

HW2 Advanced DCM

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Table 1

Variable	Categories	Percent
DISCOUNT	1	47.3
GA	1	12.3
VEH_AVAI	1	66.8
VEH_AVAI	2	17.9
VEH_AVAI	3	15.4
EDUC	1	9.8
EDUC	2	50.8
EDUC	3	39.4
WORKING	0	32.4
WORKING	1	16.4
WORKING	2	43.9
WORKING	3	7.3
HH_INC_A	10000	8.5
HH_INC_A	30000	10.0
HH_INC_A	50000	15.9
HH_INC_A	70000	19.0
HH_INC_A	90000	20.4
HH_INC_A	112500	12.6
HH_INC_A	137500	6.0
HH_INC_A	167500	7.6

Table 2

Distance	Commuting	Shopping	Business	Leisure	Total
<5	22.0	29.2	1.3	14.1	18.5
5-10	15.9	25.0	2.6	7.3	13.0
10-20	22.0	23.7	6.5	11.5	16.7
20-30	15.7	13.1	9.1	11.3	12.8
30-50	14.3	5.5	14.3	14.6	12.7
50-75	5.5	2.1	14.3	10.2	7.5
75-100	2.7	0.4	7.8	10.4	6.0
>100	1.9	0.8	44.2	20.6	12.7

Table 3

	Business	Commuting	Leisure	Shopping
Mode choice: car vs. bus	6	162	186	126
Mode choice: car vs. rail	426	1716	2538	1104
Route choice: bus for bus users	9	405	450	342
Route choice: car for car users	156	846	1176	660
Route choice: rail for car users	126	594	837	504
Route choice: rail for rail users	324	1008	1881	288
Total	1047	4731	7068	3024

Trip Purpose	Total	Avg Income	Avg Trip Distance
Business	77	98223.50	97.64
Commuting	364	84655.99	23.22
Leisure	548	75181.45	60.27
Shopping	236	76703.87	14.18
Total	1225	79816.16	42.91

