Small Turtle v.3

Investment Strategy Testing Summary

The Small Turtle v.3 strategy is **a modification of version v.1, inspired by Richard Dennis's "**turtle**"** approach. Version **v.3** retains the same key parameters as v.1, but has been **optimized** using **The Grid Search technique.** The strategy itself is a **trend-following strategy** and uses **the Donchian channel** to define entry and exit points, as well as **ATR volatility** to determine position size, stop loss distances, and pyramiding steps.

However, while the stability tests across a wide range of optimized parameters passed, **the strategy failed the Monte Carlo test.** This means that the strategy loses its profitability and generates significantly larger drawdowns when tested under suboptimal conditions. Therefore, **it is not recommended for use in real-world trading.**

I can't emphasize enough that for **a strategy to work** in real-world conditions, it must also work with **suboptimal parameters** and in **suboptimal conditions.** In short, **it must be stable** to changing market conditions.

I don't know who said these words, but they perfectly capture the problem of many optimizations:

"I've never seen a strategy that didn't work in backtests."

We don't know the future, we don't know future market conditions, but if we know that our strategy **has historically generated acceptable results** in various market conditions and across various parameter ranges, we are **a step ahead of other** market participants. However, the Small Turtle v.2 strategy **is not among them.**

Contents

Step 1: Formulate an investment strategy

The Small Turtle v.3 strategy originated from the classic "turtle" strategy, and compared to version v.1, **parameters were optimized** using **The Grid Search technique.** The basis is the observation that **the largest trends arise after breakouts from long-term consolidations.** The system defines such a consolidation as the price range from the last, relatively long period (entry Donchian channel) and treats **a break above its upper boundary as a signal of the start or continuation of an uptrend** (long position), while **a break below its lower boundary as a signal of a downtrend** (short position).

At the moment **of a breakout, the first unit of a position is opened,** the size of which is selected so that a price movement by a specified multiple of the current volatility (measured by the ATR) in an unfavorable direction translates into a predefined percentage decline in the portfolio's value. If **the trend develops as expected,** a price movement towards the open position by a fixed portion of this volatility (e.g., a fraction of the ATR) **results in the addition of a second unit (pyramidization).** A stop loss is maintained for the entire position at a fixed multiple of the ATR from the last entry level, allowing for pre-defined risk control at the level of a single transaction.

The market exit occurs via a counter-movement breakout from the shorter Donchian channel – the long position is closed when the price breaks down through the lower boundary of this channel, and the short position is closed when the price breaks up through its upper boundary. As a result, **the system gives back some profit at the end of the trend, but in return, it holds the position for most of the strong move.**

In **Small Turtle v.3, this logic remains unchanged,** while the Donchian channel lengths, adopted ATR multiples, and unit limits are treated as **parameters subject to optimization** in order to find stable, market-useful configurations.

The Small Turtle v.3 strategy uses:

- **Donchian channel to open a position** – identifying a breakout from a long consolidation;
- **Donchian channel to close a position** – a signal of the end of a trend;
- **Average True Range (ATR)** – for determining position size, stop loss and pyramiding levels;
- **Pyramiding** – adding units towards profit, up to a maximum number of units;
- **Portfolio limits** – maximum number of units in correlated markets and in one direction.

Characteristics of the strategy and its strengths and weaknesses:

- **Strengths:**
  - **Natural trend-following system** – profits from rare, large trends;
  - **Fully mechanical** – no discretion, easy to test and automate;
  - **Pyramiding Winners** – Increasing your exposure when the market behaves as expected;
  - **Risk scaled by ATR** – adjusting the position to current volatility.
- **Weaknesses:**
  - **Poor performance in consolidations** – numerous false breakouts and short, losing trades;
  - **Delayed entries** – joining the trend only after a breakout from the range;

- **The need for broad diversification** – a single market may not generate profitable trends for a long time.

The Small Turtle v.3 strategy, despite its relatively simple structure, requires the acceptance of longer periods of drawdowns and consistent adherence to money management principles, but in return it gives the opportunity to participate in large, directional price movements.

Step 2: Determine investment principles

Below is **the pseudocode** for the **Small Turtle v.3 strategy** on daily data:

1. **Calculation of indicators:**
    a. **Entry Breakout (XX days):**
        i. **Upper Boundary:** Highest price of the last XX sessions;
        ii. **Lower Boundary:** Lowest price of the last XX sessions.
    b. **Exit Breakout (YY days):**
        i. **Upper Boundary:** Highest price in the last YY sessions;
        ii. **Lower Boundary:** Lowest price of the last YY sessions.
    c. **ATR(20):** 20-day average true volatility range.
2. **Entry – long position (buy):**
    a. **Entry condition:** the candle's high falls above the upper border of the 20-day Donchian channel.
    b. Calculate the unit size so that a downward price movement of ZZ × ATR(20) represents a 0.5% decline in the portfolio value.
    c. Open your first long trade; set a stop loss ZZ × ATR(20) below the entry price.
3. **Entry – short position (sell):**
    a. **Entry condition:** the low of the candle falls below the lower border of the 20-day Donchian channel.
    b. Calculate the unit size as in point 2b.
    c. Open the first short unit; set a stop loss ZZ × ATR(20) above the entry price.
4. **Pyramiding positions:**
    a. If the price has moved towards profit by QQ × ATR(20) since the last entry price, add another unit in the same direction (long/short).
    b. Do not add more than 2 units per instrument (including the first one).
5. **Exiting a position:**
    a. **Long position:** Close all units when the price falls below the lower border of the YY-day Donchian channel or when a stop loss is activated.
    b. **Short position:** Close all units when the price rises above the upper border of the YY-day Donchian channel or when a stop loss is activated.
6. **Daily monitoring:**
    a. Update Donchian channel values (XX and YY days) and ATR(20).
    b. Check entry, pyramiding, exit conditions and compliance with portfolio limits.

The above rules are described in a way that allows them to be directly converted into a script in the chosen testing platform, which ensures the accuracy of the historical simulation and the reliability of the test results.

The tests are carried out assuming that the risk of one position is **0.5% of the total capital,** with **the stop loss order** placed at **ZZ x ATR (20 days) from the position opening point.**

Step 3: Pre-test your investment strategy

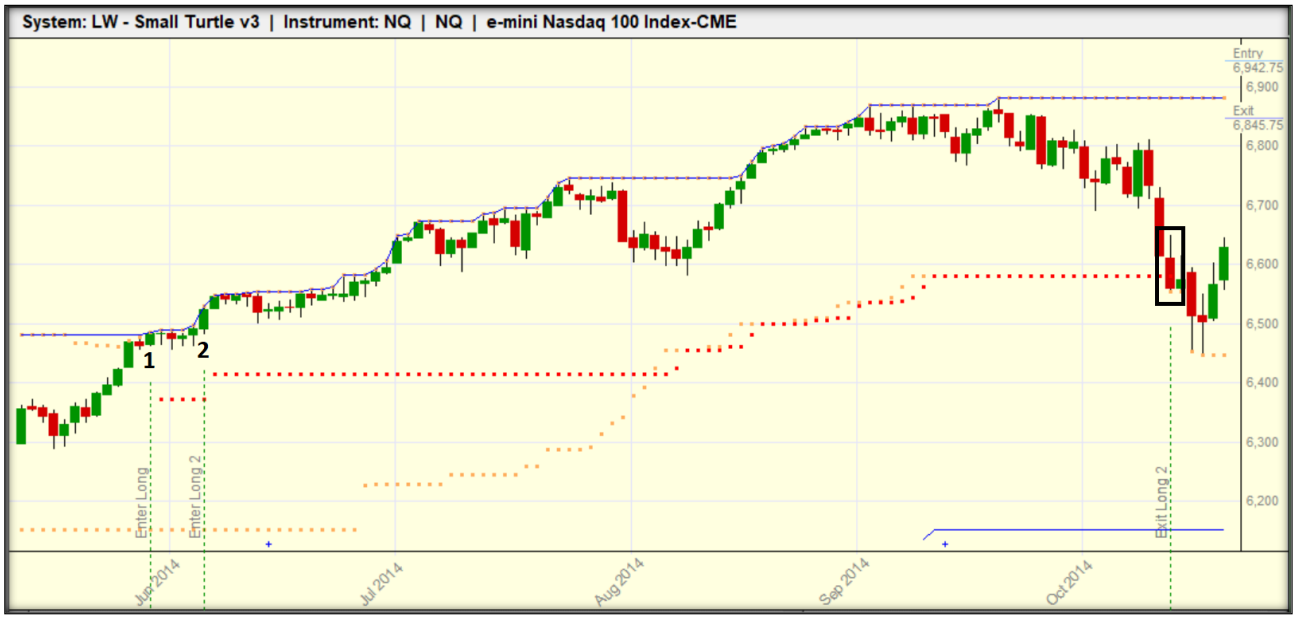
Below are some purchase and sale transactions that allow you to verify the following aspects:

- **Correctness of generated signals;**
- **Direction of opening a position;**
- **Moment of opening the position;**
- **The opening price of the position;**
- **Moment of closing the position;**
- **Closing price of the position;**
- **Compliance of the transaction with the theoretical assumptions of the investment strategy.**

At this stage, **it doesn't matter** whether the trades are **profitable,** what **instrument was used,** or whether they occurred **recently** or **in the distant past.** The key is **to verify that the trades are generated correctly** and in line with the assumptions described in the previous step.

