Report: The Review of Health Insurance Claim Forecasting Model for Unicorn Insurance

Executive summary:
The Unicorn Insurance provides approximately 15 million customers with health insurance services in the Asia-Pacific region. The corporation conduct annual reviews on random selected projects to enhance its risk management. According to the company's risk management policy, there is a review on the pricing team's claims forecast model for Cranberry city, which has been regarded as a part of the internal review program for this year. As an actuary in the Unicorn Insurance, I have been assigned to conduct this review.

Specific tasks involving this review are as follows: building an independent model through analyzing historical data provided, making a comparison between the own model and the model from the pricing team, and putting forward reasonable suggestions for improvements. The Generalized Linear Model method has been taken to carry out an analysis on historical data and construct an independent model to perform the comparison with the outputs of the newly constructed model and the model of the pricing team.

The conclusion is that the model of the pricing team is reasonably good to forecast claims for Cranberry city, although there are still some improvements that should be taken to optimize the pricing model. Therefore, several recommendations have been discussed in this report, which include 1. Enriching the database. 2. Including more relative variables in the model. 3. Enhancing supervisory method and feedback control cycle.

1. The analysis of the demographic composition of policyholders

In order to assure an integrated analysis of data provided, we separate historical data based on different demographic features of policyholders, then analyse the changes in these demographics respectively over the time period of database. The analysis results are as follows:

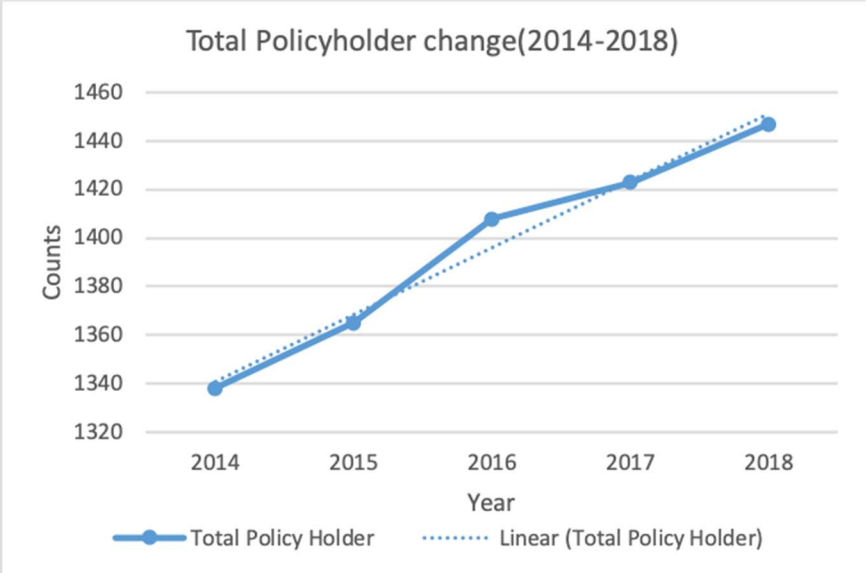

Figure 1

The statistics from the year 2014 to 2018 have reflected a near linearly growth of the number of total policyholders, although there is a relatively higher increase between 2015 and 2016.

