Yale SCHOOL *of* MANAGEMENT

YALE UNIVERSITY
School of Public Health

YALE UNIVERSITY
School of Engineering and
Applied Science

# Run Value Added and Win Probability in Baseball


Edward H. Kaplan

William N and Marie A Beach Professor of Operations Research
Yale School of Management

Professor of Public Health
Yale School of Public Health

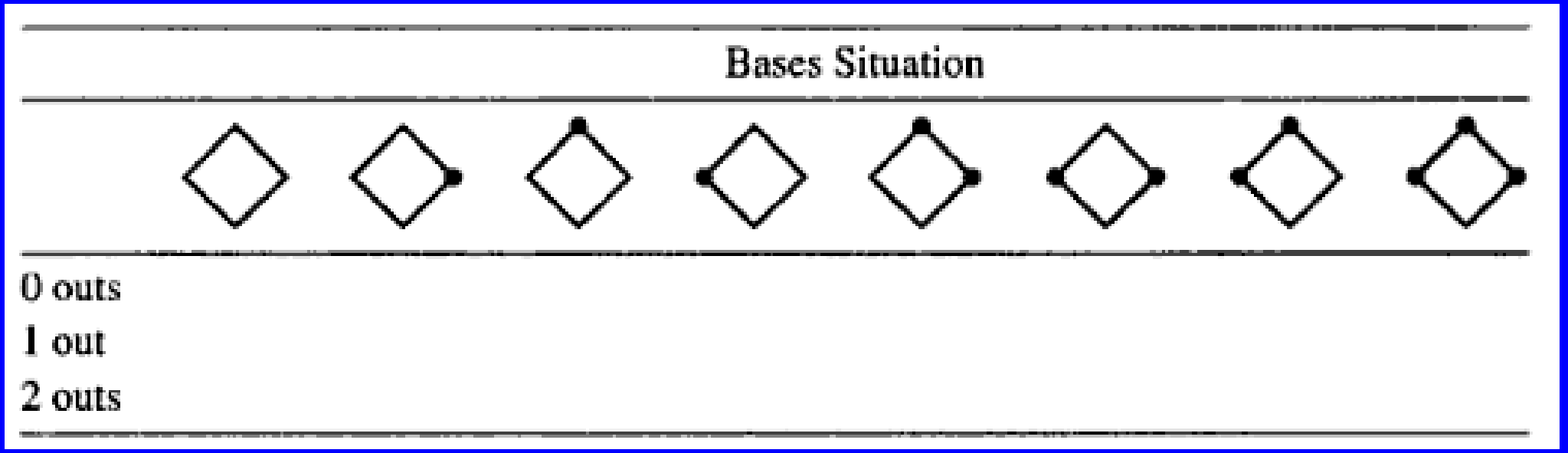
Professor of Engineering
Yale School of Engineering and Applied Science
New Haven, Connecticut

# Context in Baseball

- What key attributes describe context?
  - Score differential
  - Inning
  - Top/Bottom of inning
  - Balls/strikes
  - Outs
  - Men on base (which bases are occupied)

# Starting Point for Baseball: Consider a Half-Inning

- Think of 24 different possible base/out combinations at start of each plate appearance




» Source: Albert J, *Teaching Statistics Using Baseball,* Washington, DC: Mathematical Association of America, 2003.

# State Space Evolution

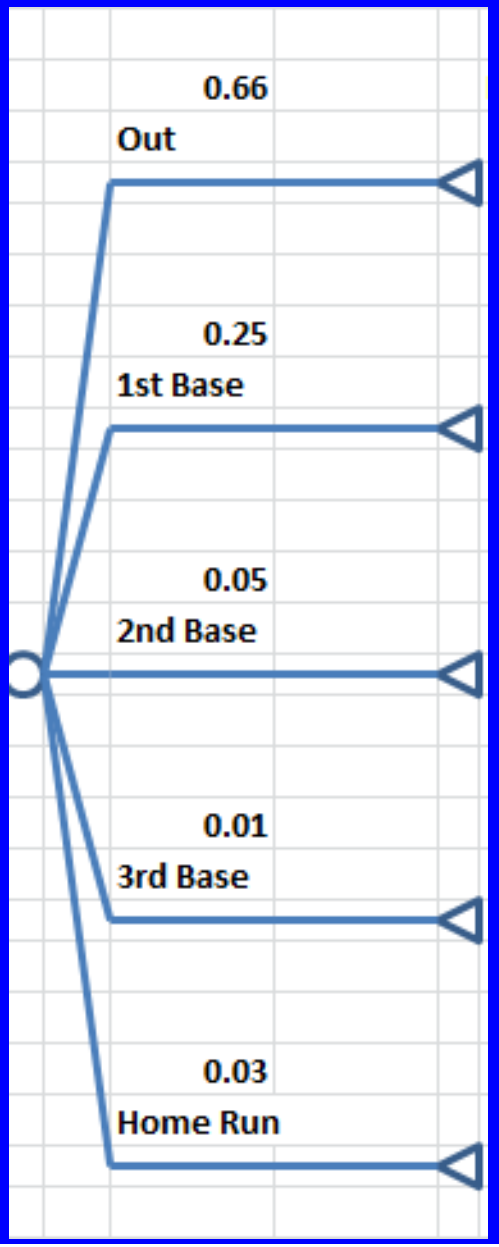
- Baseball is a game of situations
- Game moves from state to state
- Given that the game is currently in a base/out state $i$, let $p_{ij}$ denote the probability that the next base/out state is state $j$
- Can assess these by looking at empirical transition rates

# Example: Bases Empty/0 Outs

- With prob 0.66, batter out, next state is Bases Empty/1 Outs
- With prob 0.25, batter reaches 1st base, next state is Man on 1st/0 Outs
- With prob 0.05, batter reaches 2nd base, next state is Man on 2nd/0 Outs
- With prob 0.01, batter reaches 3rd base, next state is Man on 3rd/0 Outs
- With prob 0.03, batter hits home run, next state is Bases Empty/0 Outs

# State Space Evolution

- Given that the game is currently in a base/out state $i$, let $p_{ij}$ denote the probability that the next base/out state is state $j$
- Can assess $p_{ij}$'s by looking at empirical transition rates
- e.g. 0 out bases empty



# State Space Evolution

- Can think of one-step transitions for *all* possible base/out states
- Result: state transition matrix showing probability of going from any state to any other state
- Most of these probabilities equal 0 (can't reach Bases Empty/1 Out from Man on 2nd/2 Outs!)