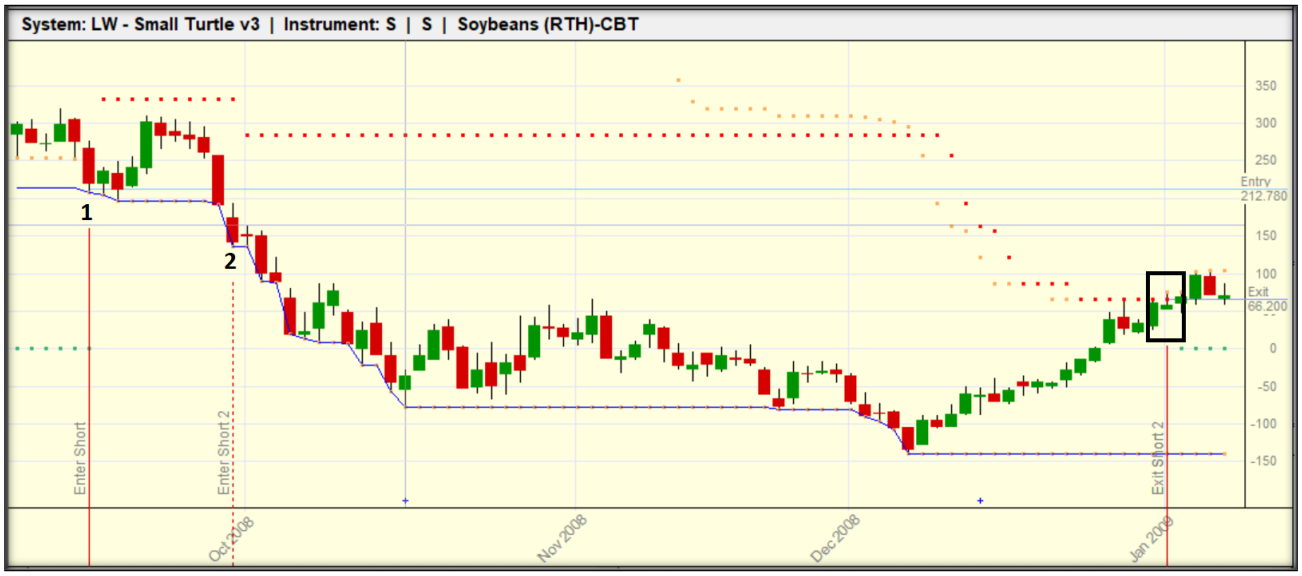
The first trade was executed on a futures contract for the Nasdaq 100 index. At the end of June 2013, **the price broke out above the long-term Donchian channel (200 days),** which, in accordance with the Small Turtle v.3 strategy, **generated a signal to open a long position** (candle marked 1). The system thus opened **the first long unit,** setting an initial **stop loss at a distance of 2.5 × ATR(20)** below the entry level (red dots on the chart). In the following days, the market continued its upward movement; when **the price moved up by 1 × ATR(20)** from the first entry, **the system added the second** —and last—allowable **unit of the position** (candle marked 2). **The protective stop for the entire position** was then adjusted to remain **approximately 2.5 × ATR(20)** from the last entry level.

According to the Small Turtle v.3 strategy rules, **a long position is held as long as the price remains above the lower boundary of the shorter Donchian channel (50 days) or the stop loss level is not reached.** In mid-October 2013, a strong downward correction occurred; **one of the large candles** (marked with a rectangle) **broke down the lower boundary of the exit channel,** which generated a signal to close the position. **Both long units were closed on a sell stop order.** The 2.5 × ATR(20) stop loss level remained intact throughout the transaction, and the position was closed precisely when the price crossed the exit channel. **The system worked correctly.**



The second trade was executed on a soybean futures contract. In early September 2008, **the price broke down the long-term Donchian channel** (entry), which, in accordance with the Small Turtle v.3 strategy, **generated a signal to open a short position** (candle number 1). The system opened the first short unit, setting **an initial stop loss at a distance of 2.5 × ATR(20)** above the entry level (red dots above the price). In the following days, the market continued its downward movement; **when the price moved down 1 × ATR(20) from the initial entry, the system added the second** —and last—allowable **short unit** (candle number 2). **The protective stop for the entire position** was then adjusted to remain **approximately 2.5 × ATR(20)** from the last entry level.

According to the Small Turtle v.3 strategy rules, a **short position is held as long as the price remains below the upper boundary of the shorter Donchian channel (exit channel) or the stop loss level is not reached.** In early January 2009, the market entered a stronger uptrend; **one of the candles** (marked with a rectangle) **broke above the upper boundary of the exit channel,** which generated **a signal to close the position.** Both short units were **closed with a buy stop order.** The 2.5 × ATR(20) stop loss level remained intact throughout the transaction, and the position was closed precisely when the price crossed the exit channel. **The system worked correctly.**



Once we are sure that the transactions are generated correctly, we can proceed to the first test of the strategy on the full **in-sample data set.** These tests are conducted on **baseline parameters** that, in my opinion, **should align with the strategy's stated goals.**

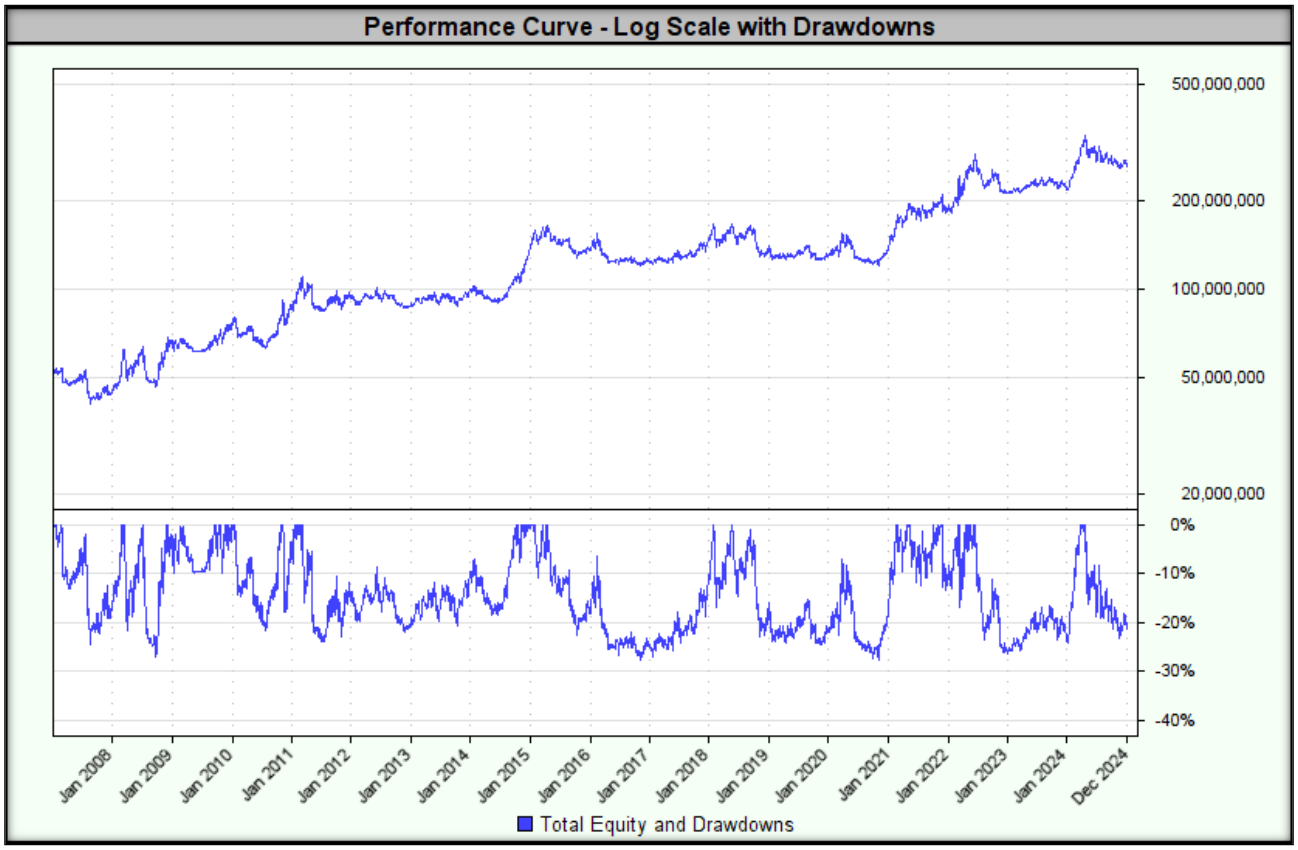
First, **we reject strategies that linearly lose capital.** If a strategy exhibits this pattern, it's a clear signal that any parameter optimization is pointless.

Our basic expectation is that the strategy generates **positive results,** even if they are at a low level.

Tested base parameters:

- **Entry Breakout (days):** 200;
- **Exit Breakout (days):** 50;
- **ATR (days):** 20;
- **Stop loss:** 2.5 × ATR(20);
- **Pyramiding (Unit Add):** every 1.0 × ATR(20);
- **Max units in one instrument:** 2;
- **Position sizing method:** Fixed Fractional, 0.5% of capital per unit;
- **Position direction:** long and short.

The test result is shown below.



Indicators/Measures	Concluding a transaction at the opening price
CAGR%	9.7%
MAR Ratio	0.35
RAR%	9.3%
R-Cubed	0.15
Robust Sharpe Ratio	0.45
Max Drawdown	27.5%
Wins	31.2%
Losses	68.8%
Average Win%	1.14%
Average Loss%	0.34%
Win/Loss Ratio	3.14
Average Trade Duration (days)	79
Percent Profit Factor	1.54
SQN	0.97
Number of transactions	1655

In summary, the system is working properly and generating signals as expected. Furthermore, tests on the baseline parameters yielded satisfactory results. We can now move on to the most interesting stage of creating an investment strategy – **optimization and stability.**

Step 4: Optimizing and assessing the stability of the investment strategy

This stage of strategy development and testing is **crucial** because it determines how **effective** the strategy will be in **real-world conditions. I cannot** emphasize enough that for **a strategy to work** in real-world conditions, it must also perform under **suboptimal parameters** and **conditions.** In short, **it must be stable** to changing market conditions.