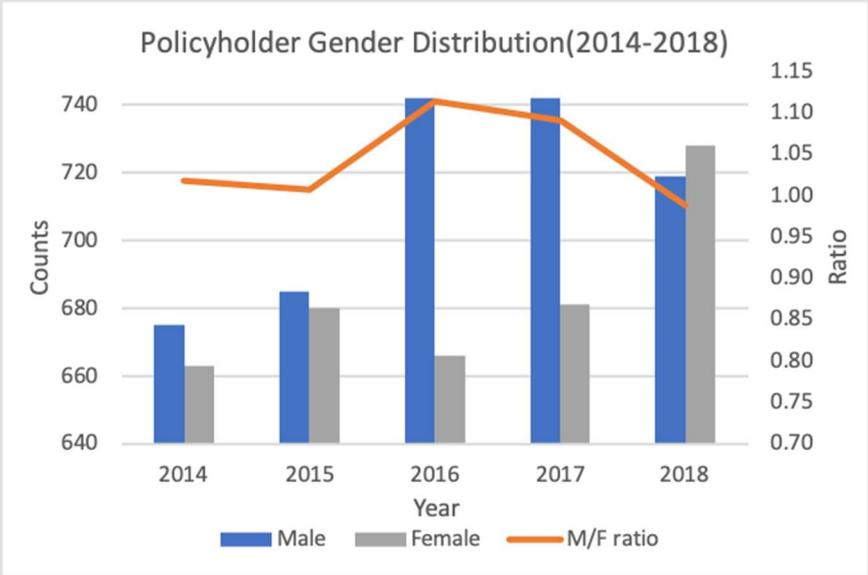

Figure 2

The Male/Female ratio of policyholders fluctuates only slightly between 1.0 and 1.1 from 2014 to 2018. The number of male policyholders increases from 2014, and then it has a peak of 742 in both 2016 and 2017, afterward, it shows a decreasing tendency. In addition, the number of female policyholders has a fluctuation between the years 2014 and 2016, after which it has a significant growth until the year 2018.

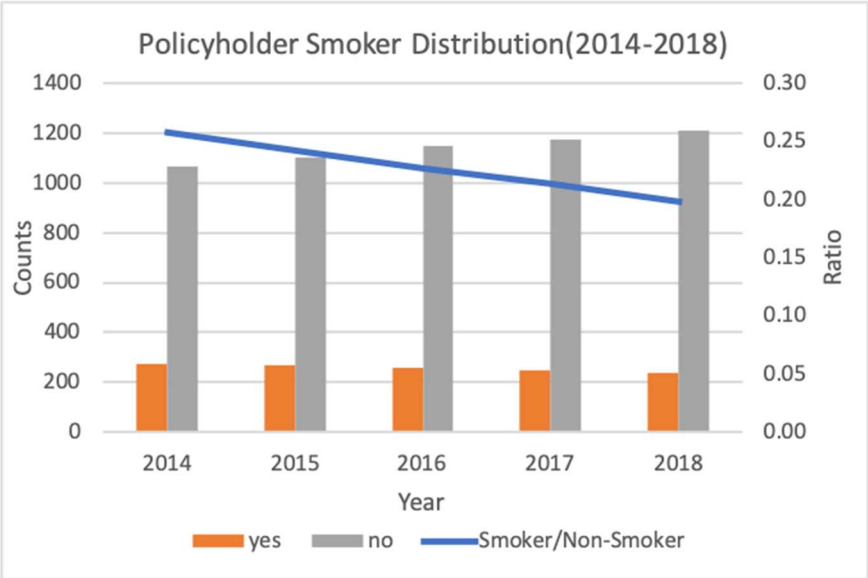

Figure 3

Considering the smoking status of the policyholders, the majority of policyholders are non-smokers, while the number of smokers approximately remains unchanged over the five years. In addition, the ratio between smoker and non-smoker is around 0.25 in the year of 2014, and then it begins dropping to 0.20 until 2018.

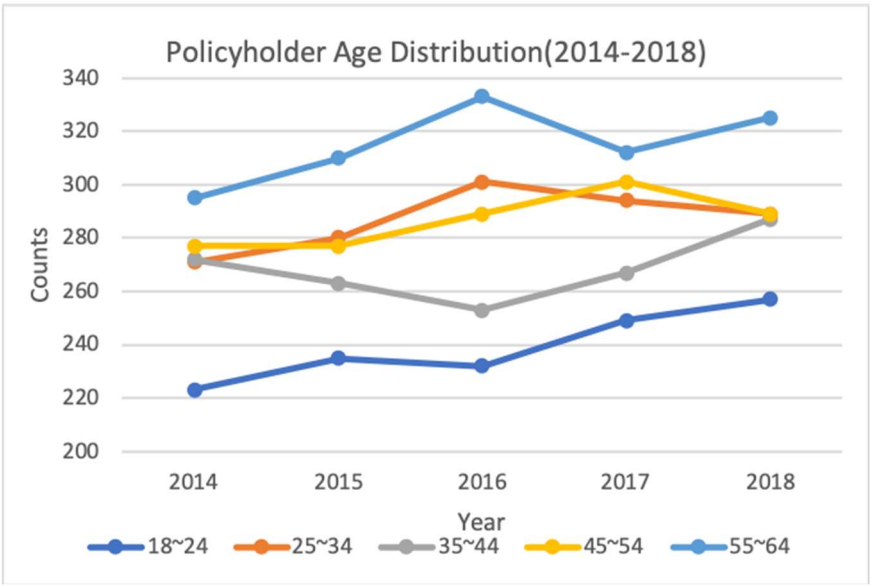

Figure 4

Policyholders have been separated into five age groups based on the range of ages of given policyholders: 18-24, 25-34, 35-44, 45-54, and 55-64. The number of youngest and elderly groups respectively take up the least and most significnat proportion of total policyholders, and both of these age groups show a similar increasing trend. The policyholders aged 45-54 have an increase and achieve around 300 in 2017; then it decreases gradually. Likewise, people between the ages of 25 and 34 grow and have a peak of approximately 300 in 2016, after that it starts declining steadily. It is found that the policyholders aged 35-44 have an opposite trend compared with the 25-34 age group.

