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Financial Analysis of Solar Electric Bus in India

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ABSTRACT

Present day buses in India utilize fossil fuels which cause a concern for environmental pollution and energy security. This research paper looks into the possibility of development of bus transit using solar electric infrastructure in Gujarat. The paper presents the case of replacing diesel buses with a solar electric buses and a financial analysis thereof in light of present policies and subsidies offered by the government. The results indicate close to desirable internal rate of return over 25 years' time frame, considering an optimistic scenario of governmental support. The research brings into discussion the need for developing indigenous infrastructure elements and for exploring alternative financial models for enabling sustainable bus transport.

KEYWORDS:Electric bus, renewables, financial feasibility, internal rate of return

INTRODUCTION

According to the intergovernmental panel on Climate Change, the transport sector is responsible for approximately 23 % of total energy-related CO_2 emissions in the world. According to the Central Electrical Authority (2014), Ministry of Power, GoI, India's grid is highly carbon intensive with 950 gCO_2/KW h compared to other countries in the world. Thus there is a need to establish more aggressive and sustainable practices in the transport sector. Use of efficient vehicles that consume low energy and clean energy is one way of mitigating the pollution due to carbon emissions and counteracting the health hazards that are related to the pollution. The fifth IPCC assessment report gives high confidence to reduction of carbon intensity of fuels through use of electricity produced from low GHG sources. Present day buses in India utilize fossil fuels viz. diesel/ CNG fuels for transporting passengers. Thus, in addition to pollution concerns, there is also a concern for energy security. In order to improve the quality of life of cities that are already undergoing the multiple challenges of urbanization, it is imperative to look into the development of bus transit using renewable energy and explore the underlying possibilities thereof.

The Government of India reflects its vision for providing a Sustainable Urban Transport System through the 2006 National Urban Transport Policy (NUTP). The input-oriented efforts are aimed to contain and reduce the environmental impacts that are a consequence of traffic growth in the cities. The Ministry of Urban Development has initiated a Sustainable Urban Transport Project with support of Global Environment facility and the World Bank to promote environmentally sustainable urban transport in India and to improve the usage of environment-friendly transport modes through demonstration projects in selected cities. Many other long term plans are in place by GOI and state governments that include policies related to vehicle emissions, promotion of public transport (bus and rail) and promotion of electric vehicles.

In an attempt to explore sustainability through use of renewables in the transport sector, this research paper presents the model for development of solar electric bus transport and examines the financial implications of replacing a partial fleet of three diesel buses with three electric buses, the electricity for which may be generated using solar power.

ELECTRIC VEHICLES: A LITERATURE REVIEW

Electric vehicles (EVs) are one of the most promising technologies in the transportation sector to reduce GHG emissions in the post 2020 timeframe (IPCC 2012; IEA 2013). The main benefit associated with the battery electric vehicles is that they emit no tailpipe emissions and have potentially very low fuel-production emissions. This makes them highly environmentally sustainable. Besides, their drive train efficiency is also usually higher as compared to internal combustion engine. According to study by Wu et al. (2015), EV is more efficient when driving on in-city routes than driving on freeway routes. This makes them better for adoption in urban road transport. However, it has not been easy to implement the electric bus due to the multiple challenges associated with the vehicle and the development and management of associated infrastructure. Tran et al (2013) observe that the emergence and wide spread adoption of EVs are faced with challenges as in development of new technologies, support infrastructure and investments. Presently, the battery electric vehicles have a limited driving range. High storage batteries are required for mobility of the electric bus, which requires high recharging time and are expensive. Besides, these high storage batteries required for pure electric buses are not indigenously manufactured. There is also a dearth in the nature of charging equipment associated with the batteries. The International Energy Agency 2011 report also highlights the constraint of consumer understanding and expectations towards adoption of EVs.

Sierzchula (2014) studied the factors influencing purchase decisions of US and Dutch fleet organizations that adopted EVs. The major influential factors according to this study were: (a) Attempting to test new technology (b) Lowering the environmental impact (c) government grants and (d) Improving the organization's public image. The most significant finding of this research was that the expansion of EV fleet was motivated by firm specific rationales as opposed to cost reduction. As an attempt to support EV diffusion, Sierzchula has recommended (a) Pilot projects for testing EVs (b) High purchase price reduction and (c) Provision of charging infrastructure.

