1	35	3.5	10.07	79.14
3	Traffic fatalities per 1000 vehicles	# fatalities	1	35	0	5.185	85.19
4	Operational costs of the public transport system	Cost recovery ratio	1	22	175	91.1	45.16
5	Convenient access to public transport service	% of population	1	20	100	49.72	37.15
6	Greenhouse gas emissions from transport	Tons/cap	1	2.75	0	1.2064	56.13

4.8 AHP Method

The AHP is a technique for decision analysis that takes into account both qualitative and quantitative data. Recent years have seen a rise in the adoption of the AHP approach proposed by Saaty (Saaty, 1980) to evaluate the criteria weightings in MCDM (Su et al., 2010).

Table 7: Pair-wise comparison matrix

	Indicator 01	**Indicator 02**	**Indicator 03**	**Indicator 04**	**Indicator 05**	**Indicator 06**
Indicator 01	1.00	2.00	2.00	5.00	6.00	3.00
Indicator 02	0.50	1.00	2.00	3.00	5.00	5.00
Indicator 03	0.50	0.50	1.00	4.00	3.00	4.00
Indicator 04	0.20	0.33	0.25	1.00	2.00	3.00
Indicator 05	0.17	0.20	0.33	0.50	1.00	2.00
Indicator 06	0.33	0.20	0.25	0.33	0.50	1.00

Table 8: Normalized comparison matrix

	Indicator 01	**Indicator 02**	**Indicator 03**	**Indicator 04**	**Indicator 05**	**Indicator 06**	**Weight Value**
Indicator 01	0.37	0.47	0.34	0.36	0.34	0.17	0.34
Indicator 02	0.19	0.24	0.34	0.22	0.29	0.28	0.26
Indicator 03	0.19	0.12	0.17	0.29	0.17	0.22	0.19
Indicator 04	0.07	0.08	0.04	0.07	0.11	0.17	0.09
Indicator 05	0.06	0.05	0.06	0.04	0.06	0.11	0.06
Indicator 06	0.12	0.05	0.04	0.02	0.03	0.06	0.05

The Value of the Average Random Consistency Index RI for n = 6 is 1.24. According to Equation (3), the consistency ratio is a popular metric used to determine if a comparison matrix is consistent or not. where RI is the average random index with the same dimension as A, CR is the consistency ratio, CI is the consistency index, and CI is the consistency index.

$$C.R.=\frac{C.I.}{R.I.} \quad (3)$$

where RI is the average random index with the same dimension as A, CR is the consistency ratio, CI is the consistency index. Table 8.3 contains the average random index value, and Equation (4) computes the consistency index.

$$C.I.=\frac{\lambda_{max}-m}{m-1} \quad (4)$$

Table 9 contains the average random index value, and Equation (4) computes the consistency index where n denotes the matrix's dimension and max denotes the maximal eigenvalue of the comparison matrix A. If CR is less than 0.1, the matrix can be considered a consistent matrix; if CR is greater than 0.1, the matrix needs to be changed until it is acceptable.

Table 9: Determine the Consistency Ratio

Consistency Index (C.I.)	0.0748
Random Consistency Index (R.I.)	1.24
Consistency Ratio (C.R.)	0.0603

Table 9 shows the AHP method used for measuring the indicators by ranking them in chronological order. It depicts that affordability is the priority that needs to be emphasized more to ensure the sustainability of the Rajshahi-Kushtia highway. The travel costs as a share of income of people are much higher than the standard one. So, the travel cost needs to be affordable for the roadway users and it should be kept as minimum as possible to ensure sustainability.