I don't know who said these words, but they perfectly capture the problem of many optimizations:

"I've never seen a strategy that didn't work in backtests."

My goal is not to find **optimal parameter values** – **my goal** is to find **a wide range of parameters** for which the strategy will generate **acceptable results. We don't know the future,** we don't know future market conditions, but if we know that our strategy **has historically generated acceptable results** in various market conditions and across various parameter ranges, then we are **one step ahead of other** market participants.

What **parameters to choose** for the next period is the topic of consideration in **Step 5, "Walk-Forward Analysis",** but before we get to that, **we need to know** whether our strategy is even **stable.**

1. Stability across a wide range of optimized parameters

This version of **the Small Turtle v.3 strategy assumes optimization of the parameters proposed by the strategy's creator, Richard Dennis.** We will optimize using **the Grid Search method,** which involves **fully optimizing all specified parameters by creating a wide range of possible combinations.** Our goal is to find **parameter ranges** that **will keep the strategy stable (robust),** allowing us to assess its suitability in real-world market conditions.

The key criterion for assessing stability is that all test results must demonstrate a positive MAR, and the maximum drawdown must not exceed 250% of the drawdown for the result with the highest MAR. If any test produces a negative MAR, or if the drawdown exceeds 250% of the drawdown for the result with the highest MAR, the strategy is rejected entirely.

In the first step, we test the stability of the parameters on **in-sample data.** To do this, we define **ranges of** parameter values so that **the ratio of the highest to lowest value of the range is at least 150%.**

In the tested strategy, the ranges defined in this way are:

- **Entry Breakout (days):** range **170-260 (step: 5);**
- **Unit Add (ATR):** range **0.5-1.0 (step: 0.5);**
- **Stop (ATR):** range **2.0-3.0 (step: 0.5);**
- **Exit Breakout (days):** range **40-60 (step: 2).**

Other parameters remain unchanged.

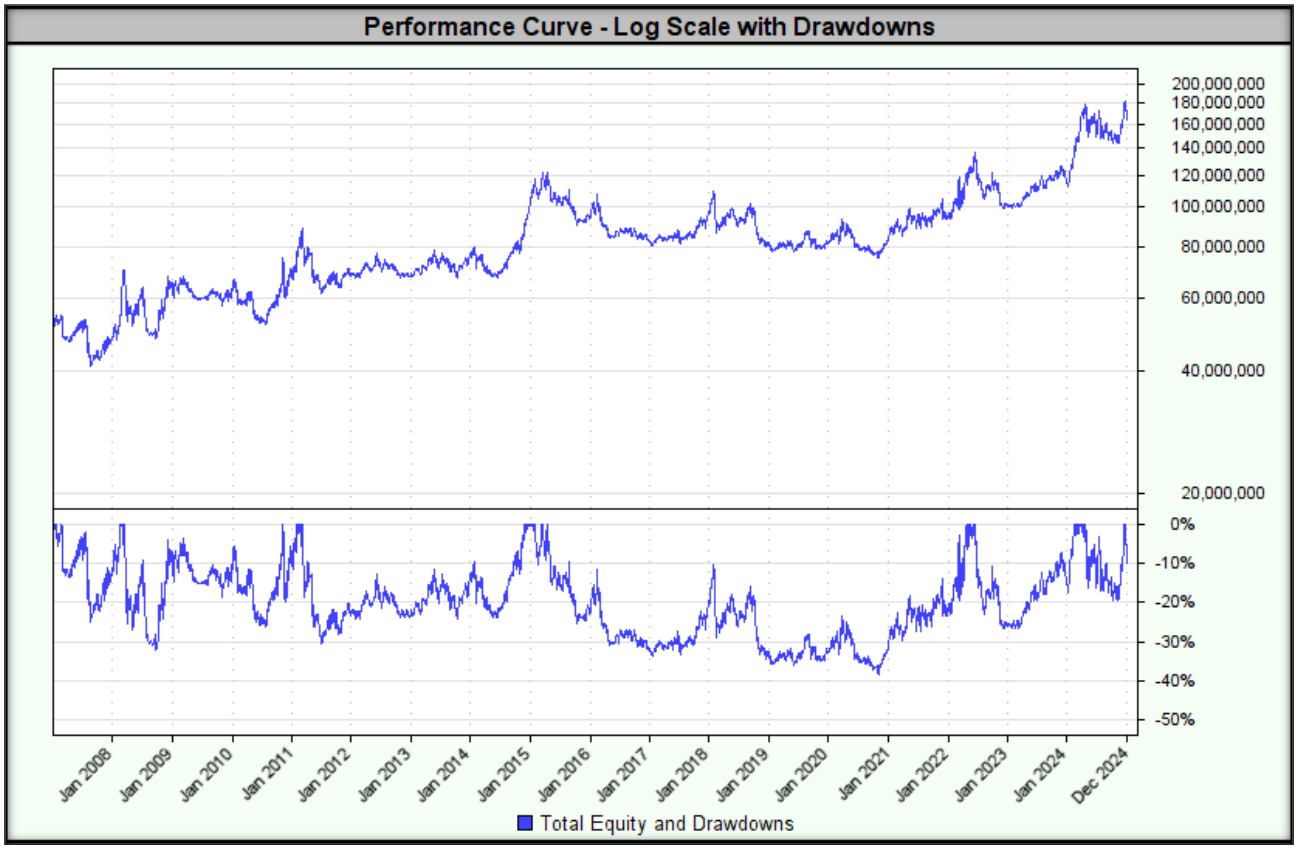
The lowest MAR value of 0.18 was achieved for the following parameters:

- **Entry Breakout (days):** 260;

- **Unit Add (ATR):** 1.0;
- **Alloy (ATR):** 2.0;
- **Exit Breakout (days):** 60.

Test	Entry Breakout (days)	Unit Add (ATR)	Stop (ATR)	Exit Breakout (days)	End Balance	CAGR%	MAR	Sharpe	Ann. Sharpe	Max TE DD	Longest DD	Trades	R3	RAR [%]
1232	260	1.0	2.0	60	$169,877,160.56	7.03%	0.18	0.42	0.43	38.3%	85.5	1628	0.05	4.89
1166	255	1.0	2.0	60	$171,506,377.95	7.09%	0.19	0.42	0.43	37.9%	84.9	1645	0.05	4.95
1098	250	1.0	2.0	56	$157,708,656.49	6.59%	0.19	0.40	0.46	35.1%	49.2	1697	0.06	5.38
42	170	1.0	2.0	56	$171,212,097.03	7.08%	0.19	0.40	0.46	37.3%	45.5	2005	0.08	6.89
108	175	1.0	2.0	56	$169,206,828.91	7.01%	0.19	0.40	0.45	36.9%	45.4	1970	0.07	6.60
1100	250	1.0	2.0	60	$168,221,761.96	6.97%	0.19	0.41	0.43	36.4%	84.9	1669	0.05	4.93
1032	245	1.0	2.0	56	$163,346,291.06	6.80%	0.19	0.40	0.47	34.9%	49.2	1707	0.06	5.45
1034	245	1.0	2.0	60	$173,082,014.19	7.14%	0.20	0.42	0.44	36.6%	49.2	1679	0.05	5.01
1164	255	1.0	2.0	56	$166,134,669.02	6.90%	0.20	0.41	0.48	35.3%	49.2	1669	0.07	5.68
999	245	0.5	2.0	56	$167,060,085.61	6.93%	0.20	0.40	0.42	35.2%	49.2	1726	0.07	6.17
174	180	1.0	2.0	56	$174,905,161.98	7.21%	0.20	0.41	0.46	36.5%	45.4	1943	0.08	6.63
44	170	1.0	2.0	60	$190,171,605.30	7.70%	0.20	0.43	0.45	38.8%	45.4	1977	0.07	6.61
1065	250	0.5	2.0	56	$166,638,071.70	6.92%	0.20	0.40	0.42	34.7%	49.2	1717	0.07	6.23
110	175	1.0	2.0	60	$192,624,521.12	7.78%	0.20	0.43	0.45	38.5%	44.9	1942	0.07	6.54

