Teaching Decision Making with Baseball Examples

J. Eric Bickel
Department of Industrial Engineering
Texas A&M University
3131 TAMU, College Station TX 77843-3131, USA
ebickel@tamu.edu

Abstract

Sports examples can be wonderful vehicles for teaching OR/MS concepts. Baseball is particularly well suited to teaching statistics/probability, Markov decision processes, and decision analysis. This paper details a baseball example I developed to teach fundamental decision making skills. This example has been used successfully to teach decision making to undergraduates and graduates in technical and non-technical disciplines. It has also been used effectively in industry for training new MBAs and seasoned executives.

Editor's note: This is a pdf copy of an html document which resides at http://ite.pubs.informs.org/Vo5No1/Bickel/

1. Introduction

Sports examples can be wonderful vehicles for teaching OR/MS concepts for several reasons. First, their well-defined structures and rules lend themselves to quantitative analysis. Second, most students can immediately relate to a sports example because they have either participated in or watched many sporting events. This is not always the case with other examples (e.g., newspaper boy). Finally, sports examples are enjoyable, and students learn more effectively when they are having fun.

Baseball is a strategic and mentally challenging game. No one has said it better than Roger Kahn (2000) when he defined baseball as "chess at 90 miles per hour." Baseball is particularly well suited to probabilistic and decision analysis. Examples can be created to teach basic probability/statistics, probabilistic systems, Markov decision processes, simulation, and decision analysis.

This paper gives an overview of a baseball example I developed while a graduate student in the Department of Engineering-Economic Systems at Stanford University[(1)]. I have been very successful teaching decision making with this example to technical and non-technical audiences. At Stanford, I used this example with MS and PhD students. These students came from diverse cultural backgrounds and were generally quite comfortable with advanced mathematical techniques, but may not have been familiar with Markov processes. While the Stanford audience is quite technical, an advanced technical degree is certainly not required. At Strategic Decisions Group[(2)], I used this example many times during new consultant orientation, which was comprised mostly of MBAs. I am currently simplifying this example to teach decision-making skills to gifted and at-risk teenagers through the Decision Education Foundation[(3)]. Therefore, I believe this example can be adjusted to fit many different audiences. Markov process modeling is the most complicated concept and can be deemphasized or eliminated if desired. Conversely, one could expand this aspect of the case for specific OR/MS audiences. In this paper I focus on using baseball to teach decision-making and decision analysis skills-not Markov processes.

As mentioned above, the feedback to this example, while informal, has been quite positive. Most students,

(1) Now the Department of Management Science and Engineering http://www.stanford.edu/dept/MSandE/
(2) http://www.sdg.com
(3) http://www.decisioneducation.org

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consultants, and executives have told me that this example helped to deepen not only their understanding of decision analysis in particular, but their appreciation for quantitative analysis in general. Students can immediately see how OR/MS thinking improves their understanding in a domain with which they are most likely familiar. This "new insight into an old situation" is quite powerful for students and helps to make the example both effective and memorable.

As an instructor, I have found that this example cements understanding of fundamental decision analysis concepts and excites the students about the field in general. Students seem to be energized after the demonstration and participation in future lectures in increased.

I introduce this example after the students have been exposed to basic decision analysis concepts (e.g., decision trees, probabilistic structuring, and tree roll-back). The students need not have an understanding of utility theory or its axioms, because, as the reader will see, the objective is to simply maximize the probability of winning.

My biggest concern with the use of this example was the audience's prior understanding and exposure to baseball. I was particularly worried about using this example with students from countries where baseball is not a significant sport. To address this concern, I offer "just in time" baseball training, some of which is covered in §2. In addition to the material in §2, I describe several types of baseball "plays" (e.g., the steal, sacrifice, bunt, and intentional walk). My experience has been that this level of training is sufficient for the audience (even an international one) to appreciate and understand the example, which is fundamentally about decision making-not baseball. That being said, other instructors should be cautious when developing examples such as these for audiences that lack a baseball background. The interested reader can find the definitions of many baseball terms on the Major League Baseball (MLB) website[(4)].

