Modeling Mode Choice Sensitivities: Analyzing the Influence of Transport Attributes on Ridership Using Multinomial Logit Model

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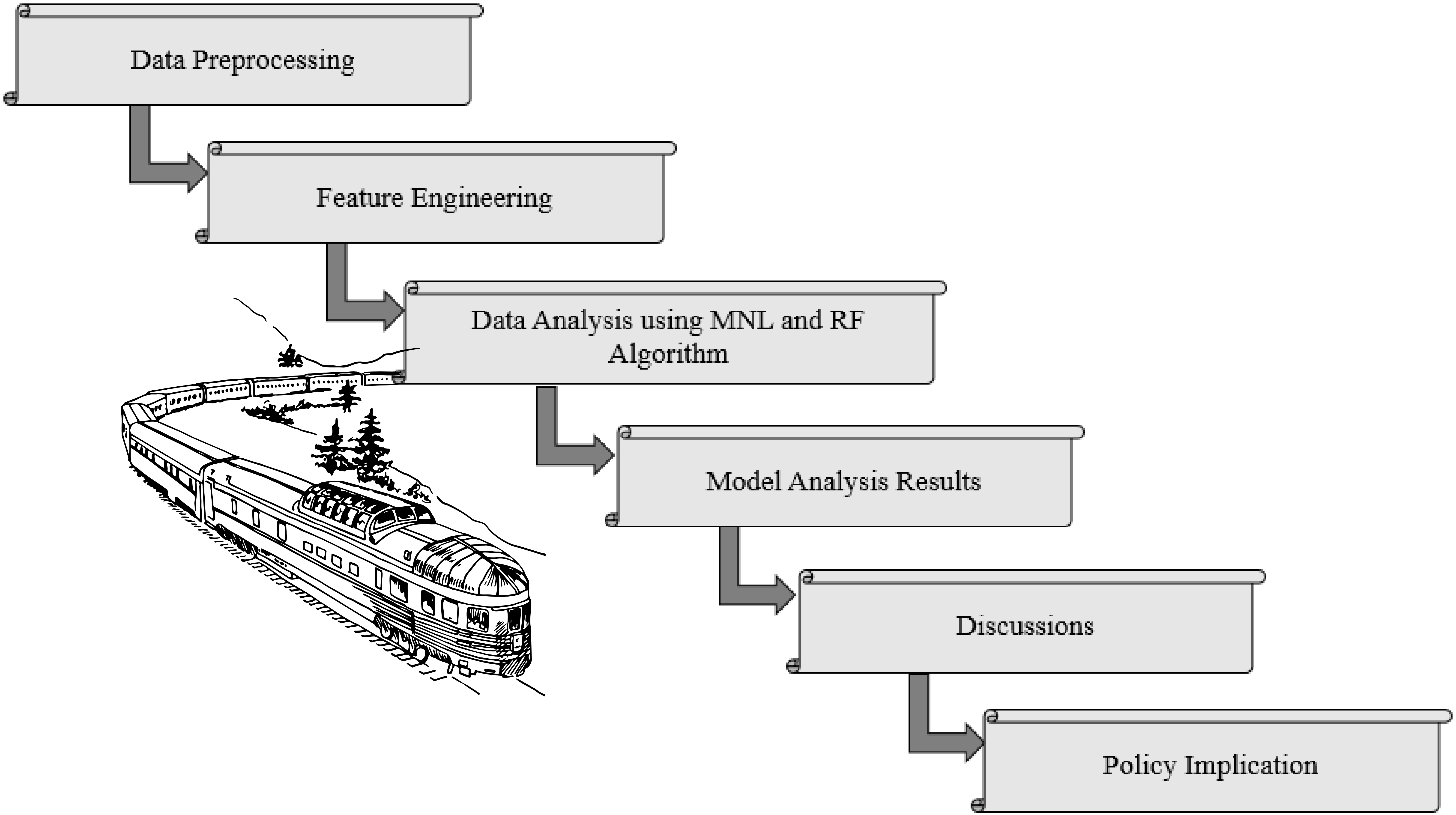
OBJECTIVES

- To Estimate Parameters using MNL Models based on Data Analysis.
- To Understand How Sensitive each Mode is to Changes in its Own Attributes.
- To Analyze How Changes in One Attribute of Public Transport Influence the Selection of Different Modes Based on Elasticities.

