

#### Assignment 4: Mode choice modeling: Multinomial logit model

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##### Ans No 1

(i) I have used this parameter as requirement to initiate.

```
apollo_beta=c(asc_car = 0,  
              asc_bus = 0,  
              asc_air = 0,  
              asc_rail = 0,  
              b_tt_car = 0,  
              b_tt_bus = 0,  
              b_tt_air = 0,  
              b_tt_rail = 0,  
              b_access = 0,  
              b_cost_car = 0,  
              b_cost_bus = 0 ,  
              b_cost_air = 0 ,  
              b_cost_rail = 0)
```

Everything is done in relative to fix  $\text{asc\_car} = 0$

```
apollo_fixed = c("asc_car")
```

After running the model, the alternative specific constant and generic parameters are ,

	Estimate	Std.err.	t-ratio(0)	Rob.std.err	Rob.t-ratio(0)
asc_car	0	NA	NA	NA	NA
asc_bus	1.944738	1.751338	1.11043	1.649688	1.178852
asc_air	2.763012	1.496215	1.846668	1.513346	1.825763
asc_rail	2.380101	1.546863	1.538663	1.560661	1.52506
b_tt_car	-0.00231	0.001944	-1.18709	0.001982	-1.16432
b_tt_bus	-0.0096	0.003209	-2.99058	0.003049	-3.1474
b_tt_air	-0.02117	0.007309	-2.89701	0.007303	-2.89933
b_tt_rail	-0.01303	0.005182	-2.51415	0.005278	-2.46841
b_access	-0.01149	0.007044	-1.63143	0.006766	-1.69829
b_cost_car	-0.01796	0.013856	-1.29622	0.013761	-1.30519
b_cost_bus	-0.03994	0.017346	-2.3023	0.017815	-2.2418
b_cost_air	-0.03462	0.004837	-7.15727	0.004814	-7.19113
b_cost_rail	-0.03631	0.006211	-5.84609	0.006158	-5.89593

(ii) Comment on the Signs of the Parameters

Travel Time (b_tt)	All negative, indicating that an increase in travel time decreases utility, which is intuitive.
Access Time (b_access)	Negative, showing that longer access time reduces utility, as expected.
Travel Cost (b_cost)	Negative, indicating that higher costs reduce utility, which aligns with rational behavior.
ASCs	Positive, meaning these alternatives provide a baseline utility above the reference mode (car).

The signs are consistent with economic theory.

### (iii) Comment on the Relative Magnitude

Travel Time	Magnitudes suggest air travel is most sensitive to travel time, followed by rail, bus, and car. This intuitively reflects the higher value of time for air travelers.
Access Time	The single parameter for access time applies uniformly. Its magnitude suggests a moderate sensitivity across modes.
Travel Cost	Air travel is least sensitive to cost changes (higher magnitude reflects higher willingness to pay for convenience). Bus users are most sensitive to cost.
ASCs:	Air travel has the highest ASC, indicating a preference for air travel over other modes. Bus has a lower ASC, suggesting lower utility compared to rail and air.

Now i have used this method to calculate value of travel time and value of access time

```
# Calculate VTT and VAT
vtt_car = -estimates["b_tt_car"] / estimates["b_cost_car"] * 60
vtt_bus = -estimates["b_tt_bus"] / estimates["b_cost_bus"] * 60
vtt_air = -estimates["b_tt_air"] / estimates["b_cost_air"] * 60
vtt_rail = -estimates["b_tt_rail"] / estimates["b_cost_rail"] * 60

vat_car = -estimates["b_access"] / estimates["b_cost_car"] * 60
vat_bus = -estimates["b_access"] / estimates["b_cost_bus"] * 60
vat_air = -estimates["b_access"] / estimates["b_cost_air"] * 60
vat_rail = -estimates["b_access"] / estimates["b_cost_rail"] * 60
```

(Iv and V)

Table of Value of Travel Time(VTT) and Value of access time(VAT)

	A	B	C
1	Mode	VTT_EuroPerHour	VAT_EuroPerHour
2	Car	-7.709001759	-38.38776469
3	Bus	-14.4194657	-17.26429092
4	Air	-36.69945777	-19.91723431
5	Rail	-21.52804706	-18.99014632

### Comment of VTT

- Air has the highest VTT, reflecting high-value time travelers.
- Bus has the lowest VTT, indicating lower economic value of time.

