ETM

ENGINEERING & TECHNOLOGY MANAGEMENT

Decision Model for Portland Metro Bike Commuters

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Instructor: Dundar F. Kocaoglu, Ph.D.

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Author(s): Justin Thompson (Team Lead), Bennett Barnwell, Timothy Calderwood, Arvind Kumar, Sath Vang

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Executive Summary

Many people commute to work in Portland using various modes of transit. However, we will focus on the bike commuters. We will develop a model that you could use to select a commuter bike. To do so, we developed a Hierarchical Decision Model containing the important criteria that a commuter uses when selecting a bike. We chose this model because it allows the user to have multiple levels of criteria and manufacturers can use it to see where they can improve their products.

This paper will look at the main features of a typical bicycle; the frame, cost, and basic components; though many features are available that would make one bike or the other more suitable for commuting, we felt that this was representative of the factors for the typical commuter. Our team, after extensive research, is the self-styled 'experts' for evaluation of bicycle features using a pairwise comparison.

Using the model and inputting a few bicycles for sale around town revealed the top choice to be a Novara Big Buzz followed by the full-suspension Marin Bridgeway.

Introduction

Portland area bicycle commuters have been growing rapidly over the past decade. Bicycle traffic has increased from 2,855 to over 16,000, partly due to facility improvements at workplaces and additional bike lanes on roads [1]. Approximately 8% of commuters bike to work in Portland, the highest proportion of any major U.S. city and about 10 times the national average [2]. We are going to apply the Hierarchical Decision Model (HDM) to help determine which elements of a bike are best suitable for the commuter. We will analyze the weighted priority of each element using the pairwise comparison method. The hierarchical model is a decision system that relates each level of criteria to the ultimate decision: what is the best bike for a Portland commuter. The calculated weight required at each stage involves the quantification of subjective values implicit in the decision maker's judgment [3]. The decision hierarchy for our project consists of bicycle criteria selections and alternatives.

Selection Criteria

Our ideal commuter bike will be evaluated on three main criteria; cost, components, and frame material. We have selected three main areas of a bicycle to evaluate, there are many other unique characteristics that could go into selecting a bike, but we feel these will result in a representative selection. Other factors that a buyer may want to consider are construction, tires, and brand. These and other factors were left out of the decision model to reduce the burden on our panel of experts.

Cost is important to the buyer who wishes to save money. Based on our research, the cost of a commuter bike will be evaluated in ranges of: less than $300, $301 to $499, $500 to $899, and greater than $900.

The components of a bicycle are important items that affect comfort, ride, and safety. We broke down components further into four criteria: suspension, brakes, saddle, and gears.

The suspension on a bicycle can come in many forms: front, rear, full, or none. Suspension is important because a commuter's ride involves variable terrain, this can be comfort or safety driven choice. Another selection criterion is the braking system. It is a critical component to have on a bicycle because it allows the rider to slow down or stop. We broke down brakes into three types: clamp, disk, and other (coaster, sneakers, etc). The saddle or seat type, our third component criterion will affect the bike commuter's comfort. Some riders prefer hard, soft or other styles. The last feature of a bike that is important to the rider is the gears. Gears allow the rider to go up hills easier and have different ranges of speeds available. More gears on a bicycle will cost more money and add more weight, which are important consideration for the bike commuter. We evaluate the gears ranging from: 1 to 6, 7 to 12, 13 to 18, and 19 to 27.

The four frame materials that are common in commuter bikes are: titanium, carbon fiber, steel, or aluminum. The material affects the comfort of the ride, weight of the bike, and durability.

The HDM is shown here and will be discussed below.

