Analyzing MaxDiff Data with Scale Factors:
Applications of
Latent GOLD® Basic + Choice 5

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Introduction to MaxDiff applications

A typical MaxDiff experiment obtains data for estimating preference utilities for about 8 to 40 items (brands, product features, priorities). In the usual MaxDiff task, respondents are shown a set (subset) of the possible items to be evaluated and are asked to indicate (among this subset) the best and worst items (or most and least important, etc.). Respondents typically complete 12 or more such sets where each set contains a different subset of 4 or so items. The combinations of items are designed very carefully towards the goal that each item is shown an equal number of times and each *pair* of items is shown an equal number of times. Each respondent typically sees each item two or more times across the MaxDiff sets.

Since 2003, the *Sequential BestWorst* model, implemented in Latent GOLD Basic + Choice (LG Choice), has been used by many to analyze both single and multi-attribute choice data. For an example of the latter, see LG Choice Tutorial #6. Such analyses were conducted using the replication scale feature by coding the (optional) replication scale variable as 1 for the best and -1 for the worst. Due to the popularity of such analyses, the **new scale type 'BestWorst' has been implemented in release 5 of LG Choice** to simplify and automate the model setup, and thus users no longer need to utilize the replication scale *trick* to set up the model.

As an alternative to the (*Sequential*) *BestWorst* model, **the *MaxDiff* model, also known as the *Joint BestWorst* or MaxDiff Quasi-Independence model, has been implemented in the *syntax* version of LG Choice 5**[1]. Unlike the sequential model which assumes that respondents always select the Best option prior to selecting the Worst option, the MaxDiff model assumes that one simultaneously selects that (best,worst) combination which offers the maximum difference in utilities. While the sequential BestWorst and MaxDiff models

[1] While the Basic and Advanced versions of LG Choice utilize the point-and-click module to run various kinds of models and view output, the LG-syntax module allows extensions of these models by simply including additional keywords or modifying equations in a syntax editor. See the LG-Syntax User's Guide for full details.

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often provide similar results, the BIC can be used to compare the fit of these models for given data.

As always, for the new MaxDiff as well as other discrete choice models, LG Choice allows for K latent class segments to be estimated simultaneously with the estimation of utilities for each segment (see e.g., Magidson, 2003). Various model fit statistics can assist in determining the number of segments that best fit the data.

Introduction to Scale Factors

Traditionally, utility estimation for MaxDiff data takes place under the restrictive assumption that scale factors are identical for all respondents, and also are the same for best and worst responses, leading to potential bias in the utilities. New options in Latent GOLD Choice version 5 allow **inclusion of a scale model to allow separate scale factors for those responses selected as *worst* from those selected as *best*, for different latent classes or to identify latent subgroups of respondents** (***latent scale classes***) **having different scale factors.** The scale model is available for *any* discrete choice model, and attributes can also be included in the scale model for further flexibility.

LG Choice tutorial

Goals: The primary goal of this tutorial is to show how BestWorst models can be estimated that allow for scale factors using the Advanced and Syntax versions of LG Choice 5.

- Advanced: Estimate BestWorst models with a different scale factor for *worst* responses*, or allow classes to have different scale factors.*
- LG-Syntax: Illustrate how latent *scale* classes can be correlated with latent classes.

A secondary goal is to introduce the Joint BestWorst model (also referred to as the MaxDiff model) that can be estimated using the syntax version of LG Choice (new in version 5).

- LG-Syntax: Estimate Joint BestWorst (MaxDiff) models.

Unlike the BestWorst models, it is *not* possible to estimate MaxDiff models with a different scale factor for worst responses because for that model a single scale factor applies to all options in the joint choice space. However, similar to BestWorst models, it *is* possible to estimate MaxDiff models with different scale factors for subgroups of respondents, where the subgroups are either latent or observed.

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For this tutorial, all analyses are performed using the 3-file format. They can also be performed using the LG Choice 1-file format (see Tutorial 8B) or a Sawtooth .cho file. We begin by estimating models using the LG-Choice point-and-click module and then show how to use the LG-Syntax module to estimate some advanced models.

Data: 'SydneyTransport_resp.sav', 'SydneyTransport_alt.sav', 'SydneyTransport_set.sav'

Data from the Sydney transport project[2] are used in this tutorial. These data were collected by CenSoC in a study to help set priorities. Respondents were asked to choose between 9 short term improvements (9 alternatives). The LG Choice Alternatives file lists the 9 improvements that are evaluated (see Figure 1: Alternatives file.Figure 1).

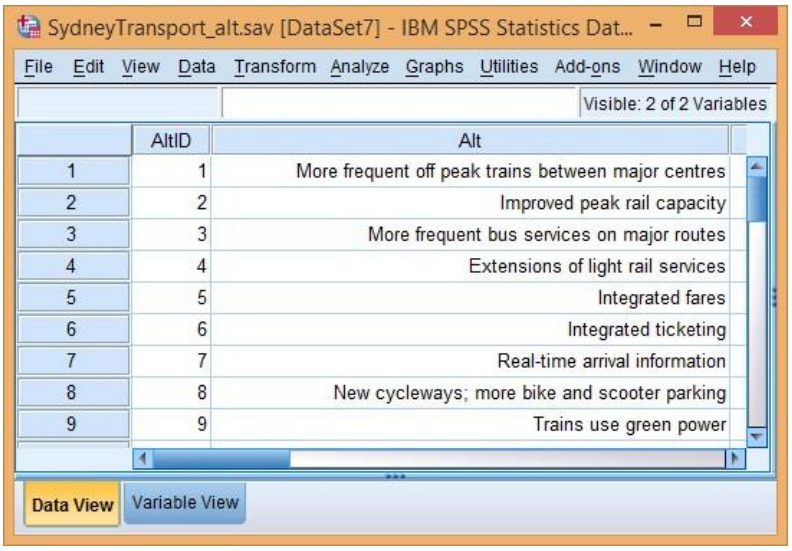

Figure 1: Alternatives file.

Specifically, respondents were presented with 12 tasks (see Sets file in Figure 2), each consisting of a subset of 3 of these 9 alternatives. For each of these tasks (sets), respondents were asked to choose the option that should receive the *highest* priority and that which should receive the *lowest* priority, the latter being flagged as '1' in the Response file (see Figure 3) using the dummy variable 'worst'.

[2] For further information on these data, see the forthcoming book: Best Worst Scaling: Theory and Practice, by Louviere, Flynn, & Marley.

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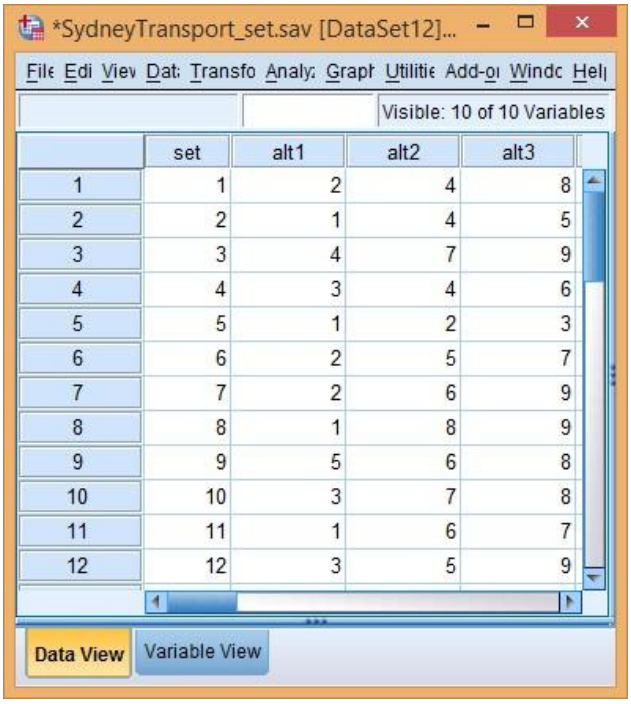
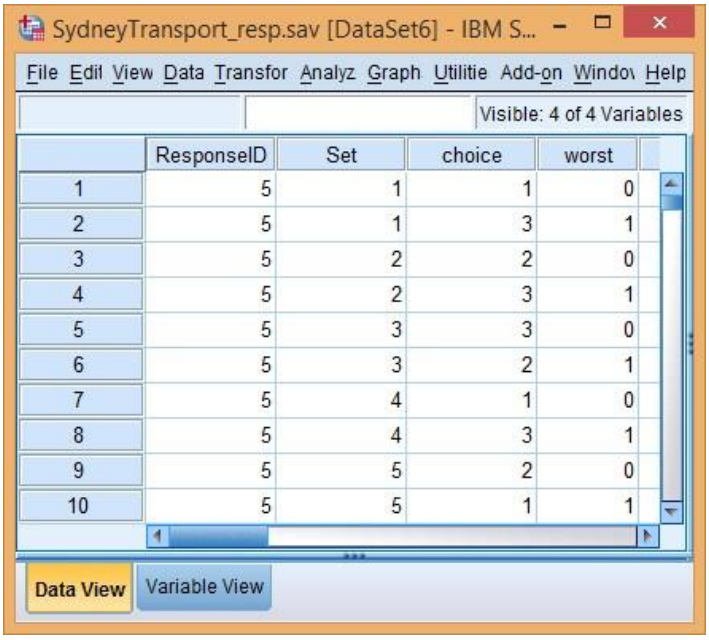


	set	alt1	alt2	alt3
1	1	2	4	8
2	2	1	4	5
3	3	4	7	9
4	4	3	4	6
5	5	1	2	3
6	6	2	5	7
7	7	2	6	9
8	8	1	8	9
9	9	5	6	8
10	10	3	7	8
11	11	1	6	7
12	12	3	5	9

Figure 2: Sets file.

Figure 3 illustrates the response file for the first 5 choice sets for '*RespondentID*' = 5. For example, for choice set 1, this respondent selected the first option as their highest priority ('choice'=1 when 'worst'=0) and the third as lowest priority ('choice'=3 when 'worst'=1).



	ResponseID	Set	choice	worst
1	5	1	1	0
2	5	1	3	1
3	5	2	2	0
4	5	2	3	1
5	5	3	3	0
6	5	3	2	1
7	5	4	1	0
8	5	4	3	1
9	5	5	2	0
10	5	5	1	1

Figure 3: Response file.

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This MaxDiff design is balanced and has the following properties:

1. Each alternative is included in exactly four choice sets.
2. Each alternative is compared with each of the other alternatives exactly one time.

For example, alternative 9 ('Trains use green power') is included as the third of 3 choice options in choice sets 3, 7, 8, and 12 (see column 'alt3' in Table 1 below). In these choice sets, it is compared with alternatives 1-4 which are offered as the first option (shaded blue below) and alternatives 5-8 as the second option (shaded green below).

Set	alt1	alt2	alt3
3	4	7	9
7	2	6	9
8	1	8	9
12	3	5	9

Table 1: Choice sets containing alternative 9 ('Trains use green power') as the third option.

Opening Previously Saved LG Choice Models

We will begin by opening previously saved models.[3]

In LG Choice:

- Click on File→Open.
- In the Open window, click on the 'Files of type' drop down menu and select 'LatentGOLD files(*.lgf)' (see Figure 4).
- Click on the file 'SydneyTransport_3file.lgf' and then click 'Open'.

[3] For a step-by-step tutorial on how to set up a model in LG Choice using the 3-file format, determine the number of classes, and save model definitions in a .lgf file, please see Tutorial 1. Note that Tutorial 1 deals with standard choice models (scale type = 'Choice'), while this tutorial deals with BestWorst and MaxDiff models (scale type for the dependent variable 'choice' is set to 'bestworst' or 'joint bestworst').

