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IISc Sustainable Transportation Lab (IST Lab)

Paper: 43

Investigating the Effects of Individual and City Tier Characteristics on Motorized Two-Wheeler Usage Behaviour: A Multilevel Modelling Approach

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Outline

- Background & Introduction
- Aim & Research Questions
- Data Description
- Framework: k-means Clustering
- Framework: Multilevel Modelling
- Results and Discussions
- Implications and Conclusions

Background & Introduction

- **Two-wheeler in India -**
  - Most popular transport mode across India
  - Maximum share of all motorized vehicles in production (79.8%) and sales (80.8%)
  - 49.7% of the households in India
  - Highest households ownership in Punjab (75.6%), Rajasthan (66.4%, and Tamil Nadu (63.9%)

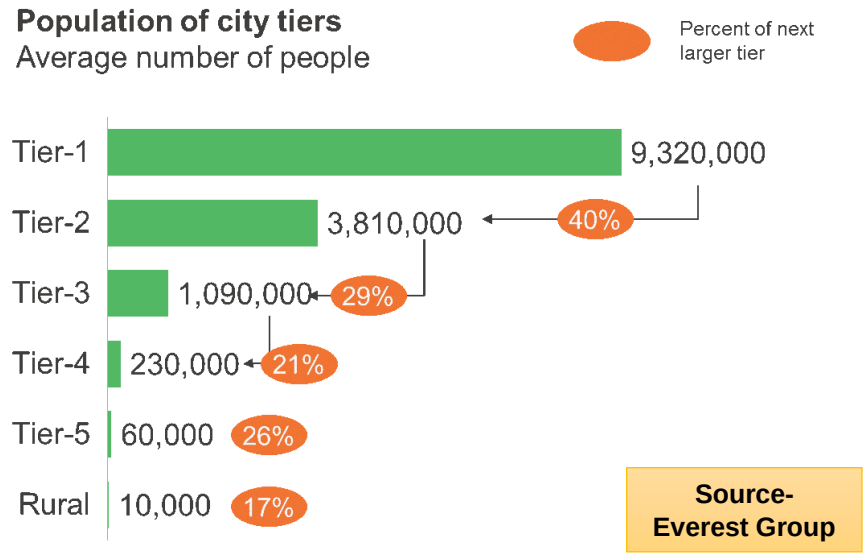

Source- AutoCar

- **Reasons for Popularity -**
  - Easy navigation capability through city traffic
  - Low purchase and maintenance cost
  - Convenience, less space requirement, and reduced travel time
  - Suitability to heterogeneous traffic conditions
  - Preferred choice for female and/or middle-income groups
  - Increased urban sprawl
  - Lack of Public Transit services


Source- Deccan Chronicle

Background & Introduction

- **Across City Tiers-**
  - Share of trips is high in tier-2 cities compared to tier-1 cities
  - Average distance travelled higher in tier-1 and tier-2 cities
  - Parking for a short duration in tier-2 cities
- **Traditional Two-wheeler Usage Policies -**
  - Common for all tiers
  - No account of two-wheeler usage variation across city tiers
  - Tier classification based on population composition
- **Understand**:
  - The motorized two-wheeler usage aspects of individuals
  - Variation among city-tiers



Source- Everest Group

Source- DtNext

Aim & Research Questions

To investigate the effect of individual and city tier characteristics on motorized two-wheeler

What are the different tiers of cities and can we re-define them?

Is there a variation in motorized two-wheeler usage characteristics among the different tiers of cities?

How much is the variation, and which variables are causing the variation?

What are the resulting policy implications?

Data Description

Data

- Online Survey (Google forms)