Below is a graph of the equity curve for **the strategy with the lowest MAR.**



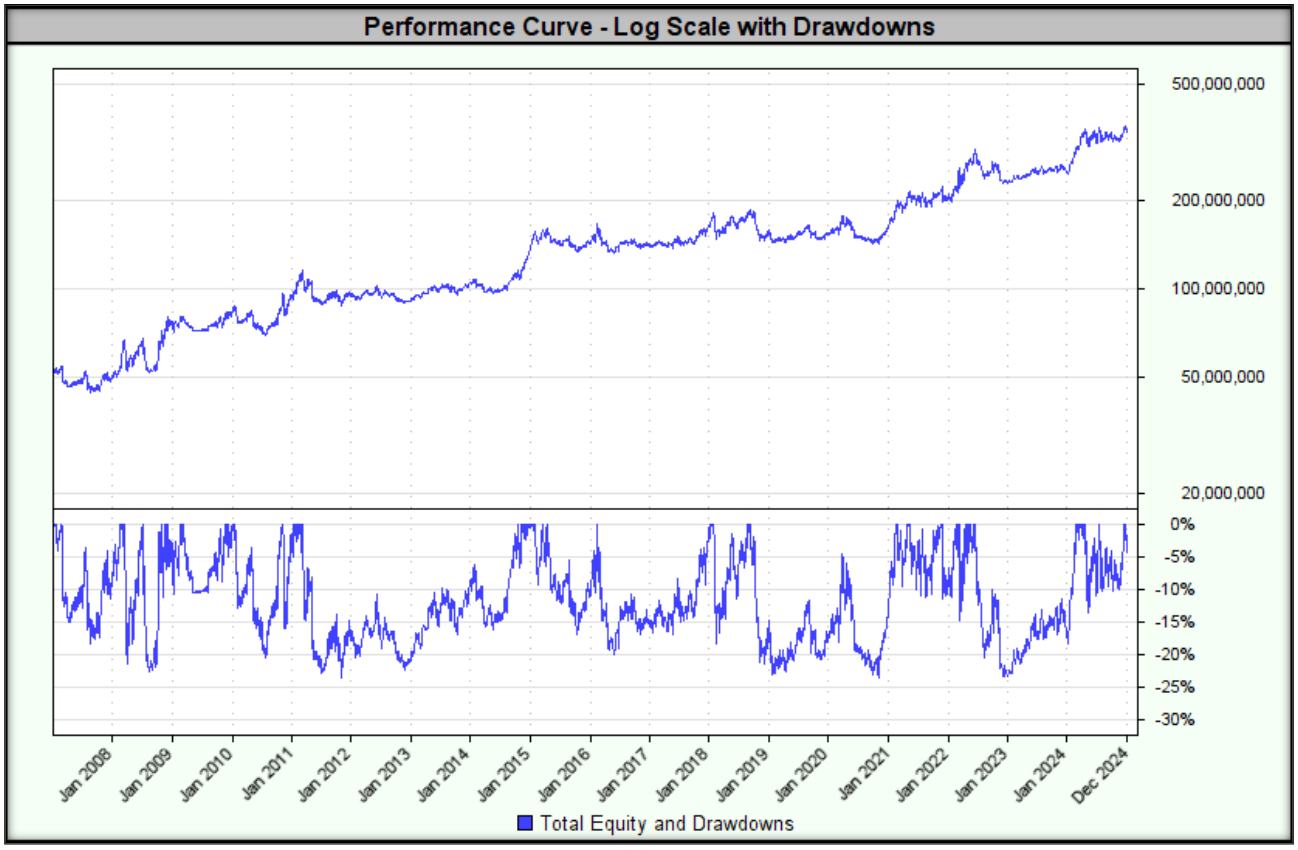
The highest MAR value of 0.48 was achieved for the following parameters:

- **Entry Breakout (days):** 230;
- **Unit Add (ATR):** 0.5;
- **Alloy (ATR):** 3.0;
- **Exit Breakout (days):** 48.

The highest MAR value was accompanied by **a drawdown of 23.6%.**

Test	Entry Breakout (days)	Unit Add (ATR)	Stop (ATR)	Exit Breakout (days)	End Balance	CAGR%	MAR	Sharpe	Ann. Sharpe	Max TE DD	Longest DD	Trades	R3	RAR [%]
819	230	0.5	3.0	48	$343,328,688.36	11.30%	0.48	0.65	0.76	23.6%	43.4	1452	0.20	9.72
489	205	0.5	3.0	48	$331,189,640.30	11.08%	0.47	0.64	0.66	23.6%	42.7	1544	0.21	10.02
753	225	0.5	3.0	48	$335,698,287.36	11.16%	0.47	0.64	0.74	23.8%	43.4	1471	0.20	9.73
555	210	0.5	3.0	48	$329,113,996.66	11.04%	0.47	0.64	0.68	23.7%	42.5	1524	0.21	10.02
687	220	0.5	3.0	48	$310,160,860.54	10.67%	0.46	0.62	0.71	23.4%	44.3	1492	0.19	9.18
621	215	0.5	3.0	48	$319,543,993.92	10.86%	0.46	0.63	0.69	23.8%	44.3	1502	0.19	9.52
488	205	0.5	3.0	46	$309,369,375.26	10.66%	0.44	0.62	0.67	24.3%	43.4	1570	0.20	9.83
818	230	0.5	3.0	46	$307,007,796.68	10.61%	0.44	0.62	0.77	24.2%	44.2	1476	0.19	9.39
816	230	0.5	3.0	42	$294,681,064.21	10.36%	0.44	0.62	0.76	23.7%	44.8	1516	0.19	9.14
478	205	0.5	2.5	48	$368,739,702.54	11.74%	0.44	0.62	0.73	26.9%	42.7	1662	0.18	11.15
423	200	0.5	3.0	48	$299,600,352.47	10.46%	0.43	0.61	0.63	24.3%	43.4	1575	0.19	9.35
815	230	0.5	3.0	40	$287,529,919.64	10.21%	0.43	0.61	0.74	23.7%	45.4	1551	0.17	8.52
808	230	0.5	2.5	48	$367,312,395.72	11.72%	0.43	0.62	0.82	27.3%	44.8	1569	0.20	10.40
885	235	0.5	3.0	48	$313,947,856.75	10.75%	0.43	0.63	0.71	25.0%	44.3	1443	0.18	9.12

Below is a graph of the equity curve for **the strategy with the highest MAR.**



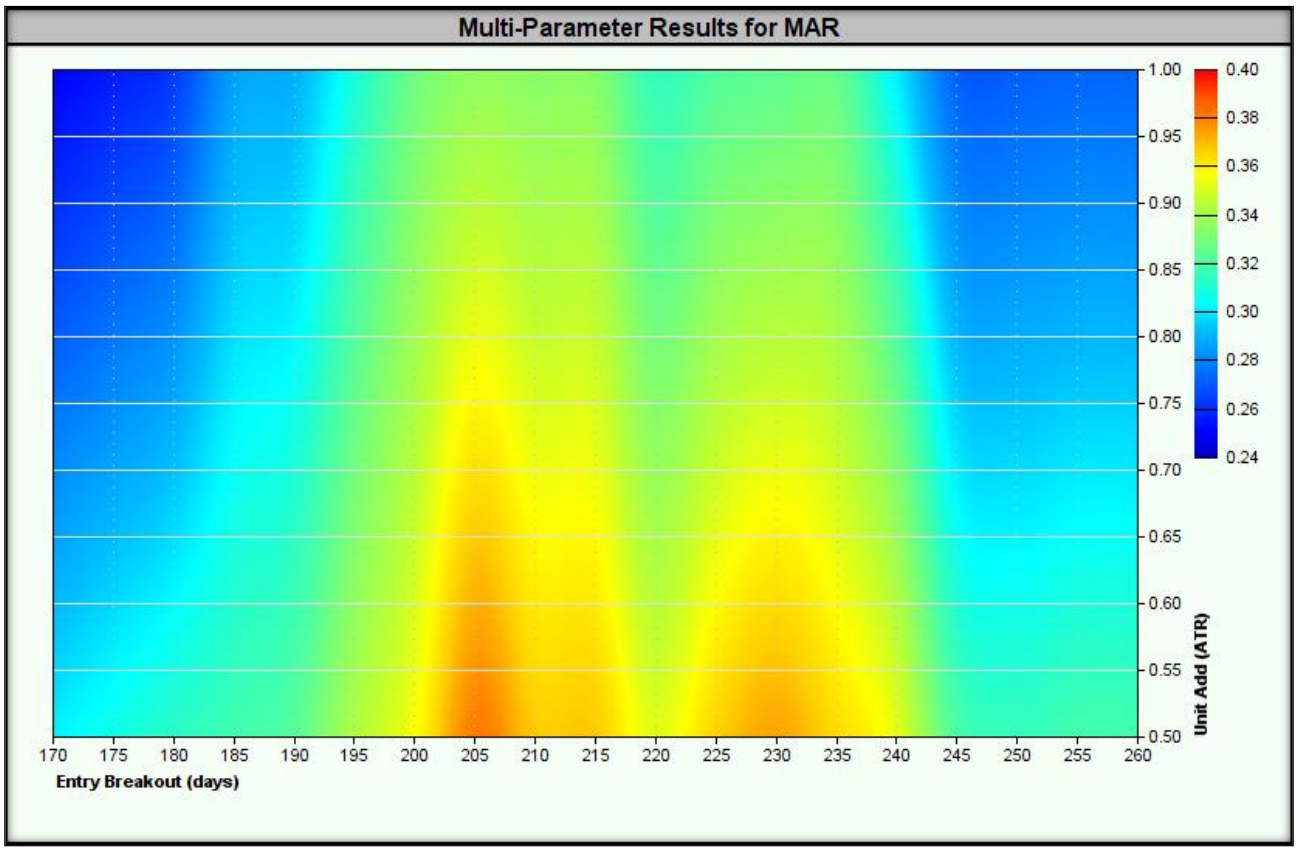
For all combinations of tested parameter ranges, **the highest drawdown was 39.5%.**

