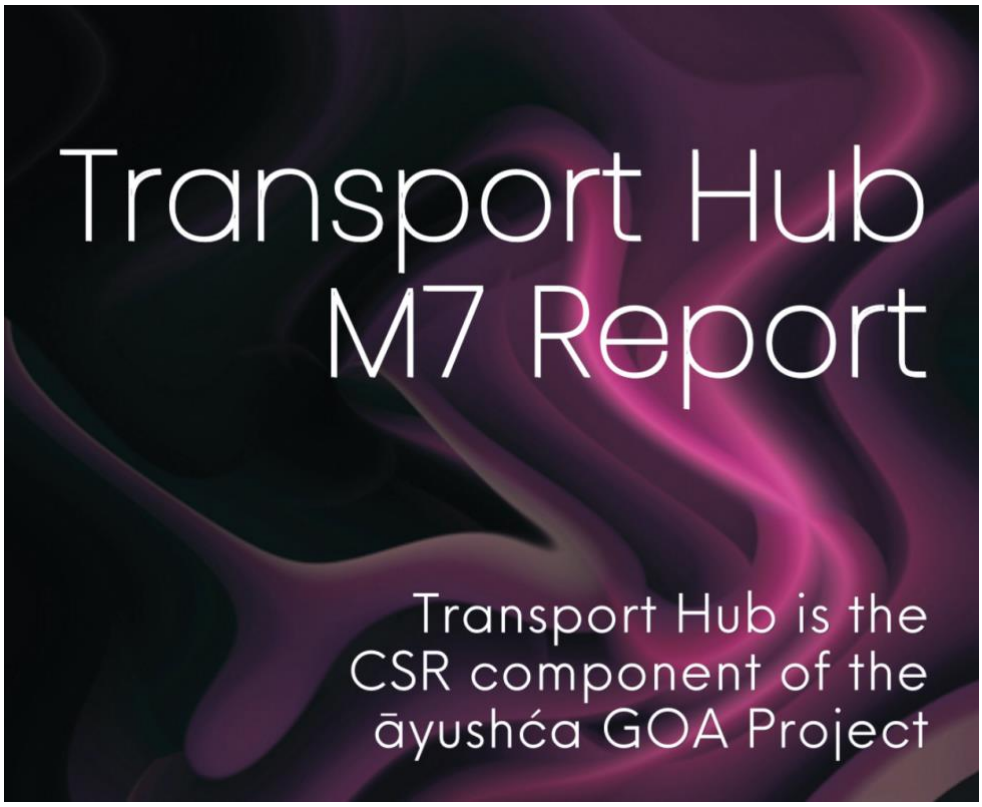

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DETAILED PROJECT REPORT

iit ALUMNI COUNCIL

Data source: Working papers on Bus Transport Projects. World Bank, Washington DC.

BRT in this report refers to both Bus Rapid Transport as well as Quality Bus System.

This report is to read with the M7 report which can be downloaded from transport.iitcouncil.org

The Ayushca concept report can be downloaded from ayushca.org

The initial Goa consultation paper is available on goa.ayushca.org

Transportation Hub DPR: One page Summary and Document Guide.

Based on an evaluation of the existing public bus infrastructure and a review of the traffic in Goa, it is recommended that an additional overlay comprising of 1200 ebuses and three transport hubs be created. The hub infrastructure would include civil works and land to provide for an expansion of fleet upto 5,000 vehicles. Beyond this capacity additional hubs would need to be created. The total capital cost of the transportation network has been estimated at around Rs 2500 crores and could require one time viability gap funding support of upto Rs 1,000 crores. After this one-time injection of grant funds, the operation is expected to be self-sustaining and viable.

The plan does not propose any change to the existing structure and operations of the Kadamba Transport Corporation as KTC does not manufacture buses or own any of the fuel stations. KTC operates a bus service using the traditional format of fixed bus routes, open air parking depots and manually controlled bus frequencies and timings. Drivers are on the payroll of KTC. The additional infrastructure being created envisages 100% replacement of the entire fleet of Kadamba with eBuses over a reasonable window. The plan envisages provision of these buses at a flat Rs 35 per km (subject to minimum 80,000 kms per annum per bus). This excludes government levies and taxes if any. This target amount of Rs 35 per km includes provision of the bus, maintenance of the bus, charging/replacement of batteries, provision of hydrogen or alternate fuel for onboard charging of the serial hybrid buses and live/passive advertising panels. KTC will need to bear the cost of the driver/conductor and insurance. KTC will own the revenue.

The Ayushca proposal envisages the creation of three entities, two of which would be specifically for the transportation module. The main Ayushca entity would own the Global Alumni Hub assets in North Goa and has been created as a Section 8 non-profit foundation. The open parking lot for the convention centre in the Alumni Hub would host a transportation hub and service centre at no cost to the transport project.

The two entities to be created would be one PPP company to own the transportation hubs and one conventional company for owning and leasing the rolling stock. The PPP (public private partnership) company would primarily be for the development and ownership of the one million square foot transportation hub infrastructure in Provorim spread over 30,000 sqm plinth area and 100,000 sqm total land area which would be acquired by the PPP company at designated circle rate of the land. This entity would also own a multimodal transport hub in south Goa along NH66. The fleet owning company would be an independent leasing company providing eBuses to both the PPP company as well as to KTC.

This document comprises of the following sections:

I. Background, Task Force members and Summary of DPR consultation
II. Study of BRT projects globally along with key learnings
III. AI based redesign of the entire transportation paradigm
IV. Core values and needs which form the foundation for this project.

Section 1.1: Transportation Task Force

The nine member BRT Transportation Task Force was set up by the IIT Alumni Council in September 2019. The Task force was expanded to fifteen members in 2024.

The terms “Quality Bus Network” and “BRT” have been used interchangeably. The abbreviation BRT here does not refer to the conventional Bus Rapid Transport which is implemented with dedicated bus lanes.

The Task force has held over 100 meetings over the period October 2019 to May 2024.The task force included eminent IIT Alumni from various domains relevant to the project and comprises of:

- The founding Chairperson was Late Prof Dinesh Mohan (passed on after a Covid infection in 2021), a distinguished alumnus of IIT Bombay/ University of Delaware and a professor of transport engineering at IIT Delhi since 1976. Prof Dinesh Mohan was involved in the conceptualization of the BRT corridor in New Delhi for the Commonwealth Games which though considered a failure (and subsequently reversed) served as an important experiment on what can work and what should be avoided in India. The task force is currently led by Mr Ravi Sharma on a temp basis in his capacity as Chief Volunteer.

- The energy transition member of the Transport Group was Late Prof Prasad Durjoti (passed on after a covid infection in 2020), a distinguished alumnus of IIT Kanpur/ University of Delaware. Prof Durjoti did path breaking work in the microbial conversion of Indian coal into methane and hydrogen which could be used to re-configure standard BEV (battery electric buses) into serial hybrid buses based on an onboard, self-charging 40KW electric generator based on either a H2 powered fuel cell or a CNG powered Maruti Ertiga Engine. He is succeeded by Dr Rohinton Dehmubed, an alumnus of IIT Bombay/Columbia University. Dr Dehmubed is a Distinguished Fellow of the IIT Alumni Council in the area of advanced materials for climate change applications.

- The development sector member of the Transport Group was Late Ashok Madhukar (passed on in 2022), a distinguished alumnus of IIT Kharagpur and a Lifetime Achievement Awardee of the IIT Alumni Council for his work in development economics and for setting up the Social Fund for Development in Egypt, which is one of the largest and most successful social funds in the world. He is succeeded by Dr Ashok Khosla, founder of Development Alternatives and a key advisor to the global Ayushca campuses. Dr Ashok Khosla invented the concept of “sustainability”, delivered the first course on the subject at Harvard (where Al Gore was his student) and helped set up the Ministry of Environment in India and several other countries as head of the UNCEP.

- The alumni coordinator member is Mr Ravi Sharma, a distinguished alumnus of IIT Roorkee. He is a former corporate leader and has headed several corporates

including British Telecom, Alcatel Lucent, Adani Power etc. He is currently the President and Chief Volunteer of the IIT Alumni Council.

- The finance member and project coordinator is Mr Satish Mehta, an alumnus of IIT Mumbai who has been a consultant to the World Bank on local utilities from 1987 to 2002. He was also instrumental in setting up TRAI & SEBI in addition to corporatization of DoT into BSNL. He is the convenor of the IIT Alumni Social Impact Fund which is providing part of the viability gap funding for the project. He is a life fellow of the IIT Alumni Council in the area of photogrammetry.

- The decision support member is Mr Sanjay Nagi, an alumnus of IIT Roorkee. He has been working in decision support for over 25 years. His firm – Market Insights – is the leading consultant in the aviation sector and has over fifteen years experience in the design, audit and repurposing of areas within airport terminals. He leads the team designing the public amenities in the proposed transport hubs. He is a Life Fellow of the IIT Alumni Council.

- The architecture and town planning member is Mr Anil Sharma, an eminent architect and alumnus of IIT Roorkee. He has designed close to 150 five-star hotels around the world including the Khyber in Gulmarg which is among India's highest average room rent hotels. He is a Life Fellow of the IIT Alumni Council in the area of Hotel architecture.

- The digital card member is Mr Tarun Mohan, an alumnus of IIT Delhi. He has been a pioneer in the development of the single mobility card and has developed SIM overlays which allow a low cost featurephone to be used for tap and pay applications in areas like bus ticketing and card tokenization.

- The public policy member is Dr Mahesh Uppal, an alumnus of IIT Kanpur and Cambridge University. He is one of India's leading public policy experts in the areas of connectivity. He is a distinguished fellow of the IIT Alumni Council in public policy.

- The AI member is Dr Jyoti Joglekar, an alumnus of IIT Bombay. She is one of India's leading experts in the area of AI. She has served as an expert for ISRO on Chandrayaan and is a Professor of Computer Science for over twenty years. She is a distinguished fellow of the IIT Alumni Council in Artificial Intelligence.

- The management consulting member is Dheeraj Rathi, an alumnus of IIT Bombay. He is the Managing Director of RKCA Ecovis, the Indian partner firm of the global Ecovis platform which has operations in over ninety countries. Ecovis provides a wide range of project advisory services including techno economic feasibility studies and financial accounting. He is a Life Fellow of the IIT Alumni Council in Accounting Automation.

- The media and branding member is Mrinalini Gupta, an alumnus of FMS, Delhi and a Honorary Fellow of the IIT Alumni Council. She has served as the Chief Operating Officer of Hindustan Times, Head of Broadband for Airtel and is

Chairperson of Anytime Media – a subsidiary of Anytime Pte - a joint venture of the Hollywood Studios.

- The GIS and Geo-Spatial members are Dr Rajshekhar Nyati and Dr Yogita Shukla, CTO and Board Member respectively of Genesys International – India's largest digital twin company. Dr Rajshekhar is an alumnus of IIT Mumbai, Department of Geology whereas Dr Shukla has a Phd from the Indian Institute of Remote Sensing.. Genesys is the global field partner of Google Earth, Google Streetview and Apple Maps. They have successfully built the Digital Twin of Varanasi and Ayodhya – and are currently developing the Digital Twin of Mumbai, Mecca and Goa. Dr Rajshekhar is a Distinguished Fellow of the IIT Alumni Council in the area of 3D Mapping. Dr Yogita Shukla is a Honorary Fellow in Remote Sensing.

- The project finance member is Dr Rakesh Seth. He is an alumnus of IIT Bombay and a career investment banker. He is the Managing Director of Scsi Global which is the largest boutique investment banking firm in the highly specialized domain of setting up and administering investment funds including Social Funds, Venture Funds, Angel Funds, Private Equity funds and Fund of Funds. He is an established angel investor and book running lead manager on global platforms such as Nasdaq Nordic. He is a Distinguished Fellow of the IIT Alumni Council in Fund Management.

- The waste management member is Manoj Karmarkar. He is an alumnus of IIT Bombay and has been an expert in handling toxic and waste material for recycling and creating net zero campuses. He is a Life Fellow of the IIT Alumni Council in Waste Recycling.

Section 1.2: Schedule of Dates

The BRT Transportation Task Force was constituted by the Forum Mission of the IIT Alumni Council in 2019. The relevant dates are as under:

Constitution of Task Force:	October 2019
First Recommendation Report:	March 2022

The task force recommended that each Ayushca campus proposed to be built should have a large climate change project aimed at helping local communities and that such a project be supported to the extent of around 15% of the project cost of the Ayushca. The support was to be given as a one-time grant to cover the viability gap subject to the project becoming self-sustaining and independent pursuant to the grant. The report was put up for consultation at www.ayushca.org in the period April 2022 to September 2022. Based on feedback from the consultation process, it was decided to set up Ayushca Campuses in each state of India as well as overseas. The first campuses were proposed for the following locations:

Global Alumni Hub with convention Centre:	Goa
Global Wellness Hub:	Upper Himalayas
Global Biodiversity Hub:	Adjacent to a forest

Goa Recommendation Report:	March 2023

The task force recommended that Ayushca in Goa be configured to support climate change projects in the area of waste management and local transportation. The waste management area was decided on the basis of the IIT Alumni group involvement in setting up the Goa Waste Management project (under the leadership of Late Manohar Parrikar). This project was configured to recycle the huge waste (organic and well as others) which was expected to be generated by the booming tourism economy. The proposal was to convert organic waste in biogas which would be used to generate power. The local transportation project was conceptualized based on the findings of the task force that the primary constraint to growth of the Goa Tourism GDP was the lack of adequate roads commensurate with the needs of 7.5 million tourists that are expected to arrive in Goa during the peak tourist month in 2028.

With an average stay of four days, this could translate into a floating tourist population upward of one million tourists. This in turn would translate into a need for four million local commute trips per day just for tourists. At 25 kms per trip and 30 passengers per bus – in ideal 100% occupancy scenarios – this would translate into a theoretical need for 15,000 ebuses. If this demand is met by cars and taxis, it would choke the roads and lungs of Goa completely making it impossible for tourists to move around, other than by new options like flying taxis and tourist boats.

This is a manifold increase over the existing tourist inflow of 8 million tourists per annum which translates into a maximum 1.2 million tourists in the peak month resulting in 200,000 commutes per day which in theory can be met by 670 buses (and by roughly 1340 to 2010 buses in real life scenarios). This 20x increase (from 200K commutes per day to 4000K commutes per day) is likely to choke the roads of Goa as well as cause severe air pollution. This would lead to city wide traffic jams and irreversible damage to the environmental ecosystem.

This report was put up for consultation from April 2023 to September 2023. Based on the feedback from the various stakeholders, an amount of USD 100 million was approved as a viability gap grant fund for a public transportation initiative in Goa.

Ayushca Goa Investment Plan:	October 2023

The Ayushca Goa proposal was put up to the Investment Committee of the IIT Alumni Social Fund seeking Rs 700 crore viability gap support for a local transportation project with non-polluting ebuses. The project was put up for consultation at www.goa.ayushca.org from October 2023 to December 2023. The project was thereafter submitted to the state government for their perusal and acceptance. It was jointly decided based on meetings with the Smart City Goa Council and other community leaders to assess the traffic situation during a large MICE event. This event was identified as the India Energy Week (IEW 2024) which was to be held in the southern part of Goa during February 2024. Accordingly, the task force mandated various alumni groups to survey the event from inside the ground, from the adjoining cities, from the road (using google street view type equipment) and from the air using drones and specially fitted out aircraft. The simulations carried out prior to the event clearly indicated that the roads adjoining the venue would all get choked. In keeping with expectations, the event led to massive traffic jams. It took visitors upto three hours to reach the venue from their hotels and upto four hours to reach the hotel back using the complementary public transport provided by the event hosts. Because of these traffic jams, speakers were unable to reach the venue for their events. The project served as an excellent study case for preliminary planning of the bus network.

Goa Budget Coverage:	February 8, 2024

The Global IIT Alumni Hub project was announced by the Hon'ble Chief Minister as part of the State Budget Speech on the 8th of February 2024. The state government gave a go ahead for completion of the DPR thereafter.

DPR Consultation Draft:	Feb 15th to April 15th, 2024
DPR Consultation:	Upto May 30, 2024.
DPR Draft post consultation:	June 1, 2024.

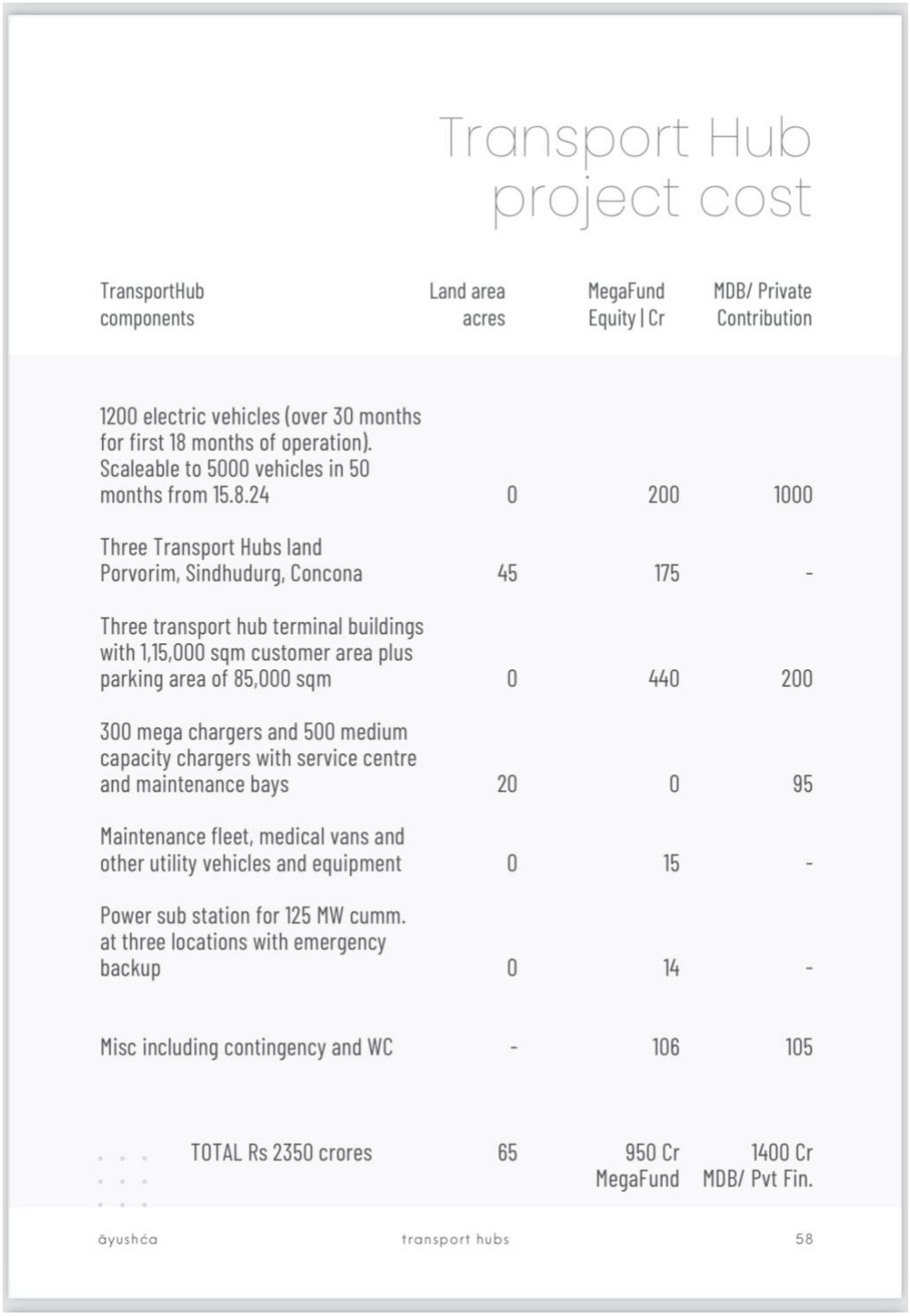
Next Steps:

Approval of PPP Entity and Land Allotment for first Hub.	Target 30.7.2024
Start of project:	Target 15.8.2024.

This document is being issued on the 1st of June 2024 and constitutes the Draft DPR which would be finalized based on feedback from the State Government.

State government interaction request:	07.06.2024 TO 16.06.2024

Section 1.3: Summary of Consultation DPR
(refer to download from www.transport.iitcouncil.org)



Transport Hub project cost

TransportHub components	Land area acres	MegaFund Equity	Cr	MDB/ Private Contribution
1200 electric vehicles (over 30 months for first 18 months of operation). Scaleable to 5000 vehicles in 50 months from 15.8.24	0	200	1000
Three Transport Hubs land Porvorim, Sindhudurg, Concona	45	175	-
Three transport hub terminal buildings with 1,15,000 sqm customer area plus parking area of 85,000 sqm	0	440	200
300 mega chargers and 500 medium capacity chargers with service centre and maintenance bays	20	0	95
Maintenance fleet, medical vans and other utility vehicles and equipment	0	15	-
Power sub station for 125 MW cumm. at three locations with emergency backup	0	14	-
Misc including contingency and WC	-	106	105
TOTAL Rs 2350 crores	65	950 Cr MegaFund	1400 Cr MDB/ Pvt Fin.

Transport Hub means of funding

TransportHub components	MegaFund Equity	Cr	MDB/ Private Contribution
1200 electric vehicles (over 30 months for first 18 months of operation). LEASE FINANCE WITH 20% MARGIN	200	1000
Three Transport Hubs land OUTRIGHT PURCHASE OR FOR EQUITY	175	-
Three transport hub terminal buildings FUTURE RENTAL DISCOUNTING OF RS 200 CRORES.	440	200
CHARGERS ON VENDOR FINANCE	0	95
Maintenance fleet, medical vans and other utility vehicles and equipment VENDOR FINANCE FROM JAPAN	15	-
Power sub station for 125 MW cumm. OUTRIGHT PURCHASE OR FOR EQUITY	14	-
ROTATING CONTINGENCY FUND FROM DONOR CORPUS	106	105
TOTAL Rs 2350 crores	950 Cr MegaFund	1400 Cr MDB/ Pvt Fin.

Ayushca Goa Project - Transport Hub
Transport Hub is the CSR component of the āyushća Global Alumni Hub

Aim of transportation hub

- The aim of this hub is to establish a space that seamlessly integrates all modes of transportation, creating a vibrant environment for living, working, and leisure activities, whether individuals are using public transit or not.
- It will introduce a safe, comfortable 24/7 place for tourists to rest in between visits during monsoon months and at odd hours.