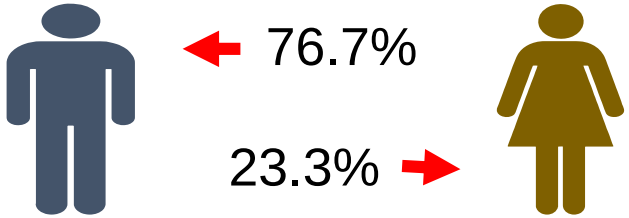
Distribution

- Social Media and Emails

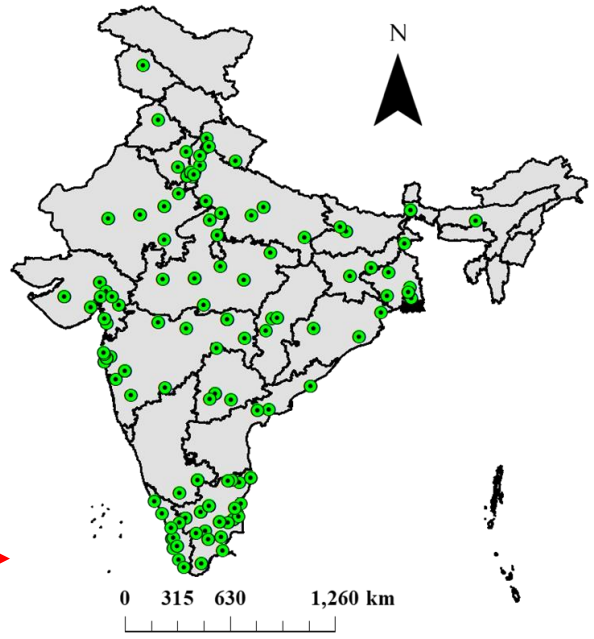
Final Response

- Total - 528
- Regular Two-Wheeler Users - 399
- Spread of respondents' - 110 Cities

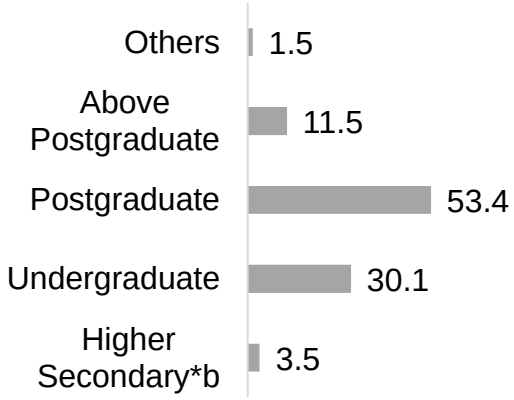
Gender



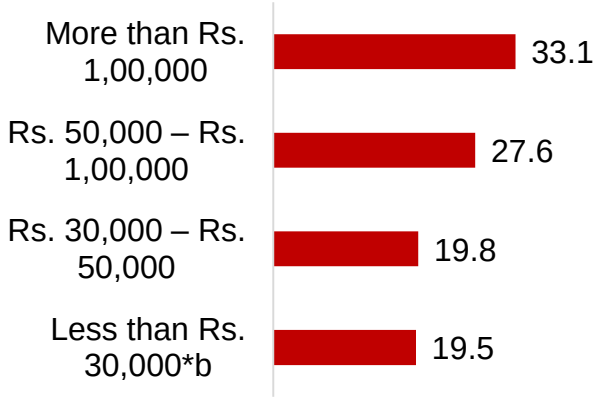
TW users India (M-70% & F-30%)



Education (%)



Monthly Income (%)

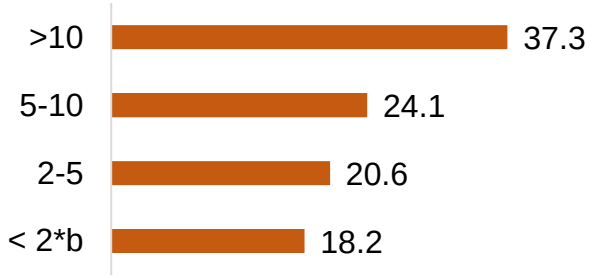


*b Variables are considered as a base in the models

Data Description

Motorized Two-Wheeler Usage Characteristics

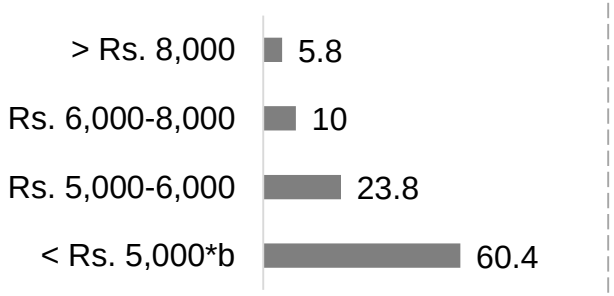
Years of Usage in %



Frequency of Usage

Everyday	62.9%
Otherwise*b	37.1%

Annual Maintenance Cost



Helmet Usage

Always	65.9%
Sometimes or Never*b	34.1%

PUC Check

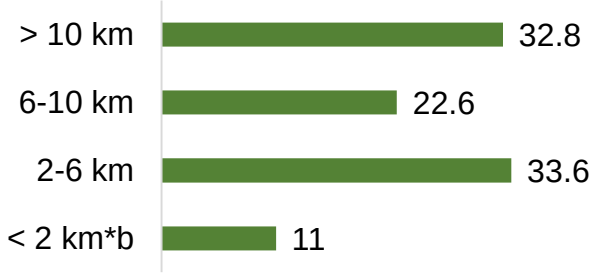
At least twice a year	38.1%
Less than twice a year*b	61.9%