Hong Kong was the first place in the world to implement a trial scheme to convert all public light buses (PLBs) on the road from diesel to alternative fuel vehicles (AFVs) including EVs. Loo et al conducted a stated preference (SP) survey to solicit the preferences of PLB operators on eight commercial vehicle attributes and seven forms of government support. They have used multinominallogit model for analysis. On analysis, Loo et al. find that the significance given by PLBs for the eight vehicle attributes is in the order of fuel type, fuel price, no. of seats, vehicle life, horsepower, shortest refueling distance, range and vehicle price. They concluded that unless the government provides further incentives or the market situation changes (for example, the diesel price goes up), voluntary fuel conversion is unlikely to succeed in the PLB industry. A second SP study seeked views of public transport operators on the most desirable package of government support. The findings in order of importance were reducing distance to refueling stations, long-term fuel price subsidy, attributes of allowing more seats on PLBs and providing low interest loan; financing R&D to increase vehicle range and horse power were not significantly ranked and lastly, vehicle price subsidy was not powerfully represented. Overall, the government support utility model suggested that the government should work harder towards providing better infrastructural support.

An advanced vehicle simulator model called ADVISOR has been developed at the National Renewable Energy Laboratory, USA to allow system-level analysis and trade-off studies of advanced vehicles. Lajunen (2014) used this simulator for evaluating energy consumption of hybrid and electric city buses. The simulation results indicate that the energy efficiency of the city bus can be significantly improved by hybridization and electrification. This improvement depends strongly on the degree of electrification thus how much electrical energy can be used for the operation.

Lajunen et al have conducted the cost-benefit analysis of hybrid and electric city buses. The variables taken into account in the life cycle cost calculation are: (a) capital costs: purchase costs of buses & charging equipment if needed (b) operating costs: diesel and electricity consumption and maintenance costs (general repair & spare parts) and (c) Costs of the energy storage system replacements. Below findings are deducted:

- On an average, more no. of electric buses are required for various routes (simulated by ADVISOR) due to the time consumed in battery charging.

- Hybrid buses have almost the same life cycle cost than the diesel city bus. Due to the high capital cost and expensive battery replacements of the electric city bus, it is the most expensive choice in all the routes.
- The results also show that if the capital costs of hybrid buses are 40% higher than conventional diesel bus, the hybrid buses could have lower life cycle costs in certain operation routes. The variation is very large for the electric bus meaning that it should be carefully evaluated in which kind of operation electric buses are used.
- The replacement costs for the energy storage system seemed to play an important role for plug-in hybrid and electric bus as these costs are about 25% of the total operating costs for the plug-in hybrid and more than 50% for the electric bus.
- Also 25% higher fuel costs reduce the life cycle costs of the electric vehicle configuration.
- The 25% reduction to the capital cost reduces significantly the life cycle costs of each bus configuration and would make them more profitable in terms of life cycle cost than the conventional diesel bus.
- The most efficient way to increase the cost efficiency of the hybrid and electric city buses is to reduce capital and energy storage system costs.
- Also, the cost-benefit analysis shows that the variation of the life cycle cost is large between the different operation routes. This underlines the importance of choosing the alternative technology on the basis of the operation.

CONCEPTUAL MODEL

The concept of the research explored herein is to harness solar energy through rooftop area utilization of a bus depot. This energy is to be utilized further for charging high storage batteries that will aid in the locomotion of electric buses in the selected bus rapid transit corridor. It is envisaged that the rooftop will be grid connected so that the charging of buses can be done at night through the grid and the energy generated by the solar photovoltaic rooftop will replenish the grid during daytime. The technology of net metering has already been established in the state of Gujarat, India. Using this technology, a balance of energy can be achieved through the grid throughout the year.

The study references a circular route in the city of Ahmedabad, Gujarat that originates and ends at the regional transport office (RTO). It is approximately a 37.1 km stretch with 37 bus stations enroute. The parking of these buses is done at Ranip Depot which is the closest depot to the origin/destination station. The Ranip depot has 2700 sq. meters of rooftop area. Twelve diesel buses ply daily on this route and the total travel of each bus comes out to be 212 km per day.The diesel buses considered for the study have Euro IV technology buses and cost INR 56 lakhs. The service life of bus is assumed to be 9 years after which it has a salvage value of 5.6 lakhs. The mileage of the bus is assumed to be 2.1 km/liter. The cost of diesel in the analysis is assumed to be INR 50 /liter.

