An Analysis of the Automatic Balls and Strikes System in the MiLB

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Introduction:

Minor League Baseball has implemented automated balls and strikes (ABS) in their highest division (AAA) since the 2022 season and in its lower leagues since 2019. Its design has gone through many changes centered around how the height is calculated for each batter, depth of the strike zone, and how it is utilized in respect to the game. The technology was most recently used during the first half of each weekly series and the league has rich data on these games publicly available, allowing us to test the effects of these changes in a quasi-experimental setting. By comparing the pitch tracking data and call results from the games where ABS was used to where it was not we can identify how different pitches get called and test for umpire biases. Our results will help us determine the impact ABS has on the product of the game as a whole, and find crucial takeaways to assess the system's future use in professional baseball.

Data Section:

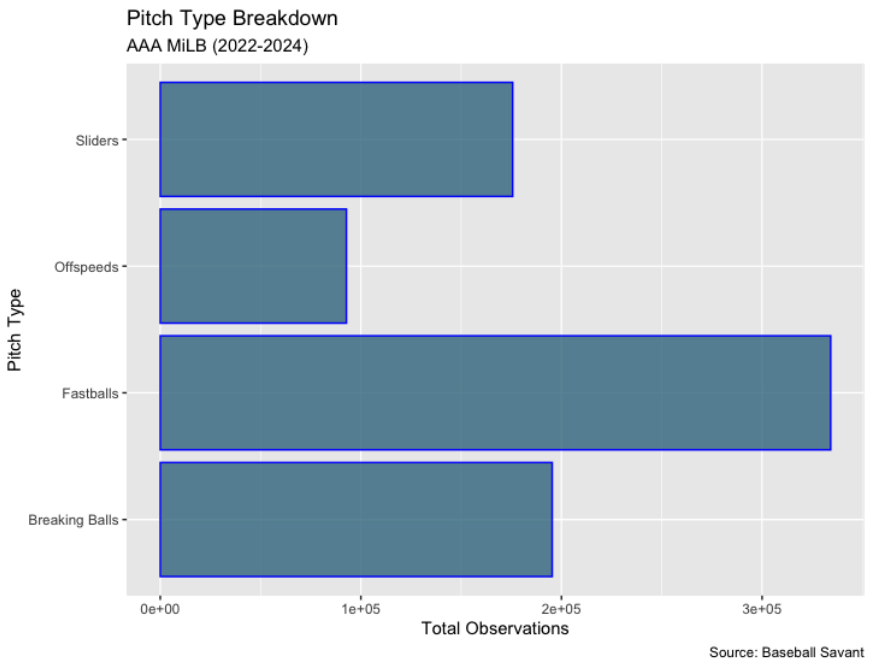
Our data comes from MLB's Statcast database, where we pulled just under 800,000 individual observations of pitches tracked between the 2022-2024 seasons, including pitch type, location, speed, and game situation for each.

Fig. 1

Pitch Type Breakdown

	Observations	Percentage
Fastballs	334195	41.81%
Offspeeds	92804	11.61%
Breaking Balls	195377	24.44%
Sliders	175670	21.98%

Source: BaseballSavant



Games could be called under a challenge system or full-ABS. Full-ABS has no autonomy for the home plate umpire, in this system they are fed calls made by ABS in real time through an earpiece, and call each pitch as told. However, under the challenge system, ABS runs in the background while the home plate umpire makes each call at their discretion. Teams can then challenge these calls made by the human umpire at a limited amount per game, where a call would be changed if it were determined the umpire missed it. The way this was implemented changed year over year. In 2022, ABS debuted in all parks of the western Pacific Coast League as well as exclusively at Charlotte home games for the eastern International League. In 2023, the league implemented the system in all ballparks, and began using a six game series model for their schedule. During this year, all games played Tuesday-Thursday would use full-ABS and the Challenge system would be used in any Friday-Sunday games. In 2024, they utilized that same system until midseason, then opting to use only the challenge system post-June 25th.

Fig. 2

Total Observations by Year and System

	Total	ABS	Chal
Total	799361	351151	448210
2024	344874	83983	260891
2023	359469	172150	187319
2022	95018	95018	N/A

Source: BaseballSavant

To make calls in game, the MLB uses the plate x and z coordinates recorded by the Hawkeye tracking system. These numbers reflect where each pitch crossed home plate from the catcher's perspective, (camera behind the plate), capturing horizontal and vertical location. The strike zone is set as a two-dimensional plane horizontally defined as the width of the plate, or 17 inches. Vertically, the strike zone is set between 27% and 51% of the batter's height, so it is fluid

throughout the game, and calculated before the first pitch a batter sees in real time. For each pitch, we used an algorithm on its horizontal and vertical location as it crossed the plate to determine if it was inside or outside of the strike zone and subsequently added a binary variable for whether or not the call on the field was correct or missed. We also parsed through and identified the system each game was played under to group our results.

Results:

The MLB wanted to test both of these systems in real game action before adding it to the professional ranks; the initial results from both fans and players were overwhelmingly in favor of the challenge system. Commissioner Rob Manfred confirmed this as the MLB's viewpoint when he stated, "those who have played with it do have a strong preference for the challenge system over ABS calling every pitch. And that has certainly altered our thinking on where we might be headed." (Feinsand, 2024) Why such a sudden shift in opinion after the ABS system was just recently heralded as the future of the sport? To answer this, we need to look at the differences in how the game played under each system.

