TRANSFORMATIVE MOBILITY SOLUTIONS FOR INDIA

CHARRETTE PRE-READ DOCUMENT

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PASSENGER MOBILITY:

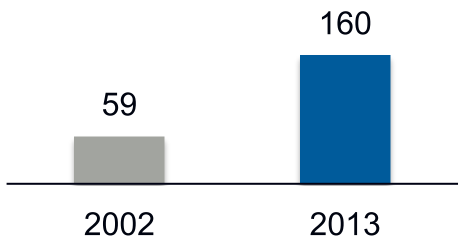
EMERGING TRENDS AND OPPORTUNITIES

1. TRADITIONAL MOBILITY SYSTEM
2. NEW MOBILITY PARADIGM
3. POTENTIAL LEAPFROG FOR INDIA

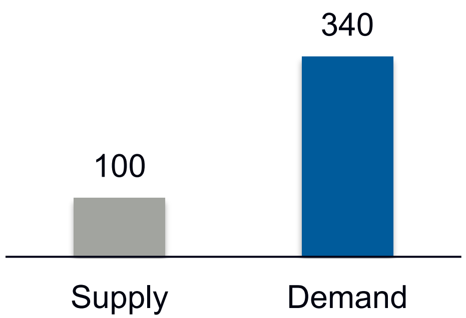
INDIA IS AT A CRITICAL JUNCTURE FOR THE FUTURE OF ITS MOBILITY SYSTEM

INDIA HAS A MOMENTOUS OPPORTUNITY TO INVEST IN A WORLD-CLASS TRANSPORTATION SYSTEM IN ORDER TO MEET ITS GOALS OF ECONOMIC GROWTH AND CITIZEN PROSPERITY

Private vehicle growth
Private vehicles grew 2.7x from 2002–2013 to 160M



Public transit shortage
Demand for 340k buses exceeds India's 100k stock



Pressing Factors

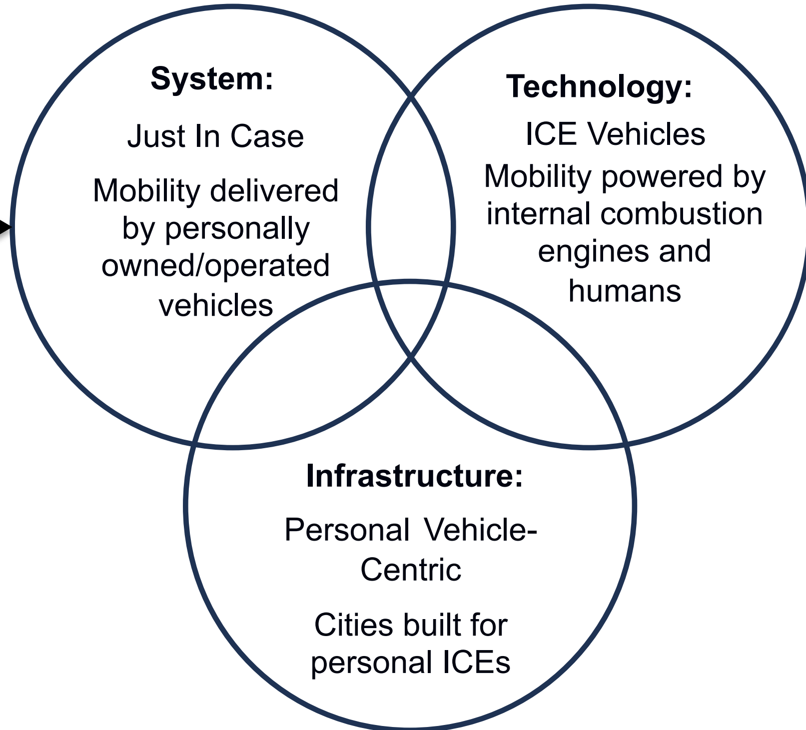
- Increased mobility is a positive economic force—citizens on the move enhances commerce and drives the economy.
- India will need upgrades to provide transportation to its citizens.
- Infrastructure is expensive and difficult to uninstall—India must not pursue mobility futures leading to high costs, heavy pollution, and/or inefficiency.
- Growing demand cannot be met just through non-motorized transit.

INVESTMENTS IN TRADITIONAL MOBILITY SOLUTIONS IN THE U.S. HAVE LOCKED IN UNFAVORABLE OUTCOMES

INVESTMENT BY DEVELOPED NATIONS IN AN INEFFECTIVE, PRIVATE-VEHICLE-FOCUSED SYSTEM HAS LED TO DECADES OF "LOCK IN" EFFECTS

Underutilized:
Personal vehicles sit unused 95% of their life.

Expensive:
Mobility is the 2nd highest expense for U.S. families, and the highest expense for many low-income families.



Dirty:
ICEs emit 1.2 gigatons of CO_2 each year, along with NO_x and SO_x.

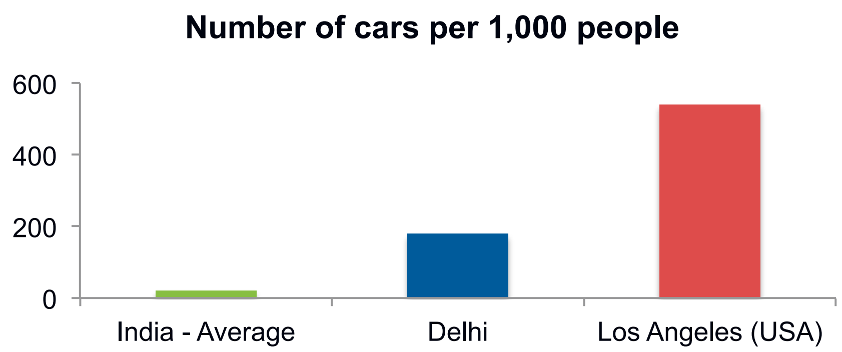
Inefficient:
About 1% of total energy used goes to actually moving people.

Congested:
Gridlock traffic, stress, and other indirect costs amount to almost $2 trillion in societal expenditure in the existing system.

Dangerous:
Automobile accidents kill over 1,000,000 people each year; 33,000 in the U.S. alone.

INDIA HAS THE POTENTIAL TO AVOID THESE CONSEQUENCES AND LEAD THE WORLD IN THIS MOBILITY PARADIGM SHIFT

EVEN AT RELATIVELY LOW LEVELS OF FOSSIL-FUEL-BASED PERSONAL VEHICLE OWNERSHIP, INDIA IS ALREADY FACING SIGNIFICANT CHALLENGES



- More than 80% of India's petroleum is imported.
- India spent $112 billion spent on crude oil imports in 2014–15.
- India is suffering GDP losses of 1–6% due to poor urban planning.
- Traffic fatalities cause more than 150,000 deaths annually.
- More than 70% of demand for mobility is still largely served by non-motorized public and commercial modes of transit.

An opportunity now exists to invest in integrated mobility solutions that will save significant energy and capital over time

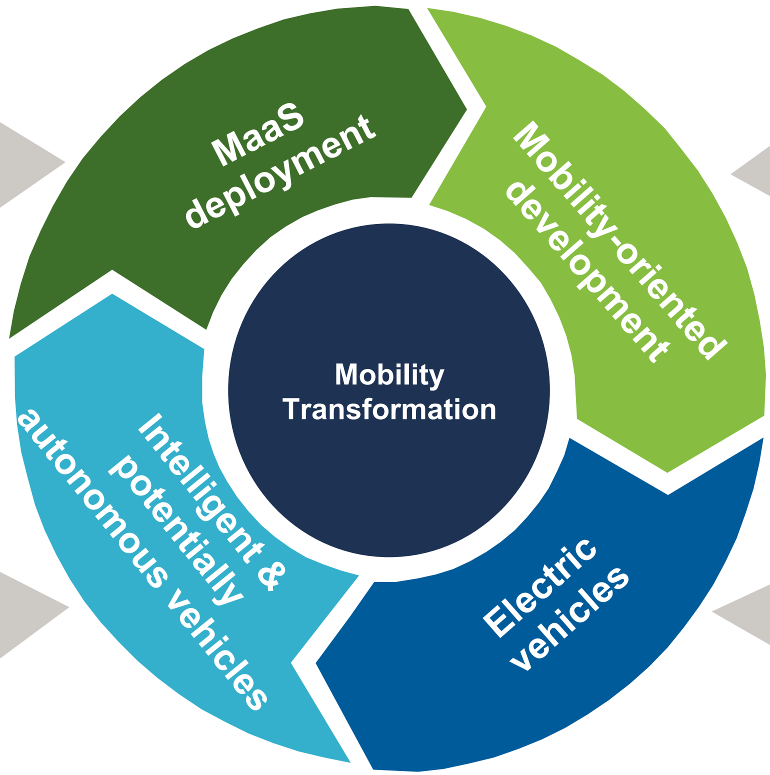
Enabling Factors[1]		
Social	**Economic**	**Environmental**
Demand for manufacturing and technology job growth	Growing cost of oil imports and personal vehicle ownership	Stricter fuel economy standards
Growing young and urban populations	Declining capital costs and lower-than-ICE operating costs for EVs	International commitment to climate change mitigation
Shift toward service-based economy	Major innovations in data, connectivity, and communications	Growing concerns over air pollution and public heath

[1] PPAC, WHO, and MoRTH, Global Commission on Economy and Climate, 2016

AN ALTERNATIVE MOBILITY SYSTEM—ONE UNIMAGINABLE EVEN A FEW YEARS AGO—IS CONCEIVABLE TODAY

- Social and economic factors support the proliferation of shared mobility services.
- On-demand services are growing in market share, unlocking higher utilization of public transit.
- Integrated data platforms connect multimodal transit options seamlessly.

- Development incorporates walking and biking, making it non-motorized transit safe.
- Urban forms enable cheaper, more comfortable on-demand services and public transit.
- Declining demand for parking reclaims land for greenspace and commercial/residential development.



- Vehicle intelligence improves road safety.
- Autonomy increases utilization of vehicles, further improving electric fleet vehicle economics.

- Lower emissions per mile address growing air pollution concerns.
- Electric fleets providing shared offer attractive economics.
- EV batteries benefit the electrical grid by supporting RE integration and ancillary services.