METHODOLOGY

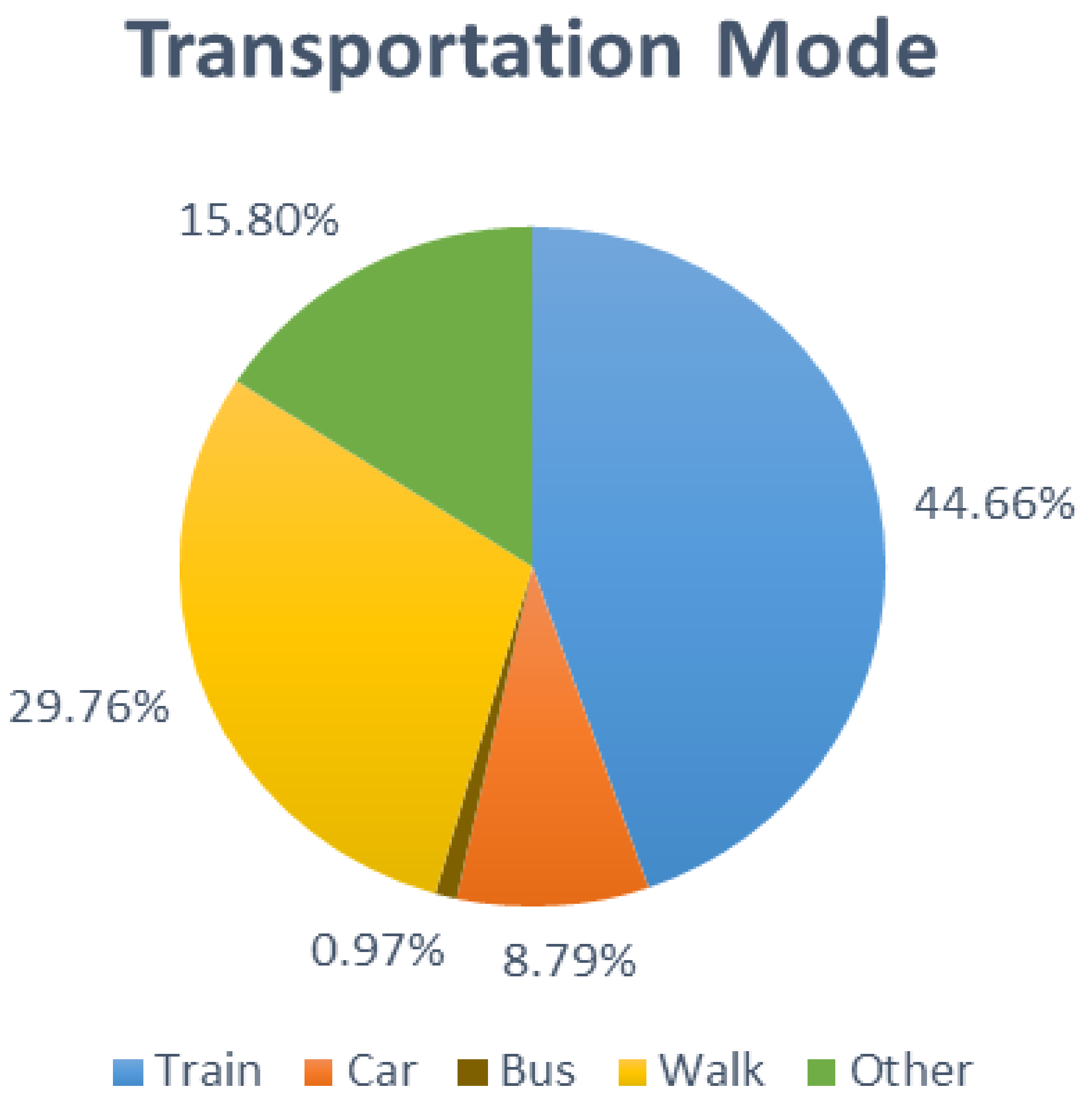


DATA PREPROCESSING

MODE CHOICE ANALYSIS (SHIBUYA)