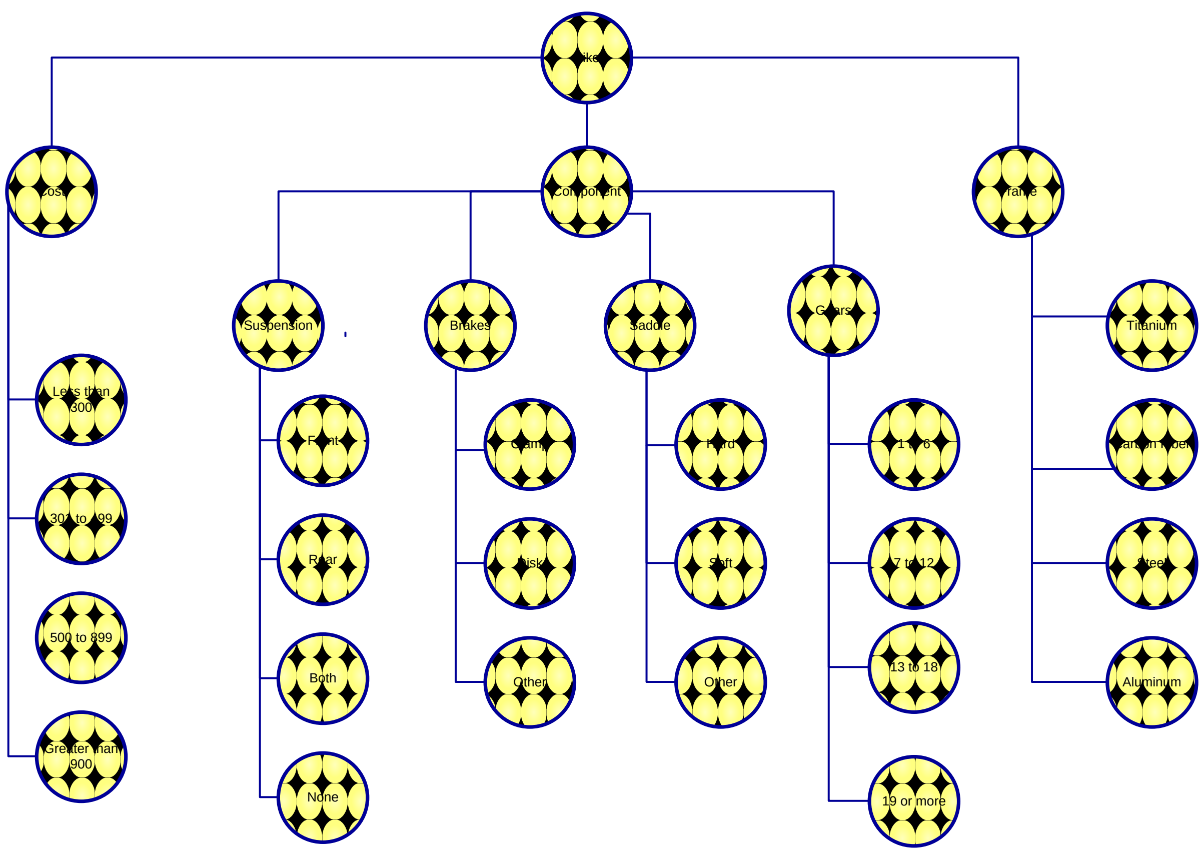

Figure 1, Hierarchical Decision Model

Assumptions

The selection criteria above are based on a series of assumptions. The first assumption is that authors are experts in commuter biking. In addition, the following is a list of the key assumptions made to simplify the model.

1. Brand names could inject bias into the model and were not included.
2. Not all bike specifications were compared.
3. Commuter demographics are not discussed.
4. The typical bike for a commuter does not take into account recreational or other styles of riding.

Methods Used

The methods that we used to determine the best commuter bike were the HDM and pairwise comparison, which go hand in hand to solve decisions that depend on multiple levels.

Taking a deeper look at the HDM we first asked, "What is the mission for a commuter?" This can be answered in several different ways. For example, some commuters are looking for a bike that is comfortable, reliable, and cost effective. Others are looking for a bike that will get them from point A to point B, but will also allow them to cross-train either on the trails or on the road on their way to and from work. Considering these factors, each expert compared features they felt were important to have on their particular bicycle. We believe that cost, components, and frame material actively portray a commuter's decision-making process.

The next step in the HDM is to address what the goals are that will allow us to achieve the objectives. In the commuter's case we decided on a range of attributes under each objective. The forth level in this model is strategies. For example, one goal of the commuter on the level above is selecting a saddle, which will ultimately affect their objective of maximizing their components. However, the commuter must choose a strategy, or particular saddle that they prefer. These choices create the pathways that the decision maker uses to find the bike that will fit their needs. The last level in the model is the action level. This is quite simply which bike best fits the commuter's desires based on the results of the pairwise comparison. This model, as shown in the diagram below accurately shows the complexities of a decision.