First, we looked at what percent of all pitches not swung on were deemed an incorrect call over different groupings of the data. The algorithm found the ABS system made an incorrect call on 4.44% of pitches it decided. It is important to note there are some errors in the statistic that account for such a high number here. The first is that the data used to set the strike zone on gameday is different than what we utilized and it is only roughly half of the total pitches involved in the game, so this does not signify a failure to correctly identify calls generally by the ABS system. Other factors like accounting for the radius of the baseball and various inconsistencies in the dataset play into the error as well. For reference, the challenge system missed just under 7% of pitches decided on, which labels the ABS as still a vast improvement. In

Fig. 3

Missed Calls on Pitches Taken By System

AAA MiLB (2022-2024)

	ABS	N.A	CHALLENGE	N.C	DIFFERENCE	SE
Total	4.44%	351151	6.99%	448210	-2.55%	0.000516
Home	4.37%	169255	6.95%	218967	-2.58%	0.000675
Away	4.50%	181896	7.02%	229243	-2.52%	0.000692
Fastballs	4.07%	147415	7.08%	186780	-3.01%	0.000786
Offspeeds	4.05%	40656	5.65%	52148	-1.60%	0.001352
Breaking Balls	4.87%	85757	7.55%	109620	-2.68%	0.001039
Sliders	4.88%	76619	6.84%	99051	-1.96%	0.000692

Home and Away denotes the hitting team

Fastballs include 4-seam and Cutter

Offspeeds include Changeup, Knuckleball, and Split-Finger

Breaking Balls include Curve, Knuckle-Curve, Slurve, Screwball, Sinker, and Eephus

Sliders include Slider and Sweeper

Source: BaseballSavant

our analysis we wanted to specifically see if there were any significant statistical differences in how certain types of pitches were called. We found that the ABS system is very consistent in its proportion of correct calls between fastballs and offspeeds, and similarly between breaking balls and sliders. The human umpires, however, showed a statistically significant difference in their variance in correct calls between fastballs and offspeeds. Intuitively, this makes sense, a human umpire could naturally show deficiencies at being able to read pitches based on how fast they are coming in, whereas a robot would perform better in this scenario. We saw similar trends when it came to correctly calling breaking balls and sliders, which would assess ability to correctly read horizontal vs vertical movement. ABS once again outputs its calls very consistently, while human umpires tend to do better at reading horizontal movement. The last important piece of is

the home-away splits which show little variance in proportion of missed calls under both systems.

To contextualize the error, we need to analyze the biases behind why they are there to further understand its true effect on the game. To do this we can further categorize each of these decisions made by whether or not they were favorable to the team at bat. Meaning, if the call helped extend the at bat, (i.e. supposed to be a strike and ruled a ball), it was considered favorable. It would be unfavorable if it effectively helped shorten the at bat.

Fig. 4

Bias Towards Hitters By System

AAA MiLB (2022-2024)

	ABS			Challenge			
	FAVORABLE	UNFAVORABLE	DIFF	.FAVORABLE	.UNFAVORABLE	.DIFF	DIFF.BETWEEN.BOTH
Total	2.66%	1.78%	0.88%	3.70%	3.69%	0.01%	0.87%
Home	2.63%	1.74%	0.89%	3.73%	3.70%	0.03%	0.86%
Away	2.69%	1.81%	0.88%	3.68%	3.68%	-0.00%	0.88%
Fastballs	2.39%	1.67%	0.72%	3.62%	3.74%	-0.12%	0.84%
Offspeeds	2.66%	1.39%	1.27%	3.45%	3.03%	0.42%	0.85%
Breaking Balls	2.93%	1.94%	0.99%	4.14%	3.96%	0.18%	0.81%
Sliders	2.87%	2.01%	0.87%	3.51%	3.63%	-0.12%	0.99%

Home and Away denotes the hitting team

Fastballs include 4-seam and Cutter

Offspeeds include Changeup, Knuckleball, and Split-Finger

Breaking Balls include Curve, Knuckle-Curve, Slurve, Screwball, Sinker, and Eephus

Sliders include Slider and Sweeper

Source: BaseballSavant

In contrast to Figure 3, testing for bias shows a much more consistent output from the human umpires under the challenge system, and uncovers a deeper nuance to the game as well. The working theory of most fans is that umpires would show bias towards the home team, and for good reason, it is a tough job to remain firm in an individual decision knowing that there are 10,000+ people right behind you who will audibly show their disdain towards your decision based on who you call in favor of. Yet, these numbers effectively demonstrate no bias shown by umpires based on which team is at the plate, while strengthening the working theory of lesser ability to correctly read offspeeds and breaking balls. These results highlight a part of the game often forgotten by the average fan. It is inherently baked into the game to have slight errors by coaches, players, and umpires alike. The greatest at each position, though, are the ones able to contribute in their role most consistently. What the strike zone looks like can vary based on who is the one making the calls, but the important part is that it stays the same throughout each game. It is a subtle, but defining feature of baseball to have a person making these decisions with conviction showing as little bias as possible to either side, which is lost in a full-ABS system. This is why I believe the challenge system was better received by everyone involved, and can help continue to usher in a new age of technology into the game of baseball that even the most traditionalist of fans can get behind.

References

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