Table 9: Ranking of the indicators using AHP method

No	Indicator	Normalize value	Weight	Value	Rank
1	Public transport quality and reliability	18.132	0.343	6.215	3
2	Affordability – travel costs as a share of income	79.143	0.257	20.374	1
3	Traffic fatalities per 100.000 inhabitants	85.186	0.193	16.434	2
4	Operational costs of the public transport system	45.163	0.091	4.132	4
5	Convenient access to public transport service	37.150	0.062	2.294	5
6	Greenhouse gas emissions from transport	56.132	0.054	3.010	6

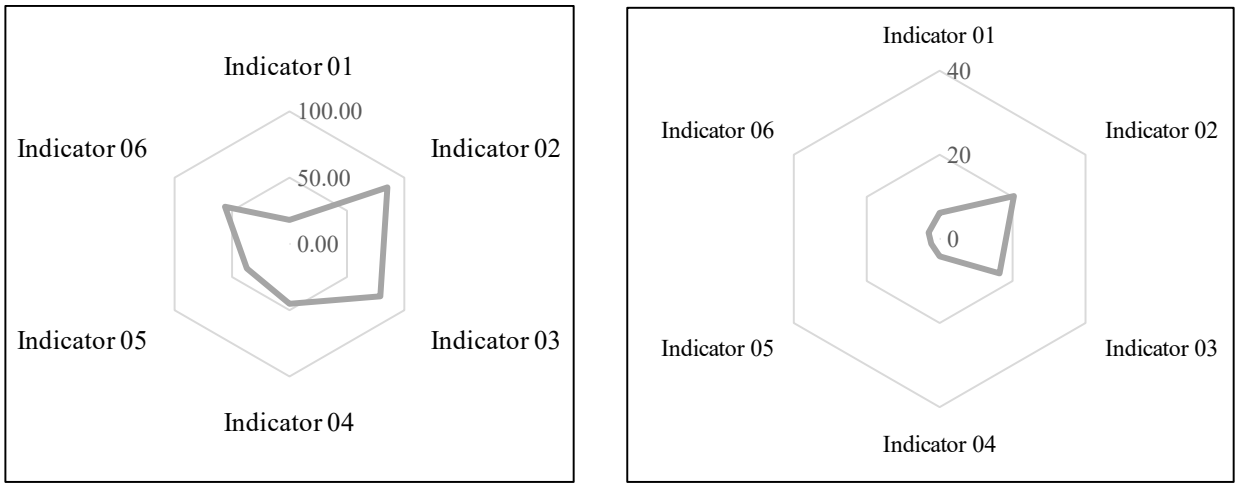


Figure 04: (a) Spider diagram using various indicators (Equal weight method). (b) Spider diagram using various indicators (AHP method).

The normalization values of the indicators are also shown in a spider diagram in Figure 4(a). The figure depicts the higher normalization value for traffic collisions and roadway fatalities on the highway. Again, the affordability of travel costs by the users has also a great influence shown on the diagram. People have to share a huge amount of their income for the travel cost. Figure 4(b) also visualizes the priority issues concerning the sustainability of the highway using the spider diagram. It shows that the affordability-travel cost as a share of income needs to be addressed as a priority and it should be emphasized in ensuring the sustainability of the roadway.

5. CONCLUSIONS

Sustainable transport systems are designed to enhance service quality, reduce pollution, limit the state subsidies to urban transport, increase the efficiency of transport networks and land usage, enhance the mobility of people with disabilities and prevent conflicts of interest among the public transportation stakeholders.

The research presents the sustainability indicators for transportation roads and their implementation in highway roads for investigation and evaluation of performance measures progress toward sustainable roads. The most significant output of the study is the geometric mean of several indicators which is around per cent, which visualize that the roadway sustainably is quite deviated from the sustainability standard. Again, the AHP method is performed to make a pair-wise ranking based on the expert opinion on the selected indicators. The ranking shows that affordability- travel cost as a share of income of people is the priority that needs to be emphasized more to ensure the sustainability of the Rajshahi-Kushtia highway. Focusing on other indicators, the ranking shows that the traffic fatalities issue, public vehicle quality and services, the increasing rate of operational costs for the highway, the convenient access to the public transport services and the greenhouse gas emission issue from vehicles need to be prioritized accordingly. The assessment result supported policymakers in identifying policy gaps and prioritising additional measures and investment strategies required to improve urban transport systems. Hence, the Rajshahi-Kushtia highway will be more sustainable according to the Sustainable Urban Transport Index,

will provide better services to the highway users, and the roadway performance will be more developed and flourish

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