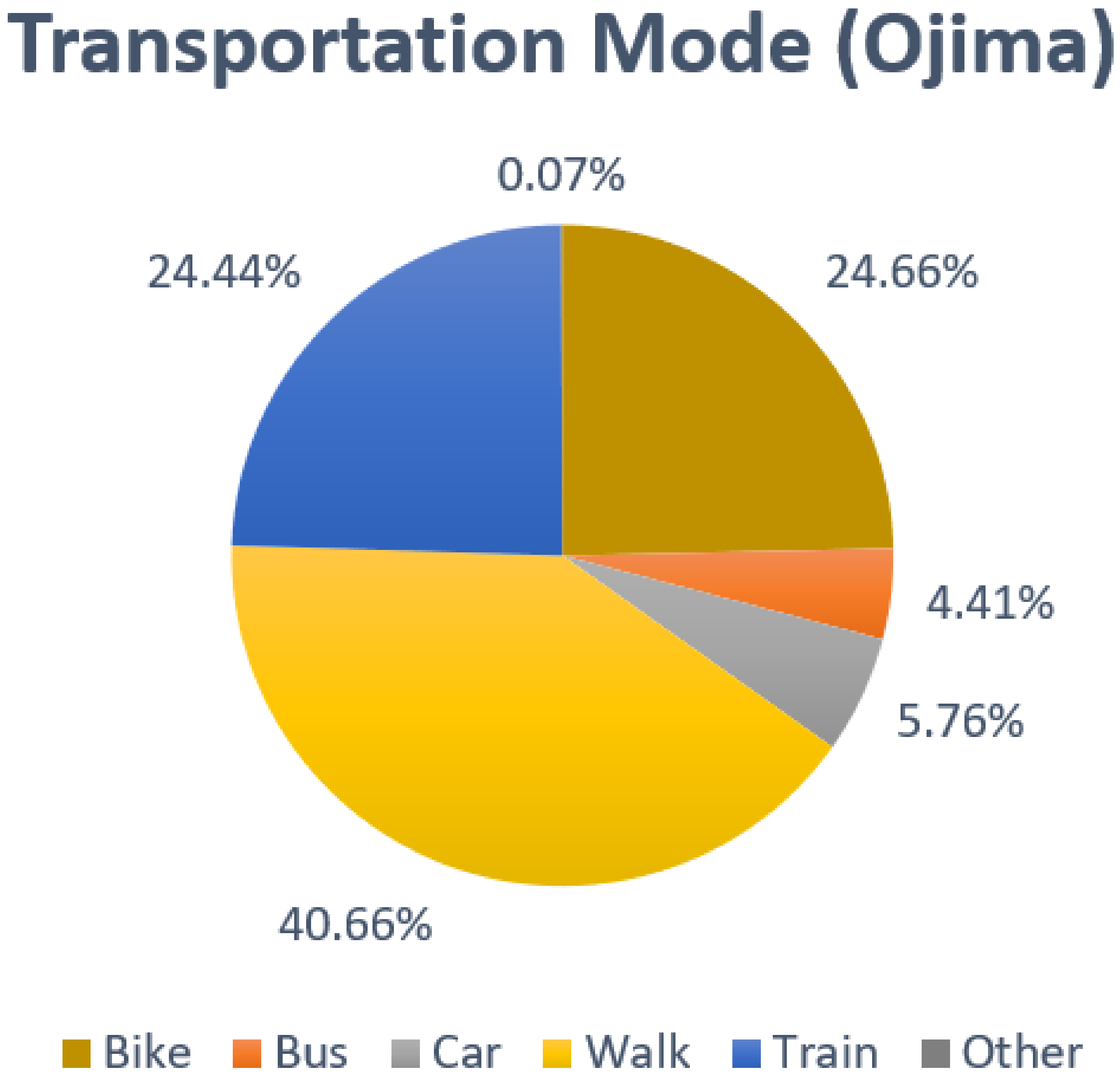
Others

Subway	8.23 %
Bike	5.78 %
Freight Car	0.28 %
Taxi	0.26 %
Motorcycle	0.13 %
Tram	1.06 %
Shared Bike	0.02 %
Monorail	0.04 %



MODE CHOICE ANALYSIS (OJIMA)

Bike	24.66%
Bus	4.41%
Car	5.76%
Walk	40.66%
Train	24.44%
Other	0.07%



FEATURE ENGINEERING

COMPOSITE ATTRIBUTES AND NON-LINEAR INTERACTIONS

```
##### COMPOSITE ATTRIBUTES ####
data['Speed_Train'] =  np.log(((data['Distance_Train']) / (data['Total_Time_Train']))+ 1)
data['Speed_Bus'] =  np.log(((data['Distance_Bus']) / (data['Total_Time_Bus'])) + 1)
data['Speed_Car'] =  np.log(((data['Distance_Car']) / (data['Time_Car'])) + 1)
data['Speed_Walk'] =  np.log(((data['Distance_Walk']) / (data['Time_Walk'])) + 1)


#### NON - LINEAR RELATIONSHIPS ########
data['log_Time_Train'] = np.log(data['Total_Time_Train'] + 1)
data['log_Time_Bus'] = np.log(data['Total_Time_Bus'] + 1)
data['log_Time_Car'] = np.log(data['Time_Car'] + 1)
data['log_Time_Walk'] = np.log(data['Time_Walk'] + 1)

data['sqrt_Distance_Train'] = np.sqrt(data['Distance_Train'])
data['sqrt_Distance_Bus'] = np.sqrt(data['Distance_Bus'])
data['sqrt_Distance_Car'] = np.sqrt(data['Distance_Car'])
data['sqrt_Distance_Walk'] = np.sqrt(data['Distance_Walk'])

data['sqrt_Fare_Train'] = np.sqrt(data['Fare_Train'])
data['sqrt_Fare_Bus'] = np.sqrt(data['Fare_Bus'])
```

- The speed attributes provide a better reflection of the efficiency of each mode by accounting for both distance and time in a non-linear way, enhancing the model's explanatory power.
- The log transformation addresses how small changes in lower values have a larger impact on choice.
- The square root transformation captures a more balanced relationship between distance and fare, mitigating the influence of extreme values.

DATA ANALYSIS USING MULTINOMIAL LOGIT MODEL AND RANDOM FOREST ALGORITHM

DATA ANALYSIS USING MNL

SHIBUYA TRIP DATA				
Attributes	**Model (MNL-4a/Base)**	**Model (MNL-4c)**	**Model (MNL-4d)**	**Model (MNL-4e)**
Restrictions (d)				
Total Time	-1.1682	-0.9191	-	-
Distance	-	-0.9420	-	-
Fare	2.0029	1.9862	-	-
No. of Change Transportation	-0.4823	-0.4397	-0.3196	-0.3309
Modified Restrictions (d)				
Log-Time	-	-	-2.7231	-2.0464
Sqrt-Distance	-	-	1.0258	-
Sqrt-Fare	-	-	1.9057	1.8987
Speed	-	-	0.0622	0.1063
Mode Constants (b)				
Train	0.7290	0.7267	0.8319	0.7844
Bus	-3.5324	-3.4516	-3.6336	-3.4797
Car	-1.2506	-1.2499	-1.1599	-1.1546
Walk	0.0000	0.0000	0.0000	0.0000
LL @ 0	-5388.5262	-5388.5262	-5388.5262	-5388.5262
LL @ Convergence	-3245.5084	-3230.7784	-2993.2398	-3007.4999
rho-squared	0.3977	0.4004	0.4445	0.4419
Adjusted rho-squared	0.3964	0.3989	0.4428	0.4404

OJIMA TRIP DATA				
Attributes	**Model (MNL-1a/Base)**	**Model (MNL-1c)**	**Model (MNL-1d)**	**Model (MNL-1e)**
Restrictions (d)				
Total Time	-1.5979	-0.5108	-	-
Distance	-	-1.7302	-	-
Fare	2.2262	2.1213	-	-
No. of Change Transportation	-1.1015	-0.8570	-0.5911	-0.607196
Modified Restrictions (d)				
Log-Time	-	-	-1.5421	-2.0314
Sqrt-Distance	-	-	-0.5855	-
Sqrt-Fare	-	-	1.9624	1.9332
Speed	-	-	0.1358	0.0965
Mode Constants (b)				
Train	-0.6211	-0.6710	-0.7048	-0.6885
Bus	-2.3794	-2.3103	-2.4562	-2.4867
Car	-1.9604	-1.9541	-1.8997	-1.9002
Walk	0	0	0	0
LL @ 0	-1395.9984	-1395.9984	-1395.9984	-1395.9984
LL @ Convergence	-850.5520	-828.6218	-788.4334	-790.0754
rho-squared	0.3907	0.4064	0.4352	0.4340
Adjusted rho-squared	0.3857	0.4007	0.4288	0.4283