The electric buses considered for the study are of the make BYD-China. The electric bus costs INR 2.5 crore. The service life of bus is 15 years and the salvage value is considered to be 1.5 % of the capital cost which amounts to INR 3.75 lakh. The energy consumption of the bus is 1.3 kWh per km and maximum driving range is 250 km. It uses iron based batteries of capacity 324 kWh that cost 60 lakh INR each. The batteries need to be replaced every 5 years.

A charging station will be required at the Ranip depot and it is assumed to be a level II charger that costs INR 1 lakh and takes about 5 hours to charge a bus. The service life of the charger is assumed to be 15 years.

The solar rooftop will feed back the power to the grid during daytime. The sizing of the solar rooftop has been worked out and thus the capital investment needed to install it is also calculated. The annual mean daily solar radiation in Ahmedabad is 5.8-6 kWh/m^2/day. The Ranip bus depot, which is under consideration in the study, has a potential of being utilized as a solar PV rooftop with an area of 2700 sq. m.This much area is just sufficient to install solar panels with total capacity of 270 kW.Orientation wise, there is possibility of providing south faced orientation with some leeway to the southwest or southeast. It is observed that the presence of shady trees and tall structures in the vicinity of the selected array location is minimal and thus full unshaded power of sun can be captured during most of the daytime.

The total energy requirement per bus is 325 kWh as per bus battery specifications. The bus serves a maximum range of 250 km. If an insolation level of 5.8 kwh/sqm/day is assumed, system size for one bus is calculated as 73 kWp. The rooftop area required will be 730 sq.m. per bus. The estimated capital cost of the rooftop PV plant has been worked out as 55 lakhs as shown in Fig. 1 and the value is comparable to results from solar rooftop calculator by MNRE and Solar Mango Rooftop calculator.

Table 1: Cost of Solar Rooftop Plant

Item	**Lakh INR**
PV Modules	23.5
Inverter	6
Balance of System (transformers, cables and wires, tracking devices, etc.)	18
Installation (civil & general works)	4.8
TOTAL CAPITAL COST	**52.3 ~ 55 Lakh INR**
O & E Expenses for 1st year (0.75 % of project cost)	0.41
Inflation in O&E Expense	5 %

Because of the area constraint of rooftop at Ranip bus depot, the given rooftop area can serve only three buses. This leads to a total system size of 219 kWp and rooftop area requirement of 2190 sq. m.

Three scenarios were considered based on subsidy and incentive availability and the most optimistic scenario is expressed in terms of benefit cost ratio and internal rate of return.

POLICIES AND SUBSIDIES

In this section, the subsidies and policies available for deployment of solar power and electric buses are studied. According to Ministry of new and renewable energy, the Jawaharlal Nehru National Solar Mission launched in January 2010 has set a target of deploying 20,000 MW of grid connected solar power by 2022. The objective of the Mission is to “create a policy and regulatory environment which provides a predictable incentive structure that enables rapid and large-scale capital investment in solar energy applications and encourages technical innovation and lowering of costs.” State Governments are encouraged to promote and establish solar generation Parks with dedicated infrastructure. It is also recommended in the document that custom duties and excise duties concessions/ exemptions be made available on specific capital equipment, critical materials, components and project imports. Gujarat state has its own power policy which was notified in 2015.

According to report on JNNSM titled “Towards Building SOLAR INDIA” the fund requirements for the Mission would be met from the following sources or combinations: (a) Budgetary support for the activities under the National Solar Mission established under the MNRE (b) International Funds under the UNFCCC framework, which would enable upscaling of Mission targets.

Prior to JNNSM, in 2008, the Ministry of New and Renewable Energy had launched a program on "Development of Solar Cities", under which a total of 60 cities/towns are proposed to be supported for development as "Solar/ Green Cities". Plenty of financial incentives are provided under various heads to cities selected as model/pilot cities.

The national electric mobility mission plan came into effect in 2012 with an aim of encouraging reliable, affordable, & efficient EVs that meet consumer performance & development of indigenous manufacturing capabilities, required infrastructure, consumer awareness & technology. The plan broadly aims to resolve the existing barriers divided mainly in four categories: (a) Consumer Acceptability (b) Technology development (c) Manufacturing investments and (d) Infrastructure.

