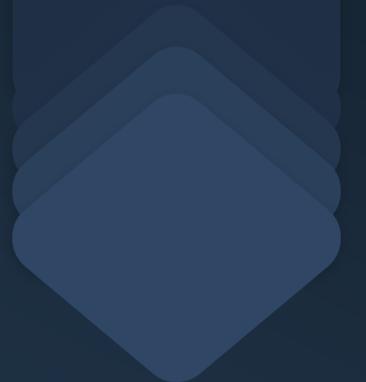




Inventory Accuracy

WHITEPAPER

The Auburn University RFID Lab explores the processes, formulas, and metrics used for measuring inventory accuracy.



Technology and Inventory Accuracy

The advancement of technology has greatly impacted the efficiency and accuracy of measuring and managing inventory. The benefits are considerable: less time counting inventory, more accurate inventory counts, better on-shelf availability, and ultimately, higher customer satisfaction. In the past, inventory accuracy has been calculated in many different ways. This paper reviews the most prominent inventory accuracy methods and proposes the most appropriate method for measuring inventory accuracy across industry lines.



Perpetual Inventory (PI) is what is believed to be in a store or facility at any given time, and PI Accuracy is how closely the actual count of units in the store is to what is thought to be there. The underlying notion of PI Accuracy seems universal, but it is debated on how this exact metric should be calculated and interpreted. This paper also explores these differences in detail, including their calculations and associated implications.

Why Inventory Accuracy Matters

1. Customer Satisfaction

Customer satisfaction begins with the right product, at the right time, and in the right place.

- ▶ Inventory Accuracy
- ▶ Product Availability
- ▶ Omnichannel Opportunity
- ▶ Sales Growth

2. Cost Savings

Better inventory management reduces costs throughout the supply chain.

- ▶ Reduced Shrink
- ▶ Reduced Claims
- ▶ Reduced Carrying Costs
- ▶ Better Forecasting

Terms to Know

Actual

The number of physical units that are in the store. For our purposes, RFID tags are used to identify products and quickly capture the number of physical items in a store.

On-Hand (OH)

The number of physical units a store **believes** to be in stock at any given time.

Exact Match

When the Actual count and On-Hand count are equal; when a store has the correct amount of actual units in store.

Overstated

When the On-Hand count exceeds the Actual count for a particular SKU, or when a store claims to have more units than they actually do.

Understated

When the Actual count exceeds the On-Hands count for a particular SKU, or when a store claims to have fewer units than they actually do.

Frozen Out-Of-Stock

When a SKU has an On-Hand count but no Actual count, or when a store claims units are in-stock when they are not.

Stock Keeping Unit (SKU)

A unique number used by retailers and manufacturers to identify and track a type of product.

Visualizing Inventory Accuracy

Visualizing inventory accuracy helps demonstrate its implications and establish the best overall method for calculating inventory accuracy.

A standard format will be used, in which a SKU is represented as a collection of individual units. **Green**, **Red**, and **Blue** colors represent whether this SKU's units are an exact match, overstated, or understated, with respect to Actual and On-Hand counts.

- Actual < On-Hand (Overstated)**
Any **Red** shows that this SKU has units that are not physically present but are recorded by the On-Hand system.
- Actual = On-Hand (Exact Match)**
Green reflects alignment of the Actual and the On-Hand records; a circle that is completely green shows an Exact Match between Actual and On-Hand units.
- Actual > On-Hand (Understated)**
Any **Blue** shows units captured by an Actual count but not seen in the On-Hand record.