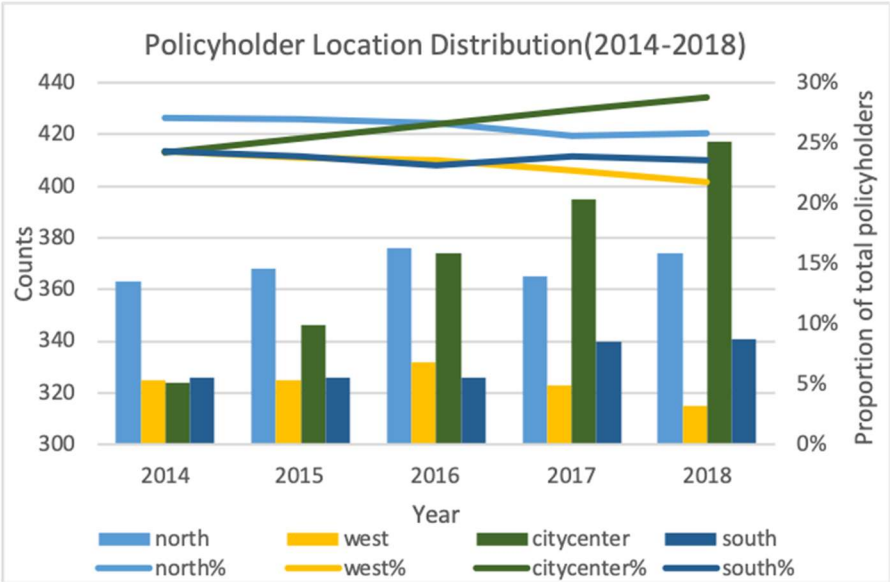

Figure 5

The policyholders living in the north keep a high and steady proportion from 2014 to 2018. The number of people living in the west is relatively small and shows a decline from 2016, and the percentage of southern policyholders rises slowly during the same period. It is noticeable that there is a significant growth of city center people over the five years, from 5% to 24% approximately.