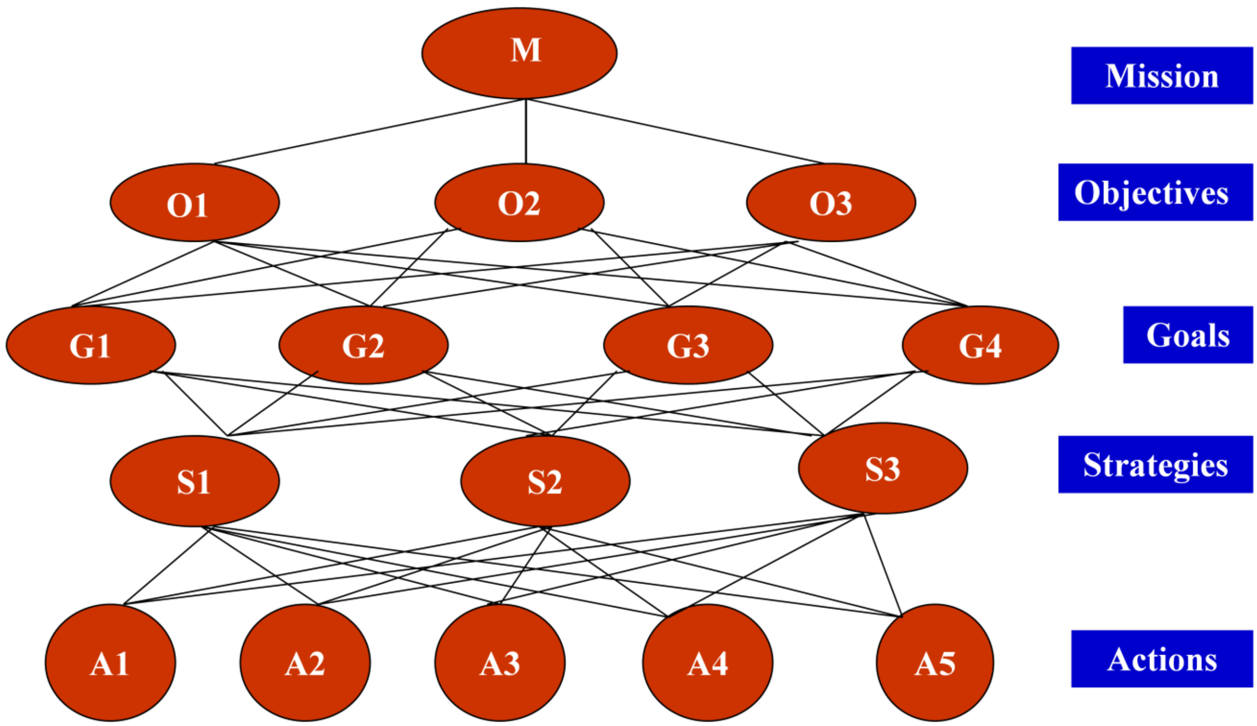

Figure 2, MOGSA Hierarchical Decision Model

In order to evaluate each level of the model, compare a pair of objectives at a time by distributing a total of 100 points between the two elements [3]. For example, when comparing cost and components; cost might get 55 while components get 45. In this example, cost is slightly more important to the decision maker than components are. In our decision, compare cost and frame material, cost and components, and components and frame material. By performing multiple comparisons, the pairwise comparison method will accurately evaluate the comparisons and give each component a weighted priority.

The first step in a pairwise comparison is to determine what the categories are that need to be compared. Now each expert compares each objective against the other. For comparisons, the experts were asked to fill in the table below:

Table 1

Cost:	Components:
Cost:	Frame Material:
Components:	Frame Material:

One of the experts filled in the table in the following way:

Table 2

Cost: **89**	Components: **11**
Cost: **68**	Frame Material: **32**
Components: **23**	Frame Material: **77**

The next step is to create a series of constant sum matrices showing the relationship between the different elements. The first matrix, called Matrix A, is shown below. It shows the relationship between the columns and rows. For example, the second column and first row matrix element represents the relationship between components and cost where as the first column and second row elements shows the compliment relationship.

Table 3

Matrix A	Cost	Components	Frame Material
Cost	X	11	32
Components	89	X	77
Frame Material	68	23	X

The second matrix, Matrix B, is created to show the relationship between the two objectives. For example, the relationship above would give us 11 and 89 respectively. To compute Matrix B divide a matrix element in Matrix A by its reciprocal. The table below shows the results of these computations.

