Decision Analysis Report 1

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1 Introduction

In this report, we aim to present our results of MCDA methods for a real life problem. In this example, our goal was to choose the best house for the decision maker. He wants to live in Melbourne, so we only looked at houses in this area.

2 Dataset

2.1 Basic description

The data is a snapshot of the Melbourne housing market from September 2017 and was taken from kaggle (available under link:
https://www.kaggle.com/datasets/dansbecker/melbourne-housing-snapshot). The decision maker's goal was to choose a house that is affordable and sufficient for his needs. He specified 9 criteria on which we evaluated the alternatives. As stated previously, the most important factor for him was price, since he is still a student and cannot afford an expensive house. In our example we consider 50 houses drawn as a random sample from the dataset (for reproducibility, we used seed 42 when constructing a sample). In the original dataset there were 13580 different houses (alternatives) and 21 columns (criteria). We dropped features which included nominal variables leaving us with 9 decision criteria.

One of the most interesting houses considered was the one with the identifier 8257. Despite being built about 80 years ago its price is over 1.1 million dollars. In contrast, it is quite close to the city center and the property is quite sizeable in terms of land area (572 square meters).

2.2 Criteria description

The criteria in our dataset are both discrete and continuous and their ranges also differ. Their lower bound, upper bound, as well as variable and criterion type are described below

Criterion	Lower Bound	Upper Bound	Criterion Type	Variable Type
Rooms	1	6	Gain	Discrete
Price	361000	2440000	Cost	Continuous
Distance	2.1	45.9	Cost	Continuous
Bedroom2	1	6	Gain	Discrete
Bathroom	1	3	Gain	Discrete
Car (number of car spaces)	0	5	Gain	Discrete
Landsize	0	1452	Gain	Continuous
BuildingArea	46	314	Gain	Continuous
YearBuilt	1890	2013	Gain	Continuous

Table 1: Preference Criteria Table with Variable Types

As we see, there are 4 criteria that are discrete:

- **Rooms -** defined values: 1, 2, 3, 4, 5, 6
- **Bedroom2 -** defined values: 1, 2, 3, 4, 5, 6
- **Bathroom -** defined values: 1, 2, 3
- **Car -** defined values: 0, 1, 2, 3, 4, 5

2.3 Criteria importance

The criteria are not of equal importance. Below are the weights on the scale 1-10 of how important we assess these criteria to be for the decision maker. As we can see, the number of car spaces, distance to the city centre and the number of bathrooms is not the main focus of this problem.

- **Rooms**: 5
- **Price**: 10
- **Distance**: 2
- **Bedroom2**: 3
- **Bathroom**: 2
- **Car**: 2
- **Landsize**: 3
- **BuildingArea**: 5
- **YearBuilt**: 3

2.4 Dominance relations

In some cases, some alternatives are visibly worse than others. If one of them is at least as good on all alternatives as the other and better in at least one criterion, one can call this a dominance relation. In the case of our dataset we managed to find 6 such cases.

Table 2: Pairwise Dominance Relations

	Rooms	Price	Distance	Bedroom2	Bathroom	Car	Landsize	BuildingArea	YearBuilt
Dominating (9084)	3	600000	14.8	3	1	3	406	196	2005
Dominated (9165)	2	1100000	16.7	2	1	1	258	106	1980
Dominating (9084)	3	600000	14.8	3	1	3	406	196	2005
Dominated (8840)	2	645000	16.0	2	1	1	105	64	1970
Dominating (6594)	2	600000	5.1	2	1	1	1452	96	1970
Dominated (13118)	2	653000	10.9	2	1	1	84	77	1970
Dominating (11048)	3	815000	16.1	3	2	2	609	168	1980
Dominated (9838)	3	877000	17.9	3	1	2	533	135	1965
Dominating (10957)	4	870000	14.8	4	2	2	463	307	2012
Dominated (9165)	2	1100000	16.7	2	1	1	258	106	1980
Dominating (7764)	6	1455000	7.8	6	3	4	768	285	1997
Dominated (6124)	4	2200000	11.2	4	2	2	734	272	1920

2.5 Best/worst alternatives comparison

In theory, it is likely that the best alternative would have strong advantage on few criteria rather than small advantage on many criteria. Criteria that are most important are: Price, Rooms, Landsize and YearBuilt; other are important but not that much (e. g. it is nice to have many bathrooms at home but paying aditional 100k is not worth it). This implies that we look for affordable house with 3-4 bedrooms, built recently.

