



Development of sustainable public–private partnership model for bus rapid transit system in Western India: a case study approach

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Abstract

Sustainable transport is the need for an emerging economic nation like India. This paper aims at carrying out a socioeconomic feasibility study for development of a sustainable public–private partnership (PPP) model for a megacity like Ahmedabad in India. The proposed model would operate on solar and electric modes. The charging of the batteries can be done with the solar panels installed at some designated bus stops. The primary sustainability components considered for the proposed PPP model include environmental, social, economic, system effectiveness and stakeholders perception. The total proposed network has a corridor of 486.7 km. The proposed model would need a soft loan of INR 55,000 million (USD 733.33 million) at 3% interest to be paid in five ten-yearly installments of INR 49,670 million (USD 662.26 million), investment of INR 75,000 million (USD 1000 million) at 8% interest in form of tax-free green bonds that can be liquidated every 5 years and annual profit of INR 2000 million (USD 26.67 million) to the private operators. Such a model is expected to generate an internal rate of return of 15.25%.

Keywords Public–private partnership · Sustainable · Bus rapid transit system · Net present value · Internal rate of return

Introduction

Adoption of a sustainable mode of transportation for a megacity like Ahmedabad in western India was very much required to meet the increasing mobility requirement of the people and for the promotion of green and clean energy. Solar electric bus rapid transit system (BRTS) appeared to be a feasible sustainable mode of transport which required the coordination and support from the public and private agencies to make the use of alternative technology successful. This objective and motive could be achieved through the development of public–private partnership (PPP) model which could promote and implement the proposed sustainable BRTS model. The proposed sustainable PPP model is

expected to take care of the present transport problems faced by Ahmedabad city. Sheth et al. [23] worked on sustainable transport for Ahmedabad city, and they identified that though the mobility of the people has increased, accessibility for a suitable means of public transport still remains an issue in terms of time, cost and convenience. As described by Sheth and Sarkar [22], the crisis situation of Ahmedabad city is described by environmental pollution, traffic inequity and fatalities and also high levels of congestion. Authors have also raised special concern about the mobility needs of the poor. In India, PPP models are quite popular, particularly for the implementation of highway projects. The factors contributing to such projects' success and failure are having unique characteristics of their own and typically depend upon the project's geographical location. Unique characteristics of success and failure depending on geographical locations include the monthly traffic flow depending on the location of the PPP project, the eagerness of the people to use the toll road and pay the toll, the political environment of the location of the project and also statutory regulations imposed by the local bodies on the project. Gupta et al. [9] focused on the PPP model in infrastructure development in India. The authors identified the risks and uncertainties for the ongoing PPP highway projects under National Highway Authority of

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India (NHAI) and Madhya Pradesh Road Development Corporation Ltd (MPRDC). A questionnaire survey was carried out, and responses were obtained from experts associated with the highway projects in India. The study showed that PPP projects carry higher risk throughout the project life cycle because of long duration and also face the highest risk during the construction phase. The primary objective of this study is to understand the sustainability components associated with highway projects and then to propose a sustainable PPP model for an infrastructure transportation project like bus rapid transit system in Ahmedabad which is a megacity in western India. The proposed model would be technoeconomically feasible in Indian scenario.

Literature review

Frameworks for transportation sustainability

Jeon and Amekudzi-Kennedy [13] identified three major types of frameworks for addressing sustainability of a system. The frameworks identified by the authors were impact based, linkage based and influence based. As a part of their research, the authors have revealed that the impact-based framework primarily focuses on the nature and extent of various categories of impacts that collectively determine the sustainability of a transportation system without the involvement of the causal factors affecting the sustainability development. It has been observed that the three-dimensional framework of the variables and indicators based on environmental impacts, societal impacts and economic impacts are quite common. Many researchers have used these tripartite models to evaluate the sustainability indicators for infrastructure projects. These include the Litman [17] model and the Rijsberman and Van de Ven [19] model which are also found relevant for study and application to transportation infrastructure system. The linkage-based models include the Pressure State Response (PSR) model, Drivers Pressures State Impact Responses (DPSIR) and the Environment Economy (EE) models. These linkage-based models primarily deals with the causal factors and their effects for achieving the transportation sustainability. The causal factors affecting the linkage-based model include the impact of the system on the economy, impact of the system on the environment, impact of the system on social well-being and also the impact of the system on the natural environment. The necessary corrective mitigation measures for the identified adverse effects are also recommended. Finally, the influence-based model has been developed considering the level of influence and role of the organization carrying out the study. The various actions taken by the concerned organization that influences the process for achieving the sustainability in transportation sector are considered. A

comparison developed by three reputed organizations like Transport Canada (TC), United States Department of Transportation (USDOT) and the European Union (EU) may be considered as guidelines for evaluation of the parameters and indicators for achieving transportation sustainability.

Policy landscape for sustainable transport in India

The Government of India (GOI) reflects its vision for providing a Sustainable Urban Transport System through the 2006 National Urban Transport Policy (NUTP). The efforts are primarily aimed to minimize the environmental impacts that are creating due to the rapid increase of the traffic in the Indian cities. With the co-operation and support of World Bank (WB) and Global Environment Facility (GEF), the Ministry of Urban Development, India, has initiated the promotion of environment friendly and sustainable urban transport through pilot project in some selected cities. GOI and different state Governments have adopted many policies and long-term plans to reduce the emission levels created by the vehicles and also to promote electric vehicles and other sustainable modes for transportation. The national biofuel policy of India (2018) encourages the use of biofuel especially in the transportation sector. The policy is applicable solely for non-food feedstocks raised on non-agricultural land and promotes cultivation, production and use of biofuel feedstocks. At present, 20% blending of biofuels has been proposed but envisaged to increase in future. Electric vehicles (EVs) are one of the most promising technologies in the transportation sector to reduce GHG emissions in the post-2020 timeframe (International Panel for Climate Change (IPCC) 2012; International Energy Agency (IEA) 2013). The use of battery EVs would reduce the emission levels to a huge extent and provide a strong sustainable mode of transportation. This makes them highly environmentally sustainable.

Electric vehicles and biodiesel application for sustainable transport

According to study by Moro and Helmers [18], electric vehicles (EVs) are more efficient when driving on in-city routes than driving on freeway routes. The EVs thus provide a green and sustainable mode of urban transportation. But the implementation of the electric buses as a primary mode of public transport faces many challenges pertaining to the issues related to the technology and also operation and management of the buses and the infrastructure associated with it. Tran et al. [27] observe that the emergence and widespread adoption of EVs are faced with challenges as in development of new technologies, support infrastructure and investments. A review on the potential of biodiesel in Pakistan [21] gives insight on feedstocks, biodiesel production

process, barriers and future developments. The biodiesel production capacities and the indigenous oil-based feedstock potential of Serbia have also been addressed in the literature [7]. The active market acceptance and barriers of using biodiesel in Spain through a model have been examined [8]. The important factors identified in their model were attitudes toward the use, knowledge and self-identity.

