Choice modelling-based policy evaluation for gender-inclusive mobility

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Authors

Dr. Ubaid Illahi, Dr. Gayathri Harihara Subramanian, Prof. Ashish Verma

IISc Sustainable Transportation Lab

Department of Civil Engineering

Indian Institute of Science, Bangalore

Context and background

- **Men** and **women** have **different transportation needs** due to the difference in their **daily activity-travel patterns** and the **associated factors**.

- **Convergence** in **mode choice** due to:
  - Women's **increasing labour force** participation
  - **Decline** in the normative **male-breadwinner-female-housewife** model
  - **Increasing licensing** and **car ownership** among women

- **PT** and **NMT not** being the **preferred** modes

- **Mode choice behavior** affects **sustainability**

Objectives

1. To **develop** a **mode choice model** using the RP-SP survey data set.

2. To **explore, identify,** and **test** the impact of **transport policy bundles** (consisting of policy instruments) on the modal split across men and women.

3. To **test and analyze** the impact of identified policy bundles across the **gender-income groups**.

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Methodology

1 Decision maker –individual (based on gender)

Man Woman

2 Alternatives (available transport modes)

Walk Cycle Car eeler Auto-rickshaw

Bus Metro

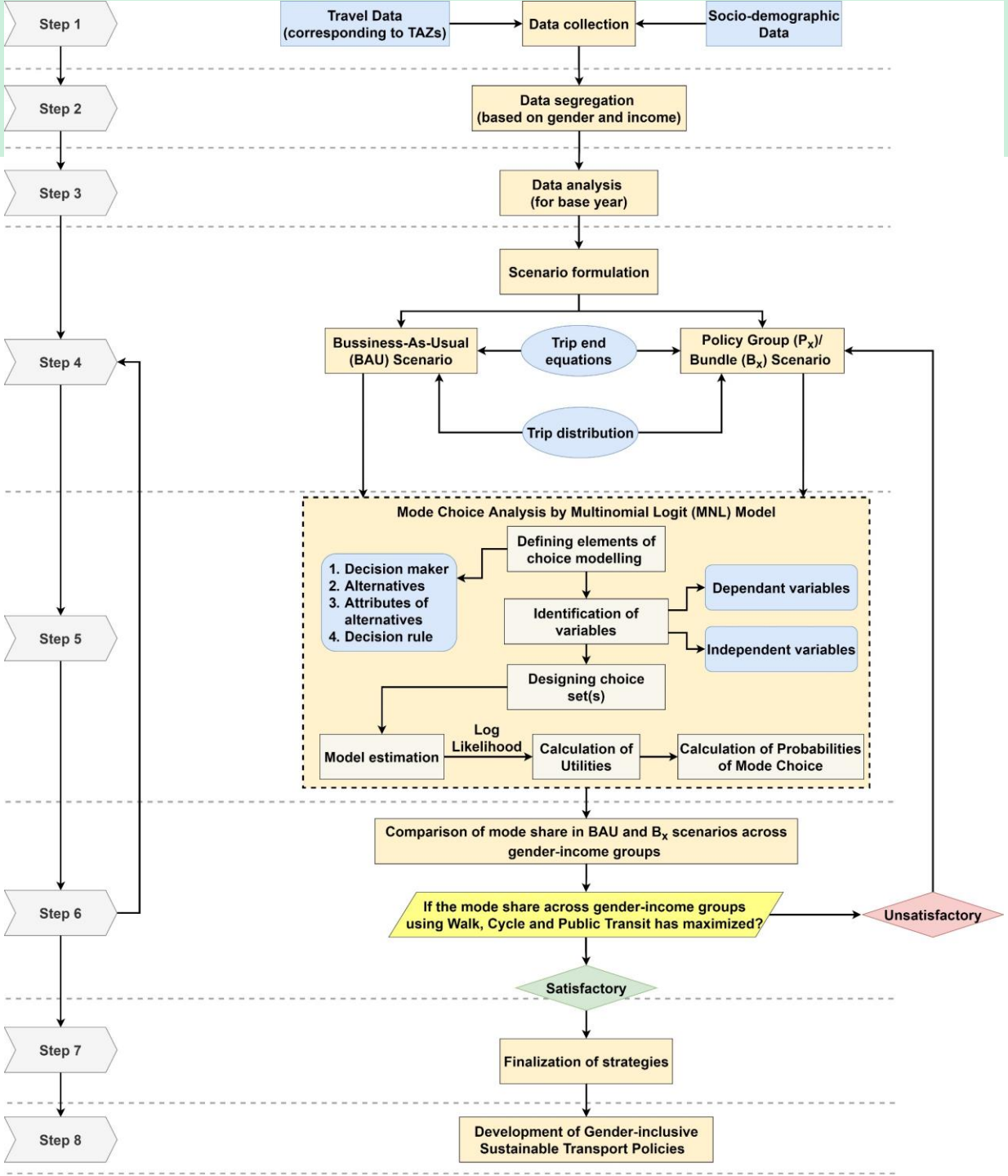
3 Attributes of Alternatives (measures of service)