Random Forest Algorithm Model (Shibuya)	
Attributes/Parameters used for Training (Y = Used)	
Total Time	Y
Distance	Y
Fare	Y
No. of Change Transportation	Y
Purpose	-
Access Time	Y
Egress Time	Y
Access Distance	Y
Egress Distance	Y
Availabilty of Modes	
Train	Y
Bus	Y
Car	Y
Walk	Y
RF Model Details	
T_T Split	70 / 30
Random state	25
No. of Trees	99
Sampling Method	Random Over Sampler
Max. Depth of Trees	25
Training Accuracies	
Accuracy	0.99988
Precision	0.99988
F1_Score	0.99988
Testing Accuracies	
Accuracy	0.96681
Precision	0.74643
F1_Score	0.68644

Random Forest Algorithm Model (Ojima)	
Attributes/Parameters used for Training (Y = Used)	
Total Time	Y
Distance	Y
Fare	Y
No. of Change Transportation	Y
Purpose	-
Access Time	Y
Egress Time	Y
Access Distance	Y
Egress Distance	Y
Availabilty of Modes	
Train	Y
Bus	Y
Car	Y
Walk	Y
RF Model Details	
T_T Split	65 / 35
Random state	25
No. of Trees	109
Sampling Method	Random Over Sampler
Max. Depth of Trees	25
Training Accuracies	
Accuracy	1.0
Precision	1.0
F1_Score	1.0
Testing Accuracies	
Accuracy	0.951
Precision	0.610
F1_Score	0.603

MODEL ANALYSIS RESULTS

SHIBUYA MNL MODEL 4d: FINAL RESULTS

MNL Model 4d (Shibuya)			
Results			
		Estimated Parameters	T-statistics
b1	Train	0.832	0.008
b2	Bus	-3.634	-0.272
b3	Car	-1.160	-0.051
d1	Log Time	-2.723	-0.136
d2	Sqrt Distance	1.026	0.114
d3	Sqrt Fare	1.906	0.083
d4	No. of Change of Transportation Modes	-0.320	-0.009
d5	Speed	0.062	0.001
b4	Walk	0	0

MNL Model 4d (Shibuya)	
Current Function Value	2993.240
Iterations	30
Function Evaluations	390
Gradient Evaluations	39
LL(0)	-5388.526
LL	-2993.240
Rho-Squared	0.4445
Adjusted Rho-Squared	0.4428

OJIMA MNL MODEL 1d: FINAL RESULTS

MNL Model 1d (Ojima)			
Results			
		Estimated Parameters	T-statistics
b1	Train	-0.705	-0.057
b2	Bus	-2.456	-0.335
b3	Car	-1.900	-0.224
d1	Log Time	-1.542	-0.207
d2	Sqrt Distance	-0.585	-0.080
d3	Sqrt Fare	1.962	0.147
d4	No. of Change of Transportation Modes	-0.591	-0.039
d5	Speed	0.136	0.007
b4	Walk	0	0

MNL Model 1d (Ojima)	
Current Function Value	788.433
Iterations	19
Function Evaluations	240
Gradient Evaluations	24
LL(0)	-1395.998
LL	-788.433
Rho-Squared	0.4352
Adjusted Rho-Squared	0.4288

DISCUSSIONS

DISCUSSIONS (SHIBUYA)

- The MNL model appears to fit the data well, as indicated by the rho-square and adjusted rho-square (0.44) values, both of which suggest the model captures a substantial proportion of the variability in choices.

- Many T-statistics are significant, suggesting that the model fit is good overall, and some individual parameters strongly influence the choice behavior

DISCUSSIONS (OJIMA)

- The **Rho-square** value, which is 0.4288, indicates that the model explains about 42.88% of the variation in the data. This is a decent fit for MNL model, as values between 0.2 and 0.4 are typically considered reasonable for choice models.