Public–private partnership for sustainable transport

Public–private partnership (PPP) models have gained popularity in an emerging economy like India, but the need of the hour is incorporation of the sustainability component in the PPP models. Built Operate and Transfer (BOT) toll, BOT annuity, Built Operate Lease and Transfer (BOLT), Built Own and Operate (BOO) and Hybrid Annuity Model (HAM) are popularly used for highways, railways, ports, airports and some other infrastructure projects. PPP models for sustainable transportation project like bus rapid transit system (BRTS) for a megacity in India like Ahmedabad need to be developed.

It has been found from the available literature that Durdyev and Ismail [6] performed SWOT analysis and factors for successful implementation of BOT model for sustainable transport projects and viewed it as an infrastructure privatization strategy for Turkmenistan. Evenhuis and Vickerman [29] examined the issues of incorporating social marginal cost pricing to incorporate the sustainability component in public–private partnerships questioning the PPPs from the point of incentives. Al-Saadi and Abdou [1] were the main proponents to explore the factors critical for the success of PPP models for infrastructure projects in UAE. Debela [5] explored and carried out their work on the critical success factors (CSFs) of PPP road projects in Ethiopia. Sarkar and Singh [20] were the main proponents to work on the risks associated with the mass rapid transit systems (MRTS) which would finally enable to develop a feasible PPP model for the same. Tsamboulas et al. [28] developed an evaluation framework for assessing the preference of PPP financing on sustainable transport projects that is based on multi-criteria analysis approach which includes the social attributes of the scheme in addition to the value for money approach. The framework has been applied on Indore-BRTS in India. Siemiatycki [25] developed a set of criteria to evaluate a PPP from planning and sustainable perspective and analyzed three case studies. In the process of analysis, the researcher identified that the short-term and long-term impacts of the PPP on infrastructure project delivery are different. Whereas the short-term effect of the model was seen positively in fundraising for new facilities and financial risk transfer to private sector, its negative effect was seen in terms of limited transparency and lesser community engagement. Similarly, whereas in the long-term, non-competition

clause in concession agreement led to restriction in flexibility, lawsuits due to deteriorating relationships got common. PPP highway projects depend to a considerable extent on the factors affecting the project's success and failure. The factors affecting the loss are primarily the risk factors that need to be identified, evaluated, and mitigated by the project authorities. Thomas et al. [26] carried out perception risk analysis for the Indian BOT road projects stakeholders. A survey was conducted among four significant PPP project stakeholders—Government, promoters, lenders, and consultant, by identifying eight risk components. The study's primary objective among the country's stakeholders is to evaluate the project participants' perceptions. They conclude that traffic revenue and demand risk are the significant constraints of any PPP project. All the stakeholders are blaming that other stakeholders should bar such all kinds of risk as they had a better way to assess and handle. Gupta et al. [9] focused on the PPP model in sustainable infrastructure development in India. They aimed at identifying the risk variables of in-progress PPP highway projects under National Highway Authority of India. A questionnaire survey among experts, ten risk categories, and 41 risk variables was identified and considered for risk evaluation. The study showed that PPP projects carry higher risk throughout project life because of long duration and face the highest risk during the construction phase. For risk profile, the regulator was suggested the mitigation measures that would help manage the rapid switch in socioeconomic environment and to recommend actions to minimize the risks in upcoming projects. Some of the recommended mitigation measures include following a robust mechanism for land acquisition and proper negotiation need to be done with the affected parties. The resettlement and rehabilitation package need to be attractive. The utilities coming within the alignment of the BRTS corridor need to be identified with proper utility drawings, and their diversion schemes need to be implemented properly. The trees coming within the alignment need to be identified at least six to eight months before the starting of the construction work, and the necessary drawings need to be submitted to the forest and environment department. Rigorous follow-up need to be done with the officials of the forest and environment department for the necessary action for removal or relocation of the tree. Proper Health Safety and Environment (HSE) department needs to be established to ensure proper safety measures throughout the lifecycle of the project. Proper quality control and quality assurance department should be established to maintain quality throughout the entire lifecycle of the project.

Zhang [31] studied the critical success factors affecting sustainable infrastructure development under PPP. In the present study, Zhang discussed the various factors that may lead the PPP project toward success by incorporating the sustainable development components. Jefferies [12]

discussed the success factors of PPP sectors. A case study of a dome construction in Sydney under the BOOT model's PPP concept has been considered in his study. Jacobson and Choi [11] discussed the success factors for public works and PPP. In the present study, they identified success factors for public–private partnerships and public works projects simultaneously. A total of 10 factors were identified from questionnaires and interviews with participants. Jin [14], Jin and Doloi [15] conducted a study related to the risk allocation mechanism considering the sustainability component within PPP projects.

Cheung and Chan [3] had discussed expanding drift of public–private partnership in developing sustainable public infrastructure in China. However, severe risk variables are engaged in PPP ventures when contrasted with the traditional delivery method. Shrivastava and Rao [24] presented success factors of the PPP projects considering the sustainability component in the Indian context. India is a developing country and hoping for the best from PPP in road sectors. This need arises to identify the critical success factors considering the sustainability component in the road sector of India. Initially, they explained the different model concessionaire agreements and their salient features. Total 22 success factors were identified and analyzed from BOT projects in India. Nigeria is one of the developing countries and needs to develop more infrastructures using PPP. Critical success factors for Nigeria's PPP ventures were studied [2]. Favorable economic conditions, government guarantee, effective procurement, available financial market, and project implementation are the five prime parameters for the project's success. They also discussed various projects under the PPP models. Cheung et al. [4] studied and compared the accomplishment aspects contributing to sustainable PPP projects within Hong Kong, Australia, and the United Kingdom. From the literature review, approximately 18 success factors are affecting all three countries. Xu et al. [30] discussed the concession pricing in PPP contracts and how pricing should vary concerning the private sector's risks and incorporate equitable risk division between the public and private sectors to limit concession price make sure successful risk management. Xu et al. [30] discussed the risk evaluation model of the PPP model using soft computing. They used the literature review of past researchers and the Delphi survey method for the data collection, and collected data were analyzed using the fuzzy technique. Overall, 37 individual factors were identified after the first round Delphi survey, and 17 critical risk factors were divided into six groups after the second round of the Delphi survey.

Hwang et al. [10] discussed the public–private partnerships procurement of projects in Singapore. They aimed to assess the critical success variables and positive and negative variables that influence the attractiveness of the sustainable PPP ventures and essential variables of risk

and favored risk allocation of PPP ventures in Singapore. Kumar et al. [16] discussed the issues related to the financial risk and their assessment using modeling technique for Indian highway project under PPP mode. They considered the factors affecting the project finance like traffic, discount rate, toll, project cost, concession period, construction period, operation, and maintenance cost. They conclude that the NPV-at-risk is used for risk analysis of the BOT projects under PPP.