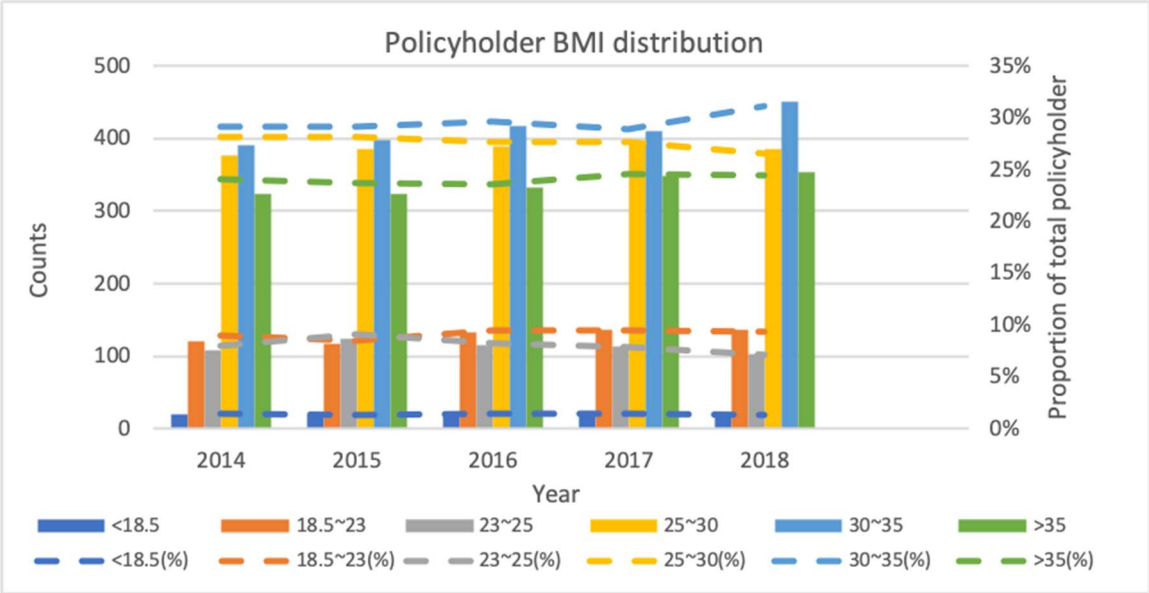

Figure 6

We separate policyholders into five groups based on their BMI levels. The proportions of policyholders with different levels remain stable from 2014 to 2018. The percentage of people with a BMI under 18.5 is the lowest, people who have BMI over 25 account for the most substantial proportion. Additionally, the healthy people (i.e., people who have a BMI between 18.5 and 25) have a moderate size of the number.

2. Experience analysis of claims

Considering discussing the relationship between features and claim costs, we use the Generalized Linear Model to assist this analysis. Since some features described by strings, we need to convert strings data into numerical values by the following rules: "male"→ 1, "female"→2, "yes"→ 1, "no"→0, "citycenter"→1, "north"→2, "south"→ 3, "west"→ 4. We construct the Generalized Linear Model, in which the response variable is claim costs that fit the data of age, sex, bmi, smoker, location, and year by using least squares. The result table is shown below:

Table 1

Variable	Estimate	Standard Error	t-Statistic	P-Value
age	253.936	5.15604	49.2503	0.
sex	77.4428	144.751	0.535009	0.592661
bmi	301.038	11.767	25.5833	0.
smoker	23783.	186.78	127.331	0.
location	-92.9337	65.0743	-1.42812	0.153303
year	-5.52766	0.2456	-22.5067	0.
$R^2 = 0.88$				

Through comparing P-Value with an assumed significance level of 0.05, we can conclude that changes in these variables (i.e., age, bmi, smoker, and year) are correlated with changes in claim costs. However, the variables (sex and location) are insignificantly associated with claims, and hence, we remove these in significant variables and perform the modeling again. Here is the adjusted result:

Table 2

Variable	Estimate	Standard Error	t-Statistic	P-Value
age	253.972	5.1558	49.2594	0.
bmi	301.795	11.7549	25.674	0.
smoker	23797.7	186.536	127.577	0.
year	-5.59633	0.201847	-27.7257	0.
$R^2 = 0.88$				

From this adjusted result table, it is found that the variables of "age", "bmi" and "smoker" are positively correlated with claim costs while the variable "year" has negatively correlated with claims, and the coefficient of determination is 0.88 by using Generalized Linear Model, which means that the model is reasonably suitable to fit the data.

3. Modeling

In order to model the future claims that need to be paid by policy insurer, we can use regression analysis to perform the modeling. Through using analysis of historical data, we obtain a general equation of the model for claims:

$$Claims = c_1 \times age + c_2 \times bmi + c_3 \times smoker + c_4 \times year + \varepsilon$$

where c_i is the undetermined coefficient, and ε is the error term. Before modeling the expected claim costs for the 400 policyholder profiles, there are several assumptions that should be built based on the experience analysis above:

1. Since the amount of the claim of historical data is inflation-adjusted to 2019 AUD values, we assume the expected costs for 2019 are also inflation-adjusted, which keeps the consistency of modeling.
2. Since there is no "year" variable consideration in the 400 policyholder profiles, we assume the coefficient of year in the equation above: $c_4 = 0$.
3. We do not consider "sex" and "location" due to the following reasons:
   Qualitative: during the five-year period of historical data, the gender ratio almost stays 1; thus, the effect of gender is relatively small. In addition, due to the short study period, the impact of population mobility cannot be reflected within a short time-frame.
   Quantitative: through the use of the Generalized Linear Model, we can obtain that the P-Values of "sex" and "location" are 0.592661 and 0.153303 respectively, both of them are larger than the predetermined significance level (i.e., 0.05).
4. The data of "age" and "bmi" in 400 policyholder profiles only contain several specific values (i.e., ages are 20, 30, 40, 50 and 60. bmi are 18.5, 23, 25, 30 and 35), thus we consider it is assumed that the values of "age" and "bmi" have been rounded.
5. The proportion of policyholders who have bmi less than 18.5 is deficient; therefore, we do not consider such policyholders.
6. The variables: "age", "bmi", "smoker" and "year" are statistically independent in this model.
7. The variables: "age," "bmi" and "smoker" are positively correlated with claim costs. For these reasons:
   Qualitative: these three variables are closely related to policyholders' health status, and hence, we assume that the policyholders with elder age or with a higher bmi and the smoker policyholders tend to have high claim costs.

