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11th Urban Mobility India Conference & Expo 2018

PRESENTATION FOR

URBAN MOBILITY CONFERENCE, NAGPUR

2ND NOVEMBER 2018

# SOLAR ELECTRIC BRTS – AHMEDABAD EFFORTS

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2ND NOVEMBER 2018

INSTITUTE OF URBAN TRANSPORT (INDIA)

# INTRODUCTION AND BACKGROUND

- Urban Transport: Lifeline of an economy especially necessary for a fast paced urban economy

However,

- Urban Transport: A major contributor of air and noise pollution
- Urban Transport: Fossil fuel dependent causing energy insecurity and future resource depletion
- Electric mobility in various vehicle segments is being promoted by public authorities, supported by industry and private sector and being researched
- 2 wheeler and 4 wheeler privately owned vehicles: Difficult to penetrate as it is user's choice and cannot be forced
- 3 wheeler: Pilots have started working but a regulatory body is needed for high penetration
- **Bus segment: Good potential to put in practice if feasible as it is generally city transport authority decision**
- Metro rail and other rail: Already on grid electricity, may venture into possibilities of renewable power for grid

# Scope and contents of presentation

**Scope: Case Study of electric BRTS for Ahmedabad**

1. **Transport Sustainability:** Indicators, models and frameworks
2. Public transport sustainability **framework for Ahmedabad**
3. **Energy in Gujarat** and Ahmedabad: capacity addition for electricity based transit
4. Concept of solar **E-BRTS**
5. Pilot analysis: Financial feasibility using solar rooftop model: Potential failure
6. Phases: Concept development to implementation to operations to salvage and after-life disposal
7. **Total Cost of ownership**: Diesel Vs. Electric and Strategic route identification for phase wise development
8. Similar scope for **AMTS** and Similar scope for most Indian cities
9. Electric BRTS: Current state: Routes, Contract conditions, Fund Sanctioned and other details
10. **Social benefit cost ratio:** One way to look at it
11. Existing investment Vs. additional cost : Great potential for **value addition** to city
12. **Asset Management Plan**
13. Conclusion and future scope
14. Thanks and request for support and collaboration

# TRANSPORT SUSTAINABILITY CONCEPTS

- Study of Indicators (collection of 150 indicators in literature), (12) models and frameworks
- Public transport sustainability (very few specific models)

**Linkage based**

- The PSR Model (Pressure – State – Response)
- The DPSIR Model (Drivers – Pressures – State – Impact – Responses)
- The Environment – Economy linkages model

**Impact based**

- The Litman (2003) model
- The Pearce and Vanegas (2002) model
- The Rijsberman and van de Ven (2000) model

**Influence oriented**

- The Transport Canada model
- The United States Departments of Transportation models
- The European Union model

# Public Transport Sustainability framework for Ahmedabad

- Sustainability model for Ahmedabad: Recommended 30 indicators under 5 dimensions

**7 major concerns**

1. Shortfall of share of public transport
2. Newer route demands
3. Accessibility
4. Environmental concern
5. Quality and reliability of service
6. Economic feasibility
7. Safety

**30 Simplified Indicators**

**5 Dimension scale model**

1. Economic
2. Social
3. Environmental
4. System Effectiveness
5. Stakeholder perception

Reference: Sheth A. and Sarkar D., "Development of Public transport sustainability model for Ahmedabad", International Journal of Application or Innovation in Engineering & Management (IJAIEM) Volume 6, Issue 7, July 2017 ISSN 2319 – 4847

# Energy in Gujarat and Ahmedabad

- 5 % Surplus energy generation in Gujarat but against that many industries already demanding more power
- In many other Indian cities, power shortfalls on supply side or just sufficient to meet the city demands
- Electricity for e-BRTS will come from ??
- Assuming Solar Captive power plant/ Rooftop solar system
- Capacity addition required for entire Ahmedabad BRTS system (as on 2018) to be electrified is estimated at: 25714 Kwp

# CONCEPT OF SOLAR E-BRTS CONSIDERED

Solar captive power plant to generate electricity

Transmission and distribution network to bring power to parking area/terminal

High level chargers to supply terminal power to bus battery

Bus battery to store power and utilize for locomotion as well HVAC

Recharging at terminals/parking areas

# Pilot analysis: Financial feasibility using solar rooftop model: Potential failure

Solar Rooftop at Ranip Terminal was considered for case, the major findings were:

1. Solar Rooftop area availability constraints limit the no. of buses that can be charged (Demonstrated max. 3 buses may be charged with entire terminal area rooftop)
2. Solar rooftop will not give economies of scale of entire transit system
3. Solar rooftop can generate sufficient energy for maybe HVAC but not locomotion (325 kWh per bus typical requirement)
4. Transmission and distribution and rooftop installations and grid connectivity will get complicated if multiple rooftops used

