Determining the Value of a Baseball Player

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6/1/2012

Abstract

Baseball is a game of numbers, and there are many factors that impact how much an individual player contributes to his team's success. Using various statistical databases such as Lahman's Baseball Database (Lahman, 2011) and FanGraphs' publicly available resources, we compiled data and manipulated it to form an overall formula to determine the value of a player for his individual team. To analyze the data, we researched formulas to determine an individual player's hitting, fielding, and pitching production during games. We examined statistics such as hits, walks, and innings played to establish how many runs each player added to their teams' total runs scored, and then used that value to figure how they performed relative to other players. Using these values, we utilized the Pythagorean Expected Wins formula to calculate a coefficient reflecting the number of runs each team in the Major Leagues scored per win. Using our statistic, baseball teams would be able to compare the impact of their players on the team when evaluating talent and determining salary.

Focusing Question

Our investigation's original focusing question was "How much is an individual player worth to his team?" Over the course of the year, we modified our focusing question to: "What impact does each individual player have on his team's performance over the course of a season?" Though both ask very similar questions, there are significant differences between them. Our original question was intentionally vague because we were still in the first stages of our investigation and were unsure about exactly what direction we would take. As our investigation progressed, we developed a better idea of what we actually intended to accomplish through our study. We eventually selected the latter question because our investigation's emphasis fell on each player's personal contribution to their team's performance rather than their monetary worth.

Introduction

In the world of baseball today, there are innumerable statistics that measure nearly every aspect of an individual's on-field performance. Whether one is interested in a statistic measuring a hitter's on-base percentage, a pitcher's strikeout-to-walk ratio, or even an individual's aesthetic value, there is most likely a formula or recording present in the world of sabermetrics. Sabermetrics is the objective study of baseball using uniformly gathered statistics. This term is derived from the Society for American Baseball Research (SABR). Using various quantifiable statistics, sabermetrics allows people to objectively compare players to one another (Albert, n.d.).

One of these statistics is known as Wins Above Replacement (WAR). WAR is generally considered the overarching sabermetric statistic due to its culmination of all raw data into one coherent value in terms of wins above a replacement player. The current formula evaluates wins above replacement by computing Runs Created from an offensive, defensive, and pitching standpoint. However, what even is a replacement player?

The idea of a replacement player was defined in *The Book: Playing the Percentages in Baseball* by Tom Tango (Tango, Lichtman, Dolphin 2007). He introduces the concept as a means of comparing players to one another, statistically speaking. Although these replacement players are generally spoken of in theoretical terms, the definition that Tango produces is that a replacement player is an easily replaceable back-up for any Major League player. This theoretical player is identified as a "AAAA" caliber player. In other words, he is essentially trapped between the Triple-A minor league system team affiliated with a Major League team and the actual Major League team itself. Another aspect of a replacement player is that they are worth the league minimum wage of $414,000 per year. According to speculation on a Fangraphs Article by Steve Slowinski (n.d.) detailing a replacement player, we came to the conclusion that a team filled with replacement level players would theoretically win 48 games in a 162-game season.

Methods and Process

Bill James, one of the most influential statisticians in sabermetrics history, wrote, "With regard to an offensive player, the first key question is how many runs have resulted from what he has done with the bat and on the basepaths. Willie McCovey hit .270 in his career, with 353 doubles, 46 triples, 521 home runs and 1,345 walks -- but his job was not to hit doubles, nor to hit singles, nor to hit triples, nor to draw walks or even hit home runs, but rather to put runs on the scoreboard. How many runs resulted from all of these things?" (Tango, Lichtman, Dolphin 2007)

The concept of offensive runs created completely embodies this statement (Albert, n.d.). It essentially multiplies an individual's on-base factors by his advancement of his teammates already on-base. Then, that product is divided by the number of opportunities that that individual had in order to make his contributions. Bill James (1985) combined all of these factors in his offensive runs created formula:

$$RC = \frac{(H + BB - CS + HBP - GIDP) \times \left(TB + \left(0.26 \times (BB - IBB + HBP)\right) + \left(0.52 \times (SH + SF + SB)\right)\right)}{AB + BB + HBP + SH + SF}$$