Quantitative: through regression analysis, we can clearly find that the coefficients of these three variables are more extensive than 0, which means that claim costs will increase with the rising of the values of these three variables.

Using the same method above, here is the result table:

Table 3

Variable	Estimate	Standard Error	t-Statistic	P-Value
age	192.851	4.91044	39.2737	0.
bmi	30.8221	6.88132	4.47909	0.
smoker	23316.2	195.677	119.157	0.
$R^2 = 0.87$				

From the table above, we can find that the three variables are positively correlated with claim costs. Specifically, the expected claim costs will be added by 192.851 whenever the policyholder with one more year older; the growth of bmi per unit will increase claim costs with 30.8221; the smokers among the policyholders tend to have more 23316.2 on the claim costs. In addition, the P-values of "age", "bmi" and "smoker" are extremely small, and the coefficient of determination is 0.87; thus, we can conclude that this model is reasonable. Here is the model equation:

$$Claims = 192.851 \times age + 30.8221 \times bmi + 23316.2 \times smoker$$

We apply the model equation above with the 400 policyholder profiles to obtain the new estimates of the expected claim costs. The estimate result of the model is attached as the appendix.

4. Comparison and Recommendation

Using the model and the data of 400 policyholder profiles to calculate expected claims, then make a comparison between the outputs of the pricing team model and actuary model:

Similarity:

1. The claim costs are correlated with two variables: "age" and "smoker", and both of them show positive correlation with claims.
2. Claim outputs of these two models may have the same result, since the policyholders have the same feature on correlative variables, however different features on other variables which has insignificant association with claim costs.
3. We can compare the claim outputs between the pricing team and actuary through the plot, the vertical and horizontal axis represent the expected claims of model of the pricing team and the model we newly construct, here is the plot below:

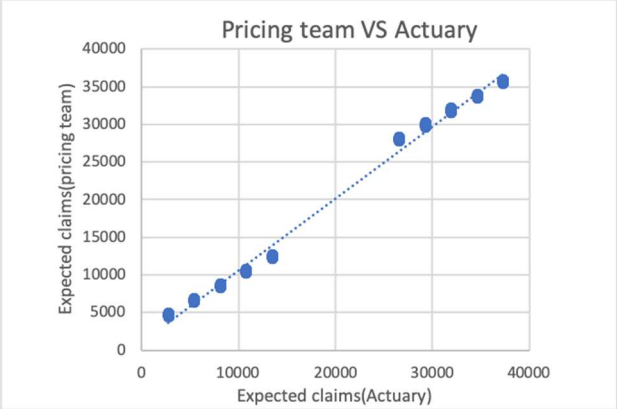

Figure 7

It is found that the expected claim outputs between models of the pricing team and ours display an approximately linear relation, which means that our model has no significant difference with the pricing team's model (i.e., there is consistency between the outputs of these two models).

Differences:

1. For the pricing team model: a) the expected claims are only positively correlated with two variables: "age" and "smoker". b) application range of this model is limited, since there are only some specific values can be used in terms of "age" and "bmi" (i.e., age:20, 30, 40, 50 and 60; bmi: 18.5, 23, 25, 30 and 35)
2. For the newly constructed model: a) the expected claims are positively correlated with three variables: "age", "bmi" and "smoker". b) this model can be used more general (i.e., age can be more integer numbers. Bmi can be more values)

5. Recommendations

1. The expected claim costs of the model of the pricing team vary only with "age" and "smoker". Therefore, a broader range of variables should be considered to improve the accuracy, integrity and comprehensiveness of claims predictive.
2. More valid historical data should be selected and collected for the testing model to modify models effectively.
3. The broader coverage of data should be considered (e.g., a broader range of age).
4. Review the model more frequently to handle the occurrence of emergency. Any necessary update should be considered.
5. Conduct claims leakage analysis since it focuses on some claims leakage problems which can not be explained statistically by the patterns in historical data. This approach will provide a well-rounded improvement on the claim costs.
6. Claims quality self-assessment can be implemented by claim managers to perform a periodic test to ensure that the claim operations can be performed smoothly.