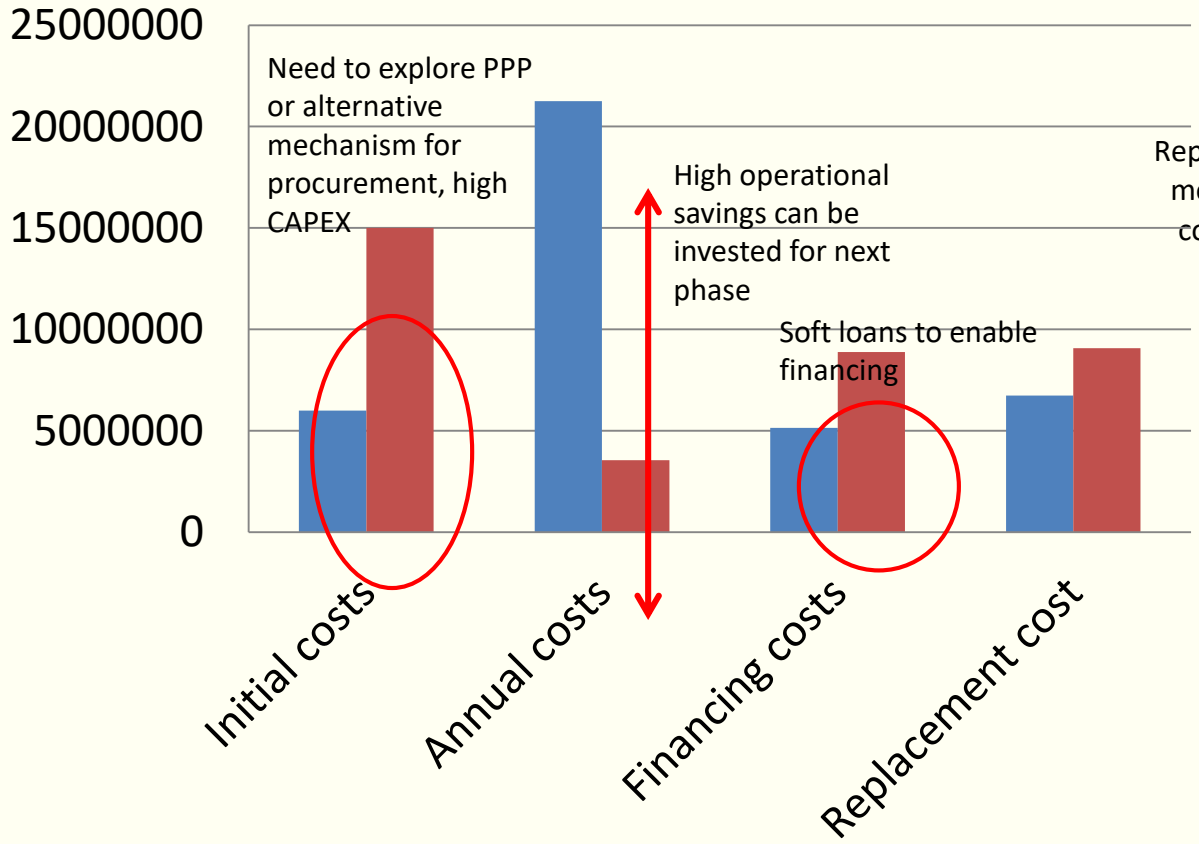
Reference: Sheth A. and Sarkar D., "Financial Analysis of Solar Electric Bus in India", International Journal of Engineering Technology, Management and Applied Sciences www.ijetmas.comJuly 2017, Volume 5, Issue 7, ISSN 2349-4476

# Phases of development and implementation

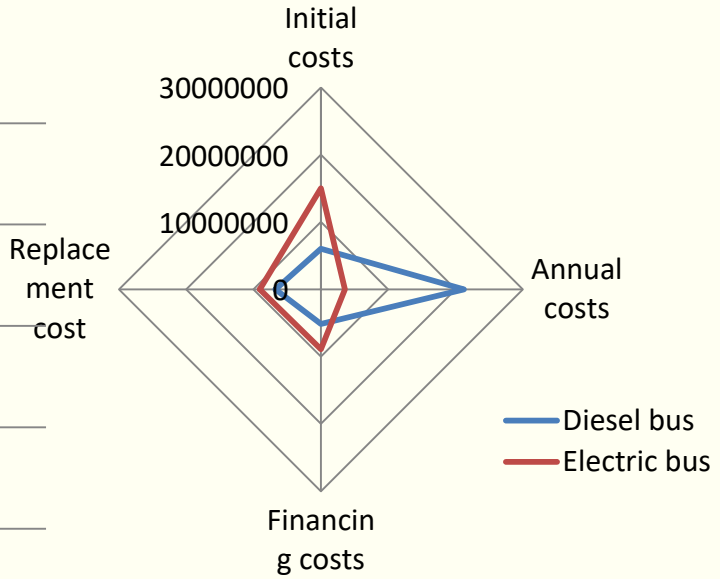
- Concept development
- Technical feasibility
- Financial and economic feasibility and project appraisal
- Permissions, Support and Awareness
- Infrastructure development requirement
- Training of personnel
- Implementation: Bus procurement, charging station procurement etc.
- Operations and maintenance and replacements
- Salvage of buses and after-life disposal of batteries

# Findings: TOTAL COST OF OWNERSHIP ANALYSIS of brts

## Cost components of diesel and electric bus




## TCO for diesel and electric bus operation




*Reference: Sheth A. and Sarkar D., "Total Cost of ownership of electric BRTS", under publication*

