Avalanche

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1/23/2021

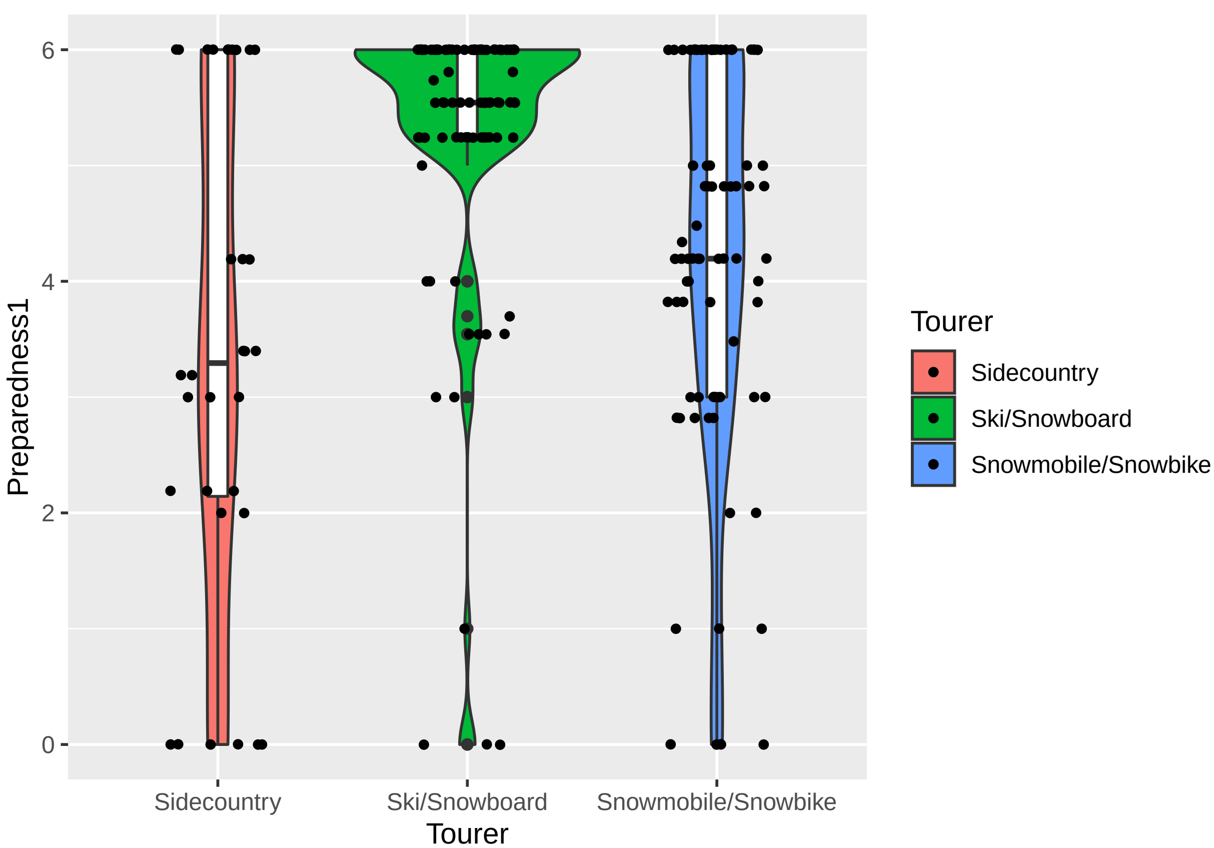
Preparedness

`Shovel`, `Beacon` and `Probe` are coded as ordinal variables. The variables are coded as

None	0
Some	1
All	2

Missing values for these variables are imputed to be the mean of the observations within corresponding Tourer category.

Preparedness score 1 We define preparedness as the sum of three variables `Shovel`, `Beacon`, and `Probe`. Comparison in preparedness in three Tourer category is given in the following figure.

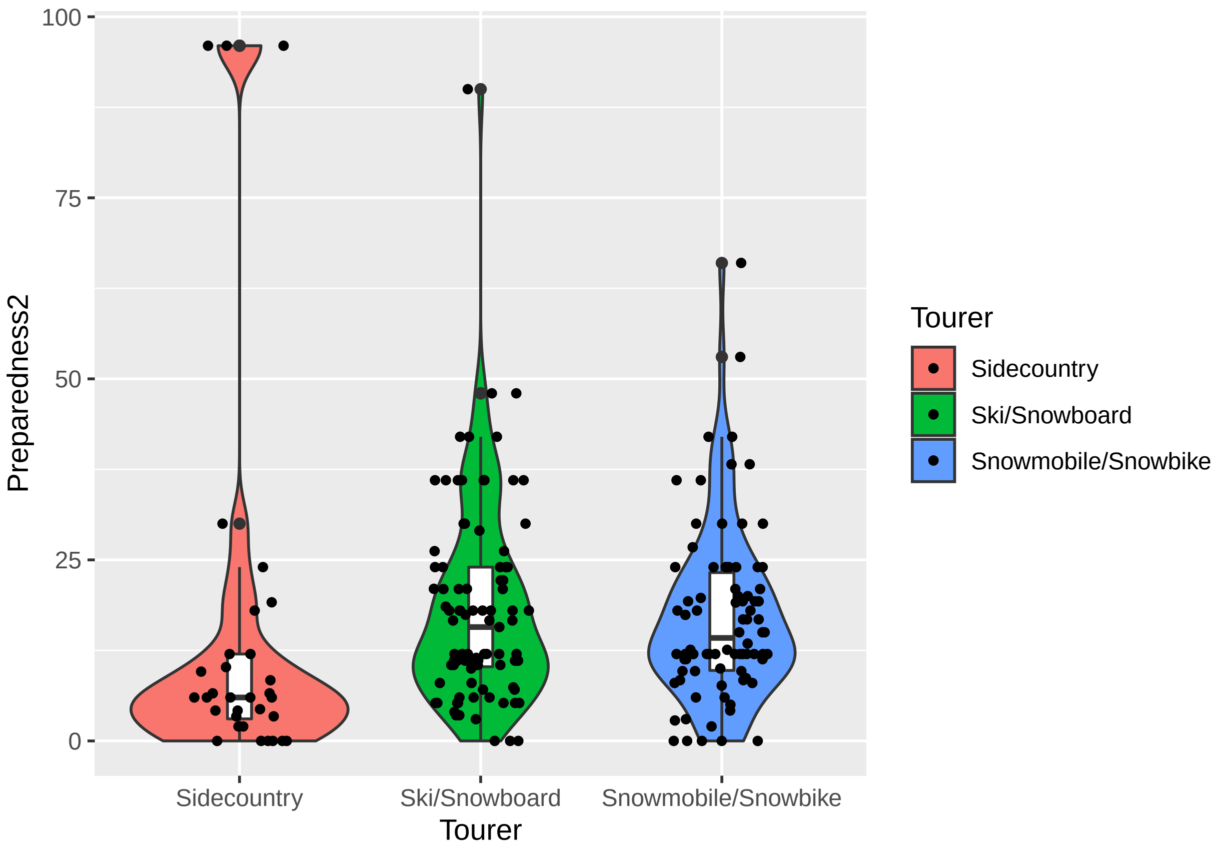


Observations:

1. Ski/Snowboarders are one an aveerage more prepared other than few exception.
2. Preparedness of people in sidecountry group are evenly distributed meaning that there are people who are well prepared, somewhat prepared and not-prepared.
3. Most of the people were somewhat prepared on the Snowmobile group.