Transportation Hub:

- The transportation hubs are being designed to include access to various modes of transport like virtual metro, buses, water taxis, and flexible vehicles, as well as direct point-to-point connections.
- They plan on enhancing the surrounding landscape of the hub to attract tourists.
- **Hub's vision:** the multiport is envisioned as a lively gathering spot, reviving Goan's eclectic culture and serving as a hub for social interactions, public performances and calendar events

Digital Card

- āyushća goa card will be a Aadhar or passport linked id smart card based on the India Technology Stack.
- The card will permit access to and payment on all transport facilities, parking, government services, toll charges, tourist attractions entry charge, use of electric carts in pedestrian areas etc.
- The card will be compatible with the Kodoy health card for continuous health monitoring.

Project Details:

Project cost	**INR 2350 - 2450 CR**
Land required	65 acres
No of electric vehicles	Initially 1200, going up to 5000
Lease finance funding	INR 1000 CR with INR 200 CR margin
Social impact equity funding	INR 750 CR
Commercial finance	INR 400 CR
Main transport hub and first location	Porvorim
Tentative start date	15th Aug, 2024
End date	30 months from start
Stakeholders	• Office of the Chief Secretary • Kadamba Transport Corporation • Smart City Goa & Panchayats • Goa Industrial Development • Indian Navy, Civil aviation • The Goa campus of BITS Pilani

	• Sustainability division of ITC Ltd

- India's first card for paying transit fares, parking fees, and utility bills across different modes of transportation.
- Project to be housed in a PPP (Public-Private Partnership) company which targets to start operations on 15.8.24.

Current Public Transport in Goa

KTC buses	**450**
Private buses	1150
Other buses	4500
Goods vehicles	55000
Taxis	37000
3 & 2 wheelers	35000

- Electrifying this would cost over Rs 25,000 crores.
- Charging the fleet at night over four hours would require over 500MW of power, which exceeds the grid's capacity.
- The State grid's supply of 560MW falls short of peak demand by approximately 100MW, resulting in power cuts.

Ayushca CSR Intent: accelerate the path to electrification and upgradation of the public tourist infrastructure.

Proposal:

Vehicle Fleet	**5000**
Standalone high speed charging stations	300
embarking gates/ stops with pantograph chargers*	200

*Pantograph chargers - the use of an overhead charging system that allows electric vehicles to charge while they are in motion

Phase 1

Upgrade buses	**500**
Comfort buses upto 12m	100
Luxury coaches upto 9m	120
Longhaul metro upto 24m	30
Amphibian sightseeing 12m	15
Mobile clinics 12m	15
Hotel coaches upto 7m	400
Emegency response 12m	10
Support Vehicle 20m	5
Water cruisers 15m	5
Total	1200

Out of these 1200, a total of 400 vehicles would be contributed by partner hotels and restaurants who will also provide parking and charging infrastructure.

Transport Hub

- The passenger transport market broadly consists of two segments - locals and tourists.
    - Locals primarily use two wheelers.
    - Tourists: Ola and Uber are not available in Goa. Thus tourists use taxis or rent self-drive cars.
    - KTC buses supplement private buses to provide affordable local transportation options at low levels of customer convenience.

Need for Transport hub:

- The key limiting factor to the growth of tourist numbers is the traffic bearing capacity of the local roads. This will necessitate a shift to shared modes of transport such as electric buses.

Goa Mumbai Highway Route | Source: Times of India

NH66 - Goa Mumbai Highway

Goa Tourist Bifurcation:

Current no of tourists	**8 million**
Tourists who travel by air	3 million
Tourists who travel by road and rail	5 million
Expected no of tourists in 2029	18 million
Expected no of tourists who will travel by road in 2029	10 million

Problem with current buses in Goa:

If one assumes four days per tourist and 60% tourist in the four peak months for the 10 million road arrivals, the bus footfall per day in tourist season would be upward of 500,000 with an average trip length of 30 kms yielding 15 million passenger kms. Assuming 5000 passenger-kms per bus per day - this will need 3,000 buses. In contrast Kadamba currently has around 500 ageing buses. Thus, in effect Goa needs an indicative 5000 buses including long distance buses. To cope up with future demand by 2028, depending on the scenario selected, as many as 30,000 small buses may be required to keep pace with tourist demand alone.

Solution:

- In order to ramp up from the existing 500 Kadamba Buses to 5000 over 50 months would require the addition of **100 buses per month.**

Transport Hub Description:

- Transport hub will host multiple electric vehicle technologies including pure electric, hydrogen and serial hybrid with fully automated hands-free charging.
- Electric vehicle parking, charging & maintenance and repair service stations will be established at the three transport hub locations.
- Facilities:
    - boarding gates, digiyatra access, baggage handling, food courts, retail spaces, lounges, prayer room, clean washrooms, medical care, walkathons, large information screens, airconditioned access till boarding gates, public wifi, direct connectivity to other airports/stations etc.
    - The Porvorim hub spread over close to one million square feet has been conceived of as the main tourism hub with direct loop route connectivity to large hotels, both airports, railway stations, leisure areas, tourism landmarks, beaches etc.
    - The Sourthern hub, spread over fifty acres near the Lalit Hotel Golf Course and Helipad, has been conceived as a multimodal hub connecting the virtual metro, luxury buses, and water transport.
    - The Northern hub spread over two hundred and fifty acres in-between Sindhudurg and Mopa on NH66 will house a 18 hole golf course, helipad, main convention centre and Global Alumni Hub. It will also house the main maintenance and servicing area for the bus fleet.
    - Transport hub will host multiple electric vehicle technologies including pure electric and serial hybrid.

Autonomous Virtual Metro

- Launch Date: 2025
- Connectivity: northern tip of the state at Sindhudurg Airport with the Sourthern Hub via the Porvorim Hub in under 100 minutes.
- The fully AI based system will use white painted tracks on NH66 to lock the wheels accurately to the Rails.
- The virtual rail movement will by synchronised with the traffic lights so that the lights are green when the virtual rail is passing by.

Electric Vehicles

The EVs are of the following categories:

Comfort Buses	Replace buses currently used by Kadamba Transport Corporation.	Charged and maintained at transport hub	Movement will happen through a transit card
Luxury Coaches	Distinctive look, low cost, bespoke interiors, large glass panels, easy fast charging and low cost	heavy luggage and easy disembarking for wheelchair passengers	developed through initiatives of the Council indigenously
Long Haul Virtual Metro	-	-	-
Estate buggies	Use inside the āyushća campuses and in the pedestrian zones near tourist attractions.	vehicle to vehicle charging	-
Amphibian Sightseeing	It is like a bus used in water for transport	provide safe travel on land or in water	used for disaster management or in flooded areas during the rainy season
Mobile Clinics	first set of MegaLab buses were flagged off on May 1, 2020 as an emergency fleet to help manage the covid pandemic in Mumbai & other cities	-	-
Emergency Response Vehicles	wide range of functionalities from medical facilities on board to satellite connectivity for communications backup	live video broadcast to hosting remote control rooms.	-

Support Buses	handle breakdowns and other maintenance issues including depot to depot transfer for remodelling, battery replacement, change of interiors, software upgrade etc	-	-
Water Cruises	high speed yachts	The zero pollution boats can take luxury tourism to the next level.	-

Real Time Digital Twin

Alumni partner companies developing Digital Twin, Street View type real time functionalities

State-Wide Digital Operating System

The "born digital" system would be "cloud native" to ensure the fastest response times and minimal delays.

Challenges in e-bus financing:

Challenges	**Overcome Challenges**
Public charging infrastructure	Modification of commercially available electric buses to operate with partial battery pack and serial hybrid type onboard charging station.
Substantially higher capcost vis a vis diesel buses	Rapid indigenisation of the drive train and other modules including invertors and control systems
Financial health of subsidised bus operation/ PSU enterprises	Working out subsidised transfer pricing on a per km basis for the buses. Cross subsidising the local buses from premium ticketing on tourist and luxury buses
Practical issues including ticket prices/affordability and employment for locals.	Transferring the transport hub terminals to a REIT based on rental discounting to unlock capital which can be used to subsidise operations to the extent of around Rs 600 crores.

Section 1.4: Feedback from consultation process

Based on the feedback from the consultation process, the following activities have been carried out:

- Several queries were raised regarding the AI system to ensure availability of bus on demand and the functionality proposed therein. In response to the same, two workshops were held to explain the research papers based on which the system was being developed. The abstract of these papers is included in Section 3 of this document for context. There is a general agreement that this approach can considerably reduce total kilometres covered per bus, reduce waiting time, improve customer comfort and substantially improve on transit times.
- The donor group also went through the pilot project carried out between Sonepat in Haryana and Jehangirpuri in Delhi for students of Ashoka University. The said pilot project involves around 3,000 students booking a seat on a shuttle bus via their Uber app. The app facilitates a bus on demand which is meshed with onward connectivity in New Delhi via metro or single user Uber cab without any waiting time. The rationale of a three hub approach with one main transshipment hub, one land to water hub and one airport hub. It was agreed upon that Porvorim was the best location for the transshipment hub. Similar integration with the Goa Miles app would need to be explored.
- Detailed assumptions relating to the proposed pricing of the eBus on a per km basis were discussed with scenario analysis. It was generally agreed upon that a simple single number was the best format to work with. Tenders of various states were analysed and it was agreed upon that Rs 35 for a 35 passenger capacity bus with a suitable increase for larger buses (based on ratio of passenger capacity) and suitable reduction for smaller buses was an appropriate and fair number.
- The effort and cost involved in upgrading the battery type eBuses to serial hybrid was discussed and detailed comparisons were provided comparing hydrogen and CNG based onboard electric generators. Given the power situation in Goa and the possibility of demand going up faster than supply – it was felt that at least 50% of the fleet should be upgraded to serial hybrid based on hydrogen. This will also allow for a truly green service since most of the electricity consumed in Goa is currently not green. It will also allow for higher range of upto 800 kms. With hydrogen refilling it could be even more.
- Discussions were held regarding the proposal to bottle CNG which is being flared at the Goa Waste Management Company. As per interactions with BITS Pilani,,it has been estimated that 5,000 cu.m. gas with an average 56% methane content is being flared daily. The capital cost of setting up a plant to bottle this is estimated at Rs 2.5 crore with a variable annual cost of around Rs 12 lacs. This will yield CNG with a retail market value of around Rs 4.5 crores pa. It is also possible to divert CNG from power generation to increase the gas output to close to Rs 10 crores pa (though capital cost will be higher). This CNG can be converted into an indicative one ton per day of hydrogen and three tons of graphene. This hydrogen is adequate to power 20,000 bus kilometres or 50 buses at 400 km per day. The graphene can be used to build water jetties using extra strength concrete and carbon nanotubes or fibres (in place of steel).
- The success of the 6m Karsan electric bus in Japan was debated. This bus is built using a drivetrain from BMW on similar basis as is being attempted for the water boats. The bus body itself is made in Turkey and then shipped to Japan. An identical model can be

made for India. The Karsan vehicle has several advantages. For one it can climb very steep roads. Second it has a wide 1.2m automated door which allows for a passenger to embark with baggage or in a wheelchair. This is not possible in a conventional bus. The vehicle can host 12 sitting passengers with a provision for ten more standing passengers. By using a home theatre kind of seating (each row is higher than the earlier one) – a unique ergonomic profile has been created which is ideal for a 270 degrees sightseeing view. The bus partners have already started development of bus units with this form factor. The government is being pursued to provide regulatory benefits and subsidies identical to those offered for cars to this 5.85m bus which is actually shorter than a Tesla car. This format of minibus could replace the cars that were anticipated in the 5000 vehicle initial fleet. In a serial hybrid configuration, this bus can give a range of 500 kms, battery swapping in less in five minutes (using the Nio robotics from Europe) and a hydrogen range extender which can enable infinite range if hydrogen filling stations are available. A fleet of around 50,000 such buses can provide an alternative public transport which is superior to, cheaper than and faster than private taxis or personal cars. Each bus requires just one driver and has extremely fast hop on, hop off facility because of the wide entry/exit gate. The Indian equivalent of the Karsan should be available for mass deployment in early 2025 at a cost of well under Rs fifty lacs for a twenty passenger version with adequate luggage space etc.

- The financial estimates of capcost and annual opcost along with the cross subsidy rationales therein were reviewed and the project finance member was requested to rework the financials based on the Karsan type vehicle format.
- The large trans-shipment hub proposed at Porvorim was unanimously approved based on results of the aerial survey on all the available options as indicated by KTC. The land could be paid for in cash at the circle rate for the entire 100,000 square metres. The proposed hub would have a plinth area of 30,000 square metres and need height approval for 90 feet and a FSI of 1.0 (to enable a million square feet terminal with 100 boarding gates and commensurate charging stations).
- For vehicles other than those provided to KTC at Rs 35 per km – the possible business case options were reviewed. The option with maximum support was to offer an eat all you can daily or monthly pass which could be used in any bus (KTC or otherwise) at an indicative Rs 250 per person per day or Rs 1500 per month or Rs 10,000 pa. For pass users boarding KTC buses, KTC would be reimbursed the fare than KTC would receive if it were a direct retail passenger. It was decided to explore business plan options in greater detail once the hub location and PPP company were finalized.
- The functionality to be built into the Digital Twin was discussed. The coordinator shared the digital twin tenders of Varanasi, Ayodhya and Mumbai which were broadly identical. However, these tenders did not envisage the elaborate detailed and dynamic digital twin functionality required for live AI based transportation networks. Dr Nyati offered to arrange for 50 flight sorties over Goa by June 15, 2024 and help estimate the cost of developing the dynamic digital twin using the Kodoy stack with the private planes and vehicles that are used for Google street view. The partners have been gracious enough to agree to do the Digital twin development work at cost with a small overhead cover using the planes, drones and other vehicles when they are not in use for commercial projects. Dr Nyati made a presentation on the work done for the Dharavi digital twin and gave a demo of the footage already captured for Goa and for the Porvorim traffic simulation. A clip of the video is appended.

Section 2.1: Synopsis of Overseas Projects

This document serves as a brief compilation of the institutionally-funded Bus Transportation projects in emerging markets from the year 2000-2020. The primary information source used for compilation of this document are public-domain reports of the multilateral development banks including the World Bank (who have also published working papers related to many of the below mentioned case studies). It documents findings related to select aspects discussed in the case study cities, including significant experiences, challenges, successes and lessons learned, to relay practical, ground-level guidance on local bus planning and implementation. The information presented herein has been customized and collated for the purposes of the Ayushca Transport Hub which is part of the Global IIT Alumni Hub @Goa.

Among the case study cities, the implementation of BRT corridors has been believed to deliver a remarkable transformation in urban mobility, often replacing chaotic traditional transport systems and delivering tangible impacts on the city and its peoples. However, BRT implementation is a complex affair since it involves complex planning and design, adaption to local conditions, and extensive coordination of stakeholder engagement, institutional change, as well as project and financial risk management.

It is important to note here that the BRT project implemented in New Delhi in anticipation of the traffic surge during the Commonwealth Games of 2010 was an abject failure and had to be dismantled at substantial cost. At the same time, the virtual metro concept which has been experimented with in Germany as well as China seems to hold substantial promise – especially for Goa - because it is built ground up for autonomous vehicles and does not involve laying of any electrified tracks. If the virtual metro is interfaced with a smart integrated traffic light management, it can deliver most of the benefits of a metro rail system including capacity, waiting time and transit time. Rail based metro would be difficult to implement in a location like Goa which is not only spread out geographically over 3500+ square kilometres but would also be a challenging topology for construction of either underground or overhead rail lines. Most routes may not have the requisite economy of scale in terms of passenger demand. The AI based system now proposed for Goa has the promise of providing point to point on-demand services at a very low cost with an excellent consumer experience. We expect this experience to draw a significant proportion of the customers in preference to using their own cars or self drive/chauffeured taxis. The lack of migration and legacy issues would play to Goa's advantage.

This document aims to conduct an honest and balanced appraisal of local bus transport formats to understand the underlying reasons and causes for achieved results in several completed projects, thus discussing both successes and lesson.

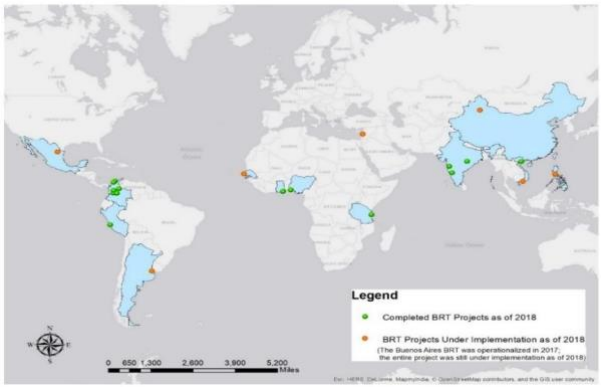
This synopsis is primarily based on desktop research with limited field work carried out by volunteers from the IIT Alumni Chapters in premium locations like Lake Como, Venice, Marbella Spain, Bali etc.

Multilaterals like the World Bank have focused primarily on BRT projects and have analysed the projects using the following framework:

Research Framework and Structure

For the period from 2000 through 2018, the World Bank financed a total of 19 BRT systems under Investment Project Financing (IPF), including nine completed BRT projects by the end of 2018, the time this research project began, and 10 in various stages of implementation.

Locations of Completed BRT Projects under World Bank-Financing (2000-2018)



These projects represent a total cost of an indicative $5 billion, of which around $2 billion or approx. 40% was financed by the World Bank. The World Bank projects are located in seven countries involving 14 cities: Accra in Ghana, Bogotá in Colombia (two projects), six cities in Colombia (Bogotá, Barranquilla, Bucaramanga, Cartagena, Pereira, and Medellín), Dar es Salaam in Tanzania, Hanoi in Vietnam, three mid-sized cities in India (Hubli-Dharwad, Naya Raipur, and Pimpri- Chinchwad), Lagos in Nigeria, and Lima in Peru. We believe that 40% project funding via multilaterals is a good thumb-rule to follow.

All completed BRT projects had similar Project Development Objectives (PDO) as Goa. They all focused on improving transport and mobility and encouraging modal shift to environmentally sustainable public transport. In some cases, PDOs included a specific aim to deliver systems that are reliable and cost-effective (Dar es Salaam). Other common objectives included improving access for the poor and strengthening institutional capacity, with one case targeting improvements in local level urban transport planning and traffic management (Accra, NUTP Colombia). A few projects highlighted developing integrated urban transport plans and policies to enhance economic productivity and quality of life (Colombia's NUTP cities, Lima, Lagos).

It is claimed that BRT became a catalyst for institutional and sector reform in some cases. The establishment of Urban Transport Authorities (UTA) specifically to lead BRT

implementation was less effective. Planned UTAs in some cases were not realized (Hanoi, India cities); some were not sufficiently robust as a political, regulatory or coordinating entity to undertake implementation of a major sector reform together with a BRT implementation (Accra); and some new BRT agencies lacked the strength to match influential power players (Dar es Salaam). In the case of Colombian cities, a central government program provided technical assistance and funding while municipalities formulated projects. In the Indian cities, establishing financial and technical resources at the state level developed a centralized capacity that was able to effectively support multiple cities in their state. Based on an analysis this far, we believe that the PPP framework entity working alongside a state government entity like Kadamba Transport Corporation can provide the best possible fit to the market and investor need.

Whilst it is important to note upfront that central lane BRT failed in New Delhi, it is none the less useful to study central lane BRT and other Quality Bus System (Improvement) projects in various emerging markets. For the purpose of this report, the term "BRT" has been used interchangeably with Quality Bus System (Improvement) projects. Virtual metro and shared minibus services have been proposed as part of the BRT framework. Key highlights of the case study cities in implementing BRT are briefly described as follows (in alphabetic order) along with a conclusion at the end of each in terms of "takeaways for the goa project":

Accra BRT :

The project did not implement the BRT due to cost overruns, opting instead for a Quality Bus System (QBS). The QBS struggles with traffic congestion due to lack of dedicated lanes and massive growth in private vehicles, which created financial hardships, but QBS provides valuable experience upon which to build ongoing improvements. Formalizing the route operators is a significant step to improving regulation and standardization of services since it establishes the government's role as facilitator/regulator of public transport. The issues raised by this deployment experiment have been addressed by the use of AI controlled, on-demand routing. This eliminates the need to have pre-defined bus routes or "time of day" based bus frequencies.

Bogotá BRT

Bogotá's TransMilenio project was developed with solid planning objectives that included a socially inclusive approach to transforming city mobility. It introduced TransMilenio SA as the network manager and built a regulatory model of private sector operators while also including existing stakeholders into the new business model. All three BRT projects in Bogotá achieved their PDOs with remarkable system performance. However, TransMilenio's earlier mandate for full cost recovery from fares of its operational expenditure proved difficult to manage, causing pressure on fares and user dissatisfaction with particular impacts on the affordability for low-income users. The quest for full cost recovery through higher efficiency and productivity manifested itself in passenger overcrowding, which negatively impacted public support. Since 2015, legislative changes involved replacing 'financial self-sufficiency' with 'financial sustainability,' allowing other funding sources to supplement fare revenue. This experiment has very useful learnings for Goa and it is desirable to build a complete

ecosystem which aligns the interests of both the state transport company as well as various private operators, self-drive car providers and hotel owners with own vehicles (besides other stakeholders).

Colombian BRT Program – Six cities (Bogotá[5], Barranquilla, Bucaramanga, Cartagena, Medellín and Pereira)

Colombia's decision to scale up the successful Bogotá's BRT under the National Urban Transport Scheme (NUTP) provided political emphasis, and offered technical assistance and a proportion of the funding required for cities to undertake their own BRT projects. In each case, a key intervention was to define a new regulatory framework to address operational problems and negative impacts of traditional bus transport. Lower than expected ridership in all cities caused financial hardship, but cities with greater success improved BRT integration with the surrounding networks and feeder services. Despite the varying levels of challenges and successes, BRT served as a catalyst for cities to develop their own integrated road-based public transport systems. While access to the poor remains a challenge, the percentage of low-income passengers using BRT increased significantly, reaching 71 percent on Barranquilla BRT and around 60 percent on Pereira and Bucaramanga BRTs. The conception of a new overlay built ground-up for on-demand point-to-point services based on eVehicles, varying levels of comfort/QoS and a hub-based changeover point can fundamentally alter the price performance of public services. This in turn can help shift a substantial proportion of tourist traffic to public transport. This would prevent choking of the roads and lungs of the city. This could enhance the State's ability to cater to many more tourists and to capture the revenue therefrom.

