

E-Bus Route and Service Planning in Emerging Public Transport Cities

Methodology and Tool for the *PM e-Bus Sewa* Cities

Himani Jain, Neerav Sharma, Samradh Singh Chauhan, Saoni Sanyal and Sourav Dhar



Image: CEEW

Executive summary

The *PM e-Bus Sewa* scheme focuses on the deployment of 10,000 electric buses (e-buses) across 100+ emerging cities of India (PIB 2026). These are the first e-buses for 80 percent of those cities; and the first organised bus service of any kind for about 32 percent cities. It funds buses, depots, and power infrastructure but local governments must bear the costs of mobility plans and detailed bus operation plans. Those cities must decide routes, depots location, and number of buses and services at each route to serve local anticipated demand. Measuring which are potential bus trips and where they

begin and end - takes months of enumeration or a year of positioning records, and it is the costliest line item in a mobility study. However, few cities have the required technical expertise to design surveys and plan data collection.

To ease the technical planning pressure on cities, this brief presents a quicker and low-cost, **e-bus route planning and service design methodology and a matching Mobility Assessment and Route Guidance (MARG) tool**.

E-bus route and service planning methodology is a robust yet quick approach that combines available Census and ward-level data with targeted small surveys. It models ridership across multiple mode-shift scenarios and jointly optimises route and charging requirements. The targeted surveys focus on immediate demand that can shift from Intermediate Public Transport (IPT); and potential two-wheeler users, cyclists, and regional bus users. This approach enables cities to develop practical bus operations plans using existing institutional capacity and limited data. CEEW and SG Architects' forthcoming study applied the methodology successfully to four case-cities, in three popular city population categories (<5 lakhs, 5-10 lakhs and 10-20 lakhs) of *PM e-Bus Sewa*.

Mobility Assessment and Route Guidance (MARG) tool is an evolving machine learning based tool which treats origin-destination evidence as a shared asset rather than a per-city purchase. The four case-cities train the tool's framework. The tool has learned how travel demand and route feasibility relate to measurable urban form. It uses only open geospatial layers and no measurement of its own, to apply that learning to a new case-city. Powered by a digital twin, the tool ingests a city's municipal boundary to provide an interactive demand surface, ranked transit corridors, candidate routes, and optimised stops. The digital twin can edit; step through hour by hour; and test under alternative fleet, route, and growth scenarios for near-future projections. A tool in continual development evolves as cities use it to develop their interim routes, refining demand-urban form algorithms.

Our methodology and MARG tool are validated on Bhubaneswar, a city with an established and robust public transit network. Three results validate the tool and methodology using passive GPS mobile data.

- Tested against Bhubaneswar's operating public bus network, a histogram-based gradient boosting classifier ranks a true route location above a non-route location 83.7 times in 100.
- Screening the top 30 percent of the road network captures 76.4 percent of Bhubaneswar's actual bus stops.
- Open geospatial data closely matched Bhubaneswar's actual travel demand, achieving a correlation of 0.83 even in areas not used to develop the model.





Limited data should not mean limited planning.

- Our method and tool validation highlights that the existing Intermediate Public Transport (IPT) concentration is a reliable proxy to identify the top corridors. Smartly planned short, targeted surveys of two-wheelers, cyclists, and regional bus users, point to bus demand estimates. We recommend that cities and their transport undertakings could collect and use limited strategic IPT and land use data to start e-bus route and service planning immediately, rather than waiting for a household survey and comprehensive mobility study.
- We find that the identified bus networks are dense and frequent built on 9-m buses, since above 90 percent of trips in all case-cities are under 10 km. Route, depot, and charging decisions must be settled together by CTU, rather than in sequence. We recommend that city or state must ensure a dedicated fund for city-wide passive mobility measurements in all transit cities and to monitor the performance and impacts of city bus services.
- We recommend that MoHUA ensure periodic base-mobility data collection in a small select sample of cities, treated as shared national digital infrastructure (rather than a per-city procurement) to train such models. MARG tool is a far cheaper and faster approach than 118 separate mobility studies.
- We acknowledge that the MARG tool is a work in progress, which cities will be able to enter in any lifecycle stage of the tool with their existing data. The tool's training and validation base shall widen over time; similar data, route identification efforts from more cities would improve accuracy and reliability of tool. Thus, we recommend that the tool's outputs be used as starting point for bus-operations planning; and be refined through local expertise and consultations.

Our method and tool, both, strive to inform the Scheme that does not just delivers buses, but one that delivers robust bus systems in cities. They are intended mainly for target Scheme cities where no formal bus-route network exists, e-buses are being introduced, and origin-destination datasets are not in existence—and where technical capacity is limited and budget outlay planning is inconsistent.

1. Technical gaps in robust route planning

The allocation of the *PM e-Bus Sewa* scheme shows where the difficulty sits. Cities that have a population of less than 5 lakh account for more than 50 percent of the scheme's target cities, with around 3,700 e-bus allocations – the largest single block – and the group least likely to hold any mobility plan (Table 1). Moreover, most of these 118 cities will be operating electric buses (e-buses) for the first time.

Unlike conventional internal combustion engine (ICE) buses, e-buses have a fixed range, require opportunity charging, and depend on strategically located depots with charging infrastructure. Their operational dynamics are different from ICE buses and significantly more complex. The *PM e-Bus Sewa* scheme provides financial assistance for Viability Gap Fund (VGF) at per-kilometre rates and funding for high-voltage grid connections for depot chargers. Before operations begin, the city or state shall develop the large infrastructure of depots and terminals with appropriate parking, charging infrastructure, and bus stops.

The scheme's financial architecture explains the gap: central assistance runs at INR 24 per km for a standard 12-m bus and INR 22 per km for a 9-m bus, for 10 years or until March 2037, with full funding for behind-the-meter power infrastructure and 60–100 percent capital assistance for depots. Cities and states carry the residual operating gap and the whole service planning responsibilities. A city starting from zero has no route history, no ridership record, and no operations team. The implementation sequence of the scheme makes this an urgent issue.