Preparedness 2

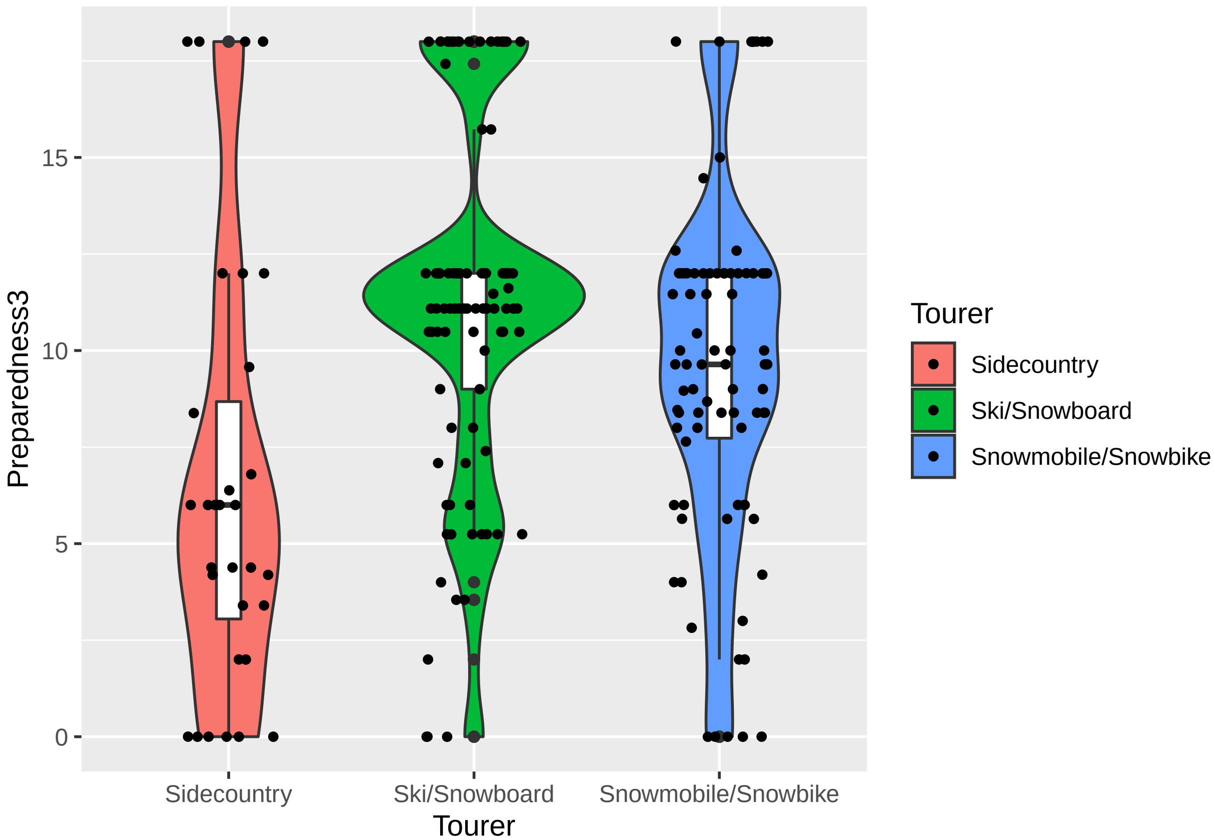
Number of people in a group also contributes to preparedness. We can also define preparedness as the product of `Shovel` + `Beacon` + `Probe` and number of people in the group. For example, if a group have three persons, all of them took shovel, some of them took probe and none of them took beacon the group will have $3 \times (2 + 1 + 0) = 9$ in prepardness score. Comparison of the groups in this scoring is given below.



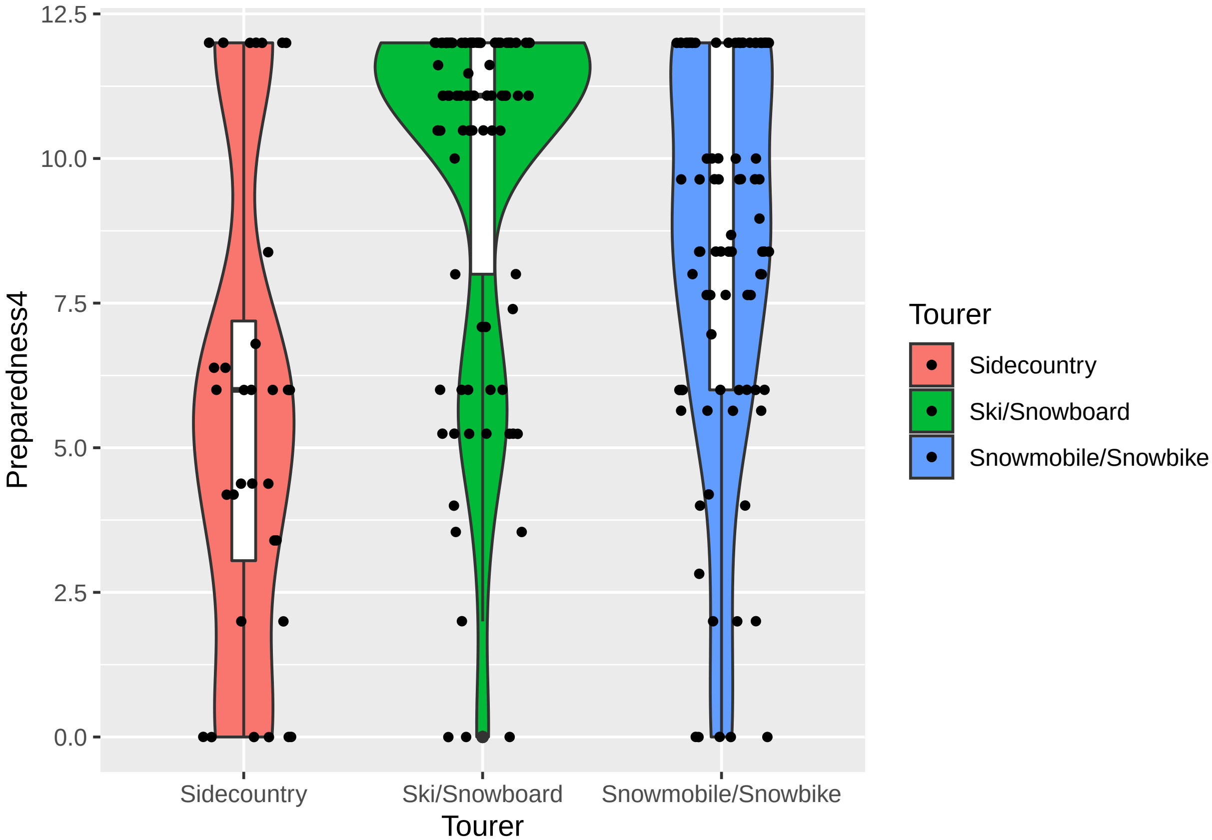
Preparedness 3

A potential problem in this scoring is that it is influenced by the size of the groups. We can overcome this problem converting the party size as

1	1
2-4	2
>4	3


Preparedness3
15
10
5
0
Sidecountry
Ski/Snowboard
Snowmobile/Snowbike
Tourer
Tourer
Sidecountry
Ski/Snowboard
Snowmobile/Snowbike

Preparedness 4



Analysis of variance

Bartlett test homogeneity of variance

`Bartlett test of homogeneity of variances`

data: Preparedness1 by Tourer Bartlett's K-squared = 14.278, df = 2, p-value = 0.0007934

`Bartlett test of homogeneity of variances`

data: Preparedness2 by Tourer Bartlett's K-squared = 40.223, df = 2, p-value = 1.844e-09

`Bartlett test of homogeneity of variances`

data: Preparedness3 by Tourer Bartlett's K-squared = 2.4318, df = 2, p-value = 0.2964

`Bartlett test of homogeneity of variances`

data: Preparedness4 by Tourer Bartlett's K-squared = 3.2074, df = 2, p-value = 0.2012

Fligner-Killeen's test

```
##
##  Fligner-Killeen test of homogeneity of variances
##
## data:  Preparedness1 by Tourer
## Fligner-Killeen:med chi-squared = 24.832, df = 2, p-value = 4.054e-06
```

```
##
##  Fligner-Killeen test of homogeneity of variances
```

```
##
## data:  Preparedness2 by Tourer
## Fligner-Killeen:med chi-squared = 2.4287, df = 2, p-value = 0.2969
```

```
##
##  Fligner-Killeen test of homogeneity of variances
##
## data:  Preparedness3 by Tourer
## Fligner-Killeen:med chi-squared = 2.0704, df = 2, p-value = 0.3552
```

```
##
##  Fligner-Killeen test of homogeneity of variances
##
## data:  Preparedness4 by Tourer
## Fligner-Killeen:med chi-squared = 7.4828, df = 2, p-value = 0.02372
```

Preparedness 1

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Tourer	2	96.38	48.19	18.01	0.0000
Residuals	202	540.49	2.68		

Table 3: One-way anova of Preparedness1 against Tourer

The preparedness is statistically different in the three categories.

Preparedness 2

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Tourer	2	165.20	82.60	0.32	0.7251
Residuals	202	51827.52	256.57		

Table 4: One-way anova of Preparedness2 against Tourer

We don't have enough evidence to say that the preparedness is statistically different among the three groups.

Preparedness 3

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Tourer	2	519.45	259.72	11.57	0.0000
Residuals	202	4536.25	22.46		

Table 5: One-way anova of Preparedness3 against Tourer

Preparedness is statistically different in three groups.

Preparedness 4

Tukey HSD test

The above table gives 95% confidence interval of difference in mean between groups.