Share with Family

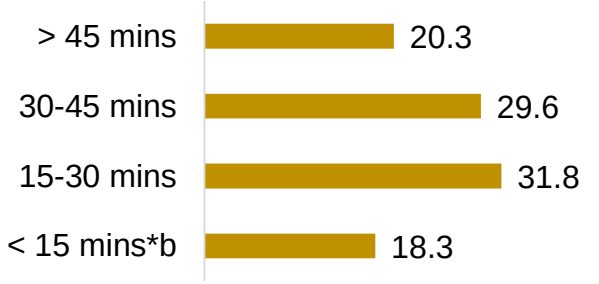
Yes	78.7%
No*b	21.3%

Travel Characteristics

Travel Distance in %



Travel Time in %



Co-Passenger

Yes	31.8%
No*b	68.2%

Parking Characteristics

Parking Type

Off-Street Parking*b	39.8%
On-Street Parking	60.2%

Parking Hour

Less than 1 hour	47.1%
Otherwise*b	52.9%

Parking Cost

No Parking Charge*b	55.9%
Less than Rs. 10	14.3%
Rs. 10-30	26.1%
More than Rs. 30	3.8%

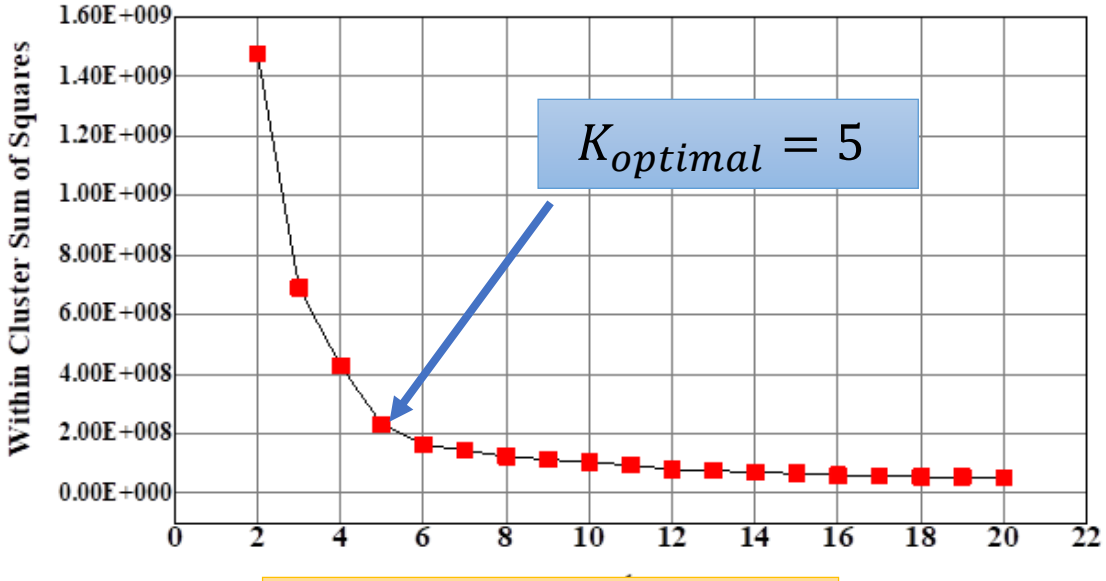
*b Variables are considered as a base in the models

Framework: k-means Clustering

- **Idea -**
  - Minimize the total within-cluster sum of squares (WSS) defined as:

$$WSS = \sum_{k=1}^{k} \sum_{x_i \in C_k} (x_i - \mu_k)^2$$

  - x_i is the observation belonging to cluster C_k
  - μ_k is the cluster centroid
- **Variables -**
  - Population Density (PD)
  - Literacy Rate (LR)
  - Gender Ratio (GR)