Table 4

```
## Model run using Apollo for R, version 0.2.6 on Windows by PHEV
## www.ApolloChoiceModelling.com
##
## Model name                : Swiss_VOT_combined
## Model description         : Model from Axhausen
## Model run at              : 2022-02-27 13:16:53
## Estimation method         : bfgs
## Model diagnosis           : successful convergence
## Number of individuals     : 1225
## Number of rows in database : 15870
## Number of modelled outcomes : 15870
##
## Number of cores used      : 4
## Model without mixing
##
## LL(start)                 : -7957.002
## LL(0)                     : -11000.25
## LL(C)                     : -10896.8
## LL(final)                 : -7722.216
## Rho-square (0)            : 0.298
## Adj.Rho-square (0)        : 0.2933
## Rho-square (C)            : 0.2913
## Adj.Rho-square (C)        : 0.2866
## AIC                       : 15548.43
## BIC                       : 15947.39
##
## Estimated parameters      : 52
## Time taken (hh:mm:ss)    : 00:07:21.44
##   pre-estimation          : 00:00:11.63
##   estimation               : 00:02:42.23
##   post-estimation          : 00:04:27.59
## Iterations                 : 66
## Min abs eigenvalue of Hessian : 0.08431
```

```

##
## Unconstrained optimisation.
##
## Estimates:
##
##           Estimate          s.e.    t.rat.(0)    Rob.s.e.
## asc_a           0.00000         NA           NA           NA
## asc_b          -0.01772        0.021162        -0.8372        0.026235
## b_tt_pt_business -0.12243        0.014559        -8.4096        0.017816
## b_tt_pt_commuters -0.10297        0.007489       -13.7494        0.010683
## b_tt_pt_leisure  -0.05844        0.003975       -14.7024        0.005586
## b_tt_pt_shopping -0.07639        0.009907        -7.7103        0.017568
## b_tt_car_business -0.12207        0.025436        -4.7991        0.042715
## b_tt_car_commuters -0.12412        0.011314       -10.9706        0.015597
## b_tt_car_leisure  -0.08599        0.008267       -10.4014        0.014047
## b_tt_car_shopping -0.10688        0.013410        -7.9699        0.020047
## b_dc            -0.05198        0.006719        -7.7368        0.009465
## b_tc_business    -0.22496        0.027799        -8.0925        0.032865
## b_tc_commuters    -0.17644        0.014954       -11.7982        0.021115
## b_tc_leisure      -0.17475        0.012176       -14.3521        0.017220
## b_tc_shopping     -0.15772        0.015713       -10.0372        0.024792
## b_ic_business     -0.90978        0.113243        -8.0339        0.142803
## b_ic_commuters    -1.18988        0.065092       -18.2800        0.102280
## b_ic_leisure      -1.05921        0.050907       -20.8069        0.077806
## b_ic_shopping     -1.07216        0.083309       -12.8697        0.129391
## b_hw_business     -0.02376        0.014321        -1.6589        0.013098
## b_hw_commuters    -0.06644        0.009211        -7.2124        0.010049
## b_hw_leisure      -0.04387        0.006237        -7.0333        0.006333
## b_hw_shopping     -0.05188        0.010226        -5.0734        0.009941
## b_bus_commuters    4.07394        1.144919         3.5583        1.683158
## b_bus_leisure     -1.20187        1.495563        -0.8036        2.781429
## b_bus_shopping     4.08600        1.685512         2.4242        2.954843
## b_rail_business    1.41490        1.018351         1.3894        1.681754
## b_rail_commuters   1.61081        0.439195         3.6676        0.626828
## b_rail_leisure     0.51729        0.393621         1.3142        0.623336
## b_rail_shopping    1.23201        0.487813         2.5256        0.611284
## b_car_inertia      1.84710        0.226322         8.1613        0.343173
## b_car_available    0.56619        0.181806         3.1143        0.293854
## b_car_male         -0.31633        0.153386        -2.0623        0.247333
## b_bus_disc         2.29675        1.200222         1.9136        2.144748
## b_rail_disc        1.60478        0.206581         7.7683        0.339129
## b_bus_ga           6.83595        3.198308         2.1374        5.208855
## b_rail_ga          1.68487        0.307259         5.4836        0.463733
## lam_dist_tt_pt_business -0.31495        0.070127        -4.4911        0.093061
## lam_dist_tt_pt_commuters -0.24862        0.035941        -6.9173        0.045229
## lam_dist_tt_pt_leisure -0.30305        0.031120        -9.7381        0.041428
## lam_dist_tt_pt_shopping -0.19142        0.055310        -3.4608        0.088292
## lam_dist_tt_car_business -0.32659        0.127720        -2.5571        0.206756
## lam_dist_tt_car_commuters -0.15578        0.058200        -2.6766        0.070002
## lam_dist_tt_car_leisure -0.42680        0.047443        -8.9960        0.081317
## lam_dist_tt_car_shopping -0.18814        0.085439        -2.2021        0.103760
## lam_dist_tc        -0.61341        0.021879       -28.0371        0.033020
## lam_inc_tc_business -0.91456        0.168550        -5.4261        0.206890
## lam_inc_tc_commuters -0.17602        0.042794        -4.1132        0.069471
## mu_mc_car_bus      0.22172        0.071929         3.0824        0.135148

```

## mu_mc_car_rail	0.54832	0.036628	14.9699	0.049873
## mu_rc_bus	0.93470	0.071907	12.9989	0.103288
## mu_rc_car	1.35149	0.130955	10.3202	0.197144
## mu_rc_rail_by_car	0.82200	0.053414	15.3893	0.077998
## mu_rc_rail	1.00000	NA	NA	NA
##	Rob.t.rat.(0)			
## asc_a	NA			
## asc_b	-0.6754			
## b_tt_pt_business	-6.8722			
## b_tt_pt_commuters	-9.6388			
## b_tt_pt_leisure	-10.4616			
## b_tt_pt_shopping	-4.3481			
## b_tt_car_business	-2.8578			
## b_tt_car_commuters	-7.9584			
## b_tt_car_leisure	-6.1220			
## b_tt_car_shopping	-5.3314			
## b_dc	-5.4924			
## b_tc_business	-6.8451			
## b_tc_commuters	-8.3558			
## b_tc_leisure	-10.1479			
## b_tc_shopping	-6.3618			
## b_ic_business	-6.3708			
## b_ic_commuters	-11.6336			
## b_ic_leisure	-13.6135			
## b_ic_shopping	-8.2862			
## b_hw_business	-1.8138			
## b_hw_commuters	-6.6111			
## b_hw_leisure	-6.9270			
## b_hw_shopping	-5.2187			
## b_bus_commuters	2.4204			
## b_bus_leisure	-0.4321			
## b_bus_shopping	1.3828			
## b_rail_business	0.8413			
## b_rail_commuters	2.5698			
## b_rail_leisure	0.8299			
## b_rail_shopping	2.0154			
## b_car_inertia	5.3824			
## b_car_available	1.9268			
## b_car_male	-1.2789			
## b_bus_disc	1.0709			
## b_rail_disc	4.7321			
## b_bus_ga	1.3124			
## b_rail_ga	3.6333			
## lam_dist_tt_pt_business	-3.3843			
## lam_dist_tt_pt_commuters	-5.4969			
## lam_dist_tt_pt_leisure	-7.3151			
## lam_dist_tt_pt_shopping	-2.1680			
## lam_dist_tt_car_business	-1.5796			
## lam_dist_tt_car_commuters	-2.2253			
## lam_dist_tt_car_leisure	-5.2486			
## lam_dist_tt_car_shopping	-1.8132			
## lam_dist_tc	-18.5768			
## lam_inc_tc_business	-4.4205			
## lam_inc_tc_commuters	-2.5337			

```
## mu_mc_car_bus          1.6406
## mu_mc_car_rail        10.9943
## mu_rc_bus             9.0495
## mu_rc_car             6.8553
## mu_rc_rail_by_car     10.5386
## mu_rc_rail            NA
```