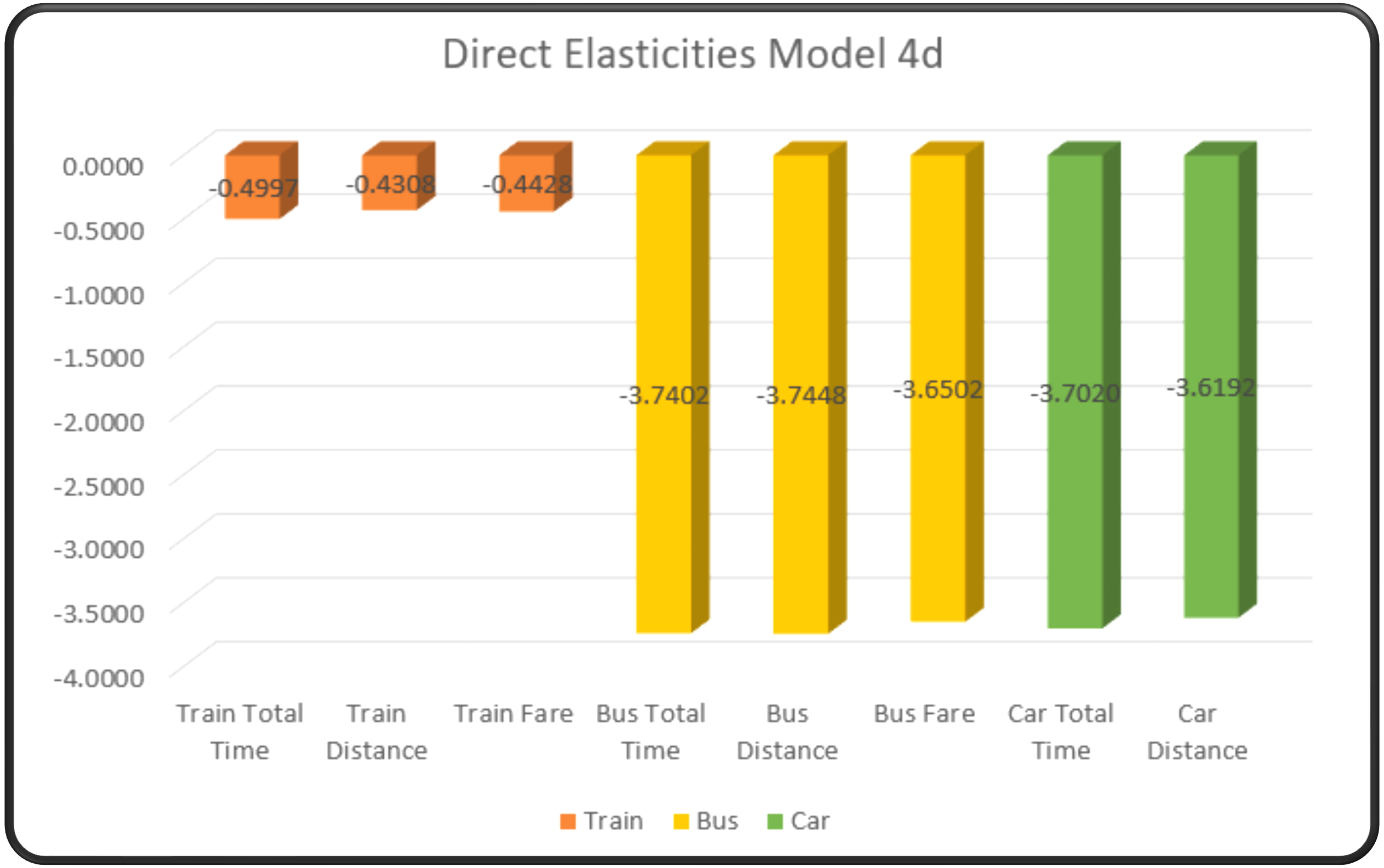
- Many of the T-statistic values suggests high significance, that the coefficients for most variables have a strong or reliable effect on the choice outcome in the model.

POLICY IMPLICATIONS

SHIBUYA MNL MODEL 4d

Sensitivity of the Modes to their own attributes

- A 1% increase in attributes results in mentioned %age decrease in the likelihood of choosing the train, bus or car, Indicating negative relationship.