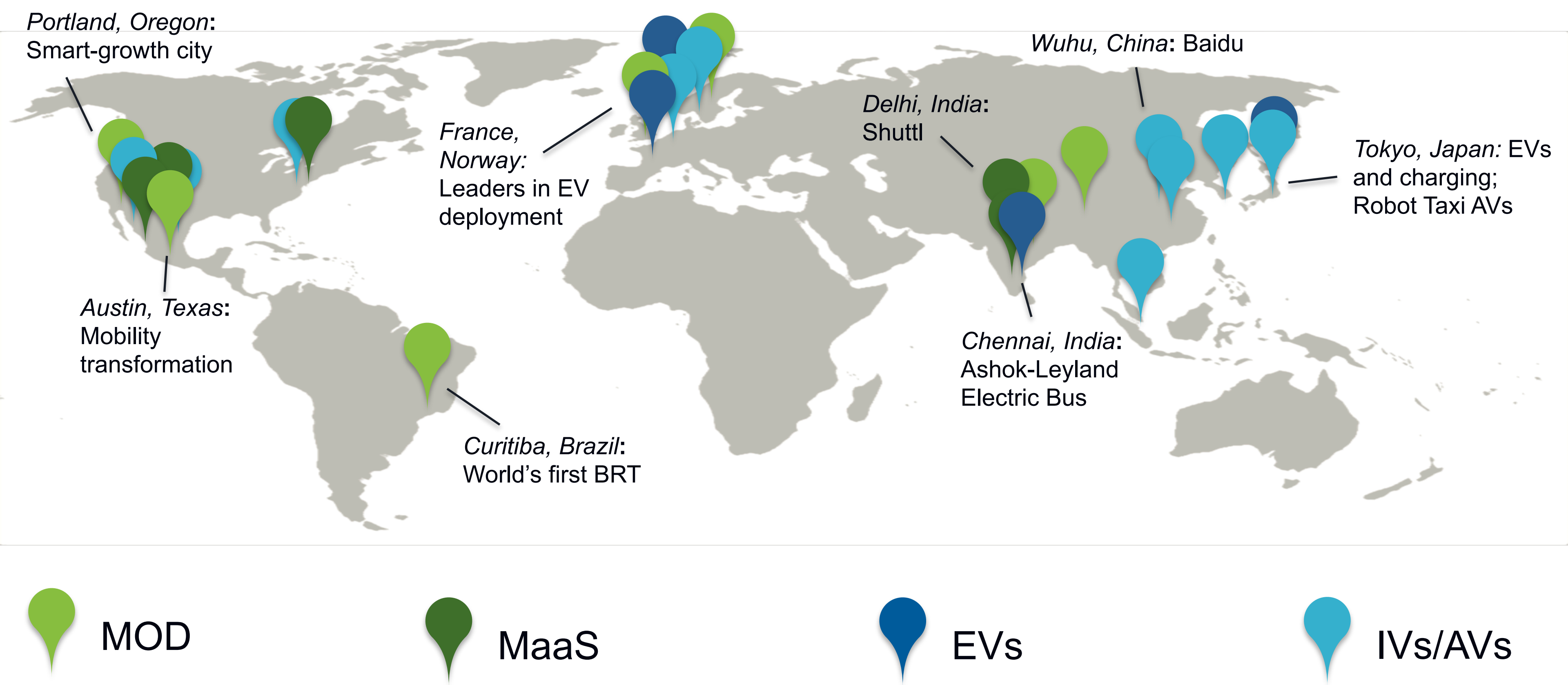
MANAGING MOBILITY DEMAND THROUGH WELL-PLANNED URBAN SPACES LEADS TO COST REDUCTION

AFTER REDUCING DEMAND, OPTIMIZING SUPPLY WITH CLEANER, SERVICE-ORIENTED, PURPOSE-DESIGNED VEHICLES FURTHER DRIVES DOWN COSTS WHILE ENHANCING USER EXPERIENCE

Action	Approach	Result
Mobility-Oriented Development Careful planning of residential, commercial, and industrial spaces to create node-and-hub-based development and transit corridors.	**Manage demand first**	Travel distances are reduced for citizens, increasing the viability of walking and biking as transit method. Infrastructure cost is reduced through careful planning.
Maas Deployment Accessible and affordable public transit or mobility as a service (MaaS) options.	**Then switch modes**	The majority of transit demand not met by walking/biking is met by public transit, with MaaS assisting in the rest.
Electric Vehicles Electrification of vehicle technology and shift towards efficient, advanced vehicle designs.	**And power the remaining demand cleanly and efficiently**	Reduction in remaining energy needs and criteria pollutants of vehicles.
Intelligent and potentially autonomous vehicles Driver assistance and potentially full autonomy.	**Optimize and enhance services using IT**	Optimization of vehicle use resulting in lower congestion and energy use. Also enhances transportation safety.

PARTS OF THE MOBILITY PUZZLE ARE EMERGING BUT HAVE YET TO BE ASSEMBLED IN A SINGLE GEOGRAPHY

INDIA COULD IMPLEMENT THESE SOLUTIONS AT SCALE TO LEAPFROG TO THE LEADING EDGE OF GLOBAL MOBILITY TRANSFORMATION



MaaS—Mobility as a service; MOD—Mobility-oriented development; EVs—Electric vehicles, IVs—Intelligent vehicles; AVs—Autonomous vehicles

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EXPERTS BELIEVE INDIA CAN LEAPFROG TO AN ALTERNATIVE, SUSTAINABLE MOBILITY FUTURE

The Indian EXPRESS

Minister Nitin Gadkari
"Road safety is the highest priority for our government because every year 500,000 accidents happen causing 150,000 deaths... We have 96,000 km of road length as national highway and 40 percent of our national traffic is on just two percent of this road—one of the reasons of accidents on the national highway."

McKinsey & Company
How to win at leapfrog

Vinod Khosla
"In a linear model, you might presume that if there are 80 cars per 100 people in the United States, then that's where India will end up and begin to plan for that.... I would look for ways to anticipate and skip what exists today while trying to lean in the right direction. I would consider the possibility that for the world in 2025, self-driving cars will be wide-spread."

THE ECONOMIC TIMES

Minister Piyush Goyal
"India can become the first country of its size which will run 100 per cent of electric vehicles. We are trying to make this programme self financing. We don't need one rupee support from the government. We don't need one rupee investment from the people of India."

The New York Times
No, No, No, Don't Follow Us

Thomas L. Friedman
"Cheap conventional four-wheel cars, which would encourage millions of Indians to give up their two-wheel motor scooters and three-wheel motorized rickshaws, could overwhelm India's already strained road system, increase its dependence on imported oil and gridlock the country's megacities."

RStv RAJYA SABHA

Rural Connectivity Top Priority

Minister Nitin Gadkari
"...road projects to create 1.5 million jobs in rural India. Pradhan Mantri Gram Sadak Yojana must get additional allocation to fast track rural road construction. It requires more money and the situation is not good."

INDIA'S UNIQUE POSITION PUTS IT IN AN EXCELLENT POSITION TO LEAPFROG TO THE NEXT MOBILITY PARADIGM

THIS COULD CATAPULT INDIA TO A LEADERSHIP POSITION IN THE WORLD OF TECHNOLOGY, INNOVATION, AND MANUFACTURING

Ability to "build right" the first time

By 2030, India is expected to build:

- 800 million sq. ft. of commercial and residential space
- 7,400 km of metros and subways
- 2 billion km of roads
- 500 GW of additional power capacity with ~250 GW coming from RE sources[2]

Strong public and private sector leadership

Indian public and private sector leadership is aligned around the need to deliver a transformative mobility vision.

Confluence of IT and manufacturing prowess

Major Indian auto companies, including Tata and Mahindra, bring decades of manufacturing and IT expertise that can make advanced vehicles a primary Indian product.

Complementarity between existing programs

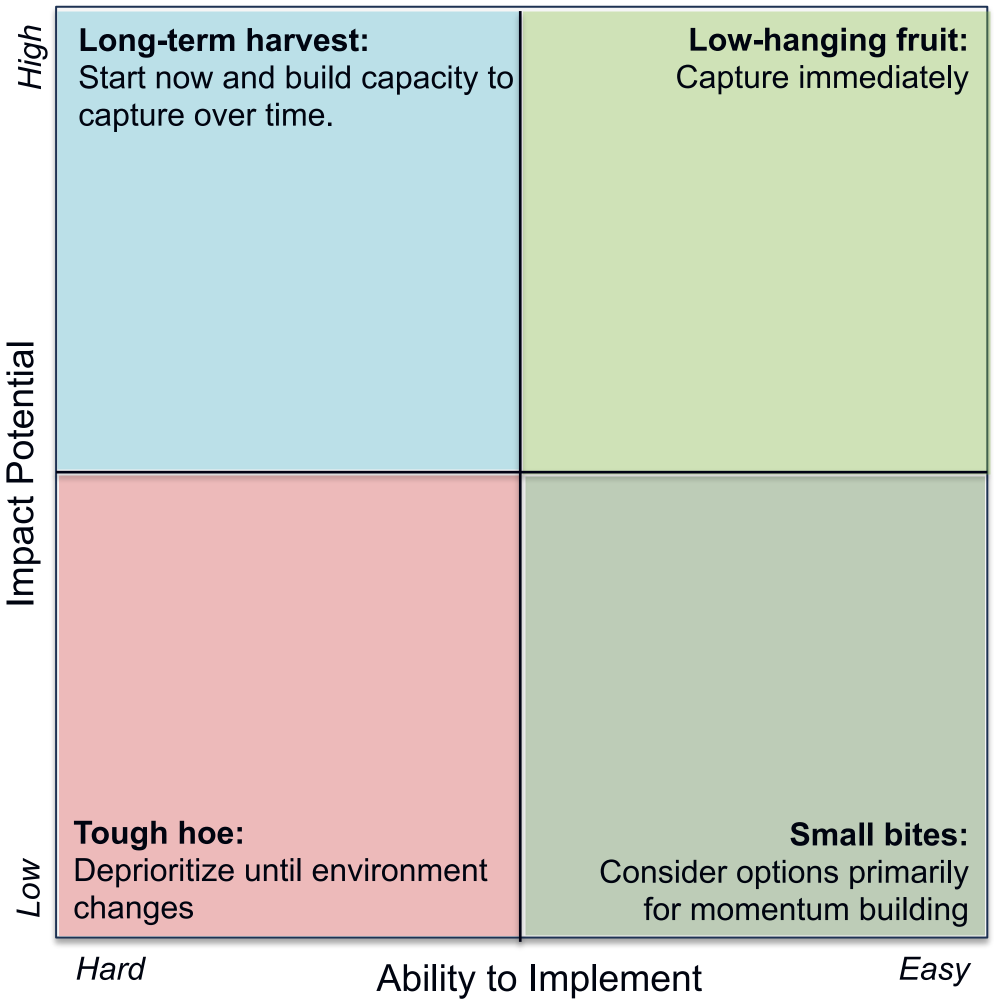
Existing programs support a new mobility paradigm:

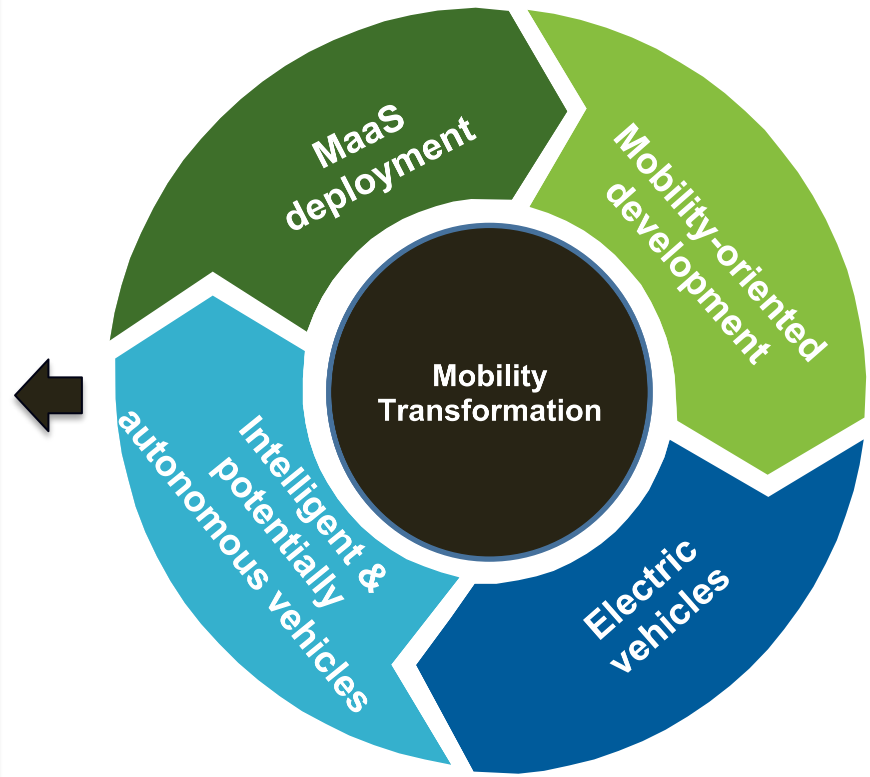
- Make in India
- Digital India
- FAME
- Smart Cities Initiative