Appendix

profile_id	age	sex	bmi	smoker	location	Expected claims
1	20	male	18.5	yes	citycenter	27743.43
2	30	male	18.5	yes	citycenter	29671.94
3	40	male	18.5	yes	citycenter	31600.45
4	50	male	18.5	yes	citycenter	33528.96
5	60	male	18.5	yes	citycenter	35457.47
6	20	female	18.5	yes	citycenter	27743.43
7	30	female	18.5	yes	citycenter	29671.94
8	40	female	18.5	yes	citycenter	31600.45
9	50	female	18.5	yes	citycenter	33528.96
10	60	female	18.5	yes	citycenter	35457.47
11	20	male	23	yes	citycenter	27882.13
12	30	male	23	yes	citycenter	29810.64
13	40	male	23	yes	citycenter	31739.15
14	50	male	23	yes	citycenter	33667.66
15	60	male	23	yes	citycenter	35596.17
16	20	female	23	yes	citycenter	27882.13
17	30	female	23	yes	citycenter	29810.64
18	40	female	23	yes	citycenter	31739.15
19	50	female	23	yes	citycenter	33667.66
20	60	female	23	yes	citycenter	35596.17
21	20	male	25	yes	citycenter	27943.77
22	30	male	25	yes	citycenter	29872.28
23	40	male	25	yes	citycenter	31800.79
24	50	male	25	yes	citycenter	33729.3
25	60	male	25	yes	citycenter	35657.81
26	20	female	25	yes	citycenter	27943.77
27	30	female	25	yes	citycenter	29872.28
28	40	female	25	yes	citycenter	31800.79
29	50	female	25	yes	citycenter	33729.3
30	60	female	25	yes	citycenter	35657.81
31	20	male	30	yes	citycenter	28097.88
32	30	male	30	yes	citycenter	30026.39
33	40	male	30	yes	citycenter	31954.9
34	50	male	30	yes	citycenter	33883.41
35	60	male	30	yes	citycenter	35811.92
36	20	female	30	yes	citycenter	28097.88
37	30	female	30	yes	citycenter	30026.39
38	40	female	30	yes	citycenter	31954.9
39	50	female	30	yes	citycenter	33883.41
40	60	female	30	yes	citycenter	35811.92
41	20	male	35	yes	citycenter	28251.99
42	30	male	35	yes	citycenter	30180.5

43	40	male	35	yes	citycenter	32109.01
44	50	male	35	yes	citycenter	34037.52
45	60	male	35	yes	citycenter	35966.03
46	20	female	35	yes	citycenter	28251.99
47	30	female	35	yes	citycenter	30180.5
48	40	female	35	yes	citycenter	32109.01
49	50	female	35	yes	citycenter	34037.52
50	60	female	35	yes	citycenter	35966.03
51	20	male	18.5	no	citycenter	4427.229
52	30	male	18.5	no	citycenter	6355.739
53	40	male	18.5	no	citycenter	8284.249
54	50	male	18.5	no	citycenter	10212.76
55	60	male	18.5	no	citycenter	12141.27
56	20	female	18.5	no	citycenter	4427.229
57	30	female	18.5	no	citycenter	6355.739
58	40	female	18.5	no	citycenter	8284.249
59	50	female	18.5	no	citycenter	10212.76
60	60	female	18.5	no	citycenter	12141.27
61	20	male	23	no	citycenter	4565.928
62	30	male	23	no	citycenter	6494.438
63	40	male	23	no	citycenter	8422.948
64	50	male	23	no	citycenter	10351.46
65	60	male	23	no	citycenter	12279.97
66	20	female	23	no	citycenter	4565.928
67	30	female	23	no	citycenter	6494.438
68	40	female	23	no	citycenter	8422.948
69	50	female	23	no	citycenter	10351.46
70	60	female	23	no	citycenter	12279.97
71	20	male	25	no	citycenter	4627.573
72	30	male	25	no	citycenter	6556.083
73	40	male	25	no	citycenter	8484.593
74	50	male	25	no	citycenter	10413.1
75	60	male	25	no	citycenter	12341.61
76	20	female	25	no	citycenter	4627.573
77	30	female	25	no	citycenter	6556.083
78	40	female	25	no	citycenter	8484.593
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85	60	male	30	no	citycenter	12495.72
86	20	female	30	no	citycenter	4781.683
87	30	female	30	no	citycenter	6710.193
88	40	female	30	no	citycenter	8638.703