The Department of Heavy Industry has notified a scheme namely FAME - India (Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles in India). This scheme aims for a cumulative fuel saving of about 9500 million litres equivalent resulting in reduction of pollution and greenhouse gas emission of 2 million tonnes with targeted market penetration of 6-7 million vehicles per year by 2020. This mission will be one of the biggest contributors in reducing pollution from road transport sector in near future. Based on the Ministry of Finance's approval, FAME India scheme with an outlay of INR 795 Crore under plan head has been launched for the initial two years – Phase I (2015-17).

Table 2: FAME India scheme components

Components of the scheme	2015-16 (INR Cr.)	2016-17 (INR Cr.)
Technology Platform (Including testing infrastructure)	70	120
Demand Incentives	155	340
Charging Infrastructure	10	20
Pilot Projects	20	50
IEC/Operations	5	5
Total (INR Cr.)	260	535
Grand Total (INR Cr.)		795

A broad range of demand incentive are available for different categories of vehicles, for buses, a minimum incentive of INR 30,00,000 and maximum incentive of INR 66,00,000 is available.

METHODOLOGY AND ASSUMPTIONS

With an objective to reduce diesel consumption and diesel dependency, the case of solar rooftop supporting electric mobility of three buses is examined for cost comparisons. The major costs considered in the analysis are cost of rooftop, cost of electric bus, battery cost, charger cost, O&M of rooftop and bus. The benefits accrued are counted in terms of diesel savings. The salvage value of bus is also considered. The financial analysis for deploying three numbers of solar charged electric buses (partial fleet) is carried out in terms of net present value and internal rate of return.

The assumptions underlying the analysis are listed below:

- The project life is assumed to be 25 years which is the usual service life of a solar rooftop.
- The route length is assumed to be 37.1 km, the route under study being RTO circular route.
- The number of working days is assumed to be 365 days and the number of working hours per day is assumed to be 17 hours a day.
- The average revenue per bus is assumed to be 8341 INR per day. This is estimated on the basis of existing BRT bus revenue for this particular route. No increment in fare is assumed due to likely transition to electric bus.

- The average revenue for advertisement etc. is considered 87,000 INR per bus per year.
- The analysis has been carried out for three electric buses and the cost of each bus is assumed at 250 lakh INR with O&M being 3% of this cost annually.
- The fuel (electricity) cost is assumed at INR 5 per kWh.
- The bus km travelled is 212 km per day.
- The cost of high storage battery is assumed to be 60 lakh INR and it is to be replaced every 5 years. No spare batteries are assumed for this analysis. The cost of the batteries is assumed to be decreasing over the period of 25 years.
- The cost of charger is assumed to be 1 lakh INR and it is to be replaced every 15 years.
- The mileage of the electric bus is assumed to be 1.3 kWh/km.
- The cost of solar power plant is assumed to be 55 lakhs for 73 kWp. (1 bus equivalent). Three such installations have been considered for three buses.
- The periodic maintenance of the solar panel is assumed to be 0.75 % of the capital cost.
- The depreciation rate of the solar power plant as well as electric bus is assumed at 40 %.
- The inflation rate is assumed at 5.14 %.
- The contingency is assumed at 8 % of the capital cost.
- The discount rate is assumed at 12 %.

Following benefits have been considered to apply in the analysis:

- All kinds of taxes are exempted.
- A subsidy of 30 % on the solar power plant and an incentive of 66 lakhs on the solar bus based on policies discussed prior.
- Availability of INR 50 lakh from the urban transport fund that is collected for FSI development along the BRT corridor.
- Carbon credit at a rate of INR 5734.1 (equivalent to USD 85) per credit.