STRATEGIC ROUTE SELECTION FOR MAXIMUM EARLY BENEFITS

TCO CALCULATED FOR INDIVIUAL ROUTES OF THE NETWORKS

13 BRTS ROUTES

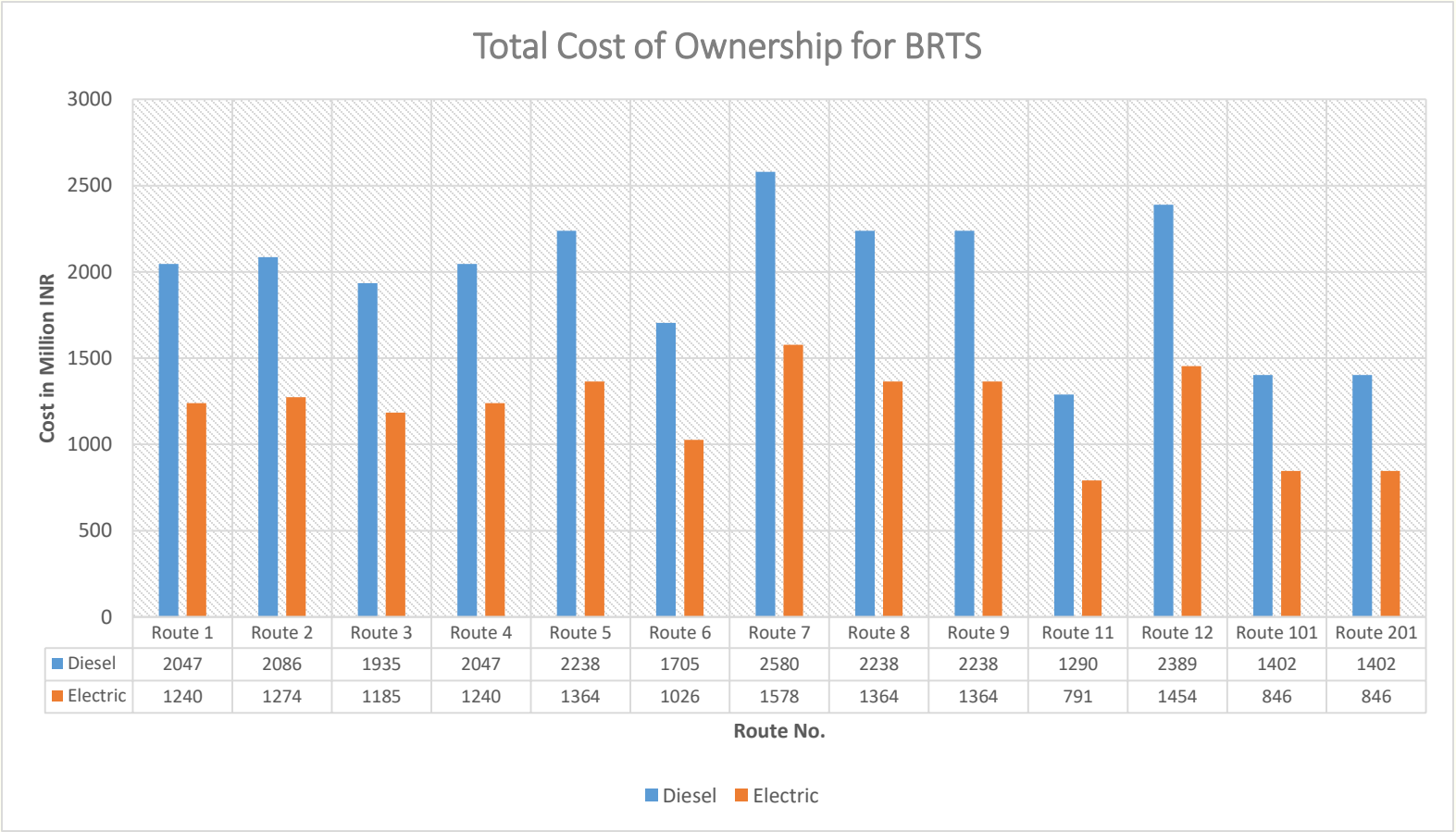
180 AMTS ROUTES

# LCCA FOR BRTS AHMEDABAD

# LCCA FOR AMTS AHMEDABAD

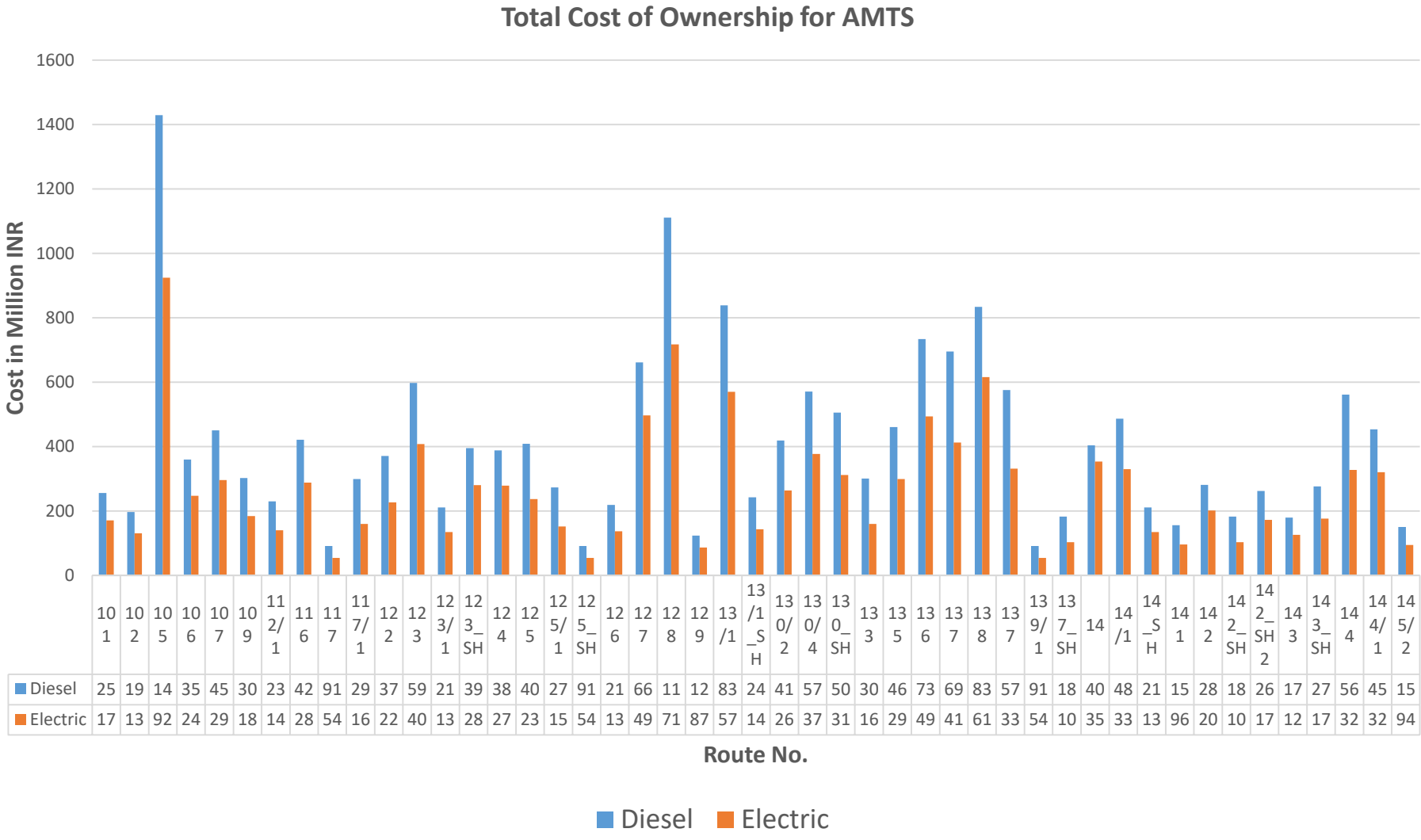
*Reference: Sheth A. and Sarkar D., "Total Cost of ownership of electric BRTS", under publication*