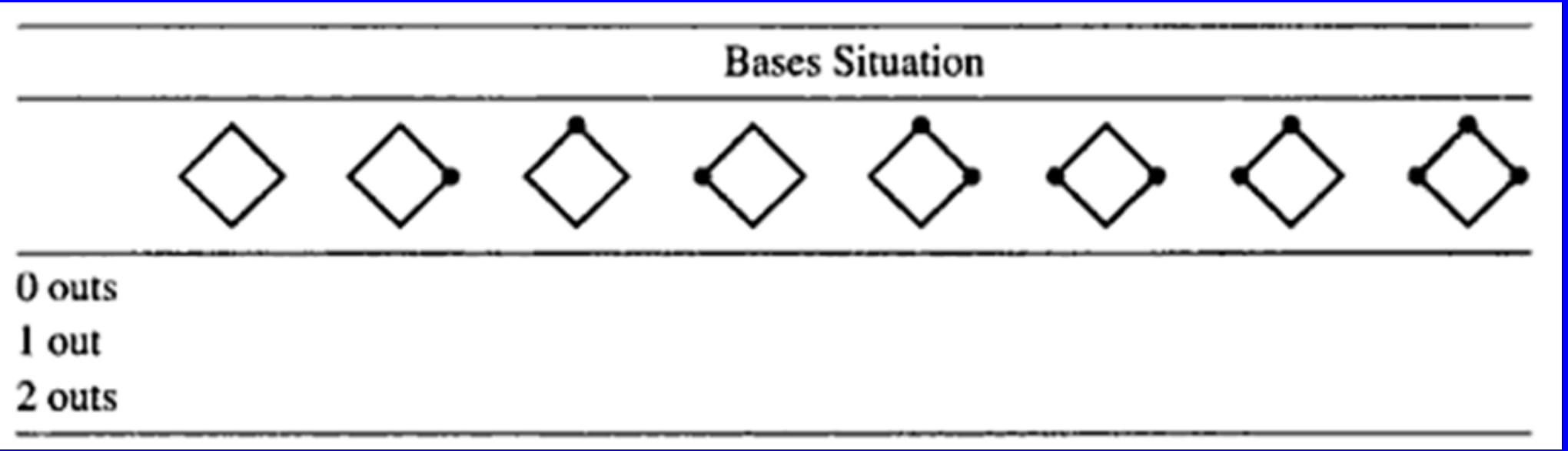
# The Base-Out Transition Matrix

| | END | OUTS | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 OUTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| START | | BASES | ___ | 1__ | _2_ | __3 | 12_ | 1_3 | _23 | 123 | ___ | 1__ | _2_ | __3 | 12_ | 1_3 | _23 | 123 | ___ | 1__ | _2_ | __3 | 12_ | 1_3 | _23 | 123 | ___ | 1__ | _2_ | __3 | 12_ | 1_3 | _23 | 123 BASES |
| OUTS | BASES | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 0 | ___ | | 0.0300 | 0.2500 | 0.0500 | 0.0100 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.6600 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 0 | 1__ | | 0.0300 | 0.0000 | 0.0100 | 0.0100 | 0.2100 | 0.0400 | 0.0400 | 0.0000 | 0.0000 | 0.4100 | 0.1300 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.1200 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 0 | _2_ | | 0.0200 | 0.0500 | 0.0500 | 0.0100 | 0.1100 | 0.1000 | 0.0000 | 0.0000 | 0.0000 | 0.0100 | 0.3600 | 0.2800 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0100 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 0 | __3 | | 0.0202 | 0.1717 | 0.0505 | 0.0101 | 0.0000 | 0.1212 | 0.0000 | 0.0000 | 0.2323 | 0.0000 | 0.0000 | 0.3939 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 0 | 12_ | | 0.0300 | 0.0000 | 0.0100 | 0.0100 | 0.0400 | 0.0300 | 0.0400 | 0.1700 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.3200 | 0.1000 | 0.1400 | 0.0000 | 0.0000 | 0.0100 | 0.0100 | 0.0900 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 0 | 1_3 | | 0.0303 | 0.0000 | 0.0101 | 0.0101 | 0.1515 | 0.0404 | 0.0404 | 0.0808 | 0.0000 | 0.1818 | 0.0505 | 0.0000 | 0.0202 | 0.2323 | 0.0505 | 0.0000 | 0.0909 | 0.0000 | 0.0000 | 0.0101 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 0 | _23 | | 0.0202 | 0.0505 | 0.0505 | 0.0101 | 0.0101 | 0.1010 | 0.0101 | 0.1414 | 0.0000 | 0.0000 | 0.0909 | 0.1515 | 0.0101 | 0.0101 | 0.3434 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 0 | | 123 | 0.0303 | 0.0000 | 0.0101 | 0.0101 | 0.0505 | 0.0303 | 0.0404 | 0.1717 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0808 | 0.1010 | 0.0404 | 0.3131 | 0.0000 | 0.0000 | 0.0000 | 0.0808 | 0.0101 | 0.0000 | 0.0303 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 1 | ___ | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0297 | 0.2475 | 0.0495 | 0.0099 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.6634 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 1 | 1__ | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0300 | 0.0000 | 0.0200 | 0.0100 | 0.2100 | 0.0500 | 0.0300 | 0.0000 | 0.0000 | 0.4300 | 0.0900 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.1300 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 1 | _2_ | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0202 | 0.0606 | 0.0505 | 0.0101 | 0.1515 | 0.0707 | 0.0000 | 0.0000 | 0.0000 | 0.0101 | 0.4242 | 0.1919 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0101 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 1 | __3 | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0198 | 0.1782 | 0.0495 | 0.0099 | 0.0000 | 0.1485 | 0.0000 | 0.0000 | 0.2178 | 0.0198 | 0.0099 | 0.3366 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0099 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 1 | 12_ | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0303 | 0.0000 | 0.0202 | 0.0101 | 0.0505 | 0.0303 | 0.0404 | 0.1515 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.3535 | 0.1010 | 0.0808 | 0.0000 | 0.0000 | 0.0202 | 0.1111 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 1 | 1_3 | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0297 | 0.0000 | 0.0198 | 0.0099 | 0.1386 | 0.0396 | 0.0396 | 0.0792 | 0.0000 | 0.1782 | 0.0693 | 0.0000 | 0.0198 | 0.2178 | 0.0297 | 0.0000 | 0.0000 | 0.0099 | 0.0000 | 0.1188 | 0.0000 | 0.0000 | 0.0000 |
| 1 | _23 | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0198 | 0.0495 | 0.0495 | 0.0099 | 0.0099 | 0.0693 | 0.0099 | 0.2376 | 0.0000 | 0.0099 | 0.0891 | 0.1287 | 0.0099 | 0.0198 | 0.2772 | 0.0000 | 0.0000 | 0.0000 | 0.0099 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 1 | | 123 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0303 | 0.0000 | 0.0202 | 0.0101 | 0.0505 | 0.0303 | 0.0404 | 0.1616 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0808 | 0.1010 | 0.0505 | 0.2929 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0202 | 0.0101 | 0.1010 | 0.0000 |
| 2 | ___ | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0300 | 0.2500 | 0.0500 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.6700 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 2 | 1__ | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0303 | 0.0000 | 0.0202 | 0.0101 | 0.2020 | 0.0505 | 0.0202 | 0.0000 | 0.0000 | 0.6667 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 2 | _2_ | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0198 | 0.0792 | 0.0594 | 0.0099 | 0.1782 | 0.0297 | 0.0000 | 0.0000 | 0.0099 | 0.0099 | 0.6040 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 2 | __3 | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0200 | 0.1400 | 0.0400 | 0.0100 | 0.0000 | 0.1700 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.6200 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 2 | 12_ | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0294 | 0.0000 | 0.0294 | 0.0098 | 0.0490 | 0.0490 | 0.0294 | 0.1275 | 0.0000 | 0.0098 | 0.0000 | 0.0000 | 0.6569 | 0.0098 | 0.0000 | 0.0000 |
| 2 | 1_3 | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0204 | 0.0000 | 0.0204 | 0.0102 | 0.1122 | 0.0510 | 0.0204 | 0.1020 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.6633 | 0.0000 | 0.0000 |
| 2 | _23 | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0200 | 0.0800 | 0.0500 | 0.0100 | 0.0000 | 0.0300 | 0.0000 | 0.2200 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.5900 | 0.0000 |
| 2 | | 123 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0297 | 0.0000 | 0.0297 | 0.0099 | 0.0495 | 0.0495 | 0.0297 | 0.1188 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0099 | 0.0099 | 0.0000 | 0.6634 |
| 3 | ___ | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 3 | 1__ | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 3 | _2_ | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 3 | __3 | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 3 | 12_ | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 | 0.0000 | 0.0000 |
| 3 | 1_3 | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 | 0.0000 |
| 3 | _23 | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.0000 | 0.0000 |
| 3 | | 123 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1.0000 |

# What's The Value of a Play?

- How do individual plays contribute to the success of a baseball team as measured by:
  - Runs scored
  - Change in "run expectancy"
  - Change in "win expectancy"
- For example, bases loaded/no outs, home run!
  - How many runs score? (4, duhhhh…)
  - How much credit should batter get? (4 RBI?)
  - How much does this change chance of winning?

# Back to the State Space!




- Define $r_{ij}$ = expected runs scored transitioning from state $i$ to state $j$
  - e.g. Suppose state #1 is bases empty/0 outs
  - $r_{11} = 1$ (why? )
  - If state 8 is bases loaded/0 outs, what's $r_{81}$?

# Runs and State Transitions

- Define $b_i$ = # men on base in state $i$
- Define $o_i$ = # outs in state $i$
- Suppose batter either goes out or reaches base in transitioning from state $i$ to state $j$ (so ignore stolen base/advance on error)
- Then (drum roll):

$$1 + b_i = r_{ij} + b_j + o_j - o_i$$

- Batter + men on base either score, stay on base, or go out!

# Runs and State Transitions

- Since $1 + b_i = r_{ij} + b_j + o_j - o_i$ we have

$$r_{ij} = 1 + b_i - b_j + o_i - o_j$$

- e.g. state $i$ = 1 out/1st and 3rd, state $j$ = 1 out/2nd, assume no steals/error, how many runs?
- Answer: $r_{ij} = 1 + 2 - 1 + 1 - 1 = 2$
- Suppose state $j$ had 2 outs instead of 1?
- $r_{ij} = 1 + 2 - 1 + 1 - 2 = 1$

# Runs and State Transitions

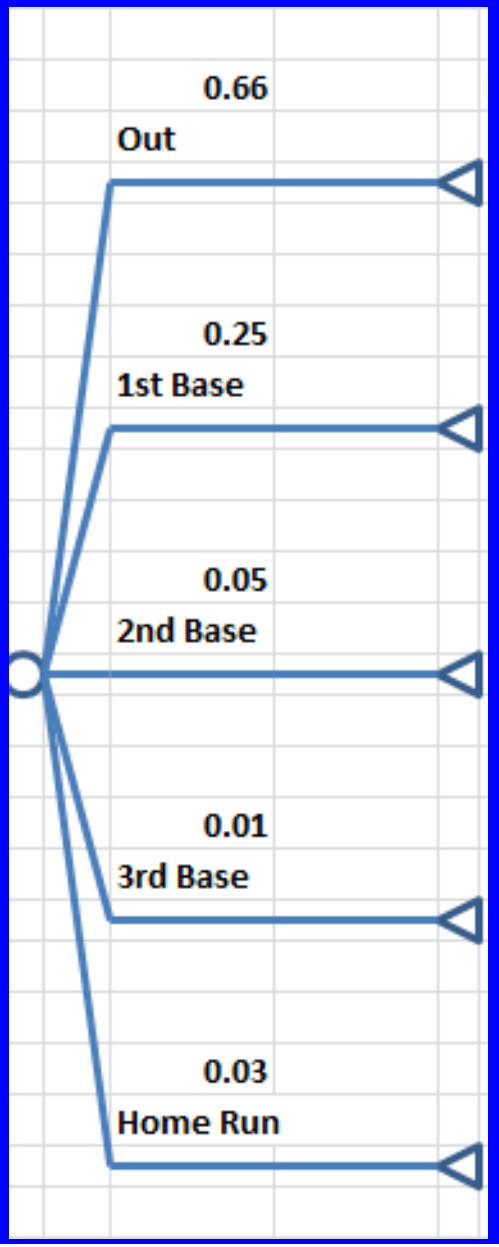
- So *if* the batter reaches base or goes out, then

$$r_{ij} = 1 + b_i - b_j + o_i - o_j$$

- Suppose we start with no outs, man on 1st
- Next state is man on 2nd, no out
- Formula above yields $1 + 1 - 1 + 0 - 0 = 1$
  - True if batter hit double and guy on 1st scores!
  - False if guy on 1st just steals second base!