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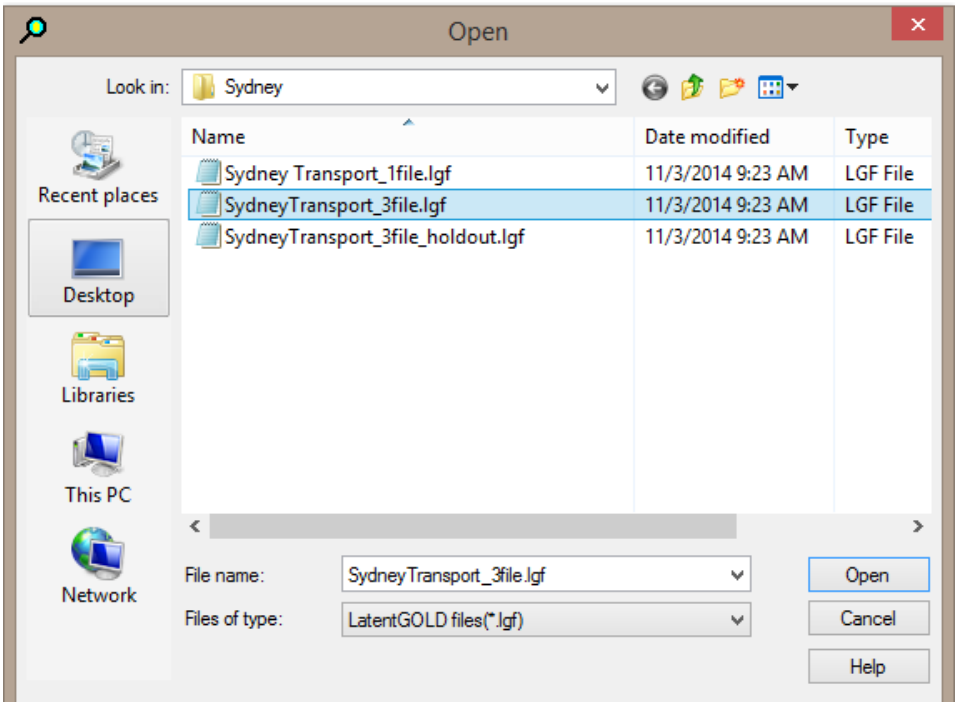

Figure 4: Opening previously saved models.

Four previously saved models appear in the left pane (see Figure 5):

1. Model '1-class': the homogeneous (1-class) BestWorst model.
2. Model '8-class': the 8-class BestWorst model.
3. Model '8-class+scale_worst': 8-class model with separate scale factor for worst.
4. Model '8-class+scale_worst+2-sClasses': model with separate scale factor for worst and also different scale factors for 2 latent subgroups (2 scale classes).

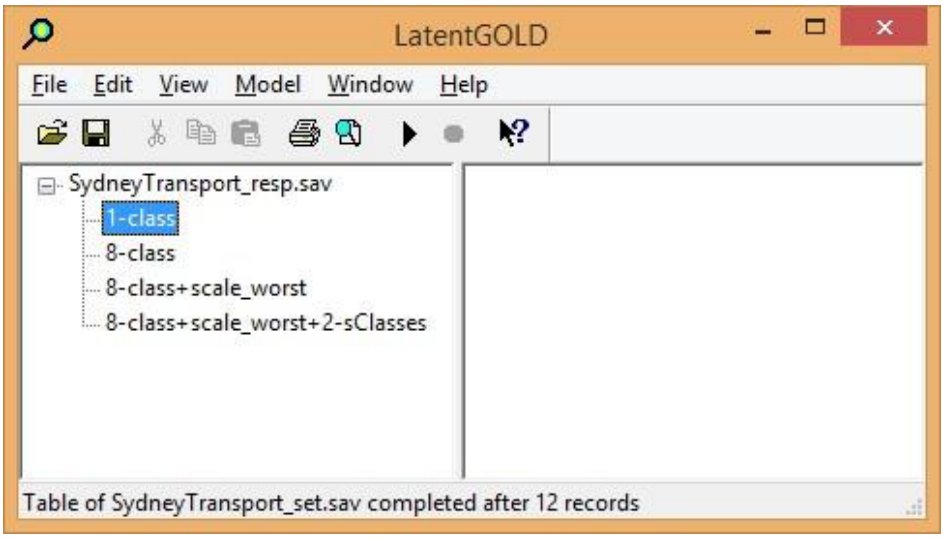

Figure 5: Four previously saved models.

➢ From the Task bar, click 'Model', then select 'Estimate All'.

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After estimation has completed:

- Click on the data file name 'SydneyTransport_resp.sav' in the Outline (left hand) pane to compare the fit of these models by viewing the Data File Summary output (see Figure 6).

Figure 6: Data File Summary Output.

According to the BIC, the 8-class model fits better[4] than the 1-class model (BIC is lower for the 8-class model). Comparing BIC for models 2 and 3, we see that the 8-class model is improved when allowing a different scale factor for the worst choices (BIC is lower for the model 3: '8-class+scale_worst'), and improved further when allowing latent subgroups to have different scale factors (BIC lowest for the model '8-class+scale_worst+2-sClasses').

Next, we will examine each of these four models in some detail.

Standard 1-class (homogeneous) BestWorst model

The utilities for the 1-class model are provided in the Parameters output. The Profile output transforms these parameters into probabilities, each being interpretable as the probability of choosing that alternative as best in a choice among all 9 short term improvements.

- Click on the Profile output for the '1-class' model (see Figure 7).

[4] One could estimate models containing 1-10 classes and verify that the 8-class model has the lowest BIC.

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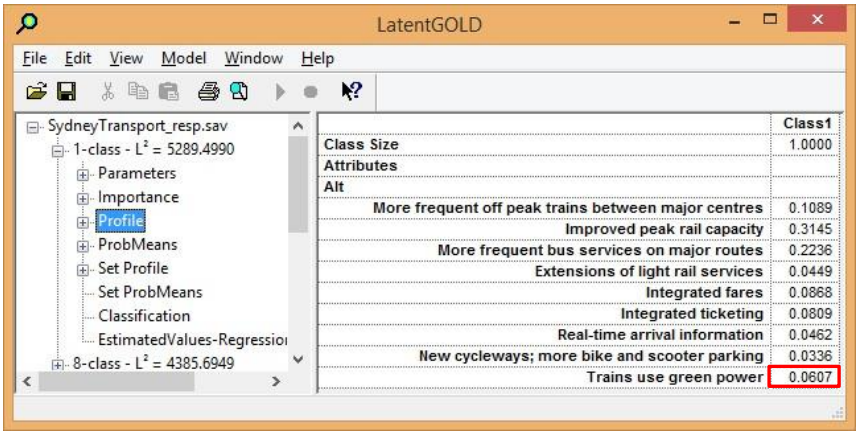

Figure 7: Profile output for the '1-class' model.

The 1-class (homogeneous) BestWorst model assumes that respondents are homogeneous in the sense that they all have the same priorities. Specifically, respondents give relatively low priority to the alternative 'Trains use green power', which would be selected as best only 6% of the time (see Figure 7). BIC rejects this homogeneous model because the patterns in the data are inconsistent with those that would be expected in a homogeneous population. A heterogeneous model with 8 latent classes, each exhibiting different priorities, is required to fit these data.

Standard 8-class BestWorst model

➢ Click on the Profile output for the '8-class' model (see Figure 8).

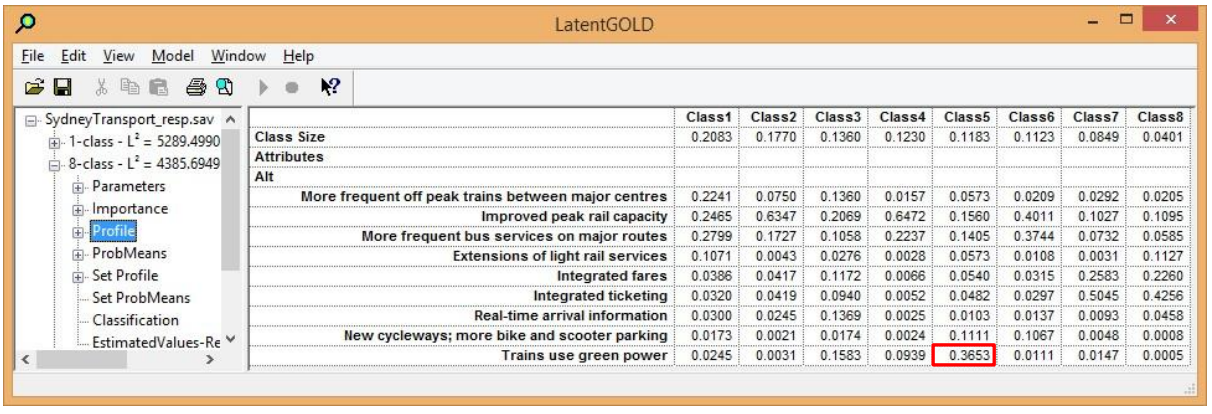

Figure 8: Profile output for the '8-class' model.

Output for each class is presented in a column consisting of the size of that class followed by the probability of choosing each of the 9 short-term improvements as the highest priority. The classes are ordered from the largest (probability = .2083) to the smallest (probability = .0401). Class 5 chooses 'Trains use green power' as its highest priority, with probability of choosing this option as highest = .3653. This is the fifth largest class (probability of being in Class 5 = .1183).

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To view these probabilities in a plot:

- Click on the the '+' symbol next to 'Profile' to expand the Profile output.
- Click on 'Prf-Plot' to view the Profile Plot.
- At the bottom of the plot, click on 'Class5' to highlight the profile probabilities for this class (see Figure 9).

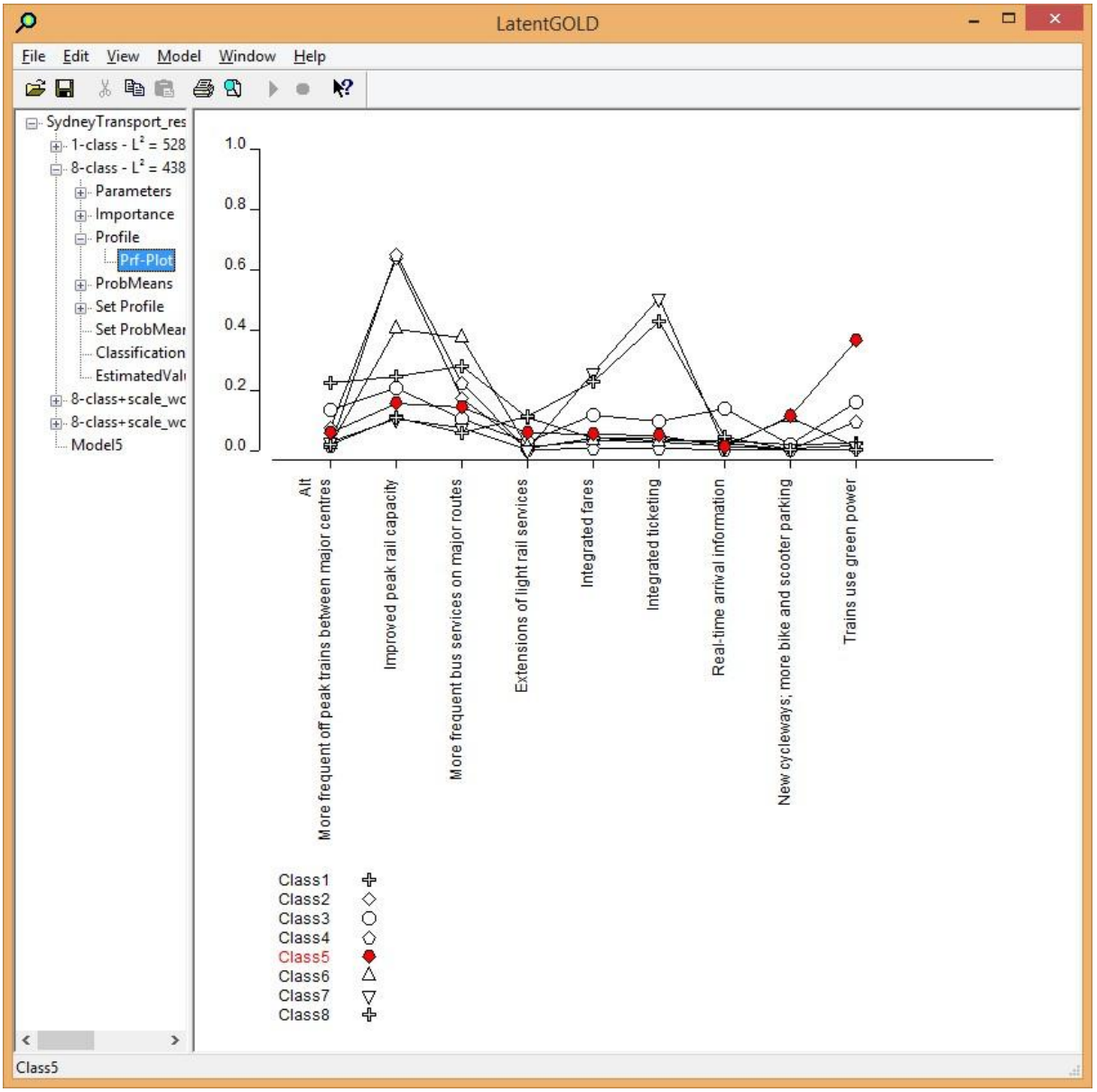

Figure 9: Profile plot for the '8-class' model.