2. Baseball Primer

Before discussing the example, a brief explanation of several baseball terms will help with what follows. According to the official rules of MLB[(5)], "baseball is a game between two teams of nine players each, under direction of a **manager**..." The manager is responsible for making all strategic decisions during a game. In the language of OR/MS, the manager is the decision maker. An **inning** is the portion of a game within which the teams alternate on offense (batting-trying to score) and defense (fielding-trying to prevent scoring) and in which there are three **putouts** for each team. Each team's time at bat is a **half-inning**. The winner of a baseball game is the team that has scored the most runs at the end of regulation play, which is nine innings-unless the game is shortened due to weather or extended because of a tie after nine innings of play. MLB specifies that the **home team** "is the team on whose grounds the game is played, or if the game is played on neutral grounds, the home team shall be designated by mutual agreement." The home team bats after the visiting team[(6)].

During the case study, my students and I analyze the decision making of the offensive and defensive teams during a single half-inning of play. In particular, I use an example from the bottom of the ninth inning. For a reason to be made clear later, baseball becomes more strategic as the game progresses and the bottom of the ninth inning in a close game is particularly interesting.

3. The Setup

The example that follows is a game played between the Houston Astros (home team) and the Atlanta Braves (visiting team) on July 20, 1996. The Astros are coming to bat in the bottom of the ninth inning. The game is currently tied 1-1. Pitching for the Braves is Greg Maddux, who is right handed. At the time, Maddux was the best pitcher in baseball and arguably the best pitcher of our generation. Going into the ninth inning, Maddux has only allowed two hits, both in the first inning. Behind the plate for the Braves is Javy Lopez, an excellent catcher.

(4) http://mlb.mlb.com/NASApp/mlb/mlb/official_info/baseball_basics/on_the_field.jsp
(5) http://www.mlb.com/NASApp/mlb/mlb/official_info/official_rules/foreword.jsp
(6) This rule was not official until 1950

Table 1 displays the Astros' batting order and relevant statistics.

Table 1: Performance Statistics for the Astros.

Astros Lineup					
Lineup Spot	**Player**	**Bat Hand**	**AVG**	**AVG vs *RHP***	**SB%**
1	Cangelosi	S	0.248	0.261	0.73
2	Biggio	R	0.285	0.271	0.5
3	Bagwell	R	0.306	0.302	0.71
4	Bell	R	0.291	0.280	0.77
5	May	L	0.282	0.284	0.73
6	Miller	R	0.269	0.290	0.50
7	Spiers	L	0.254	0.244	0.66
8	Wilkins	L	0.254	0.268	0.50
9	Pitcher	L	-	-	-

Astros Bench					
	Player	**Bat Hand**	**AVG**	**AVG vs *RHP***	**SB%**
	Berry	R	0.280	0.290	0.74
	Mouton	R	0.253	0.212	0.79

Explanation of Terms	
R	Right-Handed Batter
L	Left-Handed Batter
S	Switch Hitter (L or R)
AVG	Batting Average (Hits per At-Bat)
	Indication of Ability to Get a Hit
AVG vs RHP	AVG vs Right-Handed Pitchers
SB%	Stolen Base Success Rate

The Astros' manager is Terry Collins. At the helm for the Braves is Bobby Cox.

During the demonstration a limited set of defensive and offensive decisions is analyzed. Specifically, for the defensive team (Braves) the decision of whether or not to pitch to or intentionally walk the current batter is evaluated. For the offensive team (Astros) the decision of whether to hit away or sacrifice bunt, attempt to steal second base, third base and home plate is analyzed.

I begin the demonstration with a brief discussion of how a baseball game can be modeled. This background is provided so that the students understand the source (and the limitations) of the probabilities we use. I then describe the current situation. As the inning evolves, I analyze particular situations. I have the students tell me what they would do in this situation and describe what the major league managers actually do.