Among all alternatives, there can be chosen ones that seem to be the best and the worst:

ID	Rooms	Price	Distance	Bedroom2	Bathroom	Car	Landsize	BuildingArea	YearBuilt
Worst: 4 583	2	1 265 000	2.6	2	1	0	70	102	1890
Best: 12 946	3	485 000	20.6	3	2	1	321	150	2013

Table 3: Alternatives that seem to be best or worst

First of all, worst alternative seems to be house with ID 4583. It is very expensive, has only one bathroom and 2 bedrooms. Besides, it does not have any parking spots, has small land size and house surface is relatively low compared to high price. Finally, it is very old house and was built in 1890 and only advantage is its closeness to center of the city. In other words, this house is overpriced and has poor performance on almost all criteria (including key ones)

Second of all, best alternative seems to be house with ID 12946. It is relatively cheap (compared to minimal and maximal prices), has 3 bedrooms and 2 bathrooms. It also has one parking spot and decent land size. It has 150 square meters of surface (somewhere above the average for all houses) and was built recently - in 2013. The only problem with this house is that it has 20 km to the center of the city (above average). To sum up, house with ID 12946 has very good quality for relatively low price and has strong performance on almost all criteria (including key ones).

2.6 Pairwise comparison

2.6.1 Youngest vs oldest house

ID	Rooms	Price	Distance	Bedroom2	Bathroom	Car	Landsize	BuildingArea	YearBuilt
Oldest: 4 583	2	1 265 000	2.6	2	1	0	70	102	1890
Youngest: 12 946	3	485 000	20.6	3	2	1	321	150	2013

Table 4: Comparison of youngest and oldest house in dataset

This pair does not have to be explained because coincidentally, those two alternatives were described above - oldest house seems to be the worst alternative and youngest house seems to be the best.

2.6.2 Most expensive vs cheapest house

ID	Rooms	Price	Distance	Bedroom2	Bathroom	Car	Landsize	BuildingArea	YearBuilt
Most expensive: 6 551	4	2 440 000	8	4	3	3	500	278	2005
Cheapest: 11 314	1	361 000	7.8	1	1	1	60	53	1975

Table 5: Comparison of most expensive and cheapest house in dataset

We can see that first alternative is better on almost all criteria - the only exception is (as expected) price and the difference is huge (2 mln USD). There is also one criterion that is very similar for both alternatives (distance). It is not easy to predict which alternative is better.

2.6.3 Closest vs Furthest to CBD

ID	Rooms	Price	Distance	Bedroom2	Bathroom	Car	Landsize	BuildingArea	YearBuilt
Furthest from CBD: 8 817	4	521 000	45.9	4	2	2	978	144	1980
Closest to CBD: 13 176	2	1 300 000	2.1	2	1	1	125	124	2000

Table 6: Comparison of most houses that are furthest from and closest to city center (CBD)

We can see that first alternative is better on most criteria - it has more rooms and bathrooms, is cheaper, has more parking spots, has bigger land size and bigger building area. However, there are some criteria that are better for second alternative, i. e. distance and year in which the house was built. We expect that house with ID 8 817 should be better than house with ID 13 176

2.6.4 Comparison of the biggest and the smallest house

ID	Rooms	Price	Distance	Bedroom2	Bathroom	Car	Landsize	BuildingArea	YearBuilt
8059	1	365 000	7.4	1	1	1	0	46	1960
2757	4	2 325 000	9.2	4	3	2	638	314	1930

Table 7: Comparison of most expensive and cheapest house in dataset

Lastly, we will compare biggest and smallest house. In this case, first house is better than second house on following criteria - distance to city center and YearBuilt. However, second house wins in categories such as number of rooms, bathrooms and carspots. Additionaly , difference between prices of those two houses is very high - it is almost 2 million USD. We would assume that the bigger house will be better.

3 Promethee

For Promethee one needs to specify the criteria for the decision maker, as well as their weights. Furthermore, indifference and preference thresholds need to be specified. Below are the parameters we used in our experiments.