Model without elasticities

```
## Model run using Apollo for R, version 0.2.6 on Windows by PHEV
## www.ApolloChoiceModelling.com
##
## Model name              : Swiss_VOT_no_elas_combined
## Model description       : Model from Axhausen
## Model run at            : 2022-02-27 13:11:12
## Estimation method      : bfgs
## Model diagnosis        : successful convergence
## Number of individuals  : 1225
## Number of rows in database : 15870
## Number of modelled outcomes : 15870
##
## Number of cores used   : 4
## Model without mixing
##
## LL(start)              : -8130.363
## LL(0)                  : -11000.25
## LL(C)                  : -10896.8
## LL(final)              : -7972.844
## Rho-square (0)         : 0.2752
## Adj.Rho-square (0)     : 0.2715
## Rho-square (C)         : 0.2683
## Adj.Rho-square (C)     : 0.2646
## AIC                    : 16027.69
## BIC                    : 16342.25
##
## Estimated parameters   : 41
## Time taken (hh:mm:ss) : 00:02:50.72
##   pre-estimation       : 00:00:11.15
##   estimation           : 00:01:4.85
##   post-estimation      : 00:01:34.72
## Iterations             : 55
## Min abs eigenvalue of Hessian : 1.481433
##
## Unconstrained optimisation.
##
## Estimates:
##


|                   | Estimate | s.e.     | t.rat.(0) | Rob.s.e. |
|-------------------|----------|----------|-----------|----------|
| asc_a             | 0.00000  | NA       | NA        | NA       |
| asc_b             | -0.01891 | 0.018635 | -1.015    | 0.023398 |
| b_tt_pt_business  | -0.08364 | 0.008124 | -10.296   | 0.010041 |
| b_tt_pt_commuters | -0.10550 | 0.007850 | -13.439   | 0.011501 |
| b_tt_pt_leisure   | -0.04368 | 0.002912 | -15.001   | 0.004486 |
| b_tt_pt_shopping  | -0.07865 | 0.009988 | -7.874    | 0.019360 |