From the highlighted points it is clear that class 5 assigns highest priority to 'Trains use green power'.

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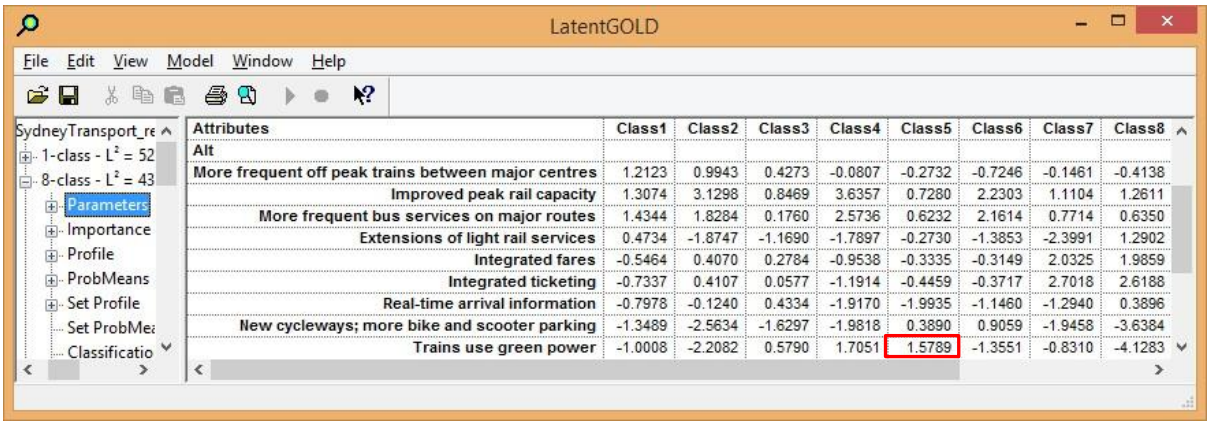
To view the (unstandardized) class-specific utilities for this model:

- Click on Parameters (see Figure 10).



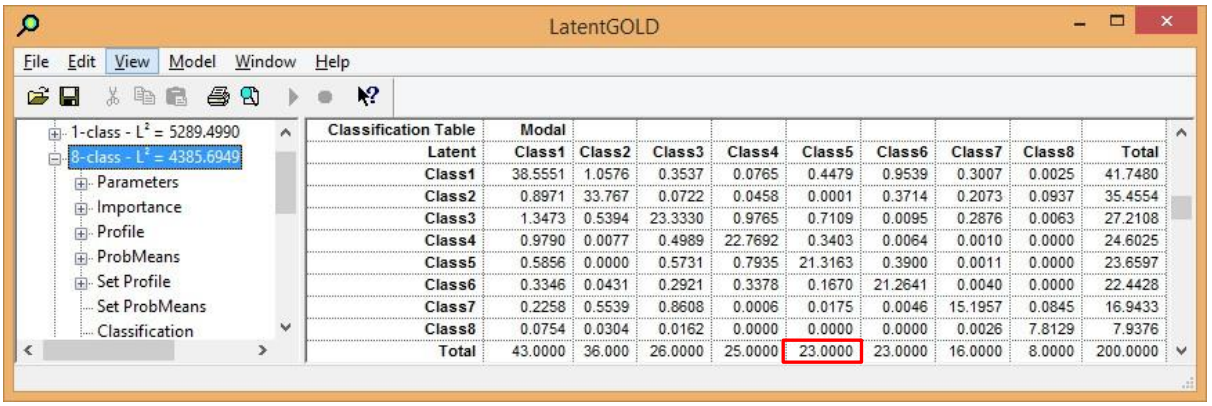
Attributes	Class1	Class2	Class3	Class4	Class5	Class6	Class7	Class8
Alt								
More frequent off peak trains between major centres	1.2123	0.9943	0.4273	-0.0807	-0.2732	-0.7246	-0.1461	-0.4138
Improved peak rail capacity	1.3074	3.1298	0.8469	3.6357	0.7280	2.2303	1.1104	1.2611
More frequent bus services on major routes	1.4344	1.8284	0.1760	2.5736	0.6232	2.1614	0.7714	0.6350
Extensions of light rail services	0.4734	-1.8747	-1.1690	-1.7897	-0.2730	-1.3853	-2.3991	1.2902
Integrated fares	-0.5464	0.4070	0.2784	-0.9538	-0.3335	-0.3149	2.0325	1.9859
Integrated ticketing	-0.7337	0.4107	0.0577	-1.1914	-0.4459	-0.3717	2.7018	2.6188
Real-time arrival information	-0.7978	-0.1240	0.4334	-1.9170	-1.9935	-1.1460	-1.2940	0.3896
New cycleways; more bike and scooter parking	-1.3489	-2.5634	-1.6297	-1.9818	0.3890	0.9059	-1.9458	-3.6384
Trains use green power	-1.0008	-2.2082	0.5790	1.7051	1.5789	-1.3551	-0.8310	-4.1283

Figure 10: Parameters output for the 8-class model.

The Profile and Parameters output provide equivalent information for the estimated utilities, the former in probability units, the latter as logits. Notice that for class 5 the utility for 'Trains use green power' is the highest among all 9 alternatives, consistent with the Profile output.

- Click on '8-class' to view the Model Summary output for this model and scroll down to the Classification Table for information on expected accuracy of the classifications based on modal assignment.

In the bottom row note that 23 of the 200 respondents (11.5%) are classified into the segment that prefers 'Trains use green power' as their highest priority.



Classification Table	Modal								
Latent	Class1	Class2	Class3	Class4	Class5	Class6	Class7	Class8	Total
Class1	38.5551	1.0576	0.3537	0.0765	0.4479	0.9539	0.3007	0.0025	41.7480
Class2	0.8971	33.767	0.0722	0.0458	0.0001	0.3714	0.2073	0.0937	35.4554
Class3	1.3473	0.5394	23.3330	0.9765	0.7109	0.0095	0.2876	0.0063	27.2108
Class4	0.9790	0.0077	0.4989	22.7692	0.3403	0.0064	0.0010	0.0000	24.6025
Class5	0.5856	0.0000	0.5731	0.7935	21.3163	0.3900	0.0011	0.0000	23.6597
Class6	0.3346	0.0431	0.2921	0.3378	0.1670	21.2641	0.0040	0.0000	22.4428
Class7	0.2258	0.5539	0.8608	0.0006	0.0175	0.0046	15.1957	0.0845	16.9433
Class8	0.0754	0.0304	0.0162	0.0000	0.0000	0.0000	0.0026	7.8129	7.9376
Total	43.0000	36.000	26.0000	25.0000	23.0000	23.0000	16.0000	8.0000	200.0000

Figure 11: Classification table for the 8-class model.

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BestWorst model with different scale factor for worst choices

As we saw above, the BIC criterion requires us to reject the standard 8-class BestWorst model, which assumes that the scale factors for the responses selected as worst are the same as those selected as *best*, in favor of an 8-class model with different scale factors for the worst responses.

To view the model definition for the '8-class + scale worst' model:

- Double click on the model '8-class+scale_worst' to open the model definition window.
- Right click on 'worst' in the Predictors window (see Figure 12).

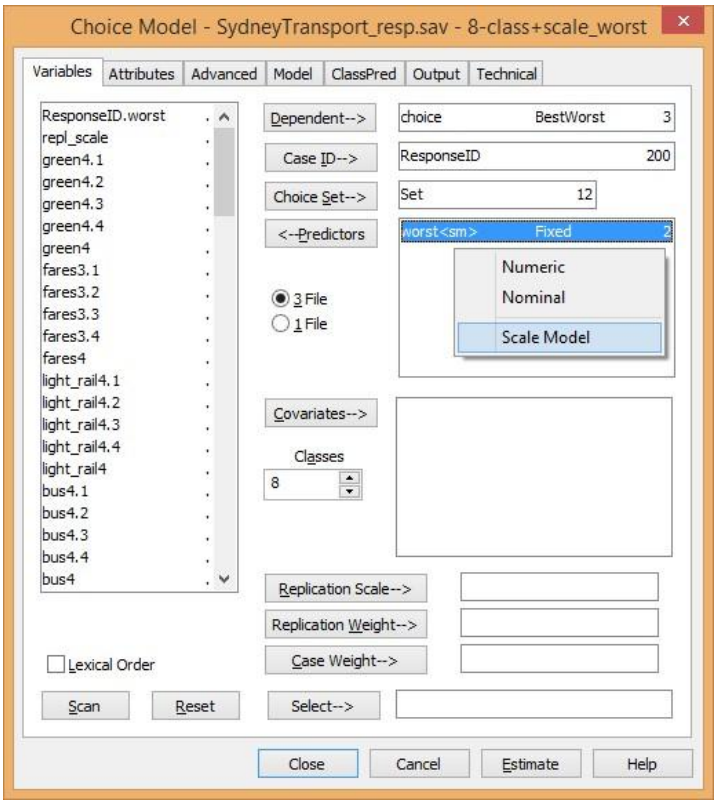

Figure 12: Including 'worst' as a scale predictor in the '8-class+scale_worst' model.

For this model, the variable 'worst' is included as a Scale Model predictor (note the keyword '<sm>' to the right of 'worst') to allow scale factors to differ for the responses selected as worst from those selected as best.

- Click 'Close' to close the model definition window.
- Click on the Parameters output for the '8-classes+scale_worst' model (see Figure 13).