The depot site, the grid connection, the terminal, the bus stops, and the opportunity charging points and charging schedule, all follow from the route plan. Decoupling route and service planning from the civil works - risks structural misalignments and infrastructure errors.

Table 1. Half the sanctioned cities, where planning capacity is thinnest, have a population less than 5 lakh

Number of cities	City population category	Buses sanctioned per city	Total buses sanctioned
66	Below 5 lakh	25–50	3,692
29	5–10 lakh	50–100	2,943
21	10–20 lakh	100 and above	2,765
2	20–40 lakh		600
118	All categories		10,000

Source: *PM e-Bus Sewa* sanction lists, September 2026

2. The two core products

Most *PM e-Bus Sewa* cities face the double constraint: data on mobility is not available and technical capacity and budgets are limited. There is no dedicated fund under the scheme for bus-system planning or CMP development. Nevertheless, *PM e-Bus Sewa* cities, especially first-time cities, must emphasise efficient planning of routes and service. To help, we developed a methodology and designed Mobility Assessment and Route Guidance (MARG), a planning-support tool. This issue brief describes the methodology and the tool.

We synthesised a simple yet practical methodology from four select case-cities and experience of developing detailed operational plans. The four case cities Ludhiana, Jalandhar, Amritsar and Patiala represent the cosmos of variable *PM e-Bus Sewa* cities. The approach incorporates successful global practices, with population and land use information from urban local bodies (ULB) s; overlays it with simple, low-cost, quick robust surveys; and leverages existing Intermediate Public Transport (IPT) corridors as a ready blueprint of shared transport

demand concentration. These datasets and commuter surveys at key locations are sufficient to identify the top 7–10 demand corridors for the initial e-bus deployment, thus negating the immediate need of large, expensive mobility surveys.

Our MARG tool combines and trains evidence from the four city operational plans, open geospatial and passive mobility data to estimate demand, rank suitable corridors, and identify candidate routes and stops. The tool's outputs integrated into digital twin enables planners to edit networks, compare alternative scenarios and assess accessibility and service feasibility. The MARG tool is evolving; as mobility data from additional cities become available, the tool strengthens progressively.

A quick, low-cost route and service planning method and the MARG tool help despite limited data and capacity.

3. E-bus route and service planning methodology

We select four case-cities – Patiala, Jalandhar, Ludhiana, and Amritsar – deploying e-buses for the first time. Together, these four cities represent more than 90 percent of the cities covered by the *PM e-Bus Sewa* scheme in terms of population; economic and social characteristics; urban layouts and land use features; and infrastructure and governance maturity. Also, the case-cities represent three key population tiers under the scheme: less than 5 lakh (Patiala); 5–10 lakh (Jalandhar); and 10–20 lakh (Ludhiana and Amritsar). Therefore, together, the four cities serve as a microcosm of the cities covered by the *PM e-Bus Sewa* scheme.

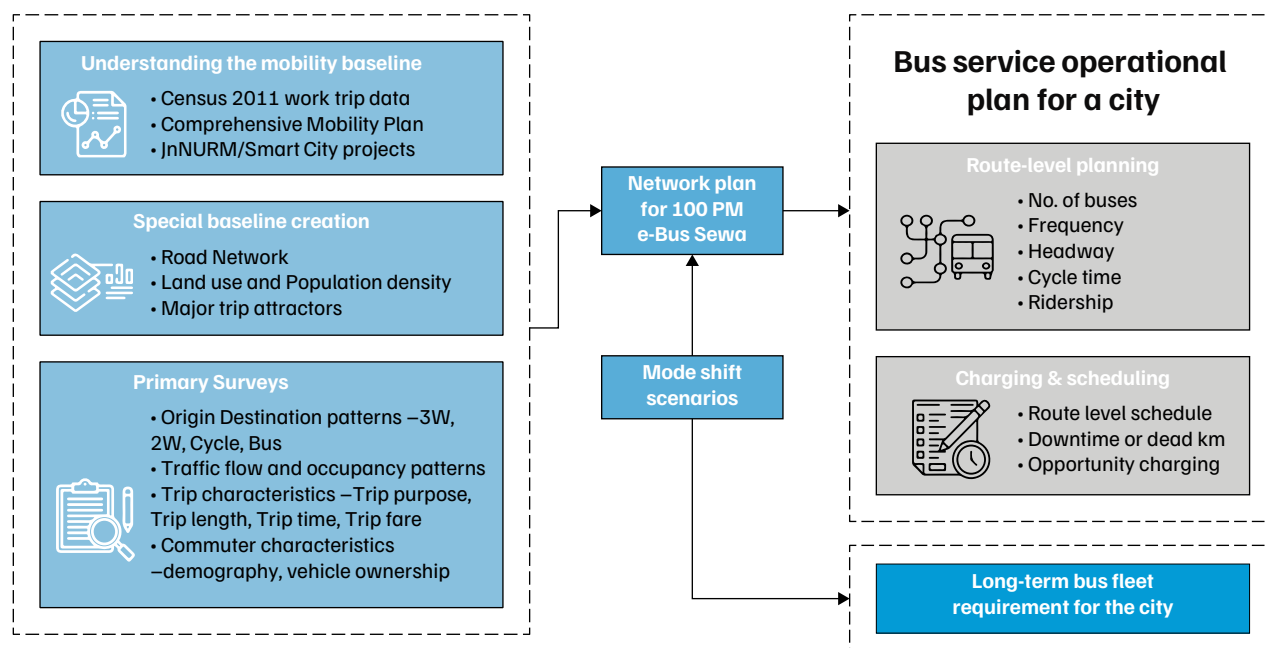
Urbanisation rates in case-cities are higher than the national average; but the formal bus supply in these is either absent or the lowest in India. This poor bus coverage is exacerbated by a high rate of private vehicle ownership: more than two-thirds of households in the case-cities own a two-wheeler. Thus, case-cities are representative of *PM e-Bus Sewa* cities and related bus system planning.

Transport is a major contributor to air pollution in the select case-cities and are designated under the National Clean Air Programme (NCAP). More broadly, 81 of the 131 NCAP cities fall within the 3–40 lakh population bracket targeted by the *PM e-Bus Sewa* scheme.