### Comment on VAT

- Car users have the highest VAT, likely due to the inconvenience of accessing the vehicle.
- Bus users have the lowest VAT, reflecting their sensitivity to delays in access.

R Code for Ans1:

[https://github.com/trewto/CE-6511-Assignments/blob/main/Assignment%204/ansno1\\_RP\\_mode\\_choice\\_mnl.R](https://github.com/trewto/CE-6511-Assignments/blob/main/Assignment%204/ansno1_RP_mode_choice_mnl.R)

## Ans No 2

FOR SP data i have used this parameter initially,

```
c(asc_car = 0,  
   asc_bus = 0,  
   asc_air = 0,  
   asc_rail = 0,  
   b_tt_car = 0,  
   b_tt_bus = 0,  
   b_tt_air = 0,  
   b_tt_rail = 0,  
   b_access = 0,  
   b_cost = 0,  
   b_female_car = 0,  
   b_female_bus = 0,  
   b_female_rail = 0,  
   b_female_air = 0  
)
```

I am comparing in respect to fix these parameter

```
apollo_fixed = c("asc_car", "b_female_car")
```

After running the model

(i)

	Estimate	Std.err.	t-ratio(0)	Rob.std.err	Rob.t-ratio(0)
asc_car	0	NA	NA	NA	NA
asc_bus	0.098328	0.538946	0.182445	0.527085	0.18655
asc_air	0.906035	0.337332	2.685884	0.330502	2.741388
asc_rail	-1.15353	0.323961	-3.56072	0.313254	-3.68242
b_tt_car	-0.00996	0.000639	-15.5794	0.00066	-15.1047
b_tt_bus	-0.01601	0.001441	-11.1121	0.001454	-11.0089
b_tt_air	-0.01922	0.002559	-7.51048	0.002437	-7.88562
b_tt_rail	-0.00314	0.001671	-1.87773	0.001644	-1.90777
b_access	-0.02265	0.002673	-8.47147	0.002623	-8.63526
b_cost	-0.05465	0.00144	-37.954	0.001681	-32.5118
b_female_car	0	NA	NA	NA	NA
b_female_bus	0.135067	0.121771	1.109183	0.164088	0.823138
b_female_rail	0.174181	0.068031	2.560298	0.095412	1.825562
b_female_air	0.241493	0.082643	2.922126	0.140764	1.715584

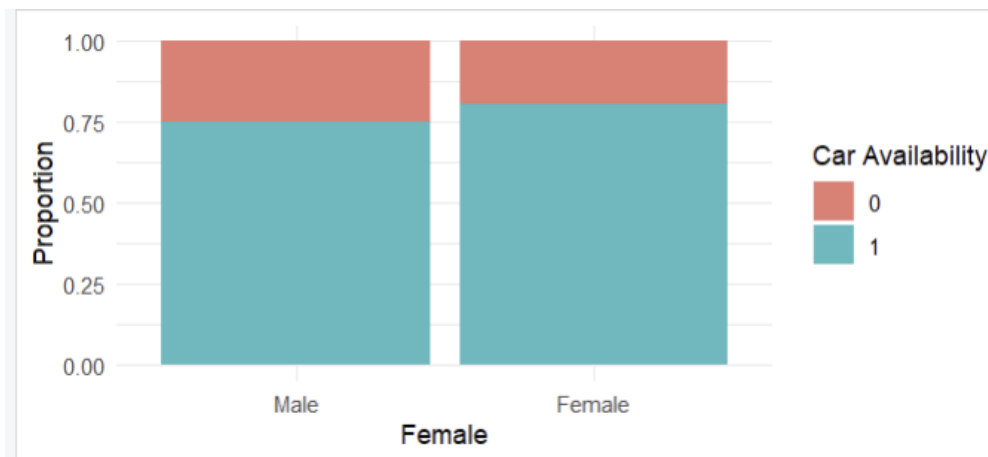
ii)