# Recall State Space Evolution

- Given that the game is currently in a base/out state $i$, let $p_{ij}$ denote the probability that the next base/out state is state $j$
- Can assess $p_{ij}$'s by looking at empirical transition rates
- e.g. 0 out bases empty



# Expected Runs to End of Inning

- Suppose start in some base/out state *i*, and imagine averaging the number of runs scored from entering state *i* thru the end of the inning; call this $v_i$ (for the *value* of state *i*)
- Can look up $v_i$'s empirically, or can model as

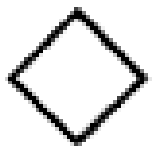
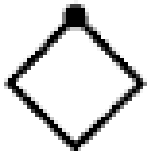
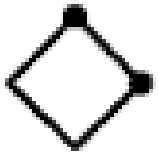
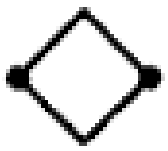
$$v_i = \sum_{j=1}^{24} p_{ij}(r_{ij} + v_j)$$

- States with high values of *v* are worth more than states with low values of *v*

# Expected Runs to End of Inning

(Kaplan computations from Markov model; compare to Table 6.2, p. 55 in text)

- Each cell entry below gives expected runs to the end of the inning starting from the specified state

| | Bases Situation | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| |  |  |  |  |  |  |  |  |
| 0 outs | 0.55 | 0.94 | 1.17 | 1.43 | 1.57 | 1.85 | 2.07 | 2.40 |
| 1 out | 0.30 | 0.57 | 0.70 | 0.98 | 0.97 | 1.22 | 1.44 | 1.65 |
| 2 outs | 0.11 | 0.24 | 0.35 | 0.37 | 0.49 | 0.50 | 0.61 | 0.81 |

# Run Expectancy Matrix, 1950-2010

## Actual Runs Scored, following each base/out state to end of inning



---

The following table presents the average number of runs that scored, from that base/out state, to the end of that inning.

All data is from 1950-2010, courtesy of Retrosheet, our sabremetric sliced bread.

*Note: Only includes: completed innings; through the 8th inning.*

| Base Runners | | | 1993-2010 | | | 1969-1992 | | | 1950-1968 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1B | 2B | 3B | 0 outs | 1 outs | 2 outs | 0 outs | 1 outs | 2 outs | 0 outs | 1 outs | 2 outs |
| __ | __ | __ | 0.544 | 0.291 | 0.112 | 0.477 | 0.252 | 0.094 | 0.476 | 0.256 | 0.098 |
| 1B | __ | __ | 0.941 | 0.562 | 0.245 | 0.853 | 0.504 | 0.216 | 0.837 | 0.507 | 0.216 |
| __ | 2B | __ | 1.170 | 0.721 | 0.348 | 1.102 | 0.678 | 0.325 | 1.094 | 0.680 | 0.330 |
| 1B | 2B | __ | 1.556 | 0.963 | 0.471 | 1.476 | 0.902 | 0.435 | 1.472 | 0.927 | 0.441 |
| __ | __ | 3B | 1.433 | 0.989 | 0.385 | 1.340 | 0.943 | 0.373 | 1.342 | 0.926 | 0.378 |
| 1B | __ | 3B | 1.853 | 1.211 | 0.530 | 1.715 | 1.149 | 0.484 | 1.696 | 1.151 | 0.504 |
| __ | 2B | 3B | 2.050 | 1.447 | 0.626 | 1.967 | 1.380 | 0.594 | 1.977 | 1.385 | 0.620 |
| 1B | 2B | 3B | 2.390 | 1.631 | 0.814 | 2.343 | 1.545 | 0.752 | 2.315 | 1.540 | 0.747 |

Source: http://www.tangotiger.net/re24.html

# Updated to 2021-24

(fangraphs.com)

## Run Expectancy Matrix, 2021-24

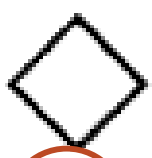
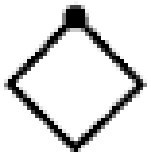
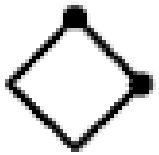
| Runners On | 0 Outs | 1 Out | 2 Outs |
|---|---|---|---|
| — | 0.50 | 0.27 | 0.10 |
| 1– | 0.90 | 0.54 | 0.23 |
| -2- | 1.14 | 0.71 | 0.33 |
| –3 | 1.37 | 0.98 | 0.38 |
| 12- | 1.51 | 0.94 | 0.46 |
| 1-3 | 1.82 | 1.19 | 0.51 |
| -23 | 2.04 | 1.41 | 0.57 |
| 123 | 2.38 | 1.63 | 0.82 |

# Run Value Added

- Keeping score with runs to end of inning
- Start play in some state $i$
- Play takes game to state $j$
- Team at bat gains $r_{ij}$ runs going from $i \rightarrow j$
- State $i$ worth $v_i$ runs to end of inning
- State $j$ worth $v_j$ runs to end of inning
- So the play changed value from $v_i$ to $r_{ij} + v_j$

*Run Value Added:* $\Delta v_{ij} = r_{ij} + v_j - v_i$

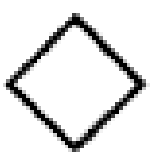
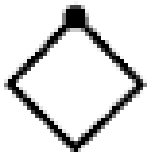
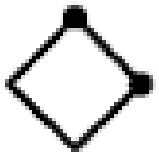
$$\Delta v_{ij} = r_{ij} + v_j - v_i$$

| | Bases Situation | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| |  |  |  |  |  |  |  |  |
| 0 outs | 0.55 | 0.94 | 1.17 | 1.43 | 1.57 | 1.85 | 2.07 | 2.40 |
| 1 out | 0.30 | 0.57 | 0.70 | 0.98 | 0.97 | 1.22 | 1.44 | 1.65 |
| 2 outs | 0.11 | 0.24 | 0.35 | 0.37 | 0.49 | 0.50 | 0.61 | 0.81 |

- What is run value added for 0 outs, bases loaded, grand slam? Should the batter get 4 runs credit?

$$\Delta v_{ij} = 4 + 0.55 - 2.40 = 2.15$$

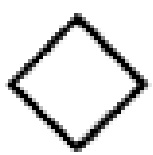
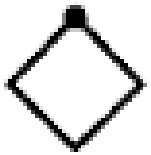
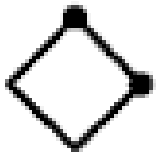
$$\Delta v_{ij} = r_{ij} + v_j - v_i$$

| | Bases Situation | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| |  |  |  |  |  |  |  |  |
| 0 outs | 0.55 | 0.94 | 1.17 | 1.43 | 1.57 | 1.85 | 2.07 | 2.40 |
| 1 out | 0.30 | 0.57 | 0.70 | 0.98 | 0.97 | 1.22 | 1.44 | 1.65 |
| 2 outs | 0.11 | 0.24 | 0.35 | 0.37 | 0.49 | 0.50 | 0.61 | 0.81 |

- What is run value added for 2 outs, bases loaded, grand slam? Higher or lower than 0 outs?

$$\Delta v_{ij} = 4 + 0.11 - 0.81 = 3.30$$

$$\Delta v_{ij} = r_{ij} + v_j - v_i$$

| | Bases Situation | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| |  |  |  |  |  |  |  |  |
| 0 outs | 0.55 | 0.94 | 1.17 | 1.43 | 1.57 | 1.85 | 2.07 | 2.40 |
| 1 out | 0.30 | 0.57 | 0.70 | 0.98 | 0.97 | 1.22 | 1.44 | 1.65 |
| 2 outs | 0.11 | 0.24 | 0.35 | 0.37 | 0.49 | 0.50 | 0.61 | 0.81 |

- How about 0 outs, bases loaded, hit into double play scoring runner from 3rd base?

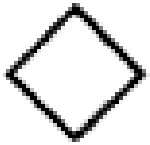
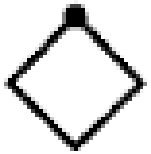
$$\Delta v_{ij} = 1 + 0.37 - 2.40 = -1.03$$

# Is This Fair?

- Some batters get chance to play hero (high potential run value added), while others come up with 2 outs and bases empty
- BUT: expected value of run value added equals 0 for every batter in every state!!!!

$$\sum_{j=1}^{24} p_{ij}\Delta v_{ij} = \sum_{j=1}^{24} p_{ij}(r_{ij} + v_j - v_i) = v_i - v_i = 0$$

# How About Bunting With Runner on 1st and No Outs?

| | Bases Situation | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| |  |  |  |  |  |  |  |  |
| 0 outs | 0.55 | 0.94 | 1.17 | 1.43 | 1.57 | 1.85 | 2.07 | 2.40 |
| 1 out | 0.30 | 0.57 | 0.70 | 0.98 | 0.97 | 1.22 | 1.44 | 1.65 |
| 2 outs | 0.11 | 0.24 | 0.35 | 0.37 | 0.49 | 0.50 | 0.61 | 0.81 |

- Bunting hurts team at bat on average!

