Comprehensive framework for adoption of Electric Vehicles:

A Case study of Jaipur city

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Research Context & Need

Context

Rapid urbanisation & Transport Demand

Since 1980, India's transport demand has grown by 8 times, with 2 times increase in population.[1]

Air Pollution

In 2019, India was the 5th most polluted countries in the world (21 out of 30 most polluted cities are of India).[2]

Dependance on Oil Imports

In 2019, 12% of overall crude oil & 64% of natural gas demand was met from domestic production and balance was met through imports.[2]

Environment & Climate Change

In 2019, India's transportation sector contributes 10% of total national GHG emissions & road transport alone contributes to 87% of total emissions in the sector.[3]

Need for **paradigm shift** in automobile sector

Indian govt. envisages **E-mobility** as a viable alternative to address these challenges

Source:
1. Report on Transforming India's Mobility: A Perspective, NITI Ayog, 2018
2. Report on Status quo analysis of various segments of E-mobility, NITI Ayog, 2017
3. A Multi-Model Assessment of Energy and Emissions for India's Transportation Sector through 2050, CEEW, 2018

Need

- **EV adoption in India has failed to achieve the desired growth rate** due lack of well defined EV Ecosystem.[1]

- Presence of **limited literature on EV Adoption** Intention & Behavior modelling in India.

- Antecedent literature focuses on **technical & infrastructure issues** in EV adoption rather than **behavioral factors**.[2]

- Absence of research taking into account needs **of all the stakeholders** involved for EV adoption.

- A **Toolkit/ Comprehensive framework** for developing an efficient EV Ecosystem is missing.

Source:
1. The speed bumps in India's EV drive that no one's talking about, Website of Economic Times, accessed on 23 April 2022
2. F. A. Bhat, M. Verma & A. Verma Measuring and Modelling Electric Vehicle Adoption of Indian Consumers, 2021

Aim , Objectives & Methodology

Aim:

To examine various factors affecting EV Adoption & assess current EV policies in order to develop a comprehensive policy framework to accelerate the growth of EVs in Jaipur.

Objectives:

- To assess the importance of EVs in Urban Mobility landscape & shifting towards environmentally sustainable and economically beneficial transport systems

- To review Global literature and policies to identify factors impacting EV Adoption

- To assess the characteristics of EV User, Potential buyers, Charging operator & EV Dealers in the city of Jaipur

- To model the EV Adoption behavior through SEM & identify the key barriers by different stakeholders through application of AHP.

- To propose a Comprehensive Planning & Policy Framework for faster & efficient EV Adoption in Jaipur city.

Methodology:

Background

Literature Review

Data Collection

Stakeholder Analysis & AHP
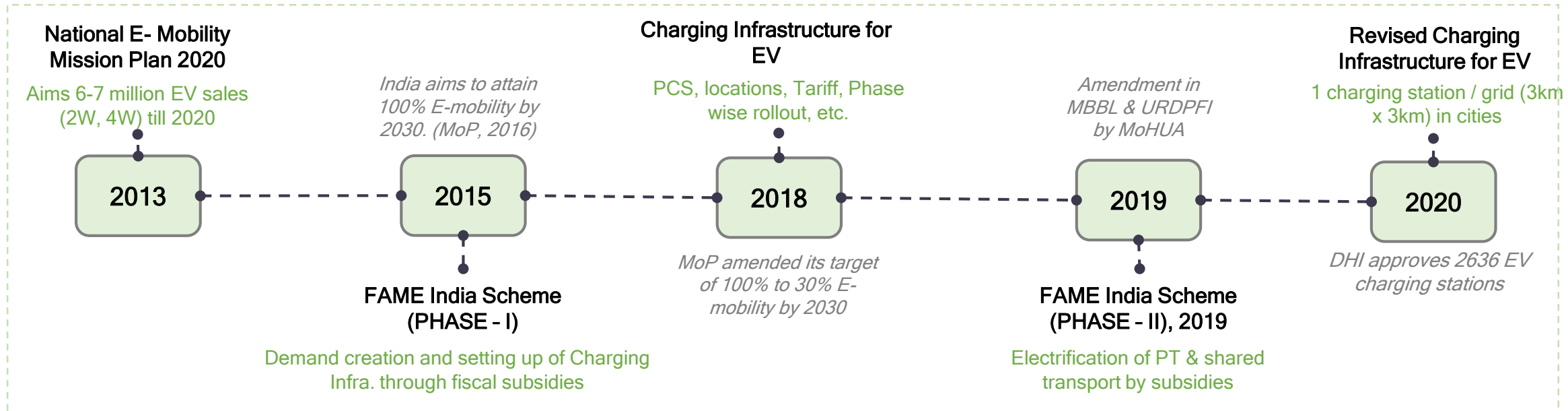
Adoption Behavior Modelling