4. Modeling the Game

Baseball can be profitably modeled as a Markov process. Groundbreaking examples include Bellman (1977), Howard (1977) and Trueman (1977). More recently Bukit (1997) developed a Markov process to determine the optimal batting order and calculate the probability of winning. Typical Markov states include the number of outs, the inning, the score, the location of runners on base, the pitch count, etc.

Lindsey (1959, 1961, 1977) was among the first to apply OR/MS techniques to baseball strategy. Based on historical study of actual major league baseball games and an underlying probabilistic model, Lindsey calculated the probability that either team would eventually win the game given a particular lead at the end of an inning. Figure 1 details Lindsey's results for odd number innings[7].

		Inning								
	Runs	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
	-14	0	0	0	0	0	0	0	0	0
	-13	0	0	0	0	0	0	0	0	0
	-12	0.001	0.001	0	0	0	0	0	0	0
	-11	0.002	0.002	0.001	0	0	0	0	0	0
	-10	0.005	0.004	0.002	0.001	0	0	0	0	0
	-9	0.010	0.009	0.005	0.002	0.001	0	0	0	0
	-8	0.020	0.017	0.010	0.006	0.003	0.001	0	0	0
	-7	0.036	0.032	0.021	0.014	0.009	0.004	0.002	0	0
	-6	0.061	0.055	0.039	0.029	0.020	0.012	0.005	0	0
	-5	0.095	0.087	0.067	0.053	0.038	0.025	0.013	0.004	0
	-4	0.142	0.133	0.109	0.091	0.070	0.050	0.029	0.011	0
	-3	0.207	0.196	0.171	0.150	0.122	0.093	0.060	0.025	0
	-2	0.290	0.280	0.257	0.236	0.207	0.168	0.122	0.063	0
	-1	0.389	0.383	0.368	0.353	0.331	0.295	0.244	0.153	0
Difference	**0**	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500
	1	0.610	0.617	0.630	0.647	0.668	0.705	0.756	0.846	1
	2	0.710	0.720	0.741	0.764	0.793	0.831	0.878	0.936	1
	3	0.793	0.803	0.827	0.849	0.877	0.907	0.940	0.974	1
	4	0.857	0.867	0.889	0.908	0.930	0.949	0.970	0.987	1
	5	0.905	0.913	0.932	0.947	0.961	0.974	0.987	0.995	1
	6	0.939	0.944	0.959	0.970	0.979	0.988	0.994	0.998	1
	7	0.964	0.968	0.979	0.986	0.991	0.996	0.998	1	1
	8	0.980	0.983	0.990	0.994	0.997	0.999	1	1	1
	9	0.990	0.992	0.996	0.998	0.999	1	1	1	1
	10	0.995	0.996	0.998	0.999	1	1	1	1	1
	11	0.998	0.998	0.999	1	1	1	1	1	1
	12	0.999	0.999	1	1	1	1	1	1	1
	13	1	1	1	1	1	1	1	1	1
	14	1	1	1	1	1	1	1	1	1

[7] Lindsey's limited his results to a range of +/- 6 runs. I have extended Lindsey's results using simple curve fitting.

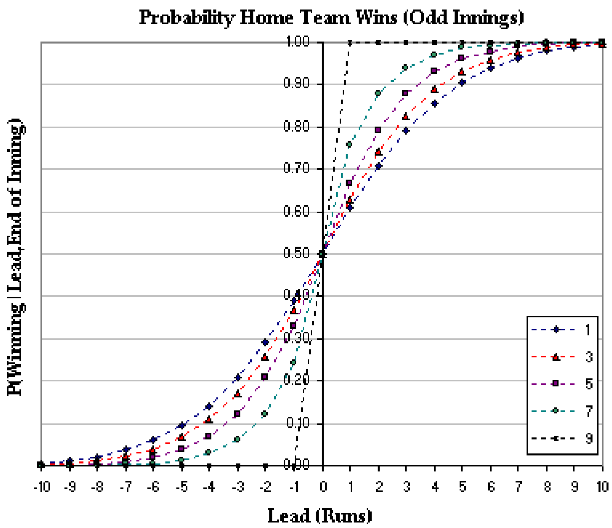

Figure 1: Probability the Home Team Wins, Given the Run Difference at the End of an Inning.