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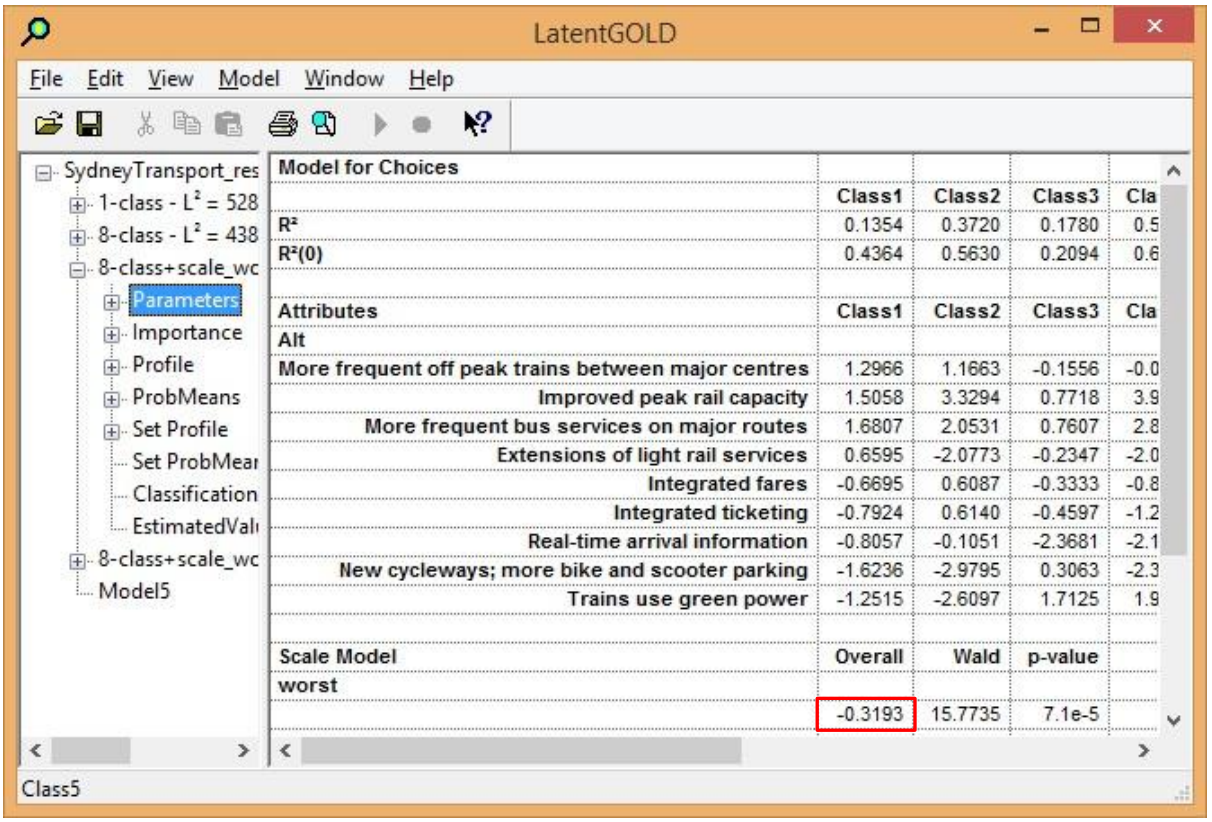

Model for Choices

	Class1	Class2	Class3	Cla
R^2	0.1354	0.3720	0.1780	0.5
$R^2(0)$	0.4364	0.5630	0.2094	0.6

Attributes	Class1	Class2	Class3	Cla
Alt				
More frequent off peak trains between major centres	1.2966	1.1663	-0.1556	-0.0
Improved peak rail capacity	1.5058	3.3294	0.7718	3.9
More frequent bus services on major routes	1.6807	2.0531	0.7607	2.8
Extensions of light rail services	0.6595	-2.0773	-0.2347	-2.0
Integrated fares	-0.6695	0.6087	-0.3333	-0.8
Integrated ticketing	-0.7924	0.6140	-0.4597	-1.2
Real-time arrival information	-0.8057	-0.1051	-2.3681	-2.1
New cycleways; more bike and scooter parking	-1.6236	-2.9795	0.3063	-2.3
Trains use green power	-1.2515	-2.6097	1.7125	1.9

Scale Model	Overall	Wald	p-value
worst			
	-0.3193	15.7735	7.1e-5

Figure 13: Parameters output for the '8-classes+scale_worst' model.

For purpose of identification, the log-scale[5] factor associated with the *best* choices is set to 0 (scale factor = exp(0) = 1). The Parameters output shows that the log-scale factor estimated for the *worst* choices = -.3193, which is significantly less than 0 (p=.000071). Under the assumption that this model is true, this result might be interpreted as follows: "the *worst* choices exhibit less consistency across choice sets than the *best* choices". Specifically, selection of the *worst* short term improvements is only exp(-.3193) = .73 times as consistent as the choice of the best short term improvement. Later in this tutorial we shall suggest an alternative interpretation.

To view the utilities estimated under this model in probability units:

- Click on the Profile output for this model (see Figure 14).

[5]Estimating the log-scale factor rather than the scale factor directly assures that the scale factor is non-negative. The approach used in Latent GOLD Choice was suggested by Vermunt (2013).

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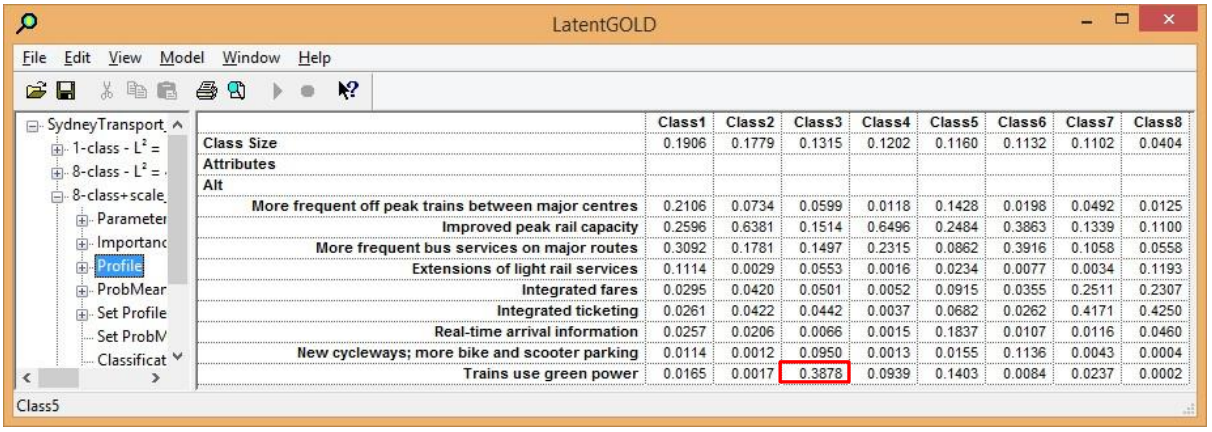

	Class1	Class2	Class3	Class4	Class5	Class6	Class7	Class8
Class Size	0.1906	0.1779	0.1315	0.1202	0.1160	0.1132	0.1102	0.0404
Attributes								
Alt								
More frequent off peak trains between major centres	0.2106	0.0734	0.0599	0.0118	0.1428	0.0198	0.0492	0.0125
Improved peak rail capacity	0.2596	0.6381	0.1514	0.6496	0.2484	0.3863	0.1339	0.1100
More frequent bus services on major routes	0.3092	0.1781	0.1497	0.2315	0.0862	0.3916	0.1058	0.0558
Extensions of light rail services	0.1114	0.0029	0.0553	0.0016	0.0234	0.0077	0.0034	0.1193
Integrated fares	0.0295	0.0420	0.0501	0.0052	0.0915	0.0355	0.2511	0.2307
Integrated ticketing	0.0261	0.0422	0.0442	0.0037	0.0682	0.0262	0.4171	0.4250
Real-time arrival information	0.0257	0.0206	0.0066	0.0015	0.1837	0.0107	0.0116	0.0460
New cycleways; more bike and scooter parking	0.0114	0.0012	0.0950	0.0013	0.0155	0.1136	0.0043	0.0004
Trains use green power	0.0165	0.0017	0.3878	0.0939	0.1403	0.0084	0.0237	0.0002

Figure 14: Profile output for the '8-classes+scale_worst' model.

Again, we see that one of the classes (Class 3) selects 'Trains use green power' as its highest priority. Class3 represents the *third* largest class (class size probability = .1315).

BestWorst model with different scale factors for latent scale classes

- Double click on the model '8-class+scale_worst+2-sClasses' to open the model definition window.
- Click on the Advanced tab (see Figure 15).

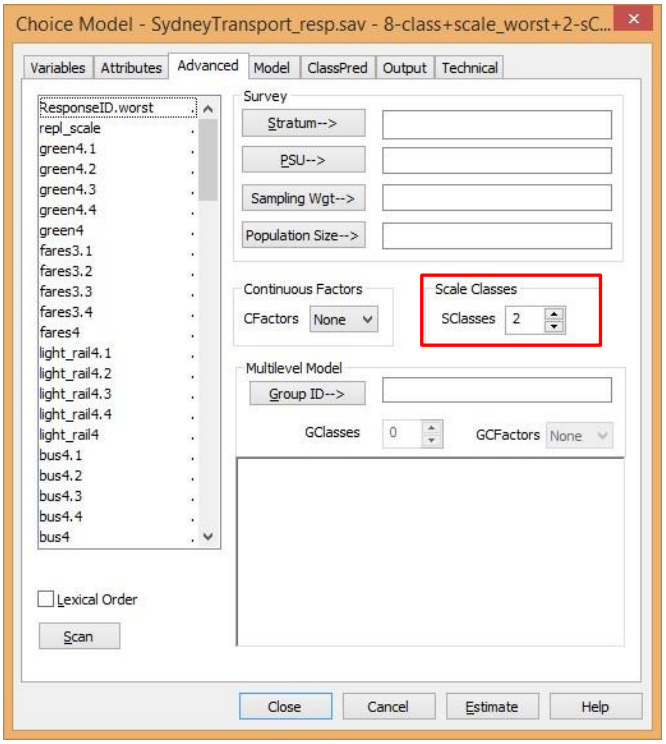

Figure 15: Including 2 SClasses in the Advanced tab.

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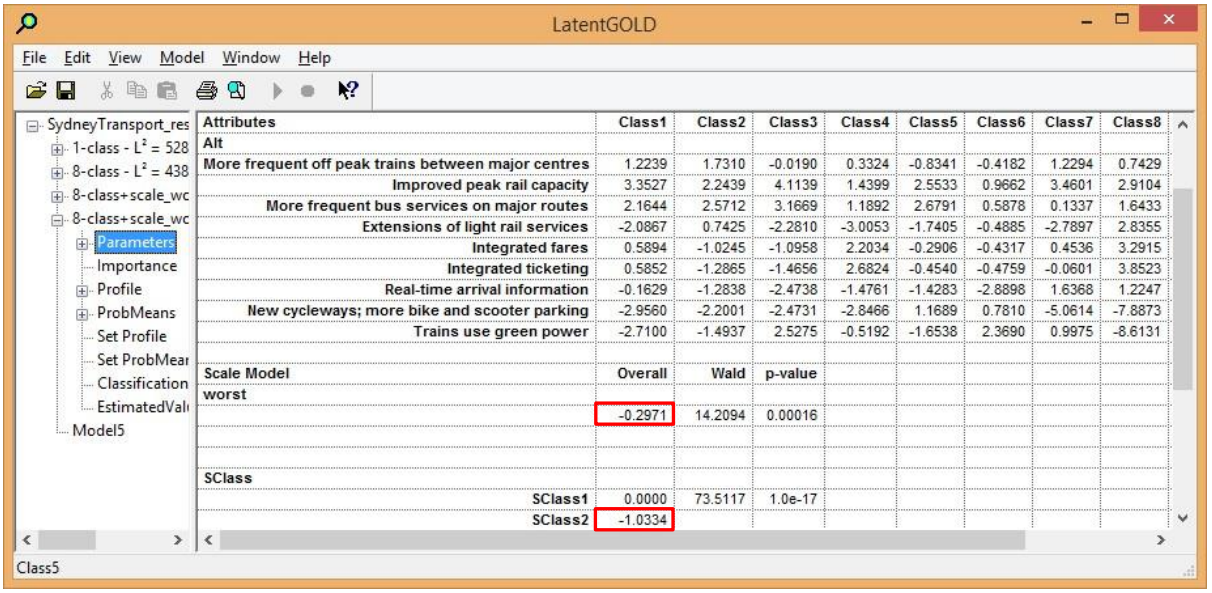
In the Advanced tab, SClasses=1 by default. For this model, we have specified SClasses=2 to allow *different* scale factors for 2 latent subgroups of respondents (latent scale classes).

- Click 'Close' to close the model definition window.

- Click on the Parameters output for the '8-class+scale_worst+2-sClasses' model (see Figure 16).