Proposed Policy EV Framework
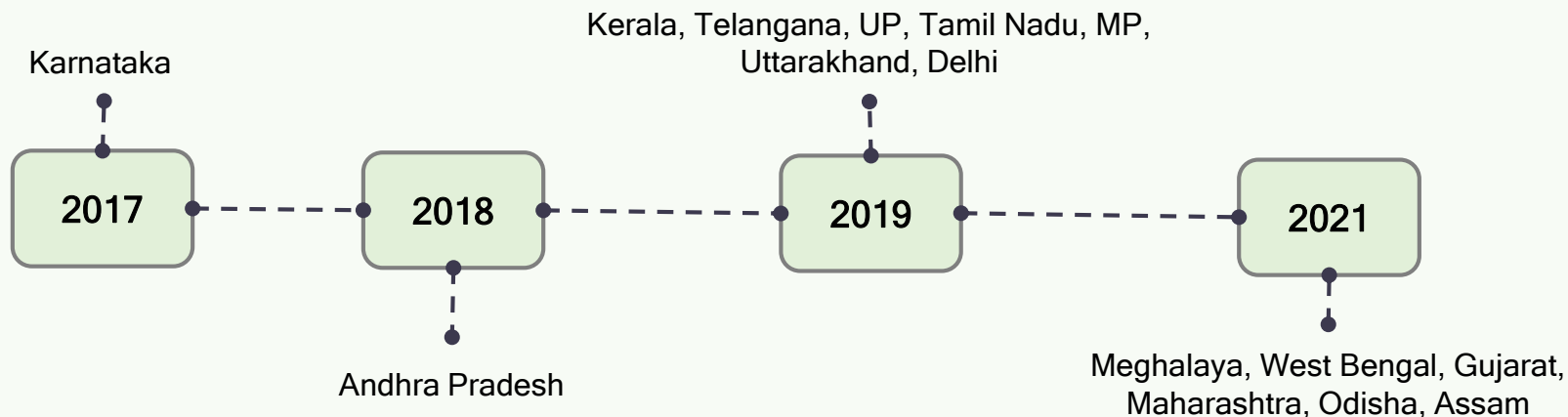
Conclusions & Recommendations

National & State EV Policy Initiatives

National EV policies

National E- Mobility Mission Plan 2020

Aims 6-7 million EV sales (2W, 4W) till 2020

2013

India aims to attain 100% E-mobility by 2030. (MoP, 2016)

2015

FAME India Scheme (PHASE - I)

Demand creation and setting up of Charging Infra. through fiscal subsidies

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Charging Infrastructure for EV

PCS, locations, Tariff, Phase wise rollout, etc.

2018

MoP amended its target of 100% to 30% E-mobility by 2030

Amendment in MBBL & URDPFI by MoHUA

2019

FAME India Scheme (PHASE - II), 2019

Electrification of PT & shared transport by subsidies

Revised Charging Infrastructure for EV

1 charging station / grid (3km x 3km) in cities

2020

DHI approves 2636 EV charging stations

State EV policies

Karnataka

2017

2018

Andhra Pradesh

Kerala, Telangana, UP, Tamil Nadu, MP, Uttarakhand, Delhi

2019

2021

Meghalaya, West Bengal, Gujarat, Maharashtra, Odisha, Assam

Inferences

- **Comparative study** of all state EV policies showed that **Karnataka & Telangana** have the best drafted EV policies.

- However, **EV density** of **Delhi** was observed the highest due to **higher fiscal incentives** provided by the Delhi govt.

Literature Review

Based on literature review of more than 30 research papers (including Indian and International case studies), few factors and issues relevant to the case study were shortlisted. These are as follows:

Factors & Issues affecting EV adoption

Factors	Barriers/ Issues	Literature Reference
Technical	Limited range of EV's/ Range anxiety	Kumar, R.R. & Kumar, A., 2019 & Stakeholder interaction
	Long Charging Time	Mukherjee, C. et. al.,2019
	Limited EV models	Stakeholder interaction
Infrastructural	Inadequate Charging Infrastructure	Bhattacharyya, S.S. & Thakre, S.,2020
	Lack of Maintenance & Repair workshops	Stakeholder interaction
	Lack of Standardization of chargers	Bhattacharyya, S.S. & Thakre, S., 2020
Financial	Higher upfront cost	Kumar P.P. et al., 2021 & Stakeholder interaction
	High cost of Fast charging at PCS	
	Lack of financing (credit) options	Stakeholder interaction
	Additional cost of charging infrastructure at home	Bhattacharyya, S.S. & Thakre, S.,2020
	Lack of subsidies on Electricity tariff	Stakeholder interaction
Behavioral	Attitude	Adnan, N. et al., 2017 Shalender, K. and Sharma, N., 2020
	Moral Norm	
	Perceived Behavioral Control	
	Subjective Norm	
	Environment Concern	

Inference

It was found that majority of the research was focusing either on a **single factor** or a **combination of two**, but none of the papers focused on an **overall perspective**, taking into account **all the issue/ barriers** that are suitable with respect to the study context.