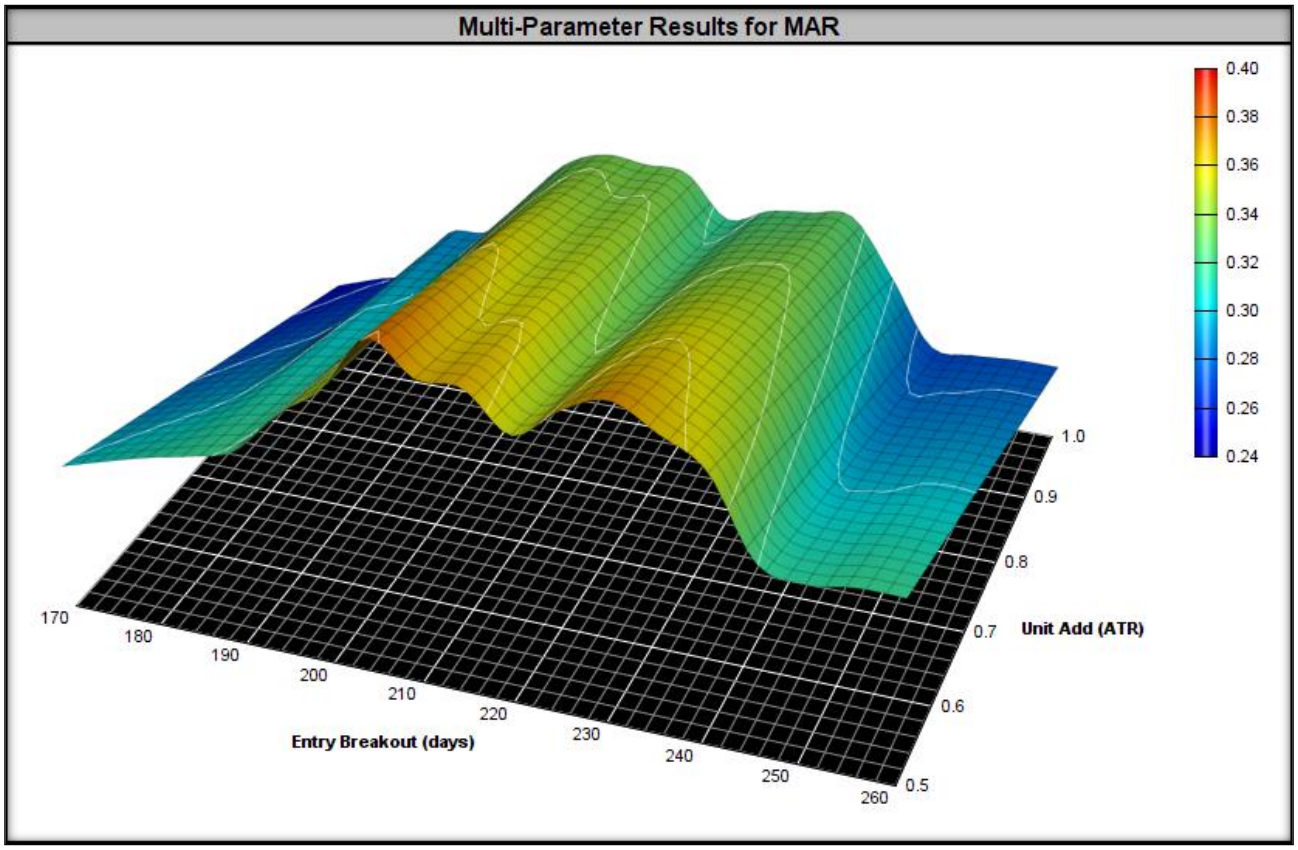
Test	Entry Breakout (days)	Unit Add (ATR)	Stop (ATR)	Exit Breakout (days)	End Balance	CAGR%	MAR	Sharpe	Ann. Sharpe	Max TE DD	Longest DD	Trades	R3	RAR [%]
11	170	0.5	2.0	60	$215,781,505.81	8.46%	0.21	0.45	0.47	39.5%	45.5	1993	0.09	7.63
77	175	0.5	2.0	60	$236,282,016.54	9.01%	0.23	0.47	0.48	39.4%	45.4	1955	0.09	7.88
143	180	0.5	2.0	60	$249,462,284.04	9.34%	0.24	0.48	0.50	39.0%	45.1	1917	0.09	8.00
44	170	1.0	2.0	60	$190,171,605.30	7.70%	0.20	0.43	0.45	38.8%	45.4	1977	0.07	6.61
209	185	0.5	2.0	60	$256,701,952.65	9.51%	0.25	0.49	0.47	38.7%	44.3	1905	0.10	8.23
275	190	0.5	2.0	60	$240,526,743.21	9.12%	0.24	0.48	0.48	38.6%	44.3	1871	0.10	8.36
110	175	1.0	2.0	60	$192,624,521.12	7.78%	0.20	0.43	0.45	38.5%	44.9	1942	0.07	6.54
176	180	1.0	2.0	60	$199,371,380.93	7.99%	0.21	0.44	0.46	38.5%	44.8	1915	0.07	6.69
1232	260	1.0	2.0	60	$169,877,160.56	7.03%	0.18	0.42	0.43	38.3%	85.5	1628	0.05	4.89
1166	255	1.0	2.0	60	$171,506,377.95	7.09%	0.19	0.42	0.43	37.9%	84.9	1645	0.05	4.95
142	180	0.5	2.0	58	$279,213,081.53	10.03%	0.27	0.50	0.50	37.7%	45.5	1928	0.10	7.85
109	175	1.0	2.0	58	$198,888,668.79	7.97%	0.21	0.44	0.45	37.6%	78.6	1953	0.06	6.22
9	170	0.5	2.0	56	$212,372,389.59	8.37%	0.22	0.44	0.45	37.5%	45.7	2021	0.11	8.12
10	170	0.5	2.0	58	$243,895,686.69	9.20%	0.25	0.47	0.49	37.4%	45.9	2004	0.10	7.66

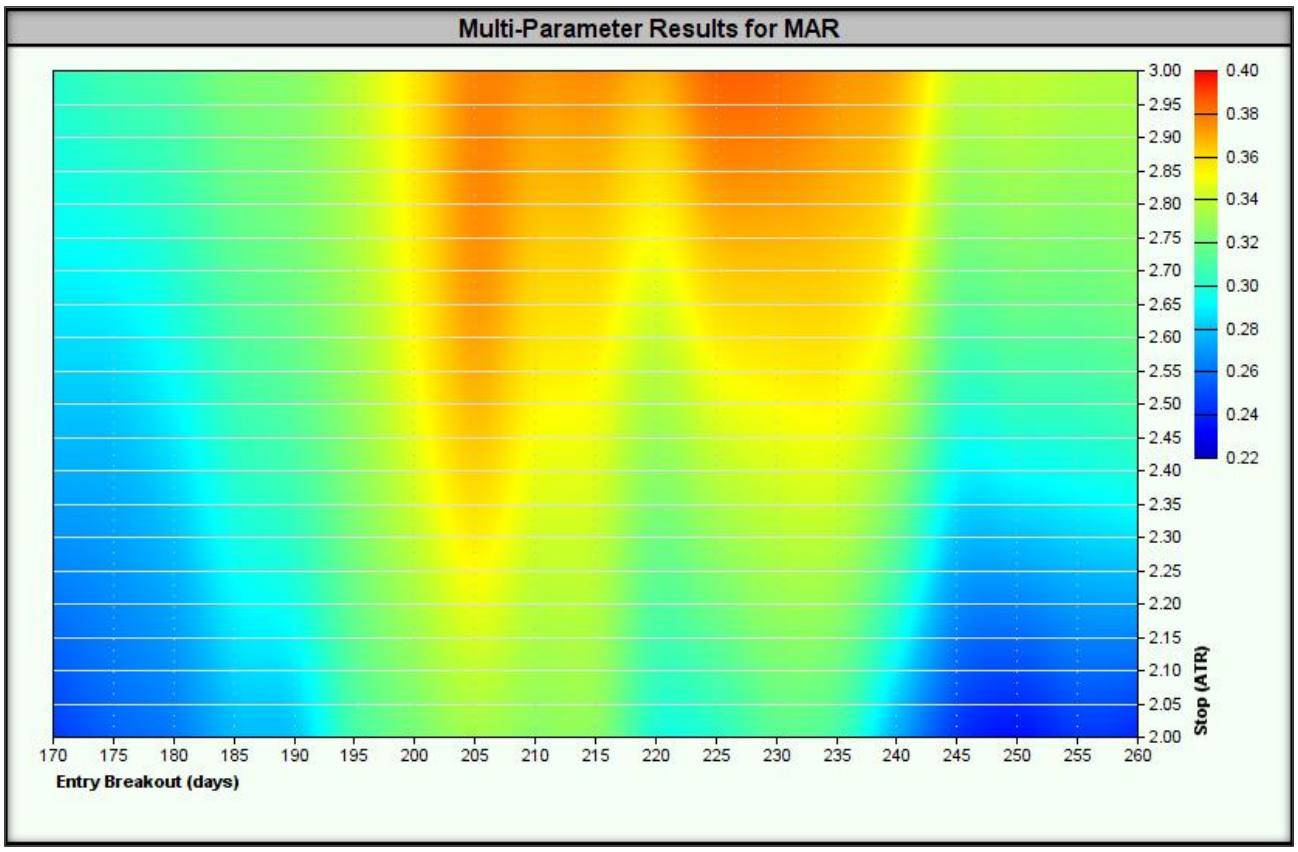
In summary, the strategy **passed the stability test** over a wide range of optimized parameters on in-sample data because:

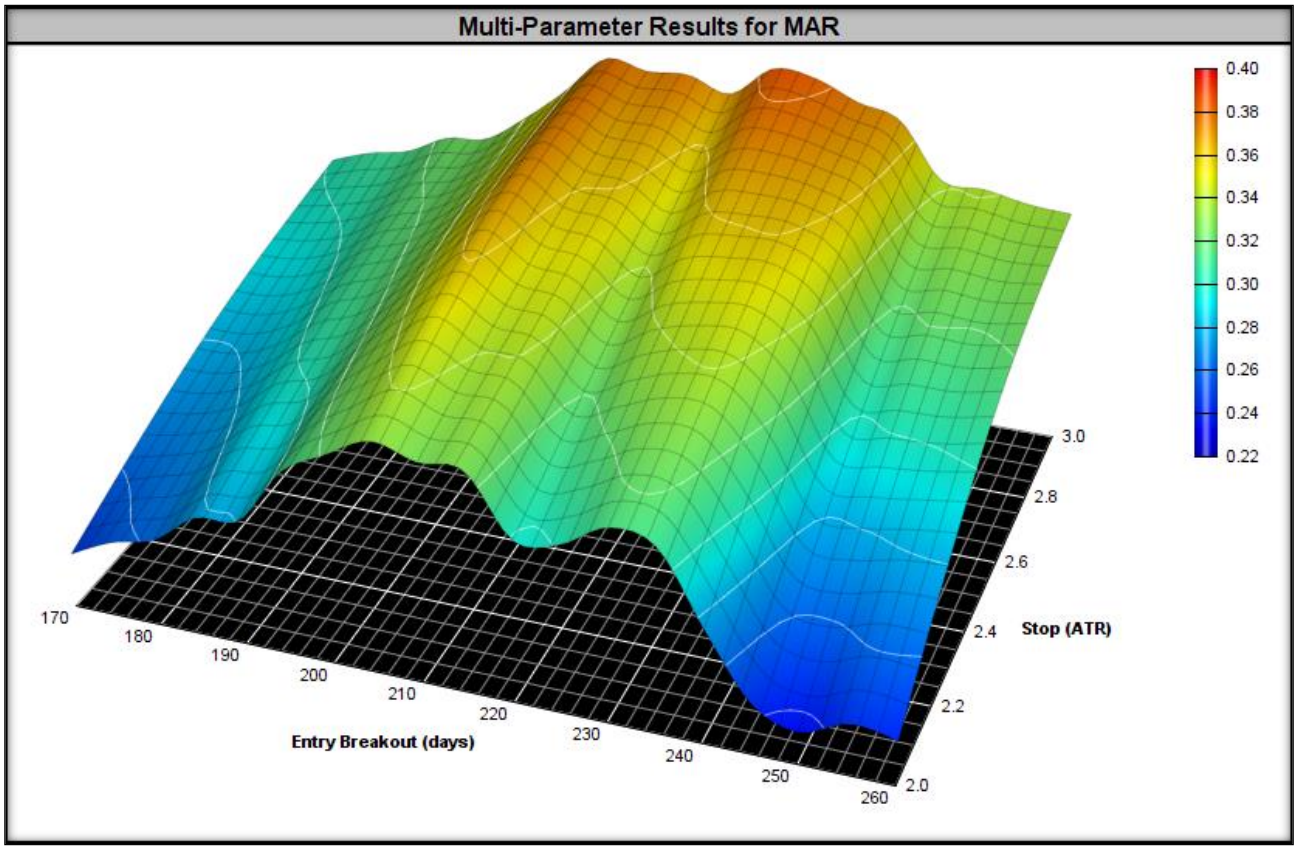
- **All test results showed a positive MAR value** – which indicates the stability of the strategy in various market conditions.
- **The maximum drawdown did not exceed 250% of the drawdown value** for the result with the highest MAR (**39.5% vs. 23.6%)** – which means an acceptable risk of deep capital drawdowns.

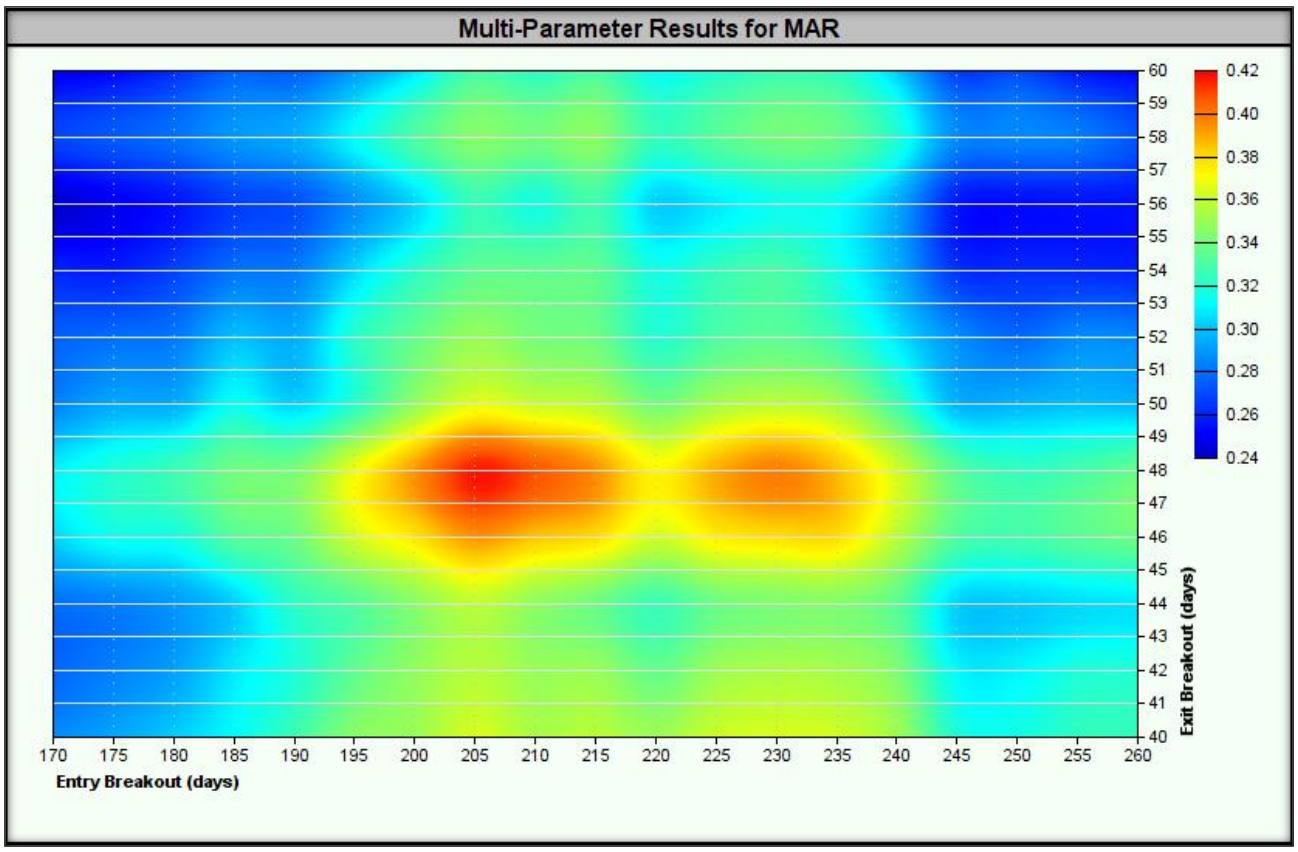
Heatmaps for the tested ranges are shown below.




Multi-Parameter Results for MAR
0.40
0.38
0.36
0.34
0.32
0.30
0.28
0.26
0.24
1.0
0.9
0.8
0.7
0.6
0.5
Unit Add (ATR)
170
180
190
200
210
220
230
240
250
260
Entry Breakout (days)


Multi-Parameter Results for MAR
0.40
0.38
0.36
0.34
0.32
0.30
0.28
0.26
0.24
0.22
3.00
2.95
2.90
2.85
2.80
2.75
2.70
2.65
2.60
2.55
2.50
2.45
2.40
2.35
2.30
2.25
2.20
2.15
2.10
2.05
2.00
Stop (ATR)
170
175
180
185
190
195
200
205
210
215
220
225
230
235
240
245
250
255
260
Entry Breakout (days)


Multi-Parameter Results for MAR
0.40
0.38
0.36
0.34
0.32
0.30
0.28
0.26
0.24
0.22
3.0
2.8
2.6
2.4
2.2
2.0
Stop (ATR)
170
180
190
200
210
220
230
240
250
260
Entry Breakout (days)