# Run Value Added Now Standard Player Evaluation Statistics

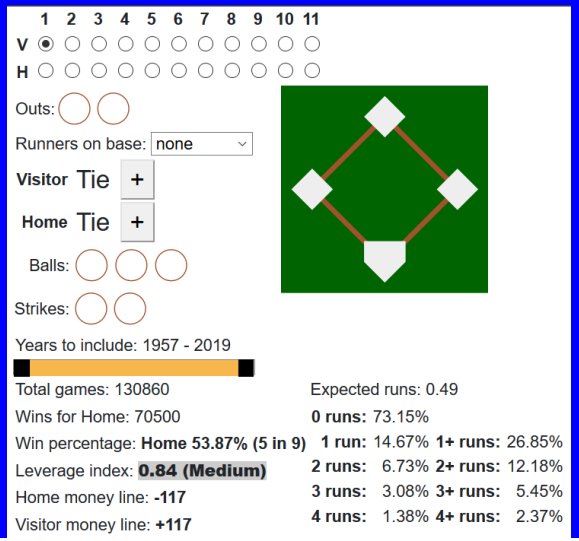
- Sabremetricians refer to this as RE24
- Included in standard sites such as http://www.baseball-reference.com and http://www.fangraphs.com

# To Summarize:

- Baseball state space gives us unique metric for "keeping score" – run value added
- Can use this to analyze baseball strategy
- Can use this to follow game evolution
- Can use this to measure value-added of individual plays, and hence individual players

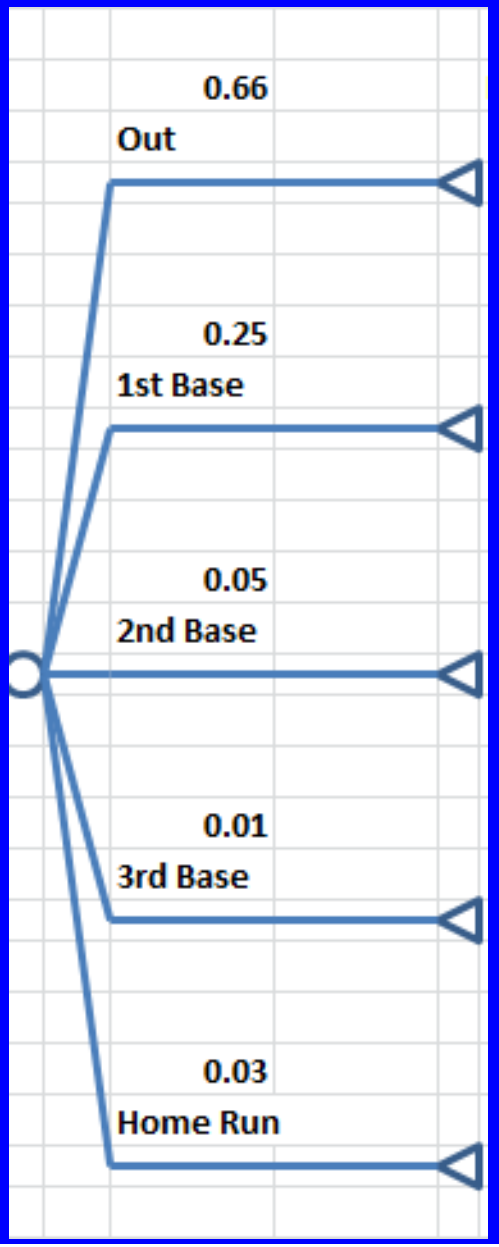
# Win Expectancy (Pr{Win}): For Each Base/Out State, Half Inning, and Score Differential

- Look at historical number of times this situation occurred
- Calculate fraction of times the team in this situation eventually won the game
- Easy to access such data over the internet
  - http://gregstoll.dyndns.org/~gregstoll/baseball/stats.php



# Recall State Space Evolution

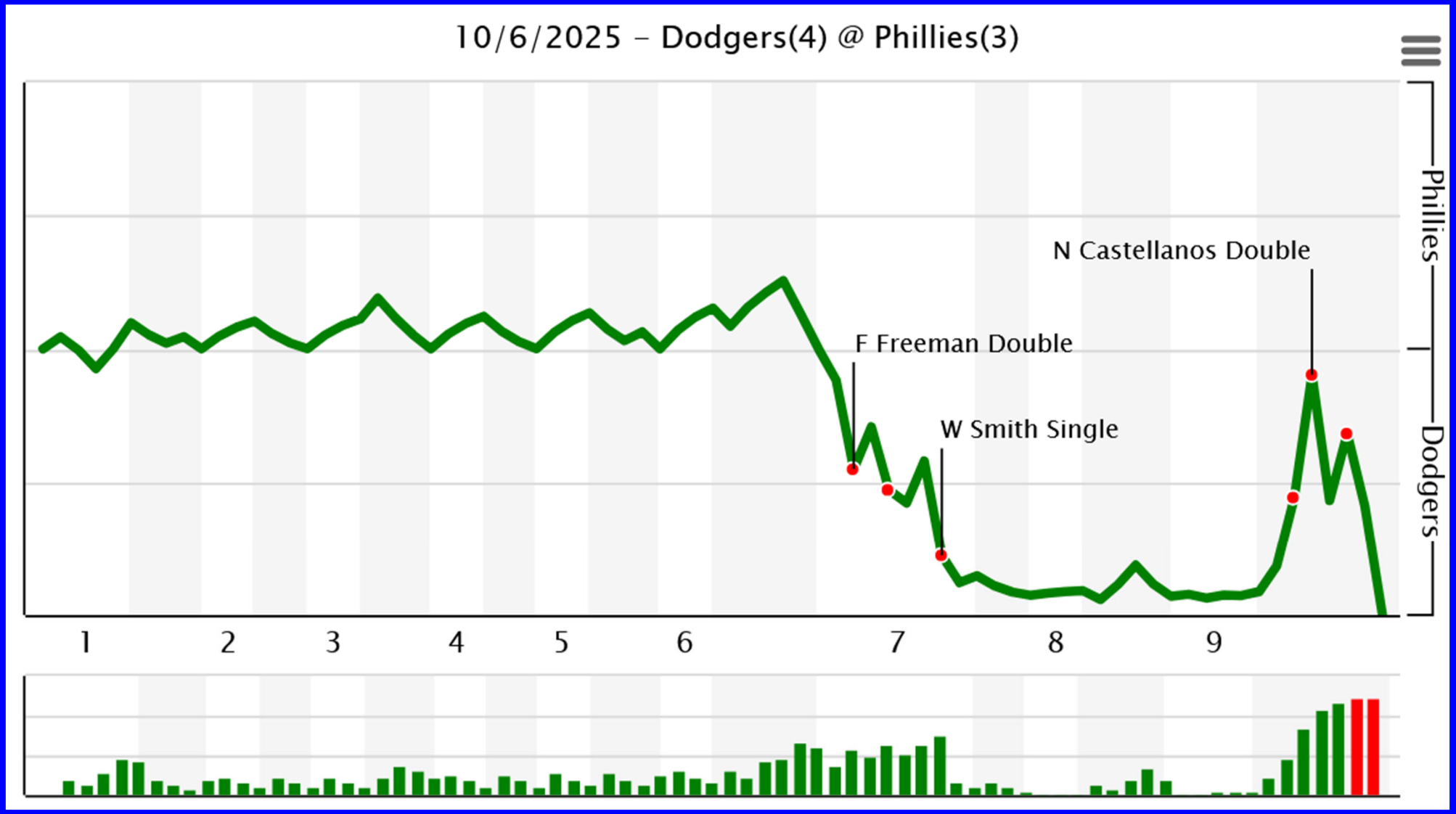
- Given that the game is currently in a base/out state $i$, let $p_{ij}$ denote the probability that the next base/out state is state $j$
- Can assess $p_{ij}$'s by looking at empirical transition rates
- e.g. 0 out bases empty



# Baseball Win Expectancy

- During any game, one actually observes transitions from one state to another
- Recall that we can compute win probabilities for any state by just looking up empirical relative frequencies
- So, why not watch the evolution of win expectancy over the course of a game?

# Easy To Watch Win Probability Change Over Course of a Game




Source: https://www.fangraphs.com/wins.aspx?date=2025-10-06&team=Phillies&dh=0&season=2025

# Same Game on ESPN.com


Source: https://www.espn.com/mlb/game/_/gameId/401809279/dodgers-phillies

# What Does Win Expectancy Really Tell Us?

- Is it the probability Dodgers beat Phillies?
- No – win expectancy based on relative frequencies across all games; represents chance *randomly selected team* would win in a given state
- BUT – Dodgers/Phillies determine actual game situations!
- SO – win expectancy reports how randomly selected team would do *given actual situations dictated by the game*

# Worded Differently…

- Win expectancy provides a different metric for keeping score!
  - How well do the Yankees play?
  - We'll score them according to the chance a randomly selected team wins *given the game situations the Yankees create*
  - Later we'll score individual players

# Really Interested in Winning the Game!

- Recall win expectancy as function of base/out state, score differential, half-inning
- Think of as fraction of times team in given situation (i.e. state) won historically
- Let $WE_i$ = Win expectancy of state $i$ where now state includes score differential and half-inning in addition to base/out info