Profile of Case Study of Jaipur

Criteria for Case Selection: Rajasthan's EV policy is in Draft stage

JAIPUR MUNICIPAL AREA PROFILE

- **Area**: 484.64 Sq.km
- **Population**: 30.46 lakh

- **Radial spread**: 15 Km
- **Avg. Trip length**: 6.7 Km

Source: Census of India, 2011

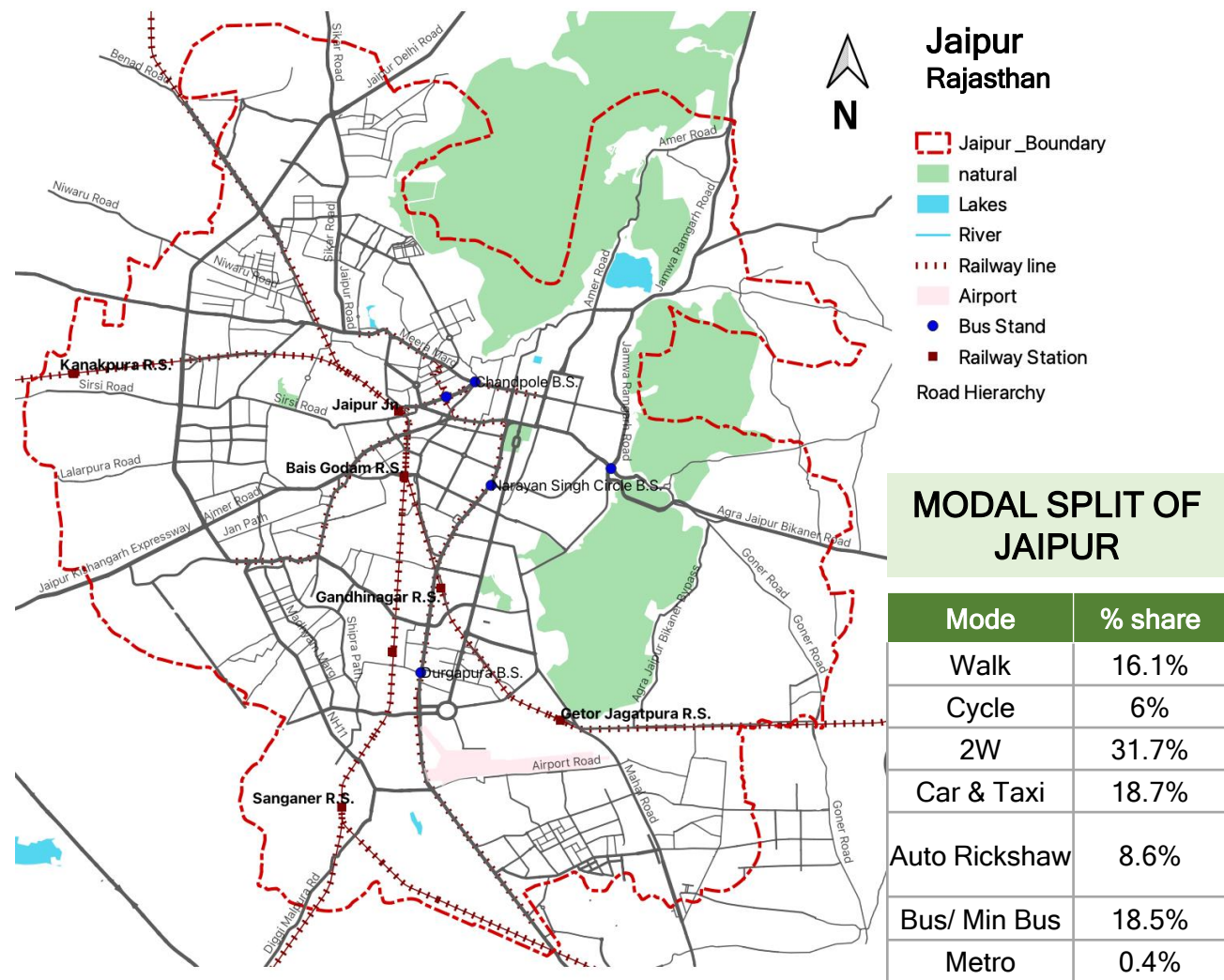*Source: CMP Jaipur, 2016*

TRANSPORT MODES OF JAIPUR

- **Private Modes**: 2W, Car, Taxi, Cycle, LCV, etc.
- **PT Modes**: Bus, Metro, RSRTC, etc.
- **IPT Modes**: Auto, E-Rickshaw, Cycle Rickshaw, etc.

Source: Master Plan of Jaipur- 2025

EV REGISTRATIONS IN JAIPUR

Vehicle Type	Total Vehicle Registrations		% share of EV
	All Vehicles (ICE +EV)	Electric Vehicles	
2W	13,61,000	8,369	24%
Car	3,88,000	696	2%
E-Rickshaw	20,786	23,627	69%
E-Rickshaw (Cart)	1,752	1,733	5%
3 Wheeler (Goods)	3,370	90	0.3%
Total	**17,74,908**	**34,515**	**2 %**

Source: Website of Vahan Sewa , MoRTH- Parivahan, Accessed on 11 May 2022

Source: Map created through Open Street Map (OSM) data on QGIS 3.1

MODAL SPLIT OF JAIPUR

Mode	% share
Walk	16.1%
Cycle	6%
2W	31.7%
Car & Taxi	18.7%
Auto Rickshaw	8.6%
Bus/ Min Bus	18.5%
Metro	0.4%

Source: Master Plan , Jaipur- 2025

Identification of EV stakeholders for Field Surveys

Identification of Stakeholders in EV Adoption, Jaipur

1. Government Officials (ULB, Transport Department, RTO)
2. Power Companies (DISCOM's)
3. EV Charging / Battery Swapping Station Operator
4. Electric Vehicle (EV) Dealer
5. Electric Vehicle (EV) User
6. Potential Buyer of EV (ICE Users)
7. EV Experts (Consultants, Academicians)
8. EV Automakers (Automobile Manufacturers)*
9. Battery Manufacturers *

There are no EV Automobile and Battery Manufacturers located in or around Jaipur.