Alternative-Specific Constants (ASC)	Air travel has a significantly higher baseline utility compared to the car. bus mode is marginally higher than that of the car Rail travel has a notably lower baseline utility compared to the car.
Travel Time Parameters	All travel times coefficients are negative, suggest that longer travel times reduce utility.

	Travelers are most sensitive to air travel time(-0.01922) Rail has the least sensitivity which is acceptable
Access Time Parameter	The negative sign reflects the disutility of longer access times, which is also expected.
Travel Cost Parameter	Cost parameters are negative, consistent with the expectation that higher costs reduce utility.
Female Dummy Parameters	Positive coefficients for females suggest that female travelers have a higher preference for air, rail, and bus compared to car. It is okay for air. But it was expected to be the opposite for rail and bus. But it may be because females has less accessibility of car/ ownership.

### Interesting Finding

A transportation engineer may need to check female accessibility with car to find why female prefer bus/rail than car. We are now using the model to check this



But, it is observed, female who travel has higher availability of car than male, but it is very surprising why they have greater coefficient of rail/ bus than car. It may be due to-

- While females may have higher accessibility to the car (more females may have access to a car), this does not necessarily mean that they will choose the car as their preferred mode
- Car costs (purchase, maintenance, fuel) might be more burdensome for females
- Social norms or safety concerns may make public transport or air travel more appealing to females.

Now i have used the similar method like (1) to calculate value of travel time and value of access time

```
# Calculate VTT and VAT
vtt_car = -estimates["b_tt_car"] /
estimates["b_cost"] * 60
vtt_bus = -estimates["b_tt_bus"] /
estimates["b_cost"] * 60
vtt_air = -estimates["b_tt_air"] /
estimates["b_cost"] * 60
vtt_rail = -estimates["b_tt_rail"] /
estimates["b_cost"] * 60

vat_car = -estimates["b_access"] /
estimates["b_cost"] * 60
vat_bus = -estimates["b_access"] /
estimates["b_cost"] * 60
vat_air = -estimates["b_access"] /
estimates["b_cost"] * 60
vat_rail = -estimates["b_access"] /
estimates["b_cost"] * 60
```

Mode	VTT_EuroP	VAT_EuroPerHour
Car	-10.9381	-24.86516006
Bus	-17.5775	-24.86516006
Air	-21.0988	-24.86516006
Rail	-3.44434	-24.86516006

Mode	VTT (Euro/hour)	Comment on value of travel time
Car	-10.93	Lower sensitivity compared to other modes, indicating car users value convenience and flexibility over shorter travel times.
Bus	-17.57	Higher sensitivity than car users, reflecting the time-conscious nature of bus users who rely on fixed schedules.
Air	-21.09	The highest sensitivity, as air travel is typically associated with premium, time-critical journeys.
Rail	-3.44	The lowest sensitivity, suggesting rail users are less affected by longer travel times, likely due to its comfort and vibe during travel.

As access time and travel cost both is generic, all the value will same.

Mode	VAT(Euro/Hour)	Comment on value of access time
Car	-24.87	
Bus	-24.87	Similar sensitivity For all
Air	-24.87	
Rail	-24.87	

R Code for Ans2:

[https://github.com/trewto/CE-6511-Assignments/blob/main/Assignment%204/ansno2\\_SP\\_mode\\_choice\\_mnl.R](https://github.com/trewto/CE-6511-Assignments/blob/main/Assignment%204/ansno2_SP_mode_choice_mnl.R)