OJIMA MNL MODEL 1d

Sensitivity of the Modes to their own attributes

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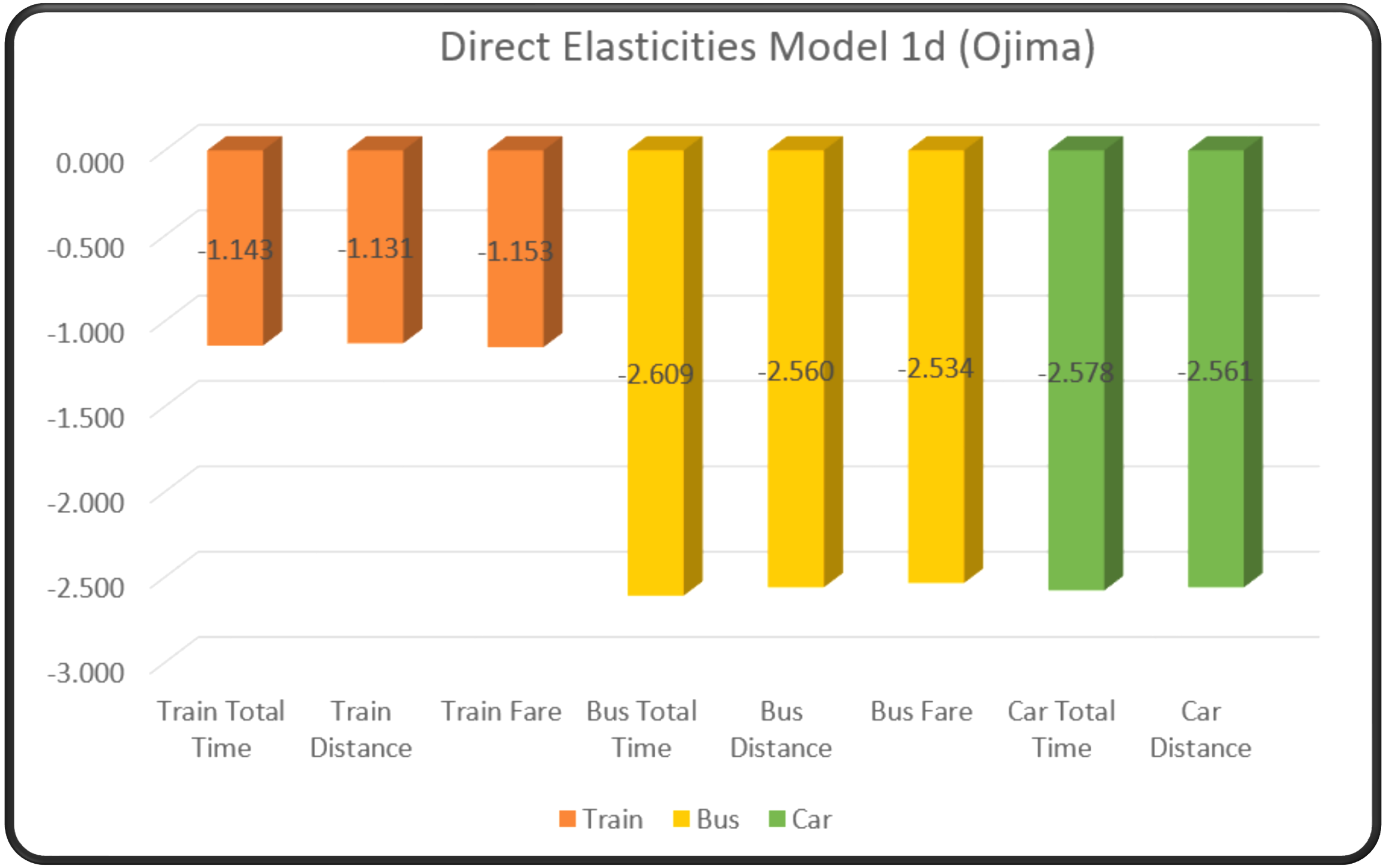
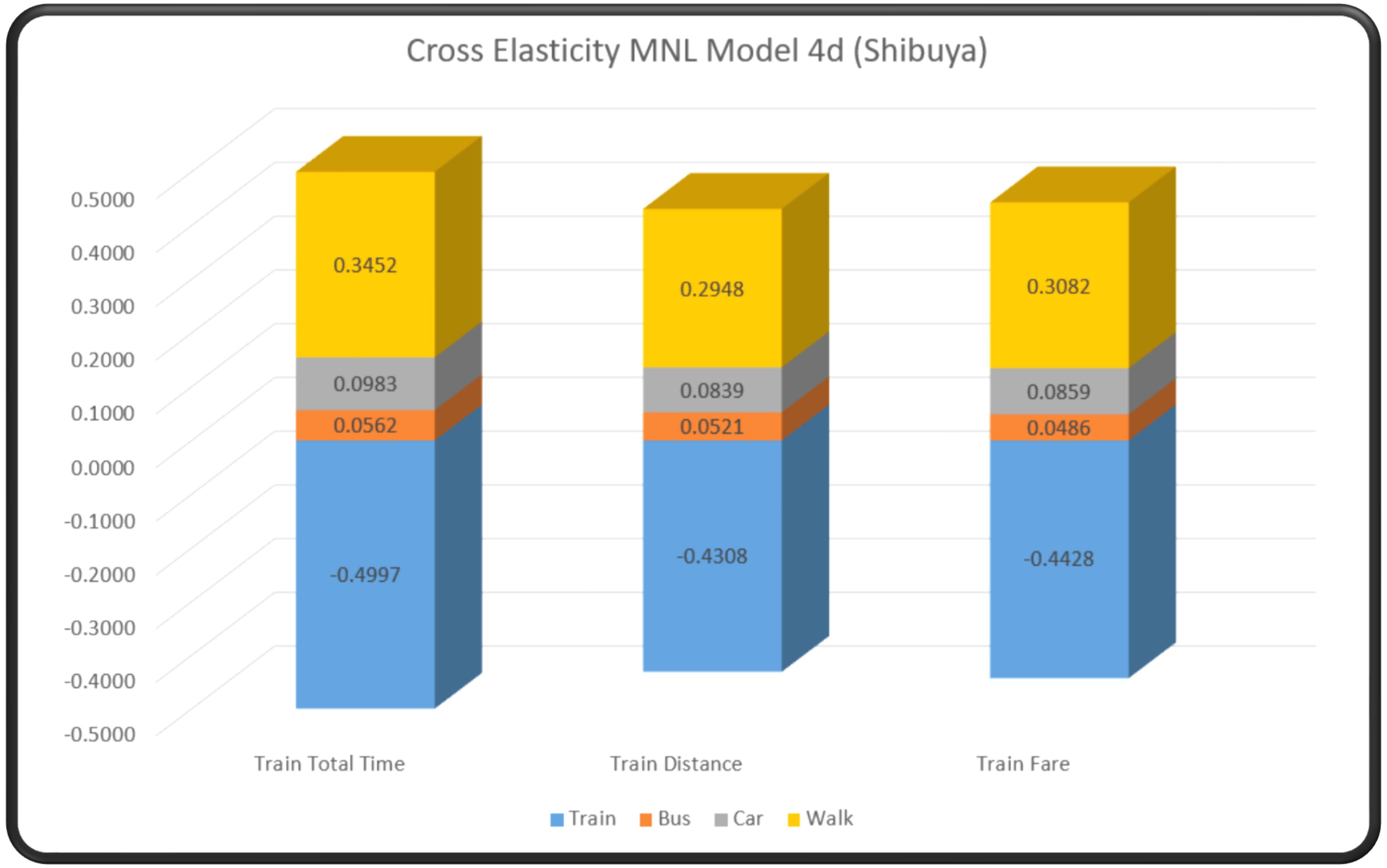
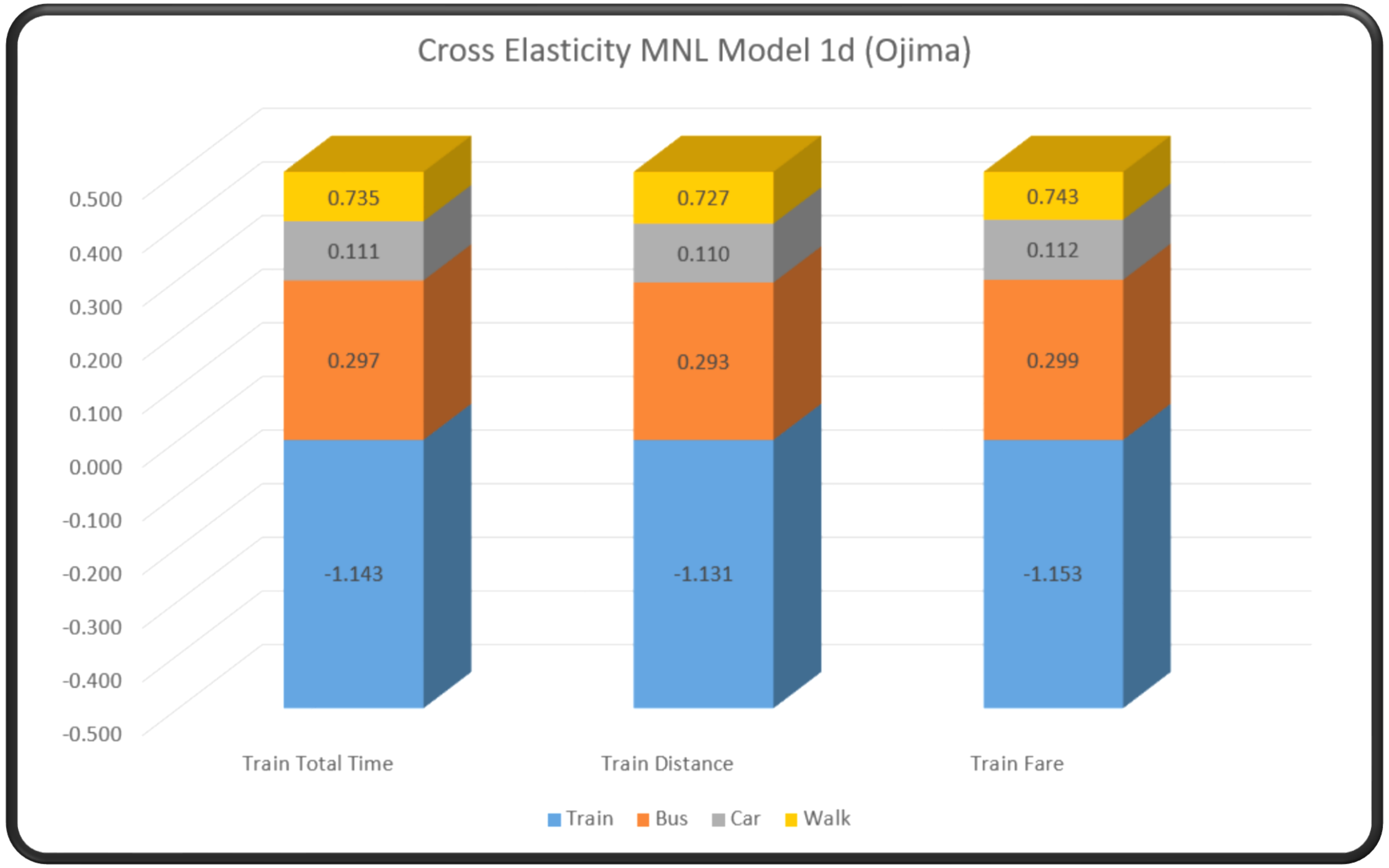