Primary Survey

- EV Adoption Survey -139 (ICE User)
- EV User Characteristics Survey - 67

Structural Equation Modelling (SEM) based on Extended Theory of Planned Behavior

- EV Dealer Survey - 14
- EV Charging/ Battery Swapping station operator Survey - 15

Analytical Hierarchy Process (AHP)

- Government Official - 7
- EV Expert - 9

Interviews & Secondary Data

Analytical Approach

Secondary Survey

- Vehicle Registration Data,
- Proposals pertaining to EV from ULB's

EV User Characteristics

Public v/s Private Charging

64% Installed Additional Charging Infrastructure at Home
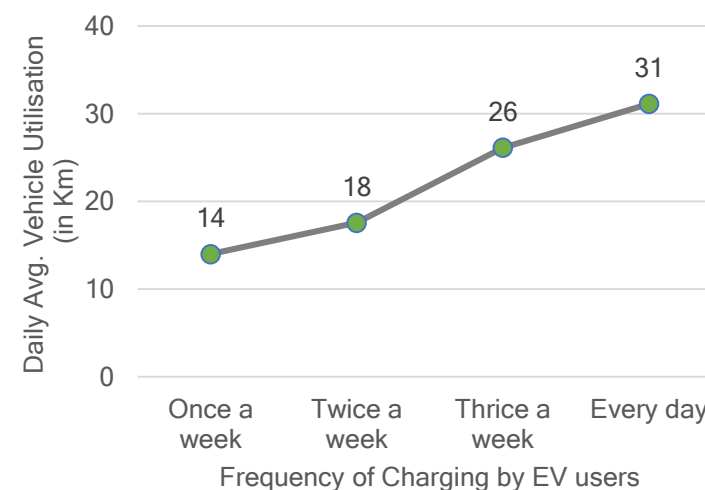
22% Prefers Public Charging rather than Private charging

Daily Vehicle Utilisation of EV users

E-Vehicle Segment	Average Daily Vehicle Utilization
2 wheeler	12 Km
E- Rickshaw	35 Km
4 wheeler	42 Km

Daily Avg. VU v/s Charging frequency

Access Distance of nearest PCS (from home) for EV users

< 5 Km	5-10 Km	10-20 Km	>20 Km
29%	7%	36%	29%

Charging Behavior of EV Users

Vehicle Segment	Avg. Charging Time	% charged	Range (in Km)
2 wheeler	1 hr	30%	26
E- Rickshaw	4 hr	50%	42
4 wheeler	30 min	50%	100

Operational Characteristics of EVs

Vehicle Segment	Charging Time (Hr)	Driving Range (Km/charge)	Cost (Rs/km)
E - 2W	5.5	78	0.5
E - Rickshaw	7	95	2
E - 4W	9.5	220	1.2

EV Dealer Characteristics

Survey Details

- Surveyed EV Dealers – 48%
- Response Rate – 100 %

Vehicle Segment	Total EV Dealers	Samples Collected
2 wheeler	17	9
E- Rickshaw	8	2
4 wheeler	4	3
Total	29	14

General Specifications of EVs

Vehicle Segment	No. of Model	Battery Capacity (KW)	Price (in Lakh)	Charging Type
2 wheeler	6	2.2 - 2.9	0.7 - 1.5	3-Plug point
E- Rickshaw	4	7.5 - 8.5	3.0 - 3.5	3-Plug point
4 wheeler	3	30 - 40	12 - 17	CCS, CHAdeMO, Type 2 AC
	2	50 - 70	23 - 25	

EV Dealers Surveyed

Operational Details of EVs

Vehicle Segment	Average Mileage (Km)	Average Charging Time (Hr)	Average Charging Cost/ charge (Rs.)
2 wheeler	90	6	43
E- Rickshaw	110	7.5	90
4 wheeler	240	11	375
	460	8.5	325

EV Charging Infrastructure Characteristics

Survey Details

- Total Charging Operators - 23
- Response Collected – 15 (65%)

Operators	No. of Stations	Response
TATA	10	9
Exicom	3	3
Fleely Energy	1	1
Xobolt	1	1
Ather	1	1
Others	7	0
Total	23	15 (65%)

Average Charging Time

Vehicle Segment	Avg. Charging Time	% Charge
2 wheeler	30 min	30%
E - rickshaw	4 hour	50%
4 wheeler	1 hr	40%