Our e-bus route and service planning methodology draws on three sets of inputs that establish the mobility baseline; build a spatial baseline; and conduct short, targeted primary surveys at key locations (Figure 1).

Using basic ULB data, existing IPT corridors, and small strategic surveys - cities can identify key 7–10 e-bus routes.

Figure 1. Bus service operational planning: Linking mobility baseline, primary surveys and mode-shift modelling to a city-level operational plan



Source: CEEW compilation

- The first set of inputs establishes the mobility baseline from material that already exists: Census 2011 work-trip data; the city's Comprehensive Mobility Plan (where available); and mobility projects taken up under the Jawaharlal Nehru National Urban Renewal Mission (JnNURM) and the Smart Cities Mission.
- The second set of inputs builds a spatial baseline – such as the road network, ward-level land use and population density, and major trip attractors – to locate demand geographically. We collected ward-level data from the respective municipalities and spatially attributed the road network layers.
- The third set of inputs adds short, targeted primary surveys at key locations. The surveys cover origin-destination patterns across potential bus users (two-wheelers, three-wheelers, cycles, and private/other buses); traffic flow and occupancy; trip characteristics; and commuter characteristics. Strategically, sampling for the primary survey covers a mix of video-based vehicle count and occupancy patterns (during peak and non-peak hours) in locations with high footfall (transport hubs, health and educational amenities) and a user survey of latent demand (IPT, two-wheeler, cycle, regional bus users) (Table 2).

Table 2. Detailed sample size ratios for primary surveys across cities of different population sizes

Type of surveys	Population: < 5 lakh Patiala	Population: 5–10 lakh Jalandhar	Population: 10–20 lakh Ludhiana and Amritsar
Origin- Destination (OD) survey	500–700 samples spatially distributed across 30–45 locations in the city	700 samples spatially distributed across 30–45 locations in the city	800–1200 samples spatially distributed across 30–45 locations in the city
15 min video-based vehicle count	20–40 locations spatially distributed across the city		
Occupancy recordings (15 min) peak/off-peak periods	20–40 locations spatially distributed across the city		

Source: CEEW analysis

Our developed methodology is unique in multiple ways-

First, it is designed to generate a city-wide insights of mobility patterns without the time and cost associated with a large-scale travel or household survey. By combining targeted primary surveys with existing secondary data, the methodology captures, within a compact study design, key characteristics such as mobility flow, travel behaviour, mode choice, and mobility needs.

Second, instead of attempting to survey a large number of samples to capture the travel demands, it adopts a potential-user approach that focuses on groups – particularly users of three-wheelers, two-wheelers, cycles, and regional buses – that are more likely to shift to bus services. Sampling is purposive and demand-based, not random; so, these ratios indicate corridor coverage intensity, not a statistical sampling fraction.

Third, as we directly examine the conditions under which existing users of alternative modes may shift to buses, it makes the suggested surveys more relevant to bus service planning. The surveys also defines the analytical scope before fieldwork, allowing surveys to be concentrated on the user groups, locations, and mobility characteristics most relevant to bus service design.

Fourth, capturing users' willingness to shift, along with their preferences and barriers, therefore provides an evidence base not only on how people currently travel, but also on where potential bus demand could emerge. This targeted approach reduces the survey burden while retaining the information to informing route planning, design service and estimating demand.

Our method, put together, provides following key outputs:

- **Set of mode shift scenarios to estimate bus demand from current IPT, two-wheeler, cycle, and regional bus users** - The scenarios are estimated under a given combination of fare, frequency, and walking access. Ridership is the parameter on which every other service decision rests; hence it cannot be assumed. Testing a range of scenarios shows which corridors clear the service-level benchmark thresholds under conservative assumptions and which depend on optimistic ones; it also gives the city a defensible basis for the frequency and fleet allocation proposed.
- **Network plan for the first 50–100 e-buses sanctioned under the Scheme to a city** - The network plan narrows the baseline to the critical five to eight corridors carrying the highest demand and allocates the sanctioned fleet across them; therefore, route design and charging design are settled together rather than in sequence. From this follows the route and service plan
- **Route and Service Plan** - The origin-destination samples establish the desire lines that fix route alignment. The short video counts at selected locations – recorded during both peak and off-peak periods – give the peak-hour load and the peak-to-off-peak ratio on each corridor. Together, these set the number of buses a route needs at its peak and the minimum headway necessary to sustain the load. The traffic flow observed along the corridor gives the route cycle- time on which vehicle and crew scheduling rests. Together, cycle time and headway

produce the route-level schedule to estimate the daily kilometres for each bus. These schedules are inputs to the charging and service-schedule plan.

- **Charging and Service Schedule Plan** - Our method estimates the route-level schedule, downtime and dead kilometres it implies, and the points at which opportunity charging is required. Our method verifies if sanctioned buses for the schedule, on a single charge, can operate both the planned daily kilometres and dead kilometres. Layover time at the terminal, and the off-peak troughs that the video counts reveals, help identify the opportunity charging windows and therefore the location of the charging points.

This methodology keeps the planning effort within the technical capacity and budgets that most *PM e-Bus Sewa* cities hold. For first-time public transport cities in particular, the return on this effort is highest at the route, schedule, and service planning stage. We note the key parameters emerging from the route and service planning efforts in case-cities using strategic surveys and analysis (Table 3).

Demand scenarios, network plan, route schedules and charging points - four key outputs are essential for e-bus planning.