If a professional baseball game is tied at the end of the ninth inning, the game goes into extra innings. Lindsey assumed that either team was equally likely to win an extra inning game. If the analysis is limited to the bottom of the ninth inning (or extra inning) games, the only probability assessment required is the probability of eventually winning if the game is tied--since the probability of winning is either 0 or 1 if the home team is behind or ahead at the end of the inning.

Notice that in the first inning, the probability of winning is an almost linear function of the lead between a run differential of -/+ 4 runs, which would be a considerable number of runs to score in a single inning. This means that in the first inning the objective of maximizing expected runs is nearly equivalent to maximizing the probability of winning. However, as the game progresses the relationship degrades. In fact, by the ninth inning, a lead (or deficit) of more than a run is no better (or worse) than a single run (i.e., it does not matter by how many runs you win). The types of strategies that maximize expected runs may not be the same as those that maximize the probability of winning late in the game. It is for this reason that baseball strategy changes as the game progresses and becomes most interesting late in the game. At this point in the demonstration, I highlight the first learning I want students to take away. In any decision situation, you must clearly state your objective. Different objectives have different implications for action. The objective of baseball is to win, not to score runs.

In order to analyze strategies *within* an inning, Lindsey's data must be supplemented with a run-scoring model. Such a model allows us to calculate a distribution for the number of runs scored in the remainder of an inning, given the current base state, number of outs, position in the lineup, etc. My scoring model is based on the model developed by Howard (1977). For the purposes of this demonstration, I assume all batters are identical and only focus on the outs and base state.

The output of this model for the first and ninth innings, combined with Lindsey's data, is shown in Figure 2.

		Bases Occupied			Prob Home Team Vins Given Inning (Game Tied)								
Base State	Outs	First	Second	Third	1st	2nd	3rd	4th	5th	6th	7th	8th	9th
None	0	No	No	No	0.549	0.551	0.556	0.561	0.567	0.576	0.587	0.604	0.607
1st	0	Yes	No	No	0.584	0.587	0.594	0.602	0.611	0.624	0.641	0.664	0.677
2nd	0	No	Yes	No	0.606	0.611	0.620	0.631	0.644	0.664	0.690	0.729	0.771
1st & 2nd	0	Yes	Yes	No	0.638	0.643	0.654	0.666	0.680	0.699	0.722	0.755	0.782
3rd	0	No	No	Yes	0.635	0.642	0.655	0.671	0.690	0.719	0.759	0.822	0.914
1st & 3rd	0	Yes	No	Yes	0.668	0.675	0.689	0.705	0.725	0.754	0.791	0.849	0.904
2nd & 3rd	0	No	Yes	Yes	0.688	0.696	0.712	0.729	0.750	0.777	0.812	0.859	0.914
Bases Loaded	0	Yes	Yes	Yes	0.709	0.716	0.732	0.748	0.767	0.791	0.820	0.860	0.908
None	1	No	No	No	0.527	0.528	0.530	0.533	0.537	0.542	0.549	0.560	0.562
1st	1	Yes	No	No	0.550	0.552	0.557	0.561	0.568	0.576	0.587	0.603	0.608
2nd	1	No	Yes	No	0.570	0.573	0.580	0.588	0.598	0.613	0.632	0.663	0.698
1st & 2nd	1	Yes	Yes	No	0.591	0.595	0.603	0.611	0.621	0.636	0.654	0.680	0.696
3rd	1	No	No	Yes	0.596	0.601	0.611	0.623	0.638	0.661	0.693	0.745	0.821
1st & 3rd	1	Yes	No	Yes	0.613	0.618	0.629	0.641	0.655	0.677	0.705	0.750	0.815
2nd & 3rd	1	No	Yes	Yes	0.635	0.641	0.653	0.667	0.683	0.706	0.735	0.777	0.822
Bases Loaded	1	Yes	Yes	Yes	0.654	0.660	0.672	0.685	0.701	0.723	0.750	0.789	0.825
None	2	No	No	No	0.510	0.510	0.511	0.513	0.514	0.516	0.519	0.524	0.525
1st	2	Yes	No	No	0.520	0.521	0.523	0.525	0.528	0.532	0.537	0.543	0.542
2nd	2	No	Yes	No	0.534	0.536	0.540	0.544	0.549	0.558	0.569	0.587	0.608
1st & 2nd	2	Yes	Yes	No	0.545	0.547	0.551	0.556	0.561	0.570	0.581	0.597	0.609
3rd	2	No	No	Yes	0.539	0.541	0.545	0.550	0.556	0.566	0.580	0.602	0.628
1st & 3rd	2	Yes	No	Yes	0.549	0.551	0.555	0.561	0.567	0.577	0.590	0.609	0.629
2nd & 3rd	2	No	Yes	Yes	0.561	0.564	0.570	0.576	0.583	0.593	0.605	0.621	0.629
Bases Loaded	2	Yes	Yes	Yes	0.577	0.580	0.586	0.593	0.602	0.613	0.627	0.646	0.641
None	3	No	No	No	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500	0.500