Travel cost

Travel time

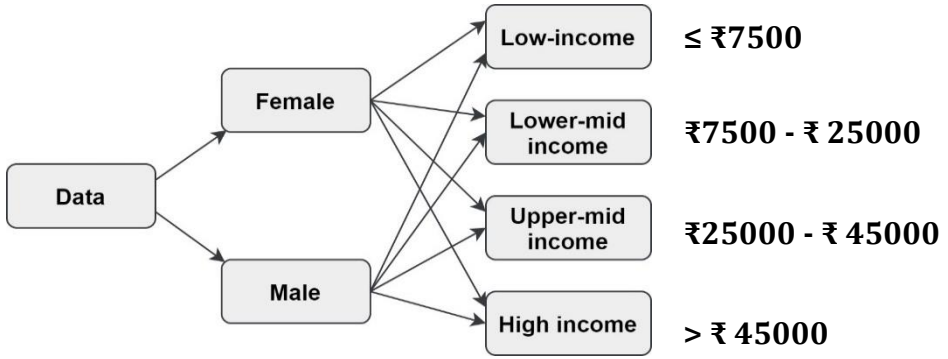
4 Decision rule

Utility Maximization Rule (UMR)



Variables

Variable category	Notation	Variable
Decision-maker	x_{11}	Age (16 to 58 years)
	x_{12}	Gender (Male = 0, Female = 1)
	x_{13}	Income (Low, Lower-mid, Upper-mid and High)
Mode (dependent)	C_{ALT}	Alternative (mode) chosen from the choice set
Attributes of alternatives	x_{CTT}	Travel Time using Car
	x_{BTT}	Travel Time using Bus
	x_{WKB}	Walking time to bus (PT)
	x_{WTB}	Waiting time (PT)
	x_{ITB}	Interchange time (PT)
	x_{TWTT}	Travel Time using Two-Wheeler
	x_{ATT}	Travel Time using Auto
	x_{CYT}	Travel Time using Bicycle (NMT)



x_{WT}	Walking Time (NMT)
x_{MTT}	Travel time using Metro (PT)
x_{CTC}	Travel Cost using Car
x_{BTC}	Travel Cost using Bus (PT)
x_{TWTC}	Travel Cost using Two-Wheeler
x_{ATC}	Travel Cost using Auto
x_{MTC}	Travel Cost using Metro (PT)

Mathematical formulation

The utility of an individual i choosing the mode m is given by the following expression: $U_{im} = V_{im} + \varepsilon_{im}$

Utility equations:

$$V_{i,CAR} = \alpha_{CA} + \beta_{TT} * x_{CTT} + \beta_{TC} * x_{CTC} + \beta_{1,CA} * x_{11} + \beta_{2,CA} * x_{12} + \beta_{3,CA} * x_{13}$$

$$V_{i,TW} = \alpha_{TW} + \beta_{TT} * x_{TWTT} + \beta_{TC} * x_{TWTC} + \beta_{1,TW} * x_{11} + \beta_{2,TW} * x_{12} + \beta_{3,TW} * x_{13}$$

$$V_{i,AUTO} = \alpha_{AU} + \beta_{TT} * x_{ATT} + \beta_{TC} * x_{ATC} + \beta_{1,AU} * x_{11} + \beta_{2,AU} * x_{12} + \beta_{3,AU} * x_{13}$$

$$V_{i,CYCLE} = \alpha_{CY} + \beta_{TT} * x_{CYT} + \beta_{1,CY} * x_{11} + \beta_{2,CY} * x_{12} + \beta_{3,CY} * x_{13}$$

$$V_{i,WALK} = \alpha_{WA} + \beta_{TT} * x_{WT} + \beta_{1,WA} * x_{11} + \beta_{2,WA} * x_{12} + \beta_{3,WA} * x_{13}$$

$$V_{i,BUS} = \alpha_{BU} + \beta_{TT} * x_{BTT} + \beta_{TC} * x_{BTC} + \beta_{1,BU} * x_{11} + \beta_{2,BU} * x_{12} + \beta_{3,BU} * x_{13} + \beta_{WK} * x_{WKB} + \beta_{WT} * x_{WTB} + \beta_{IT} * x_{ITB}$$

$$V_{i,METRO} = \alpha_{ME} + \beta_{TT} * x_{MTT} + \beta_{TC} * x_{MTC} + \beta_{1,ME} * x_{11} + \beta_{2,ME} * x_{12} + \beta_{3,ME} * x_{13}$$