Table 3. Key parameters and learnings emerging from e-bus route and service planning in case cities

Phase 1 Network coverage	Service frequency and timings	Infrastructure & charging strategy
• The planned routes achieve universal coverage - > 90 percent of municipal wards. A total municipal area coverage ranging from 35–55 percent. • Bus networks cover major trip-attracting centres - educational institutes, hospitals, bus stations and railway stations, industrial areas and religious places. • Our case-cities show that typically the network would comprise 7–12 routes (150–172 km) in 5-20 lakh population cities; and 4–5 routes (80–100 km) in smaller cities. • Roughly 90 percent of trips in Scheme cities are under 10 km - In < 5 lakh people cities – shared IPT trips concentrated in the 3–5 km range, trips >10 km are negligible. In the 5–20 lakh population cities - 3–10 km is dominant range for shared IPT modes.	• High-demand priority corridors are designed for 10–15-minute headways, while the broader network maintains a range of 10–20 minutes. • These service levels are aligned with stated willingness to wait by commuters (maximum acceptable wait time for most users is 6–10 minutes). • This justifies a dense, frequent network with short headways rather than long, infrequent corridors, and supports the use of 9 m (midi) e-buses or even smaller buses • The headways are staggered depending on the peak/off peak hours in a day.	• Under the proposed Scheme allocations – Large cities will get 50-100 or more e-buses while <5lakh pop cities would receive 50 or less e-buses. • Two distinct charging strategies developed based on city operations. – <5 lakh population cities utilise combined night-time and opportunity charging at depots, which are located within 5 km of routes. – Conversely, million-plus cities employ distributed opportunity charging at institutional hubs, the Airport, and the Bus Station railway station, if its depot is on the outskirts.

Source: CEEW analysis

4. Mobility Assessment and Route Guidance (MARG) tool

Without a measurement of where trips begin and end, there is no demand estimate; without a demand estimate, a route network is drawn on intuition. The MARG replaces measurement with a transfer along a chain in which every link is testable.

Demand is what a route network exists to serve. Demand is systematically related to measurable urban form – activity mix, built intensity, road structure, and street morphology – so the relationship can be learned once and reused. Urban form is observable anywhere from open data. Corridors and stops then follow jointly from the demand surface and from the roads that can physically carry a bus. Three terms – origin-destination evidence, origin-destination survey, passive origin-destination measurement – are kept distinct throughout this issue brief; the distinction is load-bearing rather than pedantic.

Origin-destination (OD) evidence is the umbrella: any measurement of where trips begin and end. An *origin-destination survey* is one approach for producing it: enumerators at fixed intercept points, which is what the four Punjab cities hold, as mentioned in the earlier

sections. *Passive origin-destination* measurement is the other, continuously logged positioning records covering a whole city, which is what Bhubaneswar holds in the form of passive survey data like mobile GPS data. We show in later discussions in the section that *Origin-destination evidence* and *Passive origin-destination measurement* are not interchangeable as training evidence, and the gap between them is the single largest constraint on reuse of tool. Each city and each dataset feeds exactly one part of the framework – OD and its city characteristics in relation to model identified routes.

The four case-cities earn their place as tool trainer because their alignments reflect real planning decisions that are analysed by planners, experts and accepted by the city and state agencies. This allows building a robust base of the model, rather than a mere set of described conditions. While, Bhubaneswar was selected as a validation-city because it has both city-wide passive OD measurements in form of mobile GPS data and an operating bus system with corridors and bus-stops. We show how the select trainee case-cities and validation-city have similarity in socio-economic characters and the coverage of city under MARG tool (Table 5).

Table 4. Each city and each dataset has one job; nothing is used for two purposes at once

City	Role	Dataset	What it feeds
4 case cities	Training and reference	Approved PM e-Bus Sewa route networks	Corridor labels , the positive class the classifier learns
4 case cities	Training and reference	Commuter and vehicle-occupancy surveys (origin–destination surveys)	Trip and service characteristics , trip length, fare, waiting tolerance, headway targets
Bhubaneswar	Held-out validation	Passive origin–destination measurement (Passive survey data via mobile GPS positioning records)	The demand model , the only dataset that qualifies
Bhubaneswar	Held-out validation	Operating route network and bus stops	The blind test of the corridor model , and of stop screening

Source: Reference-city route plans and survey layers; Bhubaneswar Municipal Corporation network data and passive survey data via mobile GPS positioning records, January 2025

Table 5. The five cities span the different sizes, economic characters and emerging markets for public transport

Parameter	Ludhiana	Amritsar	Jalandhar	Patiala	Bhubaneswar
Population (2025) *, lakhs	19.86	13.44	11.16	5.77	8.5
Municipal area, sq. km	160	133	115	50	161
Density, persons/ha	124	101	97	115	52.8
Wards	75	88	82	60	67
Economic character	Hosiery, bicycles	Tourism, textiles	Sports goods	Education, rail	Administration, tourism, education
Instrument coverage	Survey, 67 of 75 wards	Survey, 51 of 88	Survey, 11 of 82	Survey, 47 of 60	Passive, all 67

Note: *the initial selection of the cities for the PM e-Bus Sewa scheme was on the basis of Census 2011 population.

Source: CEEW compilation

The MARG tool operates through five connected stages: measure, learn, rank, plan, and simulate (Figure 2) to estimate and identify the outputs of ranked bus routes, maps and feature information (related to potential bus

stop locations, loading variations on corridors, transfer points, hourly and daily variations in demand), and the potential service plan outline. We explain each of these stages.

Figure 2. The five-stage MARG methodology

MARG planning workflow

From city evidence to an actionable bus-network plan

CITY INPUTS

● City boundary	● Open geospatial data	● Reference-city evidence
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FIVE-STAGE PROCESS

① MEASURE	Assess 39 indicators every 200 m
② LEARN	Learn relationships from five reference cities
③ RANK	Prioritise demand and bus-service potential
④ PLAN	Design routes, stops, headways, fleet and charging
⑤ SIMULATE	Test hourly scenarios and growth to 2050

CITY INPUTS

Ranked bus network	Maps and GIS layers	Fleet and charging plan
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Source: CEEW analysis