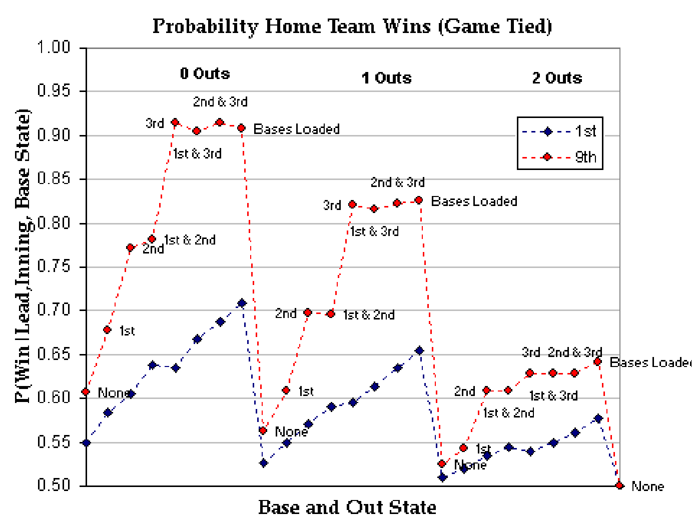

Figure 2: Probability the Home Team Wins, Given Base, Out and, Inning State.

Figure 2 displays the probability that the home team eventually wins the game, if they are currently tied, given the out/base state. For example, with bases loaded and no out in the first inning, the home team has a 70.9% chance of eventually winning the game. The probability the home team wins given the same situation in the ninth inning is 90.8%. Many students ask why in the ninth inning a runner on third base with no outs is better than any of the other states with a runner on third base and at least one other base occupied (e.g., runner on first and third or bases loaded). Aren't more runners always better? No! Again, we must be clear about the objective. The goal is to win and additional runners do not help if the runner on third scores. In fact, the additional runners make the home team susceptible to a double play (two outs on a single play), or the easier to complete force-out at home if the bases are loaded (1^{st}, 2^{nd} and 3^{rd} base occupied). This reasoning is why it is common for a visiting team to issue an intentional walk when the home team has a runner on third base or runners on second and third with less than two outs in the ninth (or any subsequent) inning.

Another interesting feature of Figure 2 is the fact that the probability the Astros win the game when they come up to bat in the ninth inning is 60.7%, not 50%. Why? This is because the Braves have already had their turn at bat in the top of the ninth inning. If the Astros score a single run they win the game.