Dar es Salaam BRT

Following the style of Latin American models, Dar es Salaam built a high-quality system that inspired other sub-Saharan Africa (SSA) cities looking for ways to transform urban mobility. Dar es Salaam's Line 1 has been operating for over five years, and further expansion is underway. At opening, the BRT carried 180,000 daily passengers and reduced travel time along the corridor by a remarkable 50 percent. Lack of institutional readiness, uncertainty surrounding the business model and risk assignment, and an unclear plan on how to incorporate the displaced daladala minibus sector posed difficult implementation challenges. It would seem that aligning the incentives of the private operators by giving them buses with charging and parking on a "per km based rental" may help to get them on board.

Hanoi BRT

Hanoi's BRT experience presents valuable lessons on the complexity of implementing BRT. Despite its challenges, the case provides an example of a pilot BRT system that is replicable in other corridors. The project also instilled into city managers the confidence in their ability to improve public transport. While other PDOs were met, ridership fell well below the target with 14,000 daily at opening, partly reflecting the limited integration with regular bus services. Over 50 percent of surveyed users report being previous motorcycle riders. The key challenge in Goa is to shift tourists from vehicles carrying an average of 2 or 3 passengers to those that can carry 10 or 15 tourists in one vehicle which is of the same size.

India BRT Program-Three mid-sized cities (Hubli-Dharwad, Naya Raipur and Pimpri-Chinchwad):

India's three-city BRT project was remarkable in that it prioritized capacity building as a first intervention, which equipped local decisionmakers to define their own mobility initiatives around the BRT implementation and develop competency to manage unforeseen risks. This Global Environment Facility (GEF)-Sustainable Urban Transport Project (SUTP) involved a large capacity-building program in mid-sized cities where resources and capacity lag behind large cities. It utilized capacity at a state level to provide technical assistance to multiple cities. The BRT implementation programs overcame a myriad of challenges, notably land acquisition and contestations over street space. At opening, the cities achieved significant mode shift to public transport on BRT corridors. Ridership in Hubli-Dharwad rose to 100,000 daily, however in Pimpri-Chinchwad and Naya Raipur BRTs are lagging in ridership growth. The key learning here is the base infrastructure in terms of the passenger terminals and charging hubs has to be created upfront and then the rolling stock can be increased in keeping with demand.

BRT in Dar es Salaam and Hubli-Dharwad

Dar es Salaam, Tanzania

Hubli-Dharwad, India

Lagos BRT

The Lagos BRT demonstrated that a BRT project does not necessarily need to achieve 'full BRT' status, instead it can use a variety of bus system improvements appropriate to the local context. This learning is particularly relevant for Goa. Lagos Phase 1 BRT commenced with a government-sponsored BRT Lite project supported by MDB funded technical assistance. The project took a pragmatic design approach by concentrating infrastructure on where it delivered the most impact. Building on BRT Lite's success, the Bank financed Phase 2 (LUTP2), which involved system improvements and median BRT extension and road widening. System performance has been remarkable for a low-cost BRT, with daily ridership reaching 200,000 passengers. This pragmatic approach involved strategically prioritized actions, such as comprehensive public engagement and communications to build public acceptance and trust, and design/build construction contracts to reduce delays. Also notable was the early and comprehensive investment in capacity building in all aspects of transport management, which was instrumental to success. Integrated Public Transport System (the transport authority in Lagos, also knowns as LAMATA) has become a textbook example of how to develop institutional strengthening, fostering a competency to undertake a locally-derived system design and in managing unforeseen risks. The crisis of deteriorating performance of the first BRT operating company for BRT Lite demonstrates how the business model can influence behavior. In this case, the operator seized control over

revenue to gain a power advantage to exploit a financial opportunity. Fortunately, LAMATA was able to prevail and terminated the contract.

Lima BRT

Lima leveraged outstanding political support to develop a BRT system out of a chaotic transport situation. Ridership took time to build up, causing some early difficulties. However, once the system was fully operational, it exceeded its target demands and achieved its PDOs, including reductions in travel time by 34 percent, and in fatal and serious accidents by 65 percent. Despite a key objective to improve access to the poor, the project found this a challenging task, and Protransporte is now aiming to improve access and affordability by implementing a large feeder route network and also optimizing its fare policies. Fleet renewal and bus scrapping were part of the reforms but they added an extra layer of complexity that caused delays. Separating fleet renewal from the critical path of the project was a lesson to be learned. It seems important that the path to replacing the ageing fleet of KTC be defined clearly upfront.

The transportation task force of the IIT Alumni Council which worked under the Forum mission has tried to assess the reported data on the various BRT projects objectively and also compared the same with BRT experiences in cities like New Delhi. Very interesting learnings have also emerged from field work in locations like Gold Coast, Bali, Marbella etc. It must be explicitly stated that the findings of the IIT Alumni Task Force are not consistent with the findings and recommendations of the World Bank primarily because the World Bank has not factored in several major inflection points – emergence of electric vehicles, the advent of AI in route analytics, the ubiquity of smartphones, cost effectiveness of digital citizen service platforms, success of virtual metro architectures and new formats of asset and infrastructure sharing between the government, PPP entities and the private sector.

However, there are some interesting points raised in the World Bank analysis which merit a mention. These are summarized in brief from the World Bank working papers :

- While BRT offers a range of design options for both infrastructure and operations and is an effective instrument in the Urban Mobility Toolbox, it is not a 'silver bullet' solution for every city and corridor. BRT should be approached as an integrated set of measures that can be applied according to the local conditions. Characteristically, BRT aims at improving the standard of road-based public transport with quality infrastructure and high-frequency services to promote substantial ridership. The case studies consistently demonstrated BRT or its equivalent to be a key intervention and cost-effective instrument to address the urban mobility conundrum that cities face.
- In its basic form, BRT infrastructure can range from low-cost infrastructure ('lite') that offers operational-enhancements (sometimes with lower capacity), to more sophisticated high capacity infrastructure. This should not be regarded as an either/or choice, as BRT design can blend various features to satisfy the agreed objectives developed in conjunction with city managers. It is also flexible, being able to adapt to the complex local systems in which cities operate, such as by balancing intricate interplays with other road-based

transport modes and users, institutional structures, technology applications, and the prevailing political dimensions.

- Corridors with lower demand or medium-sized cities can explore Integrated Corridor Management (ICM) that seamlessly combines bus lanes and other bus improvements with traffic management, road safety features, and walking and biking facilities as a cost-efficient alternative.
- Regarding BRT corridor carrying capacity, this review found that globally, in typical cities, BRT systems have a corridor capacity threshold of around 10,000 passengers per hour per direction (phpd) before operational bottlenecks (such as berths at stations, intersections) begin to impact on efficiency and quality.
- The institutional aspects of BRT can have more influence than infrastructure on the BRT's success . Flawed design in BRT infrastructure can reduce a system's effectiveness, but a weak or botched institutional framework could see the system fail.
- The role and function of the authority/agency need clear definitions, whether it is to serve at a high level and be responsible mainly for policy, planning, and regulation (LAMATA Lagos), or at a middle level, in managing BRT day-to-day operations, service planning, and the operator contracts (TransMilenio-Bogotá, Protransporte-Lima).

Tiered Level of Functions and Risk Assignments Among Players

- Management capacity of the agency needs to be robust, with careful attention given to the relationship (or power balance) with operators. In particular, this relates to the contractual assignment of roles, responsibilities and risks between the BRT agency and operators, defining the power relationship and influencing the behavior of the players, as experienced in Dar es Salaam and Lagos BRT Lite.
- The bus operator contract is not a standard model contract; it needs to be tailored to local context and to the relative strengths of the parties. Typically,

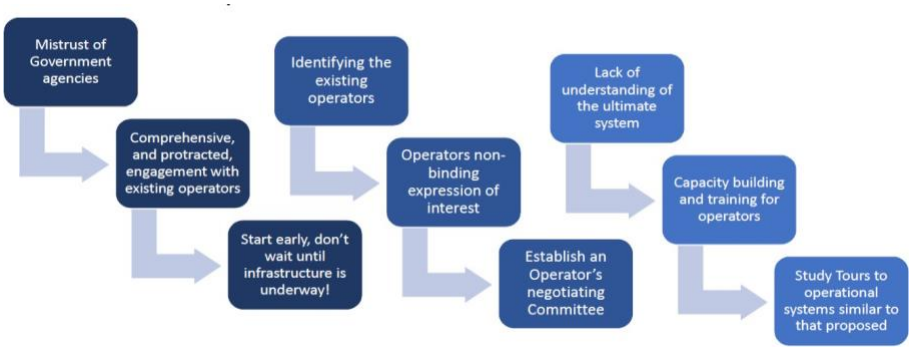
bus operator contracts are classified as net-cost contracts (NCC) where the operator carries the financial risk, and gross-cost contracts (GCC) which places revenue risk on the agency (city). *Hybrid contract models where risk is shared are becoming more common.* Due to risk exposure on both sides, it is useful to think of a hybrid contract as a partnership contract. The following figure outlines the type of contract appropriate to different circumstances, namely the experience of the operators and their ability to manage risk.

Hybrid Contracts Based on Relative Capacity of the Parties

Requires More Agency Control		Allows Some Operator Control
Suits less experienced operators	⟷	Suits more experienced operator
Protected from demand risk	⟷	Able to take some demand risk
Service planning wholly by the agency	⟷	Operator involved in service planning
Prescriptive service specifications	⟷	Greater flexibility to innovate and develop service efficiency
Paid set rate for supply of services (but could include passenger incentive)	⟷	Paid for services but business model rewards ridership growth
Strong emphasis on penalty regime to guarantee quality	⟷	**More emphasis on economic incentives** for quality service delivery (+some penalties)

- Procurement of operators for new contracting arrangements is a major challenge. Typically, operators are unfamiliar with new arrangements and/or lack trust in government, or they may have practical concerns over issues such as loss of employment. However, when a new contract identifies costs and appropriately assigns risks, it is likely to be a more sustainable business model than what operators currently have, so the city should not be hesitant to promote a transition to a new business opportunity. The figure on the next page shows important areas to consider and the subsequent steps involved in the process.

Steps of the Transition Process



- BRT can be leveraged to spearhead speedy changes to formalize the passenger transport sector and rationalize operators and services. A large investment in transport infrastructure can create momentum for change. Leveraging BRT for

sector reform should aim for a "triple win" – benefits for the city, for the customer and for the operator. Simply using BRT leverage to enact sector reform, without a clear-eyed view of local conditions, could run into serious problems.

- Paratransit private operators, while often displaced by BRT, are an essential part of the network supporting BRT. Paratransit ownership structures are not always identifiable, and their semi legal/vulnerable status often fosters political affiliations. Lack of capacity may also hinder participation by informal paratransit operators. Notwithstanding the challenges, a good approach is to focus on business transition that empowers the industry either by (1) incorporating interested parties into a formal entity to operate the BRT as a service provider company or (2) structuring operators into a business model that provides feeder services to the BRT, which can be an effective approach since it leverages their ability to fill the gaps as feeders to the BRT and to provide complementary services in lower-demand corridors and peri-urban areas.

- With BRT and public transport generally, cities need to balance financial sustainability with transport affordability and wider social objectives by fine-tuning fare policy, subsidy levels and operational efficiency. Where fare setting is a political exercise, resulting in financial deficits, stable alternative sources of funding will need to be secured. However, while subsidy or non-fare revenue is usually required, such funding should not be considered automatic compensation for financial losses. The use of subsidy funding must be a commercial decision based on well-grounded financial and economic analysis and structured in a way that avoids fostering subsidy dependency, which may dilute management's focus on business performance. Furthermore, fare policy (willingness- to-pay and affordability) must be managed, together with a strategy to achieve ridership targets. From a business management perspective, financial sustainability requires establishing the business case and taking a business-like (commercial) approach to develop the market, build ridership and revenues, and efficiently managing costs.

- The physical and operational integration of BRT as part of a public transport network is difficult to manage in part due to the unique and complex urban environments in which BRTs are built, and it usually require some trade-offs. For example, where BRT operations are disconnected from local bus services, the gain in travel time savings on the BRT could be lost in passenger transfer and access time.

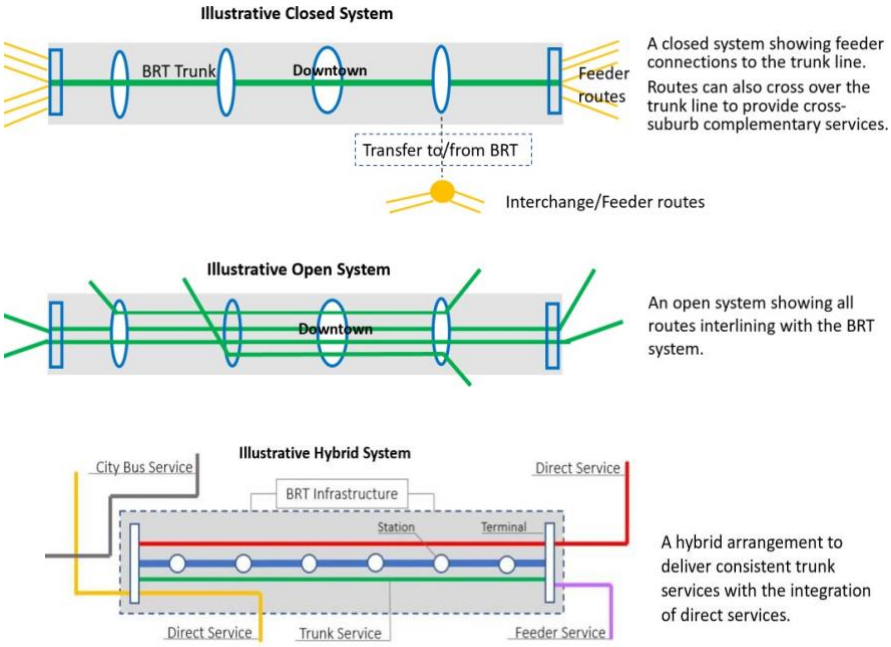
- Operations planning and infrastructure design are interdependent processes. Operations planning is a core part of the *Concept and Feasibility Plan* upon which the city gives approval, thus allowing the project to proceed to detailed design. BRT operations planning should guide the infrastructure design and not be left until it is time to operationalize the system. Common design choices as seen in the case study cities have shown that:

- The decision for curbside or median alignment is not a binary choice as systems can use both types within the one system if necessary. Curbside alignment may be suitable where roads are narrower and allows the station/bus stop facilities to be incorporated on the sidewalk, reducing the demand on road space, whereas median alignment is less subject to operations disruptions and encroachment and capable of providing higher bus throughput and frequency.

- A direct BRT system (off/on busway) improves integration by reducing passenger transfers, penetrating communities, and improves 'first-last-mile' access. Direct services are more suited to corridors of medium density and moderate ridership.

- However, a closed BRT system is more suited to higher capacity systems, avoiding the random entry of buses onto the busway which could disrupt a highly scheduled BRT trunk operation. It also allows for better allocation and utilization of resources by concentrating high-capacity vehicles on the trunk route where high demand exists and allows feeder services to be tailored to demand, using smaller buses. Passengers understand the simple design concept of a trunk-feeder system, where route design is less complex.

Illustration of Closed and Open System Design



- Intersection control is often not sufficiently prioritized in BRT design, but it plays an essential role in maintaining reliable schedules and helps to space buses properly to avoid overloading stations - a key capacity constraint.

- Station and hub designs must consider passenger capacity requirements, including convenience, safety, wayfinding, pedestrian flow, and passengers with special needs. ROW constraints at stations may require some innovative planning which could include the use of guided bus systems to improve bus docking and reduce space demand. A MDB-financed IPF project generally proceeds through a six-step cycle which is illustrated below.

- The following images serve as an ideaboard for simple design changes which can significantly improve the design of the bus system.

IPF Project Cycle

Bus Congestion on the Busway

Source: https://use.metropolis.org/case-studies/transmilenio-bus-rapid-transit-system

Congestion Affecting Service Efficiency

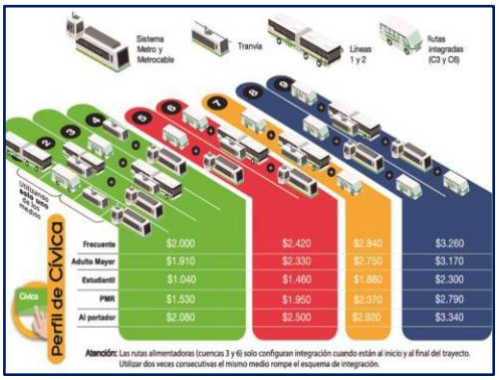
Source:https://theBogotápost.com/Bogotás-transmilenio-system-a-painful-route-to-the-future/1177/

Medellín Metro

Tranvía tramcar line T-A

Tranvia Tramcar Line

Civica Integrates Fare system



Source: https://medellinliving.com/medellin-metro/

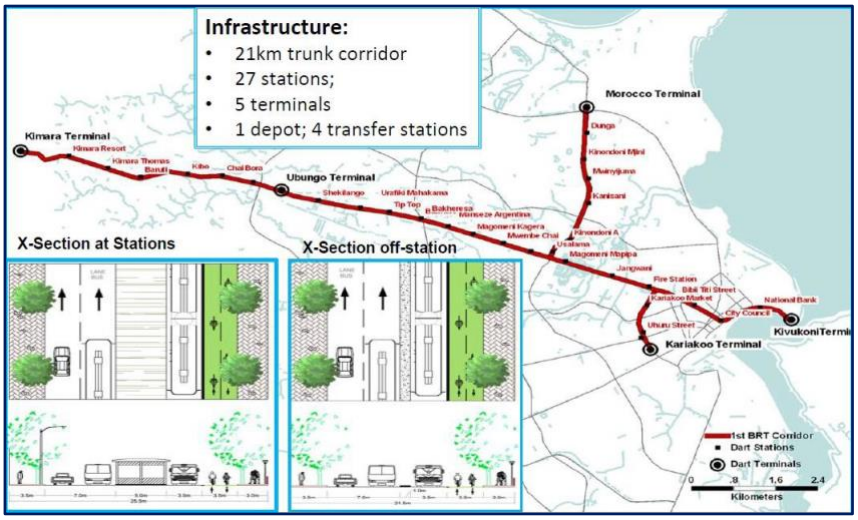
BRT station - Accessible and Air-Conditioned

Source: TransCaribe

Pre-Troncal Bus

Source: ITDP

Phase 1 BRT corridor



Source: Yonas Eliesikia Mchomvu, World Bank

Inner City Bus Congestion

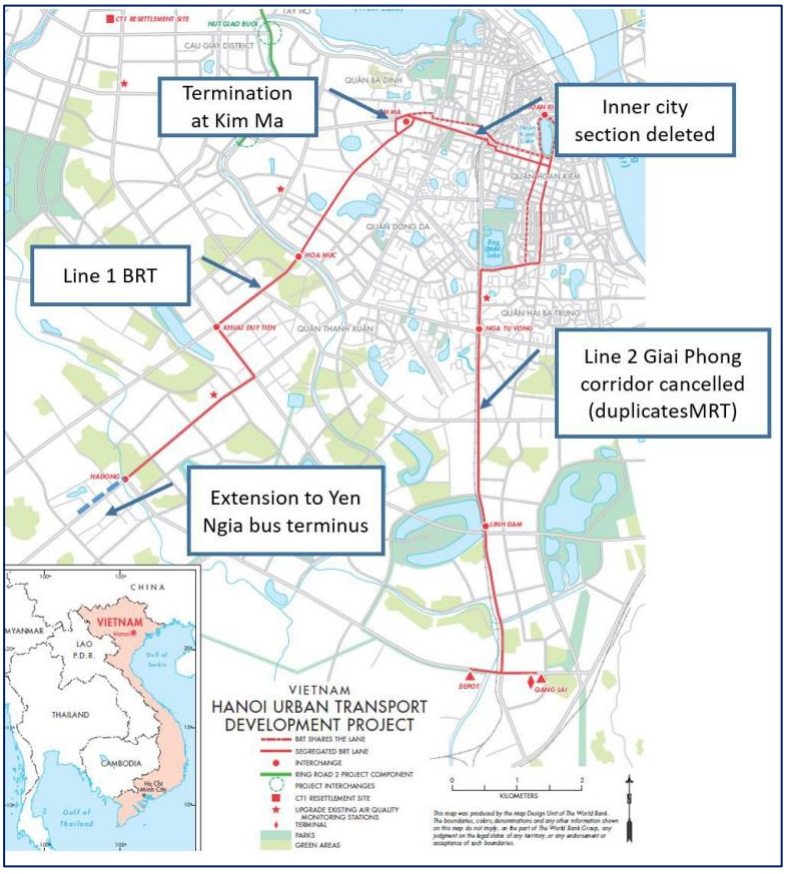
Bus Station

Source: Wenyu Jia, World Bank

Overcrowding on DART BRT (2018)

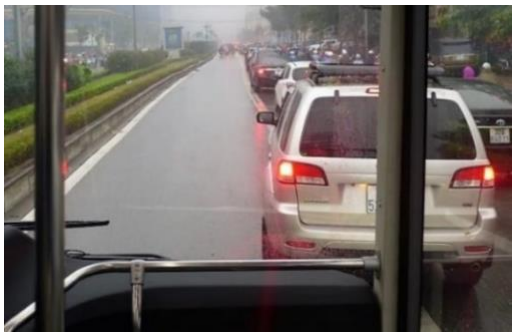
Source: Yonas Eliesikia Mchomvu, World Bank

Map of Planned BRT lines



Source: HUTPMU

Need for hard barrier



Occupancy of the BRT lane is commonplace, and despite the BRT bus horn-blowing, these violators are unwilling to move aside.
While the painted line 'soft' barrier generally separates traffic from the bus lane, the BRT driver is constantly under stress, threatened by traffic intruding on the bus lane.

BRT lane invasion

The painted barriers need constant enforcement. When traffic gets heavy, such as in wet weather motorists appear to see it as OK to take over the BRT lane.
The lack of left turn management at intersections, caused the BRT to be blocked at this intersection.