# Win Probability Added

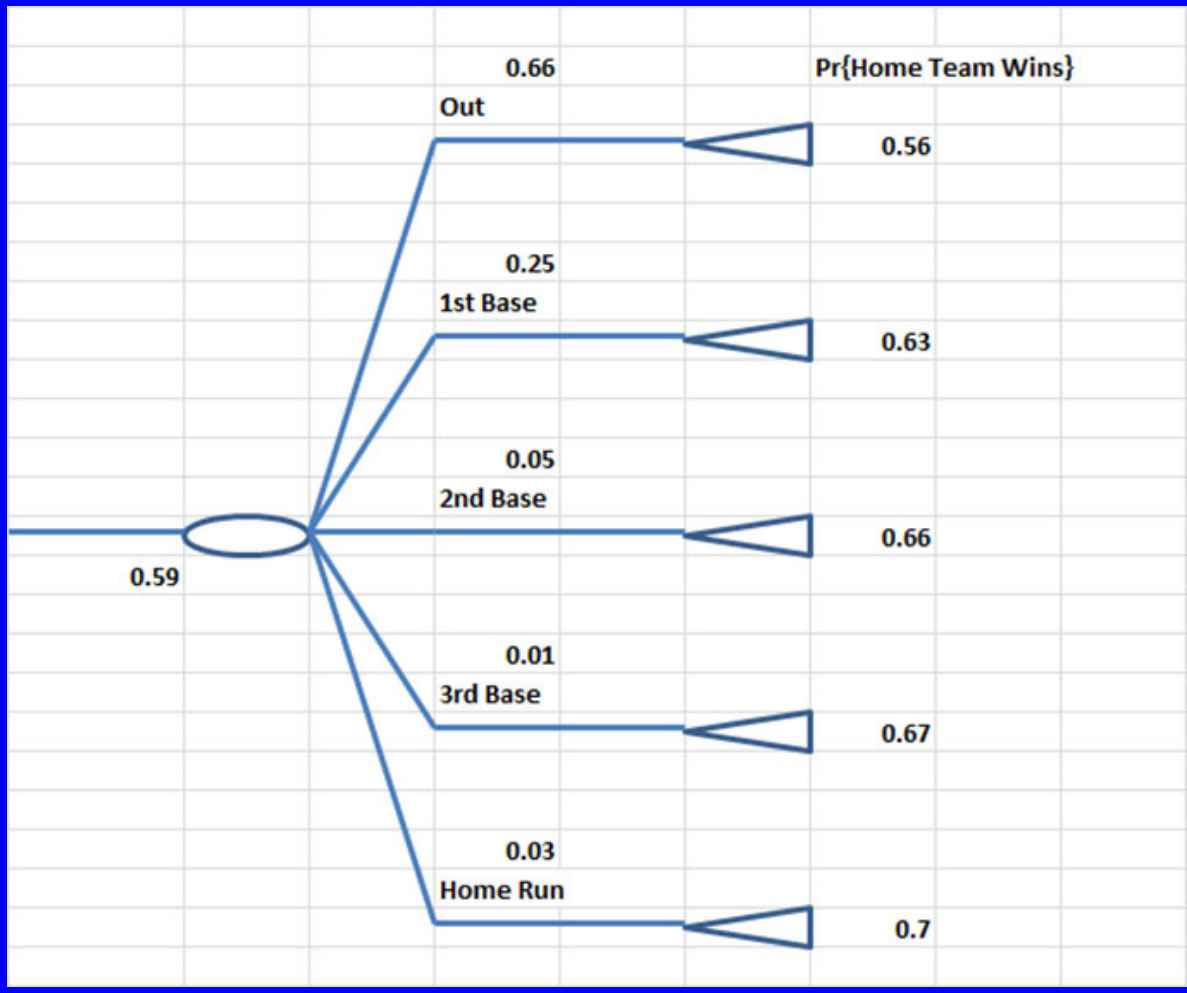
- To see impact of different plays on game, look at change in win probability!
- If game takes you from state *i* to state *j* then

$$WPA_{ij} = WE_j - WE_i$$

- Plays with $WPA > 0$ are good (for the team at bat); $WPA < 0$ plays are bad
- Can assess *WPA* for *every* play in a game, and attach to batter/pitcher pair responsible (or baserunner/pitcher pair)

# Is *WPA* Fair?

- Some batters get opportunity for walk-off hit to win, others get 2 outs, bases empty in top of 9th and down by 5
- But, for *any* batter in *any* situation, the *expected WPA* equals zero!




$$\sum_j p_{ij} WPA_{ij} = \sum_j p_{ij} (WE_j - WE_i) = WE_i - WE_i = 0$$

# Win Probability Added

- In actual game play, from vantage of batting team:
  - *Credit* batters/baserunners with *WPA*
  - *Penalize* pitchers with –*WPA*
- Note that if *WPA* < 0 (e.g. batter strikes out), then pitcher gets *positive WPA*
- On any play,

*WPA* for home team = – *WPA* for visiting team

# Standard *WPA* Implementation

- Assume each team as 50% chance of winning at start (not really true…)
- Let $WE_k$ = win expectancy after $k$ plays
  - Note: Home $WE_k$ = 1 – Away $WE_k$
- Let $WPA_k$ = *WPA* assessed after $k^{th}$ play

$$WPA_k = WE_k - WE_{k-1}$$

- Then after $k$ plays we have

$$WE_k = \frac{1}{2} + WPA_1 + WPA_2 + \ldots + WPA_k$$

# Properties of *WPA*

- If team wins the game, then

$$\sum_{\substack{all\ plays \\ at\ bat}} WPA_{batter} + \sum_{\substack{all\ plays \\ in\ field}} WPA_{pitcher} = \frac{1}{2}$$

- If team loses the game, then

$$\sum_{\substack{all\ plays \\ at\ bat}} WPA_{batter} + \sum_{\substack{all\ plays \\ in\ field}} WPA_{pitcher} = -\frac{1}{2}$$

# Over Entire Season For Given Team

$$\sum_{all\ games}\left\{\sum_{bats} WPA_{batter} + \sum_{field} WPA_{pitcher}\right\}$$

$$= \frac{1}{2} \times \#\,Wins - \frac{1}{2} \times \#\,Losses$$

$$= \frac{1}{2} \times \#\,Wins - \frac{1}{2} \times (162 - \#\,Wins)$$

$$= \#\,Wins - 81 = \#\,Wins\ over\ .500!!!$$

- So, sum of *WPA* over season = Wins over .500!

# Player Value Added!

- Suppose keep track of $WPA$ over all plays involving individual players

$$\sum_{all\ plays} WPA = \sum_{all\ players} \sum_{\substack{all\ plays \\ for\ player}} WPA_{play,player}$$

Therefore

$$\sum_{\substack{all\ plays \\ for\ player}} WPA_{play,player} = Player\ contributed\ Wins\ over\ .500$$

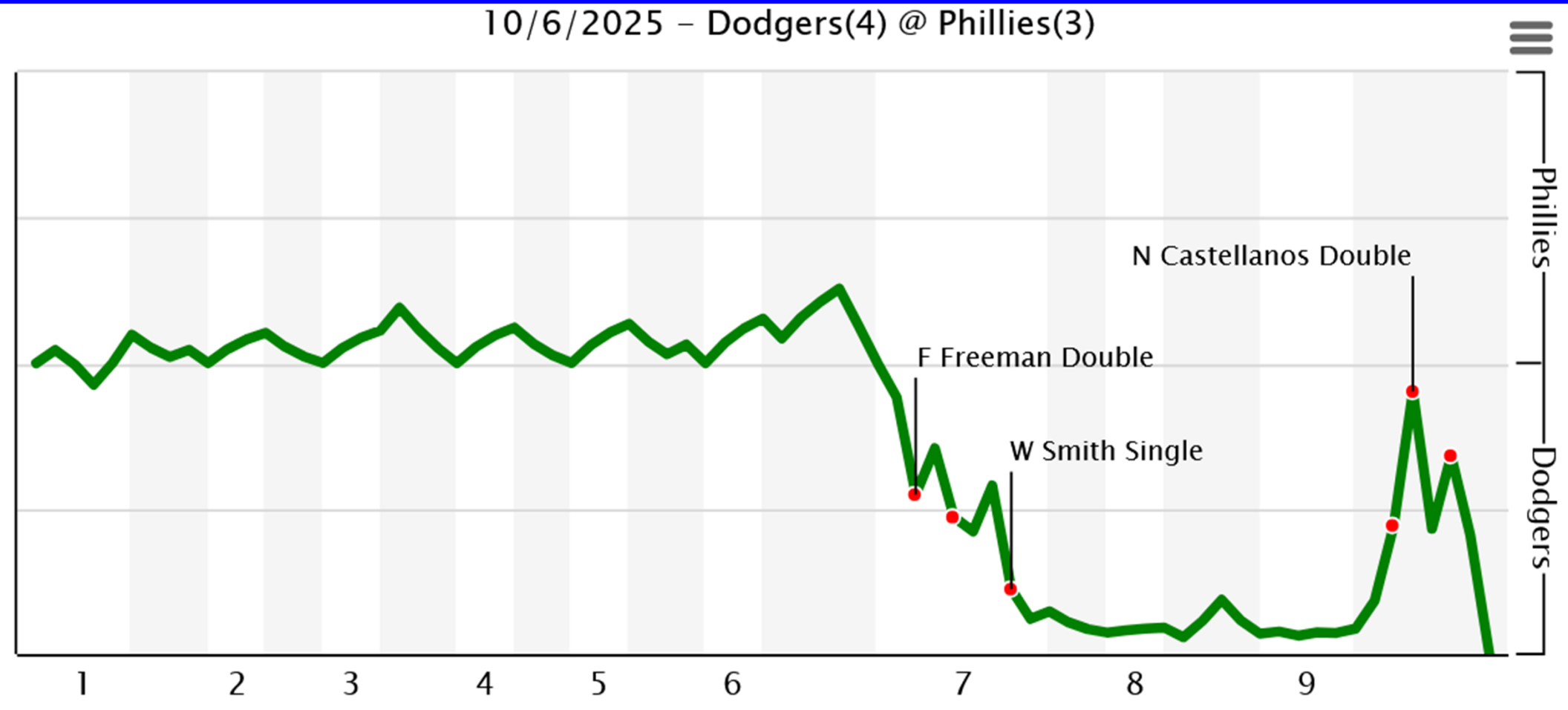
# *WPA* Leaders for 2025

| # | Name | Team | WPA |
|---|---|---|---|
| 1 | Shohei Ohtani | LAD | 5.99 |
| 2 | Aaron Judge | NYY | 5.61 |
| 3 | Juan Soto | NYM | 5.08 |
| 4 | Freddie Freeman | LAD | 4.84 |
| 5 | José Ramírez | CLE | 4.24 |
| 6 | Fernando Tatis Jr. | SDP | 4.11 |
| 7 | Pete Alonso | NYM | 4.00 |
| 8 | Cal Raleigh | SEA | 3.85 |
| 9 | Jorge Polanco | SEA | 3.85 |
| 10 | Vladimir Guerrero Jr. | TOR | 3.64 |