Table 4

Matrix B	Cost	Components	Frame Material
Cost	1.00	11/89=0.123	.47
Components	8.09	1.00	3.35
Frame Material	2.125	.299	1.00

The next step is to create Matrix C, the third matrix by dividing the element in one column by the element in the adjacent column. For example, take the top element in the cost column and divide it by the top element in the components column. This table provides you with information on how consistent the expert is in their answers as well as the weighted mean value for a given element which will then be normalized. The resulting table is shown below.

Table 5

Matrix C	Cost/Components	Components/Frame Material
Cost	1/.123 = 8.13	.123/.47 = 0.262
Components	8.09	0.299
Frame Material	7.11	0.299
Mean	(8.13+8.09+7.11)/3=7.78	0.287

The first step in normalizing these values is to determine the mean ratios for each of the objectives. The value of unity, one, is applied to frame material. Calculate components by multiplying the value of unity by the mean in the components/frame material column. In this case, it equals 0.287. Then multiply the previous answer (0.287) by the mean in the cost/components column. This results in 2.23 for cost. Add all of these results up. In our example this equals 3.52. The final step to normalization is the divide the individual results above by the total. The normalized value for cost is 2.23/3.52 = 0.63, components equals 0.287/3.52 =0.082, and frame material equals 1/3.52 =0.284. Therefore, the expert in this example puts the majority of his focus on cost and spends about 25% looking at the frame material and only 8.2% value on components.

We did these calculations for each expert and each tier of the hierarchical model to determine the weight of each element. This allows us to determine the optimal bike for the commuter as well as rate different bikes on the market based on the features of the bike.

Hierarchical Decision Model Results

Once the survey data was collected, pairwise comparison was used to determine which bike attributes were influential. To help with the calculations, a software package called PCM was furnished by Dundar F. Kocaoglu, Ph.D. to perform the pairwise calculations. The output of the software is provided in Appendix A.

Looking at the inconsistency from the output, we find that the expert panelists were consistent in some evaluations and inconsistent in others. The accepted inconsistency is less than 0.01.

Table 6

High Inconsistency Questions	Inconsistency
Objective Level	0.125
Frame Material	0.127
Suspension	0.167
Brakes	0.164
Saddle	0.147

Table 7

Low Inconsistency Questions	Inconsistency
Components	0.077
Cost	0.029
Gears	0.036

To reduce the inconsistency the experts should share their ratings with each other to find areas where they can come to better agreement, which would most likely result in a lower inconsistency values.. By using the mean values, we get the decision tree shown below.