Offensive Runs Created is calculated by inputting the raw data points into this formula. See Table 1 for the abbreviation meanings. We want to evaluate the expected runs created of a replacement player in order to determine the Value Over Replacement Player (VORP). In order to compute these values, we need to determine the league average for Runs Created per Outs. Runs Created per Out is a value that finds a player's expected runs created per out recorded. Then, we average the Runs Created per Out for each player that had a minimum of 30 plate appearances. We chose 30 plate appearances in order to get a significant amount of data in order to ensure an accurate representation of an individual's performance. The league average for Runs Created per Out was 0.132 across the entire Major Leagues. Then, we multiplied this by the replacement level, which we determined to be approximately 86.7% of the league average. We will delve further into the replacement-level later in this investigation paper. However, a replacement player is expected to create approximately 0.114 Runs per Out. In order to evaluate the Runs Created of a replacement player, we multiplied the specified individual by the number of outs. If a player had a Runs Created per Out over this 0.114 Runs Created per Out of a replacement player, then his value would be higher considering he added more Runs Created in the same amount of opportunities. In order to determine VORP, we must subtract the Runs Created by a replacement player from the Runs Created of that individual. Therefore, VORP is a measure of Runs Created above a replacement player. This process is demonstrated in Table 2. However, we still need to configure VORP for pitchers.

Offensive Runs Created is fairly straightforward, but it is imperative to remember that players have to play on both offense and defense. On the other hand, the concept of defensive runs created is a bit more abstract than its offensive counterpart. In fact, it is less a measure of how many runs they created and more of the number of runs that they allowed to be scored against their team. It did not take us long to determine that it was futile to even attempt to evaluate a fielder's defensive contribution, because defensive statistics such as errors mainly depend on subjective determinations of how a fielder performed versus how he should have performed. Defensive Runs Saved and Ultimate Zone Rating are two common fielding statistics used in sabermetrics. However, we decided to avoid the fielding contributions due to inconsistencies in the calculations. In fact, the only defensive players that have objective, uniform data are the pitchers; as a result, we decided to only evaluate pitchers' performances and measure only the other eight players' offensive contributions. At first, we considered manipulating Bill James' runs created formula to determine the runs created against a pitcher, but we quickly realized that most of the reverse statistics required, including steals allowed, total bases against, etc. Therefore, we had to use an individual pitcher's Earned Run Average (ERA) and evaluate the runs saved over a replacement player.

First, we had to determine the Runs Allowed (RA) of a pitcher for a specified time period. We were able to calculate this by multiplying the ERA by the number of innings pitched. We then found the league average for ERA by dividing the total Innings Pitched by the total number of Outs. Using the league average ERA, we were able to compute the replacement-level ERA by dividing this value by 0.867, or 86.7%. The league average ERA in 2011 was approximately 3.94. In other words, there were approximately 3.94 runs given up every nine innings pitched across the Major Leagues in 2011. If we divide this value by 0.867, the replacement-level ERA is approximately 4.55. Comparable to our procedure in the offensive portion, we must calculate the VORP by subtracting the Runs Allowed of an individual player from the theoretical Runs Allowed of a replacement player. This value, considered VORP, is actually Runs Saved over a replacement player.

We used our VORP determinations along with another formula produced by Bill James, which helps us to find a team's expected win percentage.

$$\boldsymbol{Win}\,\% = \frac{\boldsymbol{runs\ scored^2}}{\boldsymbol{runs\ scored^2 + runs\ allowed^2}} = \frac{\mathbf{1}}{\mathbf{1} + \left(\boldsymbol{runs\ allowed}/\boldsymbol{runs\ scored}\right)^2}$$

This formula, called the Pythagorean Expectancy (James, 1985), solves for the winning percentage of a team using the total team's Runs Scored and Runs Allowed. We used this formula in order to calculate the Expected Wins Above Replacement (xWAR), which is essentially the wins of a team without that player as seen in Table 3. Using the VORP for both pitchers and hitters, we were able to figure the expected wins of the team without that individual. For hitters, we subtracted their VORP values from the team's Runs Scored.

$$xWAR = \frac{162}{1 + (RA/RS)^2} - \frac{162}{1 + (RA/RS - VORP)^2}$$

Essentially, this predicts the number of wins a team would have had without that player. We subtract this value from the Pythagorean Expectation with that player in order to determine the xWAR. For pitchers, this process is altered slightly due to the fact that pitchers have a Runs Saved value instead of a Runs Created VORP.

$$xWAR = \frac{162}{1 + (RA/RS)^2} - \frac{162}{1 + (RA + VORP/RS)^2}$$

Therefore, the VORP of the pitcher is added to the Runs Allowed of the team, seeing as a replacement player would have allowed more runs than that individual (assuming the individual is above replacement level). Then, this calculated value of expected wins without the player is subtracted from the expected wins with that player to determine xWAR.