89	50	female	30	no	citycenter	10567.21
90	60	female	30	no	citycenter	12495.72
91	20	male	35	no	citycenter	4935.794
92	30	male	35	no	citycenter	6864.304
93	40	male	35	no	citycenter	8792.814
94	50	male	35	no	citycenter	10721.32
95	60	male	35	no	citycenter	12649.83
96	20	female	35	no	citycenter	4935.794
97	30	female	35	no	citycenter	6864.304
98	40	female	35	no	citycenter	8792.814
99	50	female	35	no	citycenter	10721.32
100	60	female	35	no	citycenter	12649.83
101	20	male	18.5	yes	north	27743.43
102	30	male	18.5	yes	north	29671.94
103	40	male	18.5	yes	north	31600.45
104	50	male	18.5	yes	north	33528.96
105	60	male	18.5	yes	north	35457.47
106	20	female	18.5	yes	north	27743.43
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129	50	female	25	yes	north	33729.3
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165	60	male	23	no	north	12279.97
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223	40	male	25	yes	west	31800.79
224	50	male	25	yes	west	33729.3
225	60	male	25	yes	west	35657.81
226	20	female	25	yes	west	27943.77

227	30	female	25	yes	west	29872.28
228	40	female	25	yes	west	31800.79
229	50	female	25	yes	west	33729.3
230	60	female	25	yes	west	35657.81
231	20	male	30	yes	west	28097.88
232	30	male	30	yes	west	30026.39
233	40	male	30	yes	west	31954.9
234	50	male	30	yes	west	33883.41
235	60	male	30	yes	west	35811.92
236	20	female	30	yes	west	28097.88
237	30	female	30	yes	west	30026.39
238	40	female	30	yes	west	31954.9
239	50	female	30	yes	west	33883.41
240	60	female	30	yes	west	35811.92
241	20	male	35	yes	west	28251.99
242	30	male	35	yes	west	30180.5
243	40	male	35	yes	west	32109.01
244	50	male	35	yes	west	34037.52
245	60	male	35	yes	west	35966.03
246	20	female	35	yes	west	28251.99
247	30	female	35	yes	west	30180.5
248	40	female	35	yes	west	32109.01
249	50	female	35	yes	west	34037.52
250	60	female	35	yes	west	35966.03
251	20	male	18.5	no	west	4427.229
252	30	male	18.5	no	west	6355.739
253	40	male	18.5	no	west	8284.249
254	50	male	18.5	no	west	10212.76
255	60	male	18.5	no	west	12141.27
256	20	female	18.5	no	west	4427.229
257	30	female	18.5	no	west	6355.739
258	40	female	18.5	no	west	8284.249
259	50	female	18.5	no	west	10212.76
260	60	female	18.5	no	west	12141.27
261	20	male	23	no	west	4565.928
262	30	male	23	no	west	6494.438
263	40	male	23	no	west	8422.948
264	50	male	23	no	west	10351.46
265	60	male	23	no	west	12279.97
266	20	female	23	no	west	4565.928
267	30	female	23	no	west	6494.438
268	40	female	23	no	west	8422.948
269	50	female	23	no	west	10351.46
270	60	female	23	no	west	12279.97
271	20	male	25	no	west	4627.573
272	30	male	25	no	west	6556.083

273	40	male	25	no	west	8484.593
274	50	male	25	no	west	10413.1
275	60	male	25	no	west	12341.61
276	20	female	25	no	west	4627.573
277	30	female	25	no	west	6556.083
278	40	female	25	no	west	8484.593
279	50	female	25	no	west	10413.1
280	60	female	25	no	west	12341.61
281	20	male	30	no	west	4781.683
282	30	male	30	no	west	6710.193
283	40	male	30	no	west	8638.703
284	50	male	30	no	west	10567.21
285	60	male	30	no	west	12495.72
286	20	female	30	no	west	4781.683
287	30	female	30	no	west	6710.193
288	40	female	30	no	west	8638.703
289	50	female	30	no	west	10567.21
290	60	female	30	no	west	12495.72
291	20	male	35	no	west	4935.794
292	30	male	35	no	west	6864.304
293	40	male	35	no	west	8792.814
294	50	male	35	no	west	10721.32
295	60	male	35	no	west	12649.83
296	20	female	35	no	west	4935.794
297	30	female	35	no	west	6864.304
298	40	female	35	no	west	8792.814
299	50	female	35	no	west	10721.32
300	60	female	35	no	west	12649.83
301	20	male	18.5	yes	south	27743.43
302	30	male	18.5	yes	south	29671.94
303	40	male	18.5	yes	south	31600.45
304	50	male	18.5	yes	south	33528.96
305	60	male	18.5	yes	south	35457.47
306	20	female	18.5	yes	south	27743.43
307	30	female	18.5	yes	south	29671.94
308	40	female	18.5	yes	south	31600.45
309	50	female	18.5	yes	south	33528.96
310	60	female	18.5	yes	south	35457.47
311	20	male	23	yes	south	27882.13
312	30	male	23	yes	south	29810.64
313	40	male	23	yes	south	31739.15
314	50	male	23	yes	south	33667.66
315	60	male	23	yes	south	35596.17
316	20	female	23	yes	south	27882.13
317	30	female	23	yes	south	29810.64
318	40	female	23	yes	south	31739.15