The probability of an individual i choosing the mode m is given by the following expression: $P_{im} = \frac{e^{V_{im}}}{\sum_{q \in C_m} e^{V_{iq}}}$

The probability of a mode m, which is obtained by the following expression: $P_m = \sum_{i=1}^{n} P_{im}$

Estimated parameters

Parameter	Estimate	t-ratio	Parameter	Estimate	t-ratio
α_{CA}	0 (fixed)	NA	$\beta_{2,CA}$	0	NA
α_{TW}	6.508	7.656	$\beta_{2,TW}$	-3.710	-8.032
α_{AU}	-11.983	-0.094	$\beta_{2,AU}$	12.315	0.097
α_{CY}	5.187	5.219	$\beta_{2,CY}$	-1.656	-3.645
α_{WA}	6.885	7.570	$\beta_{2,WA}$	-0.579	-1.578
α_{BU}	7.848	9.525	$\beta_{2,BU}$	-1.339	-4.244
α_{ME}	7.233	9.028	$\beta_{2,ME}$	-1.453	-4.692
β_{TT}	-0.020	-12.858	$\beta_{3,CA}$	0	NA
β_{TC}	-0.012	-5.588	$\beta_{3,TW}$	-0.063	-6.194
$\beta_{1,CA}$	0	NA	$\beta_{3,AU}$	-0.151	-5.470
$\beta_{1,TW}$	-0.080	-4.105	$\beta_{3,CY}$	-0.075	-6.003
$\beta_{1,AU}$	0.086	3.085	$\beta_{3,WA}$	-0.071	-6.524
$\beta_{1,CY}$	-0.043	-1.798	$\beta_{3,BU}$	-0.078	-8.275
$\beta_{1,WA}$	-0.052	-2.469	$\beta_{3,ME}$	-0.061	-6.635
$\beta_{1,BU}$	-0.059	-3.372	β_{WK}	-0.020	-0.874
$\beta_{1,ME}$	-0.063	-3.680	β_{WT}	-0.021	-0.980
			β_{IT}	-0.176	-2.141
Null log-likelihood = -4173.977			Final log-likelihood = -2427.871		
Rho-square = 0.4183			Adjusted Rho-square = 0.4114		
Akaike Information Criterion (AIC) = 4913.74			Bayesian Information Criterion (BIC) = 5078.20		

Note: t-ratios > 1.96 (in absolute value) means that the coefficient is statistically significant for 95% confidence level, Similarly, a threshold of 1.645 is used for 90% confidence.

Policy Bundles

Group 1 (Individual policy instruments)

Testing of Policies

Group 2 (two or more policy instruments)

B1. Providing dedicated (exclusive) bus lanes

B2. Improving cycling and walking infrastructure

B3. Zero fares on PT for Low and Lower-middle Income Women

B4. Discounted fares on PT for Women

B5. Introducing integrated platforms

B6. Improving the real-time information of PT system

B7. Improving surveillance, design & safety measures

Comparison with BAU scenario

B8. Consisting of 2 policy instruments

1. Zero fares on PT for Low and Lower-middle Income Women
2. Discounted fares on PT for Women

B9. Consisting of 3 policy instruments

1. Introducing integrated platforms
2. Improving the real-time information of PT system
3. Improving surveillance, design & safety measures