We now have two values: VORP and xWAR. The VORP represents the Runs Created of an individual over a replacement player, and the xWAR represents the number of theoretical wins a player would have contributed. Both of these values have been computed through use of raw data. The final step in our procedure is to determine the Runs Created per Win. We can find this coefficient, which is dependent on each individual, by dividing the VORP by the xWAR. This coefficient is anywhere in a range of about 7 to 12 Runs Created required per win above replacement. Therefore, the VORP divided by the xWAR is this newfound coefficient. This coefficient displaces the idea that ten runs is equivalent to one WAR. The VORP must be divided by this coefficient in order to determine the true value of a baseball player. We can calculate this coefficient on an individual basis or on a team basis. To determine a team coefficient, we must weigh the coefficients either by the outs recorded or the number of innings pitched and averages the values for the entire team. The team coefficient represents the number of runs required for one win above replacement. The VORP is in Runs Created and the coefficient is essentially the runs required per win above replacement. Therefore, we can accurately represent the value of a baseball player to his specific team.

Conclusion

A number of conclusions can be drawn as results of our investigation. One of these is that we have created a brand new formula for determining wins above replacement. Our formula outputs values for players that are generally removed from other sources' calculations, though ours is arguably more accurate. Although we calculated theoretical WAR, we decided to focus on the methodology behind our investigation instead. For reference, however, one can view our calculations for WAR in 2011 in Figure 1.

The argument for the improved accuracy of our new formula' is backed up by the fact that we replaced two previously accepted values from previous models with newly calculated rates. The first value that we redefined was the replacement level. Though this level was previously accepted as 80 percent of the league average, using our knowledge that there are 990 theoretical games above replacement in every regular season and statistical analyses of all players in the majors we found that the replacement level belongs at 86.7 percent the league average, reflecting a discrepancy of overall percent and an 8.4 percent increase above the original value. This means that the replacement level is substantially higher than was previously thought. The current formula is comparing players to a lower level of replacement, and thus formulas that use 80 percent will calculate inflated values for VORP and WAR.

The second value that we redefined has serious implications among determining wins above replacement, and is arguably the most important result of our investigation; this is our development of the win coefficient. At the onset of our investigation, we were highly suspicious that the determination that every 10 runs above replacement is equivalent to one win above replacement was an arbitrary value chosen mainly for convenience. Our results for individual and team coefficients strongly support this suspicion. As it turns out, individual values can range from as low as 7 to as high as 12 runs required per win, with the most important factor being simply what team a player played for. After averaging each team's players' coefficients to find the overall team values, we came to the conclusion that each player's WAR should be determined based on his team's overall coefficient because he is --after all --earning wins for his own team, not any other team nor the league as a whole.

However, hitters and pitchers will have two different coefficients seeing as they have separate calculations, as shown in Table 5. Due to the difference in equating Pythagorean Expectation, we can reason that the better a hitting, the higher their coefficient. Contrary to this, the better a pitching team, the lower their coefficient will be.

Discussion

Our improved determinations for WAR can be applied directly to Major League Baseball player in a number of ways. They could be used when a team is placing a monetary value on a player's performance. As long as a team understands how much each win above replacement generally costs, they can gauge how much a player's contribution should theoretically cost and subsequently conclude whether or not he's performing at a level worth his salary. In a similar fashion, teams could determine how much traded players and free agents are worth. Though we didn't look into how WAR could be translated into trade value, it can definitely be applied, even if only as one factor in deciding whether a player is worth a certain price.

Though our results could technically be used as the only source for determining a player's value to his team, it only takes into account his performance on the ball field and as a result leaves out a number of factors that greatly affect his overall value. These factors may include revenue sources such effects to ticket and jersey sales, leadership skills on and off of the field, and even how much potential he has for improvement. For example, bringing a well-known superstar into a franchise could greatly improve ticket sales because the fans will want to see him play, as well as jersey sales because the fans will be proud of their really good new player. Though these factors are much more abstract and more difficult to measure than his performance on the field, they are undoubtedly present and, though our formula doesn't take them and many others into account, play a major role in deciding players' salaries and trade values.