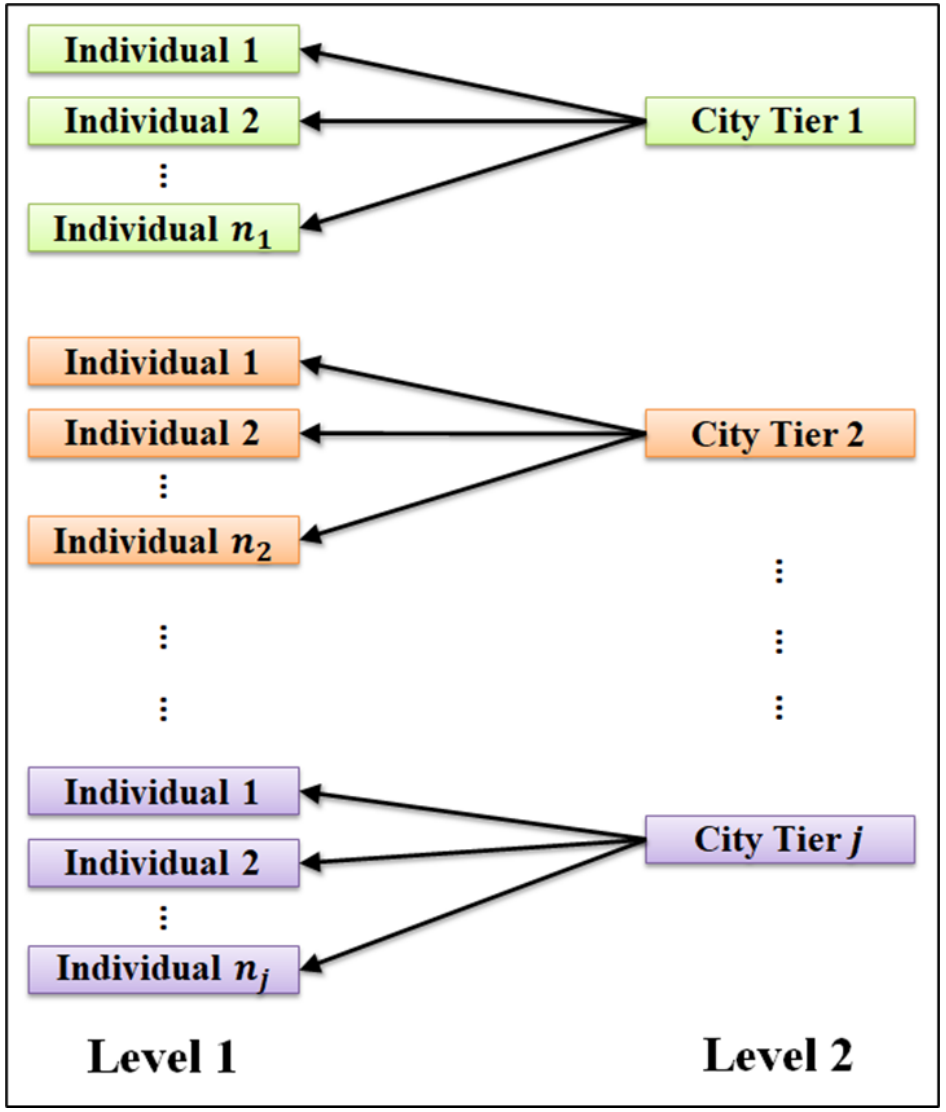


WSS vs k Plot

Centroids	Cluster-1	Cluster-2	Cluster-3	Cluster-4	Cluster-5
PD	16822	27710	2784	10663	6611
LR	87.12	86.77	85.17	85.03	88.09
GR	967	905	959	910	966

Framework: Multilevel Modelling

- **Idea-**
  - Nested data structure violates the independence of residuals assumption
  - Individuals in same cluster perform similarly than individuals in different clusters
  - Disentangle the within-cluster effects from between-cluster effects
- **Models-**
  - Empty Model- Odds of outcome variables vary from one cluster to another
  - Constrained intermediate model (CIM)- Overall effect of level-1 and Level-2 variables
  - Augmented intermediate model (AIM)- CIM+city tier-based variation of the effect of Level-1 variables
  - If $AIM \gg CIM$ → Tier level variation in Level-1 variable effects