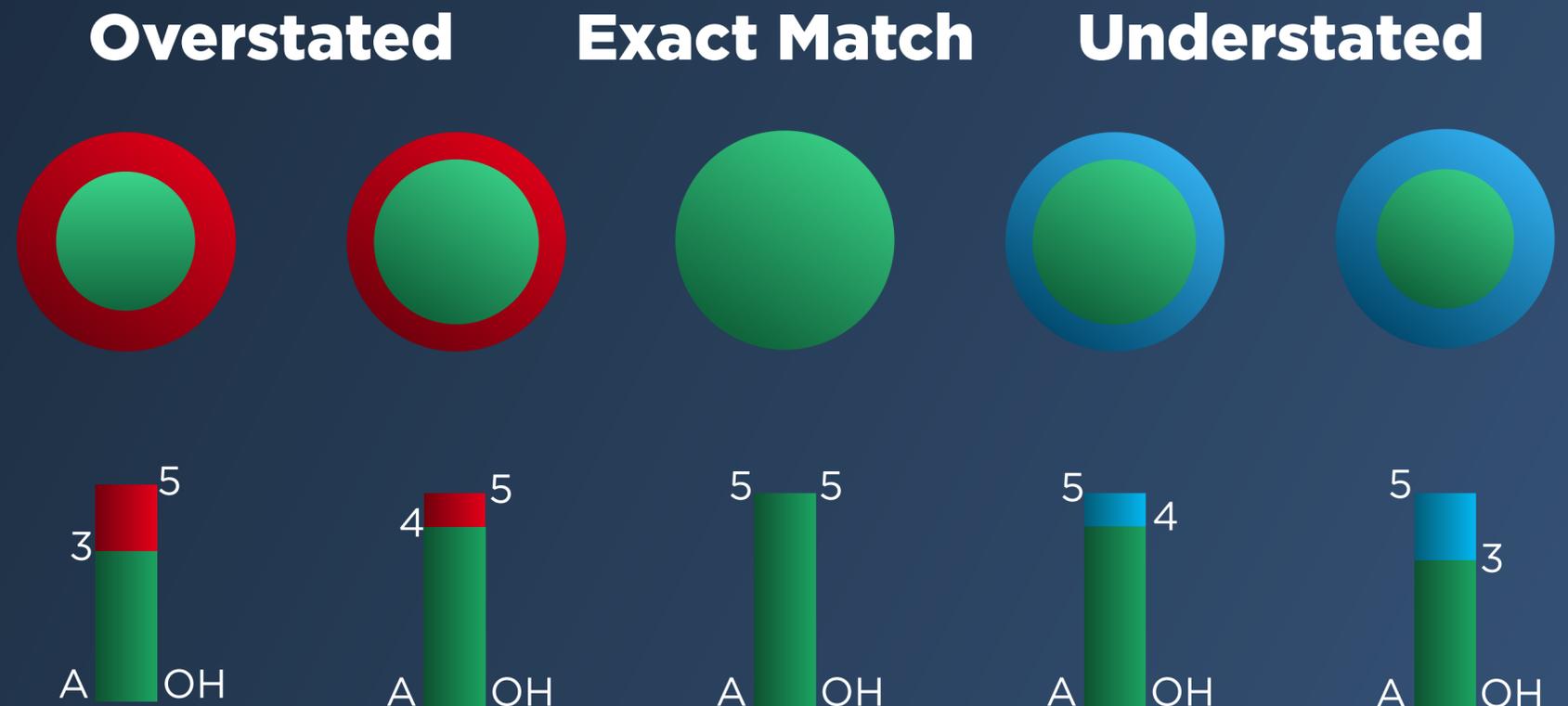


Figure 1

Characteristics of an Effective Accuracy Metric

Interpretable

Scaled between 0% and 100%



Figure 2

Symmetrical

Similar impact for overstated and understated SKUs

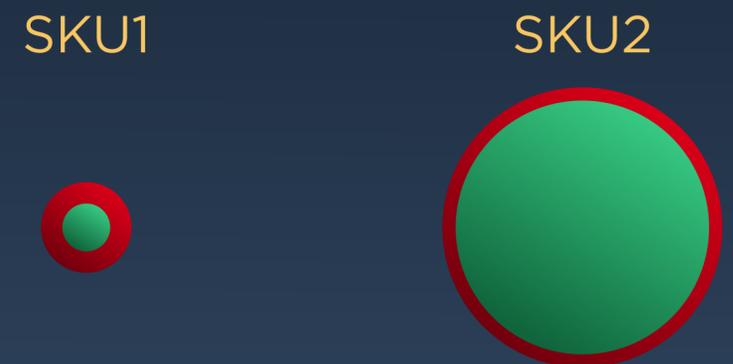


If Actual and OH values are switched, both should have similar impact on accuracy.

Figure 3

Proportional

Appropriate impact on overall accuracy for different scenarios



Both have a variance of 1 unit, but **SKU1** should be considered less accurate.

Figure 4

Total Magnitude

What is Total Magnitude?

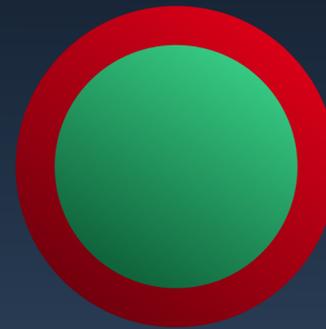
The simplest way to look at the relationship between Actual and OH is by Total Magnitude. Total Magnitude is a ratio of the total Actual and OH units across all SKUs.

$$\frac{\sum(\text{Actual})}{\sum(\text{OH})}$$

Total Magnitude can be used as a means to benchmark cycle count accuracy or evaluate the volume of tagged units in stores. It is typically between 85% - 90%.