Multi-Parameter Results for MAR
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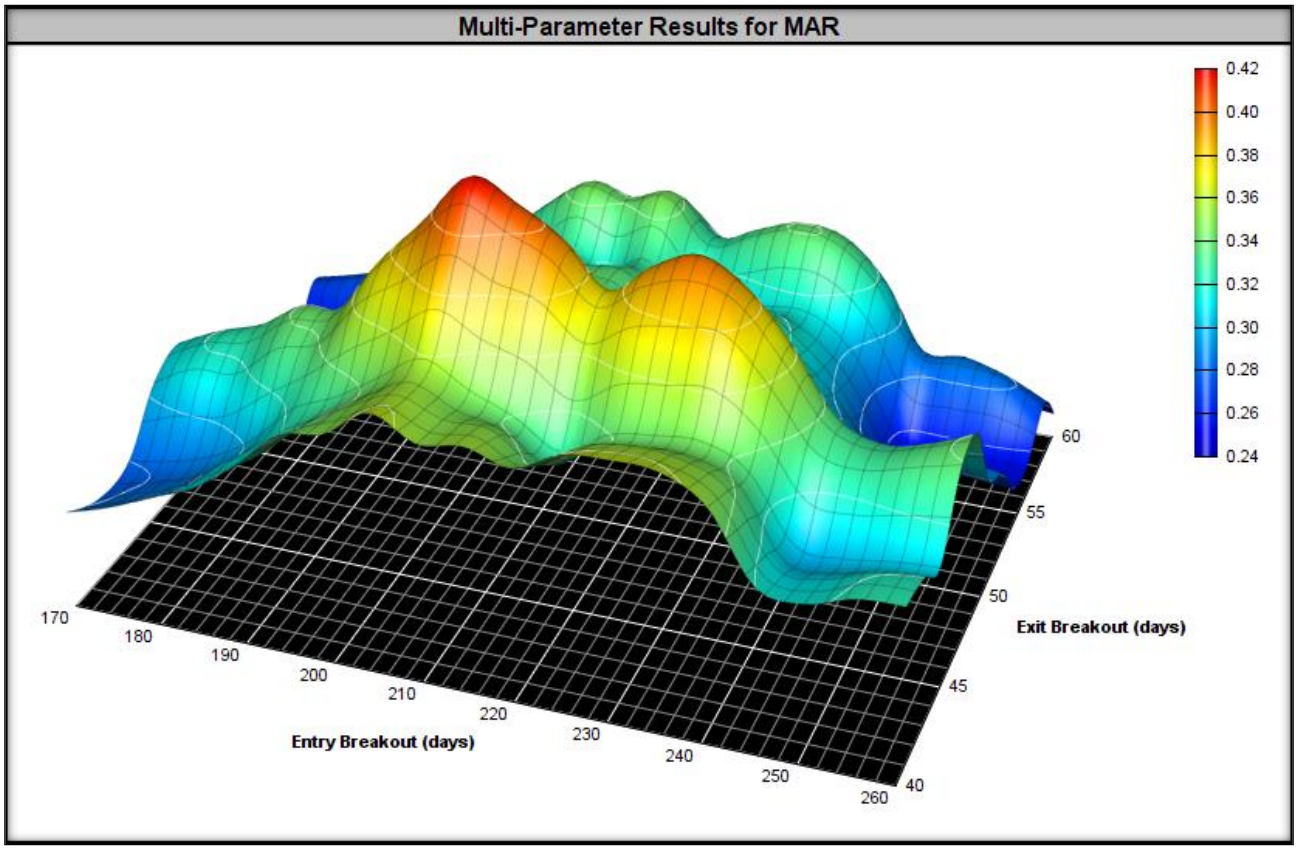
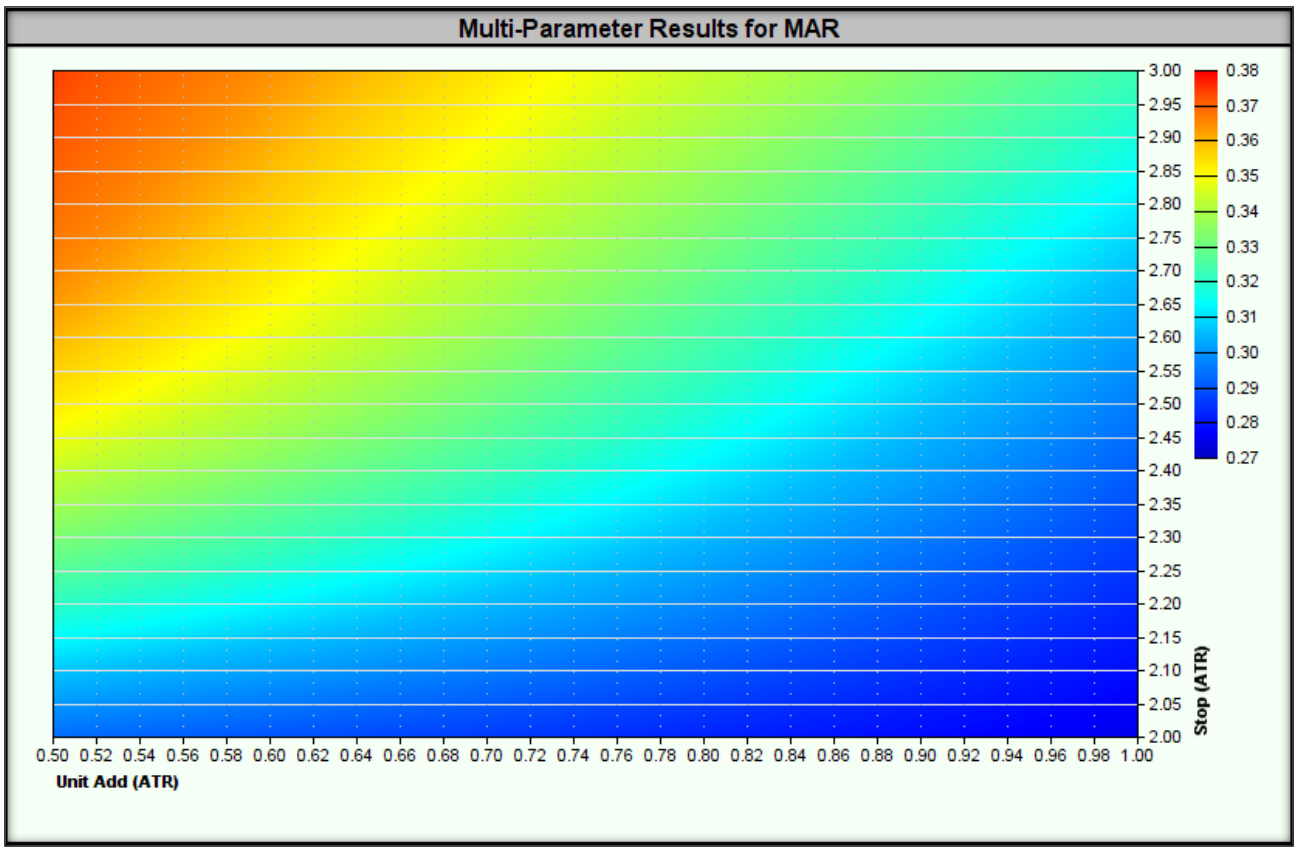
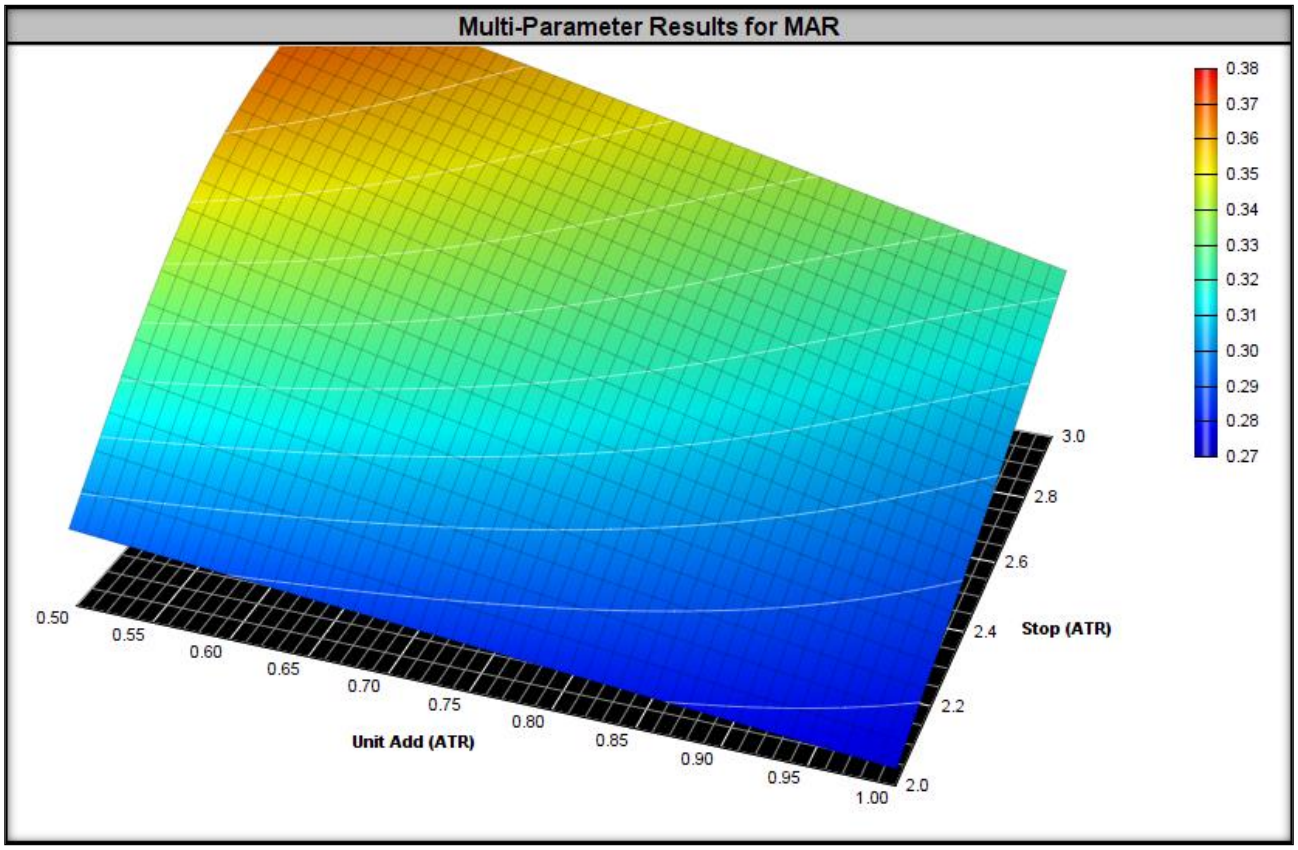
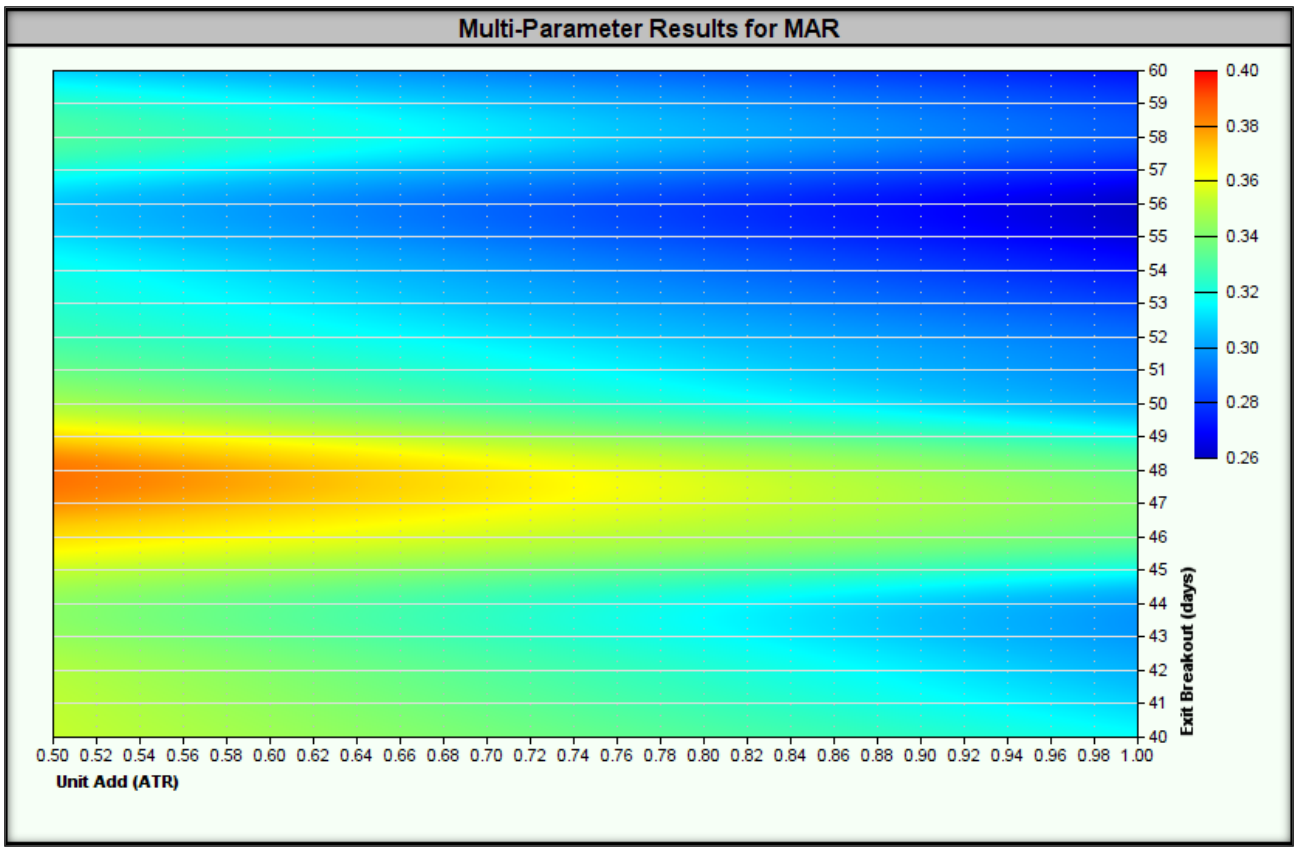
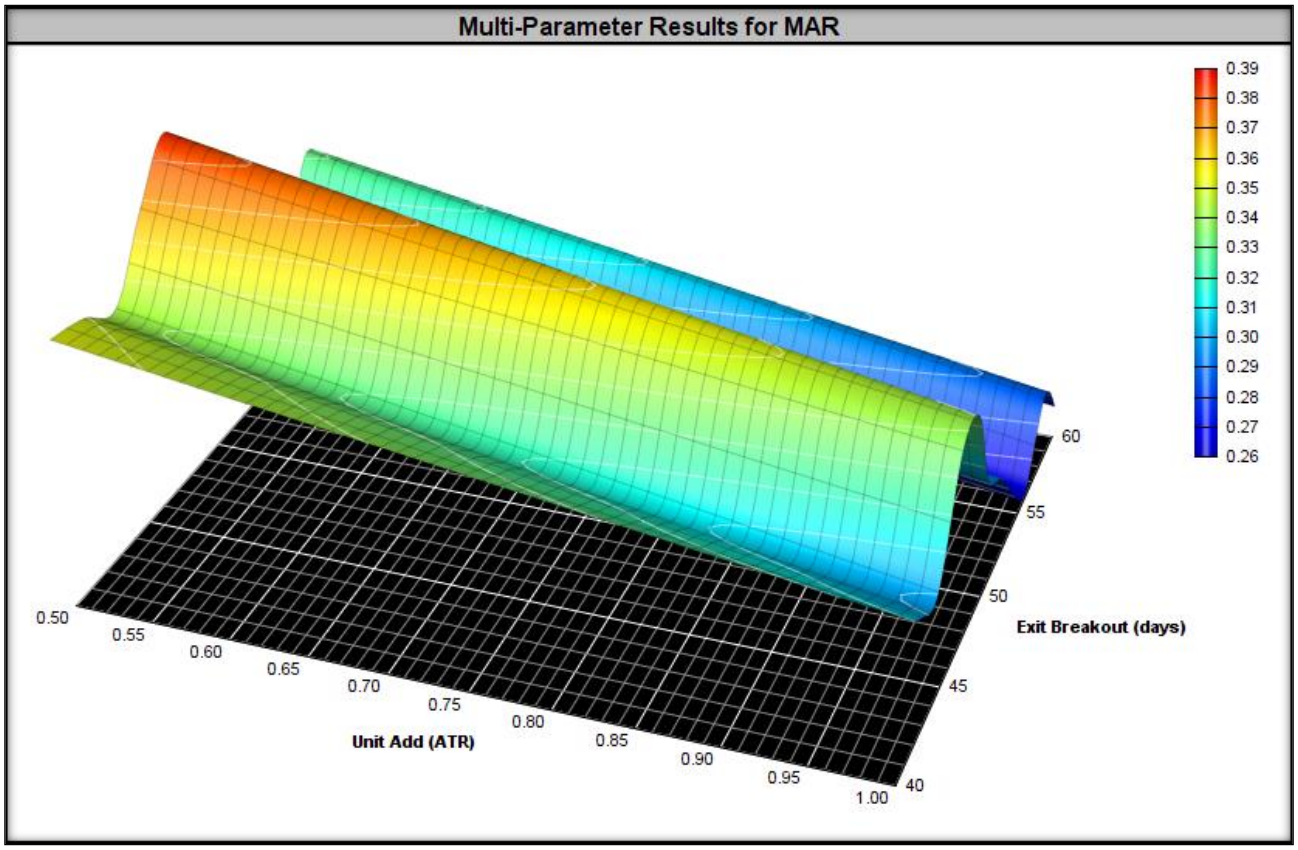
0.40
0.38
0.36
0.34
0.32
0.30
0.28
0.26
0.24
60
59
58
57
56
55
54
53
52
51
50
49
48
47
46
45
44
43
42
41
40
Exit Breakout (days)
170
175
180
185
190
195
200
205
210
215
220
225
230
235
240
245
250
255
260
Entry Breakout (days)