Reviewing the available literature, it has been observed that adequate literature is available on the PPP models implementation globally [2, 3, 24], Xu et al. [16, 20]. The available PPP models do not address the sustainable components which would make the model more green and environment friendly. The PPP models implemented are primarily for highways, railways, ports and airports. Some researchers have made attempt to develop sustainable PPP models but the work is in very nascent stage. Also, it is difficult for urban transit authorities (public domain) to be completely responsible for an electric-based or bio-diesel-based transit and need for public–private partnership model with private players like bus operators, electric power suppliers, biodiesel plant owners, etc., has been identified. Public–private partnerships for BRTS exist but for electric BRTS or biodiesel-based BRTS need to be addressed with a few more players in the project. Thereby, the present work aims at developing a sustainable PPP model for a urban mass rapid transit system (MRTS) project like bus rapid transit system (BRTS) in a megacity like Ahmedabad, India.

Methodology

The methodology adopted for this study is primary data-based research where the primary data has been collected from the existing BRTS project of Ahmedabad, India. The data were collected pertaining to the capex requirement of the project, finance sources, revenue model sources, land development data, design data and operation data. Risks involved and associated with the different phases of the project also was identified, and their severities were analyzed for the development of the proposed PPP model for the BRTS project of Ahmedabad, India. For checking the suitability of the model, data pertaining to the public sector support, private sector support, potential barriers to the development of the PPP model, details of the concession period, details of the macroeconomic variables, demand forecast, details of viability analysis, details of cash flow and income statement. The methodology adopted for this research is presented through the below flowchart as presented in Fig. 1.

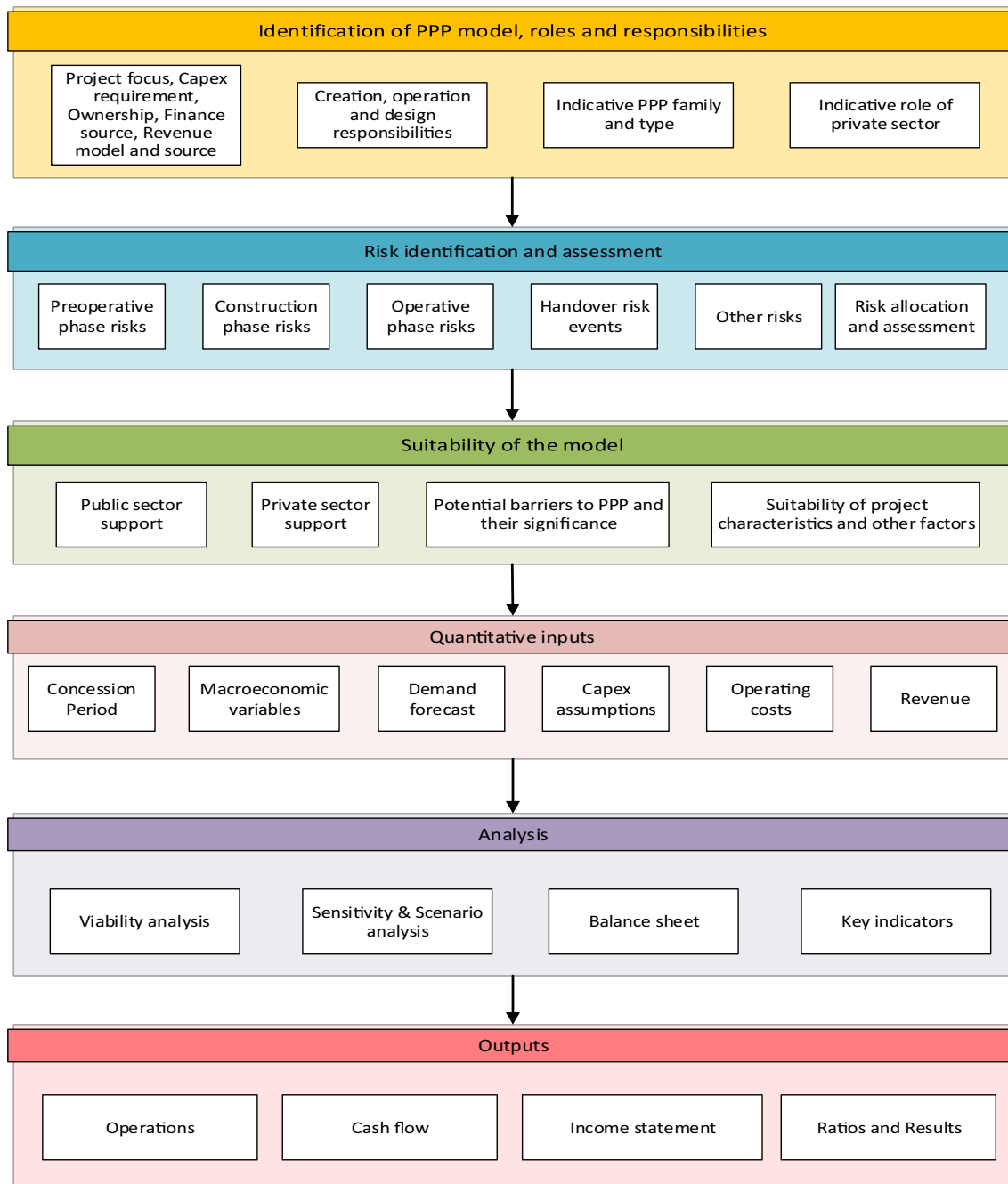


Fig. 1 Methodology for PPP model assessment

Case study

Case study considered for this study is bus rapid transit system (BRTS) project of Ahmedabad, India. This project was launched to serve the population of about 7.2 million of Ahmedabad city, which is the seventh largest metropolitan area of India. The feasibility study of this project was carried out in 2005, and the first corridor was operational in 2009. At present, a total route network of about 155 kms is covered in

the BRTS network. The existing route details are presented in Table 1.

The detailed route map of the existing BRTS is presented in Fig. 2.