The most common purpose is for financial accounting, but it does *not* serve as an effective measure of PI Accuracy.

SKU1



Actual: 42
On-Hands: 52

SKU2



Actual: 3
On-Hands: 17

SKU3



Actual: 41
On-Hands: 28

\sum Actual: 86 \sum On-Hands: 97

Figure 5

Total Magnitude = 0.89 or 89%

Total Magnitude



Σ Actual: 107 Σ On-Hands: 93

Figure 6

Drawbacks of Total Magnitude

Total Magnitude solely accounts for the total volume of Actual relative to the total OH units. Total Magnitude can exceed 100% when the Actual count is greater than the OH count, which is not interpretable. Total Magnitude can be useful for evaluating total volume, but not individual SKU accuracy.

Additionally, if Overstated and Understated SKUs offset one another, the Total Magnitude will report a score of 100%, but it fails to capture SKU-level assortment issues.

As a result, Total Magnitude is a poor measure of true inventory accuracy.

Total Magnitude = 1.15 or 115%

Exact Match

What is Exact Match?

Exact Match measures individual accuracy for each SKU based off of Actual and On-Hand counts.

Actual = OH = 1 or 100%
Actual ≠ OH = 0 or 0%

(Total Exact Match is an average of all individual values)

Exact Match considers a SKU to be correct when the count of Actual units perfectly match the On-Hand quantity, resulting in a score of 100%. A SKU is incorrect if the count of Actual units does not match the On-Hand quantity, resulting in a value of 0%. Exact Match is the average of all SKUs or all 1's and 0's. A typical value for Exact Match is within 55% - 65%.

It is often used in omnichannel operations.

SKU1



Actual: 39
On-Hands: 39
Accuracy: 100%

SKU2



Actual: 20
On-Hands: 21
Accuracy: 0%

SKU3



Actual: 1
On-Hands: 18
Accuracy: 0%

Figure 7

$$\text{Exact Match} = \left(\frac{1 + 0 + 0}{3} \right) \times 100$$

Exact Match = 33%

Exact Match

SKU1



Actual: 38
On-Hands: 39
Accuracy: 0%

SKU2



Actual: 20
On-Hands: 21
Accuracy: 0%

SKU3



Actual: 17
On-Hands: 18
Accuracy: 0%

$$\text{Exact Match} = \left(\frac{0 + 0 + 0}{3} \right) \times 100$$

Exact Match = 0%

Drawbacks of Exact Match

While Exact Match is a simple way to look at the accuracy of each SKU, it does not account for the magnitude of variance between Actual and OH values or how close a SKU is to being out-of-stock.

Figure 8 displays 0% accuracy even though each SKU is only one unit away from 100%. This outcome would be the same for SKUs whose Actual count is only a fraction of the On-Hand count. As a result, Exact Match accuracy can be misleading, suggesting worse performance than actuality.