1. **MEASURE STAGE** - the tool incorporates 39 indicators (spatial, mobility, and land use) to consider candidate locations at 200-metre intervals throughout the classified road network (Figure 3). The baseline for the framework starts from maintaining uniform consistency of spatial units. The tool analyses a multi-source open-dataset library from globally available data to estimate routes for a target city. The idea lies behind the fundamental proximities of 200-m intervals in line with the road network and a buffer catchment of 500 m.
 2. **LEARN STAGE** - the tool integrates these indicators to estimate demand, as well as the existing bus routes, in the four-reference case-cities. Our tool scales these to relationships to validation city-Bhubaneswar. The tool will scale these relationships to the target- *PM e-bus Sewa* scheme cities - instead of conducting the analysis from scratch.
 3. **RANK STAGE** - the tool generates two main baselines; one portrays the suitability of bus routes and the other presents the spatial-relations concentration of the city form and land uses.
- The LEARNING and RANKING stages depend mainly on two interlinked models: the 'corridor model' and the 'demand model'.
- First, the corridor model considers a histogram-based gradient boost classifier architecture that acts as the backbone for identifying the urban form and road characteristics of bus routes in the existing network.
 - Next, the 'demand-model' observes the trip characteristics, computes travel demand through corresponding weighting, and scales all of them to consistent 500-m catchment intervals. To avoid redundancy—neighbouring locations can pop up repeatedly in the model training samples—we cross-validate spatial blocks so that the training samples do not yield over the model's performance or undershoot it.
- If a target city comes into the framework's picture, the trained model computes and portrays demand and the feasible service layers. The model interlinks demand and the feasible service layers and interprets these using a single weight. Where the individual and independent factors—nearby population, concentration of activities, travel demand indicators—agree, that location is given priority so that it can serve ridership and the road network infrastructure can support bus operations.

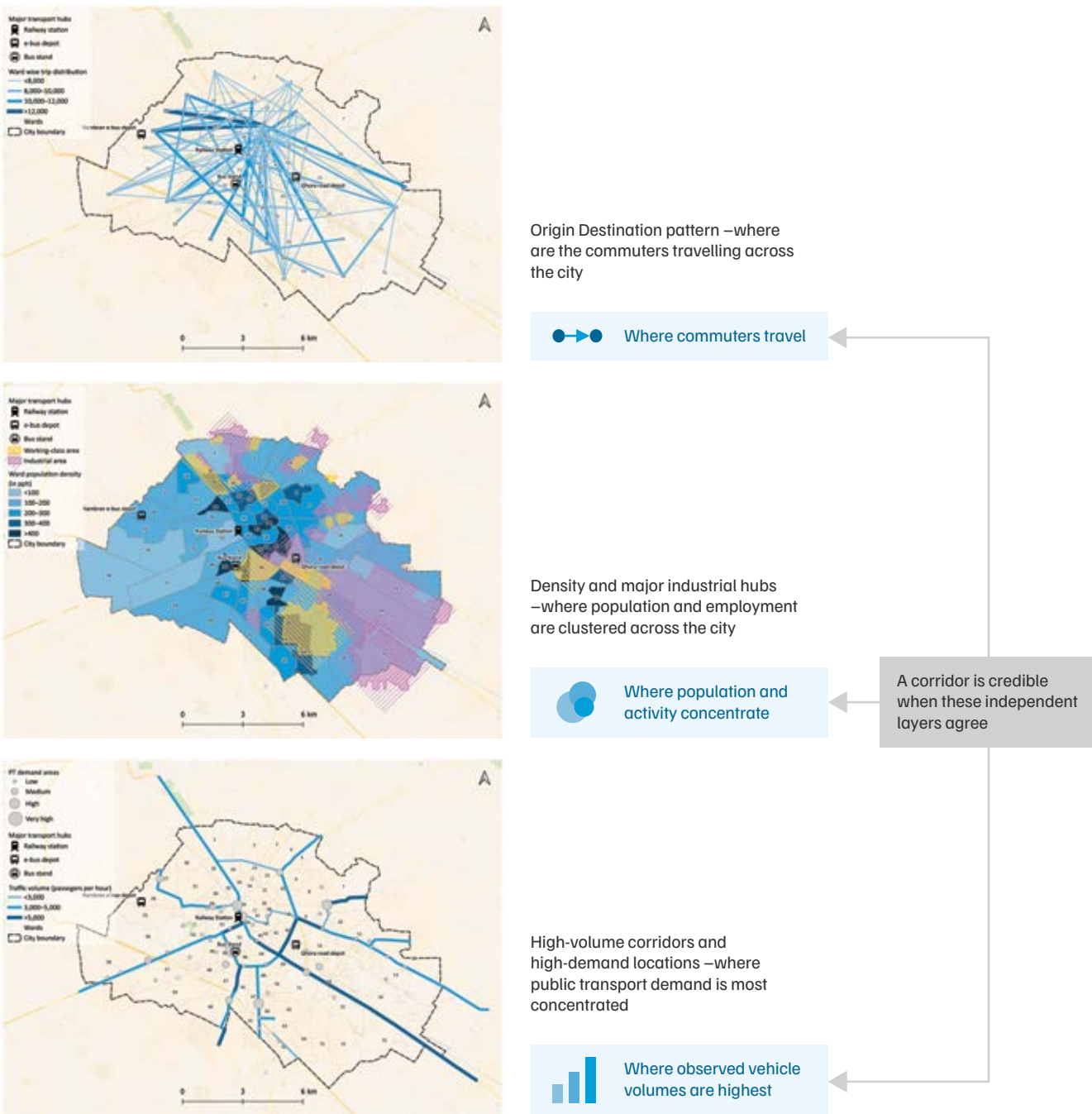
Figure 3. Spatial indicator families assessed in the MARG modelling framework

39	6	0.837
Spatial indicators tested	Indicator families	Best fit, from 14 indicators
 Road Whether a bus can physically run Road length by class —total, arterial, secondary, tertiary, local, service; road density; arterial share; distance to nearest arterial	9 indicators R^2 0.744 — nearest arterial alone	 Morphology Block structure and street permeability Junction count and density; segment count; mean segment length as a block-size proxy; lane width 5 indicators R^2 0.837 — with road, 14 indicators
 Built form Built intensity, lateral and vertical Building count; footprint area; built volume; density; coverage; mean height	6 indicators R^2 0.619 — within the activity set	 Points of interest Trip attraction Education, health, retail, food, government, transport, religion, leisure, lodging, finance; total; density 12 indicators R^2 0.618 — alone
 Land use How land is consumed Residential, commercial, industrial, retail, farmland, forest area	6 indicators Tested within the activity set	 Position Monocentric or polycentric form Distance to the built-volume centre 1 indicators Tested within the activity set

Source: CEEW analysis

Figure 4. Convergence of evidence for corridor identification

The principle underneath: Convergence of evidence



Source: CEEW analysis

4. **PLANNING STAGE** - the tool uses the two main baselines and transforms priority locations into 'candidate routes'; the tool assesses route alignment, fleet size, and route-suitability together to avoid redundant route networks.