[2] McKinsey

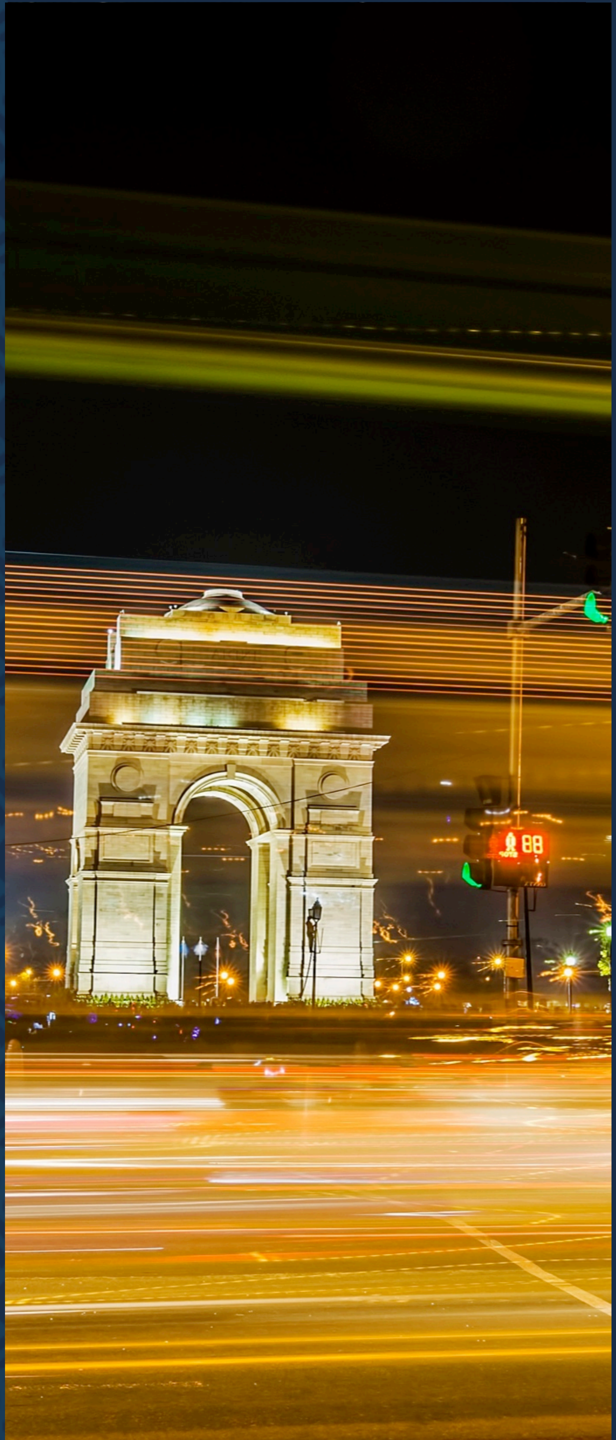
WHAT IS THE IMPACT AND FEASIBILITY FOR EACH OF THESE LEVERS?

HOW BEST TO CHARACTERIZE AND COMBINE THESE ELEMENTS IN INDIA IS A FOCAL POINT OF THE CHARRETTE — AND KEY TO JUMPSTARTING INDIA'S MOBILITY TRANSFORMATION





What other levers could potentially be deployed?



CASE STUDIES:

1. MOBILITY-ORIENTED DEVELOPMENT
2. MOBILITY AS A SERVICE
3. ELECTRIC VEHICLES
4. VEHICLE-GRID INTEGRATION
5. ELECTRIC VEHICLE MANUFACTURING
6. INTELLIGENT AND AUTONOMOUS VEHICLES
7. INTEROPERABLE TRANSIT DATA

MOBILITY-ORIENTED DEVELOPMENT CREATES VIBRANT AND EFFICIENT CITIES

DESIGNING CITIES TO ENCOURAGE THE EFFICIENT FLOW OF PEOPLE AND GOODS

Mobility-oriented development (MOD) counters growing urban sprawl and private vehicle use by creating "attractive and live-able," "high-density, mixed-use urban environments with easy access to mass transit."[3]

MOD results in reduced transportation costs, boosts to economic development, and freedom of mobility. GHG emissions, energy consumption, noise, and air pollution also decrease.[4]

Infrastructure Development

- Mixed-use: Implement appropriate and non-segregated mix of residential, commercial, and industrial zoning
- Locate high-density environments along transportation corridors
- Effectively match density and transit capacity
- Place transit centers at centralized locations provide efficient mobility with seamless mode changes
- Increase outlying connectivity with feeder lines

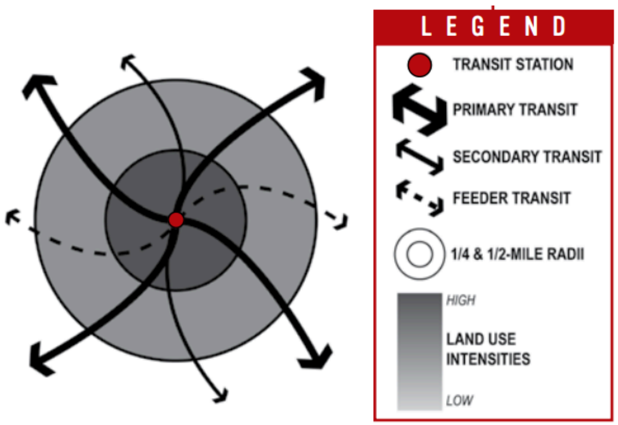


Image courtesy of Reconnecting America

Multi-modal Transit

Non-motorized transit (NMT) is a choice, not a "mandate" with MOD

- Use dense street networks to promote NMT, while still moving vehicle traffic
- Emphasize safety and convenience for pedestrians and bikes
- Promote efficient transit services within walking distance of residential, commercial, and industry
- Emphasize ground level and easily accessible activity
- Regulate parking/road use to decrease congestion and promote public transit

[3] MRSC.org, Sustainable Development and Smart Growth; McKinsey & Company, "Urban Mobility at a Tipping Point," 2015.
[4] EPA, Smart Growth.

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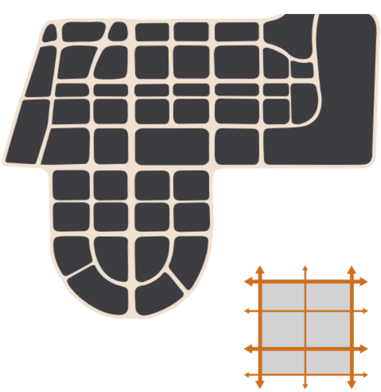
CITIES ADOPTING PROGRESSIVE DESIGN SEE HIGHER USE OF PUBLIC AND NON-MOTORIZED TRANSIT, CLEANER AIR, AND HIGHER ECONOMIC ACTIVITY

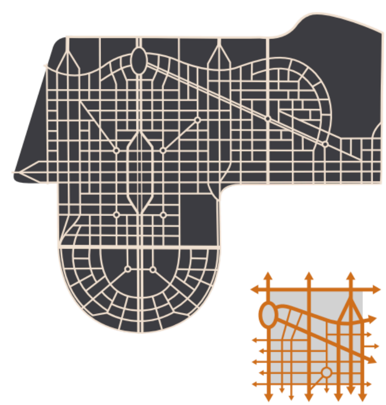
PORTLAND, OREGON, ENACTED POLICIES TO PREVENT SPRAWL AND BALANCE THE DEVELOPMENT OF PUBLIC AND PRIVATE TRANSPORT INFRASTRUCTURE

Infrastructure Development	• Light rail project replaces a freeway project (1976) • Urban Growth Boundary (1973) mandates high-density development inside a boundary
Multi-modal Transit	A "Metro Council" that oversees land use and transportation promotes MOD (established 1979) "The purpose of Metro's Transit-Oriented Development and Centers Program is to create public-private partnerships that produce transit-oriented development projects and vibrant, compact urban centers in order to increase travel by transit, walking and biking."[5]
Results[6*]	• 20% fewer miles traveled each day • Work commute: 2x as likely to use transit, 7x more likely to use bike • $1.1 billion in transportation costs saved yearly and $1.5 billion saved in time yearly (estimated at 100 million hours)



Business-as-Usual

Arterial: **freeways** and **super blocks** are **inefficient**, leading to **congestion**



Mobility-Oriented

Capillary: **smaller blocks** and **narrow streets** move people

Images courtesy of Calthorpe Associates

[5] Gibb, Megan, "Transit Oriented Development in the Portland Metro Area."
[6] Ibid.; Cortright, Joe, "Portland's Green Dividend", 2007.
* Compared to average U.S. metropolitan resident. Estimates based on 2 million residents, cost of driving at $0.40 per mile, fuel at $3 per gallon, 20 mpg fleet average.

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BARRIERS AND SOLUTIONS

	Barriers	Potential Solutions
REGULATORY	• Current zoning laws encourage private vehicle use and sprawl.	• Leverage existing programs, including the Smart Cities Initiative. • Update zoning laws for mixed use areas. • Discourage private vehicle use with parking laws, HOV policy, and carpool incentives.
INFRASTRUCTURE	• Limited availability, low efficiency, and poor integration of public transit, intermediate public transit, and first- and last-mile solutions.	• Develop transportation services to match demand. • Invest in pedestrian spaces and access to transit centers. • Unify land use and transportation planning.
FINANCIAL	• Upfront costs and perceived risk can limit MOD acceptance.	• Promote awareness that MOD reduces transportation costs and can increase economic activity. • Provide designated funding for MOD.
SOCIAL	• Fear of gentrification and disruption of low-income areas.	• Develop with equity in mind. • Focus on moving people through MOD to reduce transit costs and replace expensive private vehicle ownership. • Make affordable by design, not subsidy.[7]
PLANNING AND IMPLEMENTATION	• Minimal institutional capacity cannot oversee plans. • Poor implementation due to inadequate planning, coordination, and oversight among participating parties.	• Augment capacities in local governments and avoid scaling without adequate resources. • Increase communication and develop committees that coordinate land use and transit integration. • Avoid property development purely for monetary return.[8]

[7] Better Cities and Towns, "Overcoming barriers to transit-oriented development," 2013.
[8] Parsons Brinckerhoff, "Transit-oriented development: Applying best practice in Auckland," 2012.

IT'S ABOUT MOVING PEOPLE, NOT VEHICLES

- Optimized, on-demand transportation facilitated by IT-enabled systems and provided by both public and private modes of transportation
- Hassle-free and environmentally sound alternative to private vehicle ownership
- "It makes worries about route planning, parking, and car maintenance a thing of the past, helping people go places easier and more efficiently than ever before"[9]

On-demand & Ride-Sharing Services

- Digital ride-hailing companies for connecting customers to a pool of drivers around the customer's location
- Wide variety of choice for customers for instant short distance travel to long planned travel with different types of vehicle and ride-sharing option

Public Transportation

- Service provided by public or private agencies that is available to people paying the prescribed fare (set rate or pay-by-the-distance)

Informal & Intermediate Transportation

- Regulated or unregulated services that lie outside the ambit of public transportation agencies[10]
- Emerged due to unavailability of adequate public transport systems

[9] MaaS Finland, "Mobility-as-a-Service (MaaS) launches first on-demand mobility service in Finland," *TELEMATICS WIRE*, February 10 2016.
[10] Meghanoe, Kumar, "Informal Public Transport Modes in India : A case study of five city regions," *International Association of Traffic and Safety Science,* January 14, 2016.

ADVANTAGES OF DIFFERENT COMPONENTS OF MAAS ARE OBSERVED IN MANY COUNTRIES ALL OVER THE WORLD

On-demand & Ride-sharing Services

On-Demand and Ride-sharing Services: New York City[11]

- For taxis and shared-vehicle fleets with passenger capacities of up to ten, 3,000 ride-sharing vehicles can do the same job of the existing 14,000 taxis if each accepted up to four passengers.
- 2,000 vehicles (15% of the taxi fleet) of capacity 10 or 3,000 of capacity 4 can serve 98% of the demand within a mean waiting time of 2.8 min and mean trip delay of 3.5 min.