B10. Consisting of 12 policy instruments

B11. Consisting of 11 policy instruments

B12. Consisting of 16 policy instruments

B13. Consisting of 19 policy instruments

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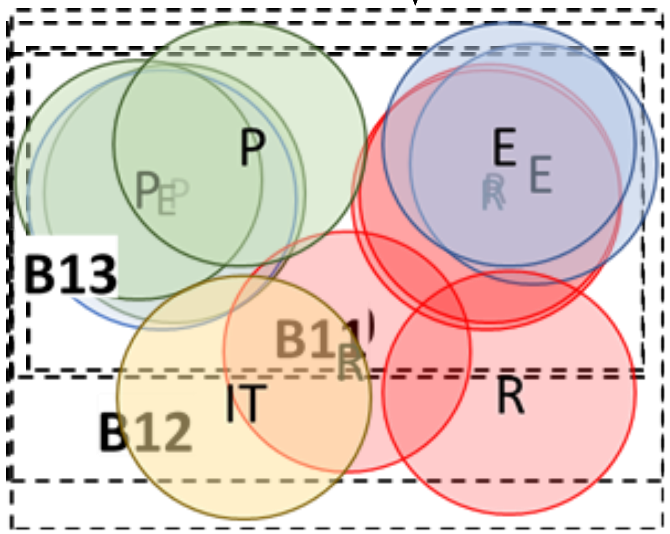
Policy Bundles