Table 1 Existing route details of Ahmedabad BRTS project

Route nos	Route details
1	Ghuma ↔ Maninagar
2	Science City Approach ↔ Odhav Ring Road (via Delhi Darwaja)
3	RTO ↔ Maninagar (via Anjali)
4	DCIS Circle ↔ LD College of Engineering
5	Vasna ↔ Naroda (via Narol)
6	Narol ↔ NarodaGaam
7	Vishwakarma College (IIT) ↔ Narol (via Kalupur)
8	ISKCON Cross Roads ↔ Naroda (via Kalupur)
9	Vasantnagar Township (Gota) ↔ Maninagar (via GeetaMandir)
11	Townhall/LD College of Engineering ↔ Odhav Ring Road
12	RTO ↔ CTM Cross Roads
101	RTO → RTO (clockwise, via Kalupur → Anjali)
201	RTO → RTO (anticlockwise, via Anjali → Kalupur)

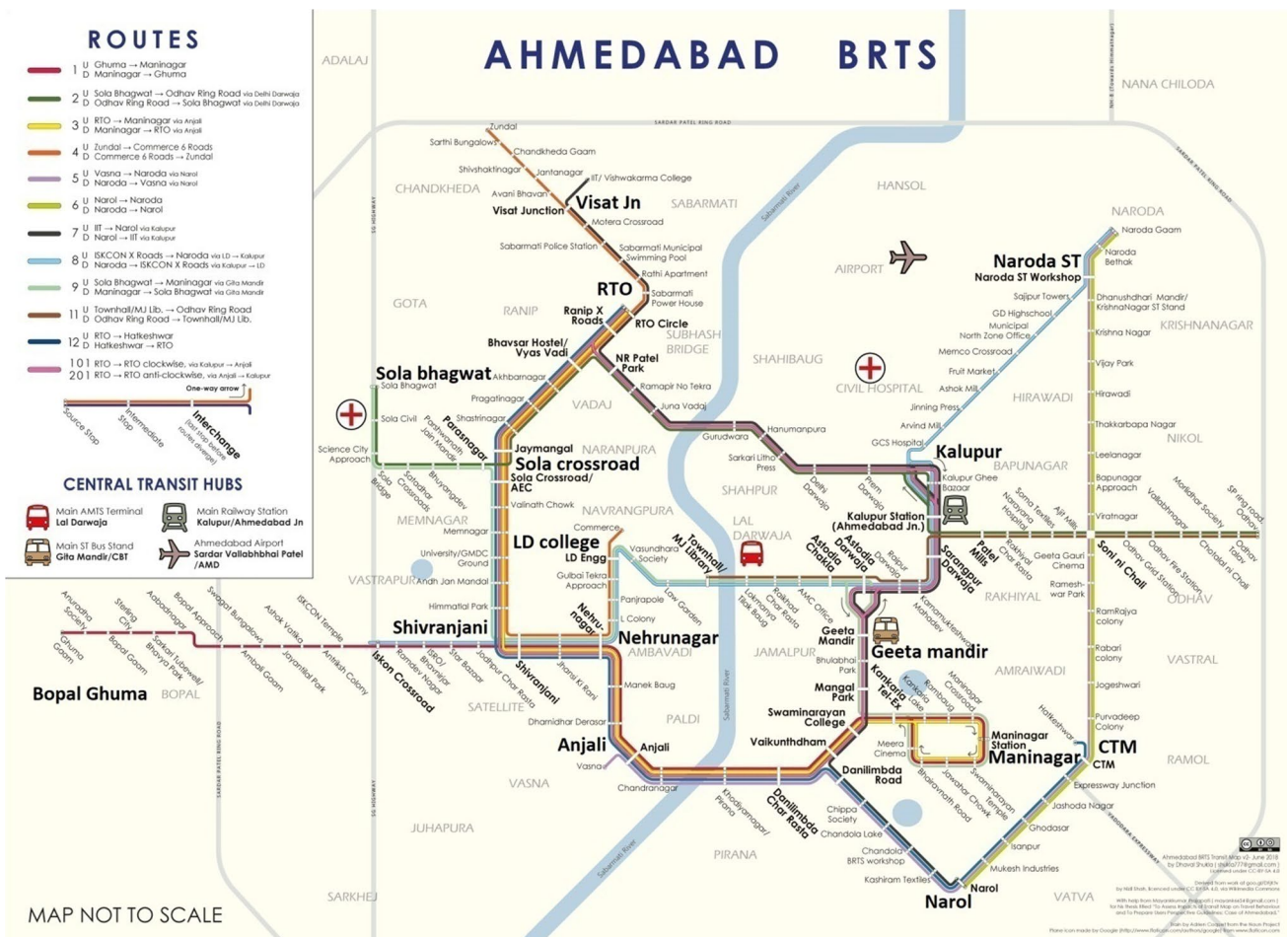


Fig. 2 Detailed route map of the proposed sustainable Ahmedabad BRTS

Public transport sustainability model for Ahmedabad

Based on the concerns of the city’s public transport, an

impact-based framework on a five dimension scale has been proposed. The five dimensions recommended for the development of the sustainable transportation model are as follows: (a) Economic, (b) Social, (c) Environmental,

(d) System Effectiveness, and (e) Stakeholder perception. Thirty indicators and control variables have been identified to develop the five-dimensional framework. Attempt has also been made to simplify and quantify most of the indicators in a tangible way. However, perception-based measurements are inevitable qualitative in nature and a scale of 0 to 10 is suggested with 10 being most positive

impact. The various indicators identified are illustrated along with their desirability and significance in Table 2.

For measuring the impact of an intervention, it is suggested to associate equal weightage to all five dimensions, which is 20%. Normalization of scores for each indicator on a scale of 0 to 10 is recommended to take care of difference in units across indicators and difference in magnitude across interventions. Switching to electric buses from

Table 2 Recommended indicators for public transport sustainability assessment for Ahmedabad

S. nos	Dimension	Indicator	Desirability	Significance
1	Environmental	Mass of total pollutants emitted (CO, HC, CO ₂ , NO _x , PM, etc.)	Lower the better	Air pollution impact
2	Environmental	dB levels from bus/rail operation alone	Lower the better	Noise pollution impact
3	Environmental	Land under bus/rail corridors and bus/rail parking and stations	Lower the better	Land resource consumption impact
4	Social	Percentage city area within 500 m of nearest bus/rail stop	Higher the better	Spatial Public Transport (PT) Accessibility
5	Social	Percentage of population served within 500 m of nearest bus/rail stop	Higher the better	Provided PT accessibility
6	Social	Rating of ride quality, comfort and security	Higher the better	Perceived accessibility
7	Social	Percentage of annual travel cost per income	Lower the better	Affordability
8	Social	No. of fatal and incapacitating accidents with involvement of public transport	Lower the better	Safety and death due to accident
9	Economic	Investment in public transport	Lower the better	Capital expenses due to PT infrastructure
10	Economic	Annual operating and maintenance cost	Lower the better	Recurring expenses of PT infrastructure
11	Economic	Revenue due to ridership (fare), advertisement & other (such as urban transport fund)	Higher the better	Monetary gains due to service provision
12	Economic	Percentage of annual travel time per year	Lower the better	Travel time savings
13	Economic	Passenger-km travelled per GDP	Higher the better	Total utilization of PT facility
14	System effectiveness	No. of seats per population	Higher the better	Capacity provision and fleet size
15	System effectiveness	Average vehicle occupancy (% of seating capacity)	Higher the better	Capacity utilization
16	System effectiveness	Percentage of PT trips overall trips	Higher the better	Modal split
17	System effectiveness	Average frequency of public transport	Higher the better	Waiting time savings
18	System effectiveness	Number of instances of late/cancelled service	Lower the better	Reliability of public transport
19	System effectiveness	Provision of information technology	Higher the better	Information technology impact
20	Stakeholder perception	Student perception rating	Higher the better	Student point of view
21	Stakeholder perception	Construction workers perception rating	Higher the better	Construction workers point of view
22	Stakeholder perception	Industrial employees perception rating	Higher the better	Industrial employees point of view
23	Stakeholder perception	Government employees perception rating	Higher the better	Government employees point of view
24	Stakeholder perception	Non-government employees perception rating	Higher the better	Non-government employees point of view
25	Stakeholder perception	Drivers and staff of PT vehicles perception rating	Higher the better	Drivers and staff of PT vehicles point of view
26	Stakeholder perception	Other employees of the PT organization perception rating	Higher the better	Other employees of the PT organization point of view
27	Stakeholder perception	Non-PT users perception rating	Higher the better	Non-PT users point of view
28	Stakeholder perception	Visually impaired perception rating	Higher the better	Visually impaired point of view
29	Stakeholder perception	Physically challenged perception rating	Higher the better	Physically challenged point of view
30	Stakeholder perception	Tourist perception rating	Higher the better	Tourist point of view