Interested readers can find all the data underlying Figures 1 and 2, and other innings, by following this link[(8)].

Before proceeding, I should note that another source for the probabilities in Figure 2 is a recent study by Birnbaum (2003[(9)]). Birnbaum used Retrosheet[(10)] data from 1974 to 1990 to estimate the probability of winning for the home/visiting team for each base/out/inning state[(11)]. Some instructors may prefer to use this source to avoid the discussion of Markov processes. However, because some situations occur infrequently, the standard error in Birmbuam's estimates can be quite large.

5. On to the Ninth

I spend about 60 minutes on this demonstration. Therefore, space does not permit me to detail the entire half-inning here. However, by analyzing a few game situations I hope the reader will get the general feel for how the demonstration progresses.

Situation 1: 0 Out, None On, Astros Pitcher Coming to Bat, P(Astros Win) = 60.7%
Pitchers are notoriously poor hitters. Given that the Astros desperately need base runners, they decide to bring in another batter (a "pinch hitter") to hit for the pitcher. The person they select is Berry (AVG vs RHP = .290, which is very good). Berry proceeds to hit a single, increasing the probability the Astros win to 67.7%.

Situation 2: 0 Out, Berry on First, Cangelosi At Bat, P(Astros Win) = 67.7%
According to Figure 2, the Astros would increase their chance of winning to 77.1% if they could move the runner from first to second. Berry, being a slow runner, is replaced with a "pinch runner" by the name of James Muton. Muton has the highest stolen base percentage on the Astros' bench.

Since Figure 2 does not include a state for base runners, the probability of winning does not change. This is a modeling simplification. A more detailed model and example could be created to illustrate this.

This brings Cangelosi (.261), an excellent bunter, to the plate.

Situation 3: 0 Out, Muton on First, Cangelosi At Bat, P(Astros Win) = 67.7%
Now things really get interesting. Collins, the Astros' Manager, has the following three alternatives:

1. **Hit Away.** Allow Cangelosi to hit away, with the hope that he will be able to advance Muton. The risk of this strategy is that he might hit into a double play or make any other type of out without advancing Muton along the bases (e.g., a strikeout).

(8) http://ite.pubs.informs.org/Vol5No1/Bickel/Figures.xls
(9) http://www.philbirnbaum.com/btn2003-02.pdf
(10) http://www.retrosheet.org
(11) http://www.philbirnbaum.com/winprobs.txt

2. **Steal Second.** Have Muton attempt a steal of second base. This means that while the pitcher is delivering the ball to plate, Muton runs to second base. If he makes it before being thrown out by the catcher, he is safe. The Astros would then have a runner on second base with no outs, and their probability of winning would increase to 77.1%. However, if Muton is thrown out, the Astros would have no runners on base with one out, and a corresponding win probability of 56.2%.

The weapon that the defense has to prevent the steal is called the pitch out, in which case the pitcher intentionally throws the ball where the batter cannot hit it, and the catcher quickly throws the ball to second base.

3. **Sacrifice.** To execute the sacrifice, Cangelosi bunts the ball (a very light type of hit). While the fielders are pursuing the bunt, Muton advances to second base. In the case of a successful sacrifice, Cangelosi is thrown out a first (we ignore the case where he reaches base safely). If this happens, the Astros have a runner at second base with one out and a 69.8% chance of winning. The risk in this strategy is that the fielders might be able to throw out Muton instead. In this case the Astros would still have a runner at first (Cangelosi) but with one out. Their chance of winning would fall to 60.8%.

There is very little the Braves can do to keep the Astros from attempting a sacrifice. They can however, position their defense in such a way to make it more likely that they throw Muton out.