Source: http://www.fangraphs.com

# Entire System Implemented at http://fangraphs.com

- For every game and every play, fangraphs records runs to end of inning (*RE*), run value added by base/out state (*RE*24), win expectancy (*WE*), and win probability added (*WPA*)
- Can follow all of above in play-by-play log
- At end of game, note that sum of *WPA* for batters/pitchers on winning team equals 0.5, same sum for losing team equals –0.5


10/6/2025 - Dodgers(4) @ Phillies(3)
N Castellanos Double
F Freeman Double
W Smith Single
Phillies
Dodgers
1
2
3
4
5
6
7
8
9

| | Inn | Batter | Pitcher | Outs | Bases | Score | Play | LI | RE | WE | WPA | RE24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ▲ 1 | S Ohtani | J Luzardo | 0 | ___ | 0-0 | Shohei Ohtani struck out looking. | 0.87 | 0.52 | 52.2% | -.022 | -0.25 |
| 2 | ▲ 1 | M Betts | J Luzardo | 1 | ___ | 0-0 | Mookie Betts singled to left (Grounder). | 0.62 | 0.28 | 49.8% | .024 | 0.27 |
| 3 | ▲ 1 | T Hernandez | J Luzardo | 1 | 1__ | 0-0 | Teoscar Hernandez walked. Mookie Betts advanced to 2B. | 1.15 | 0.54 | 46.3% | .035 | 0.39 |
| 4 | ▲ 1 | F Freeman | J Luzardo | 1 | 12_ | 0-0 | Freddie Freeman flied out to right. Mookie Betts advanced to 3B. | 1.90 | 0.94 | 50.0% | -.037 | -0.42 |
| 5 | ▲ 1 | T Edman | J Luzardo | 2 | 1_3 | 0-0 | Tommy Edman grounded out to second. | 1.71 | 0.51 | 54.9% | -.048 | -0.51 |
| 6 | ▼ 1 | T Turner | B Snell | 0 | ___ | 0-0 | Trea Turner struck out looking. | 0.87 | 0.52 | 52.6% | -.022 | -0.24 |
| 7 | ▼ 1 | K Schwarber | B Snell | 1 | ___ | 0-0 | Kyle Schwarber flied out to left. | 0.62 | 0.28 | 51.1% | -.016 | -0.17 |
| 8 | ▼ 1 | B Harper | B Snell | 2 | ___ | 0-0 | Bryce Harper walked. | 0.40 | 0.11 | 52.3% | .012 | 0.13 |
| 9 | ▼ 1 | A Bohm | B Snell | 2 | 1__ | 0-0 | Alec Bohm grounded out to second. | 0.79 | 0.24 | 50.0% | -.023 | -0.24 |
| 10 | ▲ 2 | E Hernandez | J Luzardo | 0 | ___ | 0-0 | Enrique Hernandez struck out swinging. | 0.93 | 0.52 | 52.4% | -.024 | -0.24 |
| 11 | ▲ 2 | M Rojas | J Luzardo | 1 | ___ | 0-0 | Miguel Rojas grounded out to second. | 0.66 | 0.28 | 54.1% | -.017 | -0.17 |
| 12 | ▲ 2 | A Pages | J Luzardo | 2 | ___ | 0-0 | Andy Pages flied out to left. | 0.42 | 0.11 | 55.2% | -.011 | -0.11 |
| 13 | ▼ 2 | J Realmuto | B Snell | 0 | ___ | 0-0 | J.T. Realmuto grounded out to shortstop. | 0.92 | 0.52 | 52.8% | -.024 | -0.24 |
| 14 | ▼ 2 | N Castellanos | B Snell | 1 | ___ | 0-0 | Nick Castellanos struck out swinging. | 0.67 | 0.28 | 51.1% | -.017 | -0.17 |
| 15 | ▼ 2 | E Sosa | B Snell | 2 | ___ | 0-0 | Edmundo Sosa struck out swinging. | 0.43 | 0.11 | 50.0% | -.011 | -0.11 |
| 16 | ▲ 3 | B Rortvedt | J Luzardo | 0 | ___ | 0-0 | Ben Rortvedt struck out swinging. | 0.99 | 0.52 | 52.6% | -.026 | -0.24 |
| 17 | ▲ 3 | S Ohtani | J Luzardo | 1 | ___ | 0-0 | Shohei Ohtani grounded out to second. | 0.72 | 0.28 | 54.4% | -.018 | -0.17 |
| 18 | ▲ 3 | M Betts | J Luzardo | 2 | ___ | 0-0 | Mookie Betts grounded out to shortstop. | 0.46 | 0.11 | 55.6% | -.012 | -0.11 |
| 19 | ▼ 3 | B Marsh | B Snell | 0 | ___ | 0-0 | Brandon Marsh walked. | 0.99 | 0.52 | 59.5% | .039 | 0.39 |
| 20 | ▼ 3 | O Kemp | B Snell | 0 | 1__ | 0-0 | Otto Kemp struck out swinging. | 1.59 | 0.91 | 55.8% | -.037 | -0.37 |
| 21 | ▼ 3 | T Turner | B Snell | 1 | 1__ | 0-0 | Trea Turner struck out swinging. | 1.31 | 0.54 | 52.6% | -.032 | -0.30 |
| 22 | ▼ 3 | B Marsh | B Snell | 2 | 1__ | 0-0 | Brandon Marsh was caught stealing. | 0.92 | 0.24 | 50.0% | -.026 | -0.24 |

| | Inn | Batter | Pitcher | Outs | Bases | Score | Play | LI | RE | WE | WPA | RE24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **72** | **▼ 9** | **N Castellanos** | **B Treinen** | **0** | **_23** | **1-4** | **Nick Castellanos doubled to left (Liner). Alec Bohm scored. J.T. Realmuto scored.** | **3.43** | **2.02** | **45.1%** | **.230** | **1.13** |
| **51** | **▲ 7** | **W Smith** | **O Kerkering** | **2** | **123** | **0-1** | **Will Smith singled to left (Liner). Freddie Freeman scored. Enrique Hernandez scored. Max Muncy advanced to 2B.** | **3.07** | **0.79** | **11.2%** | **.178** | **1.66** |
| 46 | ▲ 7 | F Freeman | J Luzardo | 0 | 1__ | 0-0 | Freddie Freeman doubled to right (Liner). Teoscar Hernandez advanced to 3B. | 2.39 | 0.91 | 27.4% | .167 | 1.11 |
| 71 | ▼ 9 | J Realmuto | B Treinen | 0 | 1__ | 1-4 | J.T. Realmuto doubled to left (Liner). Alec Bohm advanced to 3B. | 1.91 | 0.91 | 22.1% | .130 | 1.11 |
| 74 | ▼ 9 | H Bader | A Vesia | 1 | 1__ | 3-4 | Harrison Bader singled to left (Liner). Bryson Stott advanced to 2B. | 4.74 | 0.54 | 34.1% | .126 | 0.39 |
| **48** | **▲ 7** | **E Hernandez** | **O Kerkering** | **1** | **_23** | **0-0** | **Enrique Hernandez reached on fielder's choice to shortstop. Teoscar Hernandez scored. Freddie Freeman advanced to 3B.** | **2.57** | **1.43** | **23.5%** | **.118** | **0.78** |
| 45 | ▲ 7 | T Hernandez | J Luzardo | 0 | ___ | 0-0 | Teoscar Hernandez singled to center (Liner). | 1.54 | 0.52 | 44.1% | .059 | 0.39 |
| **52** | **▲ 7** | **S Ohtani** | **M Strahm** | **2** | **12_** | **0-3** | **Shohei Ohtani singled to right (Grounder). Max Muncy scored. Will Smith advanced to 3B.** | **0.71** | **0.45** | **6.0%** | **.051** | **1.07** |
| 73 | ▼ 9 | B Stott | A Vesia | 0 | _2_ | 3-4 | Bryson Stott reached on fielder's choice to third. Nick Castellanos out at third. | 4.33 | 1.15 | 21.5% | -.236 | -0.61 |
| 76 | ▼ 9 | T Turner | R Sasaki | 2 | 1_3 | 3-4 | Trea Turner grounded out to second. | 7.29 | 0.51 | 0.0% | -.205 | -0.51 |
| 75 | ▼ 9 | M Kepler | A Vesia | 1 | 12_ | 3-4 | Max Kepler reached on fielder's choice to first. Bryson Stott advanced to 3B. Weston Wilson out at second. | 7.15 | 0.94 | 20.5% | -.136 | -0.42 |
| 47 | ▲ 7 | T Edman | O Kerkering | 0 | _23 | 0-0 | Tommy Edman struck out swinging. | 2.03 | 2.02 | 35.4% | -.079 | -0.59 |
| 50 | ▲ 7 | A Pages | O Kerkering | 1 | 123 | 0-1 | Andy Pages fouled out to first. | 2.58 | 1.60 | 28.9% | -.078 | -0.81 |
| 44 | ▼ 6 | A Bohm | B Snell | 2 | 12_ | 0-0 | Alec Bohm reached on fielder's choice to third. Trea Turner out at third. Kyle Schwarber advanced to 2B. | 2.49 | 0.45 | 50.0% | -.065 | -0.45 |
| 43 | ▼ 6 | B Harper | B Snell | 1 | 12_ | 0-0 | Bryce Harper struck out swinging. | 2.75 | 0.94 | 56.5% | -.063 | -0.49 |
| 5 | ▲ 1 | T Edman | J Luzardo | 2 | 1_3 | 0-0 | Tommy Edman grounded out to second. | 1.71 | 0.51 | 54.9% | -.048 | -0.51 |
| 4 | ▲ 1 | F Freeman | J Luzardo | 1 | 12_ | 0-0 | Freddie Freeman flied out to right. | 1.90 | 0.94 | 50.0% | -.037 | -0.42 |