At this stage, the MARG tool transforms the (ranked) locations into feasible bus network routes and evaluates the routes for additional characteristics—such as service frequency, ridership demand, and fleet requirements—so that infrastructural decisions can be developed hand in glove with operational interventions.

5. **SIMULATE STAGE** - the tool integrates the 'candidate routes' into a digital-twin platform of the city. Then, the network is fed to the digital twin platform, a pivotal element of the SIMULATE phase, where personnel can interact with and vary the bus routes and stops, simulate to see a digital twin alongside the building footprints, and check the hour-by-hour traffic simulation in multiple scenarios.

Therefore, the MARG tool does not sketch or finalise a network; it portrays a feasible identified set of routes based on the five stages as per the corresponding indicative features for a target city to enhance the infrastructure.

Tool use flexibility for the target cities - Planners/ULB officials can compare operational scenarios by varying stops, digitising new routes, and experimenting with fleet sizes. Depending on the city land use information already available, OD datasets (proxy, evidence or passive measurements) and local technical capacity for bus planning - a city can use the MARG tool and could initiate the framework at any of the preferred or appropriate five stages. A target city having only a municipal-area boundary is initialised and placed at the MEASURE stage. A target city containing complementary datasets, a comprehensive mobility plan, and indicators enters at the PLAN stage; the tool can assist in enhancing the existing scenarios of the route network.



MARG framework - Specification, validation, and complementary data

The MARG tool assesses the feasibility of locations on the basis of the road network rather than administrative wards: if a candidate site lies near a real bus route, it is considered 'positive'; other locations are 'negative'. Therefore, by determining the parts of the candidate sample spaces that are feasible for bus routes, the model addresses the real, practical problem planners and officials face.

For each candidate sample, MARG incorporates 39 indicators encompassing urban morphology, road-network infrastructure, spatial form, and land use. This iterative combination makes the analytical pipeline uniform and comparable across the range of cities and it does not let the anomalies generated by the differences in ward size or urban form variations affect the pipeline.

For every candidate location, the indicators are fetched and estimated from OpenStreetMaps, and Google buildings, and the indicators are grouped into three main categories: points of interest and positioning; road infrastructure and urban street morphology; and built form and land use.

- *Road infrastructure indicators* comprise road classification hierarchy and road density. Urban street morphology includes land width and street-block structure.
- *Built form* consists of lateral-vertical sprawl for both the past and the future decade using land use land cover transitions.
- *Points of interest* and *positioning* give the idea of activities, their whereabouts, and where they concentrate over the city-structure.

Among all the permutations-combinations of the indicator-configurations tested, the 14-indicator model

integrating morphology and road network features yielded the best corridor-suitable result with an AUC of 0.837. This is done using a trained model from four cities of Punjab tested blindly on Bhubaneswar as a target city. This signifies different efficacies of the indicator families. Further, we establish morphological and road network characteristics are most appropriate for suitability analysis pertaining to bus operations. Therefore, morphological and road-network characteristics should be interlinked for the planning exercises, as one portrays variation of demand, while, the other portrays whether a road can host bus services and related infrastructure.

The developed corridor model incorporates 9,982 sample locations from the four case-cities. Out of these cities, 20.6 percent were associated with approved routes of e-bus. The mean AUC across the test cities was 0.905 with city-level results encompassing the range from 0.882 for Ludhiana to 0.953 for Amritsar.

Bhubaneswar is isolated and kept outside the training process, as an independent geographic test region. Bhubaneswar contributed approximately 3,112 candidate locations of which almost a third are situated near already operating bus routes. Bhubaneswar differs from all the Punjab cities pertaining to street structures, urban-spatial form, and the source-scale of mobility data. This test proved that relationships learned from case-cities could be scaled and efficiently transferred to a different urban context/region.

Common, open digital datasets can be effectively combined with passive or observed travel data to develop bus-services plan.

The model recorded a precision score of 79.4 per cent alongside a recall of 0.542. Around four out of five locations recommended by the model were associated with an operating or existing bus route. Additionally, lower recall shows that the model identifies a more selective sample space of locations without capturing parts of the existing network. This makes the output more effective in prioritising corridors than reproducing the complete network automatically.

Further, we compare the ranking with the operational bus stop locations in the city of Bhubaneswar. The top one-fifth chunk of road locations includes around 68.6 percent of the entire city's stops, while the top one-third contains just about three-fourths. This shows that tool concentrates a majority of the actual bus stops within a relatively limited portion of the entire road-network infrastructure.

Table 6. The corridor model effectively separates real bus corridors from other roads on the validation-city of another state, with a different street pattern and measurement approach

What was tested	Measure	Value	Benchmark it should be read against
Corridor identification, held-out Bhubaneswar	AUC	0.837	0.505 random; 0.659 arterial share alone; 95 percent CI [0.820, 0.853]
	Precision	0.794	Four in five recommended locations sit on a real route
	Recall	0.542	The model under-selects rather than over-selects
Stability, leave-one-city-out across Punjab	Mean AUC	0.905	Range 0.882 (Ludhiana) to 0.953 (Amritsar)
Bus stop screening, Bhubaneswar	Real stops in top 30 percent	0.764	68.6 percent in the top 20 percent
Demand surface, spatial block cross-validation	Pearson r	0.830	R ² 0.685; range 0.779 to 0.902 across six held-out blocks
	Top 30 percent demand capture	0.772	From 51,762 trip ends across 25,881 trips of 1 km or more The top 30% of predicted demand locations account for 77.2% of observed trips, indicating strong spatial concentration of travel demand.