conventional diesel buses may affect in a positive manner the parameters and indicators like the air pollutants and may negatively affect the capital investment associated with the implementation of the sustainable mode of transportation. Very important in such cases therefore is the stakeholder's perception which can be the controlling parameter for changing the nature of decision leading to some out of box thinking on the revenue model.

Proposed public–private partnership (PPP) model for sustainable transport for Ahmedabad, India

A PPP model for the proposed sustainable transport for Ahmedabad, India, has been developed. Through the life cycle cost assessments and benefit–cost ratio assessments, the techno-economic feasibility has been established. In particular, it was noticed that the proposals suggested with alternative fuel technologies are capital intensive. In addition, it is also noticed that the carbon finance available through Clean Development Mechanism (CDM) is insignificant and is not capable of addressing the financial gap. Therefore, an alternative financial instrument like PPP model is required. Also, due to the nature of the sustainability intervention, it is required that many public sector bodies and private operators get involved for a common goal and bring upon this type of development. For instance, for biodiesel-based transit, the biodiesel plant owner, the bus operator, and biodiesel fuel provider are key private entities that need to be involved. But the marginal pricing of the biodiesel and the availability and pricing of feedstock cannot happen without governmental intervention. Therefore, a joint effort through a PPP model will be required. The methodology adopted for the PPP model formulation is indicated in Fig. 3.

According to Fig. 3, the primary project details required for development of the PPP model for the sustainable transport in Ahmedabad are capex requirement, finance source, revenue model and the ownership status. In the next level, the roles and responsibilities of the public party and the private party need to be decided. The next step involves the selection of the PPP model type and the contract model. In the next level, the identification and allocation of the risks are essential. After computing the risk severity, the suitability of the PPP model with respect to the public and private support that would be provided for the project, the barriers and challenges that the project may face are evaluated. In the next step, the quantitative inputs like the tentative financial benefits that would be obtained from the project, the tentative costs that would be incurred for the project, the tentative capex and opex required for the project, and also the tentative revenue that would be generated from the project. The next step is the model development, where the details of the

soft loans availed by the concessionaire, the investment to be done by the concessionaire, the profit incentives and details of the infrastructure pricing to be carried out by the concessionaire need to be evaluated. In the final step, detailed analysis about the effectiveness of the proposed model can be carried out through Net Present Value (NPV) analysis, Internal Rate of Return (IRR) analysis and also sensitivity analysis.

The focus of the proposed sustainable PPP model is on the rolling stock and solar power plant. The PPP model has been designed for a capital expenditure focused project but includes operating and maintaining expenditure also. The capex will be required for procurement of buses, charging stations and batteries and creation of solar power generation, transmission and distribution infrastructure. The capex for all these entities will be greenfield. All the assets requiring capex will be privately owned. More than 50% of the capex will be enabled through the private partners. The private sector roles will include acquisition of buses, operation and maintenance of buses (including drivers and battery supply and management), provision and management of charging infrastructure and creation, operation and maintenance of solar power plant. The private operator will be responsible for both creation as well as operation of the assets. Some of the assets under the project will be brownfield. The private sector will be responsible for design. The PPP will be a Build Operate Transfer (BOT) type with main private sector roles being finance, create, manage, maintain, collect fare and transfer.

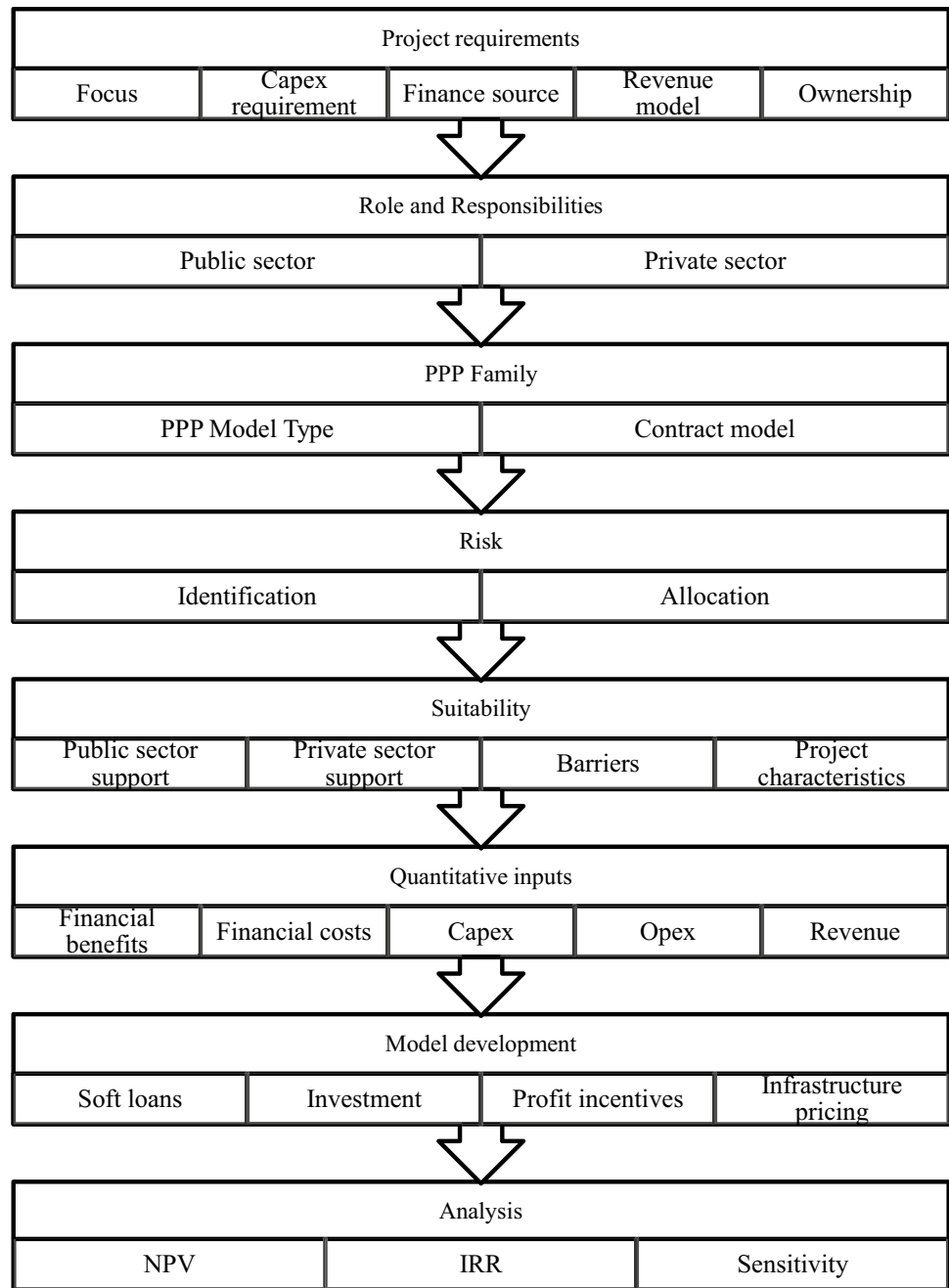
The corridor/road infrastructure will have public ownership. The preferred revenue model will be through reimbursement of pre-specified operating cost based on performance standards. A gross cost-type contract model will be adopted for the PPP. The primary revenue source for the private sector will be through ridership revenue, from which a fixed profit will be allotted to the private entity. The various risks associated with the project have been identified and allotted to either the public or private sector based on the type of risk. The details of the risk allocation are presented in Table 3.