# Life cycle costing assessment : BRTS



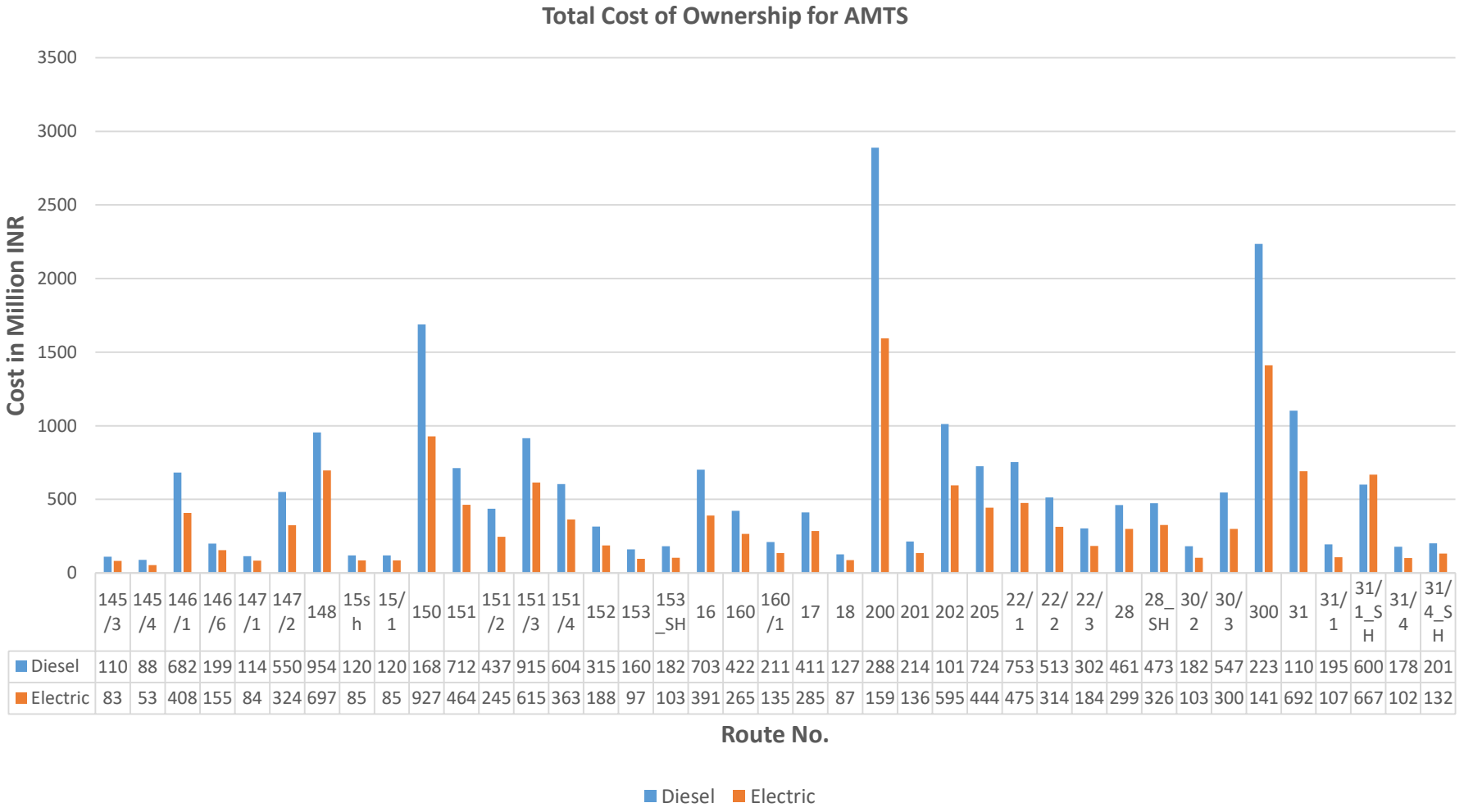

| | Route 1 | Route 2 | Route 3 | Route 4 | Route 5 | Route 6 | Route 7 | Route 8 | Route 9 | Route 11 | Route 12 | Route 101 | Route 201 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Diesel | 2047 | 2086 | 1935 | 2047 | 2238 | 1705 | 2580 | 2238 | 2238 | 1290 | 2389 | 1402 | 1402 |
| Electric | 1240 | 1274 | 1185 | 1240 | 1364 | 1026 | 1578 | 1364 | 1364 | 791 | 1454 | 846 | 846 |