Lack of traffic enforcement

Poor management of intersections has a severe effect on BRT as a large portion of signal green time is wasted by persistent cross traffic violating red lights.
Traffic rules enforcement is key.

Mixed traffic operation on an overpass

Traffic on overbridges are a major obstruction to BRT, as often the traffic is stopped. As BRT develops the city will need to make a policy decision, to remove private cars and motorcycles from the single lane overpasses and prioritize BRT.

improved discipline of traffic violators is needed

Lack of order (and consequently accidents) are largely due to the 'village driver attitudes' by motorists, who endanger themselves and others with undisciplined behavior, impulsive and erratic actions.

Ignorance of BRT rules is an accident risk

Cyclists regularly see the bus lane as a clear cycle path, putting themselves in high danger.

Source: Frits Olyslagers (2017)

Section 2.2: Synopsis of Four Indian Projects

India a fundamentally different from all other emerging markets because of three parameters. First is the level of digital penetration and digital citizen services. The digital twin work for Varanasi for example is more advanced than that done for Singapore. Similarly the digital payment ecosystem is far more mature. Second is the calibre of civil servants and government officials. India attracts the very best domestic talent in its highly competitive civil services whereas most developed countries are not able to attract comparable talent. Government jobs are pretty low down on the demand hierarchy with litigation pursuing lawyers and hedge fund managers topping the list. In recent times, the Task Force noted that the so-called experts from multilateral development banks like the World Bank are not on par with Indian civil servants. Staffed mostly by economists and not by engineers, the multilateral development banks look upon challenges without understanding or even contemplating the use of emerging frontier technologies. The ability to implement such technological advances fundamentally alters the ability of India to lead globally. New algorithms to run transportation are the third and most lethal comparative advantage for India. To that extent, the World Bank findings are more about "What was" rather than about, "What should be or can be?".

Three medium-sized Indian cities developed BRT under World Bank financing, including Hubli- Dharwad, Pimpri-Chinchwad, and Naya Raipur. As per the World Bank, "Each of the BRT systems, whether BRT Lite in Naya Raipur or fully segregated BRT in the other two cities, received very positive public responses, achieved significant modal shift to public transport in the BRT corridors and most importantly, developed capacity through 'learning by doing'."

However the experience of New Delhi with the BRT was not positive. And in fact, the entire corridor had to be dismantled at considerable direct expense and even more indirect expense caused by the delays and consequent fuel expenses/productivity loss. It is thus the view of the Task Force that a hybrid design with AI based on-demand point to point services is the ideal way to go forward. This will necessitate a much larger fleet size and a vehicles of different sizes ranging from sub 6m/22 passenger minibuses (similar to the Karsan buses piloted in Japan) to the 24m virtual metro coaches which can carry upto 500 passengers on the main elevated corridor from point to point.

In the Hubli case, the proactive involvement of the state government created the Land Transport Department, connecting the city to urban transport grants to implement small innovations at the city level. Hubli was clearly more successful; as it established a SPV BRT agency in Hubli-Dharwad which was able to coordinate planning, delivery and operations in a highly fragmented institutional setting. Whereas BRT ridership in Hubli-Dharwad rose to 100,000 daily, BRT in Pimpri- Chinchwad and Naya Raipur have yet to improve their ridership performance. The BRT implementation overcame the myriad of unforeseen problems in land acquisitions, community opposition, change to design drawings, staff turnovers and resultant design changes.

India is rapidly urbanizing. Urban population is projected to grow from 290 million in 2000 to 590 million by 2030 and urban transport problems pose a serious threat to the environment both locally and globally. High level of air pollution has been part of daily life in many big Indian cities where streets are overloaded by motorized vehicles. Under

these trends, India will soon be the world's third largest consumer of oil, only after the US and China. Unless deliberate steps are taken to develop and implement an environmentally friendly urban transport strategy in the coming decades, India's increasingly growing urban areas may well become the largest single source of GHG emissions increase. Goa which is heading towards massive increases in tourist numbers (because of the new Mumbai Goa expressway) is likely to see massive increase in numbers. The task force estimates a 20x increase in ridership from existing levels (taking into consideration both KTC and private buses). Most important is the realization that the roads and lungs of Goa will both choke under the load of incoming tourist influx in the peak months. This will lead to traffic jams like those witnessed during the IEW seminar in Feb 2024 of three hours each way. It will also lead to Delhi type AQI levels which will drive tourists away. Congestion is bad for both - tourist revenues as well as viability and thus growth of tourism dependent businesses. In a way, congestion is bad for the economy as well as for job creation.

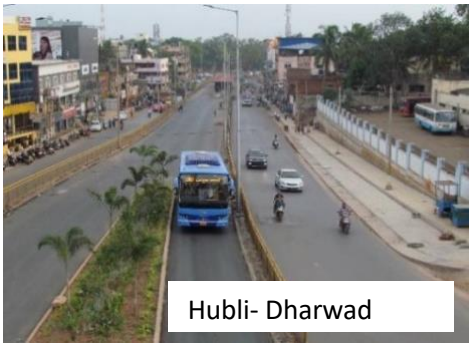
One should however look at the MDB funded projects to gauge their real performance. In 2009 the GoI formally requested the World Bank and GEF to assist to develop adequate institutional structures and capacity for implementing the National Urban Transport Policy which will in turn, abate GHG emissions. The MoUD developed an India-GEF- World Bank-UNDP Sustainable Urban Transport Program (SUTP) to strengthen the capacity of national and local governments in urban transport planning and management in more integrated and comprehensive manner. The core of this multicity program involved a wide range of activities under both capacity building and demonstration projects. Through the demonstration projects, SUTP financed BRT systems for three cities: Hubli-Dharwad, Naya Raipur, and Pimpri-Chinchwad.

The Project's Development Objective (PDO) was to promote environmentally sustainable urban transport nationally and to improve the use of environmentally friendly transport modes in the project cities.

The length of implementation was 9 years from 2009 to 2018, having been amended seven times and extended twice to accommodate new developments. One extension was by one year in December 2012 to include Hubli-Dharwad BRT, and the second time by 28 months in November 2015 to ensure completion of five of the six demonstration projects, which were critical to the achievement of the PDO. The complexity of involving multiple cities and agencies required flexibility in implementation.

BRT in Project Cities

Pimpri- Chinchwad



Hubli- Dharwad

Naya- Raipur

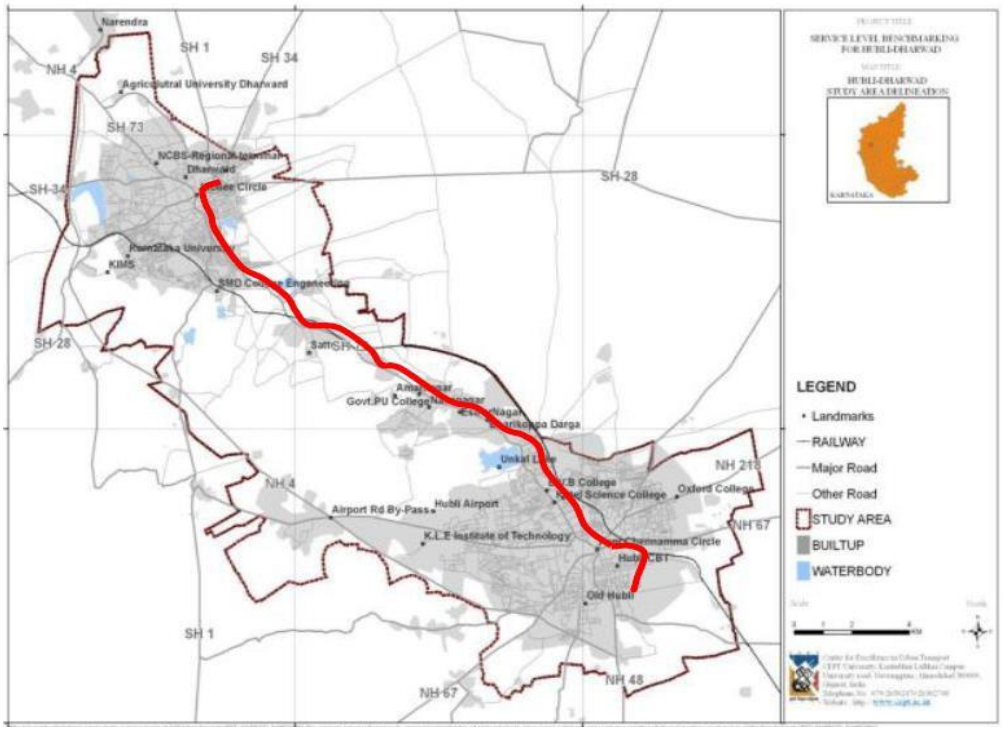

Hubli-Dharwad

Hubli-Dharwad

Hubli and Dharwad are twin urban communities, situated in the State of Karnataka. In 1961, the two cities merged to form the agglomeration of Hubli-Dharwad. Hubli-Dharwad Municipal Corporation is in charge of the city framework and organization of the twin cities. The population of Hubli-Dharwad, is 1.5 million (2018) with a population density of 4422 per square kilometer. Goa in contrast is a similar area but with a much lower resident population and a much higher floating population.

The SUTP financed the 22.25 km BRT corridor between Hubli and Dharwad. Before the project, public and private buses provided service between the two cities, at a travel time exceeding one hour. The BRT comprises 17.5 km of dedicated corridor and 5.25 km of mixed traffic lane, along with bus depots, bus stations, terminals and interchanges between city bus service and BRT, and NMT facilities. The BRT project also includes implementing an ITS and depot and terminal improvements for the city buses in general.

Hubli-Dharwad BRT

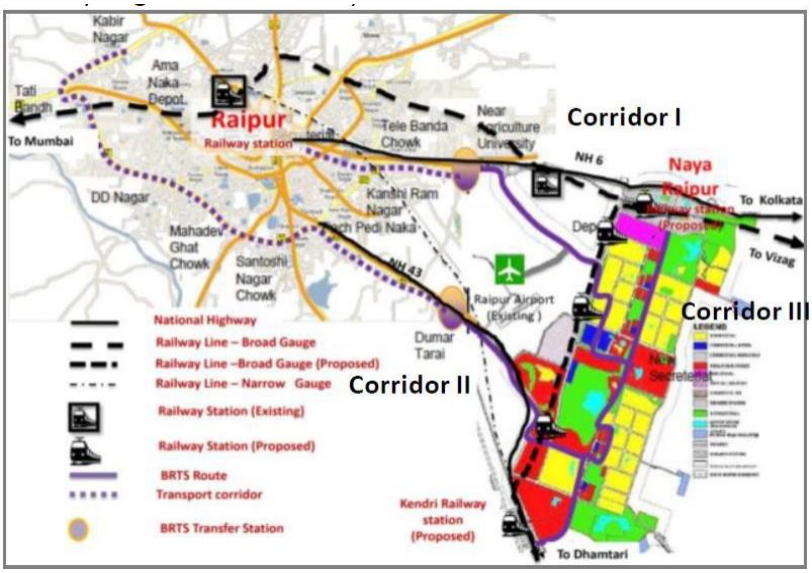


The BRT in Hubli-Dharwad is managed by the Hubli-Dharwad BRT Co, operationalizing the project in October 2018 starting as a 5-bus trial, rapidly growing to an operation of 100 bus fleet. The daily ridership was 65,000 initially and is now reaching 100,000 with travel time having decreased from one hour to 35 minutes with express services. At opening, indications were that the BRT was able to retain 50 percent of the previous bus passengers, and that 18 percent of the users have shifted from personal modes of which 9 percent are from cars.

Naya Raipur

Raipur, the original city, was the capital of the State of Chhattisgarh and the major urban center in the state. Naya Raipur, is a planned city to replace Raipur as the official legislative capital city of Chhattisgarh and is being developed as a 'green city' under the Smart Cities Mission Program by the national government. The population of Raipur in 2019 was estimated at 1.87 Million, and Naya Raipur close to 200,000 people.

Naya Raipur BRT



The SUTP financed the BRT Lite corridor (Corridor I in Figure) between Raipur and the newly developing administrative center of Naya Raipur, over a distance of 26 km, as an express service without a dedicated right of way. Before the project, and with the launch of the new state capital, passengers had to rely on personal modes of transport and a minimal public bus service. In order to avoid creating dependence on personal modes, the World Bank encouraged the Naya Raipur Development Authority (NRDA) to initiate an interim bus service. Accordingly, NRDA launched an employee- only government bus service as most commutes between the two cities were by government staff commuting to work. Two additional BRT corridors were planned: Corridor II as a BRT corridor linking Kabir Nagar (Raipur) with the Capital Complex in Naya Raipur (35 km) and Corridor III as a Quality Bus Service.

System operation was assigned to the Naya Raipur Mass Transport Ltd (NRMTL), an SPV Company commencing with Corridor 2 partially operational with a plan for full operations as the population of Naya Raipur grows. Daily ridership on the BRT Lite

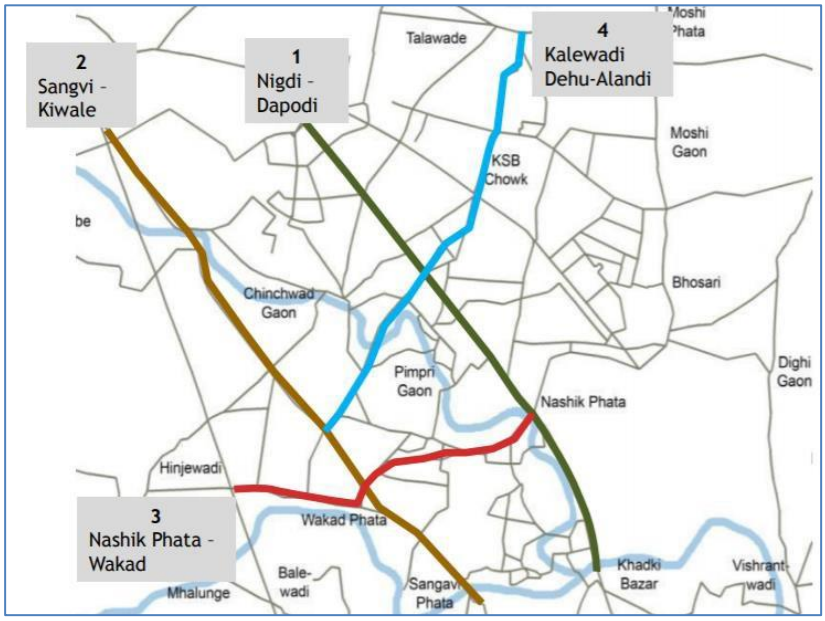
grew quickly from 950 at opening to more than 3,000 passengers per day by 2018. The public transport mode share of trips between Naya Raipur and Raipur reached over 42 percent at project close, a very significant achievement given the negligible public transport available in Raipur at the start of the project.

Pimpri-Chinchwad

Pimpri-Chinchwad, under Pune Metropolitan Region in the State of Maharashtra, is part of an urban agglomeration comprising of Pune, Pimpri-Chinchwad, and Sangavi as well as Nigdi which is under the civic body. As of 2019, its population was estimated at 2.2 million.

Pune City previously launched a pilot BRT in 2006 which was beset with many problems, which some critics blame on it not following established BRT standards. The actual situation maybe that the BRT standard itself is irrelevant in an "AI Age". This haunted the Pimpri-Chinchwad BRT especially during the implementation phase.

Pimpri-Chinchwad BRT



Pimpri-Chinchwad city implemented a network of four BRT corridors, with the SUTP financing Corridors 3 and 4 – both greenfield corridors totaling 19km that connect the two parts of the city divided by a river, railway line, and major highway, creating a grid network. The system was branded as Rainbow BRT with a new image, incorporating successful elements and learnings from the pilot project and best practice.

The system operation was assigned to Pune Mahanagar Parivahan Mahamandal Limited (PMPML), a State Transport Undertaking (STU) being the traditional bus operator in the city. At project completion, daily ridership on Corridor 2 was 80,000 and Corridor 3 17,000/day. Corridor 4 has since been operationalized. Of the passengers using BRT, 28 percent had switched modes from motorcycles, autorickshaws, walking, cycling, and cars. The overall public transport mode share for the city more than doubled, exceeding targets. Soon after its launch, the dedicated bus lanes enabled commuters to reach their destinations 10 to 15 minutes earlier than usual.

Rainbow BRT is yet to achieve its full potential. The branding itself may require rework. Ridership only increased by 12-17 percent over the three years while the number of personal motor vehicles on the road continues to grow unabated due to limitations of bus availability and resultant lower frequency of services. The ongoing Metro construction along Corridor 1, the most heavily trafficked corridor, has prevented the full operationalization of BRT services on that corridor.

Case Analysis: Government Funding limitations

India has traditionally under-invested in public transport. As of 2007, of 80 cities with a population size exceeding half a million, only 20 had organized public transport; and a large majority of bus operators had inadequate resources and technical know-how. In particular, medium-sized cities lack technical capacity and resources and have lagged in developing institutional capacity, as urban transport falls under the state government's purview and local government is the weakest tier.

The template developed by the national and state-level institutions responsible for public transport has strengthened the commitment, efficiency and capacity for project implementation to improve mobility in medium-sized cities.

At the multicity program level, the combination of capacity-building and demonstration projects focused on technical assistance as a first intervention, building the capacity for the cities to develop their own sustainable urban transport initiatives, instead of an infrastructure-led approach where capacity building needs to 'catch up' or be expected to develop in parallel.

In the absence of consistent operational subsidy support to the BRT, sustaining the quality and level of service is an ever-present challenge. Since independence, subsidy was a consistent part the transport funding arrangement in India until 1988, when the Govt of India modified its policies, withdrawing financial support, with the states largely following suit. This resulted in a low fare revenue base that was insufficient to cover the operational costs. Identifying and designating non-revenue and subsidy sources is key to meeting operational deficits and sustaining the BRT operations and infrastructure renewal. It is important that the cities pursuing BRT earmark such revenue sources so that quality BRT infrastructure and service can continue to be maintained.

In Hubli-Dharwad, the state (Government of Karnataka) established the Hubli – Dharwad BRTS Company Ltd (HDBRTS Co) as a Special Purpose Vehicle (SPV) to coordinate the planning and delivery of BRT, conduct its operations, and be the owner of the assets. This was a key factor in the success of the BRT. Apart from the Government of Karnataka, shares in the company are held by the Hubli–Dharwad Municipal Corporation (HDMC), Hubli–Dharwad Urban Development Authority (HDUDA) and North Western Karnataka Road Transport Corporation (NWKRTC). The NWKRTC is the state-run bus service company in Karnataka and it has blended BRT operations into its city bus service and an inter-city service.

In Pimpri-Chinchwad, a lack of clarity exists in the definition of roles. The Pimpri-Chinchwad Municipal Corporation (PCMC) developed the BRT infrastructure, but Pune Municipal Corporation failed to develop sections of Corridor 1 and 2 which fell within

their geographical limits. However, at the end of the project, based on the success of the BRT in Pimpri-Chinchwad, Pune had revived the proposal for extending the BRT.

The Pune Mahanagar Parivahan Mahamandal Limited (PMPML), a State Transport Undertaking (STU), is the public transport bus service provider for the twin cities of Pune and Pimpri-Chinchwad. It operates the Rainbow BRT routes and more than 300 local routes within a radius of 20 km around the two cities including the local service connecting with the BRT corridors. However, in the absence of a dedicated entity (such as the HDBRTS Co in Hubli-Dharwad) *neither the municipality nor the bus company fully owns the project*.

In Naya Raipur, the Naya Raipur Development Authority (NRDA), responsible for the management and urban governance of Naya Raipur, led the BRT development. The Naya Raipur Mass Transport Ltd (NRMTL), an SPV company, operates the BRT. However, the SPV suffers from limited staffing and financial constraints.

Stakeholder communication and coordination was essential yet time consuming, in finalizing designs, completing implementation, and finalizing operating arrangements across cities. The agreements with regard to the rolling stock designs between the twin cities, Pune and Pimpri-Chinchwad took time, and similar delays were encountered for ITS. In Hubli-Dharwad, HDBRTS Co had to coordinate continuously with NWKRTC, the public transport operator, first on the designs and later on the operations plan and operating arrangements.

Section 2.3: Conventional Approach to a BRT Network

A BRT project of the nature proposed requires coordination and management of vast and disparate aspects, a dedicated lead agency (the proposed PPP company) needs to be assigned the authority to prepare, implement and operate the system, taking the project forward while continuously coordinating with fragmented stakeholders, including the Traffic Police for lane enforcement and managing driver behavior. Land acquisition and taking away road space for BRT and managing contestations over street space are important issues for timely implementation of the project.

The project planning and schedule needs to be very thorough. The scale and innovation of the project requires a much stronger preparation for land allotment, project designs including alternatives analysis and stakeholder consultations, operations planning and financial analysis etc. and more time to cope with the unforeseen risks and allow time for the cities to 'gear up'.

An Artist's Rendering of BRT-Lite Corridor (before and after)

The system performance is reported in the public domain for Indian BRTs is:

- Carrying over 400 million passengers in the last five years;
- Average daily ridership is 180,000 passengers;
- Average load factor of 800 passengers carried per bus daily;
- Average daily trip per bus per day is 5;
- Average waiting time is 15 minutes;
- Average speed is 30km/h.

The Range of BRT Infrastructure

	Stations	Running Ways	Service Plan	Vehicles	Systems
Rapid Bus, "BRT Lite"	"Super" stops with shelters	Some dedicated lanes, Mixed Traffic, Queue Jumpers	Trunk/ Feeder: All- Stops Trunk Line	Buses with Unique Route Numbers, Head signs, livery	Next bus information at stations, IC/phone fare collection
High, Quality, Capacity (e.g., Bogota)	High Platforms, P/R, Amenities, Services	Fully dedicated running way, partially grade-separated	Combo.: All-Stops; On- Line Expresses; Integrated Feeder/ Trunk	Hybrid electric; Guided; Specialized Vehicles	Central Control Room, TSP, CAD, Off-board/ efficient fare collection

BRT Capacity

BRT carrying capacity is usually measured as passengers per hour per direction (phpd) throughput at *a single point (screen line),* however the single-point capacity does not represent the practical carrying capacity of the whole corridor in day-to-day operations.