Results and Discussions

- **Empty Model Results -**
  - ICC- Quantifies the extent to which log-odds of outcome vary between city tiers, $ICC \in [0,1]$
  - No between-tier variation in
    - Parking Hour
    - PUC Check
    - Co-passenger
    - Family Share
  - Small between-tier variation in
    - Helmet Usage
    - Parking type
    - Frequency of Usage

$$\boldsymbol{Logit\,(odds) = B_{00} + u_{0j}}$$

$$\boldsymbol{ICC = \frac{var\,(u_{0j})}{var\,(u_{0j}) + \left(\frac{\pi^2}{3}\right)}}$$

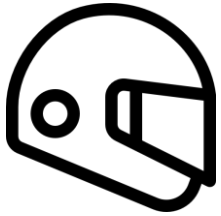
- B_{00} is the fixed intercept
- u_{0j} is the level-2 residual signifying the deviance of the cluster-specific intercept from the fixed intercept

Dependent Variables	Parameters		Log Likelihood	ICC
	B_{00}	μ_{0j}		
Helmet Usage	0.717***	0.388	-254.5	3.35
Parking Hour	--	0	-275.9	0
Parking Type	-0.411***	9.15e-08	-268.3	2.54e-15
PUC Check	-0.485***	0	-265.1	0
Frequency of Usage	0.539***	0.146	-263.0	0.01
Co-passenger	-0.761***	0	-249.6	0
Family Share	1.306***	0	-206.7	0

*** $p - value \leq 0.001$

Results and Discussions

CIM Results- Helmet Usage



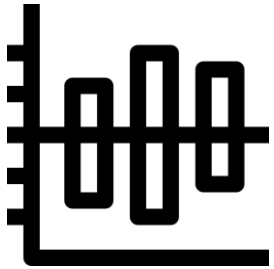
Odds of Regular Helmet Usage

- Maintenance costs
- Income
- Gender Ratio
- Literacy Rate
- Population Density

- Years of usage
- Age

$$\boldsymbol{Logit\,(odds) = B_{00} + B_{10}X_{ij} + B_{01}C_j + u_{0j}}$$

- X_{ij} is the Level-1 predictor variable
- C_j is the Level-2 predictor variable
- B_{10} is the fixed slope of X_{ij} (overall effect of Level-1 variable)
- B_{01} is the fixed slope of C_j (overall effect of Level-2 variable)



- Education
- Marital Status
- Parking Cost

Results and Discussions

CIM Results- Parking Hours

Odds of Parking Hours

- Maintenance costs
- Age
- Education
- Gender Ratio
- Population Density

- Years of usage
- Travel Time

$$\boldsymbol{Logit\,(odds) = B_{00} + B_{10}X_{ij} + B_{01}C_j + u_{0j}}$$

- X_{ij} is the Level-1 predictor variable
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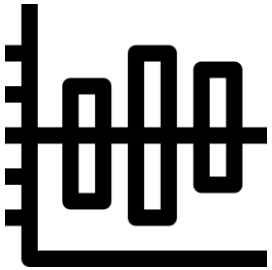
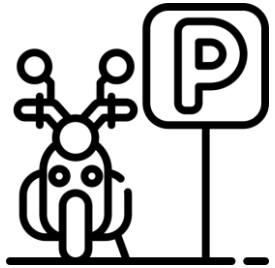


- Income
- Occupation

Results and Discussions

CIM Results- Parking Type



Odds of On-street Parking

- Years of Usage
- Travel Distance
- Travel Time
- Gender Ratio
- Population Density

- Maintenance Cost
- Age

$$Logit\,(odds) = B_{00} + B_{10}X_{ij} + B_{01}C_j + u_{0j}$$

- X_{ij} is the Level-1 predictor variable
- C_j is the Level-2 predictor variable
- B_{10} is the fixed slope of X_{ij} (overall effect of Level-1 variable)
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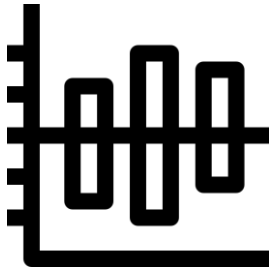


