Using a Weighted Objectives Table for Design of a Competition Robot

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Why use a Weighted Objectives Table?

When designing competition robots, teams are faced with many difficult decisions. There are often several different solutions to the challenges presented, and there is usually no clear “correct” solution. Each team must decide what strategy they will use to play the game and how their robot will execute that strategy. On top of that there are often a large number of smaller decisions which will also be part of the robot design. This is not an easy process! To further complicate things, each team must do this in such a way that the individual members all have “buy-in” to the decisions made. One tool to aid in this decision making process is a weighted objectives table (also sometimes referred to as a decision matrix).

What is a Weighted Objectives Table?

A weighted objectives table (WOT) is used as a means of comparing several different alternatives by ranking them based on a list of criteria. The way the table works is that the user pre-ranks the importance of each of these comparison criteria in advance then ranks each design option based on how well it fulfills each of the criteria.

Using a Weighted Objectives Table
Step 1 – List Alternatives

One of the best ways to understand how a WOT works, is to walk through the process of using one. One design challenge a team may face is to design an end-effector to grab a 36” ball.

The first step to solving this design challenge is to come up with several concepts for end-effectors. This is done through brainstorming. For the purposes of this example three options would be a “roller-claw”, a “pinchy-claw” and a “scoop”. These different end-effectors could all be used to pickup the 36” ball, a weighted objectives table can help a designer or team determine which option best suits their needs.

Step 2 – Determine & List Comparison Criteria

The next step is to determine the criteria each of these options will be compared on. To be successful, one must list all the comparisons important to the team. Some criteria are more general and could be used in any number of comparisons, some examples include: Wow-Factor (more is better), Cost (less is better), Complexity (less is better), Reliability (more is better), Weight (less is better), and Effectiveness (more is better). Some criteria are more specific to the comparison, for the ball grabber example above examples might include: Tightness of Grip, Required Driver Precision, Speed of Grab, and Ease of Release. One important comparison criteria might be “achievable with our team’s resources”; sometimes teams will over-reach and run into problems.

The better the job the design team does in coming up with the comparison criteria the more accurately the WOT can be used to evaluate the design alternatives. This can refer to both quantity and quality of comparison criteria!

Step 3 – Layout the Weighted Objectives Table

Once the comparison criteria are determined, the beginnings of the WOT can be constructed. The beginnings of a sample WOT for the ball grabber example can be seen below.

		Roller Claw		Pinchy Claw		Scoop	
Comparison Criteria	Weight	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Cost							
Complexity							
Weight							
Tightness of Grip							
Required Driver Precision							
Speed of Grab							
Total:							

Step 4 – Weight the Comparison Criteria

This is arguably the most important step in constructing a WOT; it is also one of the most difficult. In this step the designer (or design team) will rank each of the Comparison Criteria based on how "important" they are. In some cases, it is a good idea to set a maximum total "cap" for the weights; using this cap will force the user to make difficult choices about the importance of each criteria. In the example below, a cap of 50 was used.

		Roller Claw		Pinchy Claw		Scoop	
Comparison Criteria	Weight	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Cost	5						
Complexity	10						
Weight	5						
Tightness of Grip	5						
Required Driver Precision	15						
Speed of Grab	10						
Total:	50						

In the above example you can see that the design team values a mechanism which doesn't require a high degree of driver precision highest followed by a mechanism which grabs the ball quickly and a low-complexity mechanism.

Step 5 – Gather Information

In order to effectively compare the different design alternatives, it is important for the design team to gather information on each of them to learn how well they fulfill each comparison criteria. In an ideal world, each of the alternatives would be FULLY designed and produced, and then the best design could be chosen; however this is not always an option. It is possible to learn about each alternative without finishing it. For instance to compare each design based on the comparison criteria of “cost” it may be possible to construct a rough bill-of-materials and estimate final costs for each design. This cost won’t be perfect, but will likely be close enough for comparisons sake. One of the most useful ways to gather information on how these designs perform is a simple prototype. Build prototypes of each design alternative and test their performance. Good designers will use the lessons learned from these prototype tests during the next parts of the WOT process.

Step 6 – Score the Design Alternatives

In this step, the designer or design team needs to score the different design alternatives on how well they meet the comparison criteria. In the below example, each alternative is rated out of 5 (1 being the lowest score, 5 being the highest score). It sometimes works best to score all three alternatives at once, based on a single criterion based on differences between them.