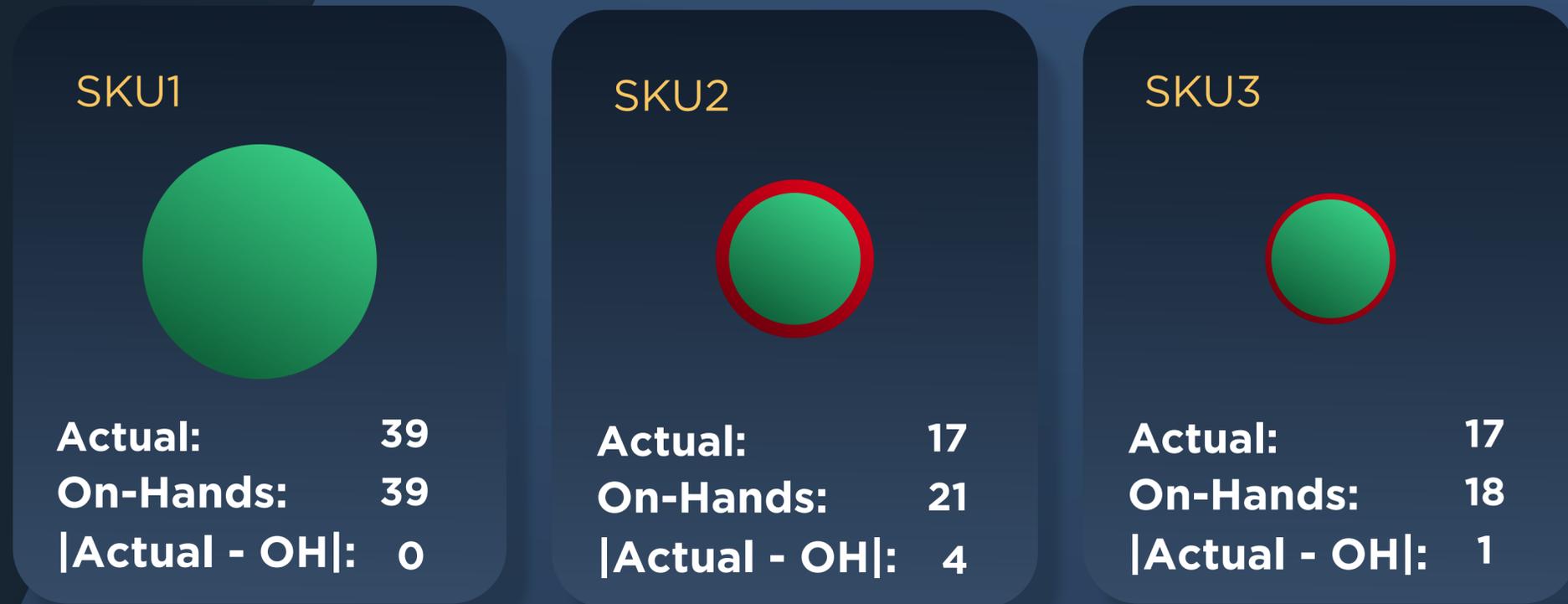
Figure 8

What is SAV?

Sum of Absolute Variance (SAV), also known as Sum of Absolute Difference, is another measure of accuracy used by a number of companies. SAV takes into account the sum of the difference between Actual and On-Hand counts and divides it by the sum of total On-Hand counts.

$$1 - \frac{\sum |\text{Actual} - \text{OH}|}{\sum (\text{OH})}$$

Because SAV uses the absolute value of the difference between Actual and On-Hand counts for each SKU, the Overstated SKUs and Understated SKUs do not cancel out, so there error is accounted for in both.



$\sum |\text{Actual} - \text{OH}|: 5$

$\sum (\text{OH}): 78$

Figure 9

SAV Accuracy = 0.94 or 94%

SAV

SKU1



Actual: 8
On-Hands: 4
|Actual - OH|: 4

SKU2



Actual: 19
On-Hands: 11
|Actual - OH|: 8

SKU3



Actual: 16
On-Hands: 5
|Actual - OH|: 11

$\sum |Actual - OH|: 23$ $\sum(OH): 20$

Figure 10

Drawbacks of SAV

While SAV can be more insightful than looking at Total Magnitude or Exact Match, it can be difficult to interpret. For example, a higher variance than the total On-Hand counts would yield a negative measure of accuracy (seen in Figure 10).

Additionally, SAV does a poor job of accounting for SKUs with less depth. SKUs with fewer On-Hand units can be masked by SKUs with far more On-Hand units. For example, a low-depth SKU that is critically out-of-stock may not affect overall accuracy, indicating better overall inventory health than reality.

SAV Accuracy = -0.15 or -15%

SMAPE

What is SMAPE?

Symmetric Mean Absolute Percentage Error (SMAPE) is a metric that altogether accounts for the three effective qualities of an accuracy metric: interpretable, symmetrical, and proportional.

SMAPE individually calculates error for each SKU based off absolute variance, Actual counts, and On-Hand counts. The equation inside the summation sign is called the SMAPE difference or error. The SMAPE Accuracy is 1 minus the average of the SMAPE difference; consider the equation below.

$$1 - \frac{1}{n} \sum \frac{|Actual - OH|}{(|Actual| + |OH|)}$$

SKU1



Actual: 39
On-Hands: 39
SMAPE Error: 0

SKU2



Actual: 17
On-Hands: 21
SMAPE Error: 0.11

SKU3



Actual: 5
On-Hands: 14
SMAPE Error: 0.47

Σ Actual:61 Σ On-Hands:74

Figure 11

SMAPE Accuracy = 0.81 or 81%

SMAPE

SKU1



Actual: 21
On-Hands: 17
SMAPE Error: 0.11

SKU2



Actual: 17
On-Hands: 21
SMAPE Error: 0.11

SKU3



Actual: 4
On-Hands: 8
SMAPE Error: 0.33

Actual: 42 On-Hands: 46

Figure 12

SMAPE Accuracy = 0.82 or 82%

Characteristics of SMAPE

SMAPE Accuracy is scaled between 0% and 100%, regardless of overstatement or understatement, making it easy to interpret.