Criterion	**q**	**p**	**w**	**Type**
Rooms	0	2	0.1	Gain
Price	10000	40000	0.3	Cost
Distance	3	8	0.05	Cost
Bedroom2	0	2	0.1	Gain
Bathroom	0	1	0.05	Gain
Car	0	1	0.05	Gain
Landsize	200	450	0.1	Gain
BuildingArea	40	80	0.15	Gain
YearBuilt	5	30	0.1	Gain

Table 8: Preference Criteria Table

3.1 Results

Below are the results of Promethee for our dataset. Presented below are the partial ranking and the full ranking of alternatives.

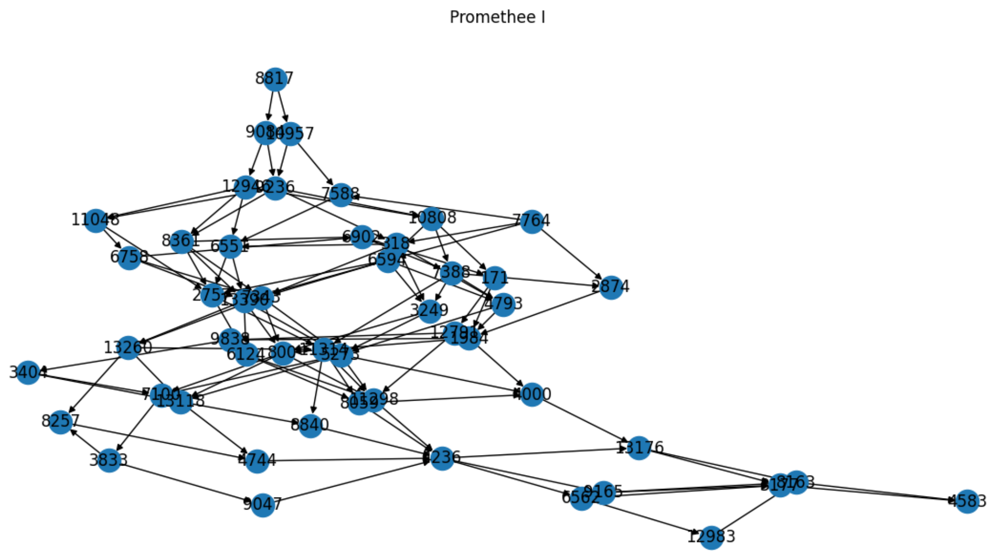

Figure 1: Partial ranking

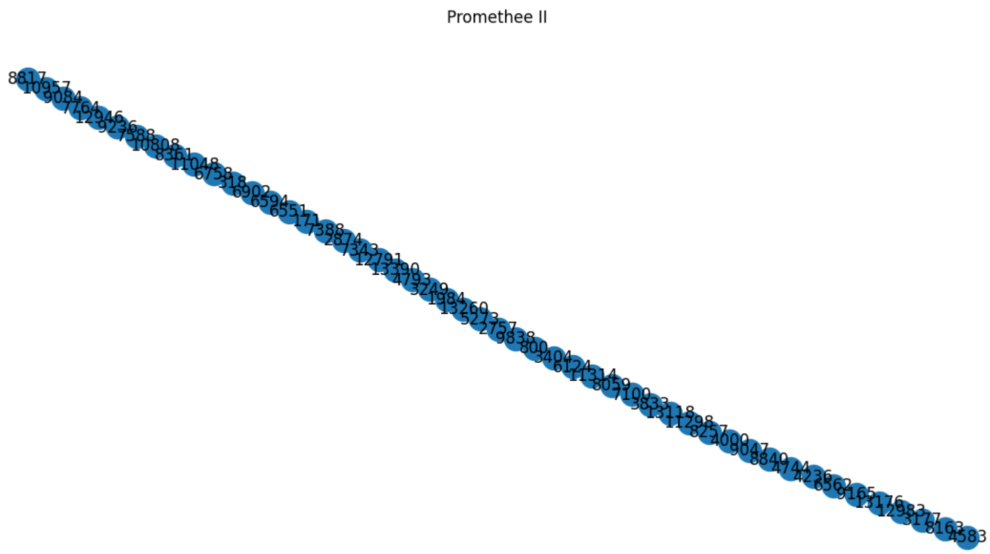

Figure 2: Full ranking

As we can see from both the partial ranking and the complete ranking a few alternatives come out on top. Alternatives with ids 8817, 9084 and 10957 are the ones that would be a good choice for the decision maker. It can also be seen that the worst alternative is the house with id 4583. On the contrary, it is harder to determine the exact order of the alternatives when it comes to the partial ranking.