Base State	Outs	Bases Occupied First	Second	Third	P(Win) 9th
None	0	No	No	No	0.607
1st	0	Yes	No	No	0.677
2nd	0	No	Yes	No	0.771
1st & 2nd	0	Yes	Yes	No	0.782
3rd	0	No	No	Yes	0.914
1st & 3rd	0	Yes	No	Yes	0.904
2nd & 3rd	0	No	Yes	Yes	0.914
Bases Loaded	0	Yes	Yes	Yes	0.908
None	1	No	No	No	0.562
1st	1	Yes	No	No	0.608
2nd	1	No	Yes	No	0.698
1st & 2nd	1	Yes	Yes	No	0.696
3rd	1	No	No	Yes	0.821
1st & 3rd	1	Yes	No	Yes	0.815
2nd & 3rd	1	No	Yes	Yes	0.822
Bases Loaded	1	Yes	Yes	Yes	0.825
None	2	No	No	No	0.525
1st	2	Yes	No	No	0.542
2nd	2	No	Yes	No	0.608
1st & 2nd	2	Yes	Yes	No	0.609
3rd	2	No	No	Yes	0.628
1st & 3rd	2	Yes	No	Yes	0.629
2nd & 3rd	2	No	Yes	Yes	0.629
Bases Loaded	2	Yes	Yes	Yes	0.641
None	3	No	No	No	0.500

I then show the students the range of outcomes graphically, as in Figure 3.

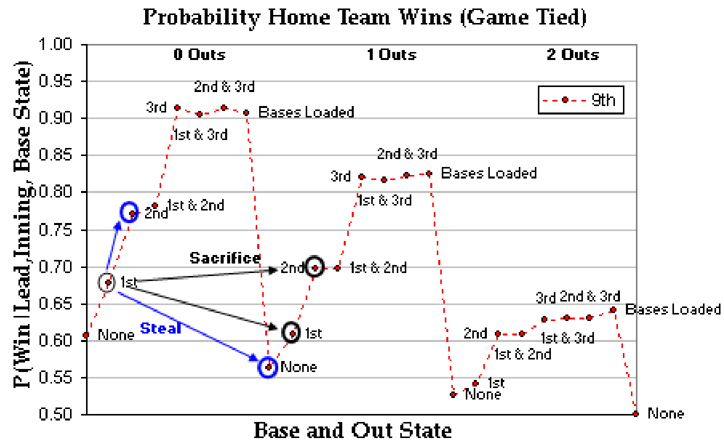

Figure 3: Range of Outcomes for the Steal and Sacrifice

Collins, the Astros' manager, faces a classic tradeoff. The steal is clearly the more risky alternative--having both the most upside and downside. The sacrifice, on the other hand, is the safety first strategy. It gives up the upside of advancing a runner without incurring an out in exchange for limiting the downside risk of giving up an out *and* losing a base runner. **The learning I want the students to take away is that quantitative analysis makes this tradeoff clear and deepens our understanding of the situation.**

What should Collins do? At this point I introduce the concept of decision trees and lay out the situation as shown in Figure 4.

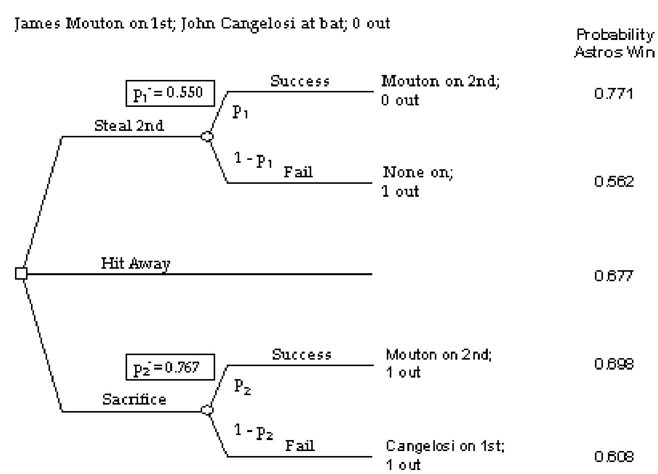

Figure 4: Figure 4. Astros' Decision Tree.