Charging Infrastructure

- Majority Stations are for - 4 W

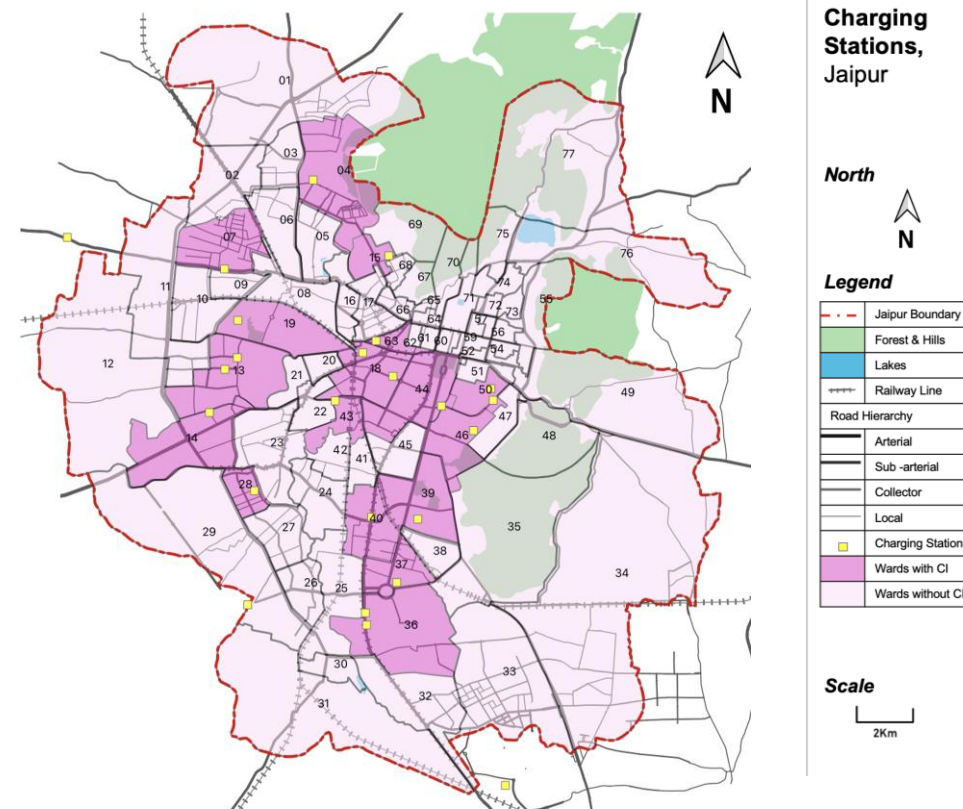| Vehicle Segment	Charging Stations	Samples
2 wheeler	2	2
4 wheeler	18	10
Hybrid	3	3
Total	23	15

Type of Charging Infrastructure

- Only Plug-in charging available

- No Battery Swapping Stations/ EV Models are available in the market in Jaipur.

Charging Infrastructure - Coverage

22% of wards are being served by existing Charging Stations

20% of Population is being served by existing Charging Stations

Location of Charging Stations

Charging Stations, Jaipur

North

N

Legend
- — · — · Jaipur Boundary
- Forest & Hills
- Lakes
- Railway Line
- Road Hierarchy
- Arterial
- Sub -arterial
- Collector
- Local
- □ Charging Station
- Wards with CI
- Wards without CI

Scale 2Km

- Wards in Jaipur city : 77
- Charging Stations in Jaipur: 23
- Wards having Charging Stations : 17
- Total Population of Jaipur City : 30.46 Lakh
- Population catered with existing Charging Infrastructure : 6.32 Lakh

Use of AHP in Stakeholders Analysis

Analytical hierarchy process (AHP) is a multi-criteria decision making method & a tool for formulating and analyzing factors or decisions, to rank the identified barriers in order of their importance.

Steps for conducting an AHP

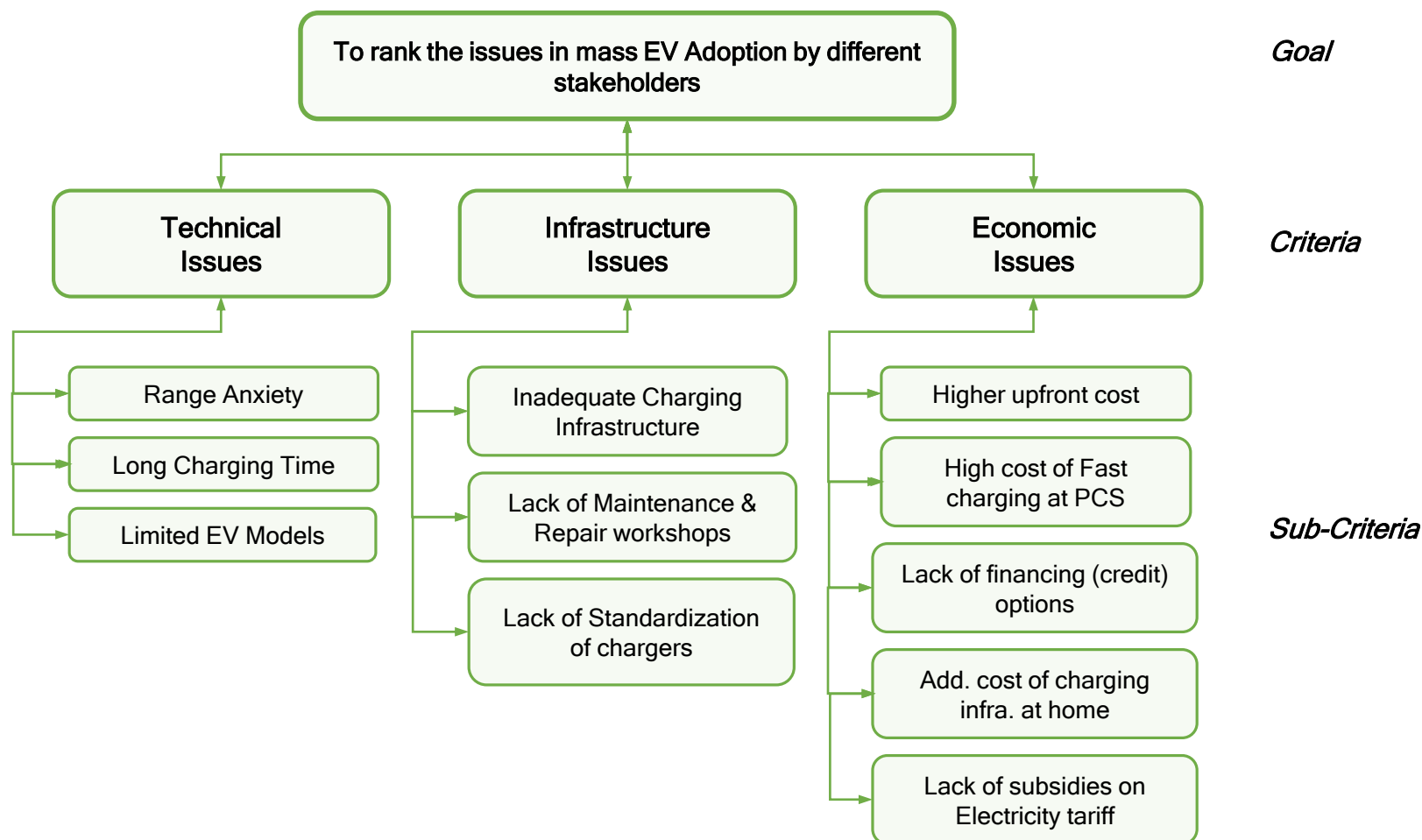**Step 1:** Set a goal and identify n no. of issues and their Categories