319	50	female	23	yes	south	33667.66
320	60	female	23	yes	south	35596.17
321	20	male	25	yes	south	27943.77
322	30	male	25	yes	south	29872.28
323	40	male	25	yes	south	31800.79
324	50	male	25	yes	south	33729.3
325	60	male	25	yes	south	35657.81
326	20	female	25	yes	south	27943.77
327	30	female	25	yes	south	29872.28
328	40	female	25	yes	south	31800.79
329	50	female	25	yes	south	33729.3
330	60	female	25	yes	south	35657.81
331	20	male	30	yes	south	28097.88
332	30	male	30	yes	south	30026.39
333	40	male	30	yes	south	31954.9
334	50	male	30	yes	south	33883.41
335	60	male	30	yes	south	35811.92
336	20	female	30	yes	south	28097.88
337	30	female	30	yes	south	30026.39
338	40	female	30	yes	south	31954.9
339	50	female	30	yes	south	33883.41
340	60	female	30	yes	south	35811.92
341	20	male	35	yes	south	28251.99
342	30	male	35	yes	south	30180.5
343	40	male	35	yes	south	32109.01
344	50	male	35	yes	south	34037.52
345	60	male	35	yes	south	35966.03
346	20	female	35	yes	south	28251.99
347	30	female	35	yes	south	30180.5
348	40	female	35	yes	south	32109.01
349	50	female	35	yes	south	34037.52
350	60	female	35	yes	south	35966.03
351	20	male	18.5	no	south	4427.229
352	30	male	18.5	no	south	6355.739
353	40	male	18.5	no	south	8284.249
354	50	male	18.5	no	south	10212.76
355	60	male	18.5	no	south	12141.27
356	20	female	18.5	no	south	4427.229
357	30	female	18.5	no	south	6355.739
358	40	female	18.5	no	south	8284.249
359	50	female	18.5	no	south	10212.76
360	60	female	18.5	no	south	12141.27
361	20	male	23	no	south	4565.928
362	30	male	23	no	south	6494.438
363	40	male	23	no	south	8422.948
364	50	male	23	no	south	10351.46

365	60	male	23	no	south	12279.97
366	20	female	23	no	south	4565.928
367	30	female	23	no	south	6494.438
368	40	female	23	no	south	8422.948
369	50	female	23	no	south	10351.46
370	60	female	23	no	south	12279.97
371	20	male	25	no	south	4627.573
372	30	male	25	no	south	6556.083
373	40	male	25	no	south	8484.593
374	50	male	25	no	south	10413.1
375	60	male	25	no	south	12341.61
376	20	female	25	no	south	4627.573
377	30	female	25	no	south	6556.083
378	40	female	25	no	south	8484.593
379	50	female	25	no	south	10413.1
380	60	female	25	no	south	12341.61
381	20	male	30	no	south	4781.683
382	30	male	30	no	south	6710.193
383	40	male	30	no	south	8638.703
384	50	male	30	no	south	10567.21
385	60	male	30	no	south	12495.72
386	20	female	30	no	south	4781.683
387	30	female	30	no	south	6710.193
388	40	female	30	no	south	8638.703
389	50	female	30	no	south	10567.21
390	60	female	30	no	south	12495.72
391	20	male	35	no	south	4935.794
392	30	male	35	no	south	6864.304
393	40	male	35	no	south	8792.814
394	50	male	35	no	south	10721.32
395	60	male	35	no	south	12649.83
396	20	female	35	no	south	4935.794
397	30	female	35	no	south	6864.304
398	40	female	35	no	south	8792.814
399	50	female	35	no	south	10721.32
400	60	female	35	no	south	12649.83