MNL MODELS

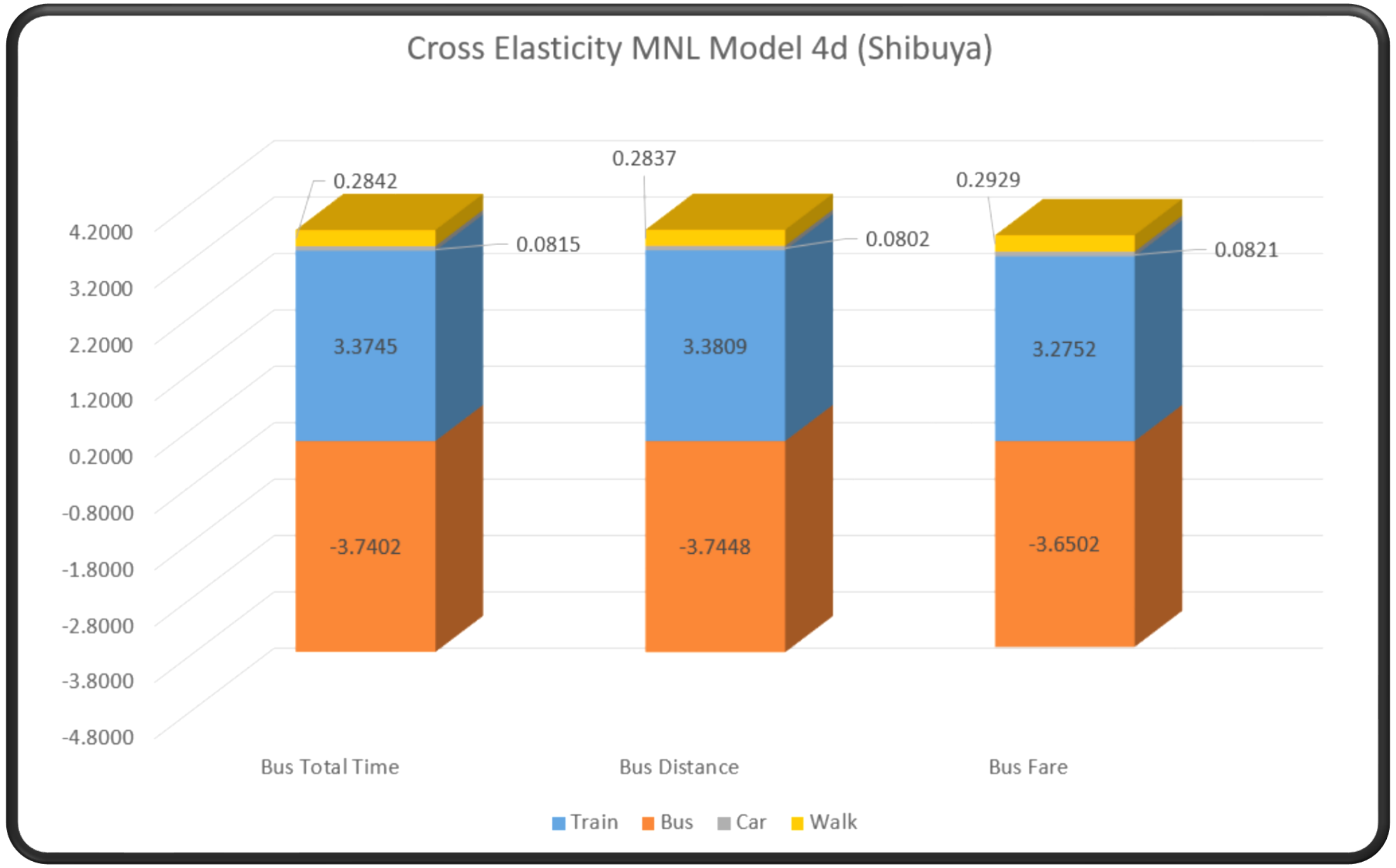
Analysis of How Changes in One Attribute Influence the Selection of Different Modes - Train