The PPP suitability based on support of public and private sector, project characteristics, potential barriers and time constraints are discussed as follows:

Public sector support:

PPPs have been specifically enabled in primary legislation, and the current government has adopted a policy for private participation in the urban transport sector. High-level political bodies exist for such a project although the local community may not be actively engaged or informed about such a project. PPP focal points also exist that have advisory powers and the sponsoring agencies might have some

Fig. 3 Public–private partnership model development methodology



capability to procure, manage and monitor the PPP. Many sponsoring agencies in the state have extensive experience in handling PPP projects. One of the other benefits is that the infrastructure would pass through a single jurisdiction of city level and therefore less complications and negotiations will be involved.

Although partial fund sanctions and national policies for solar, BRTS and electric mobility are applicable to the project, the availability of funding assistance is somewhat uncertain. However, the project is definitely eligible for viability gap funding due to its environmental benefits and

socioeconomic development features. The project may also be eligible for funding from other grant schemes as well as multilateral agencies.

Private sector support:

The extent of interest among qualified firms is not yet surveyed for the particular project; however, interest has been demonstrated for similar projects at national level. No complete project with exact same technology and scale has been demonstrated yet and so financial success cannot be

Table 3 Details of risk identification and allocation for the sustainable PPP model

Risk type	Sensitivity	Relevance during the concession	Preferred allocation
<i>Pre-operative phase risks</i>			
Delays in land acquisition	High	0–2 years	Public sector
External linkages	High	0–2 years	Public sector
Financing risks	Medium	0–2 years	Private sector
Planning	Medium	0–2 years	Private sector
<i>Construction phase risks</i>			
Design risk	Medium	0–4 years	Private sector
Construction risk	Medium	0–4 years	Private sector
Approvals	Medium	0–4 years	Private sector
<i>Operations phase risks</i>			
Operations and maintenance risks	Medium	Throughout	Private sector
Volume risk	Medium	Throughout	Private sector
Payment risk	High	Throughout	Private sector
Financial risk	High	Throughout	Private sector
Non-operation revenue risk	Medium	Throughout	Shared
<i>Handover risk events</i>			
Handover risk	Medium	Last 2 years	Private sector
Terminal value risk	Medium	Last Year	Private sector
<i>Other risks</i>			
Change in law	Low	Throughout	Public sector
Force majeure	Low	Throughout	Shared
Concessionaire risk	Medium	Throughout	Public sector
Sponsor risk	Medium	Throughout	Private sector
Concessionaire event of default	Medium	Throughout	Private sector
Sponsor's event of default	Low	Throughout	Public sector

predicted; however, many BRTS projects have demonstrated financially successful PPP models in the past few years.

Potential barriers:

The considered PPP will require major land acquisition, and this needs to be accomplished by the concessioning authority before start of construction. The PPP will have very low social and environmental impacts, in fact it has been demonstrated in this research that the project has socio-economic benefits. The PPP is expected to impact labor and employment positively. There may be some transfer of employees, and the PPP will result in creation of new jobs.

The revenue source of the project is, through fare collection, the charges of which are kept at the same rate as the existing social marginal pricing and not escalated apart from a basic annual growth, and therefore, the demand or payment risk considered is medium. The fares have been set by government sponsor based on a formula which is specified in the contract. The profit margin has been set annually in the PPP model and unless there is a major downfall in ridership (which is less probable), the PPP operator has a good likelihood of getting paid.

Project characteristics:

The project requires investment for rolling stock (buses) and solar power plant, which amounts to a project value greater than INR 75,000 million (USD 1000 Million). However, the project can be developed in phases. The other advantage is that although the operation phase costs are substantial, they are small as compared to construction and procurement phase costs. The project will actually reduce the operation phase costs being incurred presently giving life cycle benefits. The outputs of the project as defined in financial terms are measurable; however, many socio-economic outputs such as air pollution, travel time saving and such may be defined and measured but not exactly in monetary terms.

Other factors:

The major other factors that need to be considered are that the PPP procurement documents are available for electric buses for a smaller scale and can be considered at an early stage of development. The solar-related PPP documents for BRTS have not been prepared nor are any standard

documents for a project of this type and scale available. Besides, the project may be envisaged as a first of its kind, and therefore, no previous local experience is available.

Quantitative analysis of the PPP model

This section illustrates a PPP formulation for achieving desired Rate of Return (ROR) and carrying out a multi-criteria-based PPP in the best interest of public agency (through project realization and less financial burden), private agencies involved (through incentives and profit) and society involved (through marginal system pricing). The illustration presented is for proposed Solar Electric BRTS (SE-BRTS). The iterative methodology used for formulation is indicated in Fig. 4.

According to Fig. 4, the cash flow for the socioeconomic benefits and the associated costs for the project need to be computed. This would help in development of the PPP model taking into consideration the soft loan assumptions, application of the capex criteria, profit expectations and investment model for additional revenue. All these data would collectively be required for the examining the financial feasibility through Net Present Value (NPV) analysis, Internal Rate of Return (IRR) analysis and also Sensitivity

Analysis. Finally, if the IRR is found to be greater than 14%, the proposed PPP model appears to be feasible. This 14% value has been obtained from the interaction of the experts who are associated with BRTS projects across the nation and also from the past records of similar BRTS projects globally. Available literature (Cheung and Chan, 2011, Shrivastava and Rao [2, 24] Sarkar and Singh, 2019) also supports the value of 14% as the minimum acceptable IRR for socioeconomic feasibility of the PPP project.