Welch one-way test

```
##
##  One-way analysis of means (not assuming equal variances)
```

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Tourer	2	410.70	205.35	16.94	0.0000
Residuals	202	2449.23	12.12		

Table 6: One-way anova of Preparedness4 against Tourer

	diff	lwr	upr	p adj
Ski/Snowboard-Sidecountry	4.64	2.35	6.94	0.00
Snowmobile/Snowbike-Sidecountry	3.02	0.68	5.35	0.01
Snowmobile/Snowbike-Ski/Snowboard	-1.63	-3.33	0.07	0.06

```
##
## data:  Preparedness1 and Tourer
## F = 16.693, num df = 2.000, denom df = 76.244, p-value = 9.71e-07
```

```
##
##  One-way analysis of means (not assuming equal variances)
##
## data:  Preparedness2 and Tourer
## F = 0.22779, num df = 2.000, denom df = 73.908, p-value = 0.7968
```

```
##
##  One-way analysis of means (not assuming equal variances)
##
## data:  Preparedness3 and Tourer
## F = 9.4189, num df = 2.000, denom df = 81.252, p-value = 0.0002094
```

```
##
##  One-way analysis of means (not assuming equal variances)
##
## data:  Preparedness4 and Tourer
## F = 14.16, num df = 2.000, denom df = 80.648, p-value = 5.362e-06
```

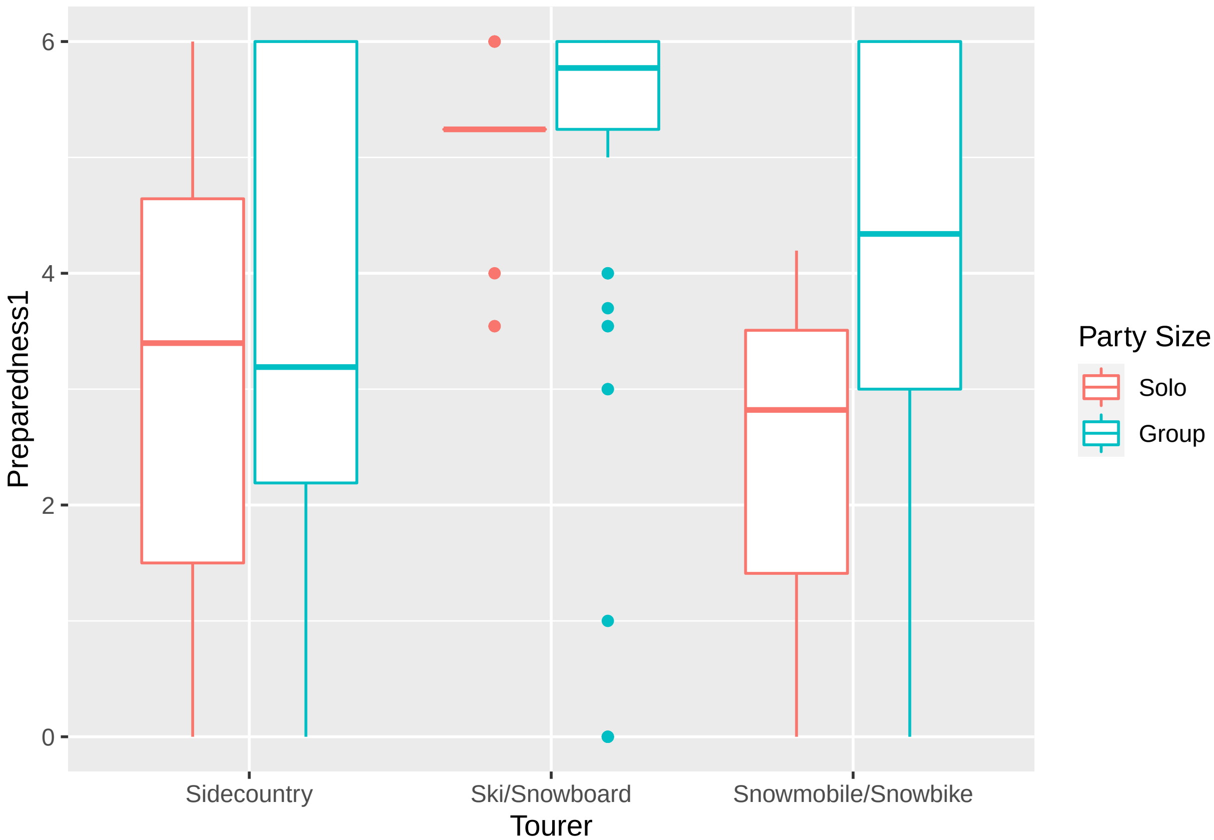
Overall comments on preparedness

Preparedness score 2 is heavily influenced by the party size and is unreliable. The Bertlett test for homogeneity of variance concludes that the preparedness scaore 1 and 2 does not satisfy the homogeneity of variance condition (p-vlaues: 0.0007934 and 1.844×10^{-9}, respectively). The other two scores (Preparedness score 3 and 4) came to the same conclusion that preparedness in the tourer groups are significantly different from each other based on the results of one-way analysis of variance.

Since the preparedness score does not follow a normal distribution, a Fligner-Killeen's test is more appropriate. According to the test, the most statistically appropriate score is the Preparedness score 3. Using the preparedness score the there is statistically significant difference (F = 11.56, p-value = 1.76×10^{-5}) in preparedness between the tourer groups.

For the post-hoc analysis of Tukey HSD test on Preparedness3. According to the test, significant differences are found between Ski/Snowboard - Sidecountry (p-value = 0.0000105) and Snowmobile - Sidecountry (p-value = 0.00723) group. We don't have enough evidence to claim that preparedness is significantly difference between the Snowmobile/Snowbike - Ski/Snowboard groups (p-value = 0.064).

A more robust test for possible violation from normality and equality of variance is the Welch one-way test. The Welch one-way test also confirms the above result.



	Tourer	Total_in_party_cat_bin	count	mean	sd
1	Sidecountry	Solo	12	3.10	2.32
2	Sidecountry	Group	20	3.58	2.14
3	Ski/Snowboard	Solo	13	5.06	0.85
4	Ski/Snowboard	Group	78	5.27	1.37
5	Snowmobile/Snowbike	Solo	3	2.34	2.14
6	Snowmobile/Snowbike	Group	79	4.27	1.67

Test for homogeneity of variance

```
## Levene's Test for Homogeneity of Variance (center = median)
##        Df F value    Pr(>F)
## group   5  4.9856 0.0002523 ***
##       199
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

So, the homogeneity assumption is violated. Also, the design is unbalanced since the number of observations vary too much. The ANOVA with Type-III sum of squares is prefered in such cases.

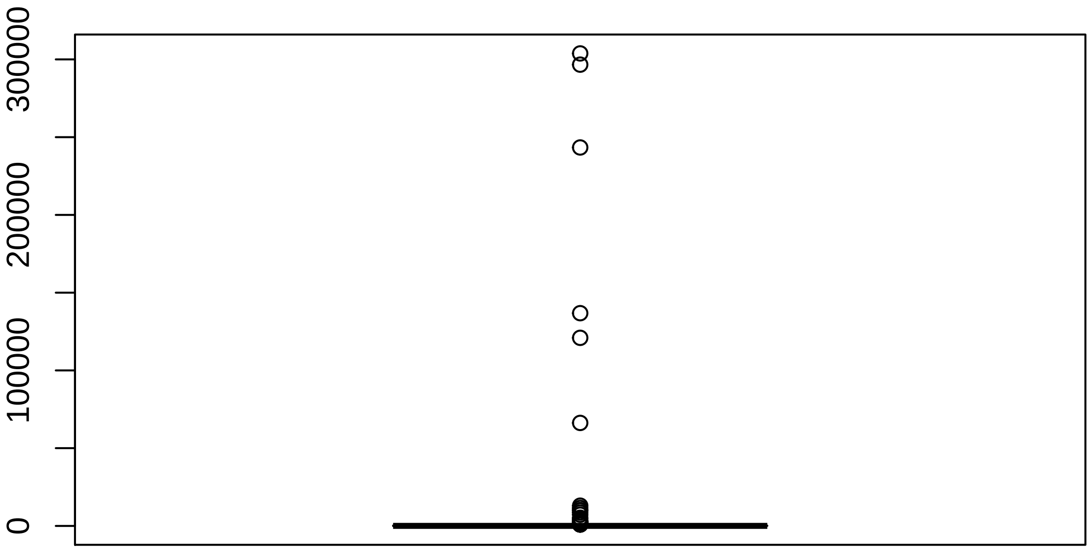
```
## Anova Table (Type III tests)
##
## Response: Preparedness1
##                                Sum Sq  Df F value    Pr(>F)
## (Intercept)                    115.17   1 43.4450 3.826e-10 ***
## Tourer                          32.51   2  6.1317  0.002605 **
## Total_in_party_cat_bin           1.72   1  0.6492  0.421348
## Tourer:Total_in_party_cat_bin    6.79   2  1.2800  0.280312
```

```
## Residuals                         527.53 199
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

The preparedness score 1 is significantly different between the three groups of tourers (F = 43.45, p-value = 3.83×10^{-10}). The evidence at hand does not show that the preparedness differes based on whether the tourer is alone or in a group.