# More on Value Added

- Always true that sum of *WPA* for winning batters = – sum of *WPA* for losing pitchers
- Always true that sum of *WPA* for winning pitchers = – sum of *WPA* for losing hitters
- Let's look at an example

http://fangraphs.com

# Dodgers and Phillies 10/6/2025

## Phillies

| Name | BO | PA | H | HR | R | RBI | BB | SO | wOBA | pLI | WPA |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Trea Turner - SS | 1 | 5 | **1** | 0 | 0 | **1** | **1** | **2** | .315 | 2.17 | -0.16 |
| Kyle Schwarber - DH | 2 | 4 | 0 | 0 | 0 | 0 | **1** | **2** | .173 | 1.24 | -0.06 |
| Bryce Harper - 1B | 3 | 4 | 0 | 0 | 0 | 0 | **1** | **1** | .173 | 1.18 | -0.09 |
| Alec Bohm - 3B | 4 | 4 | **1** | 0 | **1** | 0 | 0 | **1** | .221 | 1.19 | -0.05 |
| J.T. Realmuto - C | 5 | 4 | **1** | 0 | **1** | 0 | 0 | 0 | .313 | 1.18 | 0.06 |
| Nick Castellanos - RF | 6 | 4 | **1** | 0 | 0 | **2** | 0 | **1** | .313 | 1.36 | 0.18 |
| Bryson Stott - PH-2B | 7 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | .000 | 2.28 | -0.24 |
| Edmundo Sosa - 2B | 7 | 2 | **1** | 0 | 0 | 0 | 0 | **1** | .441 | 0.51 | 0.01 |
| Brandon Marsh - CF | 8 | 3 | 0 | 0 | 0 | 0 | **1** | 0 | .231 | 0.91 | -0.04 |
| Weston Wilson - PR | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | .000 | | |
| Harrison Bader - PH | 8 | 1 | **1** | 0 | 0 | 0 | 0 | 0 | .882 | 4.74 | 0.13 |
| Max Kepler - PH-LF | 9 | 2 | **1** | 0 | **1** | 0 | 0 | 0 | .792 | 3.76 | -0.11 |
| Otto Kemp - LF | 9 | 2 | 0 | 0 | 0 | 0 | 0 | **2** | .000 | 1.45 | -0.07 |
| Total | - | 37 | 7 | 0 | 3 | 3 | 4 | 10 | .281 | 1.59 | -0.45 |

## Dodgers

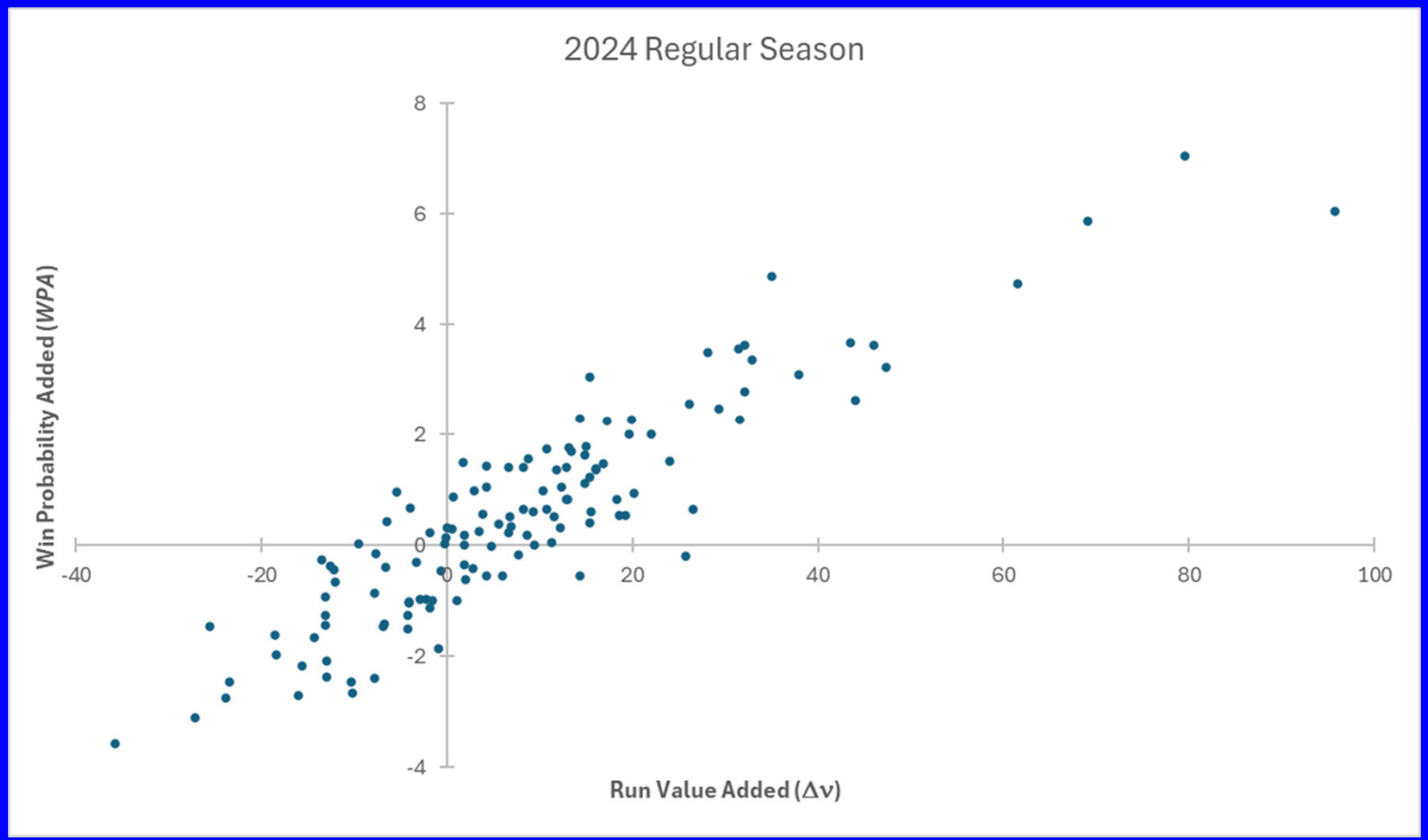
| Name | BO | PA | H | HR | R | RBI | BB | SO | wOBA | pLI | WPA |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Shohei Ohtani - DH | 1 | 5 | **1** | 0 | 0 | **1** | 0 | **2** | .176 | 0.71 | -0.02 |
| Mookie Betts - SS | 2 | 4 | **1** | 0 | 0 | 0 | 0 | 0 | .221 | 0.55 | -0.02 |
| Justin Dean - CF | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | .000 | | |
| Teoscar Hernandez - RF | 3 | 4 | **2** | 0 | **1** | 0 | **1** | 0 | .614 | 0.98 | 0.06 |
| Freddie Freeman - 1B | 4 | 4 | **1** | 0 | **1** | 0 | 0 | **1** | .313 | 1.30 | 0.11 |
| Tommy Edman - 2B | 5 | 4 | 0 | 0 | 0 | 0 | 0 | **2** | .000 | 1.08 | -0.14 |
| Enrique Hernandez - LF | 6 | 4 | 0 | 0 | **1** | **1** | 0 | **2** | .000 | 1.21 | 0.06 |
| Max Muncy - PH-3B | 7 | 2 | **1** | 0 | **1** | 0 | **1** | 0 | .972 | 1.09 | 0.03 |
| Miguel Rojas - 3B | 7 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | .000 | 0.77 | -0.04 |
| Andy Pages - CF-RF | 8 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | .000 | 0.95 | -0.11 |
| Ben Rortvedt - C | 9 | 1 | 0 | 0 | 0 | 0 | 0 | **1** | .000 | 0.99 | -0.03 |
| Will Smith - PH-C | 9 | 3 | **1** | 0 | 0 | **2** | **1** | 0 | .525 | 1.54 | 0.14 |
| Total | - | 37 | 7 | 0 | 4 | 4 | 3 | 8 | .243 | 1.00 | 0.05 |

| Name | IP | TBF | H | HR | ER | BB | SO | FIP | pLI | WPA |
|---|---|---|---|---|---|---|---|---|---|---|
| Jesus Luzardo (L) | 6.0 | 22 | 3 | 0 | 2 | 1 | 5 | 1.97 | 1.02 | 0.14 |
| Tanner Banks | 1.0 | 3 | 1 | 0 | 0 | 0 | 0 | 3.14 | 0.11 | 0.01 |
| Jhoan Duran | 1.0 | 5 | 1 | 0 | 0 | 1 | 2 | 2.14 | 0.19 | 0.01 |
| Orion Kerkering | 0.2 | 5 | 1 | 0 | 2 | 1 | 1 | 4.64 | 2.46 | -0.16 |
| Matt Strahm | 0.1 | 2 | 1 | 0 | 0 | 0 | 0 | 3.14 | 0.58 | -0.04 |
| Total | 9.0 | 37 | 7 | 0 | 4 | 3 | 8 | 2.36 | 1.00 | -0.05 |

| Name | IP | TBF | H | HR | ER | BB | SO | FIP | pLI | WPA |
|---|---|---|---|---|---|---|---|---|---|---|
| Blake Snell (W) | 6.0 | 22 | 1 | 0 | 0 | 4 | 9 | 2.14 | 1.11 | 0.36 |
| Emmet Sheehan | 2.0 | 8 | 2 | 0 | 1 | 0 | 1 | 2.14 | 0.68 | 0.05 |
| Alex Vesia (H) | 0.2 | 3 | 1 | 0 | 0 | 0 | 0 | 3.14 | 5.41 | 0.25 |
| Roki Sasaki (SV) | 0.1 | 1 | 0 | 0 | 0 | 0 | 0 | 3.14 | 7.29 | 0.20 |
| Blake Treinen | 0.0 | 3 | 3 | 0 | 2 | 0 | 0 | 3.14 | 2.10 | -0.41 |
| Total | 9.0 | 37 | 7 | 0 | 3 | 4 | 10 | 2.25 | 1.59 | 0.45 |