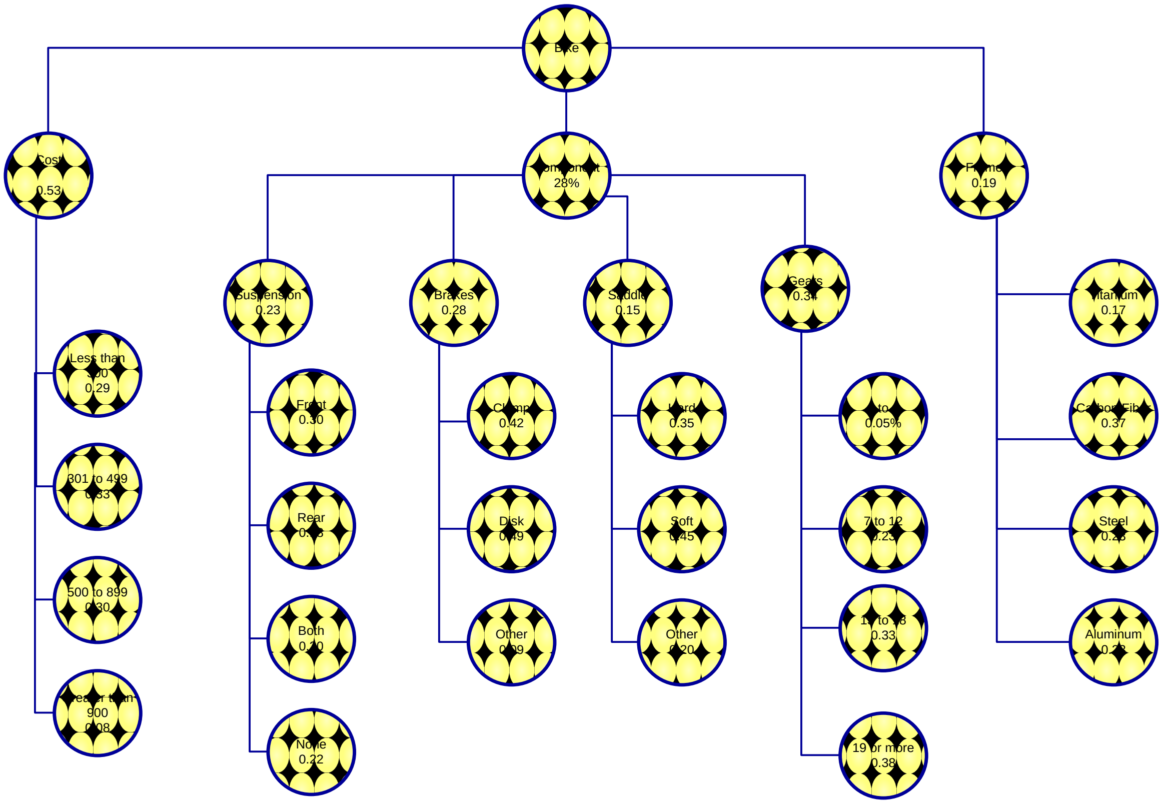

Figure 2, Hierarchical Decision Model with adjusted weights

The decision tree in Figure 2 graphically depicts the adjusted weight of each feature. For example, multiply the normalized value of carbon fiber (0.37) by the normalized value of frame material (0.19). This gives us 0.0703, the weight adjusted value. Using this value, comparing carbon fiber 0.0703 and titanium 0.0323, it can be extrapolated that carbon fiber is twice as desirable to the commuter as titanium. The rest of the calculations are shown in Appendix B. By examining these values, the "ideal bike" can be determined. The "ideal" commuter bike would be priced between $301 and $499, has a carbon frame with disk brakes, front, or full suspension, a soft seat, and has 19 or more gears. This gives a total sum of 0.3514. Front and full suspension scored equally in the pairwise comparison.

Table 8

Ideal Bike	Score	
Price	between $301 and $499	0.1749
Frame Material	Carbon Frame	0.0703
Suspension	Front or Full	0.0234
Brake Type	Disk	0.0382
Gears	19 or more	0.0361
Seat Type	Soft	0.0085
Total		**0.3514**

Evaluation

Given our "ideal" bike, let us look at the top selling bikes from www.REI.com [4].

Table 9

Novara Big Buzz Bike		**Score**
Price	$525.00	0.15900
Frame Material	Aluminum	0.04370
Suspension	None	0.01716
Brake Type	Disk	0.03822
Gears	18	0.03135
Seat Type	Soft	0.00855
	Total	**0.29798**

Table 10

Cannondale Quick 6		**Score**
Price	299.93	0.15370
Frame Material	Aluminum	0.04370
Suspension	None	0.01716
Brake Type	Clamp	0.03276
Gears	21	0.03610
Seat Type	Soft	0.00855
	Total	**0.29197**

Table 11

Marin Bridgeway FS		**Score**
Price	$549.00	0.15900
Frame Material	Aluminum	0.04370
Suspension	Full	0.02340
Brake Type	Disk	0.03822
Gears	7	0.02185
Seat Type	Soft	0.00855
Total		**0.29472**

Table 13

Scott Sportster 55 Bike		**Score**
Price	$549.00	0.15900
Frame Material	Aluminum	0.04370
Suspension	Front	0.02340
Brake Type	Disk	0.03610
Gears	24	0.01397
Seat Type	Hard	0.00665
	Total	**0.28282**

Table 12

Cannondale Synapse		**Score**
Price	$1749.00	0.04240
Frame Material	Carbon	0.07030
Suspension	None	0.01716
Brake Type	Clamp	0.03276
Gears	20	0.03610
Seat Type	Hard	0.00665
	Total	**0.20537**

As shown in Table 11, the best bike for our experts would be the Novara Big Buzz Bike from REI. Its score is 0.29798 against the adjusted weights.

The manufacturer of Marin Bridgeway FS could look at these values and determine based on the weight-adjusted value for each objective what an influential change would be. In this case, changing the gears to 13 to 18 would increase their bike's score to 0.30422, making it the most desirable bike.