Source: CEEW analysis

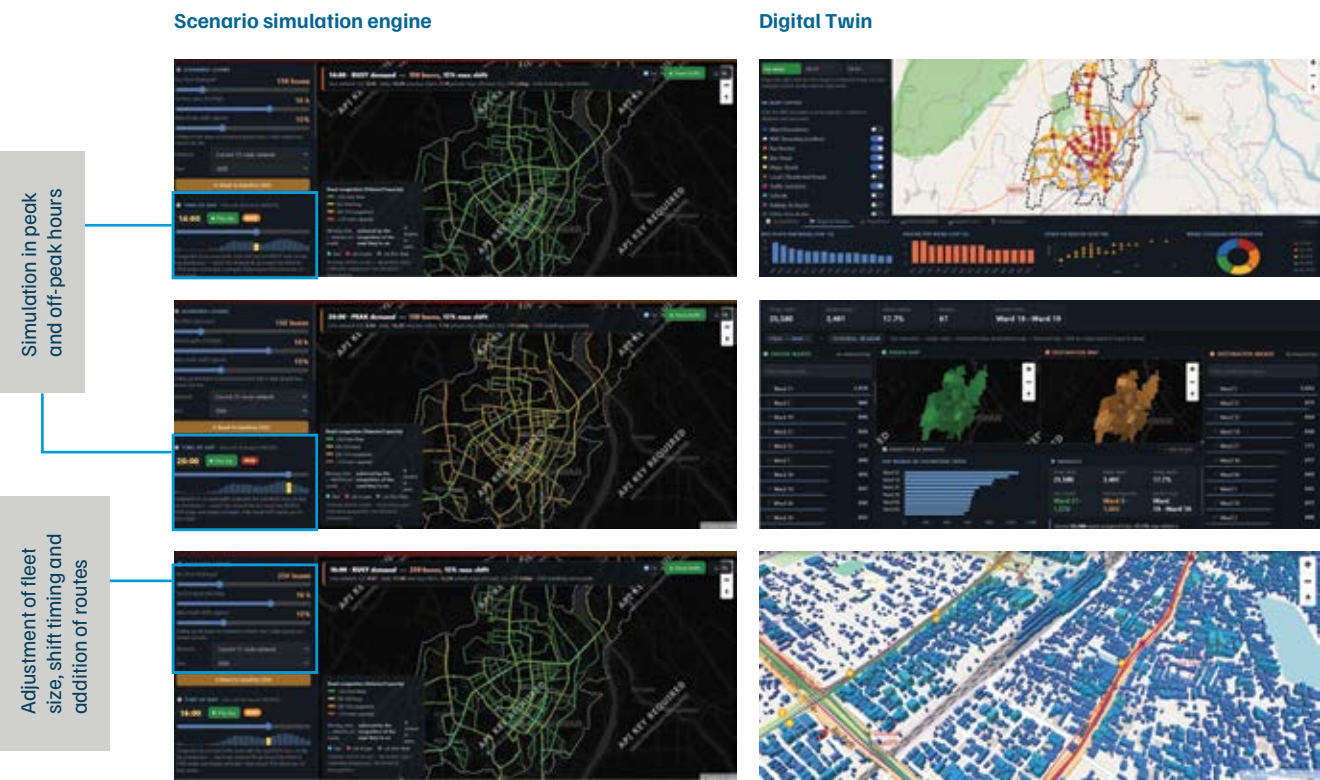
The origin-destination surveys from the reference case-cities and the passive measurement of mobility data from the city of Bhubaneswar perform complementary roles. The surveys from case-cities portray information about trip characteristics like patterns, fares, typical wait times, and length of the trips. They are useful in developing the understanding of how potential passengers travel currently. The OD data measured passively in Bhubaneswar presents complete city-wide, continuous, and more uniform passenger trip records. Combining both forms of data produces evidence that allows the MARG tool to consider detailed survey information for trips and service characteristics while incorporating passive OD and geospatial data.

The digital twin and the scenario simulation engine

Planning tools are saturated in the corridor identification phase in most cases, creating a spot where MARG steps in the most efficient way, because a first-time target city's issue is the comparison with several others before finalising, not the generation of one-unique network (Figure 5).

Bhubaneswar's digital twin, the working prototype, incorporates more than 200 bus stops along with 67 wards and 73 bus routes; in addition, it hosts 2,23,662 footprints of real buildings, of which close to three-fourths have sampled height while the remainder is assigned a ward/citywide mean.

Figure 5. Components of MARG: Digital twin, mobility, and spatial data assessment, and scenario simulation engine



Source: CEEW analysis

Ward-level metrics and characteristics are derived from the urban morphological analytics over the building footprints, and the mobility flows from ward to ward consider the 25,000+ position-derived trips. The twin scores every ward based on a transparent accessibility composite—such as served routes, count of stops, area of the ward inside the 500 m catchment area, and the trip-hotspot density.

The digital twin allows for the possibility of zooming to building-level hyperlocal scale for dynamic visualisation of geospatial data stack alongside the mobility layers at multiple viewing angles to improve the understanding of the city form. In the digital twin visualisation, there is a provision to experiment with bus stops and routes—digitising new routes and changing fleet sizes—ultimately leading to simulating the scenarios for a side-by-side comparison hour-by-hour over the day. The simulation runs the scenario forward to offer an interactive and dynamic view of the routes around the building and all the spatial layers visible at a hyperlocal scale (the neighbourhood level).

The twin also hosts the traffic simulator engine where variation in fleet size of the bus is possible. The twin then presents a dynamic traffic simulation of buses over the bus routes with probable congestion of the routes against time, extrapolating Vahan's vehicular dataset over the city through ward-wise socio-economic factors, population projections, and the road hierarchy.

The digital twin allows planners to test demand variations, routes and fleets, and assess the hourly bus supply.

5. Recommendations

As India urbanises, mega cities face a mobility deficit – 1/3rd of trips are served by public transport against the 70–75 per cent target envisaged under the National Urban Transport Policy (CSE 2026). Estimated 760 million people will live in urban areas by 2047, likely with high concentrations in cities with populations less than 20 lakh. *PM e-Bus Sewa* scheme provides to 118 cities, their first few e-buses. However, route and service planning, is the binding constraint.