Public Transportation

Bus Rapid Transit : Rio De Janeiro[12]

Rio de Janeiro implemented a multi-year plan to upgrade city infrastructure based on smart-growth principles. Two notable projects include:

- Bus Rapid Transit (BRT): located along the most densely populated areas, serving 9 million people and saving 7.7 million man hours every month. 47% of the population has easy access to the BRT. It has reported a 38% reduction in transportation-related CO_2 emissions.
- Teleferico de Alemão connects Rio's difficult-to-access, low-income communities—providing easy access to jobs and health services.

Informal & Intermediate Transportation

Informal Minibus Transport in Hong Kong[13]

- In Hong Kong, informal minibus operators (neither licensed nor insured for transit operations) began circulating illegally in the 1960s and competed directly with other formal transit services.
- A strike by formal transit workers in 1967 brought the informal operators into consideration by regulators as a useful component of a comprehensive transit system.
- The minibus system has since been "formalized" through a set of rules, allowing the operators to purchase licenses for operation and undergo inspections, etc.

[11] Poon, Linda, 17, "Can Sharing Rides Cut NYC's Fleet of 14,000 Taxis to 3,000?," *The Atlantic CITYLAB,* Jan 4, 2017.
[12] WRI, 4 Inspirations for Sustainable Transport from Rio de Janeiro, 2015.
[13] Cervero, Robert, and Aaron Golub. "Informal Transport: A Global Perspective." *Transport Policy* 14.6 (2007): 445-457.

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BARRIERS AND SOLUTIONS

	Barriers	Potential Solutions
REGULATORY	• Old/unregistered vehicles under informal transit operate without licenses	• Build strategic partnerships across the public and private sectors for planned integration of transit options and data sharing.
INFRASTRUCTURE	• Weak/non-existent public transportation in some locations (especially small cities/ villages) • Uncoordinated, or limited first- and last-mile mobility options • Congested buses and roads	• Improve mass transit through increased capacity, efficient route planning. • Explore dedicated lanes for public transit. • Improve urban design by integrating land use and transport to supply-side management. • Favor adaptable routes over fixed routes to increase the flexibility, accessibility, and convenience of the service.
FINANCIAL	• Lack of public-private financing models for supporting MaaS	• Leverage taxes and payments for building permission to create infrastructure for public parking lots connected to public and personal transport.
SOCIAL	• Social status associated with private vehicle ownership • No technical standards to ensure safety of passengers for informal transit	• Utilize advertising and communications to drive the shift from ownership to "usership." • Build infrastructure for passenger pickup and drop-off at major hubs.
TECHNOLOGY	• Planning, booking, and payment features are not aggregated in a single app, reducing convenience • Lack of standardized fare generation • Low penetration of smartphones or cellular network	• Simplify public transit fares. • Ubiquitous data gathering: vehicle speed, location, estimated time of arrival, costs, etc.

POTENTIAL BENEFITS AND IMPLEMENTATION STRATEGY

Benefits

Consumer	City and State	Mobility Service Providers/Traffic Operators/Other Companies
Optimized route planning and reliable transportation[14]	Reduction in vehicle idle time and number of vehicles on road reduces pollution and congestion	Better public/private coordination
Easy access based on diverse needs[15]	88% reduction in GHG emissions if everyone shifts to on-demand service[17]	Increased profits through high-volume, ecosystem benefits
"Ditch your car, and you save enough money every year to afford up to 882 UberX rides per year."[16]	Reduced personal vehicle ownership	Platform to integrate service and innovate new mobility services

Potential Implementation Phasing

Stage 1:

Retrofit and expand current mobility solutions

Increase capacity of public transportation and integrate informal transit options.

Improve existing technologies and penetration among people in cities to enable on-demand services.

Stage 2:

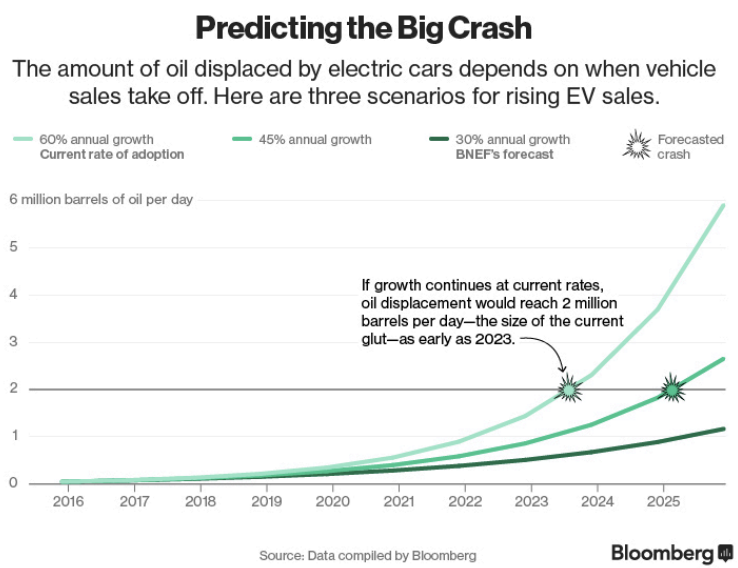
Integrate different modes of transport

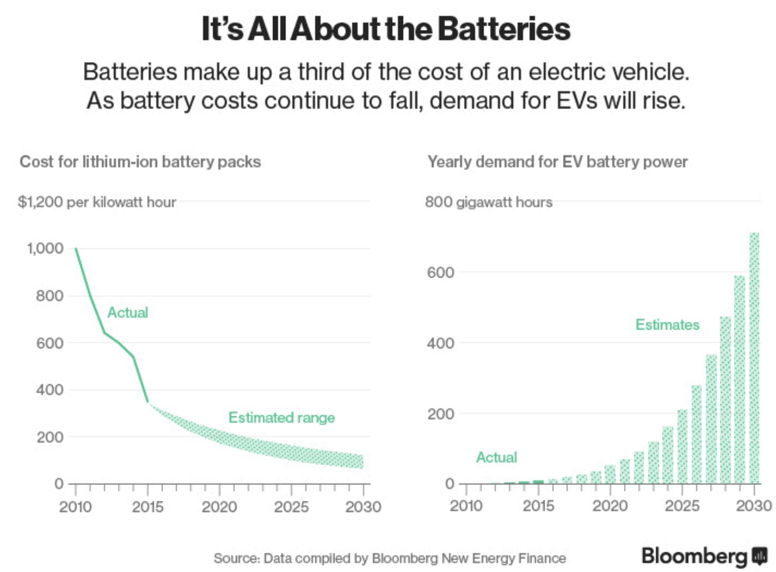
Appoint single regional authority to manage all aspects of transport, including parking, on-demand services such as car-sharing and bike-sharing, goods movement, and trip reduction.[18]

[14] Carlin, Kelly, Bodhi Rader, and Greg Rucks, *Interoperable Transit Data: Enabling a Shift to Mobility as a Service,* Rocky Mountain Institute, October 2015.
[15] Rajagopal, Deepak, "Life Cycle Analysis: Uber vs. Car Ownership," *Environment* 159, June 2, 2016.
[16] Uber Newsroom, "How Do Car Ownership Costs Compare to Using Uber?" March 4, 2013.
[17] Hietanen, Sampo and Sami Sahala, *Mobility as a Service: Can it be better than owning a car?,* Forum Virium Helsinki. |[18] World Economic Forum, *A Field guide to the Future of Mobility,* January 2016

ELECTRONS ARE THE NEW TRANSPORTATION FUEL

GLOBAL DEMAND FOR ELECTRIC VEHICLES (EVS) IS RISING, WITH A 60% GROWTH RATE IN 2015, AS BATTERY COSTS FELL >60% IN 6 YEARS — CALLING INTO QUESTION OIL'S FUTURE





Purpose Design Vehicles

- Designing the "right vehicle for the right task," with appropriate size and range, reduces cost while improving mobility services.

Electric Service Vehicles

- High-mileage electric service vehicles benefit from lower operating costs, saving over $4,000 per year by 2030.

Electric Fleet Vehicles and Buses

- With 80% of all trips less than 5 km in India, electric fleet vehicles and public buses can reduce private vehicle growth and emissions.[21]

[19] BNEF, "Here's How Electric Cars Will Cause the Next Oil Crisis," February 2016. (Left chart)

[20] Ibid; Kooroshy, et al., Goldman Sachs, "The Low Carbon Economy," November 2015. (Right chart)

[21] *The Economic Times*, "India Aims to Become 100% E-Vehicle Nation by 2030," March 2016.

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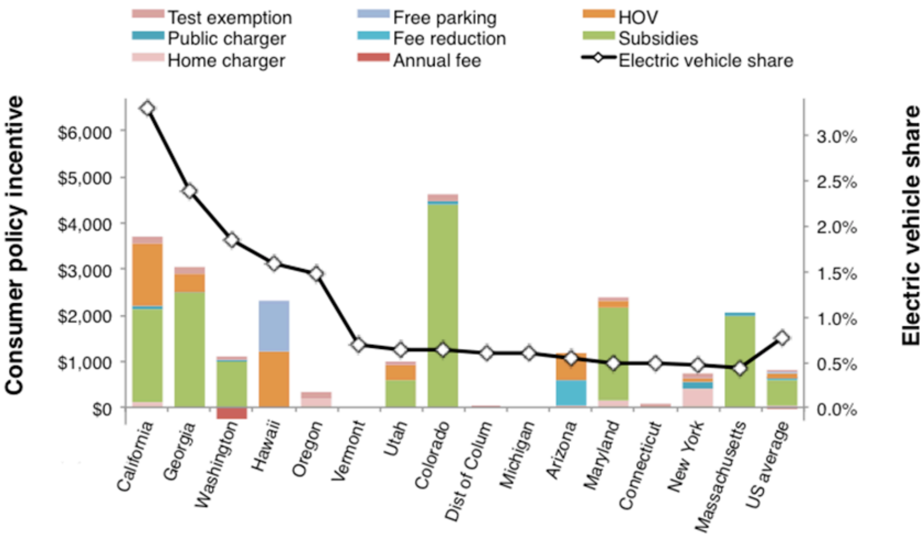
EV ADOPTION IS ACCELERATING GLOBALLY AS COSTS DECLINE AND CONSUMER DEMAND SHIFTS



<u>Purpose Design Vehicles: Munich, Germany</u>

- BMW's i3 is a lightweight, medium-range battery-electric vehicle (BEV) selling in the U.S., Europe, and other vehicle markets around the world.
- Its carbon-fiber frame; hard, narrow tires; and aerodynamic body reduce weight, rolling resistance, and drag, respectively, reducing battery size (and thus cost), making it a premiere EV for urban driving.

<u>Electric Service Vehicles: London, England</u>

- Uber put 50 EVs on the streets of London in the summer of 2016, working with OEMs Nissan and BYD to offer leasing options for LEAFs and E6s to its drivers at below-market rates.[22]
- Uber expects to increase this number and expand to other geographies in 2017, encouraging drivers to take advantage of EVs' low operating costs, which offset their capital cost premium and can produce over $1,000 in annual savings by 2018 and over $4,000 by 2030.[23]

<u>Electric Fleet Vehicles and Buses: Norway and Rio de Janiero, Brazil</u>

- Norway, in addition to a "feebate" program and extensive non-fiscal incentives, including road-toll exemption and bus-lane access, also offers incentives for company-owned EVs—together pushing adoption over 25% in 2016.[24]
- A bi-articulated electric bus, the Volvo Gran Artic 300, will run a 14-mile BRT route, with a carrying capacity of over 50,000 passengers per hour and an average speed of 35 km/h.