The two-way anova using the Preparedness1 and binary Party Size as independent variables concludes the same as the one way anova about the preparedness1. We can conclude from here that the preparedness does not depends on the party size and neither there are interaction effect of Trouer group and party size on preparedness.

Analysis on Burial_time



Some outlines are visible in the data. As we discussed, the insanely high burial time indicate that the body was found long after the incidence due to weather condition or some other reason. The inter-quartile range of burial time is

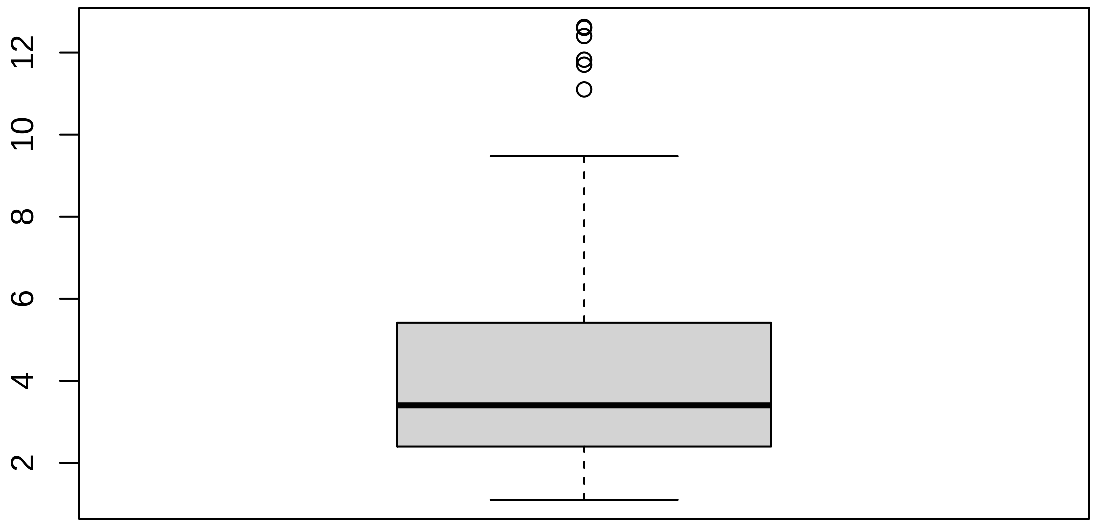
```
## [1] 207.5
```

```
## [1] 162
```

```
## [1] 41
```

There are 162 observation where Burial time is available among them 41 is above the inter-quartile range. Replacing them by the inter-quartile range makes the burial time a bimodal and analysis of a bimodal variable is not straight forward.

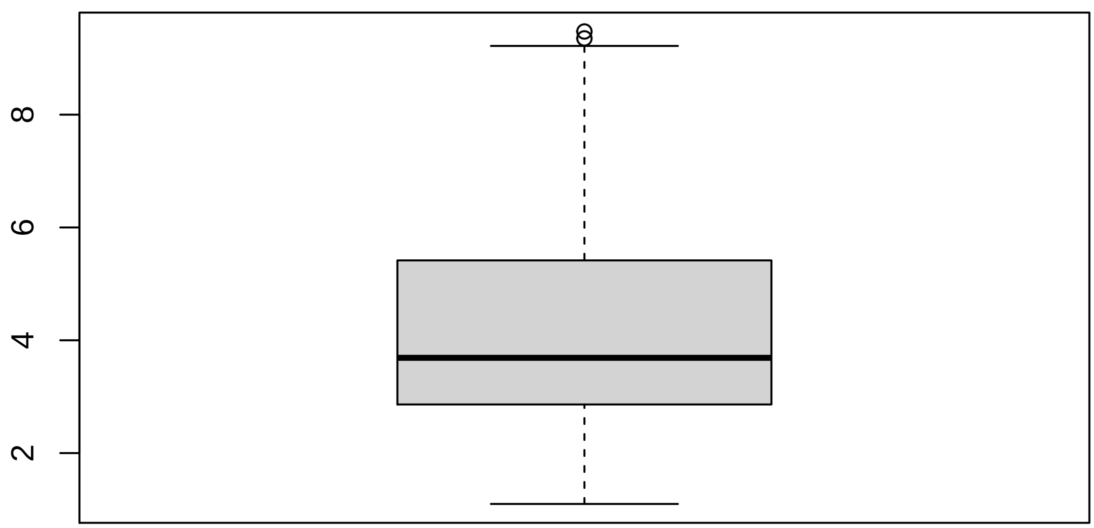
We log transform burial time and see the boxplot



We see only a few outliers here.

```
## [1] 6
```

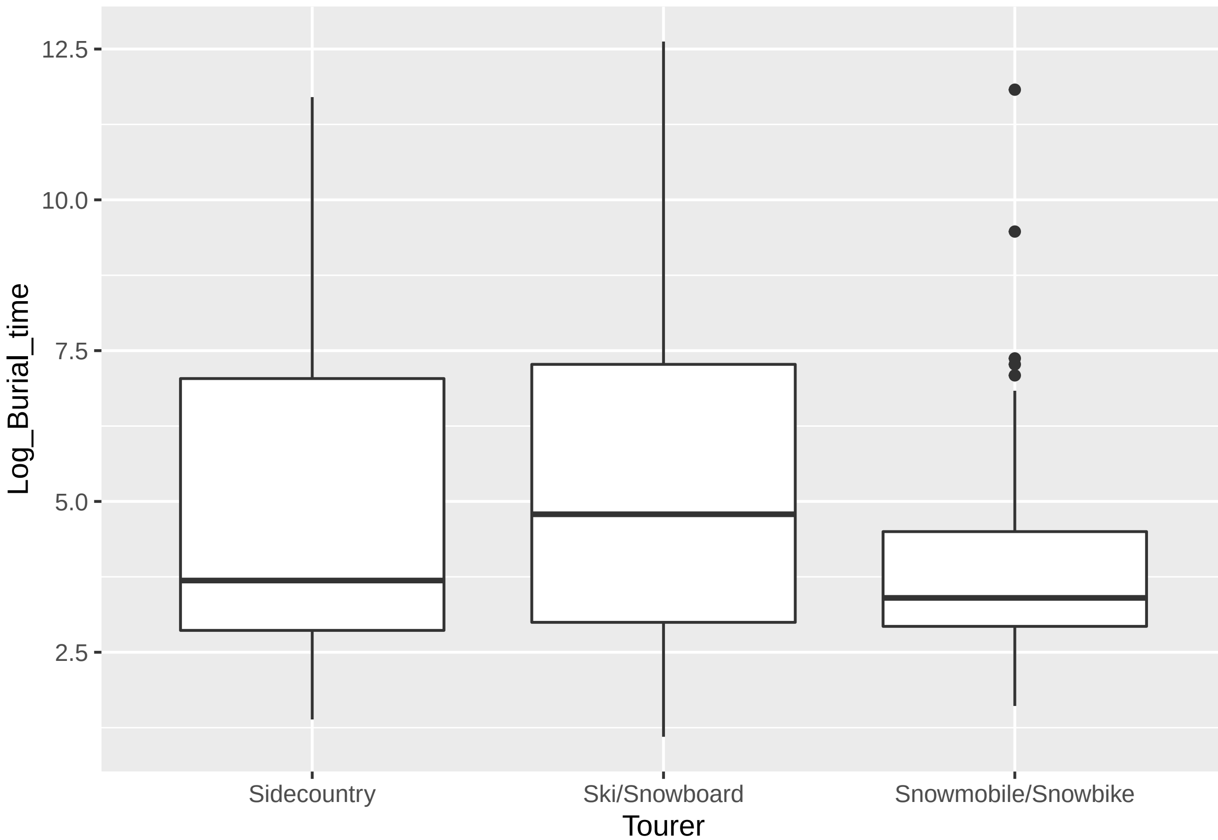
Removing 6 observations. There are 19 more observations that has burial time 0. I don't understand this and removed them from further analysis as well.



Is burial time significantly different among tourer groups?