Step 2: Pair wise comparison matrix of n x n issues for each sample & make Normalize matrix

Step 3: Calculate weight for n x n issues for each sample & calculate priority weight by GM

Step 4: Calculate the ranking for each criteria & then calculate Global ranking for all the issues

Step 5: Estimate Consistency Index and Consistency Ratio for significant results

Structure of AHP used for the study

To rank the issues in mass EV Adoption by different stakeholders — *Goal*

Technical Issues | Infrastructure Issues | Economic Issues — *Criteria*

Technical Issues:
- Range Anxiety
- Long Charging Time
- Limited EV Models

Infrastructure Issues:
- Inadequate Charging Infrastructure
- Lack of Maintenance & Repair workshops
- Lack of Standardization of chargers

Economic Issues:
- Higher upfront cost
- High cost of Fast charging at PCS
- Lack of financing (credit) options
- Add. cost of charging infra. at home
- Lack of subsidies on Electricity tariff

Sub-Criteria

AHP Results

Stakeholder & Sample size

Stakeholder surveyed	EV User	Non User	Charging Operator	EV Dealer	Govt. Official	EV Expert	Total
	15	24	6	5	7	9	66

Global Ranking

Issue	EV User	Non User	Charging Operator	EV Dealer	Govt. Official	EV Expert	Global Ranking*
Inadequate Charging infrastructure	5	4	8	7	1	1	3
Lack of Standardisation of EV chargers	11	11	10	8	10	4	8
Lack of subsidies on Electricity tariff	6	10	7	11	9	9	11
Lack of Maintenance & Repair workshops for EV	9	9	9	6	3	5	7
High cost of Fast charging at Public Charging Infrastructure	3	7	11	10	8	7	9
Range Anxiety/ Low Driving Range	4	1	4	1	3	6	2
Long Charging Time of EV's	2	3	5	4	6	3	4
Higher upfront cost of EV	1	2	1	5	2	2	1
Additional cost of EV charging infra	7	6	6	9	11	11	10
Limited Models of EV's in the market	10	8	2	2	7	8	6
Lack of financing options	8	5	3	3	3	10	5

Inferences

- **Inadequate charging infrastructure**, **higher upfront cost of EVs** & **lower driving range of EV** were the most significant issues in the process of EV adoption in Jaipur.