[22] *The Telegraph*, "Uber Unveils a Fleet of Electric Cars," August 2016.
[23] RMI, *Peak Car Ownership*, September 2016.
[24] EIA, *Global EV Outlook 2016*, November 2015.

BARRIERS AND SOLUTIONS

INCENTIVES AND INFRASTRUCTURE ARE WHERE THE RUBBER HITS THE ROAD FOR EVS

	Barriers	Potential solutions
REGULATORY	• Infrastructure capacity for non-fiscal incentives • Prevalence of TOU pricing	• Give greater access to free parking and HOV lanes and exemption from road tolling.[25] • Lower off-peak electricity rates to manage charging loads.
INFRASTRUCTURE	• Growing demand for electric vehicle supply equipment (EVSE) • Congested streets and highways	• Grow public and private investment in EVSE, including R&D, manufacturing, and deployment. • Designate lanes for EVs, HOVs, and BRT.
FINANCIAL	• Capital cost premium • Battery replacement cost	• Provide feebate, VAT or purchase tax exemption, additional subsidies, or discounted electricity.[26] • Implement battery leasing or battery-swapping facilities.
SOCIAL	• Range anxiety • Safety concerns	• Provide EVSE investment and petroleum range extenders. • Implement public education campaigns.
TECHNOLOGY	• Expensive lithium-ion batteries • Competing vehicle-grid designs	• Lower import tariffs through trade negotiations. • Implement a standardization process for V1G and V2G technology.

[25] Exemption from road tolling is 3rd most influential, and most critical non-fiscal, factor in incentivizing BEV purchase in Norway (Bjerkan et al., 2016).

[26] Bjerkan et al. (2016) show that 84% of BEV owners find VAT and purchase tax exemption sufficient fiscal incentives.; Data compiled by RMI show that electricity's cost per mile is 30–70% lower than petroleum's cost per mile.

POTENTIAL IMPLICATIONS AND IMPLEMENTATION FOR INDIA

INDIA CAN SCALE UP EV ADOPTION QUICKLY IN FLEETS AND PUBLIC TRANSIT, POTENTIALLY FUELING RENEWABLE ENERGY GROWTH AND MANUFACTURING LEADERSHIP

Benefits

Oil Independence	Cleaner Air	Manufacturing and IT Leadership
Reduce ~$100 billion annual oil import bill	Reduce emissions, regardless of source	Expand EV offerings to a global market
Indirectly reduce India's fiscal deficit	Support renewable energy penetration	Develop battery, EVSE, and EV-grid expertise

Potential Implementation Phasing

Stage 1:
Service vehicles as an entry point

Require EVs for all *new* fleet and/or service vehicles, including public transit.

All public transportation hubs should have fast-charging infrastructure.

Provide robust non-fiscal incentives (e.g., free parking, HOV-lane access, and free toll-road access).

LEAPFROG
Stage 2:
Robust incentives for private EVs

Institute a "feebate"—the charge-reward scheme for vehicle efficiency used in Norway.

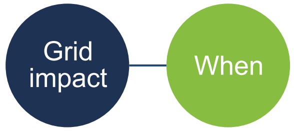
Grow public-private investment in charging infrastructure and grid improvements.

Mandate EVs for all drivers on a 2W learners' license.

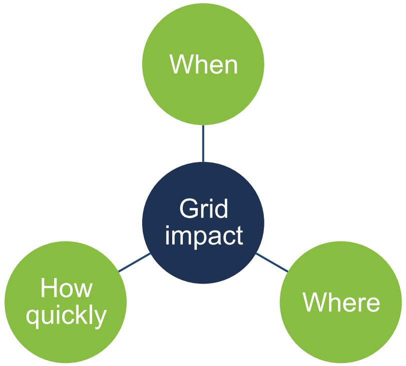
EVS ARE "BATTERIES ON WHEELS"—ADDITIONAL LOADS AND A GRID SERVICES OPPORTUNITY

- **Vehicle-grid integration:** How EVs provide grid services, including charge management (i.e., timing and capacity control) and bidirectional interaction (i.e., charging *vs.* discharging)[27]
- **Vehicle-grid (V1G):** Unidirectional electricity flow between 1 resource and 1+ actors[28]
- **Vehicle-to-grid (V2G):** Bidirectional electricity flow between multiple resources and actors, informed by real-time grid conditions[29]

"Smart" charging controls *when* EVs charge



"Bidirectional" charging controls *when*, *where*, and *how quickly* EVs charge



Smart Charging and Flexible Loads

- Optimizing EV charging can reduce peak-demand increases and help flatten load profiles.

Renewable Energy Integration

- EVs are "batteries on wheels," capable of reducing renewable energy curtailment.

Flexible Loads and Ancillary Services

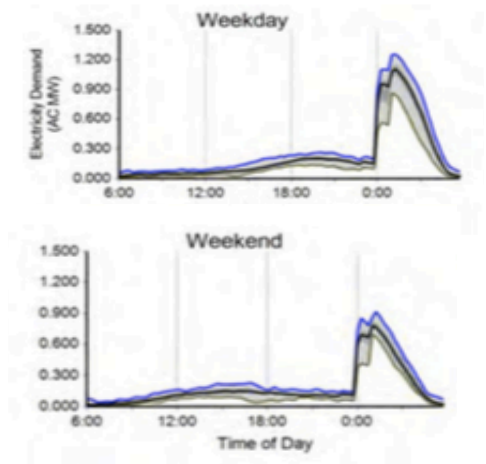
- Renewable energy penetration creates a greater need for ancillary services, which EVs can provide.

[27] T. Markel, *Electric Vehicle Grid Integration*, NREL, Jun 2015.
[28] California ISO, *Vehicle-Grid Integration Roadmap*, Feb 2014.
[29] Ibid.

VGI CAN ENABLE RENEWABLE ENERGY INTEGRATION AND OFFER VALUABLE GRID SERVICES

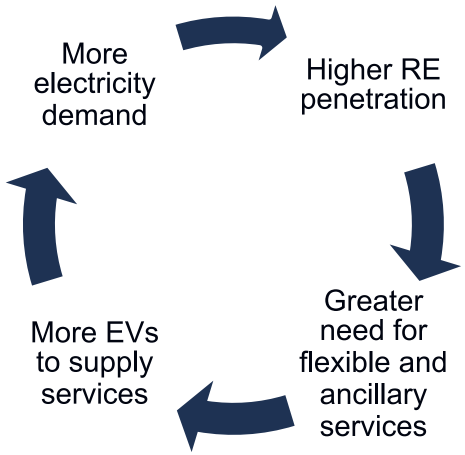
Smart Charging: California, U.S., and Japan

- In San Diego, California lower off-peak rates limit EV charging during peak-demand, shifting about 80% of EV charging to 00:00–05:00.[30]
- Nashville, Tennessee doesn't have TOU pricing, causing charging to distribute throughout the day and concentrate around peak load.
- Japan—after investing $1 billion, subsidizing electricity, and rolling out TOU pricing—has over 40,000 charging points, more numerous than gas stations.



Renewable Energy Integration: Texas, U.S.

- Simulations using the ERCOT grid in Texas show that EV batteries can provide over two times the renewable energy curtailment of the next best flexible load.[31]
- This curtailment reduction enhances renewable energy's value by 36% from $8.70/MWh to $11.80/MWh.



Flexible Loads and Ancillary Services: Hawaii, U.S.

- Flexible loads enable customers to consume over 80% of solar PV generation onsite, compared to about 50% without such flexible loads as EV batteries and smart appliances.[32]
- EVs, in addition to serving as flexible loads, can provide valuable ancillary services, which account for 5–10% of U.S. electricity cost and represent an approximately $12 billion U.S. market.[33]

[30] RAP, ICCT, and M.J. Bradley & Associates, "Electric Vehicle Integration in the U.S., Europe, and China," July 2013.
[31] RMI Internal analysis.
[32] Dyson et al., *The Economics of Load Flexibility*, RMI, August 2015.
[33] RAP et al., "Electric Vehicle Integration in the U.S., Europe, and China," 2013.

BARRIERS AND SOLUTIONS

VGI CAN SPEED EV ADOPTION AND SUPPORT ELECTRICITY-SECTOR DEVELOPMENT

	Barriers	Potential solutions
REGULATORY	• Regulated electricity markets • Market and rate design	• Allow non-generators to bid competitively. • Implement pricing tariffs that include time-of-use components.
INFRASTRUCTURE	• Substandard distribution transformers • Energy metering equipment • Generation capacity constraints	• Create voltage standards for EVs and EVSE • Grow public-private investment in distribution infrastructure and net energy metering equipment. • Load pocket avoidance and renewable microgrid deployment
FINANCIAL	• Capital cost of residential, commercial, and fast chargers	• Grow public-private investment in EVSE and partnerships to reduce upfront charger costs.
SOCIAL	• Range anxiety • Grid reliability	• Increase EVSE investment and promote petroleum range extenders. • Encourage flexible loads.
TECHNOLOGY	• EV and EVSE competition • Real-time grid communications • Payment options	• Increase EV and EVSE R&D funding and create standards for OEMs. • Use charging infrastructure management systems (CMS). • Utilize RFID pre-paid card readers.

POTENTIAL IMPLICATIONS AND IMPLEMENTATION FOR INDIA

VGI CAN FACILITATE THE RAPID DEPLOYMENT OF EVS AND RENEWABLE ENERGY IN INDIA

Benefits

Renewable Energy	Grid Services	Infrastructure
Batteries supports India's renewable energy goals	VGI enables EVs to provide flexible loads and ancillary services	Encourages EVSE investment
EV charging reduces curtailment and increases value	Support renewable energy penetration	Charging networks reduce range anxiety

Potential Implementation Phasing

Stage 1:

Deploy BEVs and EVSE and design smart charging

Support BEV adoption through incentives and EVSE investment.

Design TOU rates that enable smart charging.

LEAPFROG Stage 2:

Transition to bidirectional charging

Standardize technology.

Develop real-time grid communication network.

Launch bidirectional charging pilots.

ELECTRIC VEHICLE MANUFACTURING

ELECTRIC VEHICLES ARE COMING AND INDIA IS TAKING STEPS TO MANUFACTURE THEM LOCALLY

As a nascent technology experiencing exponential growth, EVs present a significant economic opportunity.

India is taking steps to locally manufacture EVs in all segments (2, 3, & 4 wheel).[34]

- The automotive industry is expected to be a main driver in the "Make in India" campaign. Projections suggest India will be the 3rd largest automotive market by volume in 2026.
- The National Electric Mobility Missions Plan 2020 (NEMMP) encourages hybrid and EV production in India. Goals include deploying 5–7 million hybrids/EVs on the road by 2020.
- FAME (Faster Adoption and Manufacturing of Hybrid and EV) incorporates technology development, demand incentives, and charging infrastructure development.
- India has also floated ambitions to manufacture and export EV batteries to the rest of the world.

Manufacturing EVs

Incumbent automakers are well positioned to switch to EVs as they have existing scale, branding, supply chains, and capital.[35]

- Automakers and suppliers must build new facilities and retool/expand current manufacturing.

Battery Technology

"Batteries . . . have been identified as the key technological challenge to be overcome in the successful development of the EV industry . . ."

- R&D and economy of scale are required to lower costs and drive EV adoption.
- Raw materials must be sourced.

Policy, Infrastructure, Market

Policy and infrastructure will increase demand for EVs by lowering costs without sacrificing convenience.

- Emission regulations.
- Tax incentives.
- MOD development supportive of EV use (charging stations).
- Domestic market size (aided by policy and infrastructure) will promote adoption.

[34] Make in India, http://www.makeinindia.com/sector/automobiles.
[35] International Economic Development Council, "Creating the Clean Energy Economy: Analysis of the Electric Vehicle Industry," 2013

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ROCKY MOUNTAIN INSTITUTE

DEVELOPING THE EV INDUSTRY IN CHINA

CHINA EXPERIENCES HIGH LEVELS OF AIR POLLUTION FROM TRANSPORTATION AND IS A NET OIL IMPORTER (2015). CHINA RECOGNIZED EVS FOR THEIR POTENTIAL IN A LARGE DOMESTIC MARKET.