# Do Run Value Added and Win Probability Added Match Up?

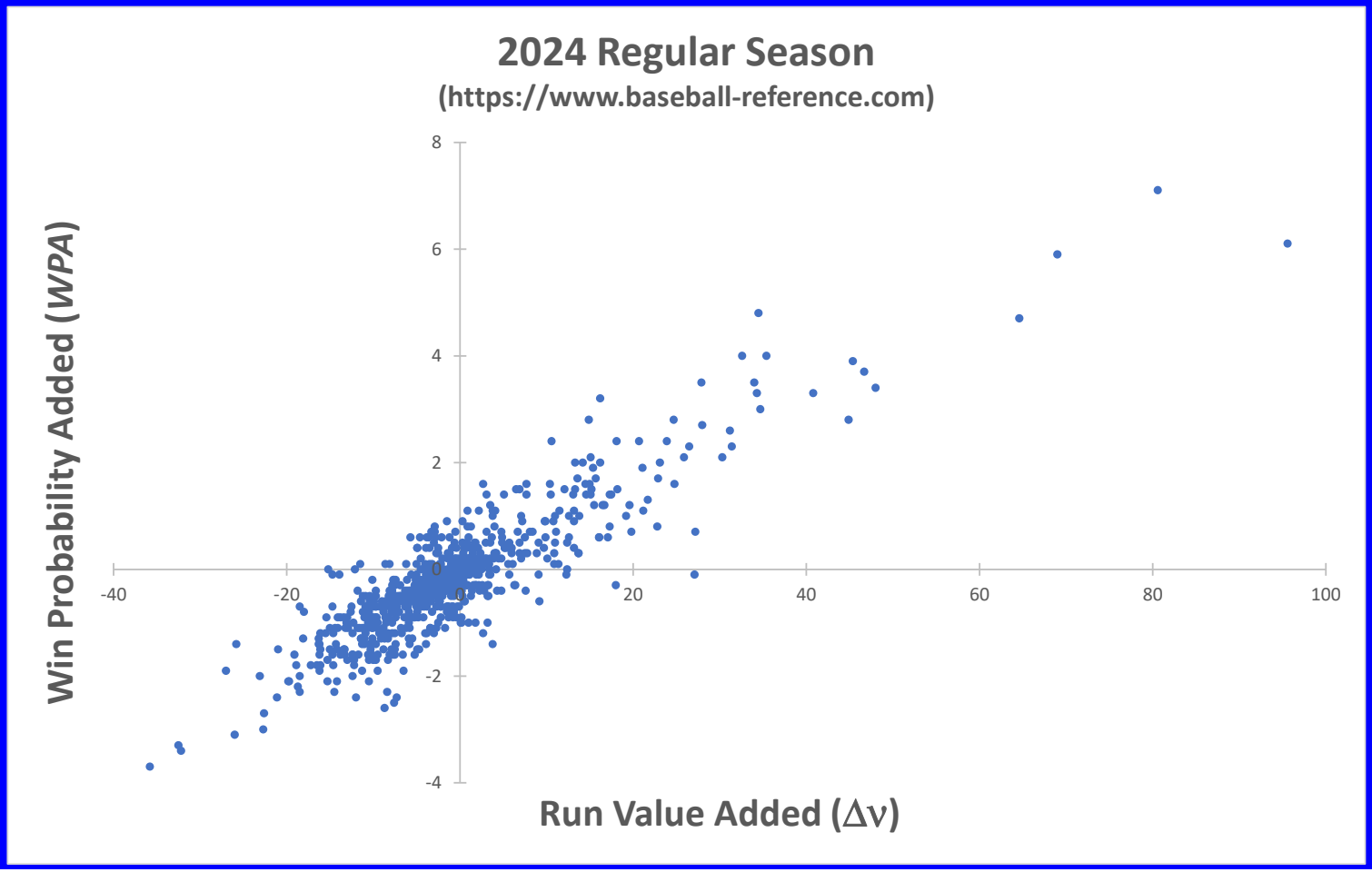
Here's a plot of *WPA* vs $\Delta v$ for 2024 using Fangraphs data (129 players)



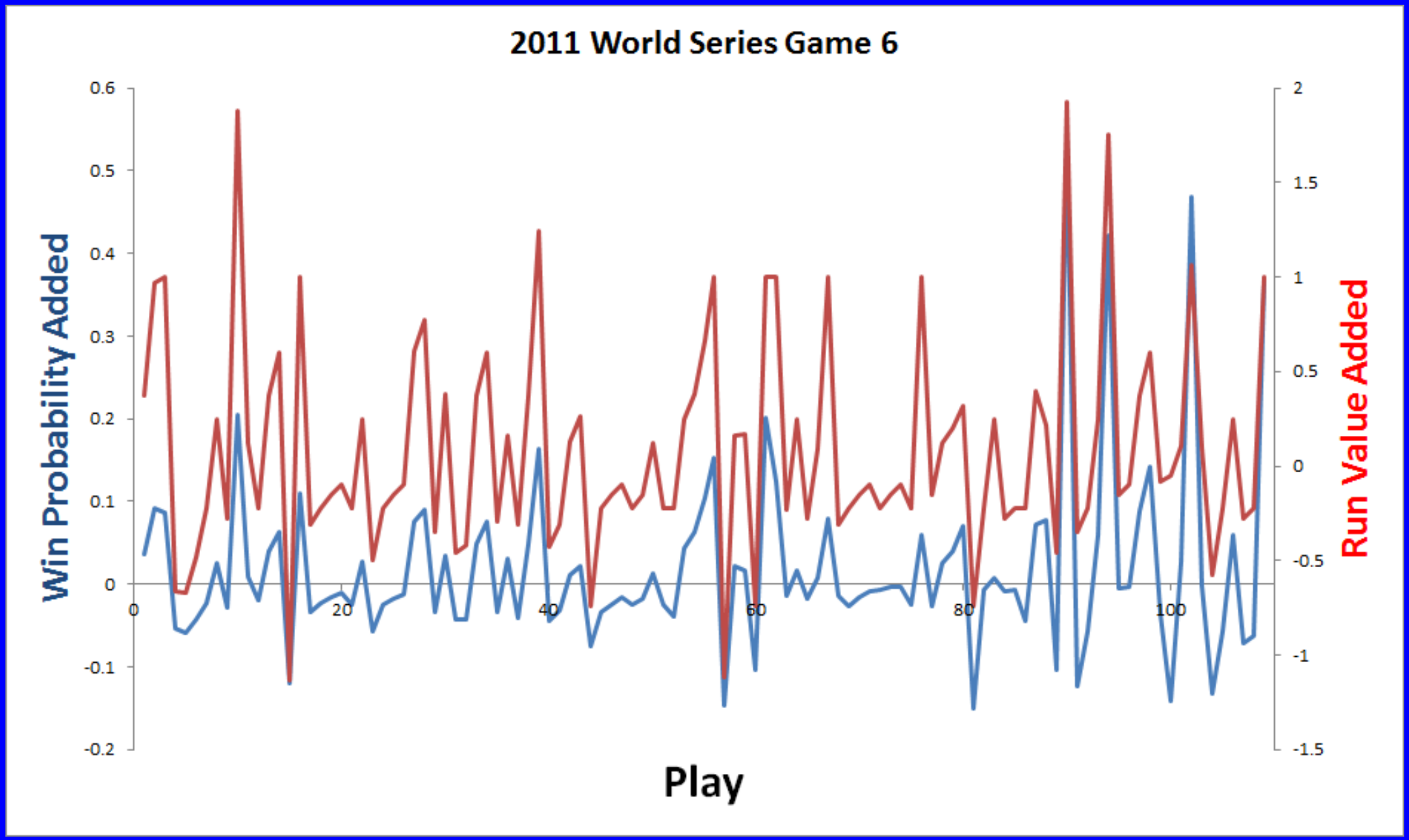

$r = 0.91$

# Do Run Value Added and Win Probability Added Match Up?

Here's a plot of *WPA* vs $\Delta v$ for 2024 using baseball-reference.com data (803 players)




$r = 0.89$


2011 World Series Game 6
Win Probability Added
Run Value Added
Play
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
2
1.5
1
0.5
0
-0.5
-1
-1.5
0
20
40
60
80
100

# To Summarize:

- Baseball state space gives us unique metrics for "keeping score" – run value added and win probability added
- Can use these to analyze baseball strategy
- Can use these to follow game evolution
- Can use these to measure value-added of individual plays, and hence individual players