# Life cycle costing assessment (TCO): AMTS



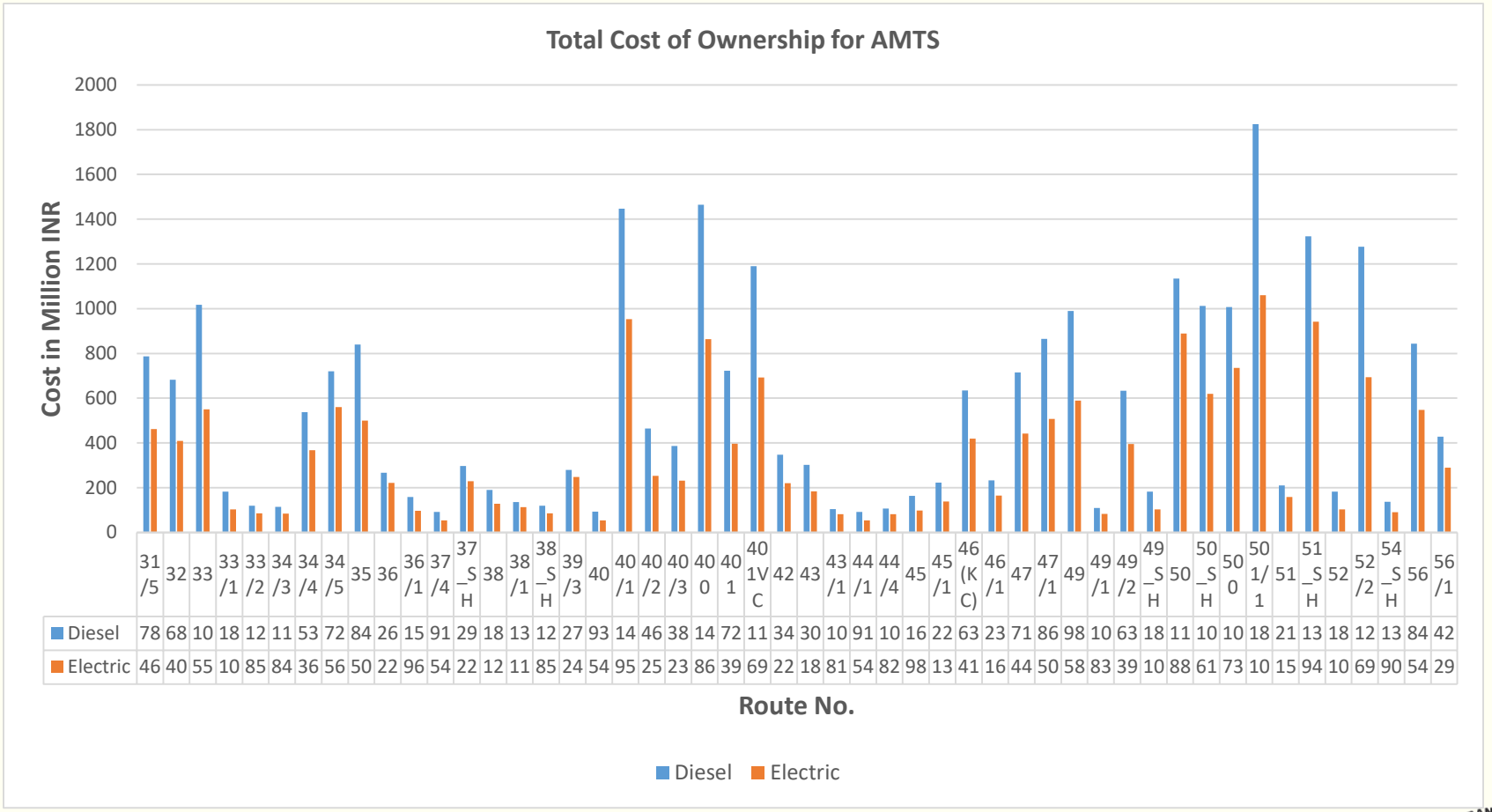

| | 101 | 102 | 105 | 106 | 107 | 109 | 112/1 | 116 | 117 | 117/1 | 122 | 123 | 123/1 | 123_SH | 124 | 125 | 125/1 | 125_SH | 126 | 127 | 128 | 129 | 13/1 | 13/1_SH | 130/2 | 130/4 | 130_SH | 133 | 135 | 136 | 137 | 138 | 137 | 139/1 | 137_SH | 14 | 14/1 | 14_SH | 141 | 142 | 142_SH | 142_SH2 | 143 | 143_SH | 144 | 144/1 | 145/2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Diesel | 25 | 19 | 14 | 35 | 45 | 30 | 23 | 42 | 91 | 29 | 37 | 59 | 21 | 39 | 38 | 40 | 27 | 91 | 21 | 66 | 11 | 12 | 83 | 24 | 41 | 57 | 50 | 30 | 46 | 73 | 69 | 83 | 57 | 91 | 18 | 40 | 48 | 21 | 15 | 28 | 18 | 26 | 17 | 27 | 56 | 45 | 15 |
| Electric | 17 | 13 | 92 | 24 | 29 | 18 | 14 | 28 | 54 | 16 | 22 | 40 | 13 | 28 | 27 | 23 | 15 | 54 | 13 | 49 | 71 | 87 | 57 | 14 | 26 | 37 | 31 | 16 | 29 | 49 | 41 | 61 | 33 | 54 | 10 | 35 | 33 | 13 | 96 | 20 | 10 | 17 | 12 | 17 | 32 | 32 | 94 |