Attributes	Class1	Class2	Class3	Class4	Class5	Class6	Class7	Class8
Alt								
More frequent off peak trains between major centres	1.2239	1.7310	-0.0190	0.3324	-0.8341	-0.4182	1.2294	0.7429
Improved peak rail capacity	3.3527	2.2439	4.1139	1.4399	2.5533	0.9662	3.4601	2.9104
More frequent bus services on major routes	2.1644	2.5712	3.1669	1.1892	2.6791	0.5878	0.1337	1.6433
Extensions of light rail services	-2.0867	0.7425	-2.2810	-3.0053	-1.7405	-0.4885	-2.7897	2.8355
Integrated fares	0.5894	-1.0245	-1.0958	2.2034	-0.2906	-0.4317	0.4536	3.2915
Integrated ticketing	0.5852	-1.2865	-1.4656	2.6824	-0.4540	-0.4759	-0.0601	3.8523
Real-time arrival information	-0.1629	-1.2838	-2.4738	-1.4761	-1.4283	-2.8898	1.6368	1.2247
New cycleways; more bike and scooter parking	-2.9560	-2.2001	-2.4731	-2.8466	1.1689	0.7810	-5.0614	-7.8873
Trains use green power	-2.7100	-1.4937	2.5275	-0.5192	-1.6538	2.3690	0.9975	-8.6131
Scale Model	Overall	Wald	p-value					
worst								
	-0.2971	14.2094	0.00016					
SClass								
SClass1	0.0000	73.5117	1.0e-17					
SClass2	-1.0334							

Figure 16: Parameters output for the '8-classes+scale_worst+2-sClasses' model.

The log-scale model now contains 2 parameters, the first associated with the 'worst' responses, the second associated with respondents in SClass 2. Formally, the scale equation expressed in terms of the dummy variables 'worst' and 'Sclass2' is:

Log(scale factor) = -.297 worst - 1.033 SClass2

where SClass2= 1 for the second scale class and = 0 for the first.

We also see that the class favoring 'Trains use green power' is now Class 6 (see Figure 17).

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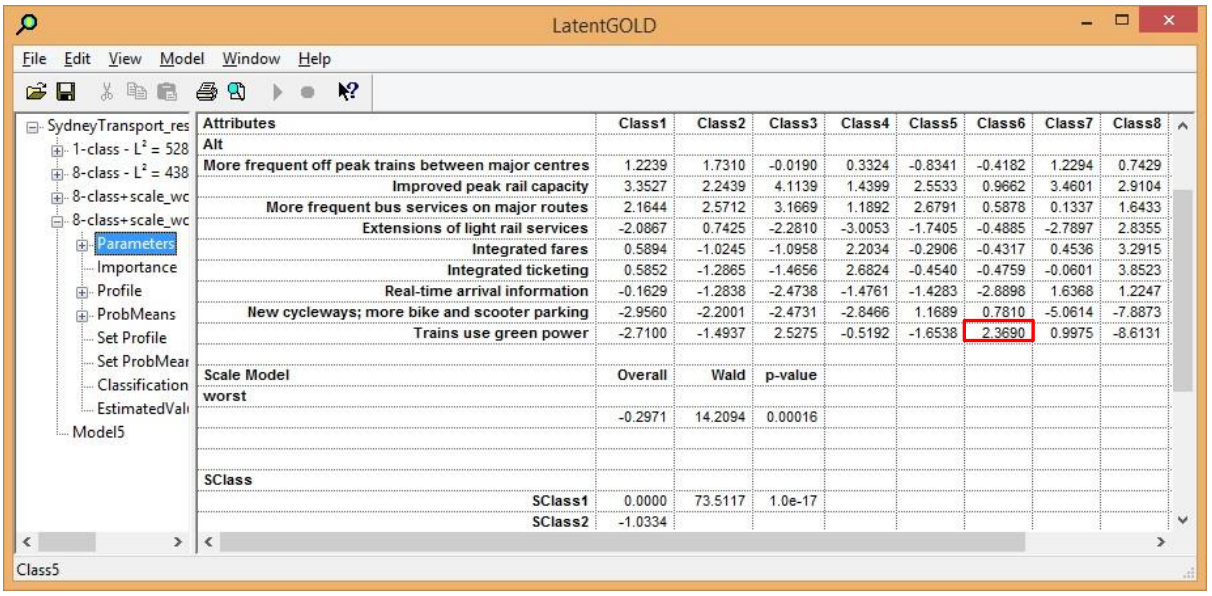


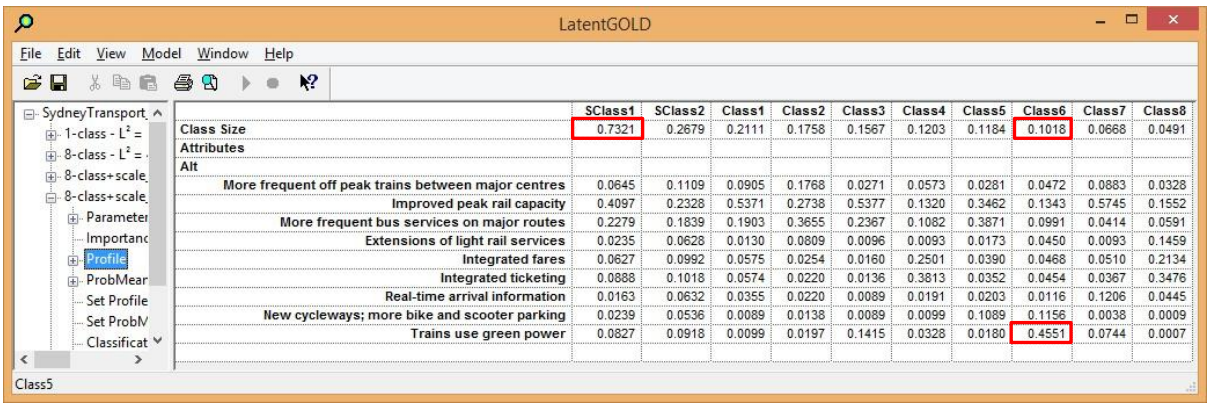
Attributes	Class1	Class2	Class3	Class4	Class5	Class6	Class7	Class8
Alt								
More frequent off peak trains between major centres	1.2239	1.7310	-0.0190	0.3324	-0.8341	-0.4182	1.2294	0.7429
Improved peak rail capacity	3.3527	2.2439	4.1139	1.4399	2.5533	0.9662	3.4601	2.9104
More frequent bus services on major routes	2.1644	2.5712	3.1669	1.1892	2.6791	0.5878	0.1337	1.6433
Extensions of light rail services	-2.0867	0.7425	-2.2810	-3.0053	-1.7405	-0.4885	-2.7897	2.8355
Integrated fares	0.5894	-1.0245	-1.0958	2.2034	-0.2906	-0.4317	0.4536	3.2915
Integrated ticketing	0.5852	-1.2865	-1.4656	2.6824	-0.4540	-0.4759	-0.0601	3.8523
Real-time arrival information	-0.1629	-1.2838	-2.4738	-1.4761	-1.4283	-2.8898	1.6368	1.2247
New cycleways; more bike and scooter parking	-2.9560	-2.2001	-2.4731	-2.8466	1.1689	0.7810	-5.0614	-7.8873
Trains use green power	-2.7100	-1.4937	2.5275	-0.5192	-1.6538	2.3690	0.9975	-8.6131

Scale Model	Overall	Wald	p-value
worst			
	-0.2971	14.2094	0.00016

SClass			
SClass1	0.0000	73.5117	1.0e-17
SClass2	-1.0334		

Figure 17: Parameters output for the '8-classes+scale_worst+2-sClasses' model.

➢ Click on the Profile output for this model (see Figure 18). Note: Right click and uncheck 'Joint'.



	SClass1	SClass2	Class1	Class2	Class3	Class4	Class5	Class6	Class7	Class8
Class Size	0.7321	0.2679	0.2111	0.1758	0.1567	0.1203	0.1184	0.1018	0.0668	0.0491
Attributes										
Alt										
More frequent off peak trains between major centres	0.0645	0.1109	0.0905	0.1768	0.0271	0.0573	0.0281	0.0472	0.0883	0.0328
Improved peak rail capacity	0.4097	0.2328	0.5371	0.2738	0.5377	0.1320	0.3462	0.1343	0.5745	0.1552
More frequent bus services on major routes	0.2279	0.1839	0.1903	0.3655	0.2367	0.1082	0.3871	0.0991	0.0414	0.0591
Extensions of light rail services	0.0235	0.0628	0.0130	0.0809	0.0096	0.0093	0.0173	0.0450	0.0093	0.1459
Integrated fares	0.0627	0.0992	0.0575	0.0254	0.0160	0.2501	0.0390	0.0468	0.0510	0.2134
Integrated ticketing	0.0888	0.1018	0.0574	0.0220	0.0136	0.3813	0.0352	0.0454	0.0367	0.3476
Real-time arrival information	0.0163	0.0632	0.0355	0.0220	0.0089	0.0191	0.0203	0.0116	0.1206	0.0445
New cycleways; more bike and scooter parking	0.0239	0.0536	0.0089	0.0138	0.0089	0.0099	0.1089	0.1156	0.0038	0.0009
Trains use green power	0.0827	0.0918	0.0099	0.0197	0.1415	0.0328	0.0180	0.4551	0.0744	0.0007

Figure 18: Profile output for the '8-classes+scale_worst+2-sClasses' model.

The top row of this output shows that Class 6 consists of 10.18% of respondents, and that SClass 1, the more consistent (more certain) SClass consists of 73.21% of the respondents. This model assumes that the latent variables Class and SClass are statistically independent, which means that each of the 8 classes consists of 73.21% of the respondents who are more certain.

The *Joint* Profile output makes clear that there are a total of 8x2 = 16 different respondent types (8 classes that differ on preferences, each of which consists of 2 response clarity types – more vs. less consistent). To view the Joint Profile output:

➢ Right click anywhere in the Profile output.
➢ Select 'Joint' (see Figure 19).

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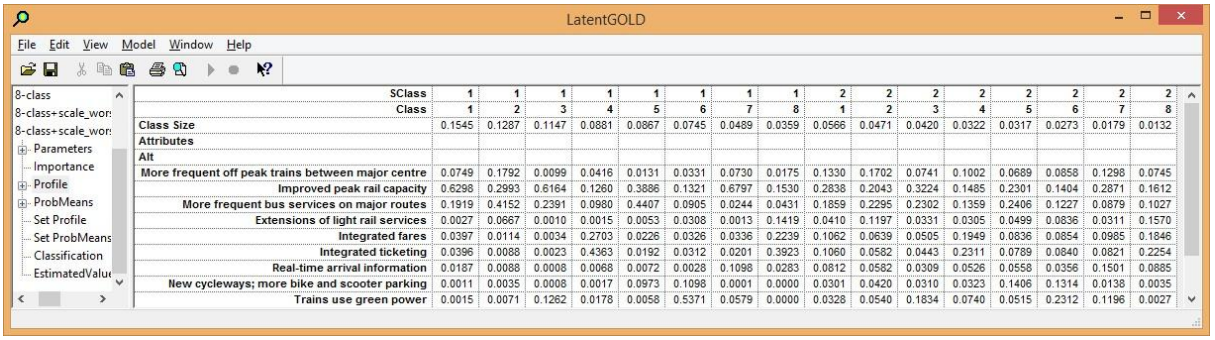

SClass	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2
Class	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
Class Size	0.1545	0.1287	0.1147	0.0881	0.0867	0.0745	0.0489	0.0359	0.0566	0.0471	0.0420	0.0322	0.0317	0.0273	0.0179	0.0132
Attributes																
Alt																
More frequent off peak trains between major centre	0.0749	0.1792	0.0099	0.0416	0.0131	0.0331	0.0730	0.0175	0.1330	0.1702	0.0741	0.1002	0.0689	0.0858	0.1298	0.0745
Improved peak rail capacity	0.6298	0.2993	0.6164	0.1260	0.3886	0.1321	0.6797	0.1530	0.2838	0.2043	0.3224	0.1485	0.2301	0.1404	0.2871	0.1612
More frequent bus services on major routes	0.1919	0.4152	0.2391	0.0980	0.4407	0.0905	0.0244	0.0431	0.1859	0.2295	0.2302	0.1359	0.2406	0.1227	0.0879	0.1027
Extensions of light rail services	0.0027	0.0667	0.0010	0.0015	0.0053	0.0308	0.0013	0.1419	0.0410	0.1197	0.0331	0.0305	0.0499	0.0836	0.0311	0.1570
Integrated fares	0.0397	0.0114	0.0034	0.2703	0.0226	0.0326	0.0336	0.2239	0.1062	0.0639	0.0505	0.1949	0.0836	0.0854	0.0985	0.1846
Integrated ticketing	0.0396	0.0088	0.0023	0.4363	0.0192	0.0312	0.0201	0.3923	0.1060	0.0582	0.0443	0.2311	0.0789	0.0840	0.0821	0.2254
Real-time arrival information	0.0187	0.0088	0.0008	0.0068	0.0072	0.0028	0.1098	0.0283	0.0812	0.0582	0.0309	0.0526	0.0558	0.0356	0.1501	0.0885
New cycleways; more bike and scooter parking	0.0011	0.0035	0.0008	0.0017	0.0973	0.1098	0.0001	0.0000	0.0301	0.0420	0.0310	0.0323	0.1406	0.1314	0.0138	0.0035
Trains use green power	0.0015	0.0071	0.1262	0.0178	0.0058	0.5371	0.0579	0.0000	0.0328	0.0540	0.1834	0.0740	0.0515	0.2312	0.1196	0.0027

Figure 19: Joint Profile output for model '8-classes+scale_worst+2-sClasses'.