Manufacturing EVs & Battery Technology

Starting in 2001, China implemented policy to pursue hybrid/electric and fuel cell vehicles and concurrently developed "multi-source energy power control unit (PCU), drive motor system, and battery and battery management system (BMS)."[36]

Plug-in hybrid electric vehicles (PHEV) matured first, followed by BEV, both of which compete on the international stage.

Policy, Infrastructure, Market

- Government acted as the main initiator/driver/investor of R&D, pilot programs, production scaling, and infrastructure development during early stages to help private enterprise manage high levels of risk. Shenzhen—a city with more than 15 million inhabitants—will provide as much as $800 million in government funding to spur demand for electric vehicles. The government aims to replace its entire bus and taxi fleet with hybrids and EVs in 5 years.
- There was communication and alignment among government agencies and private enterprise, especially during transfers of office. This long-term and complex transition requires continued coordination.
- Subsidies are scheduled to be removed to allow the market to play a role.

[36] Innovation Policy Platform, "System Innovation: Case Studies, CHINA – The Case of Electric Vehicles"

BARRIERS AND SOLUTIONS

	Barriers	Potential Solutions
REGULATORY	• Import taxes on lithium-ion batteries and other components • Value added tax varies by location	• Goods and Services Tax (GST) will help harmonize Value-added Tax reductions to decrease ambiguity. • Provide additional incentives and subsidies.
INFRASTRUCTURE	• Limited domestic supply chain and manufacturing • Battery technology	• Increase charging infrastructure for EV deployment. • Pursue component and battery R&D, or establish partners to develop advanced and affordable parts. • Ensure battery and charging station standardization. • Capitalize on manufacturing and IT strength.
FINANCIAL	• Costly R&D is required to advance battery technology and develop purpose-designed vehicles	• Continue government support to accelerate India as R&D and manufacturing center. • Phase out subsidies—allow market-driven development to prevent over-capacity and poor product.
SOCIAL	• High initial price and low resale value • Low fuel costs • Performance gap between EV and ICE	• Deploy business models for battery leasing to lower prices and abate resale concerns (e.g., Mahindra e2o in Bhutan). • Improve battery efficiency and charging infrastructure.
PLANNING AND IMPLEMENTATION	• Uncoordinated planning and implementation	• Policy integration and infrastructure development will create stability and develop the market.

POTENTIAL BENEFITS AND IMPLEMENTATION STRATEGY

FACILITATE DEPLOYMENT, INVITE COMPETITION, AND REGULATE THE MARKET WHILE INCRASING RENEWABLE ENERGY PENETRATION

	Renewable Energy	Infrastructure	Battery Development/ Procurement
Action	• Manufacturing and electrification will increase demand.	• Retool existing and develop new manufacturing facilities. • Build wide-scale community charging stations.	• Source or build efficient and affordable batteries.
Benefit	• Demand is met with clean energy source to reduce emissions.	• EVs will provide reliable, consistent demand supporting grid expansion.	• India could export batteries worldwide.

Potential Implementation Phasing

Stage 1:

Deploy hybrids and EVs

Retrofit existing ICE vehicles

Component R&D + production

Source batteries

LEAPFROG Stage 2:

EVs designed for India and made in India

Component & battery R&D + production

EV pilot programs

Purpose-designed vehicles for local and global markets

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INTELLIGENT/AUTONOMOUS VEHICLES COULD ENHANCE ROAD SAFETY AND ELECTRIC SERVICE VEHICLE ECONOMICS

- 85% of Indian consumers would ride in fully self-driving cars, compared to 58% globally.[37]
- India has the highest willingness to use shared AVs (67%), according to the same survey; China (62%) is second.[38]
- Investments in shared mobility exceeded $10 billion in 2016; several OEMs made billion-dollar AV technology deals.[39]

	Level	Definition	Benefits	Enablers
IVs	1-2	Vehicles equipped with driver assistance (e.g., adaptive cruise control, lane-keeping), with humans monitoring the driving environment	• Road safety—forward collision warning systems reduce property damage liability claims by 14%	• Supply/demand side incentives and regulations • Infrastructure investment (e.g., clear lane markings)
AVs	3-5	Systems partially to fully responsible for driving and monitoring in a range of traffic conditions	• Road safety—Google has driven >3.2 million km without causing an accident • Improved MaaS and ride-sharing increase utilization and reduce congestion, with 40–270% higher road capacity • Efficient use, electrification, and purpose design can slash fuel use up to 81%	• Regulatory assistance • Private investment • High-utilization business models • IT, Internet of Things, data interoperability • Integration with NMT and public transit

Efficiency and High Utilization

- IVs and AVs improve efficiency and enable high-utilization business models, enhancing EV economics.

Mobility as a Service (MaaS)

- Automated mobility makes possible and cheaper the shift to mobility services.

Road Safety

- Intelligent features, like lane assist and automatic braking, reduce accidents, improving road safety.

[37] BCG and WEF, "Self-Driving Vehicles in an Urban Context," November 2015.
[38] Ibid.
[39] BNEF & McKinsey, An Integrated Report of the Future of Mobility, October 2016.

IVS ARE ALREADY ON THE ROAD AND SEVERAL AV PILOTS ARE UNDERWAY, WITH MORE ON THE HORIZON

China

- *Shanghai:* The Jiading District is identifying locations for pilots to test IV/AVs in 2017; similar scoping efforts are underway in Beijing.
- *Wuhu:* Baidu started testing BYD vehicles equipped with self-driving technology in 2016.

South Korea

- The government sees AVs as essential to the fifth-largest auto-producing country's economic future and is targeting Level-3 AVs by 2020.
- Hyundai is already testing semi-AVs in Seoul.

Japan

- *Tokyo:* The government is targeting commercialization of Level 2, 3, and 4 vehicles by 2017, early 2020s, and late 2020s, respectively; Robot Taxis aims to have 1,000 driverless vehicles on the road for the 2020 Olympics.

Singapore

- A pilot starting in 2015 is testing AVs in a limited area.
- The government is focusing on AV fleets, striving to reduce private car ownership and resolve first- and last-mile challenges.

Western Europe

- *Sweden:* In 2017 Volvo plans to test 100 driverless cars on public roads with ordinary passengers in Gothenburg.
- *Netherlands:* A six-truck driverless convoy traversed the country in 2016, arriving without accident.

U.S.

- *San Francisco, California:* GM, Google, and Ford are testing dozens of AVs; Tesla has over 70,000 EVs on the road with AV functionality.
- Similar pilots are underway in Austin, Texas, and Pittsburgh, Pennsylvania.

- BCG shows 8.3% and 54.9% penetration rates for AVs by 2030 and 2050;[40] BNEF & McKinsey suggest over 40% by 2030[41]
- U.S. automakers agreed in 2016 to standardize automatic braking, a component of IV design, by 2022[42]

[40] BCG, "Revolution *vs.* Regulation: The Make-or-Break Questions About Autonomous Vehicles," September 2015.

[41] BNEF & McKinsey, *An Integrated Report of the Future of Mobility*, October 2016.

[42] Brookings Institute, *Moving Forward: Self-Driving Vehicles*, September 2016.

BARRIERS AND SOLUTIONS

IVS/AVS HAVE TO CLEAR SIGNIFICANT SHORT-TERM HURDLES, YET OFFER CONSIDERABLE LONG-TERM BENEFITS THAT CAN LEVERAGE INDIA'S AUTO AND IT STRENGTHS

	Barriers	Potential solutions
REGULATORY	• No pathway for registration or intelligent/autonomous vehicles	• Grant public road-testing permission and develop a phased implementation strategy.
INFRASTRUCTURE	• Road congestion • Lack of road signage • Need for more road infrastructure	• Develop public road testing in carefully identified areas.
FINANCIAL	• High start-up costs • High-risk, high-reward market	• Increase government funding and/or private-sector leadership.
SOCIAL	• Job loss concerns • Road safety concerns	• Create customer service, management, and software jobs. • Develop public road testing in carefully identified areas.
TECHNOLOGY	• Nascent technology • Lack of on-road IT and communications systems	• Increase government R&D funding and/or IT-TNC-OEM collaboration. • Leverage existing government platforms

POTENTIAL IMPLICATIONS AND IMPLEMENTATION FOR INDIA

"IT IS NO LONGER A QUESTION OF IF BUT WHEN AVS WILL HIT THE ROAD." —BCG[43]

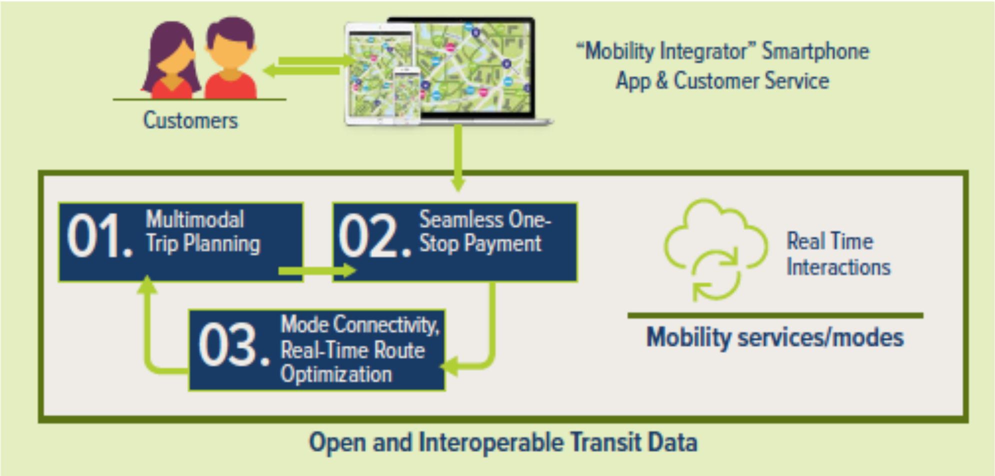
Benefits		
MaaS	**Efficiency and Economics**	**Technology**
Electrification and automation are a recipe for high-mileage electric service vehicle deployment	High-mileage electric service vehicles are more efficient and have lower operating costs than ICEs	Intelligence and automation are areas in which India can become a global leader in a nascent market

Potential Implementation Phasing	
Stage 1: **Add intelligent features into new vehicles** Incorporate adaptive cruise control, lane assistance, and automatic braking technology in most or all new EVs. Leverage domestic manufacturing and IT talent.	**LEAPFROG Stage 2:** **Pilot, then permit Level 3–5 AVs** Support public-private partnerships that develop and grow AV technology. Identify locations for preliminary AV pilots with Level 3 EVs. Test and deploy AVs on public roads with passengers.

[43] BCG, *Revolution in the Driver's Seat*, April 2015.

ITD PUTS MOBILITY IN THE PALMS OF RIDERS' HANDS—TAKING MAAS TO A NEW LEVEL

- Real-time, interconnected transit data, for both service providers and customers, to optimize trip planning and payment across multiple modes[44]
- Higher ridership, better user experience, and smarter transportation planning
- "People with access to real-time transit information have been shown to spend 15% less time waiting at bus stops than people without this information."[45]



Multi-modal Trip Planning

- ITD enables riders' cell phones to serve as personal travel planners, personalizing routes across modes and preferences.

Real-time Trip Optimization

- Routing around traffic, resolving breakdowns and congestion, and switching to faster or lower-cost modes are possible with ITD.

Seamless One-stop Payment

- Payment technology tracks riders along their routes, across modes, and handles parking and tolls, seamlessly tallying up totals.