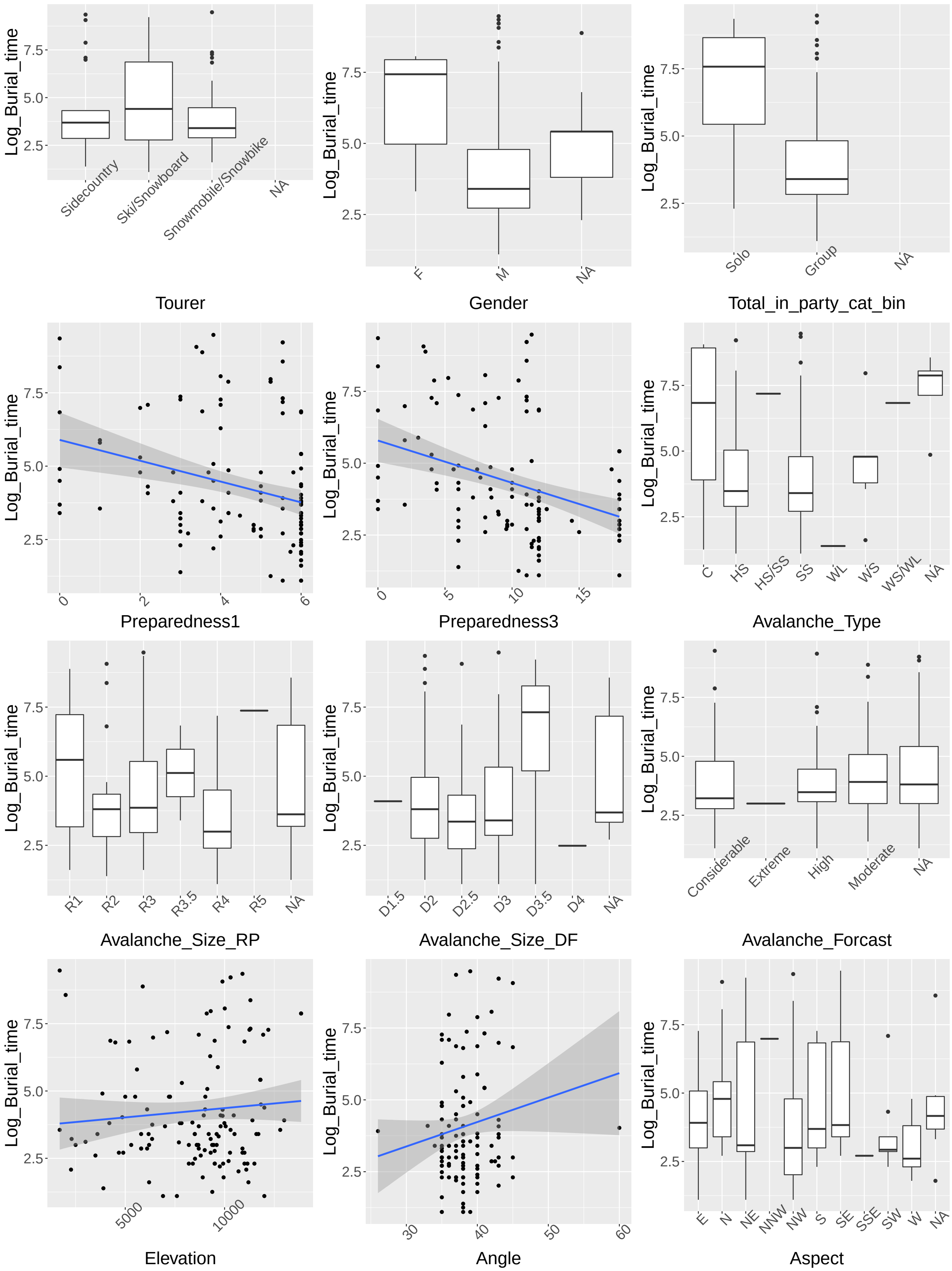
```
##              Df Sum Sq Mean Sq F value Pr(>F)
## Tourer        2   26.8  13.405    3.24 0.0422 *
## Residuals   134  554.4   4.137
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## 43 observations deleted due to missingness
```

Only a slide evidence (F = 3.24, p-value = 0.042) that the burial time is related to the tourer group.



The boxplot also confirms the ANOVA result.

Looking at burial time against other variables



Observations:

1. Burial time does not differ based on Tourer group
2. Burial time looks different for male and female
3. Burial time for single person looks higher than group
4. Burial time decrease significantly with increase of preparedness
5. Can't comment on Avalanche properties without further investigation
6. Does not looks like Elevation and Angle are associated with burial time.

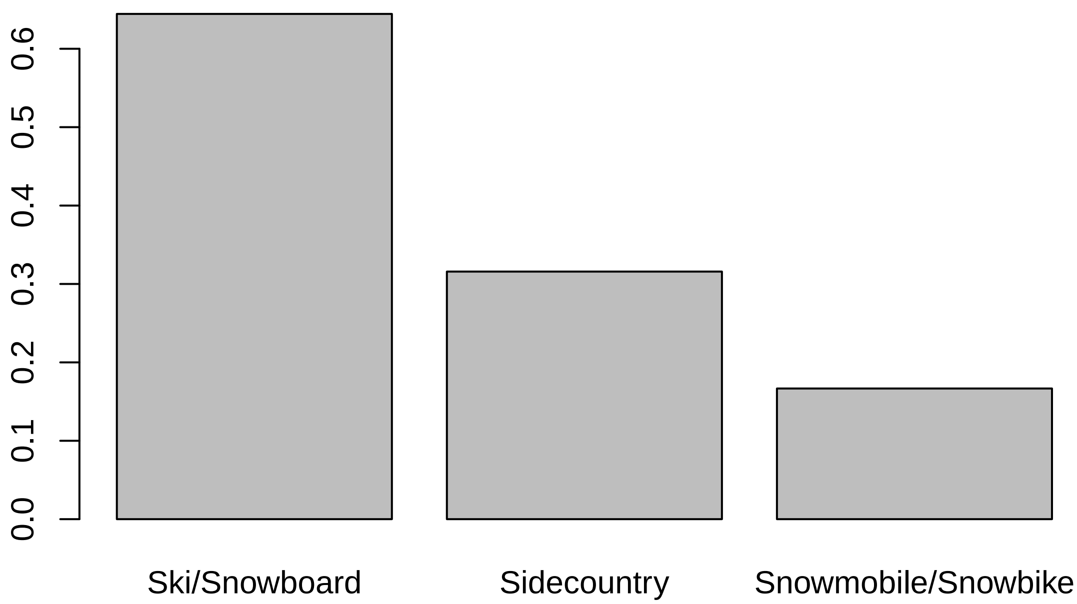
Additional analysis based on comments on Jan 7th

Analysis 1: Burial time < 15 vs ≥ 15

Comment: The only other metric for burial time that would be helpful is the number of burials that were 15 min or less (suggesting that the group was more prepared). So if there is a way to say a certain group had a statistical difference in the percentage that were 15 min or less, not including the people who weren't buried.

We perform a chi-square test of independence between the Trourer group and whether the burial time was less than or more than 15 minutes. Based on the chi-square test ($\chi^2_{df=2} = 10.82$, p-value $= 0.004$), whether burial time is less or more than 15 depends on the tourer group.

	Sidecountry	Ski/Snowboard	Snowmobile/Snowbike
more_than_15	19	45	54
less_than_15	6	29	9