Conclusion

The HDM in the quantification of bicycle features is a valuable resource to select the optimal bike for a commuter or help a manufacturer decide which features are most valuable. The model could be expanded to include more objectives and goals to enhance the selection if our assumptions were relaxed. Our decision model evaluates which bicycle to choose for the criteria selected based on preference of the experts. The "ideal" commuter bike was found to be priced between $301 and $499, has a carbon frame with disk brakes, front suspension, a soft seat, and has 19 or more gears. Our concern is the amount of inconsistency in several of the pairwise comparisons. This should be resolved by the mediation of the experts to reduce the inconsistency.

References

[1] "Portland Bicycle Counts 2008", Internet: http://www.portlandonline.com/shared/cfm/image.cfm?id=217489, Mar. 1, 2011

[2] Dougherty, Conor (May 16, 2009). "'Youth Magnet' Cities Hit Midlife Crisis". The Wall Street Journal. http://online.wsj.com/article/SB124242099361525009.html. Retrieved October 18, 2010.

[3] Winter ETM 530 Slides and Handout, Portland State University, Dundar F. Kocaoglu, 2011

[4] "Bicycles at REI.com" Internet: http://www.rei.com/search?cat=4500003_Bicycles, Mar. 1, 2011.

Appendix A

Table 14, **Basic Item Level**

Expert	Cost	Component	Frame Material	Inconsistency
Sath	0.65	0.28	0.07	0.000
Arvind	0.43	0.30	0.27	0.022
Bennett	0.63	0.29	0.08	0.000
Justin	0.63	0.29	0.08	0.000
Tim	0.33	0.25	0.43	0.005
Mean	**0.53**	**0.28**	**0.19**	**0.125**
Min	0.33	0.25	0.07	
Max	0.65	0.30	0.43	
Std Deviation	0.15	0.02	0.16	

Table 15, **Frame Material**

Users	Steel	Carbon Fiber	Aluminum	Titanium	Inconsistency
Sath	0.35	0.26	0.30	0.10	0.018
Arvind	0.12	0.43	0.20	0.26	0.002
Bennett	0.46	0.17	0.31	0.06	0.010
Justin	0.15	0.44	0.23	0.18	0.055
Tim	0.07	0.56	0.12	0.25	0.021
Mean	**0.23**	**0.37**	**0.23**	**0.17**	**0.127**
Min	0.07	0.17	0.12	0.06	
Max	0.46	0.56	0.31	0.26	
Std Deviation	0.16	0.15	0.08	0.09	

Table 16, **Components**

Users	Suspension	Gear	Brakes	Saddle	Inconsistency
Sath	0.25	0.31	0.29	0.14	0.007
Arvind	0.29	0.23	0.31	0.18	0.027
Bennett	0.11	0.28	0.39	0.22	0.025
Justin	0.22	0.45	0.24	0.09	0.034
Tim	0.26	0.45	0.18	0.12	0.012
Mean	**0.23**	**0.34**	**0.28**	**0.15**	**0.077**
Min	0.11	0.23	0.18	0.09	
Max	0.29	0.45	0.39	0.22	
Std Deviation	0.07	0.10	0.08	0.05	

Table 17, **Cost**

Users	Less than 300	301 to 499	500 to 899	900 and up	Inconsistency
Sath	0.24	0.31	0.33	0.11	0.029
Arvind	0.33	0.32	0.30	0.05	0.076
Bennett	0.31	0.32	0.30	0.07	0.053
Justin	0.31	0.35	0.24	0.10	0.038
Tim	0.28	0.32	0.31	0.09	0.034
Mean	**0.29**	**0.33**	**0.30**	**0.08**	**0.029**
Min	0.24	0.31	0.24	0.05	
Max	0.33	0.35	0.33	0.11	
Std Deviation	0.03	0.02	0.04	0.02	

Table 18, Suspension

Users	Front	Back	Full	None	Inconsistency
Sath	0.20	0.27	0.53	0.00	0.035
Bennett	0.37	0.07	0.05	0.51	0.013
Arvind	0.41	0.10	0.09	0.40	0.190
Tim	0.27	0.19	0.47	0.07	0.009
Justin	0.26	0.28	0.34	0.12	0.003
Mean	**0.30**	**0.18**	**0.30**	**0.22**	**0.167**
Min	0.20	0.07	0.05	0.00	
Max	0.41	0.28	0.53	0.51	
Std Deviation	0.09	0.10	0.22	0.22	