Typically, the practical carrying capacity of a BRT corridor will max out at around 10,000 passengers phpd, limited by choke points in the system such as bus berths at stations and intersections. Systems with a corridor capacity exceeding 10,000 passengers phpd would demand a very different infrastructure level, which many cities will not be able to achieve. Hidalgo et al. (2012) stated that: "these high capacity systems also require a much scaled up infrastructure, such as large passenger hubs/stations, overtaking lanes, level boarding, prepayment, large buses with multiple doors, express and local services, and traffic engineering measures at intersections, allowing for very large passenger throughput thus being able to reach an actual throughput of 43,000 passengers per hour per direction with average bus occupancy of 150 passengers per articulated bus, and a commercial speed of 22–24 km/h.

In contrast, Goa is currently at a need level of 40,000 phpd across all the corridors in the tourist circuit. This is likely to go up by 20x by 2028-29. This is a very large number compared to all other BRT operations set up in emerging markets by MDBs like the World Bank.

FTransMilenio (rush hour)

Source: BRT Centre of Excellence

TransMilenio (rush hour)

Source: Roberto Vargas, El Tiempo.com

Capacity Considerations: BRT vs. Metro

At a level of 10,000 (or even 15,000) passengers phpd for a corridor, Metro rail would not be financially viable, demonstrating BRT's effective niche in the mass transit market. On this basis, BRT and Metro cannot be accurately described as 'competition' or as an 'either/or' proposition. It shows BRT as being ideally placed to build up corridor demand in the medium term to support LRT/ MRT investment in the long term, mindful that BRT and LRT/Metro can complement each other in an integrated public transport network.

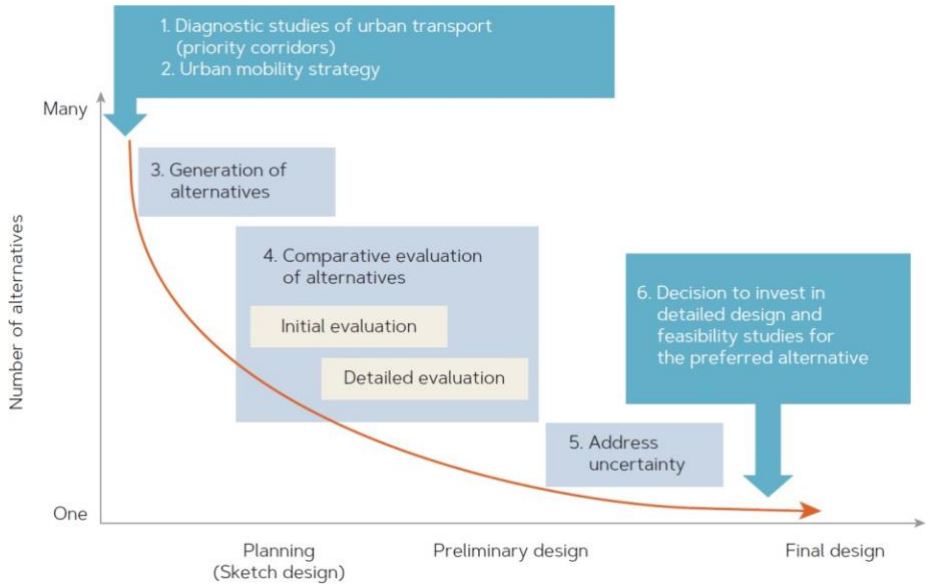
Research has suggested that a switching point exists in developing countries where BRT may have competitive OPEX costs for moving up to 25,000 passengers phpd and Metro may have comparative advantages above that value. The switching value may be lower for developed countries due to labor and other costs. However, this is a financial reckoning and may not be reflective of practical and other realities.

Rapid transit projects may be among the largest transport investments ever made in a city or metropolitan region and represents large and essentially irreversible outlays of investment capital on long-term assets in complex, interconnected, and uncertain urban systems. It is therefore critical to evaluate and compare the potential benefits and costs of alternative investments when planning the transportation system (network) and its corridors.

What is apparent, is that the choice should not be technology-driven, (rail or bus) but be 'needs driven'. Serious alternatives analysis is required which considers corridor characteristics (section width, urban form), passenger demand, integration and connectivity, and funding and financing capacity. For a new BRT, planners should consider the practical limit to the BRT capacity threshold at which it can maintain an acceptable or appropriate quality of service.

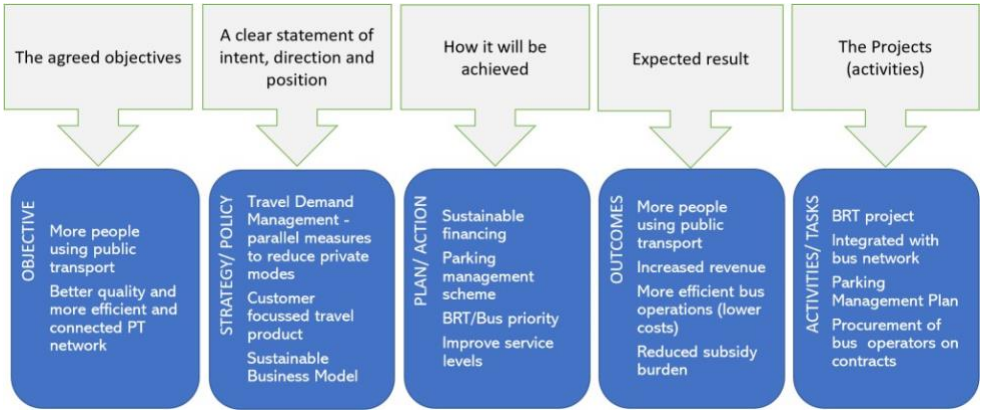
The Urban Rail Development Handbook (2018: Ch 3) describes the planning sequence and alternatives analysis for a Rapid Transit system. The logical six-step sequence, shown in Figure below is intended to help direct decision makers to develop their projects in a transparent and objective way, while still providing flexibility to tailor the process to local conditions.

Six-Step Sequence for the Rapid Transit Alternative Analysis



Source: The Urban Rail Development Handbook, World Bank, 2018

Example of a Public Transport Strategic Policy Framework



The above analysis can be used to configure the virtual metro on the same lines as A real metro service.

Establishing a PPP company

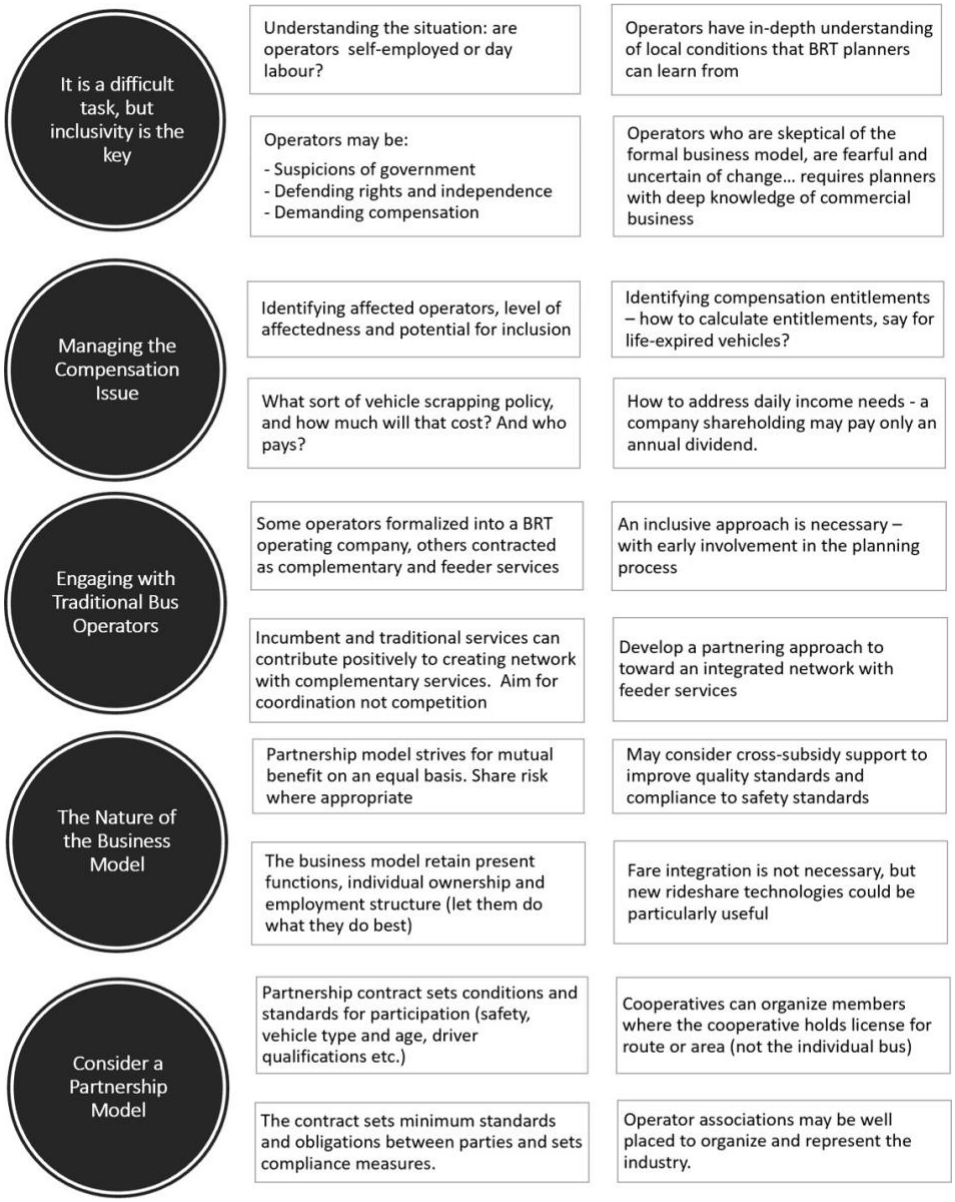
Cities typically employ a range of institutions to manage transport and traffic; however, their roles and functions are often fragmented and uncoordinated, both in budgets and operations. The model being proposed for Goa involves the following key attributes:

- KTC would continue operations and grow the same in keeping with the State's objectives of providing affordable subsidized services. The ageing fleet of KTC would be replaced by a modern fleet of eBuses leased on a per kilometre basis. The cost of the same would be similar to the cost of maintenance/fuel currently borne by KTC
- A newly established PPP company would acquire the land in Provorim to build a state of the art transport hub with multilevel parking, pantography chargers,

boarding gates and public amenities similar to an airport terminal with aerobridges. This hub would be complemented by a smaller multimodal hub in South Goa near Concona. These transport hubs would eventually be self-sustaining on an operating cost basis.

- The rolling stock would be acquired by a leasing company which would provide the same to KTC, private operators, hotels and the PPP company on a per kilometer basis – inclusive of interest, fuel, charging, maintenance, facilities management, servicing, battery replacement and depreciation.

Pointers for Engaging with Traditional Bus Operators



Financial Sustainability for BRT

Providing public transport services that are financially sustainable, at a level of fares that is affordable, is a struggle for most cities, having to balance financial sustainability with both transport affordability and wider social objectives. This typically involves managing and fine-tuning fare and subsidy policy and working to optimize operational efficiency. For political reasons, governments might be inclined to restrain fare increases and, in such cases, this will necessitate financial analysis at the backend, to ensure that any widening of the farebox ratio gap is covered by stable sources of funding. Recent cases where governments needed to secure funding for political or social initiatives are Bogotá (2013); London's hopper fare (2016), and cities opting for free transit pilots (Washington DC Circulator; Kansas City).

The expectation in early BRT projects of full OPEX recovery through the farebox proved unsustainable and was perhaps a 'too-narrow' focus. It was also implausible to expect that public transport users would pay 'fully-priced' fares (covering fare collection, fleet or even infrastructure costs) while many private vehicle users pay little if any cost for the infrastructure used for their private trips.

TransMilenio's early experience with a limited network and high efficiency allowed for farebox revenues to cover its OPEX costs[171]. Thus, when Colombia expanded BRT projects to medium-sized cities under the NUTP program, operational subsidies were not considered. The implicit (wrong) assumption was that eliminating the inefficiencies of traditional systems (over-supply of services and a redundant network route design) would fund the additional costs of the new BRT systems including the added costs of a higher standard of fleet maintenance, management and regulatory compliance (Gomez-Lobo 2019:7).

Whether this was possible or not is a moot point, as lower than expected ridership in these medium-sized cities (and also the case in India), together with the inelasticity of fares, caused financial problems to surface. Hence, for the above reasons, including the expansion to more complex networks and aspirations of city-wide coverage (in the case of Bogotá), it is apparent that fare and ridership increases cannot always absorb all the costs. When costs rise, and fares are inelastic (and possibly ridership is below expectations) the funding shortfall will need to be covered by additional non-farebox funding; otherwise operating costs will need to be reduced– sending the system into a negative spiral of service reduction (Gilbert 2008:456)

Achieving Financial Sustainability

Taking a 'business approach' in the field of public transport management, is not commonly adopted or elaborated as it is commonly thought that public transport requires subsidy. We expand the discussion to a wider appreciation of a 'business-like' (commercial) principles of management which can help to achieve financial performance. But 'commercial' does not mean 'no subsidy' – funding a subsidy can also be a commercial decision if it compensates for government price (fare) control or to fund non-commercial social service obligations.

A too-narrow focus on cost recovery through fares does not factor in the important role of subsidy and its value towards broad societal benefits of BRT. While subsidy is often

branded as inefficient and loss-compensating (which may be true in some cases), a subsidy compensating for low fares is actually a 'user-subsidy'.

Subsidy can also be viewed as a government pricing intervention which serves as an investment into good mobility outcomes and its resultant economic benefits. Van Goeverden et al. (2006)[174] lists four typical subsidy scenarios as:

1. Subsidies motivated by the 'social function' of public transport to support vulnerable groups to avoid problems of social exclusion.
2. Subsidies used as a 'second-best' instrument to address car related problems such as; noise, pollution, parking externalities and congestion, where direct action options are limited ('first-best' would be direct pricing to generate mode shift).
3. Marginal cost pricing (being welfare optimizing) leading to deficits that need to be subsidized (because public transport is characterized by economies of scale, where marginal costs are below average costs).
4. Promoting the positive externalities in public transport.

However, while non-farebox revenue/or public subsidy is usually necessary, it does not imply such funding should automatically be compensating for financial losses. The use of subsidy funding must be a commercial decision based on well-grounded financial and economic analysis, structured in a way that avoids fostering subsidy dependency which reduces management focus on customer satisfaction, ridership, revenue growth and operating efficiencies.

From a business management perspective, financial sustainability requires establishing the 'business case' with management taking a business-like approach to developing the market, building ridership and revenues and efficiently managing costs.

Lower than expected ridership has been a challenge in most BRT systems where demand forecasts have not been realized (particularly at initial stages), causing financial hardship. This has placed financial pressure on operators who either carry the financial risk (LAC cases) or demand government subsidy (India cases).

On the revenue side, *'willingness-to-pay' and affordability* are key considerations as well as reaching ridership targets. While often appearing synonymous, willingness to pay is more related to a customer's perception of value, requiring fares to be reflective of market sensitivity. Affordability on the other hand, is generally measured by the percentage of the minimum wage assigned to travel costs for certain low-income groups. Affordability considerations may also be driven by political imperatives such as a defined benchmark on cost recovery (farebox ratio) which may be a performance indicator for the system.

On the cost side, the agency needs to actively work to achieve operating efficiencies to reduce wasted kilometers or inefficient services. Unit costs also need to be defined; according to a methodology that recognizes structure of labor and inputs and is adjusted according to recognized price indices.

Ridership Forecasts

Passenger transport planning relies heavily on demand forecasts; however, the inherent weakness of travel demand forecasting could lead to flawed projections, caused by travel demand (TD) models being too-aggregated in nature to predict location-specific routes and boarding and alighting at stations. They also lack the ability to predict behavioral or social nuances in how passengers make journey decisions. Optimism bias and insufficient assessment of risk can also play a part in influencing demand forecasts.

A better approach is to plan BRT with a practical 'ridership target' using the TD forecast as one of the reference points. The city can set annual targets (e.g. modal shift, ridership) for the initial operating years, and apply strategies to develop the market and build ridership. BRT performance in three medium-sized cities in India was primarily measured through mode shift.

In most cases, passenger demand at launch is usually well below the anticipated capacity that the system could expect to reach in the medium term. Planning should therefore take into account two discrete projections, being 1) ridership projections at launch toensure sufficient fleet is provided, and 2) medium to long term ridership, to ensure the system has sufficient capacity by way of infrastructure for the future. Fundamental in the planning are the strategies and marketing to grow ridership which could include:

- Marketing and communication to identify the target market, understand varying travel needs, and to inform the design of the travel product. This requires key 'messaging' to impact customer's decisions at 'journey level'. It is good practice to interact with user groups to explore market characteristics and needs, test design decisions, and seek feedback on operations.
- Operations planning and optimization to deliver the right travel product. Barranquilla and Cartagena developed better service integration using pre-trunk services to increase ridership significantly. Lima Integrated fares across trunk and feeder services.
- Adopt an intelligent fare policy and technology applications such as ticketing and payment systems and passenger travel information that are user-friendly. In some instances, sub-optimal fare policies can deter passengers from the system or resulted in fare leakage. Using locally suitable ticketing payment systems, allowing for a single ticketing medium to transfer between BRT and other public transport modes, and offering discounts on transfers are some of the strategies employed.

The BRT business case refers to the financial sustainability of the business. As in any public transport business, satisfying the following three factors will support the business case, *but unit costs (per km cost) remain a 'wild card'* as discussed below[175]:

1. Operating efficiency of the buses – based on work practices, commercial speeds' (usually assured on a priority busway)
2. Bus Occupancy (traditionally bus operations aim for 80 percent)
3. A reasonable bus fare level (usually modelling starts with existing fares)

While traditional bus services generally have some leverage to adjust services to maintain adequate occupancy levels and optimize fleet efficiency, BRT faces a different challenge, namely, that to justify exclusive use of a busway lane, *it needs to provide a*

substantial service frequency to attract passengers; build market share and produce travel mode shift. The BRT in Bucaramanga Colombia lost political support because bus lanes were seen as mostly running empty.

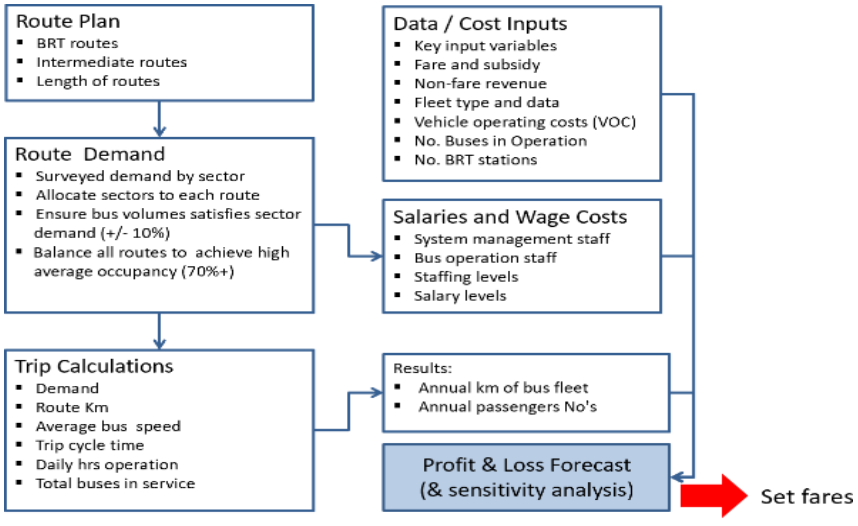
Supplementary funding will be required to provide an adequate level of service to attract passengers while initial ridership is low. Hanoi took such an approach, in that ridership was basically unknown prior to launch, so financial estimates were made based on various occupancy scenarios to forecast the amount of subsidy required during the period of initial operations. This allowed the calculation for the financial support necessary while BRT builds up ridership, and at the same time avoiding the risk of a public backlash if BRT was perceived as under-utilizing the bus lane.

However, it is incumbent on management not simply to be reliant on subsidy; it must take a business-like approach to building ridership and revenues, manage fares as a pricing mechanism to influence travel behavior - and improve the system performance and efficiency to manage costs.

In such a 'business management' role, the BRT agency is more of a manager than a regulator. A 'regulator' does not take risk, instead it manages the 'risk-takers'; whereas a manager carries and manages some risks which also gives it greater control (by having 'skin in the game')[178]. A good example is TransMilenio S.A. proactively managing demand, revenues and costs, which is arguably a key reason for its success.

As stated above, the 'wild card' may be the legitimacy of the per-km unit cost of bus operation. In the case of a city lacking organized public transport and transparent data on organized bus operations, obtaining the 'right price' through competitive tendering may be difficult. The operator (an incumbent or a new player) may exploit a knowledge /information advantage, and/or build in a risk premium to cover uncertainties, and/or gain price advantage by exploiting entry barriers that reduce competition. Critical evaluation of Vehicle Operating Costs (VOC) and developing an OPEX model would help inform the city and help mitigate risks. Figure below shows the components of an operational model which can forecast system profit or loss. It is not a 'crystal ball'; but a tool used to test data inputs for critical elements of the system.

Input and Output of An Operations Cost (OPEX) Model



Section 2.4: Proposed Approach to the Goa Transportation Hub

The approach proposed for the Goa Transportation Hub is consistent with the principles articulated in the earlier section on the conventional approach in the long term. However, in the interests of time and efficacy, it is proposed to adopt an alternate approach for the first ten years starting on 15.8.24. The three key aspects of the proposed approach are:

- To set up a parallel overlay which does not any way interfere with the operations of KTC other than to replace its ageing fossil fuel fleet of buses with contemporary eBuses at a lease cost which is comparable to the cost likely to be incurred on regular diesel buses.
- To invest in the creation of a 100,000 sqm multi-level transport hub in Porvorim, to act as the main passenger terminal with airport type passenger amenities that acts as the parking bay, charging area and trans-shipment point for a range of bus operators including KTC, private operators, hotel buses etc. This hub would be owned by a PPP company which would acquire the land at circle rate from the entity currently owning the land.
- To provide equity/margin money for a leasing company which would own a fleet of ebuses to be leased to users such as KTC on an indicative flat rate of Rs 1 per seat per km. This price we believe would be an adequate incentive for users of fossil fuel buses to change to ebuses. For KTC, it would provide one more avenue to add buses to its fleet in addition to other government subsidy schemes.