[44] Carlin et al., *Interoperable Transit Data: Enabling a Shift to Mobility as a Service*, RMI, October 2015.
[45] Ibid.

INTEROPERABLE TRANSIT DATA IS IMPROVING MOBILITY IN MANY LOCATIONS – THE FUTURE WILL COMBINE ALL ASPECTS

Multi-modal Trip Planning: Scandinavia, Europe

- The Standardized Exchange of Transport Information (SUTI) between Sweden, Norway, and Demark is a data protocol for taxis and other on-demand vehicles.
- Over 80% (30 million) of annual taxi rides in these countries utilize this service.

Real-time Trip Optimization: New York City, New York, U.S.

- OneBusAway (OBA), a U.S.-based company, offers open-source data products that distribute real-time passenger information across a number of platforms, including the web, smartphone apps, and SMS.
- An empirical study in New York City shows potential for OBA to increase weekday ridership by 1.7–2.3%.[46]

Seamless One-stop Payment: San Francisco, California, U.S.

- The TNCs Uber and Lyft revolutionized taxi payment by moving to mobile payment, a feature that should be available soon in other modes, including subways, buses, and trains.
- Imagine applying this system across a shared data platform, seamlessly enabling integrated booking and payments as riders switch from one mode to the next.

[46] Brakewood et al., “The Impact of Real-Time Information on Bus Ridership in New York City,” *Transportation Research*, April 2015.

BARRIERS AND SOLUTIONS

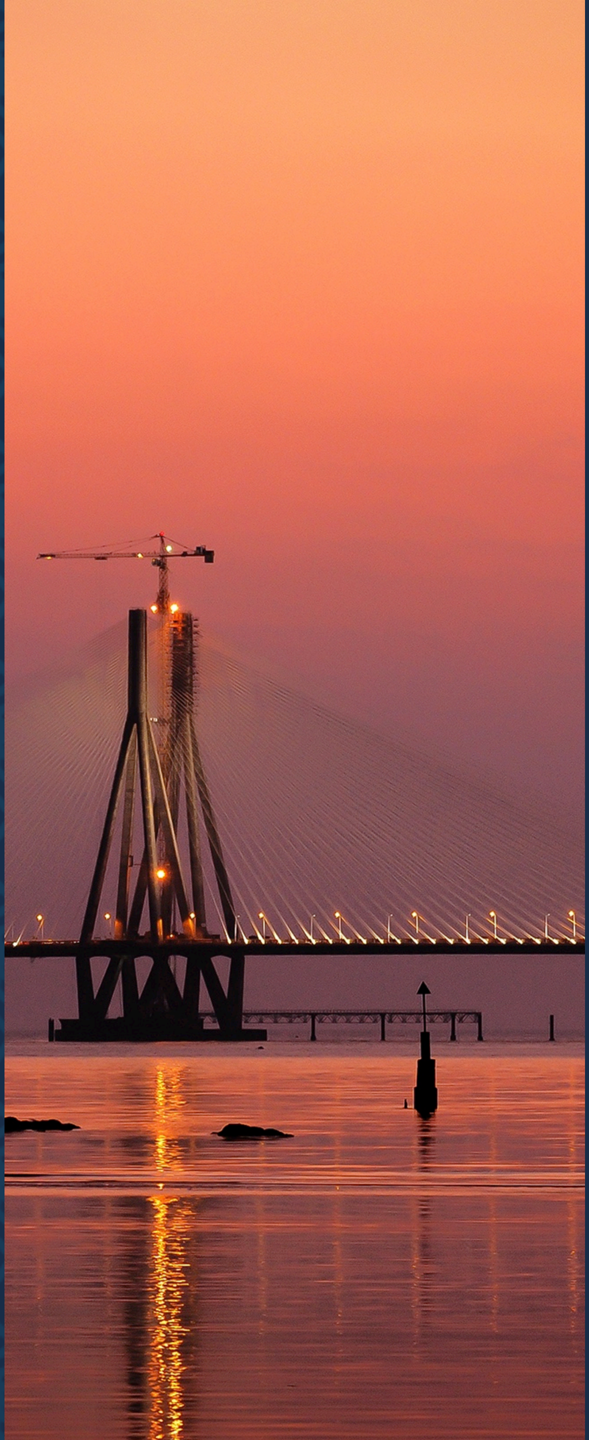
	Barriers	Potential Solutions
REGULATORY	• Unavailability of licensing for transit data: Variety of licenses hinders the rate of proliferation and use of shared transit data	• Implement country-wide data-sharing standards between public and private companies. • Establish payment standards.
INFRASTRUCTURE	• Lack of infrastructure for technology penetration	• Improve existing infrastructure-supporting technologies, such as embedded vehicle wireless connections and vehicle sensor data.
SOCIAL	• Lack of resources, knowledge, and openness about sharing the transit data: Variability in resources and knowledge within public transit agencies	• Clearly understand the savings on energy, emissions, and cost impact metrics to compare against MaaS solutions.
TECHNOLOGY	• Low penetration of smartphones and cellular network that enable on-demand service • Lack of data standardization	• Implement pilot projects to demonstrate integrated payment, new first-mile/last-mile services, new data standards, etc. • Ubiquitous data gathering: vehicle speed, location, estimated time of arrival, costs, etc. • Create data common denominators and standards. • Use third-party app integration.

POTENTIAL BENEFITS AND IMPLEMENTATION STRATEGY

Benefits		
Consumer	**City and State**	**Mobility Service Providers/Traffic Operators/Other Companies**
Better customer experience: Customer experience can become a greater competitive differentiator if data-related challenges are resolved.[47]	Cities and transit agencies can coordinate and complement private sector services.[48]	Increased market size through aggregation.[49]
Many companies would prefer to focus their energy on customer experience rather than data.	Reduced regulatory risk: City governments can provide clear policies and private transit services can provide low-cost, anonymized data that is of use to cities.[50]	Efficient use of public resources: Intelligence on transportation system needs allows public agencies to allocate resources based on the real needs of customers.[51]

Potential Implementation Phasing	
Stage 1: **Promote open and interoperable transit data** Emphasize data-driven governance to leverage data-driven decisions.[52] Increase smart phone penetration for access to cellular data & GPS navigation.	**Stage 2:** **Integrated mobility platforms** Aggregate different modes of travel and transport operators to enable users to compare, book, and pay for travel routes from A to B across a variety of different operators and modes.[53]

[47-51] Carlin, et al., *Interoperable Transit Data*, RMI, October 2015.
[52] World Economic Forum, *A Field guide to the Future of Mobility*, January 2016.
[53] McKinsey & Company, "The Race for Integrated Mobility Platforms: Dynamics and Success Factors," September 2016.



POTENTIAL IMPACT IN INDIA:

1. RMI ANALYSIS INPUTS AND SCENARIOS
2. ENERGY AND CO_2 RESULTS
3. MOBILITY IMPACT
4. MODELING AN EXAMPLE CITY

RMI ANALYZED NATIONAL-LEVEL HISTORICAL DATA AND MACROECONOMIC PROJECTIONS TO ESTIMATE GROWTH OF THE TRANSPORTATION SECTOR

WE COMPUTED COSTS, ENERGY CONSUMPTION, VEHICLE GROWTH, AND EMISSIONS UNDER 4 DIFFERENT PROBABLE SCENARIOS

Input Data

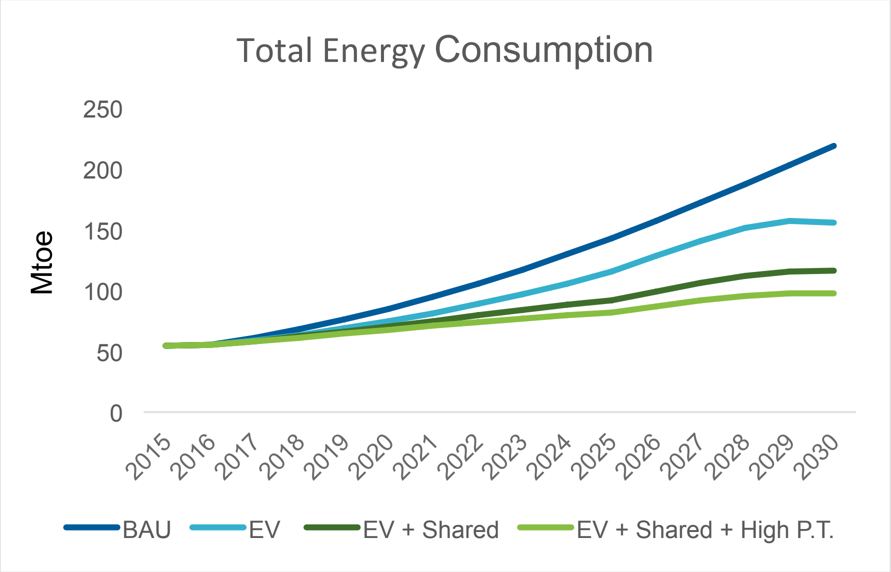
- Vehicle stock by type, fuel, ownership (Historic: 1951-2015)
- Annual vehicle utilization (km/vehicle)
- Vehicle occupancy
- Gross domestic product
- Population
- Utilization saturation level (VKT/cap)
- Vehicle cost (including O&M cost)
- Fuel cost

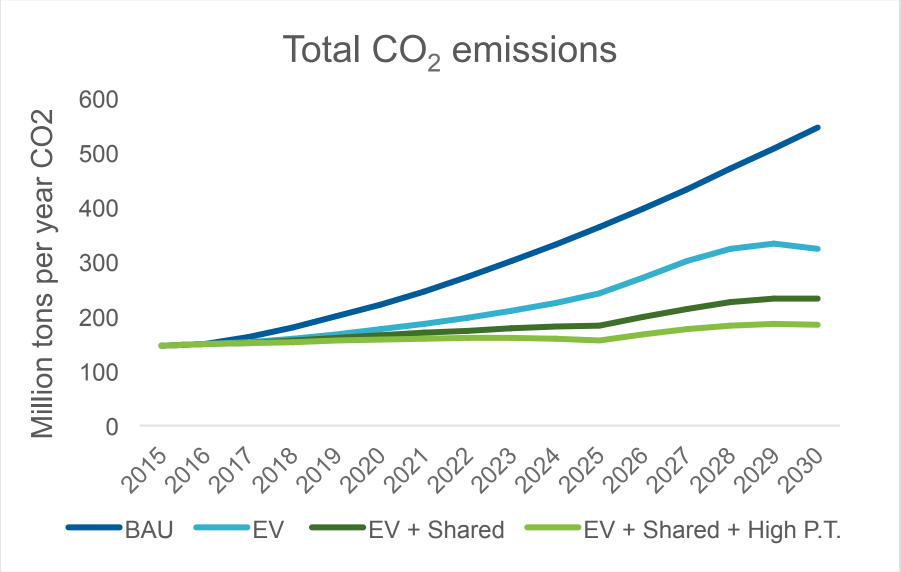
2030 Projections

- Energy demand projections
- Emissions projections
- Cost projections
- Vehicle stock by type, fuel mix, ownership mix

	Description	Key assumptions
Scenario 1: BAU Business as usual	No change in business or policy environment, limiting growth in EVs but resulting in massive shift to POVs.	
Scenario 2: EV High electrification	Policy mandates enable high turnover and electrification of fleet vehicles, including taxis, buses, and auto-rickshaws.	All new fleet vehicles are PHEVs or BEVs starting in 2022.
Scenario 3: EV + Shared High electrification and shared fleet	In addition to above, high MaaS penetration enables high occupancy in fleet vehicles.	EV + 75% of all cars are commercially owned. Low decline in car occupancy.
Scenario 4: EV + Shared + PT High electrification and shared fleet with high share of public transit	Mobility-oriented design enables high share of public and non-motorized transit.	EV + shared + percentage of public transit in total motorized travel is 60%.