# Life cycle costing assessment (TCO): AMTS



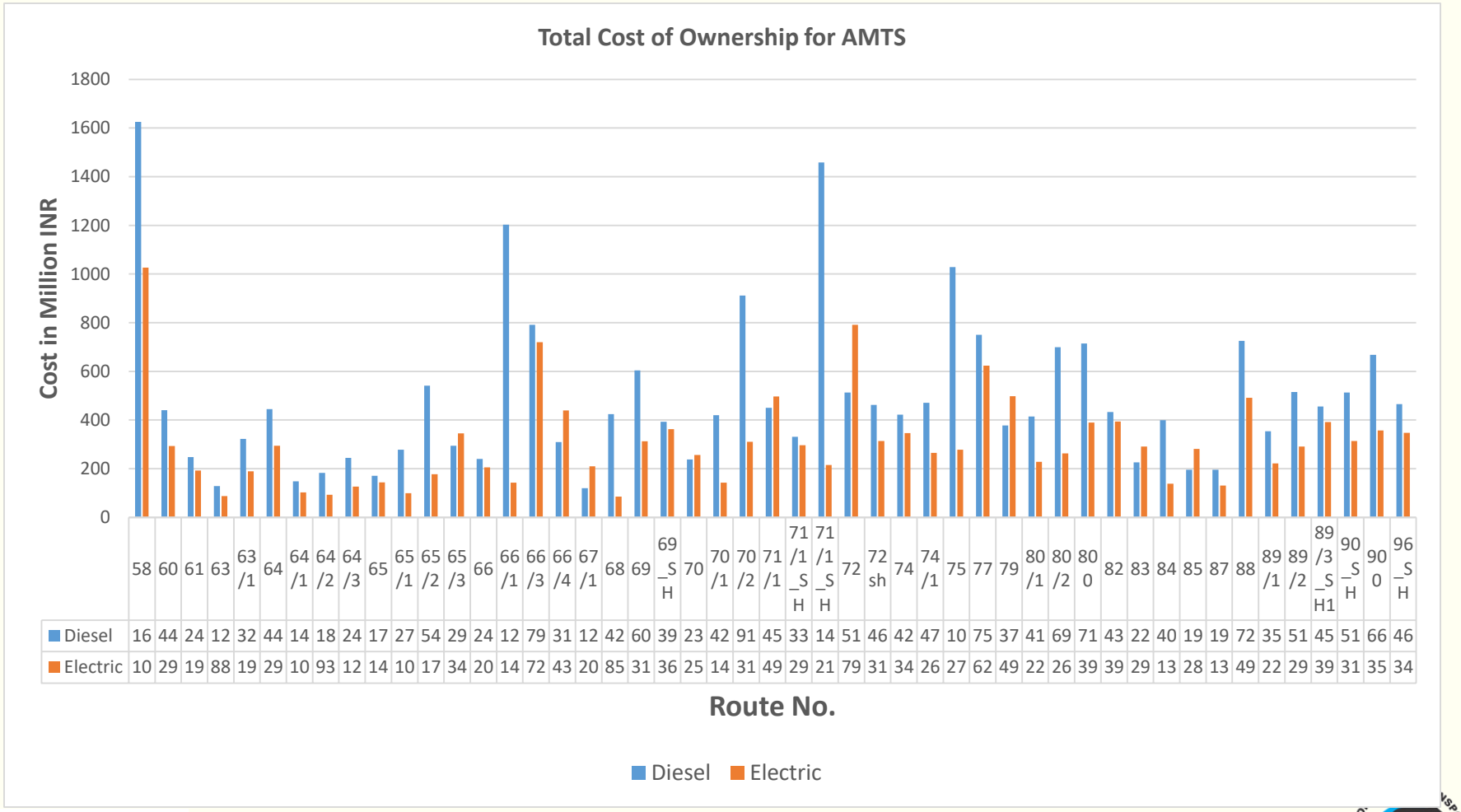

| | 145/3 | 145/4 | 146/1 | 146/6 | 147/1 | 147/2 | 148 | 15sh | 15/1 | 150 | 151 | 151/2 | 151/3 | 151/4 | 152 | 153 | 153_SH | 16 | 160 | 160/1 | 17 | 18 | 200 | 201 | 202 | 205 | 22/1 | 22/2 | 22/3 | 28 | 28_SH | 30/2 | 30/3 | 300 | 31 | 31/1 | 31/1_SH | 31/4 | 31/4_SH |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Diesel | 110 | 88 | 682 | 199 | 114 | 550 | 954 | 120 | 120 | 168 | 712 | 437 | 915 | 604 | 315 | 160 | 182 | 703 | 422 | 211 | 411 | 127 | 288 | 214 | 101 | 724 | 753 | 513 | 302 | 461 | 473 | 182 | 547 | 223 | 110 | 195 | 600 | 178 | 201 |
| Electric | 83 | 53 | 408 | 155 | 84 | 324 | 697 | 85 | 85 | 927 | 464 | 245 | 615 | 363 | 188 | 97 | 103 | 391 | 265 | 135 | 285 | 87 | 159 | 136 | 595 | 444 | 475 | 314 | 184 | 299 | 326 | 103 | 300 | 141 | 692 | 107 | 667 | 102 | 132 |

# Life cycle costing assessment (TCO): AMTS




| | 31/5 | 32 | 33 | 33/1 | 33/2 | 34/3 | 34/4 | 34/5 | 35 | 36 | 36/1 | 37/4 | 37_SH | 38 | 38/1 | 38_SH | 39/3 | 40 | 40/1 | 40/2 | 40/3 | 400 | 401 | 401VC | 42 | 43 | 43/1 | 44/1 | 44/4 | 45 | 45/1 | 46(KC) | 46/1 | 47 | 47/1 | 49 | 49/1 | 49/2 | 49_SH | 50 | 50_SH | 500 | 501/1 | 51 | 51_SH | 52 | 52/2 | 54_SH | 56 | 56/1 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Diesel | 78 | 68 | 10 | 18 | 12 | 11 | 53 | 72 | 84 | 26 | 15 | 91 | 29 | 18 | 13 | 12 | 27 | 93 | 14 | 46 | 38 | 14 | 72 | 11 | 34 | 30 | 10 | 91 | 10 | 16 | 22 | 63 | 23 | 71 | 86 | 98 | 10 | 63 | 18 | 11 | 10 | 10 | 18 | 21 | 13 | 18 | 12 | 13 | 84 | 42 |
| Electric | 46 | 40 | 55 | 10 | 85 | 84 | 36 | 56 | 50 | 22 | 96 | 54 | 22 | 12 | 11 | 85 | 24 | 54 | 95 | 25 | 23 | 86 | 39 | 69 | 22 | 18 | 81 | 54 | 82 | 98 | 13 | 41 | 16 | 44 | 50 | 58 | 83 | 39 | 10 | 88 | 61 | 73 | 10 | 15 | 94 | 10 | 69 | 90 | 54 | 29 |

# Life cycle costing assessment (TCO): AMTS




| Route No. | 58 | 60 | 61 | 63 | 63/1 | 64 | 64/1 | 64/2 | 64/3 | 65 | 65/1 | 65/2 | 65/3 | 66 | 66/1 | 66/3 | 66/4 | 67/1 | 68 | 69 | 69_SH | 70 | 70/1 | 70/2 | 71/1 | 71/1_SH | 71/1_SH | 72 | 72sh | 74 | 74/1 | 75 | 77 | 79 | 80/1 | 80/2 | 800 | 82 | 83 | 84 | 85 | 87 | 88 | 89/1 | 89/2 | 89/3_SH1 | 90_SH | 900 | 96_SH |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Diesel | 16 | 44 | 24 | 12 | 32 | 44 | 14 | 18 | 24 | 17 | 27 | 54 | 29 | 24 | 12 | 79 | 31 | 12 | 42 | 60 | 39 | 23 | 42 | 91 | 45 | 33 | 14 | 51 | 46 | 42 | 47 | 10 | 75 | 37 | 41 | 69 | 71 | 43 | 22 | 40 | 19 | 19 | 72 | 35 | 51 | 45 | 51 | 66 | 46 |
| Electric | 10 | 29 | 19 | 88 | 19 | 29 | 10 | 93 | 12 | 14 | 10 | 17 | 34 | 20 | 14 | 72 | 43 | 20 | 85 | 31 | 36 | 25 | 14 | 31 | 49 | 29 | 21 | 79 | 31 | 34 | 26 | 27 | 62 | 49 | 22 | 26 | 39 | 39 | 29 | 13 | 28 | 13 | 49 | 22 | 29 | 39 | 31 | 35 | 34 |

# Life cycle costing assessment: BRTS Results summary

| | |
|---|---|
| Diesel BRTS | INR 25596 million |
| Grid-Electric BRTS | INR 15571 million |
| Overall life cycle cost savings | INR 10025 million |
| Additional cost of solar power plant set up<br>if solar electric to be deployed (25,714 Kwp capacity worked out) | INR 17500 million |
| Biodiesel BRTS (excluding biodiesel plant set up cost) | INR 22118 million |
| Additional cost of biodiesel plant set up<br>(25.26 Tons capacity worked out) | INR 25722 million |
| | |

# Life cycle costing assessment (TCO): AMTS Results summary

| | |
|---|---|
| Diesel AMTS | INR 92693 million |
| Grid-Electric AMTS | INR 58836 million |
| Overall life cycle cost savings | INR 33857 million |
| Additional cost of solar power plant set up<br>if solar electric to be deployed (72, 626 KWp capacity worked out) | INR 98140 million |
| Biodiesel AMTS (excluding biodiesel plant set up cost) | INR 81569 million |
| Additional cost of biodiesel plant set up<br>(89.39 Tons capacity worked out) | INR 59313 million |
| | |

# Electric BRTS AHMEDABAD: Current state

- Gross Cost Contract Model with O&M cost predefined at 59 INR/km
- 8 shortlisted routes (list  routes)
- Partial fund sanctioned as per FAME India
- Other applicable policies and subsidies:
  - The Jawaharlal Nehru National Solar Mission by  the Ministry of new and renewable energy
  - Gujarat State Power Policy
  - United Nations Framework Convention on Climate Change
  - Development of Solar cities program by MNRE
  - The national electric mobility mission plan
  - FAME - India (Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles in India) scheme by the Department of Heavy Industry
  - Urban Electric Mobility Initiative by UN Habitat

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# Social benefit cost assessment: one way to appraise sustainable transport projects