The macro modelling approach for the project finance module is to provide a one time viability gap grant such that the project is self-sustaining thereafter. As and when the PPP company becomes viable, it should be planned to make the company an independent company listed on a stock market. If for some reason, the entity does not become viable, the IIT Alumni group would not be liable to bear any losses or provide additional funding over and above the amount initially provided. In any event, the PPP company should plan to transfer physical assets of the transport hub to a Real Estate Investment Trust – so as to use the funds realised therefrom to enhance the funding for the transportation operations – without having to call for fresh contributions from the promoting entities of the PPP company.

The PPP company needs to be structured like any limited liability commercial operations with the following clauses in the articles of association:

- None of the shareholders will draw dividends or sell their shares till the company is viable and listed on a stock exchange.
- The Board of Directors of the company will comprise of five independent directors and one nominee each from the state government and the IIT Alumni Council. The nominee of the state government will act as the Chairman of the Board.
- The independent directors will be IIT Alumni who are Indian Nationals and designated Fellowship awardees of the IIT Alumni Councils. They will retire after holding office for three years and would be eligible for re-appointment after a break of one year.
- The CXOs of the company would be suitable professionals hired at market salaries.

- The captable of the company will be structured in such a way that the company will not be a public sector undertaking.
- The company will be audited by a Big4 auditor.

The leasing company will be structured like any leasing company which will acquire the rolling stock against cash or on deferred payment or against debt. The rolling stock will be provided to KTC on an indicative lease of Rs 1 per km per passenger. The company will be free to price the rolling stock to non-KTC customers as per market conditions. The leasing company will be free to place its equity with any investor or to access the stock markets. Initially 100% of the equity will be owned by the PPP company and the IIT Alumni fund in a 49:51 ratio.

The target date to set up the PPP company is 15.8.24.

Section 3.1: AI Based Transportation Design- Research Abstract

Public transportation consists mostly of fixed transit systems, which have fixed stations, routes, and schedules. In this paper, a new approach for bus routing in public transportation is proposed, in which buses are traveling unbounded, adapting to passengers (not vice versa) by picking them up at their current location and transferring them to their destinations. Bus routes need to be adjusted to the passenger layout. This problem is close to the Dial-a-Ride Problem (DARP), but the solution is searched on real road-network graphs. The goal is to find a globally optimal set of paths for a given number of buses, such that all passengers are transferred to their destinations while the average travel time is minimal. In this paper, a modified Max-Min Ant System (MMAS) algorithm is utilized.

Intelligent transportation system (ITS) focuses on many issues relating to the subject of developing ground transporta- tion. Urban buses have a key role in the transit system offering scheduled routes throughout the city. By running on public roads, it has the advantage of connecting any part of a city without the need for heavy infrastructure over other means of public transportation. Organizing efficient bus routes with stops and schedules is a hard task, as bus enterprises need to consider passenger travel demands and economic benefits at the same time. With fixed stations and schedules, passengers need to accommodate the transport system which is often inconvenient for people, since transferring to one or more other means of transport may be necessary during the journey and that involves increased waiting (and travel) time. In addition, as far as elderly people and people with reduced physical capabilities are concerned, arriving at the stations - especially in suburban areas, where they are sparsely arranged - and transferring might be difficult.

An alternative approach to bus routing could be the use of flexible bus routes, which fits well into the world of smart city concept. One can picture a mobile application in which passengers can indicate their positions and destinations on the road-network. The buses have to adapt to the passenger-layout, satisfying several constraints. To the extent of our knowledge, this is the first work submitting the problem, therefore we call this the Flexible Urban Bus Routing Problem (FUBRP). Surveying the literature one can observe, that most studies focus on particular problem variants and derive domain-specific solutions, that can not be addressed to a broader set of problems. In the following subsection, the closest problem to the FUBRP found in the literature is reviewed and the differences are outlined.

Vehicle Routing Problem (VRP) is a generalization of the Travelling Salesman Problem (TSP), where the goal is to find an optimal set of routes for vehicles in order to deliver goods for customers from one or more depots. The classic VRP, also known as capacitated VRP (CVRP) considers only one depot, where the vehicles are settled and assumes several customers with known demands. Attaching constraints to VRP establishes variants, that provide the opportunity to further adjust the model for real-life appliances. A vast study on VRP and its variants can be found in [1]. A special variant of the VRP is Pickup and Delivery VRP (PDVRP) or more generally Pickup and Delivery Problem (PDP), where vehicles serve transportation requests. In one-to-one PDP vehicles must transfer commodities or people between location pairs of origins and destinations [2]. When PDP is applied for the transportation of people instead of commodities, that is referred to as DARP. In DARP, the human perspective is prioritized and that makes it different from other types of VRP, due to the fact, that human

satisfaction - or dissatisfaction - is not a mathematically exact phenomenon. There are single and multi-vehicle variants of the DARP. Multi-depot DARP allows multiple depots for vehicles to begin their routes, this way the multi-vehicle multi-depot DARP is considered as the most relevant routing problem to the FUBRP. With respect to comparison, its main features are listed:

(i) The problem is represented by a complete graph.
(ii) Each vehicle starts at its designated depot.
(iii) Each vehicle terminates at one of the many depots.
(iv) Each customer is served by only one vehicle.
(v) The pickup and delivery request of a customer is served by the same vehicle.
(vi) The pickup request of a customer must be served before the delivery.
(vii) The solution is a set of paths, where all vertices (except for depots) are visited exactly once.
(viii) The goal is to minimize the set of paths, concerning customer dissatisfaction.

Section 3.2: Neural Network Design- Research Abstract

Accurate short-term forecasting of public transport demand is essential for the operation of on- demand public transport. Knowing where and when future demands for travel are expected al- lows operators to adjust timetables quickly, which helps improve service quality and reliability and attract more passengers to public transport. This study addresses this need by developing AI- based deep learning models for prediction of bus passenger demands based on actual patronage data obtained from the smart-card ticketing system in Melbourne. The models, which consider the temporal characteristics of travel demand for some of the heaviest bus routes in Melbourne, were developed using real-world data from 18 bus routes and 1,781 bus stops. LSTM and BiLSTM deep learning models were evaluated and compared with five conventional deep learning models using the same data set. A desktop comparison was also undertaken against a number of established demand forecasting models that have been reported in the literature over the past decade. The comparative evaluation results showed that BiLSTM models outperformed other models tested and was able to predict passenger demands with over 90% accuracy.

A well-developed urban public transport system, especially bus transport, can reduce congestion and emissions and decrease the use of private vehicles (Li, Cao, et al., 2020). On-demand public transport, in particular, is seen to have the potential to improve operations further and enhance customer satisfaction. However, this type of service requires that short-term forecasts of future demands for bus services are known in advance (Liang et al., 2019; Liyanage & Dia, 2020; Liyanage et al., 2019; Smith et al., 2002; Zhou et al., 2013). Accurate prediction of future demands also helps operators to pre-allocate constrained resources such as vehicles and drivers to meet passenger demands and provide quality and reliable services with minimum waiting times. It also allows operators to optimize bus fleet management to minimise operational costs (Ma et al., 2014; Tirachini et al., 2013). Demand prediction is an integral part of business and commerce operations and helps decision makers to reduce the uncertainties of future operations. In public transport operations, the passenger service business models are highly dependent on accurate estimation of future passenger demands. Starting from route design and network planning, through to scheduling of vehicles with optimised seating capacity to meet operators' and users' objectives, and pricing each passenger vehicle on a network route, service operations in every planning horizon is dependent in one way or another on accurate estimation of future demands (Banerjee et al., 2020; Lu et al., 2021).

The focus of this paper is directly aligned with current advancements in digitalisation of urban mobility planning tasks. This is manifested through the paper's focus on development and evaluation of advanced passenger demand forecasting models which are important pillars in the planning and delivery of efficient and customer-focused on-demand public transport systems. First, the paper presents developments in app-based on-demand public transport services that are supported by technologies and advancements in IoT, Big Data and Real-Time Analytics. The paper then outlines how the success of these emerging modes of on-demand public transport, currently being run in trials in a number of cities around the world (including Sydney), relies heavily on accurate estimations of travel demand and passenger numbers over short durations up to 1 h. The paper then presents development and evaluation of advanced methodologies for passenger demand forecasting based on AI and deep learning theories that can be used for estimating future passenger demands. Another novel aspect of this work directly aligned to digitalisation of urban infrastructure is the use of smart card based field passenger demand data for model development. Unlike a large number of studies on this topic that used simulated data, this paper uses real-world field data obtained from IoT-enabled MyKi fare collection smart cards used for public transport in Melbourne.

Long-term public transport demand forecasting methodologies, including the well-established four-step models, elasticity and economic models, long-range demand models, mainly focus on planning issues and are not suited for operational forecasts (Balcombe, 2004; Ma et al., 2014). The research on short-term passenger demand forecasts

for operational purposes is far more limited. Unlike the planning models, short-term passenger demand prediction models are used to account for short-term dynamic changes in demand due to weather conditions, traffic congestion, and special events. These models have gained widespread attention from transport planners and researchers in recent years due to their important operational role (Dia et al., 2001; Noekel, 2016; Zhai et al., 2018), making them a prerequisite for proactive operations and management of bus transport services (Ceder et al., 2013; Xue et al., 2015).

Demand prediction methodologies are based on understanding the temporal and spatial relationship between different variables in historical data. The primary objective is to obtain accurate and realistic forecasting of future demands (Zhai et al., 2020). Parametric and non-parametric methods are generally the two main solution techniques for short-term demand prediction techniques (Wei & Chen, 2012; Wu, Jiang, et al., 2020). In parametric approaches (also known as linear models or statistic approaches), the Box-Jenkins methodology is the most widely used model (Box et al., 2015). This model applies ARIMA or ARMA, AR, decision tree models to identify trends (Anvari et al., 2016; Cyril et al., 2018; Gan et al., 2014; Gong et al., 2014; Milenkovi'c et al., 2018; Wu, Xia, & Jin, 2020). However, these models are limited in scope because they are developed based on linear assumptions among time-lagged variables (Bai et al., 2017). Examples where these linear approaches were applied include two studies by (Ma et al., 2014) and (Xue et al., 2015) where the authors proposed Interactive Multiple Models that combine different algorithms to forecast passenger demands during different times of the day. In the first study (Ma et al., 2014), applied AR, SARIMA and ARIMA for weekly, daily, and hourly time-series analyses, respectively. In the second study (Xue et al., 2015), applied ARMA SARIMA and ARIMA models for weekly, daily and hourly time-series analyses, respectively. However, the linear models depend on high-quality data comprising accurate and non-fluctuating patterns to develop a time-series sequence. However, real-world passenger demand data are random and unstable, which renders linear approaches incapable of describing the variations in passenger flows. Hence, other methodologies have been presented in the literature to track such non-linear characteristics.

The second category, non-linear or non-parametric approaches, constructs non-linear relationships between input and output var- iables (Wu, Li, et al., 2020). There are also hybrid approaches that combine multiple algorithms strategically. Non-parametric models include support vector machine (SVM) (Chen et al., 2015; Jiang et al., 2014; Yang & Liu, 2016), least-squares SVM (Guo et al., 2013; Sun et al., 2015; Zhang et al., 2011), Fuzzy neural networks (Buckley & Hayashi, 1994; Dou et al., 2013; Tsai et al., 2009), Bayesian networks (Roos et al., 2017; Sun et al., 2006), grey models (Hai-lan & En-chong, 2012; Wang & Zhang, 2012; Yang et al., 2013; Zhang et al., 2017) and neural networks (Chen et al., 2012; Pekel & Soner Kara, 2017; Zhang et al., 2013). Among these, Artificial Intelligence (AI) ap- proaches, based on deep learning neural network methodologies, have been identified as most promising and practical for complex time series forecasts (Lee et al., 2006) and have been shown to provide improved predictive capability (Vlahogianni & Karlaftis, 2011).

Section 4: Ayushca Community Projects – Guiding Principles

The guiding principles for the community and CSR projects in all Ayushca campuses have been drafted by Dr Ashok Khosla of Development Alternatives and have been reproduced here from his writings.

“

Our lives are no longer what they used to be. Overwhelmed by massive poverty and hunger, financial meltdowns, climate change, species extinction, unknown diseases, terrorism and other new problems that emerge over the horizon with ever greater frequency, our social systems seem often to be paralyzed. So rapid are the changes in today’s world that conventional forms of communication – let alone of thinking – are no longer adequate for us to capture the information we need as quickly as we need it. By the time we can react, the condition we wish to redress may already have changed to something else. By then what we do is often inappropriate, sometimes even counterproductive.

It need not be thus. According to the great traditions of human civilisation, the purpose of life is to live in harmony with each other and with the rest of creation -- humanity and nature supporting each other in ever growing circles of health, wellbeing and mutual fulfilment. To reorient our economies and polities towards such a purpose will require quite basic changes in our societies. This will need new mindsets. And this in turn will require fundamental transformation in each one of us.

The purpose of the Alliance for a New Humanity is to bring back the wisdom of the ages into our lives, and to bring about a world in which every human being, and indeed every living creature can complete a healthy and full life. The purpose of this new Webpage is to enable the members of the Alliance to gather together their individual energies and focus their collective will on what now needs to be done to create a better world for all.

What hope is there for this planet if the countries of the global South start to consume resources as the global North does today? Or if the vast numbers of poor in our world demand the same things the rich few already have? They are not only entitled to do so under any concept of fairness and justice, but are also being encouraged to by the forces of the global market. What will be the demographic, economic and environmental impact in the longer term if poverty and marginalisation in the economy of our world further delays the stabilisation of its population?

The goals of creating a better world for all clearly cannot be reached with today's urban-industrial lifestyles or with existing material-financial aspirations. Nor with the disparities that we have created within and between countries. Sustainable development implies not only efficient and ecologically sound management of resources, but also the need to establish social equity and political empowerment.

Among the perennial questions of northern consumption patterns and southern population growth, the central issues are, of course, *sufficiency and efficiency*. How much is enough, and how little do we have to use to get it? This means that

development goals also require us to reorient the way we produce the goods and services that we consume. The sustainability equation inexorably brings together sufficiency of consumption and efficiency of production. And this means that those who are concerned with the future will necessarily have to work more closely with those who live for the here and now.

The central aims of our lives have to be physical and material wellbeing accompanied by intellectual and spiritual fulfilment. The central goals of our social and political systems have to be to empower us to achieve these aims. The central objectives of our production systems have to be not only the generation of goods and services, but equally the creation of jobs and the efficient use of natural resources. For the poorer half of the world's people, this translates into satisfaction of basic needs, income (and purchasing power), and maintaining the productivity of the resource base. We now need to relearn and show how all these factors can be operationally linked together to get a better strategy for sustainable development.

Today's industrial methods are no good. They involve too much capital. They waste too many resources. They cause too much pollution. And they disrupt too many life support systems -- the material flows generated today by mankind are estimated to be already comparable to geological flows. Large-scale industry causes large-scale disruption, both ecologically and socially.

We need new technologies and also a new science of economics. We need to create work places - jobs - at one hundredth the cost of the ones we are creating today in our globalized economy. And we need to increase the productivity of material resource use by at least 10 times what it is today. Sustainable industrialisation will unquestionably have to be more decentralised, efficient and responsive than it is today. And it must be based on a better understanding of resource pricing, environmental accounting, scales of production, financing systems and the many other factors that are in need of fundamental change.

Today the environmental movement is at the forefront of the fight to redesign our consumption patterns and production systems. But that is not enough. It is those who are sensitive to the impacts of our lifestyles on our humanity who must ultimately take the lead. The job of ANH is to bring such insights – from traditional, indigenous wisdom to modern, science-base humanism – into the equation.

Adapting to Climate Change

Despite growing scientific evidence that our present patterns of consumption and production are leading to massive disruption of the planet's life support systems, particularly of our climate and our living resources, governments continue to hide their respective heads in the sand. International treaties have been negotiated to slow down this headlong race to self-destruction, but the foot on the accelerator pedal is stronger than the one on the brake; the biggest polluters continue to be the biggest defaulters.

Given the long lag times between cause (emission of greenhouse gases) and effect (temperature rise), the global climate is in for change no matter how soon the economies of the world reduce their use of fossil fuels and cutting of forests. The remnants from 150 years of profligate energy and material use will see to that. Much of this change, which will in turn lead to changes in rainfall, sea levels, frequency of natural disasters and other unpleasant phenomena is widely considered to be unfavourable, if not outright harmful.

While it is imperative that our scientists, environmentalists and diplomats work day and night to rectify this state of affairs, and bring about global agreements and national

policies that will reduce the future causes of global change (i.e., to mitigate them), it is also now necessary to evolve ways to live with and respond to the changes that will inevitably take place because of our past and present practices (i.e., to adapt to them).

How do we redesign our industry, transportation and agriculture so as to make them less vulnerable to the climate changes that will take place? The name of this game is "resilience". Making human activities more resilient takes proactive thinking and advance planning. Industrial processes have to be made less dependent on resources that will be adversely impacted by the external changes. Agriculture, including the choice of crops and cropping patterns, has to be redesigned to be resistant to droughts, floods, pests. Transportation and power generation have to make greater use of renewables. In other words, we have to strive towards sustainable development.

It is perhaps not surprising that any good strategy for coping with change and disasters is not very different from that for preventing it in the first place. Adaptation, then, requires much the same types of action as does mitigation – because both depend on the adoption of sustainable development trajectories. The motivation may be different but the action required is often, and largely, similar.

This becomes all the more important in a world where both population and economic activity can be expected to grow for a long time to come – probably for as long as we continue to have the inequities that characterize the world today. As we hit against the limits set by nature's finite resources, we will find it more and more essential to save, reuse, recycle our resources and simplify our lives.

But this is not a popular insight, either among the affluent whose basic needs are already met or among the poor who do not see why they should be deprived of the things the affluent already have.

The convergence between mitigation and adaptation is, of course, possible only with the large scale introduction of sustainable livelihoods and sustainable lifestyles – methods of production and ways of living that are more in harmony than those of today with the imperatives of nature. This means that appropriate technology and the other solutions being pioneered by social enterprises such as Development Alternatives become all the more important, not only for local communities but also for the global economy.

Raising energy services to reduce carbon emissions

Eradicating energy poverty is essential to any effective strategy for stabilising climate change.

Most governments drive into the future with only the rearview mirror to guide them. Despite growing scientific evidence that our present patterns of consumption and production are leading to massive disruption of the planet's life support systems - particularly its climate and living resources – the momentum of our economies seems only to grow. International treaties have been negotiated to slow this headlong race to self-destruction, but the foot on the accelerator pedal continues to press harder than the one on the brake; the biggest polluters are still the biggest defaulters.

Given the long timelag between cause and effect - the emission of greenhouse gases and changes in atmospheric temperatures - the global climate will be modified no matter how soon the world's economies reduce their fossil fuel use and forest destruction. The legacy of some 150 years of profligate energy and material use will see to that. Much of this change - which will in turn lead to alterations in rainfall, sea levels, frequency of natural disasters and other unpleasant phenomena - is widely considered to be unfavourable, if not outright harmful.

Scientists, environmentalists and diplomats must, of course, work day and night to rectify this and bring about global agreements and national policies that will reduce the future causes of global climate change, But we must now also evolve ways that go beyond the simplistic knee jerk solutions currently being sought by those who have an interest in continuing the status quo.

It is a characteristic of complex societal or natural problems - especially those for which the effect follows long after the cause - that the solutions that actually produce the desired results are not necessarily the obvious ones. The most effective ones may even be sufficiently counter-intuitive to evoke considerable derision from the experts. So it is with climate change. Responses must be in tune with the time scales of the atmospheric processes that cause it - decades or even centuries.

Of course, we need action now for immediate results – both to satisfy the public that governments and corporations are indeed responding, and because every ton of carbon not emitted is a ton of grief saved somewhere down the road. But even more urgently, we need action *now* for real long-term results, where the impact will be even greater. The carbon emissions that most urgently need to be controlled are those of the global economy fifty years from now - a world inevitably more democratized and equitable than today, and one, therefore, in which everyone will have the right to demand a much higher level of total energy use.

Counter-intuitive though it might appear, the most effective way to reduce the long term impact of human activity on the climate is to accelerate, as quickly as possible, energy use (or at least the services that energy makes possible) among the planet's poor.

The two primary numbers that will determine the state of the climate in, say, the year 2050 are the global human population and its per capita energy consumption, particularly in the form of fossil fuels. A society's population growth rate is not an independent variable: it is closely related to the level of energy services available to its members. Human fertility has a strong inverse correlation with the state of economic development. The better the living conditions and opportunities available to people, the lower, generally, the family size. UNDP's Human Development Index (HDI), a widely accepted measure of the quality of life, is highly correlated with availability of energy services. Thus, improving access to energy services is an excellent way to bring down fertility – whatever the specific causal links might or might not be. Where possible, this should be done by using energy more efficiently - but also, where necessary, by accessing additional primary energy.

The global population and thus the total annual carbon emissions would be much lower in, say, 2050 if the demographic transition to low growth takes place – and that needs, among other things, immediate delivery of improved energy services to the poor.

Paradoxical as it may seem, therefore, bringing the energy services available to the poor to a reasonable level - through improving efficiencies and use of renewables and other alternatives, not just by pouring in more raw energy - is the most important intervention required to reduce climate change. It could cut the world’s population in the year 2050 by as much as 30% from a potential of around 10 billion, resulting in a huge reduction in carbon emissions.

The Problem

The changes occurring today in our climate systems may well pose the greatest threat that life on our planet has ever faced. The United Nations Framework Convention on Climate Change (UNFCCC), signed at Rio de Janeiro in 1992 already recognized that such a threat could be addressed only through concerted, large-scale action by the entire

international community. Subsequent findings by the International Panel on Climate Change (IPCC) and others have alerted us to the alarming acceleration in the change taking place in climate processes and have underlined the need to give the highest priority to measures for mitigating this change with an urgency measured in time scales that are now down to years, not even decades.

Yet, the current state of negotiations among nations to deal with climate change is still stuck in an endless game of passing the buck from one to another. Among industrialised countries, the disagreements largely relate to issues of establishing somewhat superficial and temporary advantages, such as choice of baselines and reference dates, acceptable CO2 emission targets, time horizons, etc. Between the rich countries and the poor, the disagreements are somewhat more fundamental such as historical responsibility, fairness, per capita rights, acceptable tradeoffs between economic "growth" and emissions, etc.