```

## b_tt_car_business	-0.07906	0.008715	-9.071	0.011931
## b_tt_car_commuters	-0.12575	0.010424	-12.063	0.015042
## b_tt_car_leisure	-0.04858	0.003689	-13.168	0.006201
## b_tt_car_shopping	-0.11016	0.013148	-8.378	0.020457
## b_dc	-0.04450	0.005978	-7.443	0.008359
## b_tc_business	-0.10545	0.013376	-7.883	0.017431
## b_tc_commuters	-0.22781	0.019622	-11.610	0.031705
## b_tc_leisure	-0.09487	0.007181	-13.211	0.011195
## b_tc_shopping	-0.23204	0.026547	-8.741	0.045430
## b_ic_business	-0.81233	0.106401	-7.635	0.137558
## b_ic_commuters	-1.16193	0.064059	-18.139	0.100739
## b_ic_leisure	-1.05517	0.050543	-20.877	0.078116
## b_ic_shopping	-1.05428	0.081548	-12.928	0.125239
## b_hw_business	-0.01541	0.013239	-1.164	0.013491
## b_hw_commuters	-0.06548	0.008833	-7.413	0.009811
## b_hw_leisure	-0.03927	0.005748	-6.833	0.005708
## b_hw_shopping	-0.05159	0.009716	-5.310	0.009729
## b_bus_commuters	2.94293	0.376553	7.815	0.565552
## b_bus_leisure	1.93280	0.373419	5.176	0.749127
## b_bus_shopping	2.97295	0.489023	6.079	0.793034
## b_rail_business	1.18549	0.675798	1.754	0.868654
## b_rail_commuters	1.33050	0.357555	3.721	0.491496
## b_rail_leisure	1.18560	0.296861	3.994	0.431006
## b_rail_shopping	1.19556	0.400618	2.984	0.526031
## b_car_inertia	2.10404	0.230409	9.132	0.344759
## b_car_available	0.65114	0.157123	4.144	0.254792
## b_car_male	-0.34060	0.133911	-2.543	0.216731
## b_bus_disc	0.80523	0.333887	2.412	0.643012
## b_rail_disc	1.90590	0.209186	9.111	0.340815
## b_bus_ga	2.53430	0.786865	3.221	1.092953
## b_rail_ga	2.07056	0.306244	6.761	0.460488
## mu_mc_car_bus	0.71366	0.106026	6.731	0.127607
## mu_mc_car_rail	0.56716	0.039720	14.279	0.054519
## mu_rc_bus	0.69343	0.062468	11.101	0.083840
## mu_rc_car	1.66231	0.187143	8.883	0.283791
## mu_rc_rail_by_car	0.89225	0.057245	15.587	0.085216
## mu_rc_rail	1.00000	NA	NA	NA
##	Rob.t.rat.(0)			
## asc_a	NA			
## asc_b	-0.8082			
## b_tt_pt_business	-8.3306			
## b_tt_pt_commuters	-9.1735			
## b_tt_pt_leisure	-9.7379			
## b_tt_pt_shopping	-4.0626			
## b_tt_car_business	-6.6262			
## b_tt_car_commuters	-8.3595			
## b_tt_car_leisure	-7.8348			
## b_tt_car_shopping	-5.3849			
## b_dc	-5.3233			
## b_tc_business	-6.0497			
## b_tc_commuters	-7.1853			
## b_tc_leisure	-8.4745			
## b_tc_shopping	-5.1075			
## b_ic_business	-5.9054			

```

## b_ic_commuters          -11.5340
## b_ic_leisure            -13.5078
## b_ic_shopping           -8.4181
## b_hw_business           -1.1423
## b_hw_commuters          -6.6739
## b_hw_leisure            -6.8809
## b_hw_shopping           -5.3024
## b_bus_commuters         5.2036
## b_bus_leisure           2.5801
## b_bus_shopping          3.7488
## b_rail_business         1.3647
## b_rail_commuters        2.7070
## b_rail_leisure          2.7508
## b_rail_shopping         2.2728
## b_car_inertia           6.1029
## b_car_available         2.5556
## b_car_male              -1.5715
## b_bus_disc              1.2523
## b_rail_disc             5.5922
## b_bus_ga                2.3188
## b_rail_ga               4.4964
## mu_mc_car_bus           5.5926
## mu_mc_car_rail          10.4029
## mu_rc_bus               8.2709
## mu_rc_car               5.8575
## mu_rc_rail_by_car       10.4705
## mu_rc_rail              NA

```

LR Test

```

##                               LL par
## Swiss_VOT_no_elas_combined -7972.84  41
## Swiss_VOT_combined         -7722.22  52
## Difference                   250.62  11
##
## Likelihood ratio test-value:   501.24
## Degrees of freedom:           11
## Likelihood ratio test p-value: 1.744e-100

```

VTTs

In the utility function,

1. The travel time for public transit alternatives by trip purpose p is given by:

$$\beta_{TT,PT,p} \cdot TT_{PT} \cdot \frac{dist^{\lambda_{TT,PT,p}}}{\hat{dist}}$$

2. The travel time for car alternatives by trip purpose p is given by:

$$\beta_{TT,Car,p} \cdot TT_{Car} \cdot \frac{dist^{\lambda_{TT,Car,p}}}{\hat{dist}}$$

3. The travel cost by trip purpose p is given by:

$$\beta_{TC,p} \cdot TC \cdot \frac{inc^{\lambda_{TC,p}}}{\hat{inc}}$$

Considering VTTS for mean values of income and distance, VTTS for any alternative type and purpose is given by the following formula:

$$VTTS = \frac{\alpha_{TT}}{\alpha_{TC}} * \frac{60min}{h}$$

where $\alpha_{TT} = \beta_{TT} \cdot (1)^{\lambda_{TT}}$ and $\alpha_{TC} = \beta_{TC} \cdot (1)^{\lambda_{TC}}$