The alternative Collins should choose depends on his assessment of p1 (probability of a successful steal) and p2 (probability of successful sacrifice). The only problem is we do not know his assessment of these probabilities. We can, however, calculate the breakeven probability above which Collins would prefer the steal or sacrifice to hitting away. For example, if p1 were above (below) 0.550 then the steal would be preferable to (worse than) hitting away. Likewise, if p2 were above (below) 0.767 then the sacrifice would be better (worse) than hitting away.

Students can substitute in their own assessments for p1 and p2 to determine what they would do in this situation. My own personal assessment, given that Cangelosi is an excellent bunter, is that p2 = 0.85. Likewise, the Braves' catcher (Lopez) is very good at throwing out runners, and therefore, I believe p1 = 0.55. Based on these assessments, I would sacrifice in this situation.

The learning I want the students to take away is that there is no right answer. **The best course of action depends upon the decision maker's beliefs and reasonable people can disagree.**

After this discussion, I ask the students what they would do. In this case, Collins decided to have Cangelosi sacrifice, and it was successful, increasing the chance the Astros win to 69.8%.

Craig Biggio (.271) comes to bat next. He grounds out to the second baseman, but advances Muton to third base. The Astros' probability of winning has fallen to 62.8%. How can that be? The Astros now have a runner on third base and are only 90 feet from scoring the winning run. The additional out was more costly to the Astros than the benefit of advancing the base runner. This insight tends to be lost on the common baseball fan.

The mighty Jeff Bagwell (.302) now comes to the plate.

Situation 4: 2 Out, Muton on Third, Bagwell At Bat, P(Astros Win) = 62.8%

At this point in the game, the Braves manager (Bobby Cox) walks to the pitcher's mound to meet with Maddux and Lopez. The three of them have an extended conversation. Cox walks away, comes back, talks some more, spits, and scratches his head. He really seems to be thinking hard about something. What is it?

The Braves face a difficult decision. Should they pitch to Bagwell or intentionally walk him? Walking Bagwell would bring up the less threatening Bell (.280), but why would you ever intentionally allow a batter to reach base?

Let's look back at Figure 2. If there were no outs, intentionally walking the batter so that there were runners on first and third would lower the home team's chance of winning. This occurs because the runner on first sets up possibility of a double play. In the case of two outs (the current situation), the benefit is less clear.

Currently the Braves have a 37.2% chance of winning (1 - 62.8%). If they walk Bagwell they will face a situation of two outs with runners on first and third. The chance they will win the game in this case is 37.1% (1 - 62.9%). For all practical purposes, there is no difference between these two situations, ignoring the difference between Bagwell and Bell as hitters (both are very good, but "Bags" is a bit better). Yet, the Braves really think this through. The point I make to my students is that **many times decisions are difficult because there is little difference in value between the alternatives. When this is the case, it is difficult to discern which alternative is best. Yet, at the same time, it makes little difference what we do. Make the decision and move on!**

Eventually the Braves do decide to walk Bagwell and face Bell. At this point, I ask students if Cox made a good decision. The class generally agrees that while the alternatives were close, Cox made the right call because Bagwell is a better hitter than Bell.

On the next pitch, Bell hits a single up the middle, and the Braves lose to the Astros by the score of 2-1.

Now I make the final and most important point--the **distinction between a decision and an outcome.** I remind the class that we already passed judgment on Cox's decision. The only additional piece of information we have now is the outcome. **You can make a good decision and still have a bad outcome.** This concept is lost on television announcers who, as usual, criticize or praise the manager based on the outcome.

6. Conclusion

Sports examples can be wonderful vehicles for teaching OR/MS concepts. Baseball is particularly well suited to probabilistic and decision analysis. Examples can be created to teach basic probability/statistics, probabilistic systems, Markov decision processes, simulation, and decision analysis.

The demonstration discussed in this paper has been used quite successfully to teach fundamental decision-making concepts to engineers, MBAs, and executives.

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