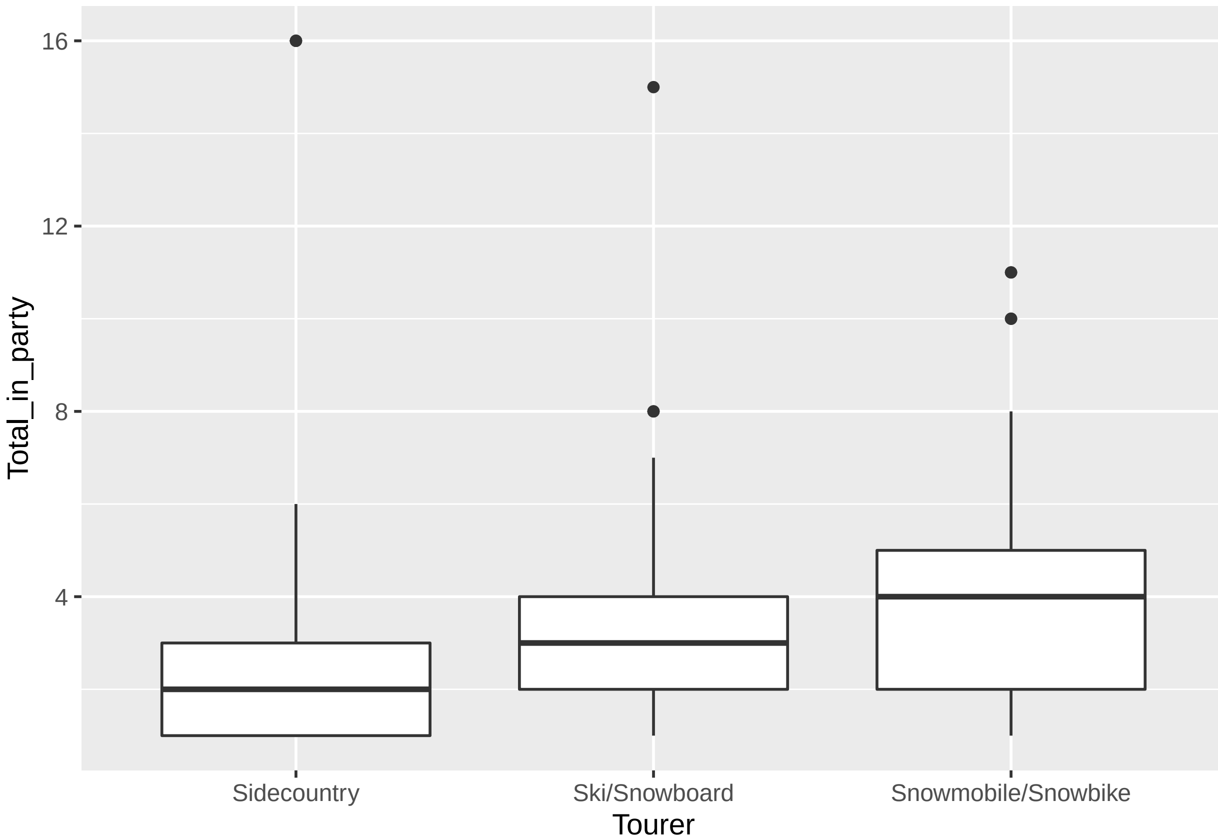

```
##
##  Pearson's Chi-squared test
##
## data:  table(dat$Burial_time < 15, dat$Tourer)
## X-squared = 10.817, df = 2, p-value = 0.004479
```

Analysis 2:

Comment: The last few things I was hoping for are some of those variables looked at individually, rather than in conjunction with burial time. For example, for avalanche forecast, is there a difference in the distribution of each forecast type among the 3 groups or are there significantly more of one forecast than another. For the following variables, I am just looking at them independently. Here would be the question for each:

1. total in party: was the average group size for each of the three groups significantly different? Could we do one graph showing that distribution?

```
##
##  One-way analysis of means (not assuming equal variances)
##
## data:  Total_in_party and Tourer
## F = 1.9479, num df = 2.000, denom df = 74.548, p-value = 0.1498
```



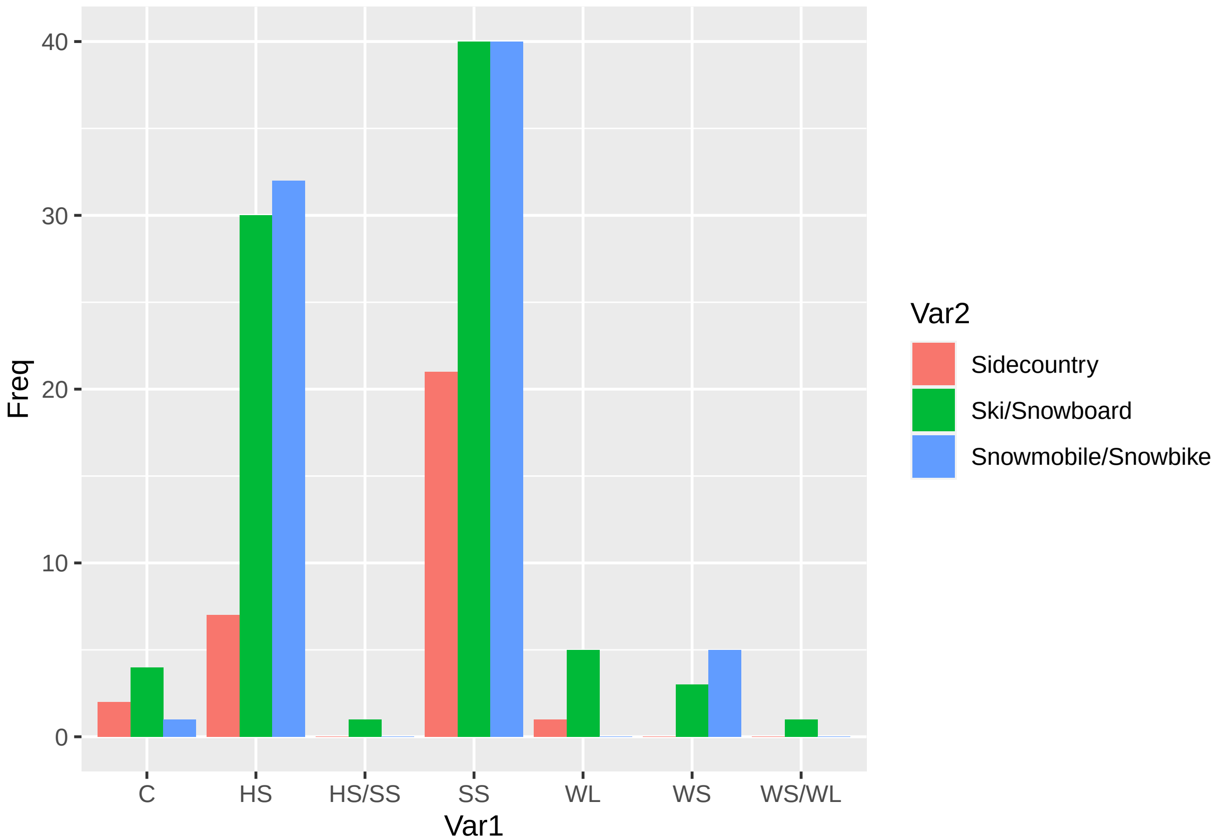
From the Welch one-way test and boxplot the data does not suggest significantly difference in average group size.

2. avalanche type: Were there more of a certain types in one group compared to another?

```
Pearson's Chi-squared test
```

data: table(dat$Avalanche_{T}ype, dat$Tourer) X-squared = 15.577, df = 12, p-value = 0.2114

	Sidecountry	Ski/Snowboard	Snowmobile/Snowbike
C	2	4	1
HS	7	30	32
HS/SS	0	1	0
SS	21	40	40
WL	1	5	0
WS	0	3	5
WS/WL	0	1	0



Chi-square test of independence can not be applied to the whole table as there are many cells with 0. We can test if HS and SS are significanly different in three tourer groups

```
##
##  Pearson's Chi-squared test
##
## data:  contin_table[c(2, 4), ]
## X-squared = 3.4149, df = 2, p-value = 0.1813
```

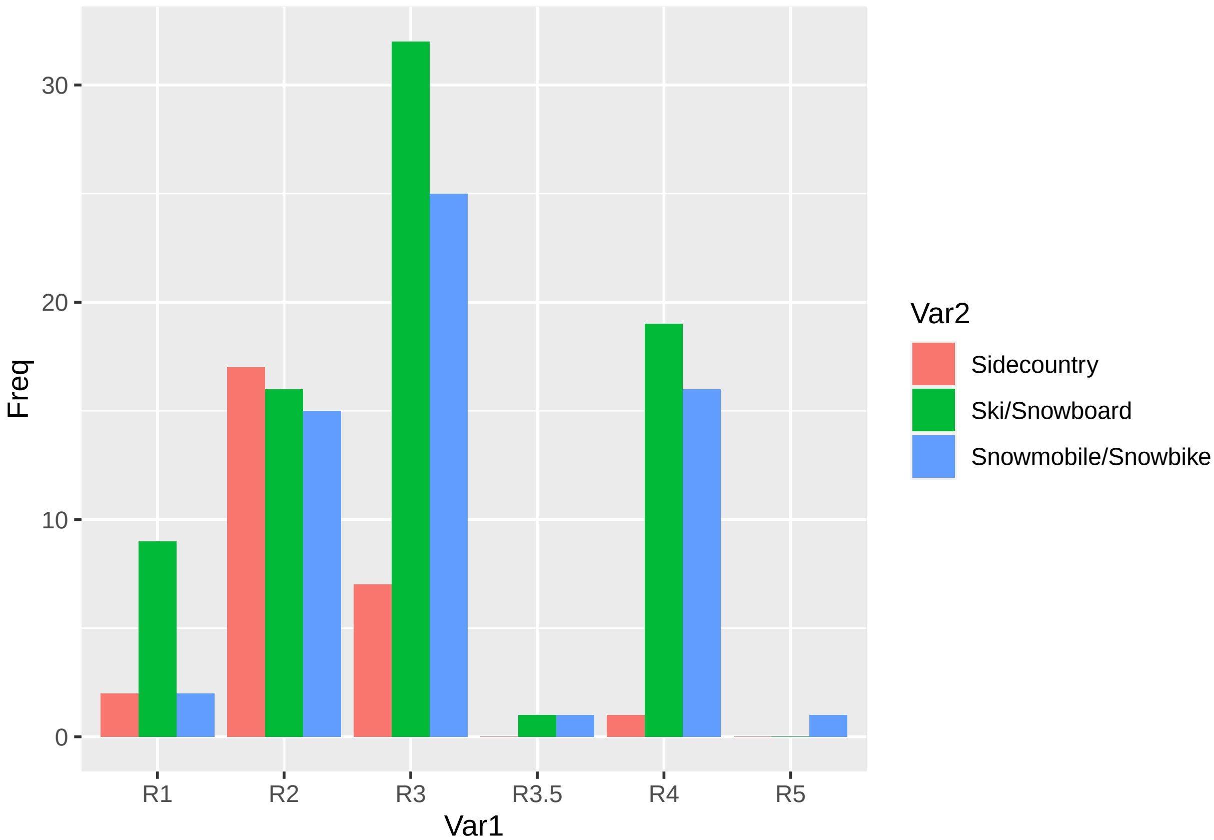
From the chi-square test of independence, we don't have enough evidence to confirm that the type of avalanche varies between the three winter activity groups (locations).