Given the entrenched positions and the strength of vested interests, there appears to be little incentive for opposing parties to come to the negotiating table with a common basis for agreement on even minor issues – other than the need to keep the discussion going. At stake are heavy economic, political and security issues underpinned by the deep commitments of nations and societies to maintaining their respective "way of life" – defined primarily by their lifestyles, consumption patterns and production systems. Supporting these commitments is the firmly held conviction of their political and corporate leaders that changes in this way of life are not acceptable to their electorates or customers, and should such changes become necessary, they ought at best to be the responsibility of others, elsewhere, or at worst introduced at the domestic level gradually and very slowly.

These views led, in the mid-1990s, to the adoption of the Kyoto Protocol, the agreement among nations to cut their respective energy consumption (and thus greenhouse gas emissions) progressively down until they reached an acceptable level. Low-income countries were temporarily exempted from these cuts. Given the gross disparities in energy use that exist among countries, and the accumulated emissions that different countries had been responsible for over the past couple of centuries, a fairer and more equitable agreement would presumably have been based on what has since come to be called "contraction and convergence"[1], aiming to bring, over a reasonable time period, the per capita emissions of all countries to a common level that is below the threshold that could cause unacceptable climate change.

However, given the asymmetries in negotiating strength in international fora, the agreement actually adopted at Kyoto specified each party's obligation in terms of how much it must reduce its carbon dioxide emissions in comparison with the levels that existed in that country in the year 1990. The Kyoto Protocol is an unusual instrument of international law, operating on a principle – requiring each party to make a percentage-based reduction in existing consumption levels – that actually perpetuates the gross inequalities of energy consumption among nations. The logic of this approach leads to the need to define "baselines", "additionality"[2] and other concepts all of which introduce large amounts of ambiguity, room for interpretation and ad hoc reasoning, usually biased in the direction of short-term self-interest.

[1] Contraction and Convergence, Global Commons Institute
[2] Boyd, E. et al (October 2007). "The Clean Development Mechanism: An assessment of current practice and future approaches for policy". Tyndall Centre for Climate Change Research. Retrieved 2009-08-08

As the Kyoto Protocol approaches the end of its validity and as the international community prepares for designing its successor at the Conferences of the Parties in Cancun in December 2010 and South Africa in December 2011, the pressure on the poorer nations to make commitments for cutting down on their carbon dioxide emissions (i.e., fossil energy use) is inexorably building up. This pressure is particularly heavy on China, India, Brazil, Russia, South Africa and other large "emerging economies". Again, as at Kyoto in 1995, there appears to be little meeting ground for the different players. The developing countries insist that they are the victims, not the perpetrators of the huge historical emissions whose residues form the stock of greenhouse gases in the earth's atmosphere; that their emissions may be significant and growing, but so are their populations – which means that per capita they are still below the industrialised countries by orders of magnitude; and by any standard of fairness it is the developed countries that have to take the primary responsibility for cutting down on global carbon dioxide emissions. The industrialised countries claim that without some reduction in the emissions from emerging economies, global change cannot be contained within the desired limits.

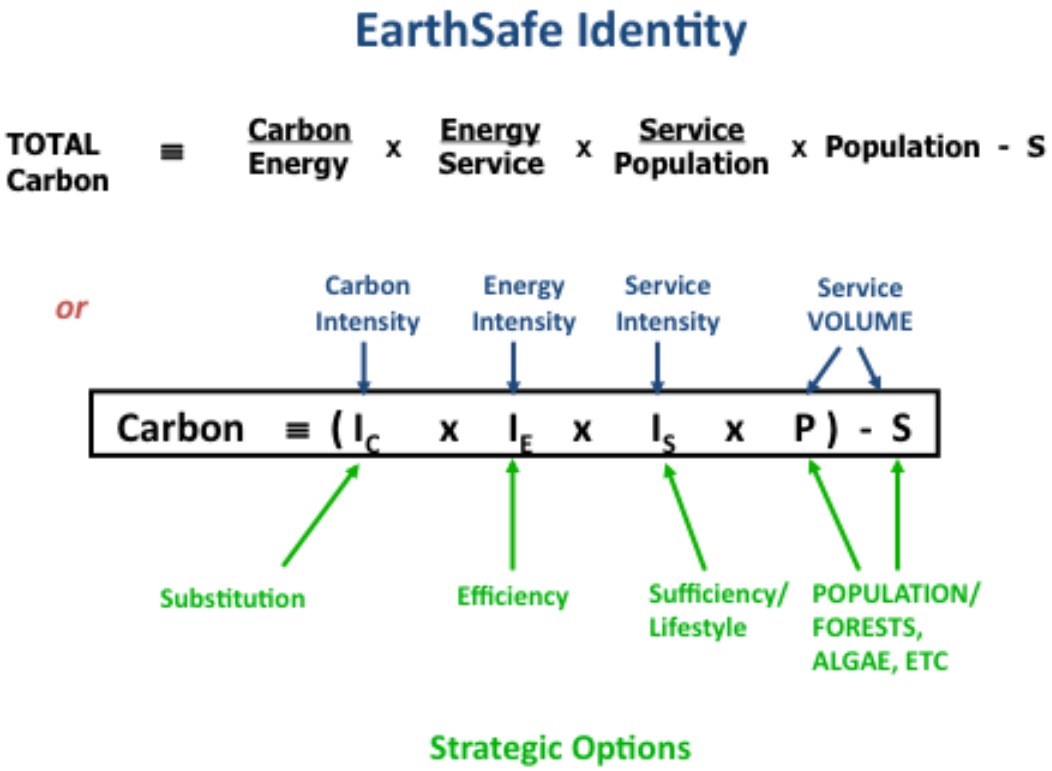
This paper suggests that one common platform that would attract and bring together almost all parties is the growing recognition that the global economy, particularly in terms of its consumption patterns and production systems, and the global population, in terms of its numbers and growth trends are now out of balance with the limits of the global resource base. There are, of course, a few states today, mainly in Europe and East Asia, whose economic and demographic situation encourages them to promote pro-natalist policies – but very few people hold the view that the world as a whole can support more people at standards of living that everyone now aspires to. The global economy, with an ecological footprint approaching 1.4[3], is already using 40% more resources than the Earth produces and it is difficult to see how this can be sustained for long.

People, Resources and the Environment

In the late 1980's, building on earlier work, Paul Ehrlich coined a simple Identity, which relates environmental impact (I) to Technological efficiency (T), per capita use of resources (Affluence) and population (P), thus relating environmental impact to people's consumption patterns, lifestyles and numbers[4]. Ehrlich's identity, (which has evolved to I = P x A x T) subsequently led to more refined variants such as the King identity, the Kaya Identity and the Schellnhuber Identity, as quoted in Schellnhuber 2008. To focus more closely on the impacts of factors that have been largely neglected in past analyses such as population and sequestration of greenhouse gases, the Identity would now need to be expanded to:

[3] Global Footprint Network

[4] Ehrlich, P. R. & Ehrlich, A. H. 1990 The population explosion.



Much of the research, literature, policy studies and international dialogue thus far have addressed Carbon Intensity and Energy Intensity issues, which largely lend themselves to technological solutions and market-based action. Governments, business and academia have focused primarily on these kinds of initiatives. Carbon intensity is amenable to substitution by "cleaner" energy sources, such as solar, wind, biomass and many other renewable fuels, as well as conservation and demand side management. Lowering energy intensity is achievable primarily by increasing the efficiency of our technologies and production systems, primarily by miniaturisation, time-sharing and various other measures to reduce bottlenecks and waste and to raise performance.

Lowering the Service Intensity, which requires changes in lifestyles and consumption patterns, has been flagged primarily by civil society and individuals with a social philosophy orientation, for whom today's way of life is out of balance with the limits of nature. Lacking quantitative analysis or enthusiastic support from the dominant sectors of society such as government, business or the media, these issues have not yet penetrated deeply into the official international dialogue on climate change.

While the role of carbon sequestration, by forests, algae, soils and other natural agents, is widely understood and accepted as a desirable goal, it too has not yet become a legitimised instrument for mitigating climate change. Despite strong campaigns for including REDD and REDD+ initiatives in any post-Kyoto regime, the likelihood of such options being adopted is still somewhat remote.

The one factor that does not seem to be on the table at all is Population. Virtually none of the literature or negotiations mentions the role of population as relevant to global efforts to reduce carbon emissions or to mitigate climate change in any way. The taboo on this subject seems to be deep and close to complete. The only mention of population in mainstream discussions is the assumption that the number of people on Earth in 2050 – or 2100 – will be "X Billion" where X is a large number usually taken

from the medium population projections of the United Nations Population Fund. The general assumption appears to be that the population in 2050 will be about 10 Billion and so the carbon emissions will be commensurately high.

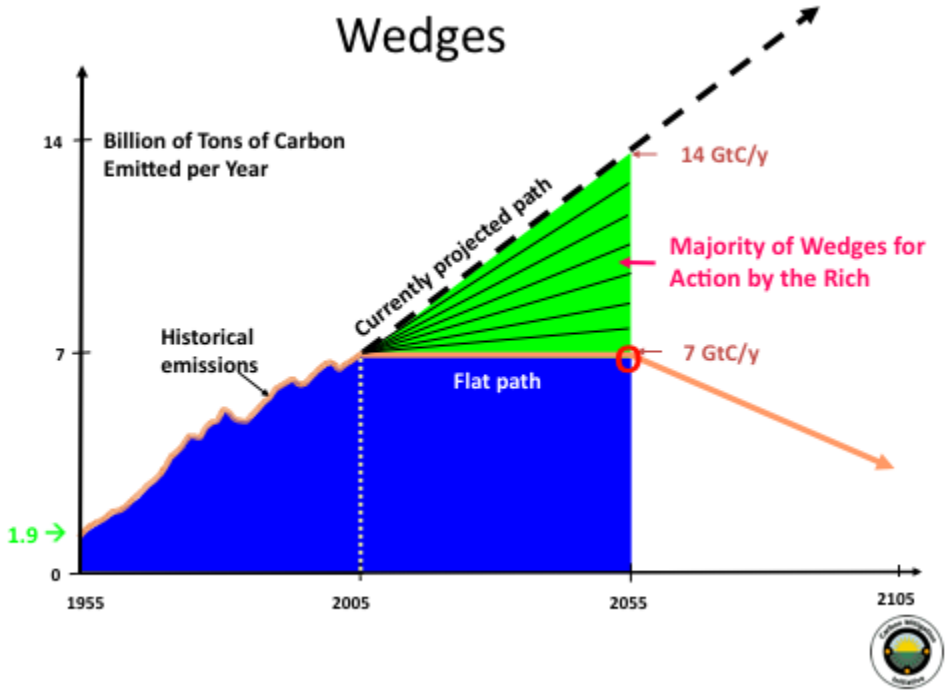
Hypothesis and Caveats

There appear to be considerable opportunities for reduction of carbon emissions through accelerated development in emerging economies, which generally leads to the reduction of desired human fertility; and, moreover, there are a variety of very low cost interventions that can speed up both processes. Since birth rates in the developed countries are already low, and in some cases even below replacement levels, this approach applies primarily to the developing countries, where the future impact on resources and climate due to population growth would be significant.

The advantage of this is that the poor countries can, by adopting the measures described here, take their rightful place in the climate change negotiations as contributors of effective solutions rather than simply as deniers of current of future responsibility. Moreover, they can legitimately demand financial and other compensation for future carbon emissions saved.

For the rich countries, the value of slowing down global population growth is extremely high, since it is the only way they can hope that future global emissions will be limited by all and thus lead to permissible limits on greenhouse gas concentrations in the atmosphere in the long run that are reasonable.

But it should be clear that these solutions based on lowering population growth cannot, at best, reduce carbon emissions by more than 25 to 30% of the reduction that needs to be achieved if the global climate is to be stabilized at a reasonable level. In the language of "wedges"[5], it can only account for one or at most two of the seven wedges needed.



[5] Stabilization Wedges: Solving the Climate Problem for the Next 50 Years with Current Technologies
S. Pacala and R. Socolow

The bulk of the carbon emission reduction will have to be achieved by and within the global North on account of historical responsibility, infrastructure and resilience to climate change built up through prior use of fossil fuels and existing financial capability. There is no viable substitute on the horizon for the action that industrialised countries must take to reduce their greenhouse gas emissions.

Secondly, in proposing the approach below, it is not the intention of the authors to suggest that improvements in the lives of the poor, the women and the marginalized in the developing countries is needed only for what they can do to mitigate climate change*. The poor, the women and the marginalized have an intrinsic right to live better, longer and more fulfilling lives. This is a moral imperative, as well as an ecological one. While education of boys is certainly important, the emphasis here on girls' education is simply in recognition of the imbalances that exist between the genders and of the need to empower and build the confidence and capability of those, often girls, who have little say in the choices that most affect their lives. Rapid social change needs rapid improvement in the ability of all to exercise their rights and entitlements.*

The case made in this paper is that international development efforts can and must be reoriented so as to solve both issues at the same time: *bringing about an equitable, fair and widely shared improvement in the lives of people and by doing so, to achieve demographic outcomes that also serve to mitigate climate change.*

It is also our view that any opportunity that creates a "positive sum", win-win situation, however small, can act as an effective common ground to enable the different sides to enter constructive dialogues that can take them beyond the initial impasse.

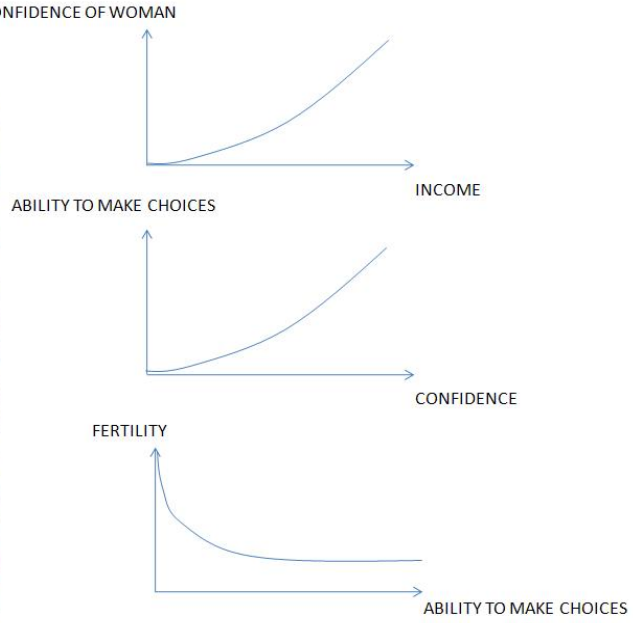
New Versions of Old Insights

As far back as 1965, Roger Revelle, Professor of Population Studies at Harvard University, who incidentally in an earlier career as an eminent oceanographer commissioned the studies at the Mauna Loa Observatory that led to his discovery that atmospheric CO2 levels are rising[6], had recognized that population growth is not an exogenous parameter, but that it is heavily influenced by social and economic factors; policy decisions can have deep impacts on fertility, mortality, migration and other demographic variables[7]. It was his firm understanding of the demographic transition process, as it is for the authors of this paper, that population growth is no less a result of the state of development than it is a determinant of it. Birth rates, in a particular society, are highly correlated with the general wellbeing people feel in that society, with their aspirations and expectations for the future and with the position of women in it. Even with their inadequacies, aggregated measures of development such as GDP and HDI show high correlation with human fertility.

The causal mechanisms underlying the relationships between development and fertility are varied, and though they are being extensively studied, it is unlikely that these relationships can be reduced to precise mathematical formulae. However, both historical (longitudinal) behaviour of societies over time and comparative (cross-sectional) behaviour among nations today demonstrate clearly an extraordinarily strong inverse correlation between the quality of people's lives and the family size they desire. The figure below shows a typical chain of causal links that underlies this process.

[6] Revelle, R., and H. Suess, "Carbon dioxide exchange between atmosphere and ocean and the question of an increase of atmospheric CO2 during the past decades." Tellus 9, 18-27 (1957).

[7] Revelle, R, "Can Man Domesticate Himself?", Bulletin of the Atomic Scientists Vol.XXII, No.2 , February 1966.



An equitable, widely shared improvement in the lives of the people is historically a well-trodden route to smaller families. One way to accelerate or short-circuit this process is to make direct investments in interventions that improve the quality of life of the poor. As the UN Conference on Population in Cairo, 1995 clearly concluded, such interventions include education for girls, livelihoods and jobs for women, effective and access to female reproductive health services and similar gender empowerment measures. Other strong determinants of human fertility have long been known to include measures to reduce infant mortality and policies for old age security. It is also widely agreed that availability of electricity, light and sources of domestic or community entertainment such as television provide inexpensive distractions that can help occupy the time families spend together.

Needless to say, easy and affordable access to female reproductive health services, and particularly to suitable contraception methods is critically important. Without these, families and particularly women cannot hope to limit the size of their families to the number of children they desire. In some parts of the developing world, this can be a major barrier to achieving smaller families.

However, most family planning programmes in poor regions of the world have focused on service delivery (primarily promoting the use of contraceptives), rather than focusing on methods to promote the desire to have a smaller family – and as a result, these measures have only been moderately successful. Many women living in these areas, particularly in rural India, are victims of gender biases and social handicaps that often prevent them from making decision about when and how many children they can have. Results from field projects of our social enterprise, Development Alternative, in rural India have shown that increasing the financial independence of women results in tremendous and very rapid improvements in their status in the community and family and consequent reductions in family size[8].

[8] For example, at Development Alternative's all women paper recycling unit in Uttar Pradesh, India, 25 women joined in 1988 and 23 of these women still remain employed at the premises. Compared to a control group (women of the same age, caste etc), the women at the recycling unit had a total of only 2 children in the course of 21 years as opposed to 25 for the control group.

This is borne out in numerous societies. In the case of Sri Lanka, the southern state of Kerala in India, and more recently Thailand, Korea, and the other states of Southern India (Tamil Nadu, Andhra Pradesh and Karnataka), various welfare measures enabled the respective States to simulate some of the conditions that exist in a developed country and thus engendered the feeling of wellbeing and hope for the future that leads to a desire for smaller families. In the brief period of a decade or two, these economies were able to make it through the democratic transition to a condition of almost replacement level fertility – and as a result to accelerate real and sustained development for their people as well. Other regions, such as the states of Northern India, Africa and the Middle East continue to exhibit low indicators of development and high fertility.

Countries or regions such as Thailand, Sri Lanka, or parts of South India, which have successfully lowered the rates of their population growth by focusing on improving quality of life, should be able to claim credit for the significant contribution they are making to reduction of greenhouse gas emissions.

The Model

The correlation between fertility and various parameters that represent human wellbeing is starkly apparent from both the historical trajectory of fertility in countries that have traversed the demographic transition and comparison of the current data of all countries. Figure A shows the relationship between fertility and per capita GDP for different countries.

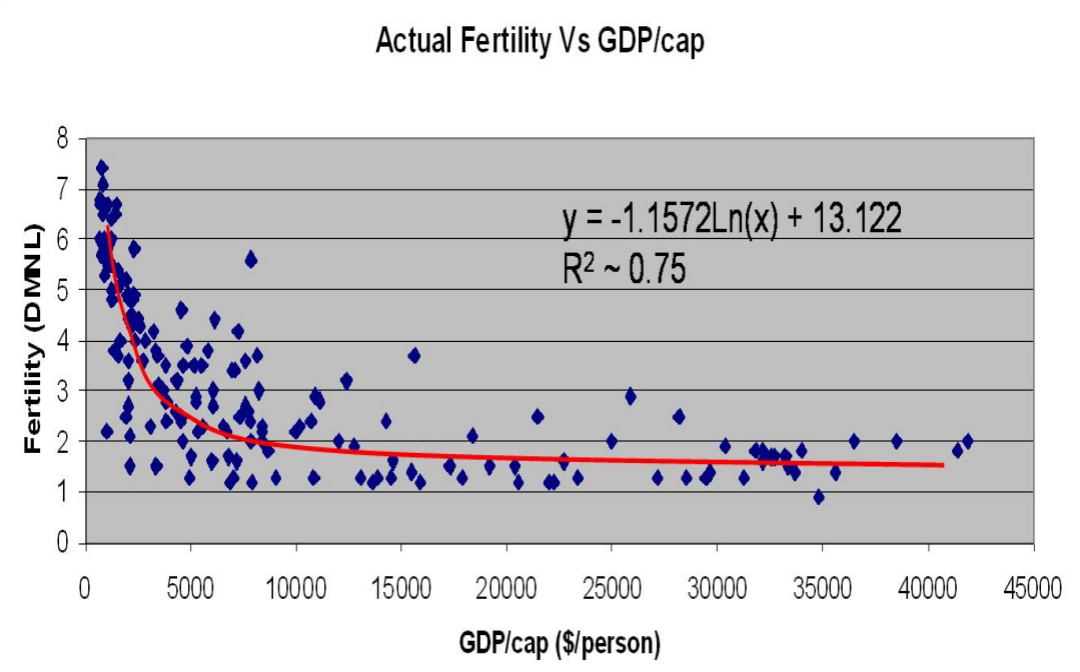


Figure A: A plot of fertility (No. of Children per Woman) vs per capita Income for all countries except OPEC members. Data from the UNDP Human Development Report (http://www.hdr.undp.org)

The maps in Figure B graphically illustrate similar relationships for fertility with other social welfare indicators such as enrolment of girls in schools, women's employment, etc.