One way that our statistic could be very useful is in determining the Most Valuable Player (MVP) every year. The MVP is generally considered to be the best player in the league, but can also be viewed as the player who made the greatest contribution to his own team's success. As such, it would seem reasonable that the player with the single highest WAR determination should be the league MVP because it tells us that he had the greatest positive effect on his team's performance of the entire Major League. We easily concluded that this means that high performing players playing for lower performing teams would have a better statistical chance at claiming the highest WAR because, though their teammates are pulling them down, they have a greater overall impact on their team's performance.

We also discussed at great length what all of the variations in team runs to wins coefficients actually meant. It is simply logical that there is something fundamentally different going on within a team with a coefficient of 8 than another that requires 11 runs per win, and we are very curious to know what exactly decides it. We threw around a number of possible explanations; chief among these was the interesting concept that some teams are simply more efficient at scoring and preventing runs than others. This essentially means that some teams are more effective at scoring runs only when they need to and playing tight defense so that they don't have to score too many runs, thus keeping their general number of runs required per win lower than that of a team that lets up a lot of runs and constantly has to scramble for wins or one that constantly overpowers their opponents and wins games by 15 runs. What this all comes down to is that different teams have different playing styles, and, though these trends undoubtedly affect individual players' WAR determinations, there are other implications beyond single players. If a team's manager knows that his team's coefficient in very high and figures out the cause, he will know what he needs to teach his team to focus on during practices and games in order to become a more efficient and better ball club. Evidently, our new method to calculating WAR has extensive uses.

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Acknowledgements

We would like to thank our advisor Mr. Christopher Kolar for his invaluable guidance throughout our investigation.

Tables and Figures

Runs Created Abbreviations List.

Abbreviation	*Statistic*
RC	Runs Created
H	Hits
BB	Walks
CS	Caught Stealing
HBP	Hit By Pitch
GIDP	Ground into Double Play
TB	Total Bases
IBB	Intentional Walks
SH	Sacrifice Hits
SF	Sacrifice Fly-balls
SB	Stolen Bases
AB	At-Bats

Table 1. This figure merely defines all of the values inserted into the Runs Created formula for reference.

Determining the VORP.

Name	Team	PA	Runs Created	Outs Recorded	Runs Created per Out	Runs Created per Out League Average	Runs Created by Replacement	VORP
Lance Berkman	Cardinals	587	109.69	365	0.30	0.11	41.77	67.92
Allen Craig	Cardinals	219	37.04	154	0.24	0.11	17.62	19.42
Matt Holliday	Cardinals	516	85.40	359	0.24	0.11	41.08	44.32
Albert Pujols	Cardinals	651	101.76	472	0.22	0.11	54.01	47.75
Nick Punto	Cardinals	166	21.55	111	0.19	0.11	12.70	8.85
Yadier Molina	Cardinals	518	66.91	386	0.17	0.11	44.17	22.74

Table 2. The figure above displays an example calculation of VORP. To determine VORP, we subtracted the Runs Created by a replacement player from the Runs Created of the actual individual.

Determining xWAR.

Name	Team	VORP	Pythagorean Expectation w/o Player	xWAR
Reed Johnson	Cubs	18.34	67.10	2.25
Carlos Pena	Cubs	39.53	64.45	4.90
Starlin Castro	Cubs	30.38	65.60	3.74
Kosuke Fukudome	Cubs	17.09	67.25	2.09
Alfonso Soriano	Cubs	13.42	67.70	1.64

Table 3. The Cubs in 2011 scored 654 runs and allowed 756 runs as a team. They were expected to win 69.34 games in 2011. The table displays the xWAR for individuals on the Chicago Cubs last year.