		Roller Claw		Pinchy Claw		Scoop	
Comparison Criteria	Weight	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Cost	5	3		3		5	
Complexity	10						
Weight	5						
Tightness of Grip	5						
Required Driver Precision	15						
Speed of Grab	10						
Total:	50						

The example above highlights one such set of scored alternatives. In this case, the design team feels that the Roller Claw and Pinchy Claw both score neutral on the cost scale while the scoop scores very well. Though this is only a hypothetical example, it is still possible to understand these scores; the roller & pinchy claws would have more moving parts than the scoop itself, including expensive motion parts. The alternatives could be ranked based on the other criteria in a similar manner:

		Roller Claw		Pinchy Claw		Scoop	
Comparison Criteria	Weight	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Cost	5	3		3		5	
Complexity	10	3		2		5	
Weight	5	4		2		5	
Tightness of Grip	5	3		5		1	
Required Driver Precision	15	5		3		2	
Speed of Grab	10	4		3		4	
Total:	50						

Step 7 – Calculate the Weighted Scores

Once the scores and weights have been determined it is a simple matter to calculate the weighted scores. Each weighted score consists of the alternative's score multiplied by that comparison criteria's weight. For example the Roller Claw received a score of 3 for Cost, and Cost has a weight of 5: this means the Roller Claw has a weighted score of 3 x 5 = 15, as seen below:

		Roller Claw		Pinchy Claw		Scoop	
Comparison Criteria	Weight	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Cost	5	3	15	3		5	
Complexity	10	3		2		5	
Weight	5	4		2		5	
Tightness of Grip	5	3		5		1	
Required Driver Precision	15	5		3		2	
Speed of Grab	10	4		3		4	
Total:	50						

The other weighted scores are calculated in a similar manner:

		Roller Claw		Pinchy Claw		Scoop	
Comparison Criteria	Weight	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Cost	5	3	15	3	15	5	25
Complexity	10	3	30	2	20	5	50
Weight	5	4	20	2	10	5	25
Tightness of Grip	5	3	15	5	25	1	5
Required Driver Precision	15	5	75	3	45	2	30
Speed of Grab	10	4	40	3	30	4	40
Total:	50						

Step 8 – Find the Total Weighted Score

This is the last step: it is now a simple manner of summing the weighted scores to find the total weighted score for each design alternative, as seen below:

		Roller Claw		Pinchy Claw		Scoop	
Comparison Criteria	Weight	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Cost	5	3	15	3	15	5	25
Complexity	10	3	30	2	20	5	50
Weight	5	4	20	2	10	5	25
Tightness of Grip	5	3	15	5	25	1	5
Required Driver Precision	15	5	75	3	45	2	30
Speed of Grab	10	4	40	3	30	4	40
Total:	50		195		145		175

Analyzing the Results

Often the total weighted scores do not match the designer's preconceptions of which design is "best". That is part of the "magic" of using a WOT to help with design decisions. The fact that each comparison criteria is pre-weighted allows for a more unbiased analysis of how well each design alternative fulfills what is most important to the designer. The results rarely lie (except when the weights or scores themselves are "fudged").

Finding Authentic Results

If a designer has a strong preconceived notion about which alternative "should" win they can rig the process by fudging some of the weights of scores. In order to make this an effective design tool it is important to remain as impartial as possible, and follow the process correctly without any pre-planning. One major way to prevent this from happening is by utilizing a design team. When multiple designers work through this process as a group they are more likely to produce good results.

Variations in WOTs

The steps outlined above are only one way to utilize a WOT in a design process. A WOT can be implemented in many different ways; there is no wrong or right way to use one. In particular, the scoring numbers can be tweaked in a variety of ways.

The weights in the example above utilized an open scale with a max total of 50 while the scores were based on a range of 1-5; these values could be done completely differently. (For example, each Weight *could* be based on a scale of 1-10 and each score based on a scale of 1-3.) Every designer needs to modify the WOT process to make it work for them.

Conclusion

This paper outlines the methods used by the author for utilizing a WOT during a competitive robotics design process. The author makes no warranty on the "correctness" of this approach, only offers it for consideration as an example to others.

As always, your mileage may vary…