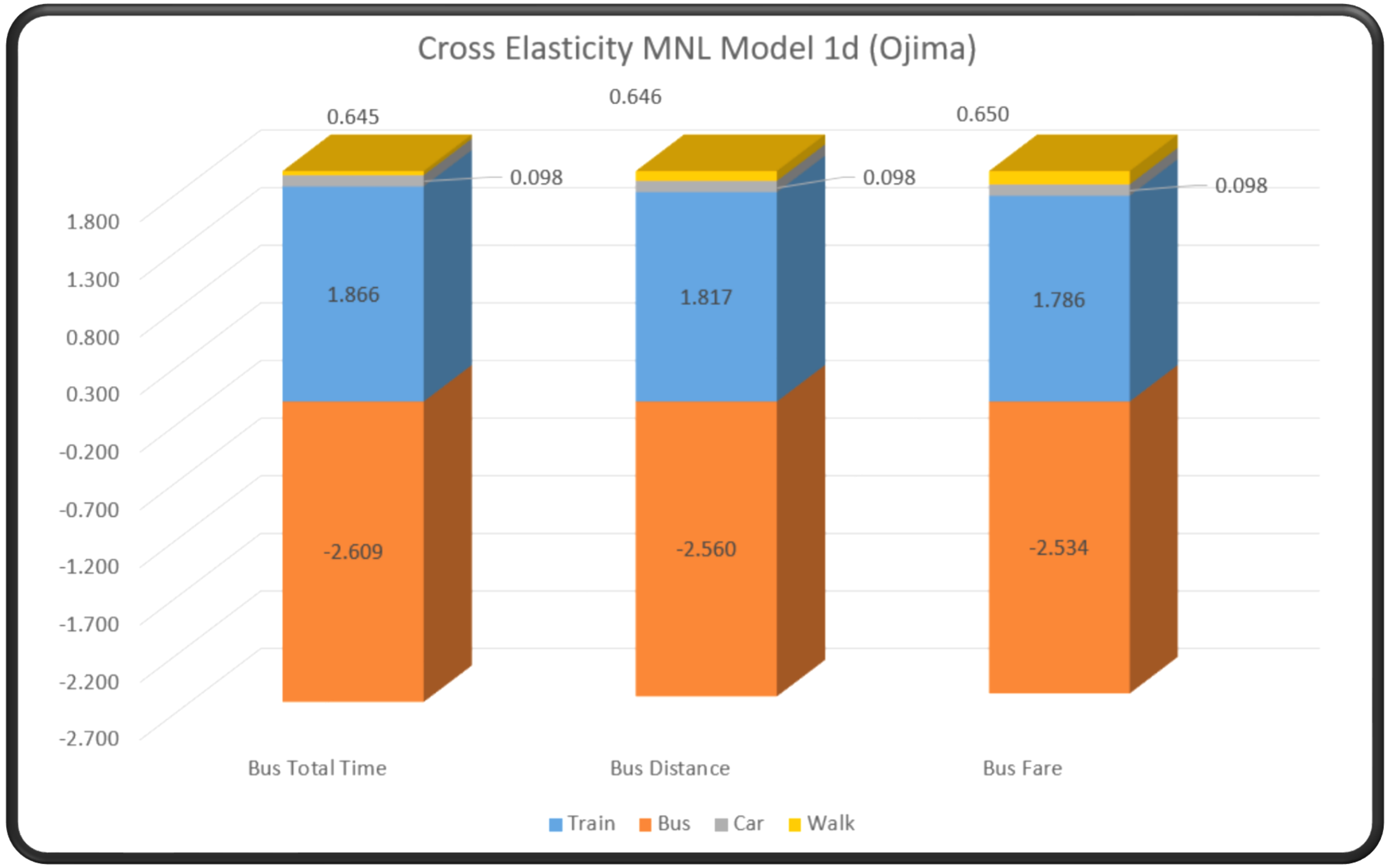




MNL MODELS

Analysis of How Changes in One Attribute Influence the Selection of Different Modes - Bus





POLICY IMPLICATION OF MNL MODELS

Analysis of How Changes in One Attribute Influence the Selection of Different Modes

Policy Simulation using Elasticities:

- If we decrease the Train Fare by 20%, the likelihood of increase in ridership will be:
  - For Shibuya: 8.856%
  - For Ojima: 23.06 %

- Conversely by decreasing Train Fare by 20%, the likelihood for decrease in ridership of:
  - Bus: 0.972 % Shibuya, 5.98 % Ojima
  - Car: 1.718 % Shibuya, 2.24 % Ojima
  - Walk: 6.164 Shibuya, 14.86 % Ojima

Thank You