- **Technical issues** were the **most significant barriers in EV adoption**, followed by infrastructure and financial issues, according to the criteria weights and overall stakeholder opinions.
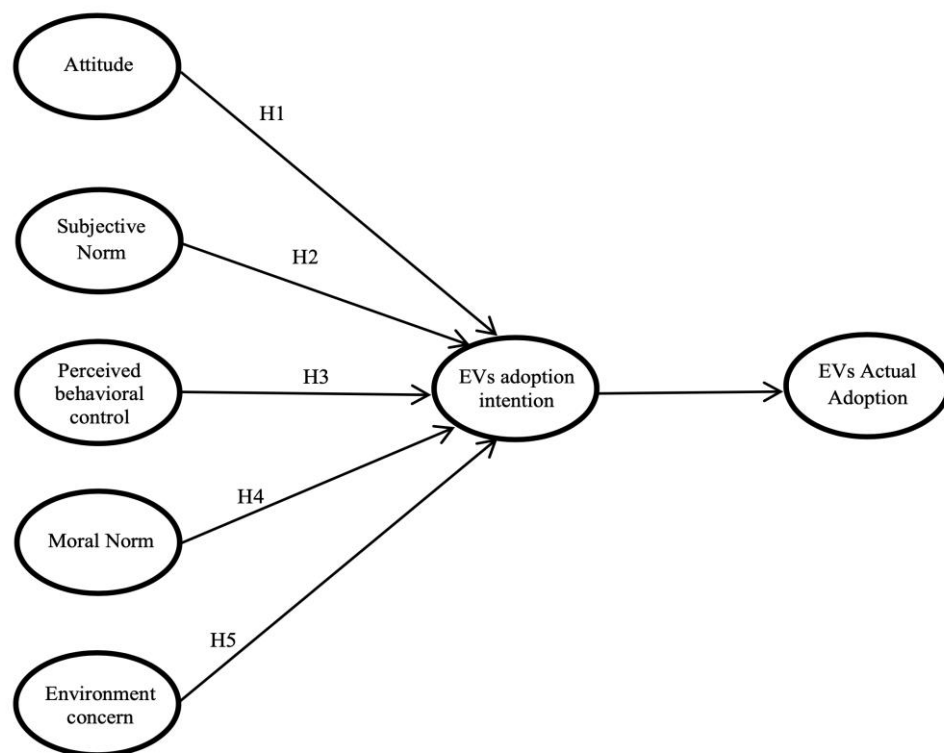
Application of Structural Equation Modelling

Steps for conducting SEM	Model specification >> Data preparation >> Estimation of SEM >> Model evaluation/ modification >> Reports of findings

Extended Theory of Planned Behavior

Source: S. Kumar and N. Sharma , Using extended theory of planned behavior (TPB) to predict willingness of prospective Indian customers to buy EV's in India., 2020
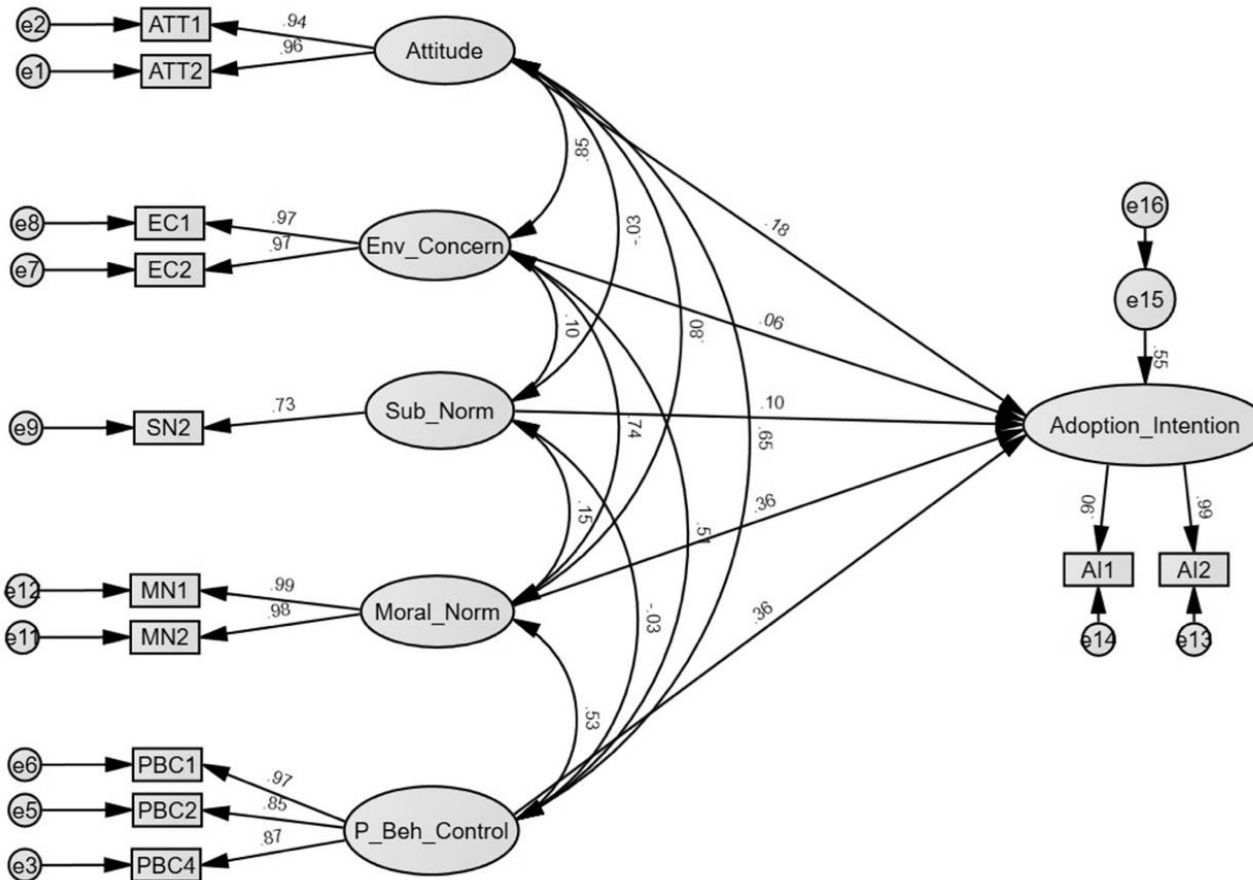
Identified Latent & Observed Variables