## CASE STUDY OF AHMEDABAD ELECTRIC BRTS SANCTIONED PROJECT

*Reference: Sheth A. and Sarkar D., "Social benefit cost assessment of electric BRTS", under publication*

INSTITUTE OF URBAN TRANSPORT (INDIA)

# Scope OF DATA SET/SYSTEM CONSIDERED

## Scope: Proposed route of 185.1 km comprising of 8 routes

| Sr. No. | Route no. | Origin - Destination | Length of the route (km) | No. of buses lying on the route |
|---|---|---|---|---|
| **1** | 1 | Maninagar to Ghuma Gam | 21.2 | 28 |
| **2** | 1 | Ghuma Gam to Maninagar | 19.9 | |
| **3** | 2 | Sola Bhagwat to Maninagar | 22.2 | 14 |
| **4** | 2 | Maninagar to Sola Bhagwat | 22.9 | |
| **5** | 3 | Isckon to Naroda Gam | 22.4 | 22 |
| **6** | 3 | Naroda Gam to Isckon | 22.2 | |
| **7** | 101 | RTO Circle to RTO Circle (Circular route 101) | 27.1 | 12 |
| **8** | 201 | RTO Circle to RTO Circle (Circular route 102) | 27.2 | 12 |
| | | Total route length | 185.1 | |

# Benefits and Costs considered for e-BRTS

**Revenue generation**

- Revenue of electric bus system: Ridership & advertisement
- Tax revenue to Government

**Savings in vehicle operating costs**

- Reduction in no. of vehicles on road (diverted traffic)
- Ceasing of diesel bus operation on road

**Environmental benefit for users**

- Due to reduction in air pollution
- Due to reduction in noise pollution

**Benefits to users due to savings in travel time**

**Benefits due to reduction in accidents**

- Benefits due to reduction in major fatal accidents
- Benefits due to reduction in minor non-fatal accidents
- Benefits due to reduction in vehicle damage

**Benefit due to non-consumption of fossil fuel**

**Infrastructure investment costs**

- Capital cost of corridor development
- Capital cost of charging infrastructure development
- Capital cost of bus procurement

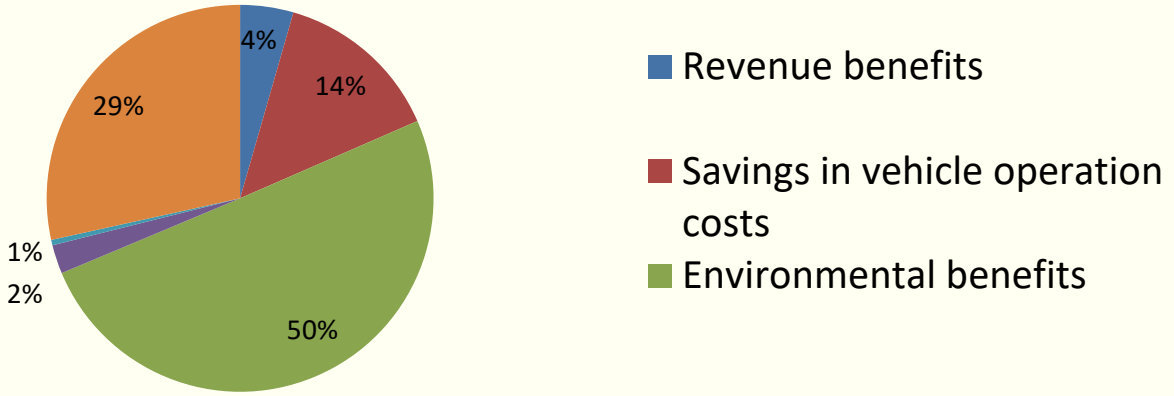
**Infrastructure maintenance cost (civil) and Replacement costs**

- Cost of replacement of ITMS infrastructure
- Cost of replacement of buses
- Cost of battery replacement
- Cost of system operation and maintenance
- Cost of additional electric power generation
- Cost of power plant installation
- Cost for transmission and distribution for the additional power

# Distribution of various benefits and costs

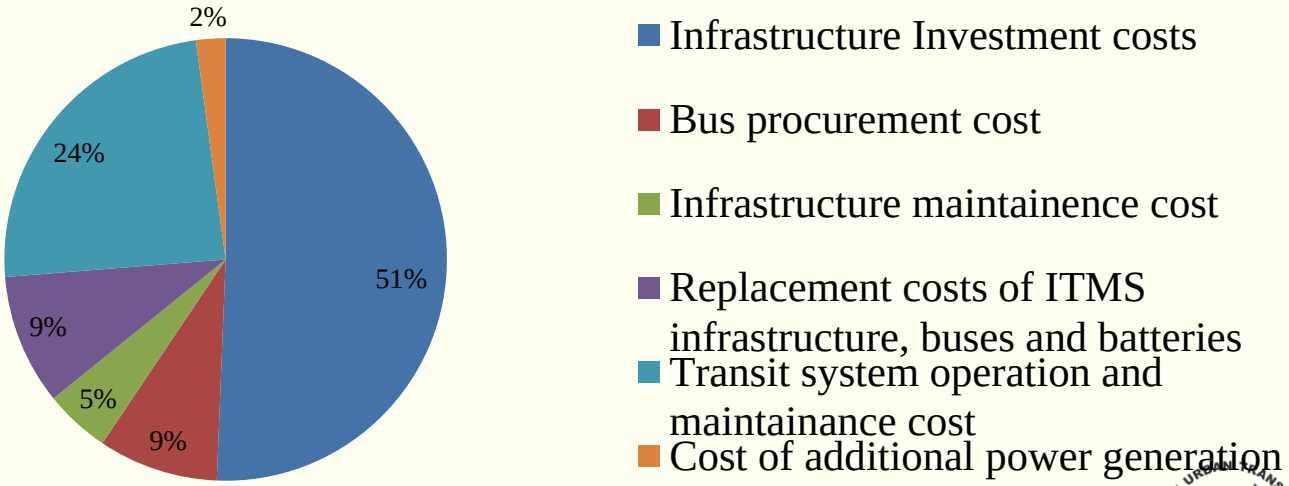
Distribution of various benefits (PW)

Total present worth of costs = INR 33,053 million (USD 479.03 million)




Distribution of various costs (PW)

Total present worth of costs = INR 22,806.21 million (USD 330.52 million)