Policy Bundle 13

Intersection of Planning, Economic, Regulatory and Info Tech instruments

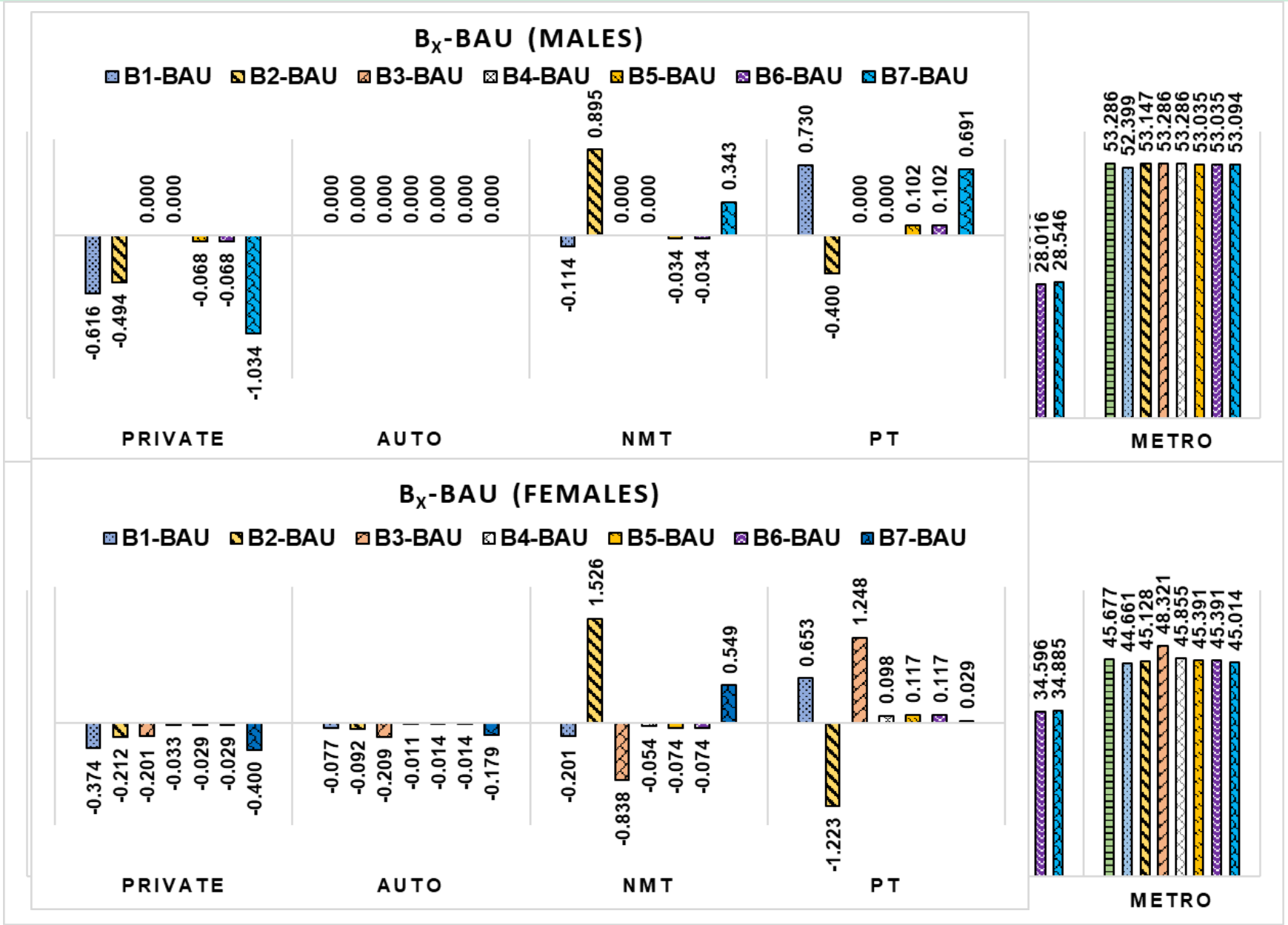


	Policy instruments
1	Increasing network coverage of PT
2	Increasing frequency of PT
3	Encouraging park and ride
4	Subsidizing PT modes
5	Defining car restricted zones
6	Encouraging carpooling and HOV Lanes
7	Increasing the fuel cost
8	Adopting the hybrid work patterns
9	Improving cycling and walking infrastructure
10	Densifying along the transport corridors
11	Enforcing congestion pricing
12	Providing Zero Fares or Low Fares on PT for Women
13	Discounted fares on PT for Women
14	Introducing Integrated platforms
15	Imposing polluter pays
16	Providing dedicated (exclusive) bus lanes
17	Improving the real-time information of PT system
18	Implementing vehicle free zones
19	Improving surveillance, design & safety measures