RESULTS

A capex of 921.92 lakh INR is calculated for the project of three solar based electric buses. The capital expenditure consists of the cost of procurement of electric buses, rooftop solar panel plant & its installation, battery and charger cost and contingency at 8 %

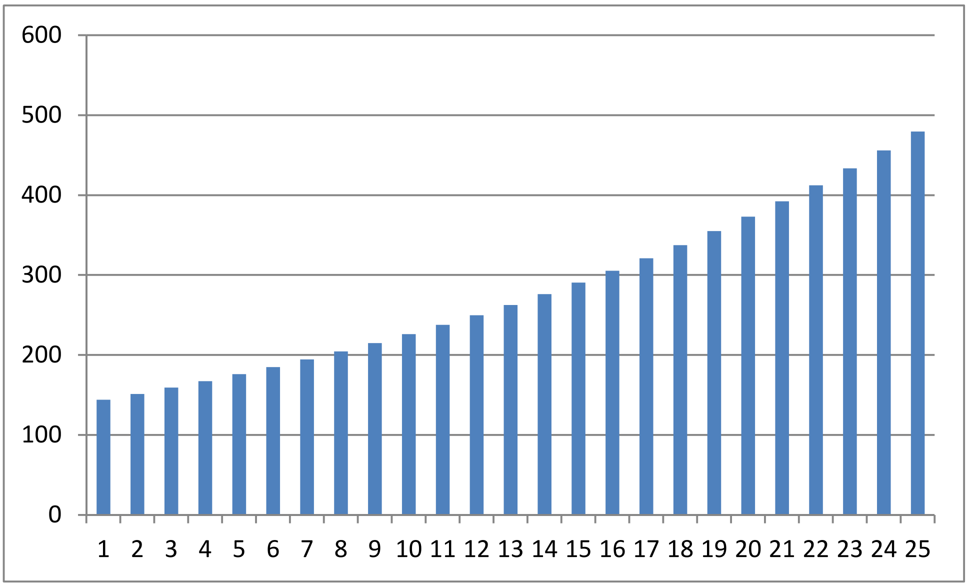

Figure 1: Revenue flow for solar based transit for 25 years in lakh INR

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The revenue flow for 25 years' time frame is shown in Figure 1. As indicated prior, the revenue is assumed to collect from the ridership fare, advertisement revenue and property development. The revenue is increased at 5% per annum every year.

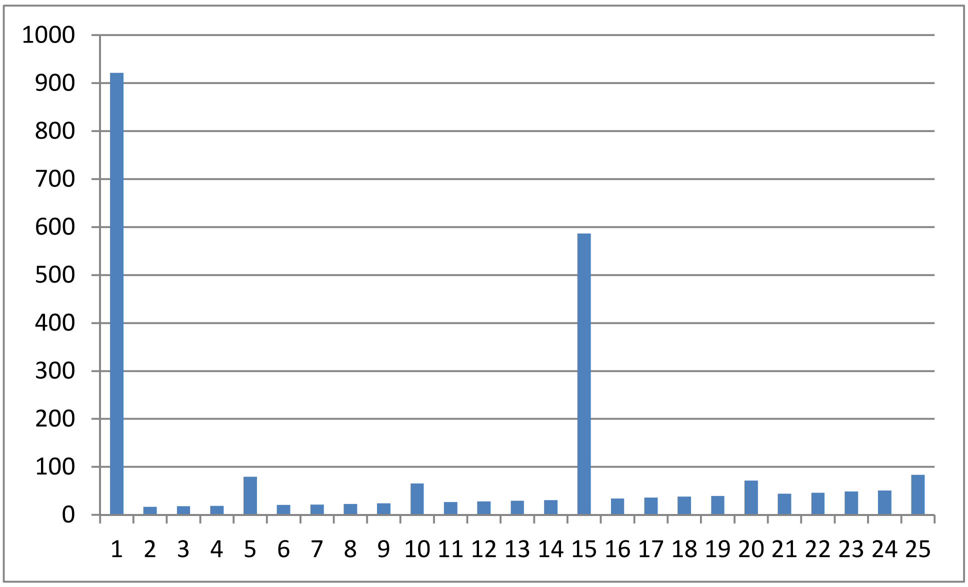

Figure 2: Expenditure flow for solar based transit for 25 years in lakh INR

The expenditure flow for 25 years' time frame is shown in Figure 2. The expenditure is highest for the first year wherein the capital expenses of bus as well as solar plant are incurred. The capital expenses of the bus are again a major expense at the end of 15 years when the buses need replacement. A slight peak is observed every 5 years due to cost of battery replacement.