Existing BRTS network: The existing BRTS network in Ahmedabad has a corridor of 256.55 km. The bus transit operates at an average speed of 23 kmph with a peak headway of 8 min and base headway of 18 min. The system operates for 4 peak hours (2 h in morning and 2 h in evening) and 12 base hours. The system presently operates mainly on diesel-fuelled buses with an average range of 250 km.

Proposed BRTS network: The proposed BRTS network has been developed as a part of this study by modifying the conventional bus transport network with a view to provide route integration and improved accessibility. The proposed network thus developed has a corridor of 486.7 km, which is distributed in the six zones of the city as indicated in Table 4. The characteristics of transit adopted for the proposed BRTS are similar to the existing BRTS otherwise. For 486.7 km long BRTS with 6 zones, approximately 50 EVs would be operating. The average daily traffic (ADT) would be approximately 0.35 to 0.4 million. There are approximately 154 bus stations in the proposed corridor. The effect of overpasses and underpasses in the proposed BRTS corridor would be positive and good as the overpasses and underpasses would reduce the travel time and would help to prevent of mixing of the BRTS buses with the normal traffic.

The proposed PPP model has been formulated and analyzed for 50 years and 486.7 km corridor length. The cash flow diagram is indicated in Fig. 5. The benefits and costs are accounted as follows:

1. The capital expenditure accounted includes cost for corridor development, cost of bus procurement, cost of charging infrastructure, cost of solar plant installation, cost of power transmission and distribution network.

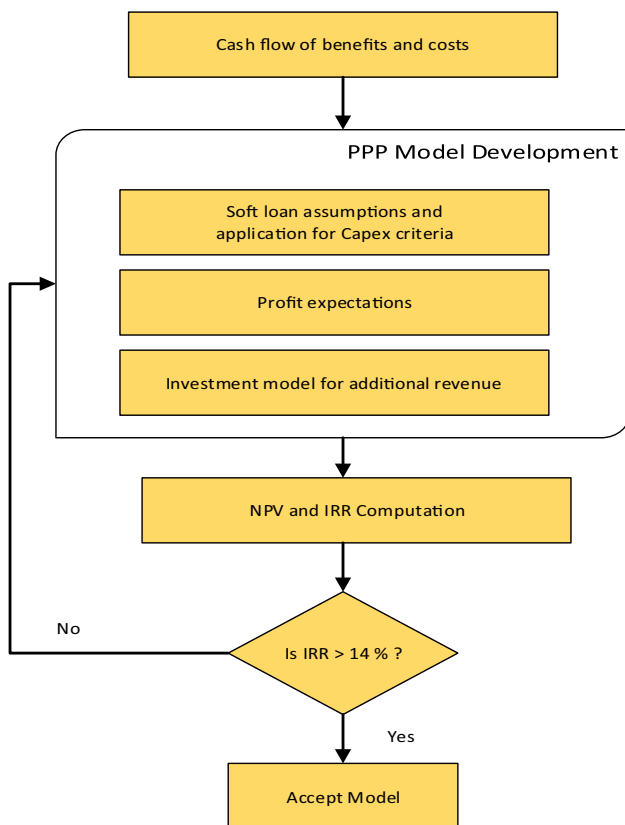
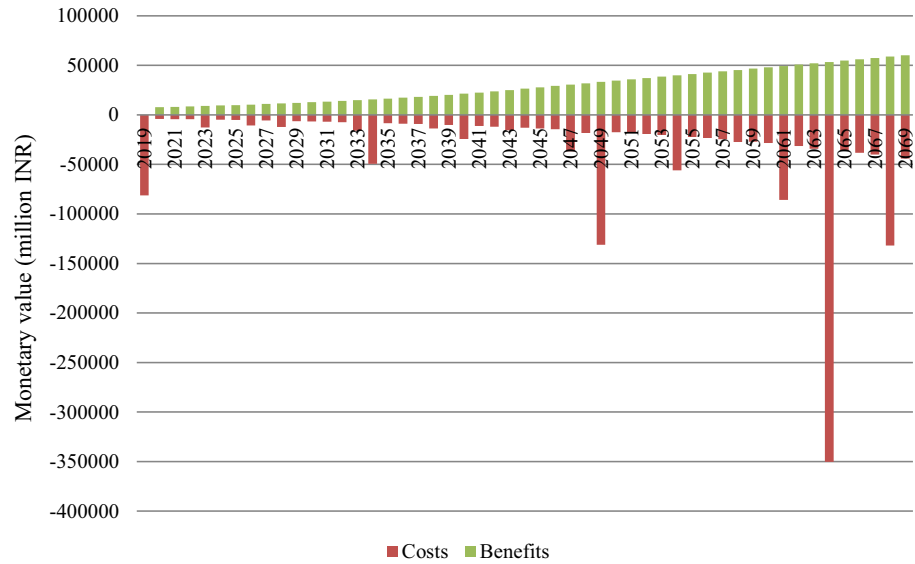


Fig. 4 Iterative methodology for the PPP model development

Table 4 Corridor length of proposed BRTS in various zones of Ahmedabad

S. nos	Zone	Corridor length (km)
1	North	49.9
2	Central	54.5
3	West	80.5
4	South	83.8
5	East	88.8
6	New West	129.2

Fig. 5 Cash flow diagram with benefits and costs without PPP implementation



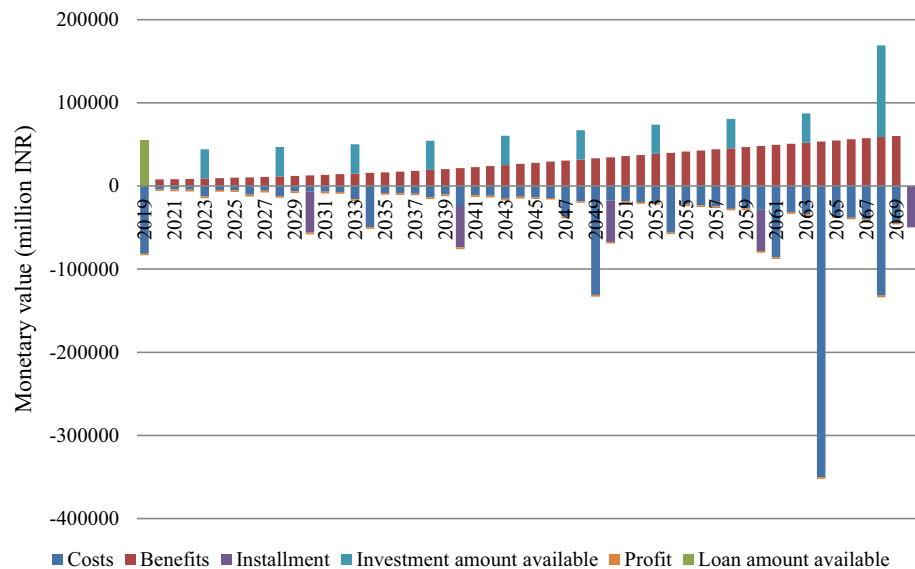
2. The annual expenditure accounted includes cost of infrastructure management and cost of system operation and management, both increasing at 5% per year.
3. The one-time recurring expenditure accounted includes battery replacement every 5 years (depreciating by 5% per year), ITMS replacement every 7 years (escalating by 7% per year) and bus replacement every 15 years (escalating by 7% per year).
4. The benefits include annual revenue through fare collection and advertisement, escalating by 5% and 15% per year, respectively.