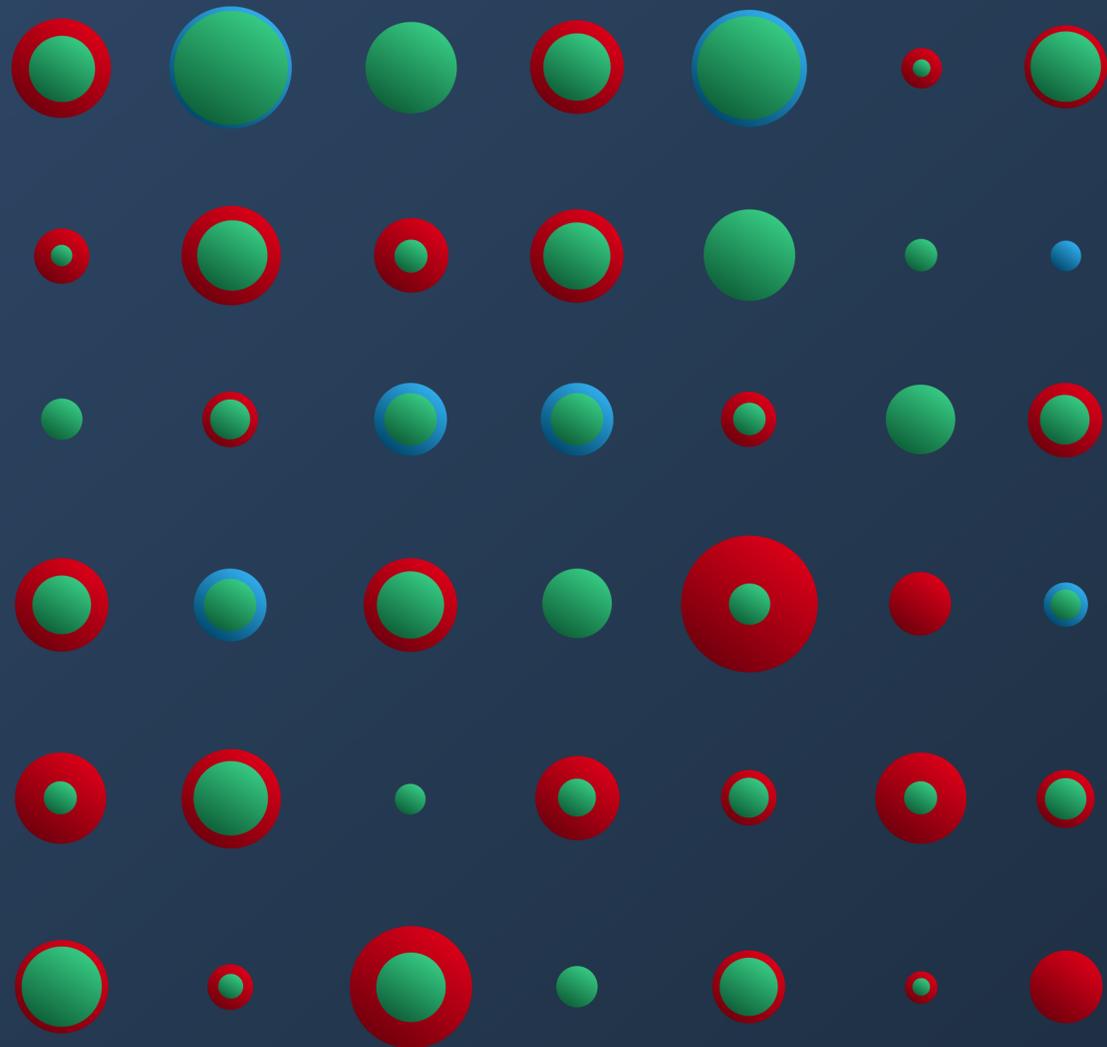
Even with opposite Actual and On-Hand values for SKU1 and SKU2 in Figure 12, the accuracy or error remains the same, so SMAPE is also symmetrical.

SMAPE also places a greater weight of error on SKUs that are nearing out-of-stock. In Figure 12, SKU3 has the same variance of units as SKU1 and SKU2 (4), but it is closer to being out-of-stock, yielding a much lower accuracy. This is a desirable characteristic, because out-of-stock SKUs pose a more critical, proportional risk to overall inventory health.