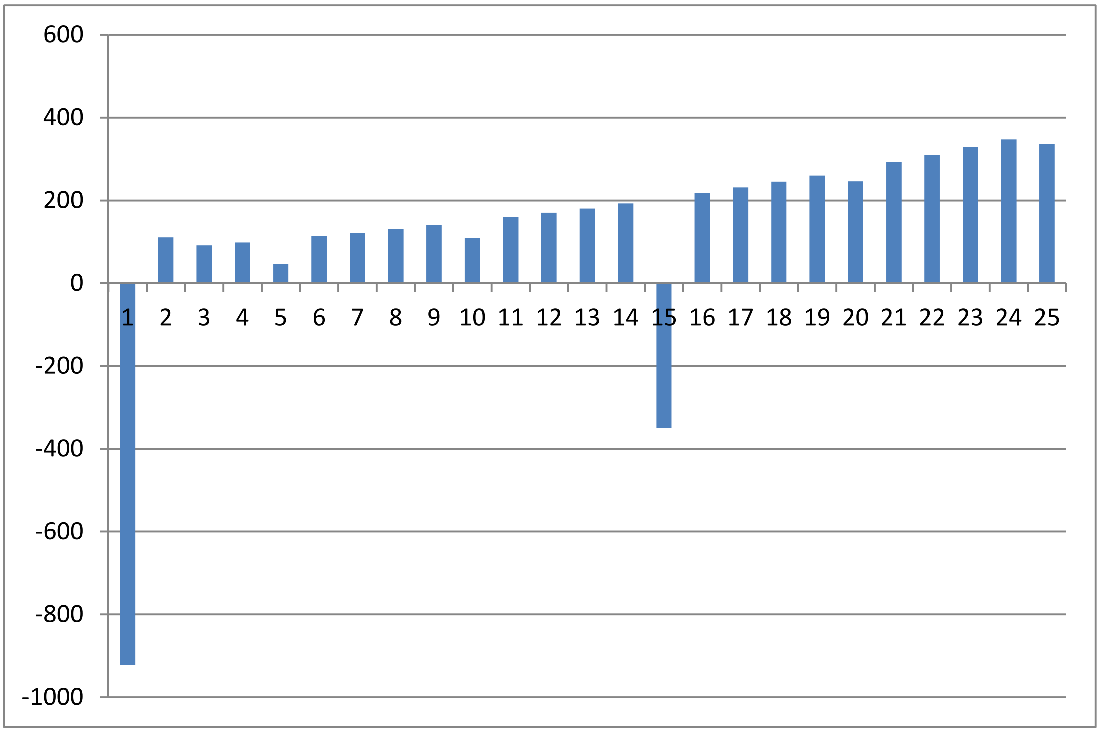

Figure 3: Profit &Lossfigure for solar based transit for 25 years in lakh INR

The profit and loss for 25 years' time frame is shown in Figure 3. There is a major loss indicated in the first year wherein capital expenses are incurred and in the 15th year wherein new buses are to be purchased. The peak may be shifted and smoothened by phase wise purchase of buses.

The analysis reveals that the net present value of the project is 73.56 lakh INR and the internal rate of return is 12.73 %. The values are todesirable from the point of view of financial feasibility. It may be noted however that an optimistic scenario of benefits has been considered for the calculations so far as the subsidies and taxes are concerned. The analysis done thus indicates that the deployment of solar based electric buses is a financially challenging step; and research needs to be done to make it viable using tools such as public private partnership.

CONCLUSION AND DISCUSSION

Literature review of research and developments worldwide suggest a definite step towards environment friendly practice of transport using electric vehicles. In developing countries like India, where funding needs can often dictate the development and implementation of major projects, it is significant to examine the financial viability of deploying electric bus transport. Solar energy is available in plenty in most parts of the country and therefore, solar rooftop for harnessing power for buses has been considered in this research to further reduce power house emissions. The results from the small scale analysis indicate that solar based electric buses can provide close competition to diesel based locomotion in the long term time frame, provided governmental support is available for development. Critical examination of the costs reveals that the expensive components such as electric bus and high storage batteries which are more popularly available as imported technology need R&D attention indigenously. Alternate financial tools such as Public Private Partnership may bring an attractive IRR and deem the project feasible. The development of such projects is often aided by funding means from international agencies such as World Bank, Asian Development Bank etc. given the project social, environmental and economic qualifications. Therefore, it may also help to establish and review the project in light of economic rate of return.

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