Breakdown of MLB WAR 2011

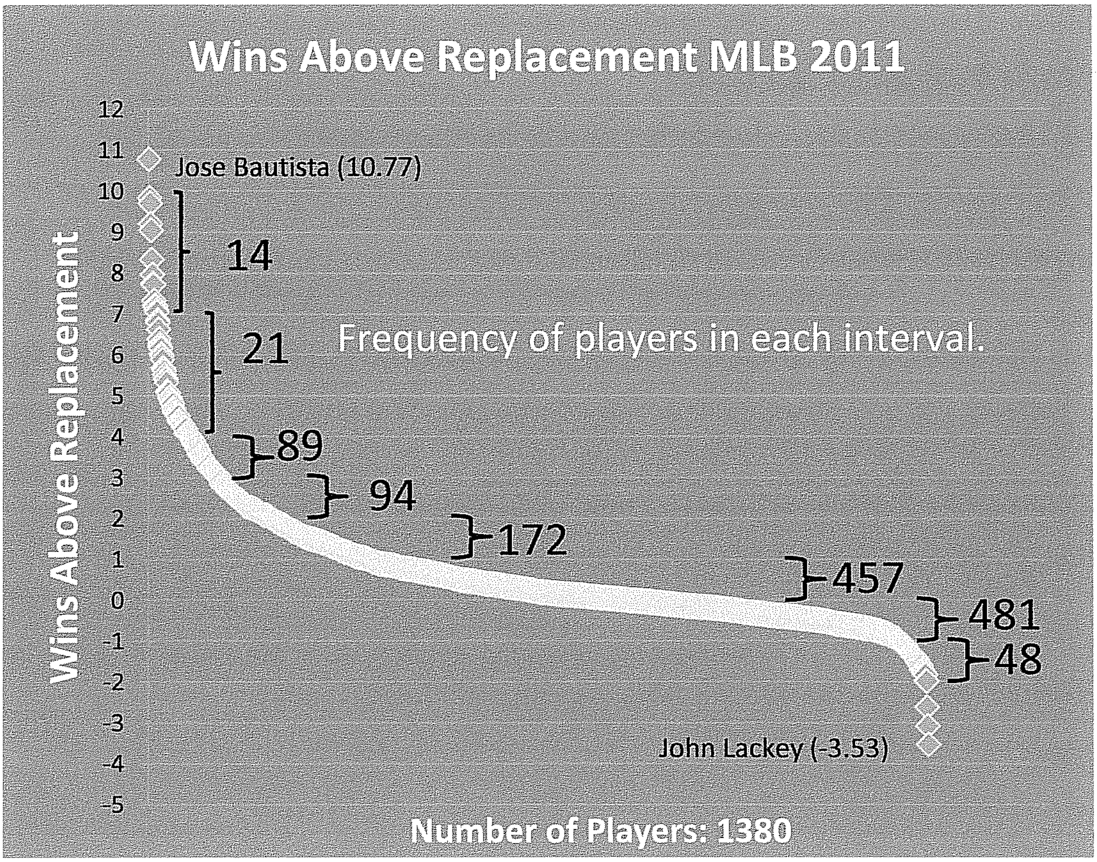

Figure 1. This figure represents our calculated WAR for hitters and pitcher across the Major Leagues for 2011. However, our WAR formula does not account for fielding statistics.

Team Pitching Coefficients 2011

Team	Team Pitching Coefficient	Team	Team Pitching Coefficient
Angels	7.88	Mets	9.19
Astros	10.50	Nationals	7.99
Athletics	8.44	Orioles	11.00
Blue Jays	9.41	Padres	7.60
Braves	7.54	Phillies	7.16
Brewers	8.03	Pirates	9.03
Cardinals	8.65	Rangers	8.84
Cubs	9.54	Rays	7.77
Diamondbacks	8.28	Red Sox	9.38
Dodgers	7.62	Reds	8.91
Giants	7.22	Rockies	8.83
Indians	9.45	Royals	8.86
Mariners	8.69	Tigers	8.31
Marlins	8.82	Twins	9.19
Mets	9.19	White Sox	8.23
Nationals	7.99	Yankees	8.49

Table 4. These are the calculated pitching coefficients for each team. These values represent the number of Runs Created per Win Above Replacement. The pitching coefficients range from about 7 to around 11.

Comparing Coefficients

Coefficient	Team	Team Coefficient
Pitching	Angels	7.879669028
Hitting	Angels	8.19062846
Pitching	Astros	10.49880296
Hitting	Astros	8.092963947
Pitching	Athletics	8.440595273
Hitting	Athletics	7.955672839
Pitching	Blue Jays	9.408550896
Hitting	Blue Jays	9.12557395
Pitching	Braves	7.540806304
Hitting	Braves	7.90710215
Pitching	Brewers	8.026820261
Hitting	Brewers	8.948937483
Pitching	Cardinals	8.649301011
Hitting	Cardinals	9.417252524
Pitching	Cubs	9.543229214
Hitting	Cubs	8.208211701

Table 5. In this figure, it is apparent that pitching and hitting coefficients are independent of one another. The stronger pitching teams will have a lower coefficient, whereas the better hitting teams will have a higher coefficient of Runs Created required per Win Above Replacement.