In our initial guess, we determined that house with id 4583 is the worst choice while 12946 would be the best one. While house nr 4583 did turn out the worst, house number 12946 landed as only the 5th best. That may be due to the fact that its distance to the city centre is very high.

When looking back at the predictions we made as far as pairwise comparisons are concerned, we correctly predicted that the oldest home will be worse than the youngest. Interestingly, the most expensive house performed significantly better than the cheapest one in the ranking despite cost being a major factor in the decision.

We were also right in our prediction when it comes to houses closest and furthest from the city centre and the biggest and smallest houses. What is quite interesting is that the house the furthest away from the city centre turned out to be the best one for the decision maker. We found it quite surprising that despite being strictly worse than all other alternatives on this criterion it came out on top. Additionaly, house with id 800 fell down in the ranking lower than we would expect. A relatively cheap house which is not that old that provides everything one would need being in the second half of the ranking was surely unexpected.

4 Electre TRI-B

4.1 Preferential information about the dataset

In Electre TRI-B algorithm we will need: boundary profiles, indifference thresholds, preference thresholds, veto thresholds, weights and credibility threshold.

Let's start with defining boundary profiles for our problem. Defined values may seem odd or inconsistent but they are a result of analysis of data gathered in dataset - each criterion is divided into 6 more less equal groups.

Since we have 9 criteria and full table doesn't fit in LaTex, instead of creating tables manually, we will insert screenshots

	Criterion	Rooms	Price	Distance	Bedroom2	Bathroom	Car	Landsize	BuildingArea	YearBuilt
0	b1	0.9	1400000	15.90	0.9	0.5	1	65	84.0	1931
1	b2	1.9	1185000	13.50	1.9	1.5	1	170	110.0	1966
2	b3	2.9	878000	10.00	2.9	2.5	2	280	134.5	1976
3	b4	3.9	750000	7.85	3.9	3.5	2	520	170.0	1981
4	b5	4.9	550000	5.00	4.9	4.5	3	650	200.0	2007

Figure 3: Boundary profiles

	Criterion	Rooms	Price	Distance	Bedroom2	Bathroom	Car	Landsize	BuildingArea	YearBuilt
0	b1	0	15000	2.5	0	0	0	4	4	10
1	b2	0	10000	2.0	0	0	0	4	4	5
2	b3	0	10000	1.5	0	0	0	6	6	5
3	b4	1	15000	1.0	1	0	1	7	7	5
4	b5	1	20000	1.0	1	1	1	7	7	5

Figure 4: Indifference thresholds

	Criterion	Rooms	Price	Distance	Bedroom2	Bathroom	Car	Landsize	BuildingArea	YearBuilt
0	b1	1	30000	5.0	1	1	1	15	10	20
1	b2	1	25000	4.0	1	1	1	20	10	10
2	b3	1	25000	3.0	1	1	1	20	15	10
3	b4	2	40000	3.0	2	1	2	30	15	10
4	b5	2	50000	3.0	2	2	2	30	20	10

Figure 5: Preference thresholds

	Criterion	Rooms	Price	Distance	Bedroom2	Bathroom	Car	Landsize	BuildingArea	YearBuilt
0	b1	2	150000	10	2	inf	inf	25	15	30
1	b2	2	1250000	8	2	inf	inf	30	15	20
2	b3	2	125000	6	2	inf	inf	30	20	20
3	b4	3	150000	6	3	inf	inf	50	25	20
4	b5	3	200000	6	3	inf	inf	50	30	20

Figure 6: Veto thresholds

Apart from indifference, preference and veto thresholds, we also have credibility threshold set as 0.65. Finally, weights for electre algorithm remained the same as those for promethee.