- Income
- Occupation
- Parking Cost
- Education

Results and Discussions

CIM Results- PUC Check

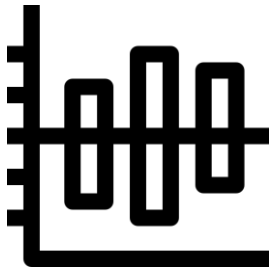
Odds of Regular PUC Check

- Travel Time
- Travel Distance
- Maintenance Cost
- Education

- Gender Ratio

$$\boldsymbol{Logit\,(odds) = B_{00} + B_{10}X_{ij} + B_{01}C_j + u_{0j}}$$

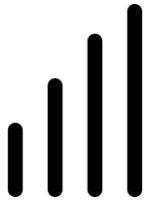
- X_{ij} is the Level-1 predictor variable
- C_j is the Level-2 predictor variable
- B_{10} is the fixed slope of X_{ij} (overall effect of Level-1 variable)
- B_{01} is the fixed slope of C_j (overall effect of Level-2 variable)



- Income
- Age
- Parking Cost
- Population Density

Results and Discussions

CIM Results- Frequency of Usage



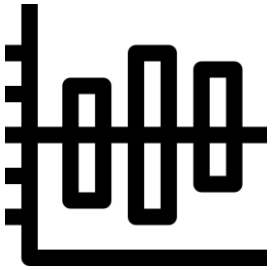
Odds of Frequent Usage

- Years of Usage
- Travel Distance
- Age
- Education
- Gender Ratio
- Literacy Rate

- Income

$$Logit\,(odds) = B_{00} + B_{10}X_{ij} + B_{01}C_j + u_{0j}$$

- X_{ij} is the Level-1 predictor variable
- C_j is the Level-2 predictor variable
- B_{10} is the fixed slope of X_{ij} (overall effect of Level-1 variable)
- B_{01} is the fixed slope of C_j (overall effect of Level-2 variable)



- Parking Cost
- Maintenance Cost

Results and Discussions

CIM Results- Co Passenger

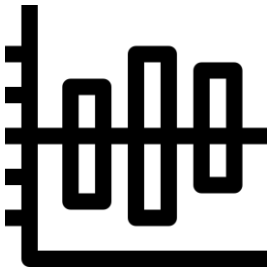
Odds of accompanying a Passenger

$$\boldsymbol{Logit\,(odds) = B_{00} + B_{10}X_{ij} + B_{01}C_j + u_{0j}}$$

- X_{ij} is the Level-1 predictor variable
- C_j is the Level-2 predictor variable
- B_{10} is the fixed slope of X_{ij} (overall effect of Level-1 variable)
- B_{01} is the fixed slope of C_j (overall effect of Level-2 variable)

- Education
- Population Density

- Years of Usage
- Age
- Gender Ratio
- Literacy Rate



- Maintenance Cost
- Parking Cost
- Travel Distance

Results and Discussions

CIM Results- Family Share

Odds of sharing with Family

- Years of Usage
- Income
- Education
- Female

- Travel Time
- Travel Distance
- Parking Cost
- Maintenance Cost

$$\boldsymbol{Logit\,(odds) = B_{00} + B_{10}X_{ij} + B_{01}C_j + u_{0j}}$$

- X_{ij} is the Level-1 predictor variable
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- B_{10} is the fixed slope of X_{ij} (overall effect of Level-1 variable)
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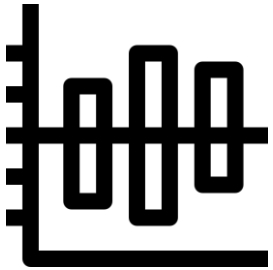


- Population Density
- Literacy Rate
- Gender Ratio

Results and Discussions

- **AIM Results -**
  - Only for variables showing non-negative ICC
  - $AIM \ll CIM$
  - City tier-based variation of the effect of Level-1 variables does not improve model results significantly

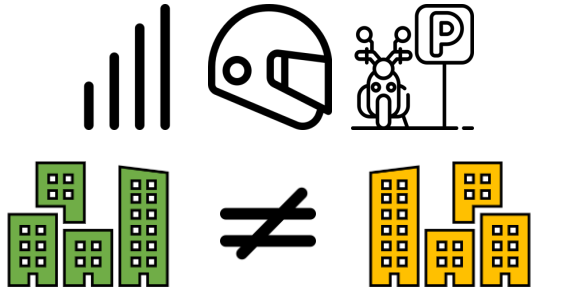
$$\boldsymbol{Logit\,(odds) = B_{00} + (B_{10} + u_{1j})X_{ij} + B_{01}C_j + u_{0j}}$$