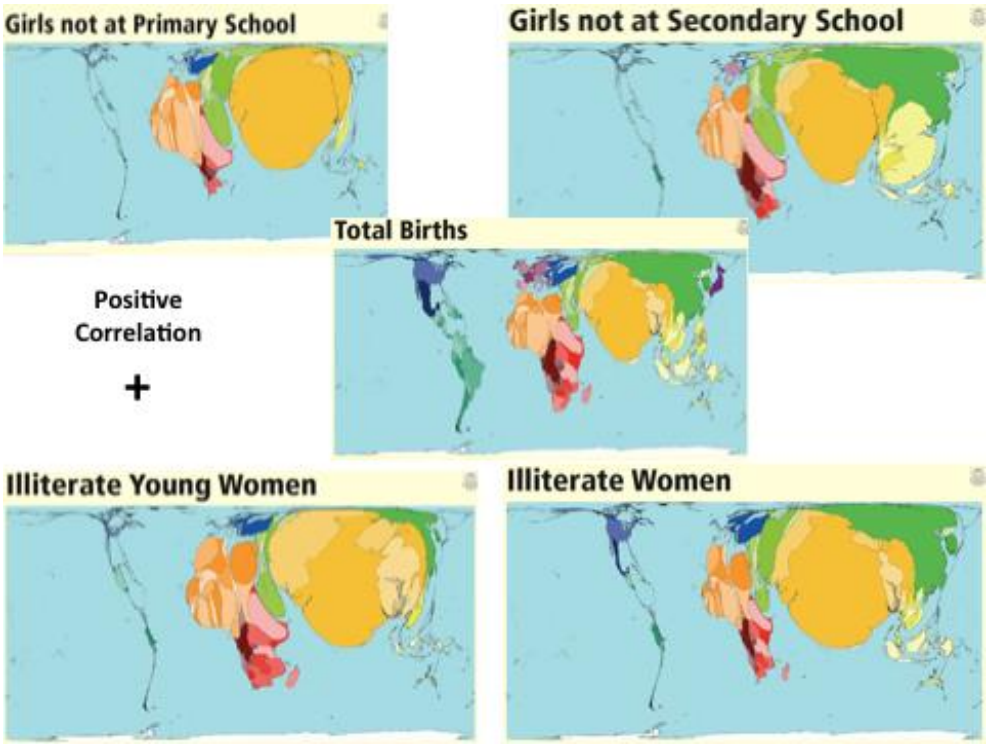


Figure B: Parametric maps showing various gender imbalances worldwide. (© Copyright 2006 SASI Group (University of Sheffield) and Mark Newman (University of Michigan).)

Figure C shows that the demographic conditions in a country such as Viet Nam (Fertility: 5 children per woman and Energy use: 500 Kg of Oil Equivalent per person per year) can easily be changed to a fertility of 2 children per woman with the addition of 1,000 KgOE/yr for each person – bringing its family size close to that of Thailand today.

An even simpler and less expensive method would be to provide the gender empowerment facilities identified by the Cairo Conference. The cost of interventions such as creating schools for educating girls and enterprises for employing women has been estimated from actual field data. Our estimate from various field studies for the cost of educating a girl to a level where she has options such as delaying marriage, getting a job, obtaining reproductive health services and other opportunities that make having a large family less attractive is approximately $ 2,000. [Ref:]

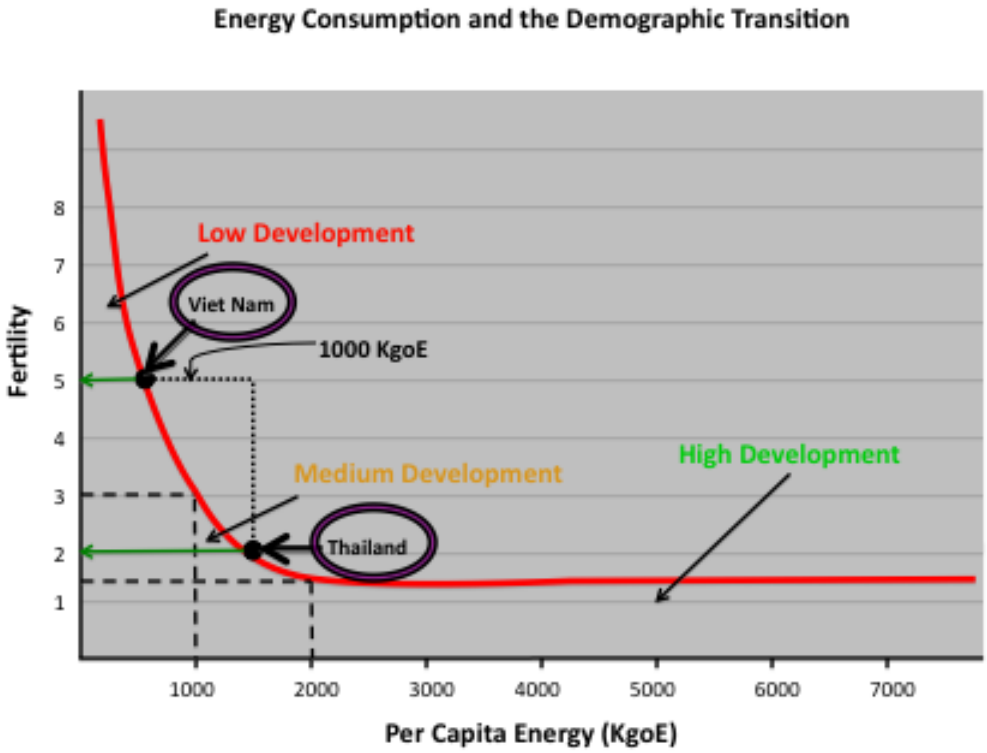
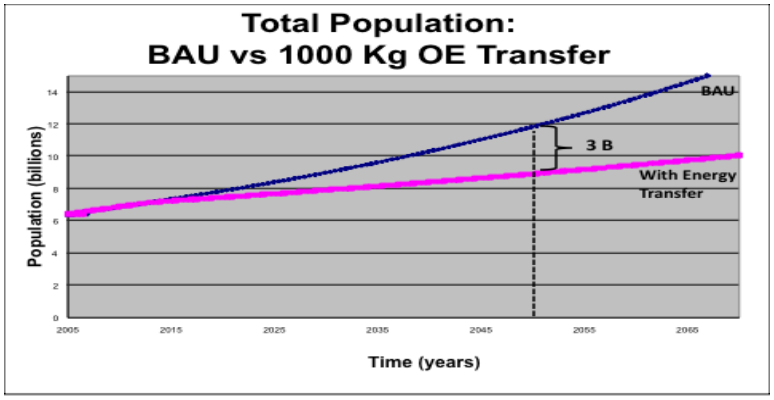


Figure C: A typical fertility transition curve.

Results

Running the model under different assumptions shows that it is possible to end up with a world population by the target dates (2050 or 2100) that would be well below the numbers that would exist if business were to continue as usual.

Using plausible assumptions on redirecting investments towards gender empowerment and other interventions aimed at improving the lives of people in the poorer regions of the world, it is possible to imagine a world in 2100 that would have several billion fewer people than is generally assumed today. By 2050, it is possible to redirect global development efforts to save as many as 1.5 to 2 Billion births through improved life and livelihood opportunities for all.



Today's average emission of CO2 stands at roughly 2 tonnes per capita. Assuming that each of the persons not born would have been responsible for a highly conservative 1 tonne of CO2 emission per year, and that he or she would have lived to an average age of 60 years, the total saving per person would be 60 tonnes of CO2. At a value of $ 16 per tonne, this is close to $ 1,000 – more or less equal to the investment made in her education.

If we include the savings due to averting the births of her children and grandchildren up to the end of the target date, the investment actually yields double the returns.

In comparison with many of the other solutions currently under consideration, this is an extremely low cost method to reduce carbon emissions. In a 50-year simulation, the model puts the cost at around $ 10 to 15 per tonne of CO2 emission saved. With a 100 year time horizon, the costs actually come down to well below $ 5. The latest estimates for Carbon Capture and Storage come out to well over $ 100 per tonne[9].

The savings in CO2 emission from this kind of approach could reach as much as 2 or more billion tonnes per year.

Relevance to Climate Mitigation

Activities that lead to reduced population growth, and as a consequence to lower emission of CO2 should be just as eligible for recognition of their contribution directly to mitigation or indirectly as carbon-offsets as are normal engineering works that try to achieve the same results through improved efficiency. Measurement of demographic parameters is a well-known science and the number of births averted can be estimated quite accurately by measuring the difference between what would have been the population had business-as-usual trends continued and what was actually the case after the interventions.

The carbon savings achieved in this manner since, say, 1990 could be allotted to the account of the country as part of its direct contribution to mitigation; the carbon saving yet to come could be the source of CDM or other carbon offset money to be used directly for the kinds of activities described here. Conventionally, carbon offset money is paid after the offsetting activity has been completed, verified and approved. This convention could be changed to provide front-end capital for setting up schools, enterprises, etc – or alternatively the future expected revenue streams could be securitized into a bank loan, which would be repaid from the carbon offset earnings when they materialize.

To be eligible for carbon offset or mitigation benefits, projects have to pass the "additionality" test, which shows that the reduction in greenhouse gases it results in would not have taken place without the incentives provided by those benefits. Given the time it takes for societies to move through the demographic transition and the well-known barriers they normally face in this process, fertility reduction resulting from female empowerment certainly meets the additionality requirements. In fact, given its inherent grounding in the behaviour of the family and community, it should be taken as an archetypal gold standard mitigation action.

[9] MOHAMMED AL-JUAIED, ADAM WHITMORE, "Realistic Costs of Carbon Capture", Discussion Paper 2009-08, Energy Technology Innovation Policy Belfer Center for Science and International Affairs Harvard Kennedy School, Harvard University

Conclusion

The model, based on System Dynamics methods, shows that there is a strong prima facie case for redirecting international development efforts towards eradicating poverty and particularly at improving the lives of women in developing countries. Preliminary calculations show that $ 1 spent on such programmes would yield more carbon emission reduction than $ 10 spent of engineering solutions such as Carbon Capture and Storage.

Needless to say, improving the lives of the poor, and particularly the women and children living in extreme poverty, is an imperative in its own right, and from many viewpoints – the moral, the ethical, the social, the ecological and the practical. It is also one of the least cost ways of achieving goals that currently can capture the support of global decision-makers. The argument presented in this paper, based on a quantitative analysis of the relationship between human fertility and specific development interventions that emphasize gender empowerment, shows that rapid, equitable development is also crucial to reduce carbon emissions, stabilize the climate, reduce the pressures of humankind on nature and its resources, and save life on Earth.

The systemic analysis summarized above shows that there exists a possible win-win strategy that can bring the competitors in the current game to play to agreed, logic-based and consistent rules. These rules would be designed to overcome the consumption-population related stand-offs that exist today in the international debate.

The analysis shows that, counterintuitive and paradoxical though it might appear, accelerating the removal of poverty throughout the world, involving access by the poor to higher energy services, not lower, provides the surest and least cost and shortest transition path to mitigating climate change. Depriving the poor of a better life can only be severely counterproductive for achieving climate mitigation goals.

Annex: The Model

Introduction

In a world of growing complexity, often neither the lessons of history nor "common sense" is adequate to help us understand the causes and effects that determine the outcomes of human interventions. Systems Thinking is a scientific art that facilitates rational analysis and clarity of understanding that permits us to make better decisions.

The more specific science of System Dynamics offers a powerful method to characterize the functions and behaviour of real world structures. The work of Jay Forrester, father of System Dynamics[10] demonstrated the value of this method in applications as varied as complex urban communities, multi-faceted industries and global societies. World3, the original global dynamics model, (further refined by Meadows et al.[11]) shows the growth of economy and population in a world constrained by resources and pollution. The methodology has since been refined through several generations of elaboration, testing and application.

The world today is beset by many successive socio-economic structural failures and concurrent crises. Of these, perhaps the most pressing one is that of climate change, recognized widely to be the result of increased levels of greenhouse gases in the atmosphere, which in turn result from anthropogenic emissions of these gases, primarily from the burning of fossil fuels. The final result is that these changes in the climate now threaten to destroy our life support systems. The solutions discussed thus

[10] Jay Wright Forrester, "Industrial Dynamics" (1961) "Principles of Systems" (1968)

[11] Dennis L. Meadows, Donella H. Meadows, Jorgen Randers, William W. Behrens, "The Limits to growth: A report for the Club of Rome's Project on the Predicament of Mankind" (1972)

far have been largely limited to technological improvements and lifestyle changes. Very little attention has been given to the effects of population growth.

The EarthSafe Model, Ver 1.3

Objective: *CO2 emissions are an indicator of our planet's poor health. This model seeks to quantify the effect of population dynamics on the amount of CO2 released annually into the atmosphere and improve the quality of life of those living in its poorest regions.*
.

Version 1.3 of the EarthSafe model represents a world comprising 4 Regions defined economically rather than geographically (Very Poor, Poor, Medium and Rich countries). Each region is further divided into 3 classes: those who live in the poorest (L Class), middle (M Class) and rich (U class) income groups, as determined by data.

Biodiversity and Ecosystem Services
-- the Priceless Resource

If our economic activity destroys the capability of the ecosystem to sustain our life support systems, which it will do if our decision-making continues to ignore their value, future generations will pay a very heavy cost.

Some ecosystem services have almost infinite value. Those that maintain the oxygen in the air we breathe, the ozone that protects us from the Sun's ultra violet rays, the quality of the water we drink and the fertility of the soil that produces our food are so basic to supporting life itself that these cannot even be evaluated. The carbon dioxide in the atmosphere that maintains the planet's temperature at levels that permit biological processes to function is another such service.
Some ecosystem services are quite obvious and even visible. These are relatively easy to appreciate: fish, game, fruits and nuts from the wild. Many crops are pollinated by bees, butterflies, bats and other natural processes, without which much of our food would be too expensive to produce. In other cases, seeds are spread or germinated by such processes. And maintaining the local microclimate, controlling the spread of crop pests and disease and binding the soil to prevent erosion are other processes that are commonly known.

Less well known but often even more valuable are the invisible processes such as those that regulate the flow of nutrients through the ecosystem – nitrogen, carbon, phosphorus, sulphur and the rest. Without these, life itself let alone crops and biomes such as forests, grasslands, mangroves, corals, would not exist.

Ecosystem services are thus responsible for regulating, recharging and purifying our water bodies – on or below the ground – for our drinking and agriculture, for producing the timber, fuel, fodder, fiber for our industries and for mitigating floods, droughts and natural disasters.
Ecosystems are well-known for other services that are greatly valued by people: as habitats for biodiversity, genetic resources, migratory species; as enablers of ecotourism and many sports and recreational activities; and as sources of cultural values in the form of aesthetic beauty, intellectual stimulation and many different disciplines of science.

'Nature-tech'—technologies inspired by nature—are among the most tantalizing prospects for realizing a low carbon, resource-efficient Green Economy in the 21st century. The natural world, in all its splendour and diversity, has already solved many of

the sustainability challenges facing humanity in ingenious, unexpected and even counter-intuitive ways. If humans could only unravel the fascinating chemistry, processes, structures and designs that organisms from bacteria and mollusks to reptiles and mammals have evolved and tested over millions of years, perhaps then we would have new and transformational solutions to the many challenges faced by a planet of inhabited by more than seven billion people.
At a more meta-biological level, not only do biodiversity and ecosystem services directly and indirectly provide us with so many life-supports, the very machinery of life and evolution is itself a major process in need of nurturing: it got us to the here and now and it will be needed to get us to there and then. There is neither a past nor a future without the process that created life and its continual unfolding over the Billenia.

Our economic systems do not fully acknowledge the value of such ecosystem services. Both as stocks (equivalent to primary wealth) and as flows (equivalent to the returns from that wealth, treated as an investment), they are almost entirely neglected in our calculations of economic activity, GNP, stock market indices or other parameters. Since they do not appear in any economic model, they are neglected by economists and therefore by policy makers.
The current crises of climate change, peak oil, water scarcity, food price fluctuations, financial systems and many others amply demonstrate the dangers inherent in such neglect. Designing strategies for sustainable development requires a much better understanding of nature's services on the part of every concerned citizen.

Annexure: Reference List

This reference list serves as a useful resource for obtaining deeper insight and guidance into specific issues touched upon in the document. These resources have been selected for their practical application rather than academic study.

TRANSIT PLANNING

Documenting transit-planning processes in Curitiba and Bogotá from 1955-95 and 1986-2001.

Arturo Ardila- Gómez (2004) Transit Planning in Curitiba and Bogotá - Roles in Interaction, Risk, and Change. Source: https://dspace.mit.edu/handle/1721.1/28791

Key areas of transit project planning and technical decisions which are equally applicable to BRT.

Pulido, Daniel, Georges Darido, Ramon Munoz-Raskin, and Joanna Moody, editors. (2018). The Urban Rail Development Handbook. Washington, DC: World Bank. doi:10.1596/978-1-4648-1272-9. License: Creative Commons Attribution CC BY 3.0 IGO Source: https://issuu.com/world.bank.publications/docs/9781464812729

A deeper dive into the impact of BRT type reforms in intermediate cities in Colombia; impacts on overall ridership, fleet size and impacts on Generalized Cost of Transport.

Andrés Gómez-Lobo (2019) BRT Reforms in Colombia: an ex-post evaluation. Source: https://www.researchgate.net/publication/333039992_BRT_Reforms_in_Colombia_an_ex-post_evaluation

The importance of the planning process and project timing in defining project outcomes – an analysis of Delhi BRT and Ahmedabad BRT

Rizvi A. & Sclar E., (2014), Implementing Bus Rapid Transit: A tale of two Indian cities. Source: https://www.sciencedirect.com/science/article/abs/pii/S0739885914000845 LA 2/10/2019

PRACTICAL BRT DESIGN

These publications are for technical guidance only. Practitioners must exercise their own critical analysis on applicability and practicability for local conditions.

APTA (2010) Bus Rapid Transit Service Design. Source: https://www.apta.com/wp-content/uploads/Standards_Documents/APTA-BTS-BRT-RP-004-10.pdf

National Academies of Sciences, Engineering, and Medicine (2007). Bus Rapid Transit Practitioner's Guide. Washington, DC: The National Academies Press. Source: https://doi.org/10.17226/23172.

NACTO (2016) The Transit Street Design Guide is a well-illustrated, detailed introduction to designing streets for high-quality transit, from local buses to BRT, from trams to light rail. Source: https://nacto.org/publication/transit-street-design-guide/

NACTO (2016) Urban Street Design Guide shows how streets of every size can be reimagined and reoriented to prioritize safe driving and transit, biking, walking, and public activity. Source: https://nacto.org/publication/urban-street-design-guide/

ENGAGING WITH PARATRANSIT and MANAGING SECTOR REFORM

Using paratransit as first-last mile feeder/ shuttle services, institutional arrangement and a Comprehensive Urban Mobility Plan

Sanskriti Menon et al. (2017) Local Area Shuttle Services for Pune: Potential as an Intermediate Public Transport Option (2017) SUM Net India. Source: https://www.sumnet.in/wp-content/uploads/2018/09/Local-Area-Shuttle-Services-for-Pune.pdf

Guidelines on managing engagement with paratransit

Schalekamp H. (2017) Lessons from building paratransit operators' capacity to be partners in Cape Town's public transport reform process. Transportation Research Part A: Policy and Practice Volume 104, October 2017, Pages 58-66 Source: https://www.sciencedirect.com/science/article/pii/S0965856415302445

Schalekamp H. Behrens R. (2009) An International Review of Paratransit Regulation and International Experience: Lessons in System Rationalisation and Improvement in South African Cities. Source: https://repository.up.ac.za/bitstream/handle/2263/11968/Schalekamp_International%282009%29.pdf?sequence=1&isAllowed=y

Schalekamp, H. Behrens, R. (2010) Engaging Paratransit on Public Transport Reform Initiatives in South Africa: A Critique of Policy and an Investigation of Appropriate Engagement Approaches Source: https://www.academia.edu/9519516/Engaging_the_paratransit_sector_in_Cape_Town_on_public_transport_reform_Progress_process_and_risks

Managing BRT impact on employment, social safeguards and a perspective on managing the transition of the informal sector.

Dave Spooner (2019) Bus Rapid Transit (BRT) and Formalisation of Informal Public Transport - A Trade Union Negotiating Guide , Global Labour Institute, Manchester Source: https://global-labour.academia.edu/DaveSpooner

TRANSIT AND IMPACTS ON THE POOR

Understanding the interaction between urban poverty and transportation – improving accessibility, mobility equity and equality.

Gail Jennings (2016) Transport, Poverty Alleviation and the Principles of Social Justice - A literature review for the Inclusive Sustainable Transport in support of action. Equity and Poverty (i-STEP) programme- Partnership on Sustainable Low Carbon Transport (SLoCaT) Source: https://www.researchgate.net/publication/311148936_Transport_poverty_alleviation_and_the_principles_of_social_justice_a_literature_review

An analysis of Bogotá's experience and balancing the needs for financial and social sustainability and impacts on the poor.

Camila Rodríguez Hernández & Tatiana Peralta-Quiros, 2016. Balancing Financial Sustainability and Affordability in Public Transport: The Case of Bogotá, Colombia. International Transport Forum Discussion Papers 2016/16, OECD Publishing. Source: https://ideas.repec.org/p/oec/itfaab/2016-16-en.html

Camila Rodriguez et al. (2015) Examining the implementation and labor market outcomes of targeted transit subsidies: SISBEN Subsidy for Bogotá's Urban Poor, Source: http://pubdocs.worldbank.org/en/865911454354497451/20160112-TRB-Bogotá-Pro-Poor-Targeted-Subsidy-FINAL-for-Publication-00000003.pdf

FLEET RENEWAL AND BUS SCRAPPING

A detailed MPA Thesis on the programme fleet renewal of mini-bus taxis in South Africa to formalise and better regulate the industry. Key issues can be drawn from this study.

Maijane Martha Baloyi, (2012) The impact of the Taxi Recapitalisation Programme on the South African Taxi Industry : a case study of Greater Mankweng Taxi Association in Capricorn District, Limpopo Province. Source: http://hdl.handle.net/10386/753

ELECTRIC BUSES

Some good references on electric propulsion technologies (Battery Electric Bus) for the technically minded.

Olli Vilppo, Joni Markkula. (2015) Feasibility of electric buses in public transport. Source: http://www.evs28.org/event_file/event_file/1/pfile/EVS28_Feasibility_of_electric%20buses%20in%20public_transport_%20Vilppo_Markkula.pdf

Adnane Houbbadi, Serge Pelissier, Rochdi Trigui, Eduardo Redondo-Iglesias, Tanguy Bouton. (2019) Overview of Electric Buses deployment and its challenges related to the charging - the case study of TRANSDEV. 32nd Electric Vehicle Symposium (EVS32), May 2019, LYON, France. 11p. hal- 02148377v. Source: https://hal.archives-ouvertes.fr/hal-02148377v2

LAND VALUE CAPTURE

A useful discussion on the application and considerations for Land Value Capture

Rick Rybeck (2004) Using Value Capture to Finance Infrastructure and Encourage Compact Development. District of Columbia Department of Transportation. Source: https://journals.sagepub.com/doi/abs/10.1177/1087724X03262828