We can test the independence assumption by comparing the fit of this model to a model that allows Class and SClass to be correlated, but to do so requires use of the LG-Syntax module, as illustrated below.

Using the LG Syntax for BestWorst models

The LG Syntax module offers various modelling option for BestWorst models which are not available in the LG-Choice point-and-click module. Two model options illustrated below are

1) allowing association between Class and SClass membership, and
2) defining joint BestWorst (MaxDiff) models

Other options include allowing the scale effects to depend upon attributes and/or to vary across Classes[6], including covariates in the model for the SClasses, utilizing continuous latent variables (random effects) to model continuous rather than discrete heterogeneity in the scale factor, and defining Choice models for longitudinal and multilevel data.

We will now illustrate the use of the LG-Syntax module to test whether there is a nonzero association between Class and SClass membership.

After setting up any of the BestWorst models with the LG-Choice point-and-click module, as we did above, we can then use the 'Generate Syntax' option to produce the syntax for these models.

- Right click on the data file name 'SydneyTransport_resp.sav' in the Outline (left hand) pane.
- Select 'Generate Syntax'.

[6] For example, by including 'worst|class' in the syntax equation for the scale model, the different scale factors estimated for best and worst choices can be allowed to differ by class.

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A separate (new) syntax tree appears above the other tree as shown in Figure 20, similar in appearance to a new dataset being opened. Note that the names of the 4 point-and-click models are preserved in the syntax.

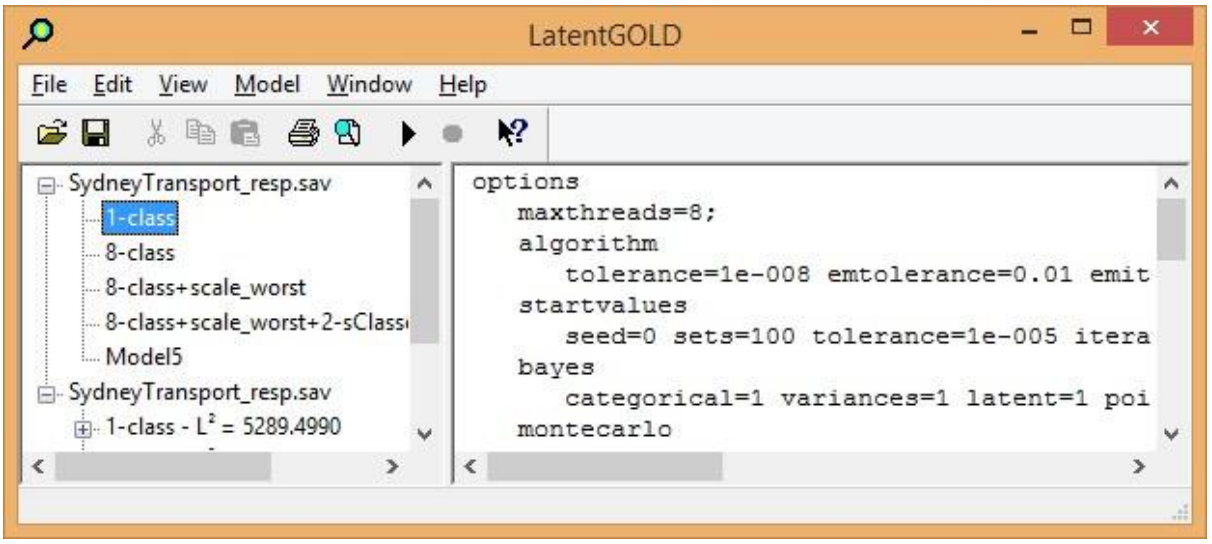

Figure 20: The 4 BestWorst models represented as syntax models.

To re-estimate our last model using the syntax module:

- Right click on the '8-classes+scale_worst+2-sClasses' model.
- Click 'Estimate'.

Verify that the model is the same as estimated earlier with the LG-Choice point-and-click module by checking that the model summary statistics match. For example, BIC(L^2) = 3655.3496 for this model. Note that the individual output sections are formatted somewhat differently in the LG-syntax and the latent classes are no longer ordered from high to low.

To estimate a new syntax model allowing correlation between Class and SClass:

- Click on Model5 (a copy of previously estimated model including SClass effects).
- On line 36, type 'Sclass <-> Class;' (see Figure 21).
- Right click on Model5 and select 'Estimate'.

Notes: Figure 21 shows that the *scale model* equation is defined using the new symbol '<<-'

choice <<- worst + (-) SClass ;

For convenience, the minus sign that appears in parenthesis preceding SClass imposes the ordering "restriction" which serves only to assure that the SClasses appear in descending order[7] in the Parameters output, as we saw earlier in Figure 17.

[7]For purposes of identification the scale parameter associated with SClass 1 is set to 0 using the 'coding = first' LG-syntax option which imposes this dummy coding. The '(-)' restriction affects the ordering of the SClasses such that for each subsequent SClass, the associated scale parameter becomes smaller. Thus, the scale parameter for SClass 2 is negative.

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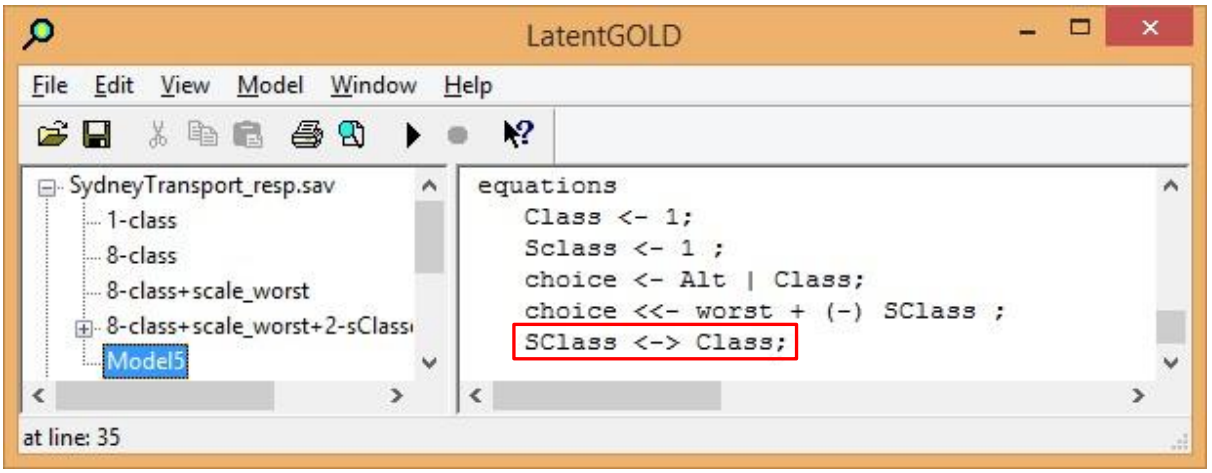

Figure 21: Addition of 'Sclass <-> Class' to the scale model allows for non-zero Class X SClass associations.

After estimation has completed:

- Click on the data file name 'SydneyTransport_resp.sav' in the Outline (left hand) pane to view the Data File Summary output (Figure 22) which compares the fit of these models.

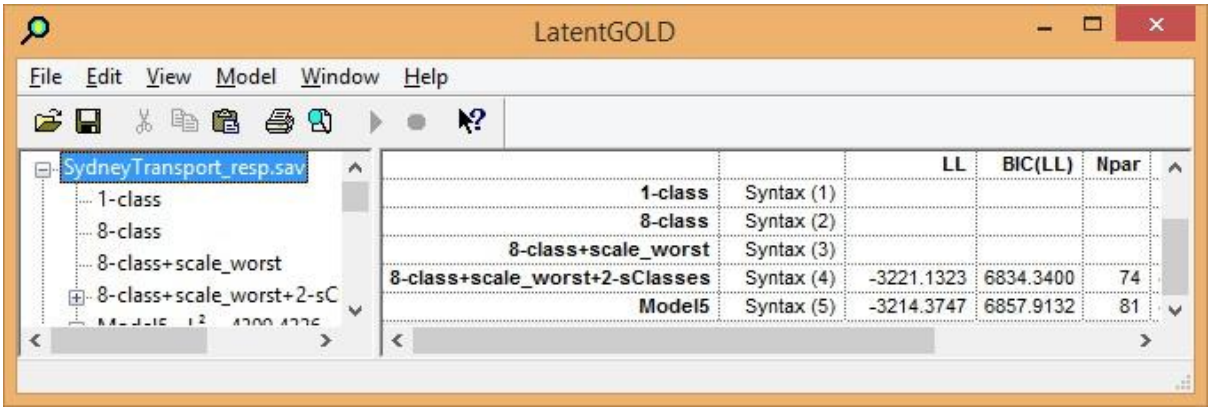

Figure 22: Data File Summary Output.

According to the BIC, allowing the SClasses to differ by class does not improve the model fit (BIC for Model 5 is higher than previous model). Hence, we reject Model 5.

Estimate MaxDiff (Joint BestWorst) models

A model closely related to the sequential BestWorst model is the MaxDiff model, also known as the Joint BestWorst model. Both are probability models for the joint (best,worst) choice. The probability structure associated with the sequential BestWorst model is:

$$P(best,worst) = P(best)*P(worst|best)$$

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while the structure for the MaxDiff model can be expressed as a quasi-independence model:

$$P(best,worst) = P(best)*P(worst)*Diag(=0) / C$$

where diag(=0) yields structural zeroes to rule out the possibility of selecting the same option as both 'best' and 'worst' for any choice set, and C is a normalizing constant which assures that the joint choice probabilities sum to 1. For further details see Marley and Louviere (2005).

In the LG Choice 5 syntax, the keyword 'bestworst' is applied to the response variable to indicate that the sequential best worst model is to be estimated (recall Figure 21). Alternatively, use of the keywords 'joint bestworst' causes the MaxDiff model to be estimated.

Estimating a standard MaxDiff (Joint BestWorst) model

We will now estimate 8-class *MaxDiff* models with and without 2 SClasses. To estimate the first model, we will copy the syntax used earlier to estimate the 8-class *sequential* BestWorst model, and modify this syntax by inserting the keyword '*joint*' prior to the keyword '*bestworst*'.

We begin by re-estimating the 8-class BestWorst model.

- Right click on the model '8-class' and select 'Estimate'.

After estimation has completed:

- Right click on the model '8-class'.
- Select 'Copy Model'.
- To rename this model, click twice on the model '8-class(1)' to enter Edit mode.
- Type the word 'MaxDiff' so that the model name is '8-class MaxDiff'.
- In the syntax insert 'joint' prior to 'bestworst' (see Figure 23).
- Click 'Estimate'.