Comparing Inventory Accuracy Metrics

Consider Retail Store A:

42 Total SKUs



Total Actual: 547

Total On-Hand: 751

Total Magnitude: 73%

Exact Match: 19%

SAV Accuracy: 65%

SMAPE Accuracy: 76%

Figure 13

Inventory Accuracy Conclusion

42 Total SKUs

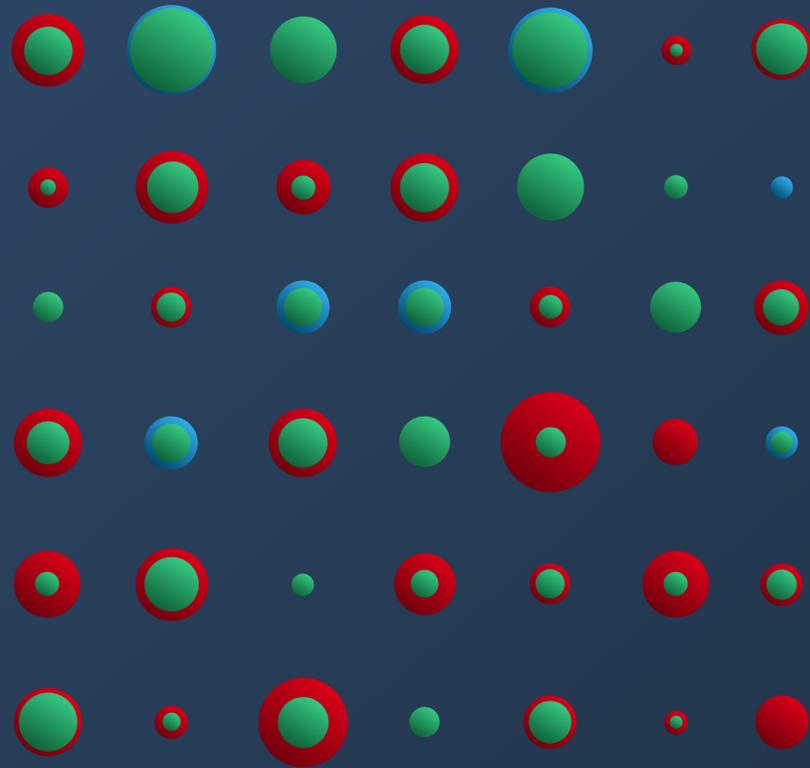


Figure 13

A universal standard for calculating inventory accuracy that is interpretable, symmetrical, and proportional will enable better inventory measurement and management across industries.

Currently, the most common way of calculating inventory accuracy is Exact Match. However, it does not convey overall inventory health; for example, Exact Match assigns the same value to a SKU that is nearly out-of-stock and a SKU that is only missing one unit. This fails to consider the magnitude of the SKU's error and therefore the overall inventory health.

On the other hand, SMAPE allows for errors to be weighted proportionally. If a SKU is very low in respect to its expected amount, it will be factored in appropriately in the total SMAPE score. As a result, SMAPE should be used as the universal standard for measuring inventory accuracy.

Total Actual: 547

Total On-Hand: 751

Exact Match: 19%

SMAPE Accuracy: 76%

Inventory Accuracy Formulas

Total Magnitude

$$\frac{\sum(\text{Actual})}{\sum(\text{OH})}$$

Exact Match

(Total Exact Match is an average of all individual values)

$$\begin{aligned} \text{Actual} = \text{OH} &= 1 \text{ or } 100\% \\ \text{Actual} \neq \text{OH} &= 0 \text{ or } 0\% \end{aligned}$$

SAV

(Symmetric Absolute Variance)

$$1 - \frac{\sum |\text{Actual} - \text{OH}|}{\sum(\text{OH})}$$

SMAPE

(Symmetric Mean Absolute Percentage Error)

$$1 - \frac{1}{n} \sum \frac{|\text{Actual} - \text{OH}|}{(|\text{Actual}| + |\text{OH}|)}$$

Contributors

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About the RFID Lab

The Auburn University RFID Lab is a research center that focuses on the business case and technical implementation of emerging technologies in the retail, aerospace, pharmaceutical, and manufacturing industries. Since its inception in 2005, the RFID Lab has conducted a series of seminal business value studies that have led to the adoption of RFID and other IoT technologies. Sponsors of the RFID Lab include Avery Dennison, Boeing, Checkpoint, Delta Air Lines, FedEx, GS1 US, Hanes Brands, Kohls, McDonald's, Nike, NXP, PVH, Sensormatic, SML, Tageos, T-Mobile, Walmart, and Zebra Technologies. If you would like to connect with the Auburn University RFID Lab, please contact Justin Patton at rfidlab@auburn.edu or 334-734-4034.