3. size (R). Is the average size and/or distribution different between the three groups?

```
Pearson's Chi-squared test
```

data: table(dat$Avalanche_{S}ize_{R}P, dat$Tourer) X-squared = 24.273, df = 10, p-value = 0.006907

	Sidecountry	Ski/Snowboard	Snowmobile/Snowbike
R1	2	9	2
R2	17	16	15
R3	7	32	25
R3.5	0	1	1
R4	1	19	16
R5	0	0	1

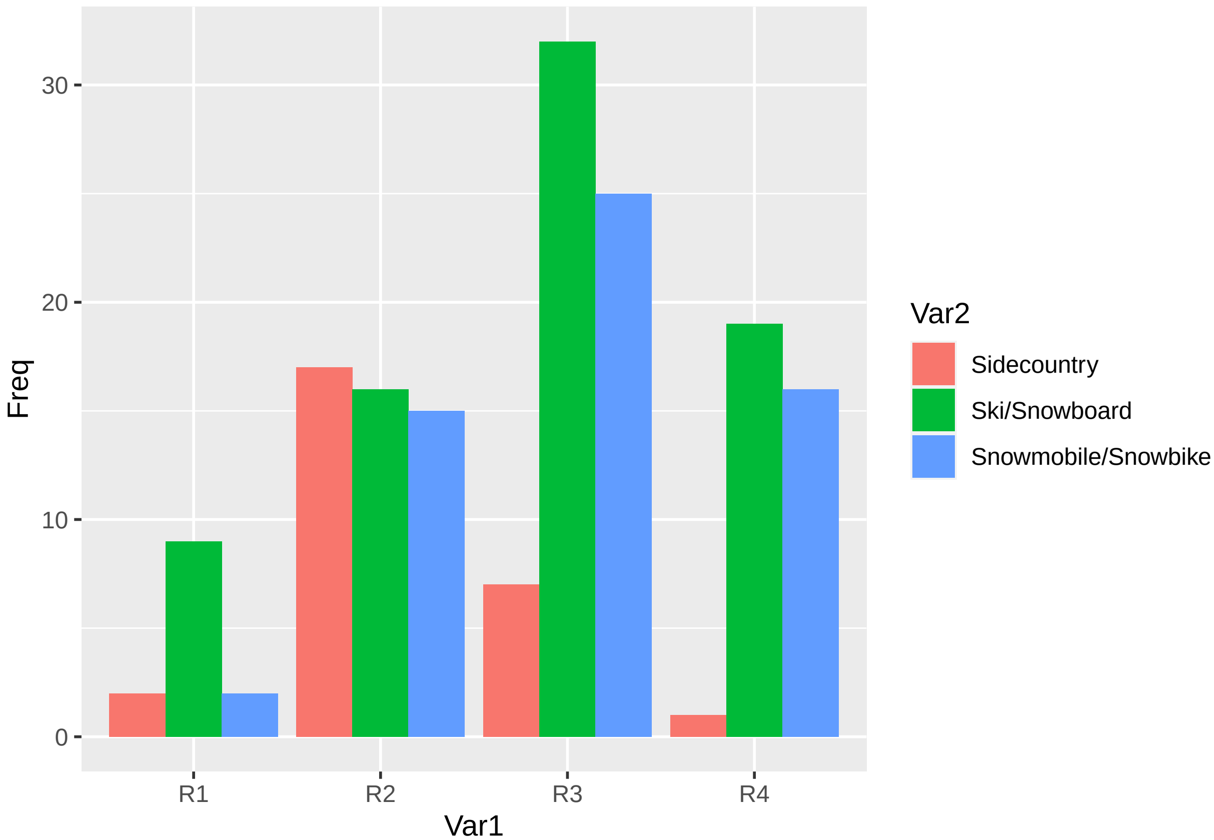


The chi-square test confirms that the avalanche type varies between the winter activity location. We remove R3.5 and R5 from the analysis of chi-square test of independence for lack of observations and re-run the test.

`Pearson's Chi-squared test`

data: table(dat$Avalanche_{S}ize_{R}P[kept], dat$Tourer[kept]) X-squared = 21.817, df = 6, p-value = 0.001307

	Sidecountry	Ski/Snowboard	Snowmobile/Snowbike
R1	2	9	2
R2	17	16	15
R3	7	32	25
R4	1	19	16



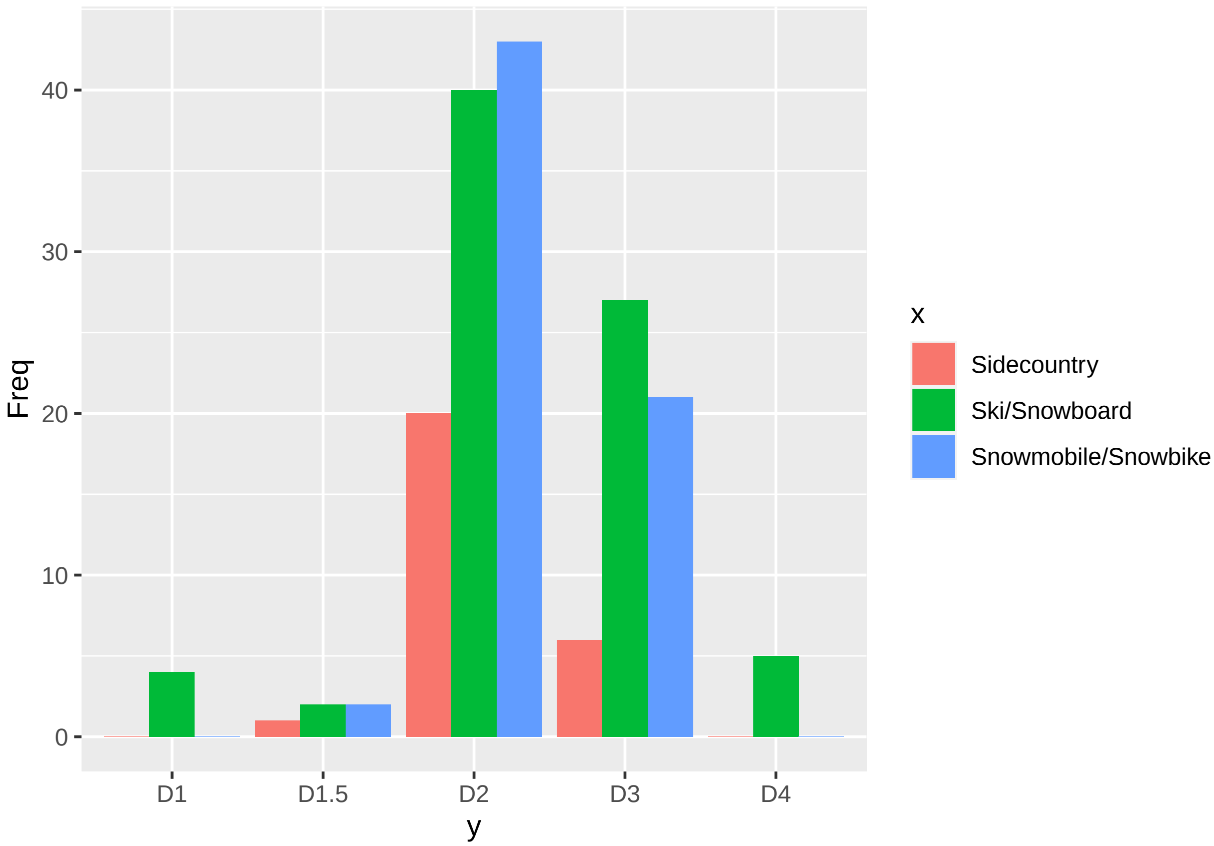
The Ski/Snowboard have much higher number of R1 and R3 avalanche compared to the other two.