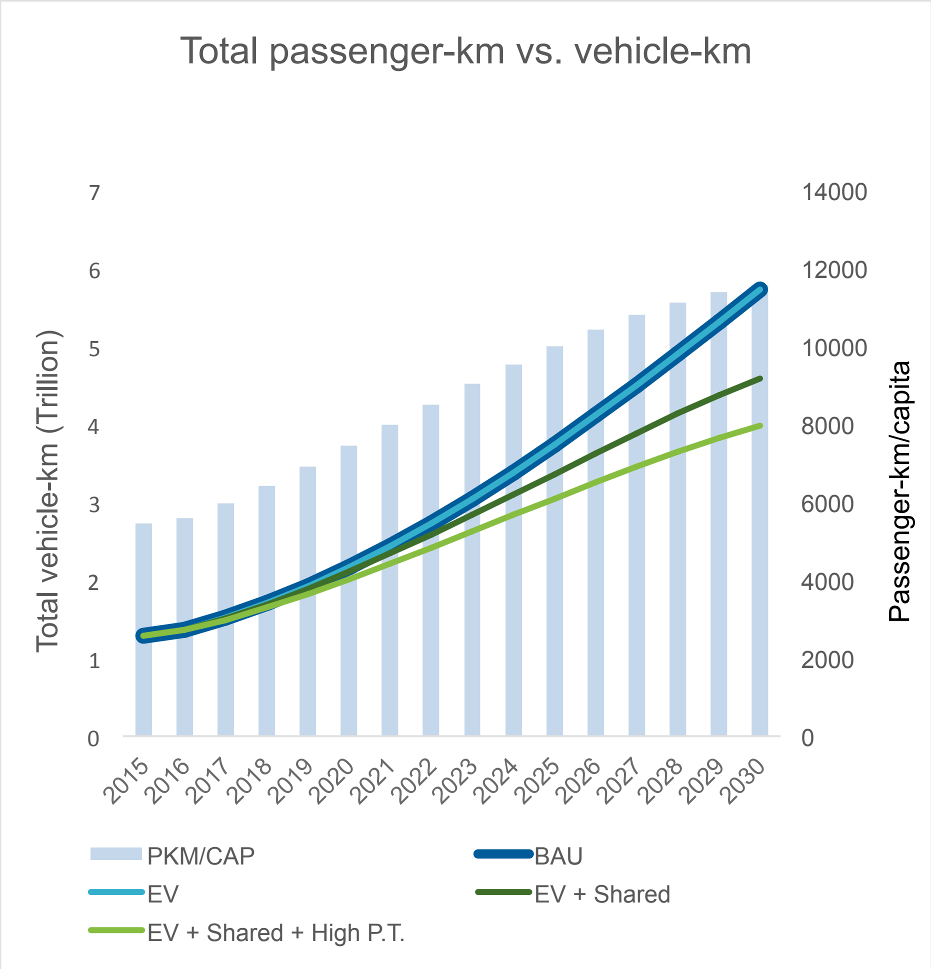
A SHARED, ELECTRIFIED, AND HIGH PUBLIC-TRANSIT FUTURE CAN REDUCE ENERGY REQUIREMENTS AND HOLD CO_2 EMISSIONS FLAT





- Compared to BAU, total energy consumption in 2030 is ~ 55% lower in Scenario 4—EV + Shared + High PT—where a large percentage of vehicles are shared and electrified, and public transit maintains a high share of mobility demand.
- Total carbon emissions are also lower by roughly 66% in this scenario.
- This reduction in energy consumption is the consequence of the synergistic impact of MaaS, EVs, and MOD.

A HIGH ELECTRIC, SHARED, AND PUBLIC-TRANSIT-RELIANT FUTURE DOES NOT IMPACT TOTAL MOBILITY



- Total passenger-km or the mobility demand rises equally in all scenarios, although the number of vehicle-km traveled (VKT) is lowest in the EV + shared + high PT scenario.
- Total VKT falls by roughly 30% in Scenario 4, resulting in lower congestion and faster average speeds.
- Lower per passenger-km cost of shared EVs and public transit also ensures that Scenario 4 is the least-cost option among the 4 scenarios.

Results from RMI internal analysis

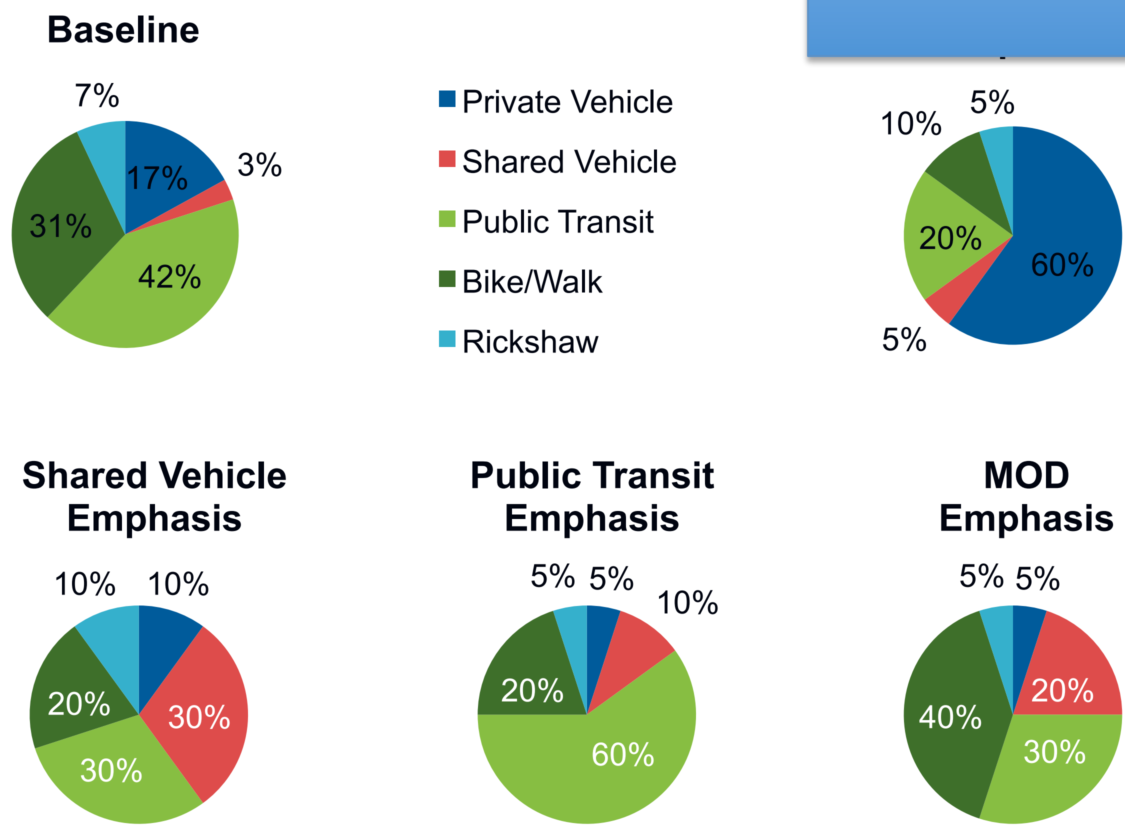
MODELING OF AN EXAMPLE CITY PROVIDES SOME IDE… PARADIGM COSTS AND BENEFITS

Some values ar

- A basic mobility model was created of an urban environment under different mobility paradigms. … city and the mobility mode shares of the scenarios are included on this slide, and the effects are

City Demographics	
Population	10,000,000
Density	11,000/sq. km.
Size	910 sq. km.
Travel Distance	10 km/citizen/day

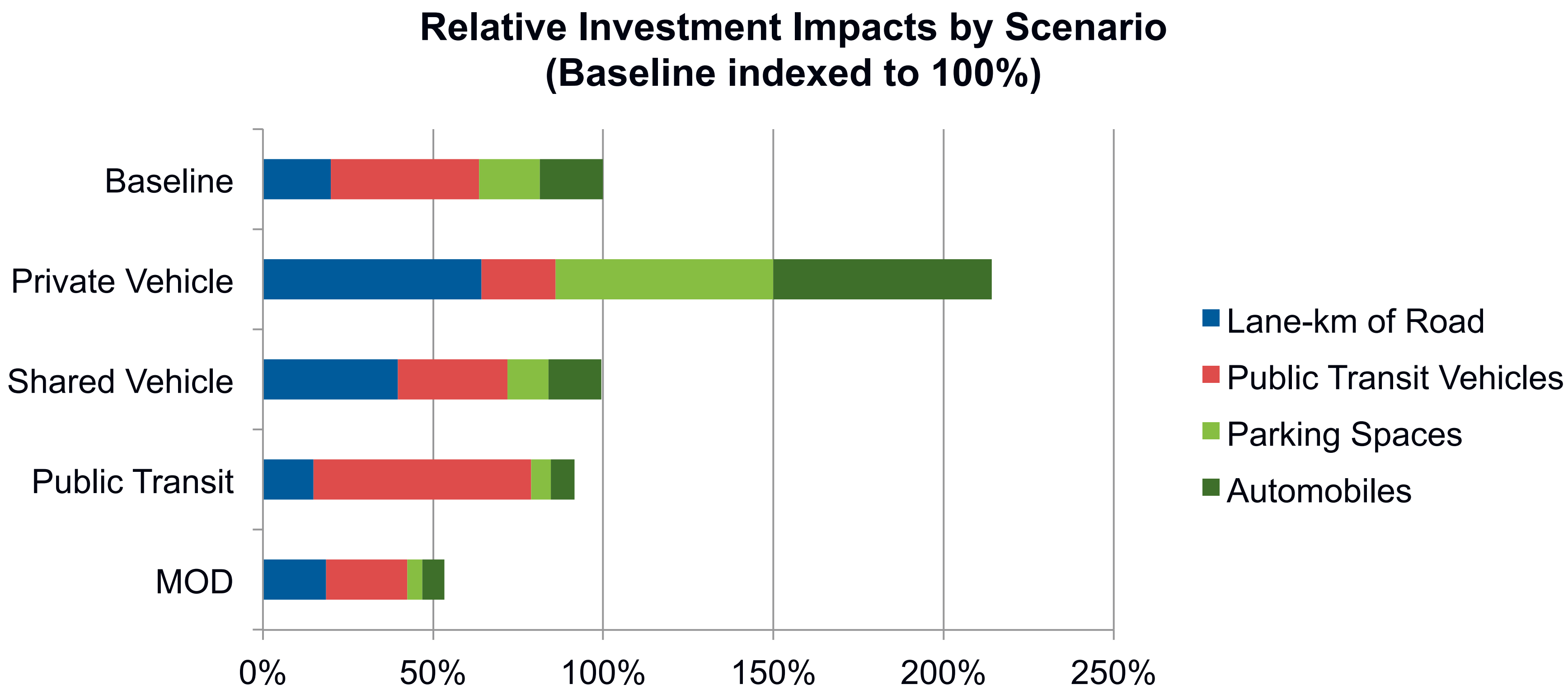
Vehicle Economics ($/km)	
Private Vehicle	$0.27/km
Private EV	$0.20/km
Shared Vehicle	$0.75/km
Public transit	$0.10/km
Walk/Bike	$0/km



Note: In MOD (mobility-oriented development), cities are designed so citizens can walk/bike to most places, with public transit and on-call shared vehicles handling remaining demand.

PRIVATE VEHICLE SCENARIO WILL REQUIRE THE LARGEST INVESTMENT IN ROADS, PARKING INFRASTRUCTURE AND VEHICLES

It is assumed that Indian citizens' demand for mobility doubles to 20 km/citizen/day, though population and density are kept constant. For comparison, U.S. urban transport demand is 40 km/citizen/day (80% by private vehicle).



Note: Transit distance per day increases by 50% less in MOD, as it is assumed that better civic planning makes lower transit distances possible.

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