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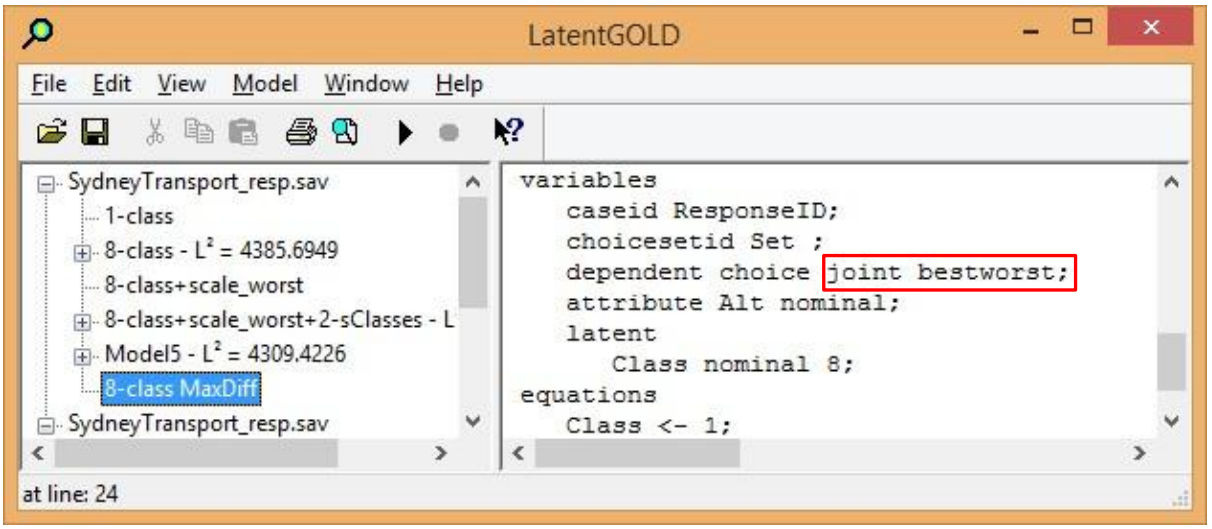

Figure 23: the keyword 'joint' to specify the MaxDiff model.

- Click on the data file name 'SydneyTransport_resp.sav' in the Outline (left hand) pane to view the Data File Summary output (Figure 24) which compares the fit of these models.

According to the BIC, the MaxDiff model fits better than the sequential best worst model (6860.7 vs. 6881.2).

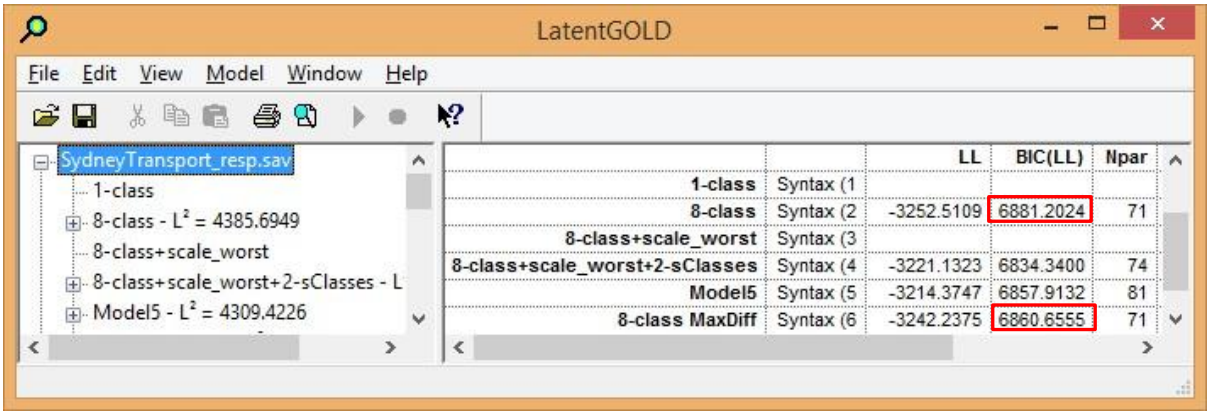

Figure 24: Data File Summary Output.

- Re-estimate '8-class + scale_worst'.
- Click on the data file name 'SydneyTransport_resp.sav'.

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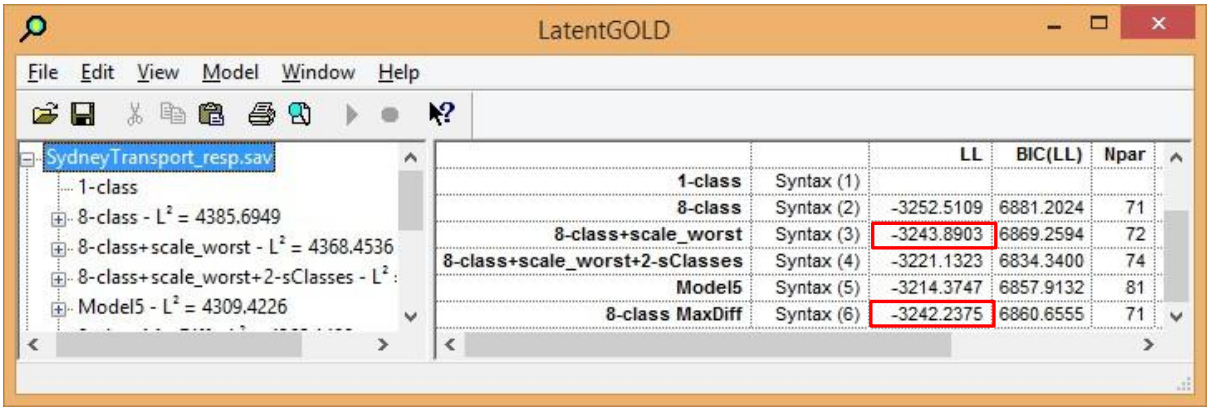

		LL	BIC(LL)	Npar
1-class	Syntax (1)			
8-class	Syntax (2)	-3252.5109	6881.2024	71
8-class+scale_worst	Syntax (3)	-3243.8903	6869.2594	72
8-class+scale_worst+2-sClasses	Syntax (4)	-3221.1323	6834.3400	74
Model5	Syntax (5)	-3214.3747	6857.9132	81
8-class MaxDiff	Syntax (6)	-3242.2375	6860.6555	71

Figure 25: Data File Summary Output.

Comparing the 8-class MaxDiff model with the 8-class BestWorst model with different scale factors for the best and worst responses, it is interesting to note that even with 1 fewer parameter (Npar=71 vs. 72) the 8-class MaxDiff model has a higher LL than the corresponding sequential model containing the additional scale parameter. It is also interesting that the LL values for these models are extremely close.

Under the assumption that the MaxDiff model is true, we might say that the significant scale factor required to be added to the BestWorst model serves as a misspecification adjustment factor. Rather than being a measure of more or less certainty, this adjustment could be interpreted as an attempt to compensate for the faulty assumption that respondents always evaluate the options sequentially by first selecting the best and then the worst, rather than making both best and worst choices simultaneously.

Comparing predicted probabilities between MaxDiff and BestWorst models

Previously we examined the Profile output from the point-and-click module to view the predicted probabilities of choosing the 9 options as best, separately for each of the 8 latent class segments (recall Figure 8 for the standard BestWorst model and Figure 14 for the BestWorst model with a different scale factor for worst responses). Since the Profile output from the syntax module is more general, for a comparable view based on the MaxDiff model (which requires use of the syntax module) we will need to view the Set Profile output[8].

Recall that each of the 12 choice sets consists of only 3 of the 9 alternatives. In order to simulate the best choice probabilities that would occur across all 9 alternatives in a standard

[8] The Profile output obtained with the syntax module is more general than that obtained by the point-and-click module. For the MaxDiff model, the comparable Profile output appears in the Attribute Profile output.

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Best-only (first choice MNL) model we needed to include an inactive set in the Sets file. Figure 26 shows that Set 99 represents this inactive set.

SydneyTransport_set.sav [DataSet12] - IBM SPSS Statistics Data Editor

File Edit View Data Transform Analyze Graphs Utilities Add-ons Window Help

Visible: 10 of 10 Variables

	set	alt1	alt2	alt3	alt4	alt5	alt6	alt7	alt8	alt9
1	1	2	4	8	.	.	.	.	.	.
2	2	1	4	5	.	.	.	.	.	.
3	3	4	7	9	.	.	.	.	.	.
4	4	3	4	6	.	.	.	.	.	.
5	5	1	2	3	.	.	.	.	.	.
6	6	2	5	7	.	.	.	.	.	.
7	7	2	6	9	.	.	.	.	.	.
8	8	1	8	9	.	.	.	.	.	.
9	9	5	6	8	.	.	.	.	.	.
10	10	3	7	8	.	.	.	.	.	.
11	11	1	6	7	.	.	.	.	.	.
12	12	3	5	9	.	.	.	.	.	.
13	99	1	2	3	4	5	6	7	8	9

Data View | Variable View

Figure 26: Sets file showing the inactive set (set=99).

To view the best choice probabilities associated with Set 99:

- Click on 'Set Profile' (see Figure 27).

LatentGOLD

File Edit View Model Window Help

- SydneyTransport_resp.sav
  - 1-class
  - 8-class - L^2 = 4385.6949
  - 8-class+scale_worst - L^2 = 4368.453
  - 8-class+scale_worst+2-sClasses - L
  - Model5 - L^2 = 4309.4226
  - 8-class MaxDiff - L^2 = 4365.1480
    - Syntax
    - Parameters
    - Importance
    - Profile
    - ProbMeans-Posterior
    - Classification-Posterior
    - EstimatedValues-Regression
    - Set Profile
    - Set ProbMeans

Set 11 (n=200)								
Choice 1	0.3622	0.3683	0.1288	0.7920	0.5771	0.6910	0.5378	0.0214
2	0.4540	0.1448	0.8519	0.1071	0.2835	0.2356	0.4204	0.8769
3	0.1837	0.4869	0.0193	0.1010	0.1394	0.0734	0.0418	0.1018
Set 12 (n=200)								
Choice 1	0.8844	0.2679	0.2932	0.8518	0.7940	0.7015	0.2641	0.2510
2	0.1019	0.2831	0.6568	0.1045	0.2035	0.0046	0.0638	0.7489
3	0.0137	0.4490	0.0499	0.0437	0.0025	0.2939	0.6722	0.0001
Set 99 (n=0)								
Choice 1	0.0310	0.1424	0.0669	0.2017	0.0915	0.0190	0.0747	0.0256
2	0.3624	0.2169	0.1461	0.2481	0.5516	0.6192	0.1487	0.1209
3	0.3542	0.0931	0.1159	0.2693	0.2021	0.2321	0.1493	0.0728
4	0.0139	0.0341	0.0073	0.1172	0.0068	0.0038	0.0672	0.1252
5	0.0488	0.0968	0.2295	0.0431	0.0542	0.0099	0.0625	0.2161
6	0.0372	0.0759	0.3626	0.0393	0.0531	0.0075	0.0593	0.3794
7	0.0188	0.1777	0.0221	0.0379	0.0342	0.0034	0.0099	0.0588
8	0.1194	0.0266	0.0096	0.0187	0.0027	0.0030	0.1024	0.0008
9	0.0144	0.1365	0.0400	0.0247	0.0039	0.1022	0.3260	0.0006

Figure 27: Set Profile output for the '8-class MaxDiff' model.

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We see that 32.6% of Class 7 respondents[9] choose 'Trains use green power' as its highest priority. For comparison, the corresponding percentages based on the segment obtained from the BestWorst model (with and without different scale factors for the worst responses), is 38.78% and 36.53% respectively (recall Figure 14 and Figure 8). The size of this segment is estimated to be 13.3%, somewhat different from that estimated from the standard BestWorst model (11.8%) but similar to the size estimated by the BestWorst model with a different scale factor for the worst responses (13.2%).