APPENDIX 1 - SMAPE

Example 1 Calculations

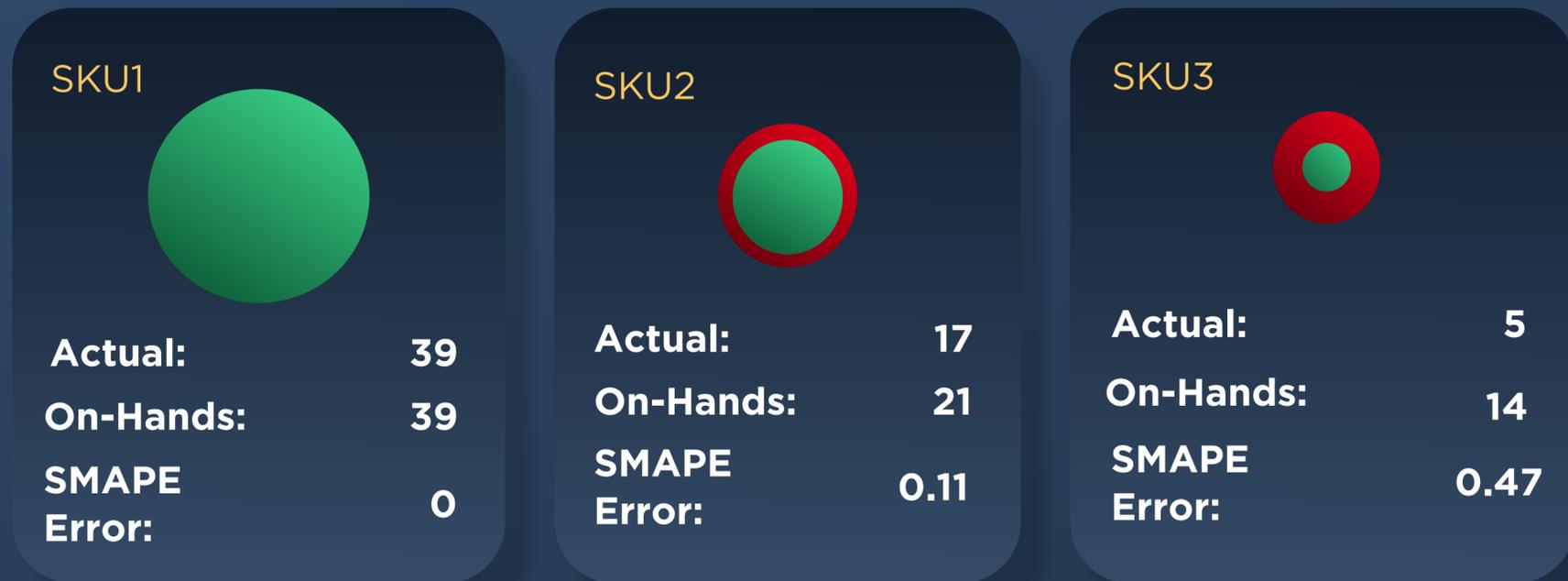


Figure 11

Actual: 61 On-Hands: 74

SMAPE Accuracy = **0.81 or 81%**

$$SMAPE = 1 - \frac{1}{n} \sum \frac{|Actual - OH|}{(|Actual| + |OH|)}$$

Individual SMAPE Difference for SKU1:

$$SMAPE \text{ ERROR SKU1} = \frac{|39 - 39|}{(|39| + |39|)}$$

$$SMAPE \text{ ERROR SKU1} = \underline{0 \text{ or } 0\%}$$

Individual SMAPE Difference for SKU2:

$$SMAPE \text{ ERROR SKU2} = \frac{|17 - 21|}{(|17| + |21|)}$$

$$SMAPE \text{ ERROR SKU2} = \underline{0.11 \text{ OR } 11\%}$$

Individual SMAPE Difference for SKU3:

$$SMAPE \text{ ERROR SKU3} = \frac{|5 - 14|}{(|5| + |14|)}$$

$$SMAPE \text{ ERROR SKU3} = \underline{0.47 \text{ OR } 47\%}$$

$$SMAPE = 1 - \frac{1}{3} \sum (0 + 0.11 + 0.47)$$

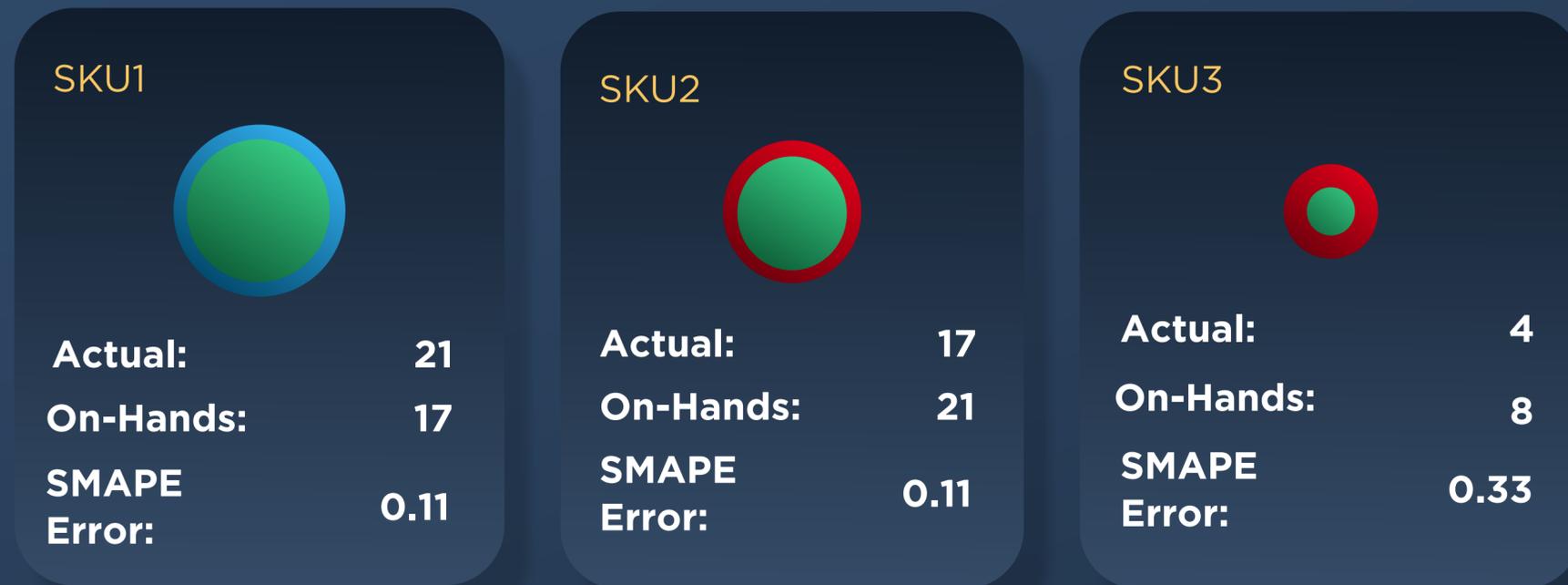
$$SMAPE = 1 - \frac{1}{3} (0.58)$$

$$SMAPE = 1 - 0.19$$

$$SMAPE = \underline{0.81 \text{ or } 81\%}$$

APPENDIX 2 - SMAPE

Example 2 Calculations



Actual: 42 On-Hands: 46

SMAPE Accuracy = **0.82 or 82%**

$$\text{SMAPE} = 1 - \frac{1}{n} \sum \frac{|\text{Actual} - \text{OH}|}{(|\text{Actual}| + |\text{OH}|)}$$

Figure 12

Individual SMAPE Difference for SKU1:

$$\text{SMAPE ERROR SKU1} = \frac{|21 - 17|}{(|21| + |17|)}$$

SMAPE ERROR SKU1 = 0.11 or 11%

Individual SMAPE Difference for SKU2:

$$\text{SMAPE ERROR SKU2} = \frac{|17 - 21|}{(|17| + |21|)}$$

SMAPE ERROR SKU2 = 0.11 or 11%

Individual SMAPE Difference for SKU3:

$$\text{SMAPE ERROR SKU3} = \frac{|4 - 8|}{(|4| + |8|)}$$

SMAPE ERROR SKU3 = 0.33 or 33%

$$\text{SMAPE} = 1 - \frac{1}{3} \sum (0.11 + 0.11 + 0.33)$$

$$\text{SMAPE} = 1 - \frac{1}{3} (0.55)$$

$$\text{SMAPE} = 1 - 0.18$$

SMAPE = **0.82 or 82%**