- X_{ij} is the Level-1 predictor variable
- C_j is the Level-2 predictor variable
- B_{10} is the fixed slope of X_{ij} (overall effect of Level-1 variable)
- B_{01} is the fixed slope of C_j (overall effect of Level-2 variable)
- u_{1j} is the Level-1 residual signifying the deviance of the cluster-specific slope from the fixed slope

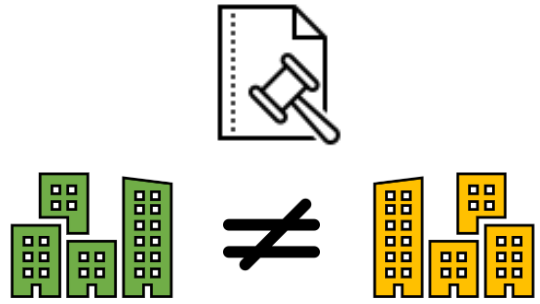
$$\boldsymbol{LR\ \chi^2(1) = Deviance\,(CIM) - Deviance\,(AIM)}$$

Dependent Variable	Model	AIC	BIC	Log Likelihood	Deviance	χ^2	df	p-value
Helmet Usage	CIM	528.8	672.40	-228.4	456.8			
	AIM	750.9	1357.3	-223.4	446.9	9.84	116	1
Parking Type	CIM	554.3	697.97	-241.2	482.3			
	AIM	771.1	1377.4	-233.5	467.1	15.2	116	1
Frequency of Usage	CIM	508.8	652.41	-218.4	436.8			
	AIM	710.7	1317.1	-203.4	406.7	30.0	116	1

Implications and Conclusions



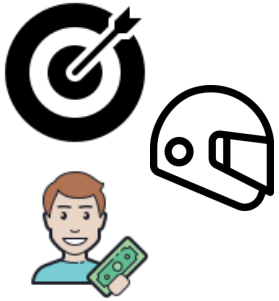
Helmet Usage, Parking type, and Frequency of Usage behaviour vary between different tiers of cities



Common policy measures may not provide consistent results across all tiers of cities

Customized policies based on city tier may ensure better enforcement

Re-organization of transport infrastructure to induce push from two-wheelers and pull towards sustainable alternatives



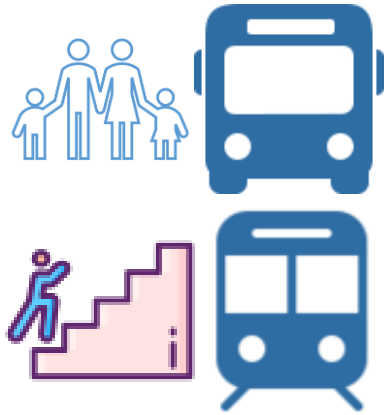
Low-income older individuals should be the target group for promoting adherence to helmet usage in densely populated cities

Policymakers must focus on low- and middle-income males to ensure regular PUC checks

Implications and Conclusions

Cities with high population density and gender ratio can modify parking charges to disincentivize people from using parking facilities for long durations

Push: People belonging to higher and middle-income groups can be chosen as the target population to administer the disincentive policies



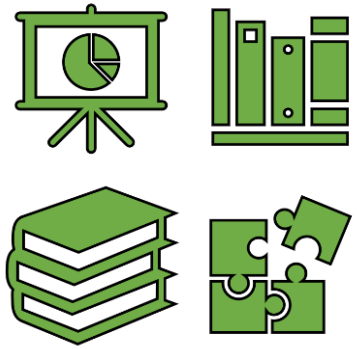
Public transit system might be the key to motivating individuals relying on family-owned two-wheelers to shift to public transit

Pull: High-income and middle-income individuals using two-wheelers for longer period need more incentive to use public transit

Implications and Conclusions

Current data set cannot bring out a significant variance in usage behaviour between city-tiers and needs more introspection

Need for customization of regulatory policies based on the population density, literacy, and gender ratio of the city remains one of the key highlights



Overall results bring out new findings that extend the existing literature on two-wheeler usage behaviour

Further research is encouraged to improve the model accuracy and perform policy analysis based on the observations

Thank You and Stay Sustainable