The cash flow diagram benefits and costs after implementation of the PPP model is indicated in Fig. 6. The following

interventions have been incorporated for the proposed PPP model:

1. A soft loan of INR 55,000 million (USD734 million) principal at a rate of 3% from an agency such as Indian Renewable Energy Development Agency (IREDA), World Bank (WB) or Asian Development Bank (ADB) is anticipated. The loan is to be paid every 10 years (i.e., in 5 instalments of 49,670 million INR)
2. An investment of at least INR 75,000 million (USD 1000 million) tax-free green bonds at a growth rate of 8% and 5-year bond period are expected.
3. A fixed fund of INR 2000 million (USD 26.67 million) is to be allocated to the private sector as a profit margin.

Fig. 6 Cash flow diagram with benefits and costs after PPP implementation



Finally, in Fig. 7, the final break even analysis has been carried out where it has been observed that the NPV is transitioning from a negative value to a positive value. Positive NPV indicates that the project is feasible and cash inflow is greater than the cash outflow. Negative NPV indicates that the project is not feasible and cash inflow is less than the cash outflow. The transitioning point where the NPV is zero indicates that this is the breakeven point where the cash inflow is equal to the cash outflow. This is also a no profit no loss point. In the proposed model, at IRR = 15.22% the NPV = 0 which is certainly the breakeven point. Thereby, any IRR greater than or equal to 15.22 would make the proposed PPP model feasible. This study has been carried out with a discount rate of 12%. This proposed model would operate with electric buses, and the electric busses would have the facility of charging their batteries with solar panels installed at the rooftops of specified bus stations.

Discussion

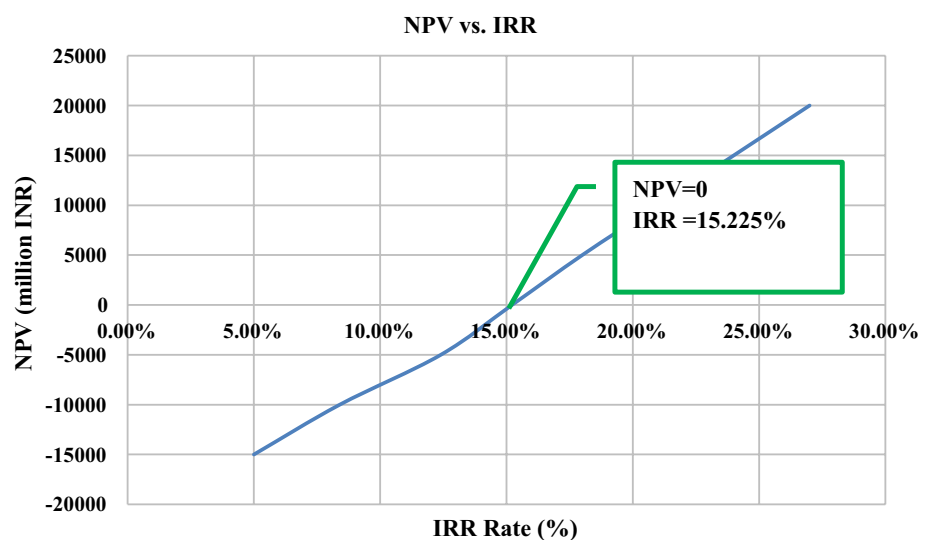
The grid electric BRTS is found to be less prudent as most cities in India have a strong competition from industry and other economic requirements to fulfill their power needs and the high requirement of electric power may not be available from the grid. In the long run, the solar electric powered BRTS may be adopted through phase-wise implementation looking to its very high social and environmental significance. The solar captive power plant may be made as part of the grid thus boosting the renewable energy share as well as ensuring the supply-side uniformity which is usually an issue with the renewable power generation. Techno-economic feasibility studies for sustainable BRTS using biodiesel as an alternative fuel need to be carried out. A specific road-map and draft policy pertaining to the different aspects of

the proposed sustainable transport need to be prepared by consulting the concerned authorities and with Government support these policies need to be implemented as early as possible.

Conclusion

From the analysis, it has been observed that the proposed sustainable PPP model for Solar Electric BRTS of Ahmedabad, India, may generate an IRR of 15.22%. Thereby, this model appears to be socioeconomically feasible. This model would be proposed to be operated through solar and electricity. Thereby, the proposed PPP model has been termed as SE-BRTS. The primary features of the PPP model include (a) soft loan of INR 55,000 million (USD 733.33 million) at 3% interest to be paid in five ten-yearly instalments of INR 49,670 million (USD 662.26 million) (b) investment of INR 75,000 million (USD 1000 million) at 8% interest in form of tax-free green bonds that can be liquidated every five years and (c) annual profit of INR 2000 million (USD 26.67 million) to the private operators. Such a model is expected to generate an internal rate of return of 15.25%. Apart from this, the policy landscape and the qualitative and practical aspects of the alternative fuel technologies (biodiesel, grid electric and solar electric) were studied in the context of the Ahmedabad city and the Indian subcontinent. A network modified from the conventional bus transport system in Ahmedabad to achieve more accessibility and route integration has been proposed. The total proposed network has a corridor length of 486.7 km. The proposed model would operate with electric vehicles and would have the facility of charging the batteries through solar panels installed in the rooftops of designated bus stations. This proposed SE-BRTS would provide environment

Fig. 7 NPV and IRR graph with PPP implementation



friendly sustainable transport for residents of Ahmedabad city of India. Since the concept is generic, similar sustainable BTRS models can be developed for other mega cities across the nation. This study would contribute to the existing body of knowledge by giving the necessary inputs to the project authorities and the policymakers about the methodology they need to follow for development of a PPP model for a BRTS project by incorporating the sustainable components. The proposed methodology would promote the use of renewable energy in public mode of transport.

Scope for future research

The scope of future research for this study lies in carrying out a Life Cycle Cost Analysis (LCCA) and Social Benefit-Cost Analysis (SBCA) for the use of biodiesel as a sustainable fuel. Furthermore, the feasibility of a PPP model for BRTS with biodiesel as the fuel needs to be carried out through NPV, IRR and sensitivity analysis.

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Compliance with ethical standards

Conflict of interest No potential conflict of interest was reported by the authors.

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