4. size (D)- you can include 2 and 2.5 in one category, 3 and 3.5 together, etc. if that is easier. Same here, is the size/distrubtion different among the groups. If we can't find any differences just having a box plot for these two size ones would be fine to show the distribution.

   Pearson's Chi-squared test

data: table(y, x) X-squared = 13.963, df = 8, p-value = 0.08274

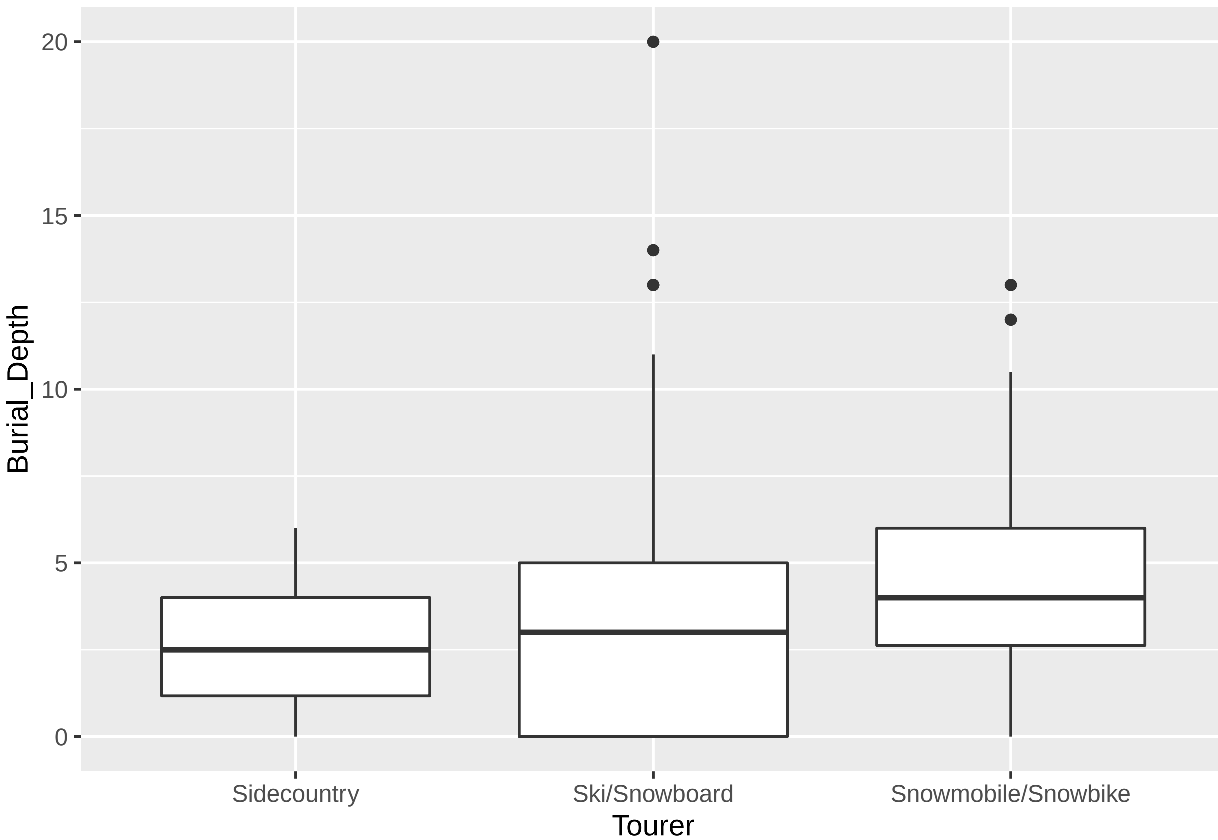
	Sidecountry	Ski/Snowboard	Snowmobile/Snowbike
D1	0	4	0
D1.5	1	2	2
D2	20	40	43
D3	6	27	21
D4	0	5	0



From the chi-square test and the bar plot Avalance size DF is not significantly differen between tourer group.

5. burial depth: are the average burial depths different among the three groups?

```
##
##  One-way analysis of means (not assuming equal variances)
##
## data:  Burial_Depth and Tourer
## F = 7.1958, num df = 2.000, denom df = 79.775, p-value = 0.001339
```



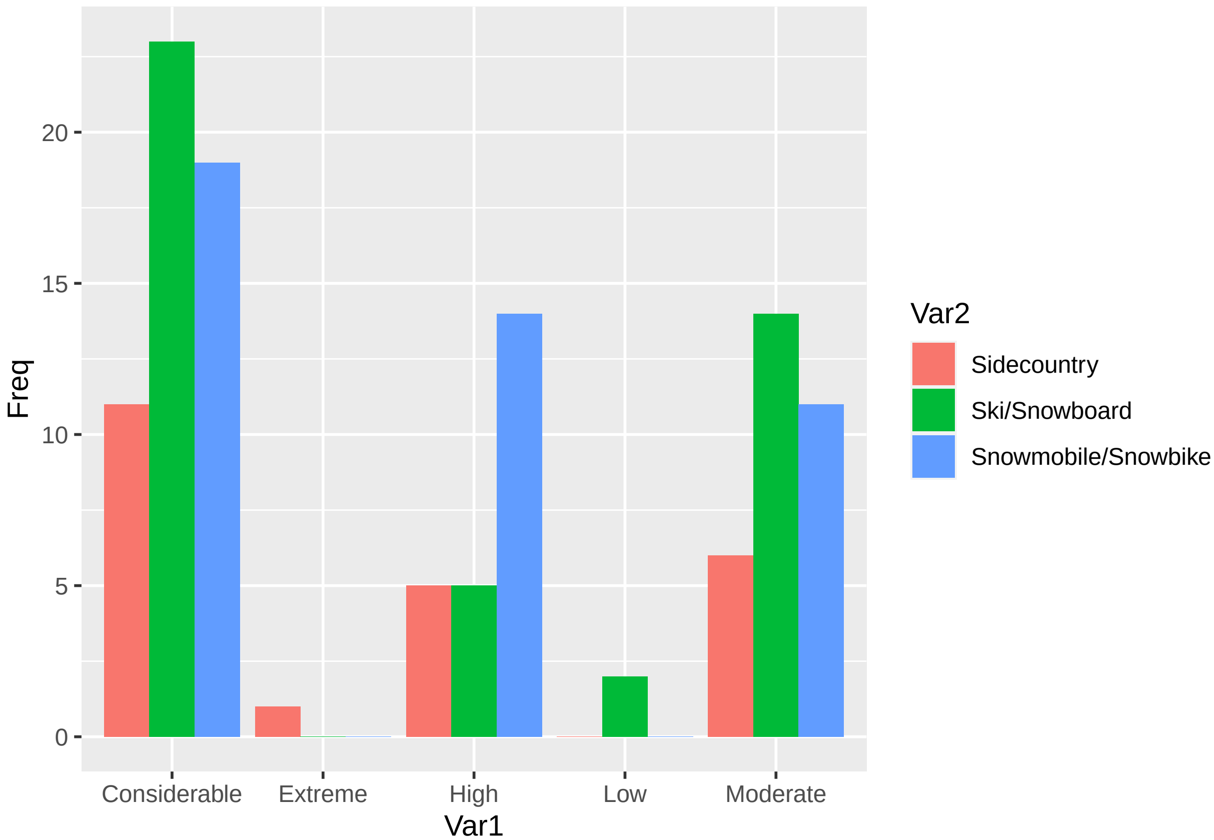
Based on the Welch one-way test, burial depth is significantly different in three tourer groups. From the box plot it looks like that the Sidecountry, ski/Snowboard are pretty similar and the difference is between these and Snowmobile/Snowbike.

6. forecast: is there a difference in distribution of the forecast or which ones are most common among the 3 groups?

```
Pearson's Chi-squared test
```

data: table(dat$Avalanche_Forcast, dat$Tourer) X-squared = 11.911, df = 8, p-value = 0.1552

	Sidecountry	Ski/Snowboard	Snowmobile/Snowbike
Considerable	11	23	19
Extreme	1	0	0
High	5	5	14
Low	0	2	0
Moderate	6	14	11



Does not look like there are statistical differences

Comments

1. Based on the results I would inclined toward Preparedness score 3 and one-way anova result and present the two-way anova result as sanity check.
2. Analysis on burial time is still incomlete. I would spend couple of hours next weekend to do something more.
3. Please send me specifict questions (I think we have already discussed some, please remind me). Specific questions will be very helpful for me when I analyze the data.