We recommend actions for

1. Cities and their transit undertakings, who must plan and operate services now;
2. MoHUA, which designs and funds the *PM e-Bus Sewa* scheme; and
3. MARG itself, a tool that is a work in progress—as this brief has been careful to state.

1. Recommendations for the cities and their transit undertaking

- **Start route planning now; no need to wait for a full mobility study** - Census 2011 work-trip data, master plans, ward-level population density maps, and targeted surveys at 20–40 locations can help identify the top 5–10 demand corridors. Where IPT concentrates, most potential bus trips and any latent ridership are likely to follow.
- **Build the core network around the 3–10 km trip band** - However, expect the network's shape to shift with city size. About 90 percent of all trips in every case city are under 10 km, which is what justifies a dense, frequent network of 9-m or smaller buses over long, infrequent routes.
- **Map depot-to-route distances before finalising a route** - Cities with centrally located depots can rely on overnight charging; cities with peripheral depots need distributed opportunity charging at institutional hubs, airports, or railway stations. Retrofitting charging capacity after construction might be costly or disruptive to the original plan. Route and schedule planning is urgent.

- **Expect near-universal ward coverage, but partial area coverage** - The four proposed networks reach more than 90 percent of municipal wards but only 35–55 percent of municipal area. It is a sensible way to serve a city's busiest corridors with the first fleet of 50–100 buses, though not every neighbourhood will be near a bus-route in phase 1.

2. Recommendations for the MoHUA and the *PM e-Bus Sewa* scheme

- **Size technical assistance and offer training to cities immediately** - Many *PM e-Bus Sewa* cities are planning a public bus network for the first time. The route planning through institutional capacity building of the new CTUs and SPVs through training of methodology and Tool is highly recommended.
- **MoHUA Fund few city-wide passive mobility measurements as shared national infrastructure** - We recommend city-wide passive origin-destination measurement to be funded in select sample cities and treated as a national asset, rather than a local procurement, every subsequent *PM e-bus* city could plan from open data alone. That proposition—far cheaper than 118 separate mobility studies—constitutes the difference between a scheme that delivers buses and a scheme that delivers bus systems.

3. Recommendations for the use of MARG tool, and its enhancements

- **MARG tool is most useful for cities lacking OD datasets and technical prowess for bus planning** - These cities typically have ward maps, city boundaries and basic land use geospatial shapefiles. MARG framework uses these basic datasets to sketch an initial level of evidence that becomes the baseline for planning of routes and services.
- **Keep widening the training and validation base** - Every number in this brief rests on four training cities and one validation city. However, one city is one observation. The framework is not a validated microsimulation: it performs no link-level traffic assignment, its congestion representation is a strategic index normalised from Vahan vehicle stock and occupancy observations, and its land-use projection modules are specified, rather than validated. Confidence will rise as the training set expands to include more cities, with comprehensive measurements.

- **Treat the output of the MARG tool as the interim position** - The corridor model provides a selective, rather than an exhaustive network. Greater precision means that the locations that the model recommends most coincide with the real bus corridor network. The transfer test results are fair, on a single held-out city, Bhubaneswar, predicted blind. The tool identifies feasible corridors and candidate stops selectively by design, and its digital twin exists precisely so planners can step through, edit, and test scenarios. Before a route is finalised, a city plan should be refined through the simulation stage with local officials and operators.
- **Strengthen the geospatial foundation as MARG expands** - The MoHUA should apply a common set of datasets, indicator definitions, and quality checks across cities and update the layers whenever better local data become available. This will keep the framework reliable and comparable, while allowing it to respond to each city's changing urban form and mobility needs.

The Methodology and MARG tool is intended mainly for target cities where e-buses are being introduced, with limited datasets, technical capacity and planning budget outlays. Consequently, early, large public investments in depots, terminals, bus stops, and charging infrastructure need to be finalised based on route and service plans. Our method and tool eases the technical burden of route and service planning on new *PM e-Bus Sewa* cities. Limited data should not mean limited planning of the transit services.

Acronyms

2W	Two-Wheeler	MARG	Mobility Assessment and Route Guidance
AUC	Area Under the (ROC) Curve	MoEFCC	Ministry of Environment, Forest and Climate Change
CMP	<i>Comprehensive Mobility Plan</i>	MoHUA	Ministry of Housing and Urban Affairs
CTU	City Transport Undertaking	MRV	Monitoring, Reporting and Verification
DISCOM	Distribution Company (electricity)	NCAP	National Clean Air Programme
DPR	Detailed Project Report	OD	Origin–destination
e-CTU	Electric-City Transit Undertaking	PM2.5	Particulate Matter up to 2.5 microns
GIS	Geographic Information System	<i>PM e-Bus Sewa</i>	<i>Pradhan Mantri e-Bus Sewa</i> (electric bus scheme)
GPS	Global Positioning System	PT	Public Transport
ICE	Internal Combustion Engine	ROC	Receiver Operating Characteristic
INR	Indian rupee	SLB	Service Level Benchmark
IPT	Intermediate Public Transport	SPV	Special Purpose Vehicle
IIPS	International Institute for Population Sciences	ULB	Urban Local Body
<i>JnNURM</i>	<i>Jawaharlal Nehru National Urban Renewal Mission</i>	VGF	Viability Gap Fund

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The authors



Himani Jain

Himani Jain
Fellow, CEEW
himani.jain@ceew.in



Saoni Sanyal

Saoni Sanyal
Research Consultant, CEEW
saoni.sanyal@ceew.in



Neerav Sharma

Neerav Sharma
Former Programme Associate, Tech & AI, CEEW
neerav312@gmail.com



Sourav Dhar

Sourav Dhar
Programme Lead, CEEW
sourav.dhar@ceew.in



Samradh Singh Chauhan

Samradh Singh Chauhan
Programme Lead, CEEW
samradh.chauhan@ceew.in

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Council on Energy, Environment and Water (CEEW)

ISID Campus, 4 Vasant Kunj Institutional Area
New Delhi – 110070, India
T: +91 (0) 11 4073 3300
info@ceew.in | ceew.in | [@CEEWIndia](https://www.linkedin.com/company/ceewindia) | [@ceewindia](https://www.instagram.com/ceewindia)



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