Estimating a MaxDiff (Joint BestWorst) model with 2 Scale Classes

- Right click on the model '8-class MaxDiff'.
- Select 'Copy Model'.
- To rename this model, click twice on the model '8-class MaxDiff(1)' to enter Edit mode.
- Type the words '+ 2 sClasses' so that the model name is '8-class MaxDiff + 2 sClasses'.
- In the syntax insert the following (see Figure 28):
  - **'SClass nominal 2 coding=first,'** on line 27,
  - **'SClass <-1;'** on line 32,
  - and **'choice <<- (-) SClass ;'** on line 33.
- Click 'Estimate'.

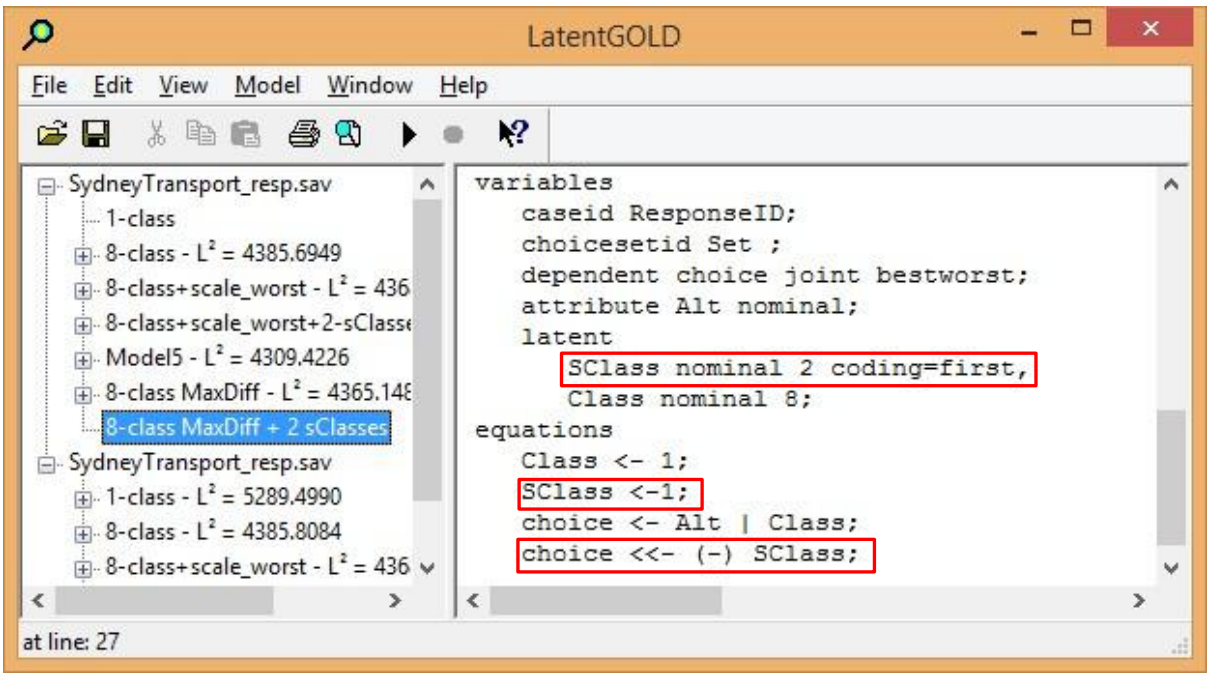

Figure 28: Adding to 2 SClasses to the 8-class MaxDiff model.

[9] Note that the order of the classes presented in the syntax module output for this tutorial may differ from that which you obtain.

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After estimation has completed:

- Click on the data file name 'SydneyTransport_resp.sav' (see Figure 29).

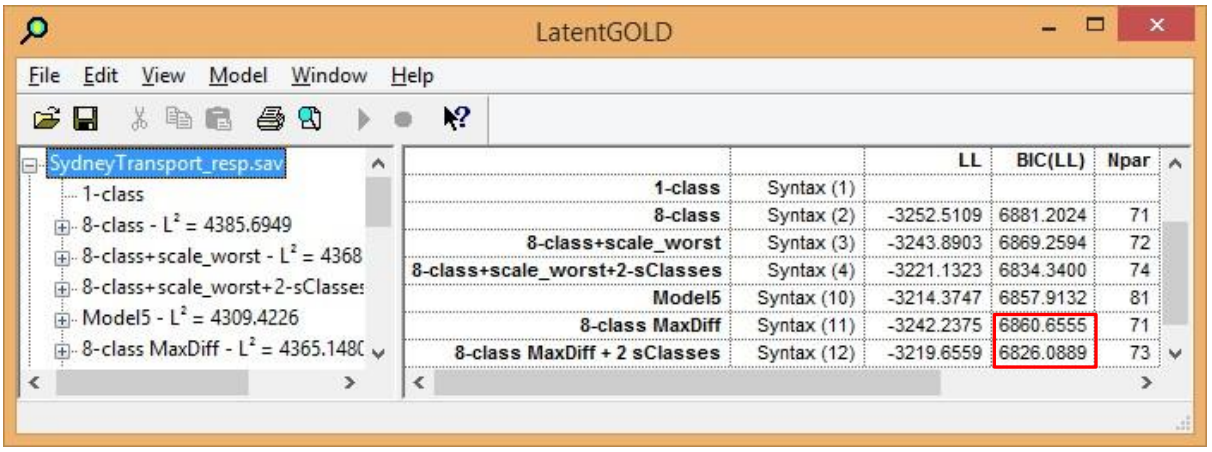

Figure 29: Data File Summary Output.

According to the BIC, adding 2 sClasses to the 8-class MaxDiff model improves the model fit (6826.1 vs. 6860.7). This model also fits better than the corresponding BestWorst model containing the 2 SClasses as well as all other models.

- Click on the Profile output for this model (see Figure 30).

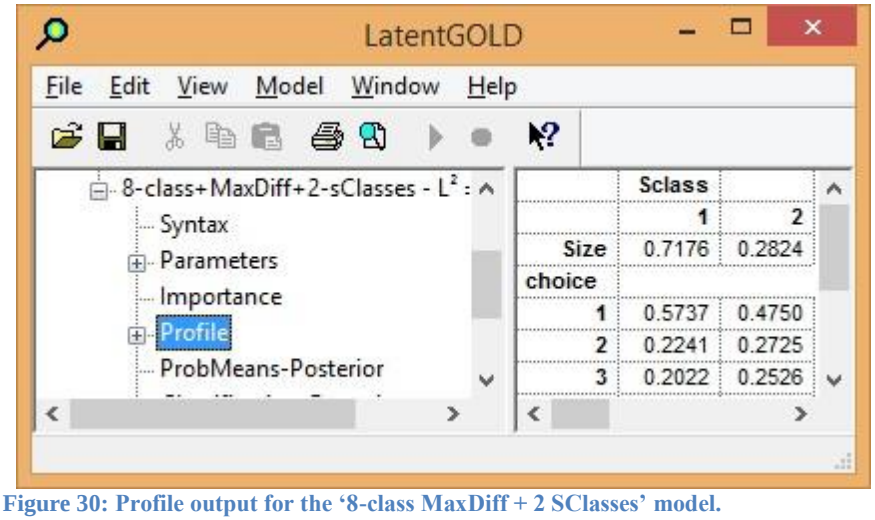

Figure 30: Profile output for the '8-class MaxDiff + 2 SClasses' model.

Notice that 71.76% of the respondents are in the more consistent SClass (SClass 1). This is similar to the result we obtained from the BestWorst model which contained different scale factors for worst responses and for the scale classes (recall Figure 18).

- Click on the Set Profile output for this model (see Figure 31).

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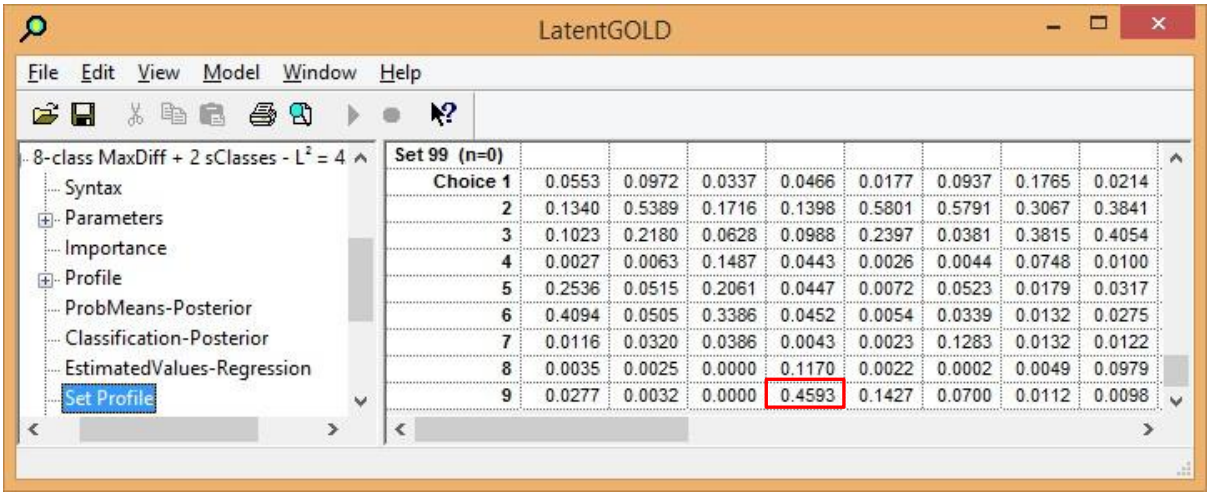

Set 99 (n=0)

Choice 1	0.0553	0.0972	0.0337	0.0466	0.0177	0.0937	0.1765	0.0214
2	0.1340	0.5389	0.1716	0.1398	0.5801	0.5791	0.3067	0.3841
3	0.1023	0.2180	0.0628	0.0988	0.2397	0.0381	0.3815	0.4054
4	0.0027	0.0063	0.1487	0.0443	0.0026	0.0044	0.0748	0.0100
5	0.2536	0.0515	0.2061	0.0447	0.0072	0.0523	0.0179	0.0317
6	0.4094	0.0505	0.3386	0.0452	0.0054	0.0339	0.0132	0.0275
7	0.0116	0.0320	0.0386	0.0043	0.0023	0.1283	0.0132	0.0122
8	0.0035	0.0025	0.0000	0.1170	0.0022	0.0002	0.0049	0.0979
9	0.0277	0.0032	0.0000	0.4593	0.1427	0.0700	0.0112	0.0098

Figure 31: Set Profile output for the '8-class MaxDiff + 2 SClasses' model.

According to this model, 38.72% of segment 4 prefers alternative 9 ('Trains use green power') as its highest priority (this represents 45.9% of the more consistent SClass as highlighted in Figure 31 and 20.4% of those in the less consistent SClass).

Summary of Results and Conclusion

In this tutorial, we demonstrated new features in Latent GOLD Choice 5 which allow scale factors to be included in discrete choice models and a new model, the joint BestWorst (MaxDiff), to be estimated. These capabilities were illustrated using MaxDiff data from the Sydney transport project (Louviere et al., 2014).

In comparing the MaxDiff model with the BestWorst model, the MaxDiff model fit these data somewhat better, suggesting that respondents selected both the best and worst options simultaneously as opposed to always selecting the best option first. When estimating the BestWorst model, we found that it was improved with the addition of different scale factors for best and worst responses, the scale factors likely serving as an adjustment for model misspecification. When these scale factors were added, the fit of the adjusted BestWorst model approached that of the corresponding MaxDiff model.

For both the MaxDiff and adjusted BestWorst models, further improvement was obtained through the addition of 2 scale classes to account for scale heterogeneity. Both models suggested that about 27-28% of respondents (Scale Class 2) were less consistent in their choices.

The following model fitting strategy could be undertaken to determine the appropriate number of Classes & Scale Classes to be estimated: fit 1-10 Classes with 1 SClass, then repeat with 2 SClasses, then again with 3 SClasses. Use BIC to determine the best fitting model.

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