Modal Split Results Across *Gender* Groups

Effect of Policy Bundles on (Modal Split) with respect to BAU scenario

Group-1

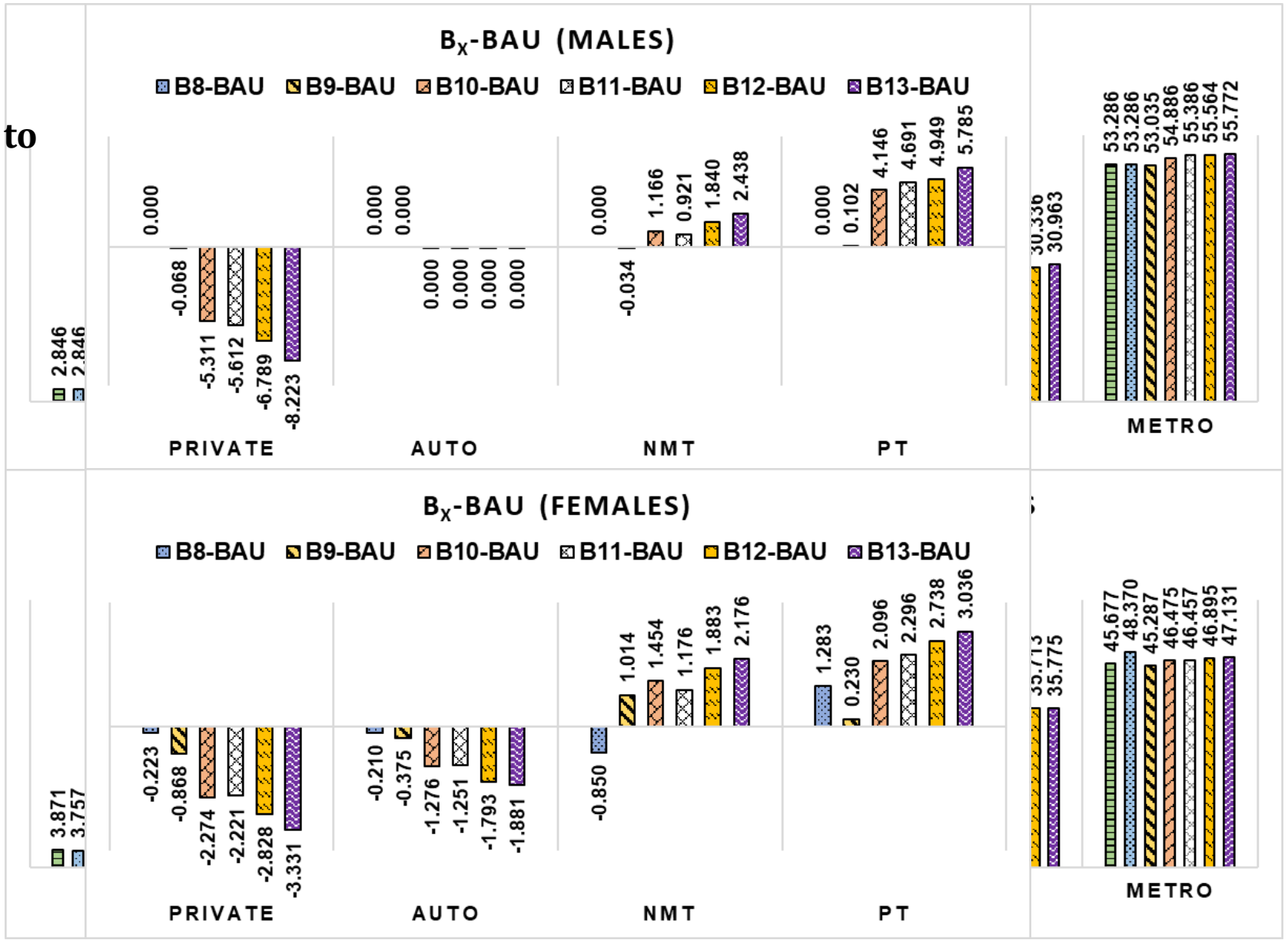


Modal Split Results Across *Gender* Groups

Effect of Policy Bundles on Modal Split

Change in the mode share (aggregated) with respect to BAU scenario

Group-2



Modal Split Result Across *Income-Gender* Groups

- **Low-income** as well as **lower-mid income females** have a significantly **higher mode share of PT (bus and metro)** and **walk mode**, compared to males.
- Surprisingly, a good proportion of upper-income males have been found to use the metro.
- To attract more users to PT and NMT modes, **policymakers need to think beyond affordability** as there is a risk of people shifting to unsustainable modes if their income levels improve.
- **Females** are more **concerned about the safety** and **comfort** which attracts them to use a car, provided there are no economic constraints. Contrarily, **males** are more **concerned about the reliability** of the mode.

Analysis of the results (B1-B9)

Bundle	Desired shift in mode	Male	Female
B1: Providing dedicated (exclusive) bus lanes	Bus	+1.62%	**+1.67%**
B2: Improving cycling and walking infrastructure	NMT Walk Cycle	+0.9% +0.63% **+0.26%**	**+1.57%** **+1.36%** +0.17%
B3. Zero fares on PT for Low and Lower-middle Income Women	PT	0.00%	**+1.25%***
B4. Discounted fares on PT for Women	PT	0.00%	**+0.10%***
B5. Introducing integrated platforms B6. Improving the real-time information of PT system	PT	+0.10%	**+0.12%**
B7. Improving surveillance, design & safety measures	NMT	+0.34%	**+0.55%**
B8	PT	0.00	**+1.28%**
B9	Car NMT PT	-0.068% -0.034% +0.102%	**-0.868%** **+1.014%** **+0.230%**

Analysis of the results (B10-B13)

The results from Bundle 10 to Bundle 13 can be summed as follows:

- **Bundle 13** showed the **best** results i.e. **max. reduction** in **car**, **two-wheeler** and **auto** modes as well as **max. increase** in **PT** (bus and metro) and **NMT** (walk and cycle) modes.
- Mode share reduced **more for females** than males in the following:
  - ✓ Car: **F (-2.644%)** and M (-2.059%)
  - ✓ Auto: **F (-1.881%)** and M (0.000%)
  - ✓ Walk: **F (+1.508)** and M (+1.336)

- Mode share increased **more for males** than females in the following:
  - ✓ Two-wheeler: **M (-6.164%)** and F (-0.687%)
  - ✓ Cycle: **M (+1.102%)** and F(+0.668%)
  - ✓ Bus: **M(+3.298%)** and F (+1.583%)
  - ✓ Metro: **M(+2.486)** and F (+1.454%)

However, the mode share of bus (in B13) for females is **35.775%** which is more than that of males (30.963%).

Conclusions and Policy implications

1. The policies in **B1 to B7** demonstrated that **females** are likely to shift more towards **PT and NMT modes**; however, the shift could be undesirable also if it does not target all the modes.
2. **B10 to B13** demonstrated the **benefit** of using **combination of policy instruments**. Using these, policymakers can target all the modes and improve the overall modal split.
3. Among the NMT modes, **females** are more likely to **walk** while the **males** are more likely to **cycle**.
4. Considering the **cost subsidies** in the PT, **women** are more likely to use **metro over bus**.
5. Among the private modes, **two-wheeler** is a preferred mode for **males** while **females** prefer **car**.
6. Among the public modes, **mode share of bus** is more for **females**.
7. **Low-income** as well as **lower-mid income females** have a significantly **higher mode share of PT** (bus and metro) and **walk** mode.
8. **Two-wheeler** is a preferred mode for **males** across **lower, lower-mid, and even upper-mid income** groups.
9. The mode share of **car** is observed to be **higher for females** across **upper-mid** and **high income** groups.
10. The study would be beneficial for policymakers to target a specific gender or specific issue or a combination of issues to make the modal split equitable.

Making Living Sustainable

Thank you