Table 19, **Brakes**

Users	Clamp	Disk	Other	Inconsistency
Sath	0.29	0.71	0.00	0.051
Bennett	0.28	0.58	0.14	0.035
Arvind	0.56	0.27	0.17	0.095
Tim	0.31	0.64	0.05	0.035
Justin	0.65	0.25	0.10	0.006
Mean	**0.42**	**0.49**	**0.09**	**0.164**
Min	0.28	0.25	0.00	
Max	0.65	0.71	0.17	
Std Deviation	0.17	0.21	0.07	

Table 20, **Saddle**

Users	Hard	Soft	Other	Inconsistency
Arvind	0.09	0.65	0.26	0.174
Sath	0.45	0.21	0.34	0.036
Bennett	0.47	0.38	0.16	0.000
Justin	0.45	0.41	0.14	0.029
Tim	0.28	0.58	0.14	0.035
Mean	**0.35**	**0.45**	**0.20**	**0.147**
Min	0.09	0.21	0.14	
Max	0.47	0.65	0.34	
Std Deviation	0.16	0.18	0.09	

Table 21, **Gears**

Users	1 to 6	7 to 12	13 to 18	19 or more	Inconsistency
Sath	0.08	0.28	0.32	0.32	0.032
Arvind	0.05	0.22	0.33	0.39	0.023
Bennett	0.03	0.21	0.30	0.46	0.057
Justin	0.04	0.23	0.32	0.40	0.036
Tim	0.05	0.22	0.39	0.34	0.021
Mean	**0.05**	**0.23**	**0.33**	**0.38**	**0.036**
Min	0.03	0.21	0.30	0.32	
Max	0.08	0.28	0.39	0.46	
Std Deviation	0.02	0.03	0.03	0.05	

Appendix B

Object Weights

Table 22, Cost Weights weight given Object Weight (O.W)

	Less than 300	301 to 499	500 to 899	900 and up
(O.W.) * (Mean)	(0.53)*(0.29)	(0.53)*(0.33)	(0.53)*(0.30)	(0.53)*(0.08)
Calculated	**0.1537**	**0.1749**	**0.159**	**0.0424**

Table 23, Frame Material weight given Object Weight (O.W)

	Steel	Carbon Fiber	Aluminum	Titanium
(O.W.) * (Mean)	(0.19)*(0.23)	(0.19)*(0.37)	(0.19)*(0.23)	(0.19)*(0.17)
Calculated	**0.0437**	**0.0703**	**0.0437**	**0.0323**

Table 24, Components weight given Object Weight (O.W)

	Suspension	Gear	Brakes	Saddle
(O.W.) * (Mean)	(0.28)*(0.23)	(0.28)*(0.34)	(0.28)*(0.28)	(0.28)*(0.07)
Calculated	**0.064**	**0.095**	**0.078**	**0.019**

Components Weights

Table 25, Suspension weight given Object Weight (C.W)

	Front	Rear	Full	None
(C.W.) * (Mean)	(0.078)*(0.30)	(0.078)*(0.18)	(0.078)*(0.30)	(0.078)*(0.22)
Calculated	**0.0234**	**0.01404**	**0.0234**	**0.01716**

Table 26, Brake weight given Components Weight (C.W)

	Clamp	Disk	Other

(C.W.) * (Mean)	(0.078)*(0.42)	(0.078)*(0.49)	(0.078)*(0.09)
Calculated	**0.03276**	**0.03822**	**0.00702**

Table 27, Saddle weight given Components Weight (C.W)

	Hard	**Soft**	**Other**
(C.W.) * (Mean)	(0.019)*(0.35)	(0.019)*(0.45)	(0.019)*(0.20)
Calculated	**0.00665**	**0.00855**	**0.0038**

Table 28, Gears weight given Components Weight (C.W)

	1 to 6	**7 to 12**	**13 to 18**	**19 or more**
(C.W.) * (Mean)	(0.095)*(0.05)	(0.095)*(0.23)	(0.095)*(0.33)	(0.095)*(0.38)
Calculated	**0.00475**	**0.02185**	**0.03135**	**0.0361**