# Existing vs. Future benefits and costs

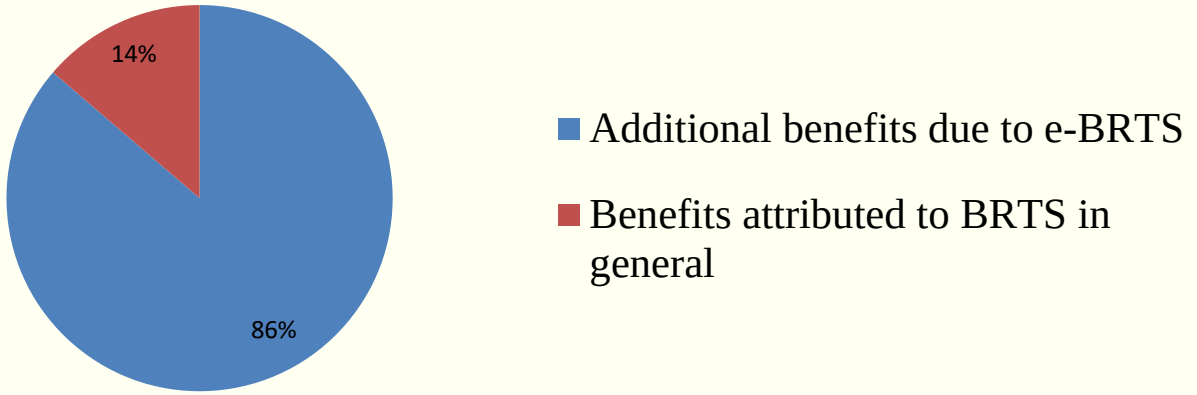
**Value addition:**

86 % or INR 28,250 million worth additional benefits

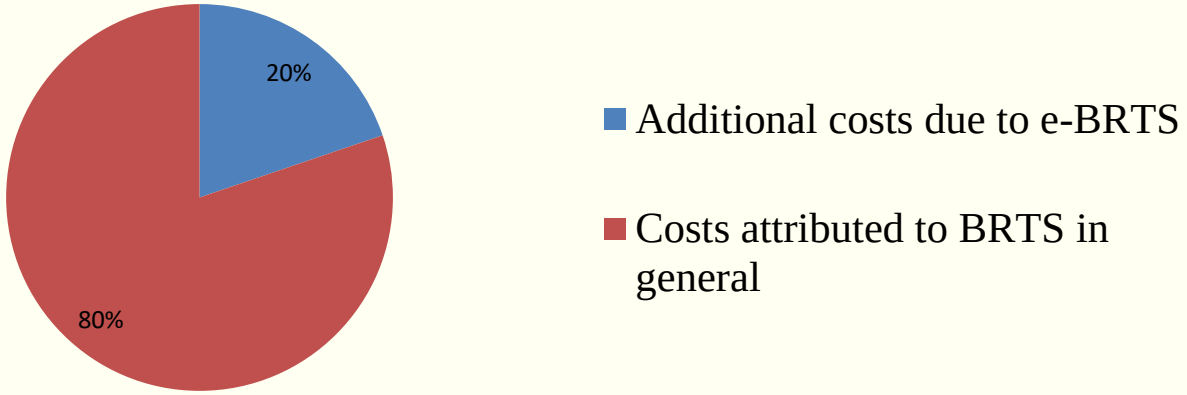
Against

20% or INR 4,514 million worth additional costs for converting Diesel BRTS to Solar electric BRTS

Distribution of existing benefits (BRTS) and future benefits (e-BRTS)




Distribution of existing costs (BRTS) and future costs (e-BRTS)



# Social benefit cost analysis: major findings

- Electric BRTS implementation : Favourable as the present worth of benefits exceeds those of the costs.
- The social benefit cost ratio for a discount rate of 12 % and life cycle of 25 years is found to be 1.45 and the internal rate of return is estimated at greater than 18 %.
- The social benefit cost ratio at 8 %, 10 % and 18 % discount rates are estimated to be 1.72, 1.58 and 1.15 respectively.
- The major beneficiaries are the road users and as much as 50% of the benefits (amounting to INR 16,600 million for the studied case) can be attributed to life cycle environmental benefits.
- The major cost (51 %) involved for implementation of an e-BRT project is for infrastructure development (amounting to INR 11,549 million for the studied case), its major subcomponent being corridor development.
- The additional benefits foreseen due to e-BRTS (86% or INR 28,250 million) far outweigh the additional costs (20% or INR 4,514 million) incurred for its successful implementation. This is viewed as a value addition for the efforts and investment already put in by the city for various socio economic causes.

# ASSET MANAGEMENT PLAN

| Principle Applied | Association | Project Benefit |
|---|---|---|
| Risk Management | Tackling different identified risks through set protocols | 1. Continuity of Service<br>2. Safety<br>3. Avoiding human or physical asset loss/damage |
| Contingency Plan | Tackling with emergency situation of charging | 1.Continuity of service<br>2.Uninterrupted performance |
| Disposal of Assets | Organized phasing out of old diesel buses | 1.Revenue generation<br>2.Minimal monetary loss |
| New Asset Delivery | Purchasing ideal electric buses based on desired specifications | Ideal Procurement of assets from Market<br>(Minimal investment for best results) |
| Maintenance plan | Ensures efficient system | Economic and Sustainable service Delivery |
| Performance Indicators | Target setting, reviewing system | Leads to improvement strategies |
| Whole Life Costing | Benefits of investments and Project approval | 1.Financial feasibility<br>2.Rate of return on investment |

# CONCLUSION AND FUTURE SCOPE

1. Solar electric BRTS is a promising way for sustainable public transport
2. Social benefit cost assessment reveals positive investment and major value addition with small efforts on additional infrastructure development
3. Life cycle benefits should be looked at as opposed to short term goals
4. Strategic phase wise planning may be helpful
5. A suitable PPP model can aid and enable faster development especially by supporting high CAPEX on finance side and operation-maintainance on responsibility side
6. The project is eligible for international funding including Clean Development Mechanism and these can easily support the viability gap.
7. Environment impact assessment may be able to justify the project better.
8. The model can be easily reciprocated for AMTS as well as other city bus transport in India.

References available on request.
Publications available online.

# Thank you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Students & Colleagues at CEPT University
Other professionals who have guided and shared views in the subject
Delegates who supported us in UMI 2016 at Gandhinagar
God and Family


Questions ?
Feedback ?

*If interested, we look forward to collaborating in terms of:*

1. *Publication*
2. *Outreach*
3. *Training*
4. *Pilot Project*
5. *Implementation*
6. *Developing business cases*


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