4.2 Final result; Optimistic and Pessimistic Assignment

4.2.1 Best Alternatives according to Pessimistic Assignment (all assigned to class C4)

- House with ID **171**
- House with ID **9 084**
- House with ID **10 957**
- House with ID **12 791**

4.2.2 Worst Alternatives according to Pessimistic Assignment (all assigned to class C1)

- House with ID **2 757**
- House with ID **3 177**
- House with ID **4 000**
- House with ID **4 236**
- House with ID **4 583**
- House with ID **4 793**
- House with ID **5 273**
- House with ID **6 124**
- House with ID **6 551**
- House with ID **7 588**
- House with ID **8 059**

- House with ID **8 163**
- House with ID **8 817**
- House with ID **8 840**
- House with ID **11 314**

4.2.3 Best Alternatives according to Optimistic Assignment (all assigned to class C6)

- House with ID **2 757**
- House with ID **2 874**
- House with ID **3 404**
- House with ID **6 124**
- House with ID **6 551**
- House with ID **6 594**
- House with ID **7 588**
- House with ID **7 764**
- House with ID **8 817**
- House with ID **9 236**
- House with ID **10 957**
- House with ID **11 314**
- House with ID **13 260**
- House with ID **13 390**

4.2.4 Worst Alternatives according to Optimistic Assignment (all assigned to class C1)

- House with ID **8 059**
- House with ID **8 840**
- House with ID **13 118**

4.2.5 Final thoughts on the assignments

There is only one problem with electre TRI-B algorithm and this dataset - some alternatives are incomparable and thus some rankings look odd and are extremely long. However, we can see that in both cases best alternative is house with ID 10 957. Analogically, we can see that in both cases worst alternatives are: house with ID 8 059 and house with ID 8 840.

4.3 Comparison between predictions and results

We predicted that best result will be house with ID 12 946. Electre algorithm assigned classes C3 (pessimistic assignment) and class C5 (optimistic assignment).

Our second prediction was that worst result will be house with ID 4 583. Implemented algorithm assigned classes C1 (pessimistic variant) and C5 (optimistic variant)

As said previously, the problem here is with incomparabilitites and those incomparabilities lead to strange output.

4.4 Pairwise comparison

4.4.1 Youngest vs oldest house

In both assignments (pessimistic and optimistic) - youngest house was preferred to oldest house (as expected).

4.4.2 Most expensive vs the cheapest house

In both assignments (pessimistic and optimistic) both houses were assigned to the same classes. Probably the problem is that they are not comparable with boundary profiles.

4.4.3 Closest to vs furthest from CBD

In case of pessimistic assignment house furthest from CBD (city center) is better than the one closest to it. In case of optimistic assignment, house closest to city center is better.

4.4.4 Biggest vs smallest house

In case of pessimistic assignment both houses are equally good. In case of optimistic assignment, bigger house is better.

5 Comparison between Promethee and Electre TRI-B

5.1 Similarities between methods

- Both algorithms use outranking relations
- Both algorithms use preference thresholds
- Both algorithms are helpful when dealing with complex decision problems

5.2 Differences between methods

- Promethee algorithms can be used for ranking, when ELECTRE TRI-B is more suitable for classification/sorting - it assigns categories such as very bad, good etc and based on that we can infere what is the best and what is the worst alternative
- Promethee uses preference functions and outranking net flow to calculate outranking relations, Electre uses concordance and discordance to decide
- Electre algorithm is more complex (due to concordance, discordance relations and credibility index computation) when Promethee algorithm is simpler and uses preference functions for comparison
- Electre algorithm uses more thresholds (preference, indifference, veto) than Promethee
- Promethee algorithm allows alternatives to compensate bad behavior on one criterion with very good behavior on other criterion, when Electre vetos the alternative with very bad score on one criterion
- Promethee algorithm outputs a rankked list of alternatives with preference score (sorted from best to worst) and Electre TRI-B assigns alternatives to categories (bad, medium, good etc)
- Electre may encounter alternatives as incomparable, which may lead to some problems when Promethee can't

5.3 Comparison of the results of Promethee and Electre TRI-B

- Both solutions pointed house with ID 10 957 as one of the worst alternatives
- Each of best three and worst three alternatives from Promethee were assigned respectfully to best or worst class in at least one assignment (optimistic or pesimistic)
- Promethee algorithm is more suitable for this task because it didn't produce incomparabilities in contrary to Electre
- Promethee predicted similarly to our beliefs that house of ID 12 946 is one of the best alternatives and that house with ID 4 583 is the worst one. Electre algorithm had similar results but had some problem due to incomparabilities