Latent Variable	Coding	Observed Variable
Attitude	ATT1	I consider adoption of EV favourable
	ATT2	Driving an EV will be a wise decision
Environment Concern	EC1	I take into consideration environment consequences while buying an EV
	EC2	Buying an EV would help reducing air pollution & contribute to environment for saving future generation
Moral Norm	MN1	I believe, it as my moral responsibility to adopt EV.
	MN2	I take into consideration environment consequences while buying an EV
Perceived Behavior Control	PBC1	Overall cost of owing an EV would be low due to incentives
	PBC2	EV's are as safe as compared to ICE Vehicles
	PBC3	I will save on fuel expenses, as op. cost an EV would be lower
	PBC4	The price of EV is important when I decide to adopt it
Social Norm	SN1	EV is a status symbol for me
	SN2	I will consider the wishes of my family / friends while adopting EV
Adoption Intention	AI1	I would definitely adopt Electric Vehicles in the future.
	AI2	I would recommend the adoption of Electric Vehicles to others

*SEM is a multivariate technique which uses a combination of factor analysis and linear regression

SEM Results

Path Diagram

*This model is a result of a primary survey conducted on 139 ICE vehicle users of Jaipur on a 5 point Likert scale for measuring their intention to adopt EVs

Hypothesis Testing

Path			Path Coefficients (>.05)	T-value (>0.9)	Hypothesis testing
AI	<---	PBC	0.36	3.45	Supported
AI	<---	MN	0.36	2.23	Supported
AI	<---	ATT	0.18	2.36	Supported
AI	<---	SN	0.10	7.04	Supported
AI	<---	EC	0.06	2.17	Supported

Inferences

- **All the factors are positively influencing** the EV adoption intention.

- **Perceived Behavior Control, Moral Norm and Attitude** are the most important variables influencing EV Adoption Intention and Behavior as highlighted by **Shalender, K. et al. (2021) and Khurana, A. et al. (2020)**.

- **Environment concern** and **Subjective norm** are not a strong indicator of EV adoption, due to lack of awareness and promotion of EV benefits among the people

Proposed EV Policy parameters & Framework

Policy Drivers	Existing Policies	Proposed Strategies/ Targets/ Proposals
State EV Policy	No (Only in draft stage)	• Rajasthan EV policy to notified with realistic targets, ensuring benefits to all stakeholders
Regulatory Incentives	No	• 30% Share of EV till 2030 and 50% till 2050. • Target higher % Share of New EV Registrations in all segments including passenger and freight transport
Direct Purchase Incentives	Yes (but lower than others)	• Higher Purchase Incentives on EV's for first 5 years • Loans at subsidized Rate of 4% from RFC for EV
Indirect Incentives	Yes (but lower than others)	• 100% SGST Reimbursement and Registration Fees Waiver in all vehicle segment • Other Tax Benefit (Permit fee/ Tolls/ Green Tax Benefits)
Awareness Programs	No	• Advertisement of EV & its benefits by Print, TV, Radio & Social Media • Awareness to be created through Exhibitions, EV Expo, E Mobility zones for tourists & information dissemination for promoting EV's
Charging Infrastructure Incentives	No	• Planning of Fast and Slow EV Charging Stations/ Battery Swapping Stations in the city and its implementation framework with desired Guideline & Standards • 25% capital subsidy for purchase of equipment/ machinery for first 100 PCS /Battery Swapping stations
Complementary Policies	No	• Subsidized Electricity Tariff for PCS and promote electricity generation through Solar power & V2G technology • 100% exemption on Electrical Duty and provision of Repair & Maintenance Workshops all over the city
Institutional Framework	No	• State Level Committee to be formed for setting up, implementing and monitoring charging infrastructure • Creation of an Umbrella (non-lapsable) "State EV Fund" to be funded through Add. taxes, cess, fees etc. • EV Cell in ULB for planning & implementing Incentives & Infrastructure
Upskill Training & Job Creation	No	• Setting up Research/ Training Institutes, EV Testing Centres, Quality Control Labs, Promoting Start-ups • Develop skill enhancement centres for vocational courses on EV ecosystem

Conclusions & Recommendation

Conclusions

- Vehicle Registration Data shows that **7.8% of new vehicles are EV's in Jaipur**, which is less.

- Primary surveys shows that **64% of EV Users charge their EV's at home due to inadequate Public charging infrastructure and limited access to existing charging stations**.

- **EV market is very small** as compared to ICE vehicle market due to lower demand, that too with a **high upfront price**.

- EV Adoption behavior model shows that **Attitude, Moral Norm & Perceived Control Behaviour majorly influences EV adoption Intention** of potential EV buyers

- **Higher upfront cost, Low Driving Range & Inadequate charging Infrastructure are priority issues** for all the stakeholders & hence critically influences EV adoption.

Recommendation

- **Government policies need to be more inclusive** on both demand and supply side, thus **benefitting all the stakeholders** in the process of EV Adoption

- While formulation of any public policy/ incentive, **behavior of the potential users** should be analysed and taken into consideration

Contribution of the research

- **Assessment of issues** considering **multiple stakeholders** involved in EV Adoption, & their inter-dependencies in policy making.

- **Addition of behavioral approach** for promoting EV's in India with the other technical, infrastructure and financial factors.

Thank you