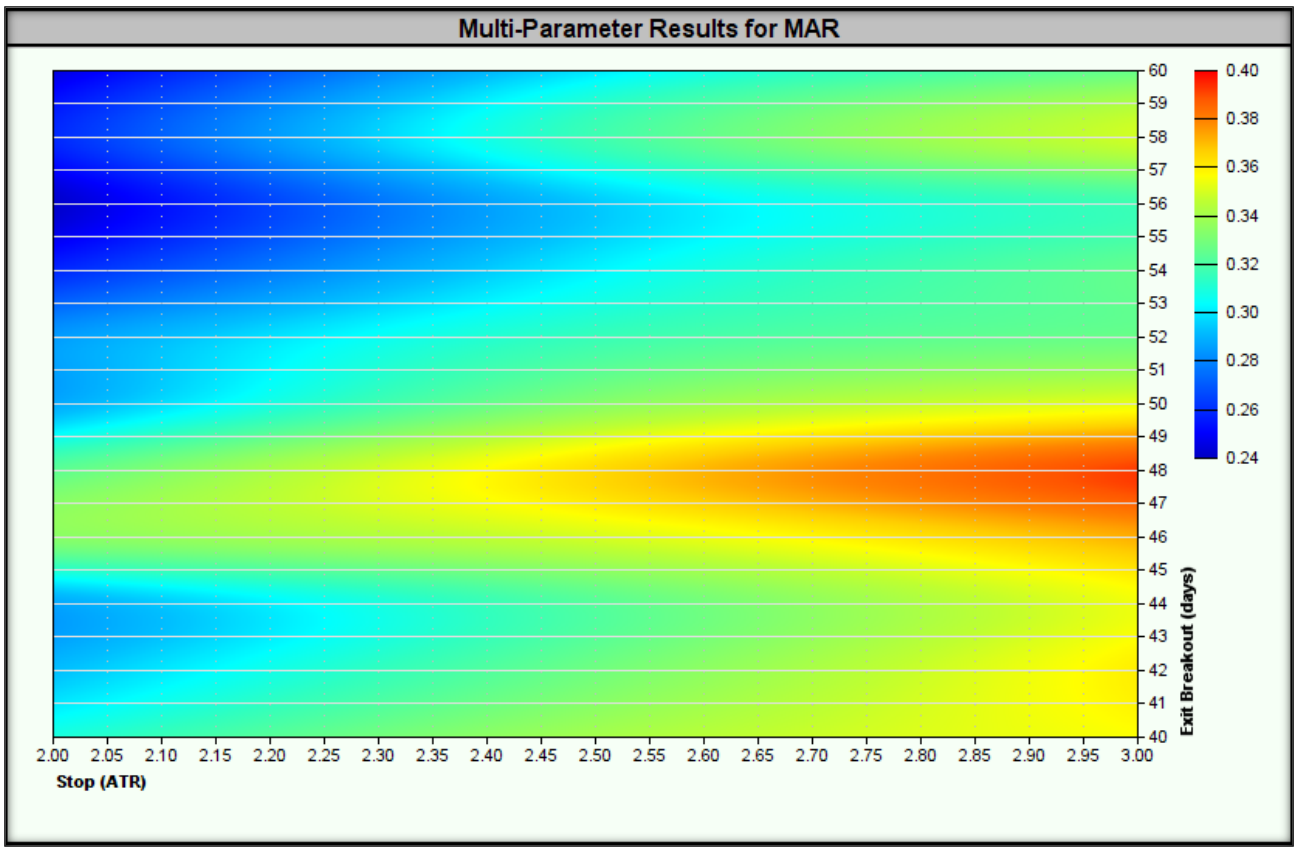

Multi-Parameter Results for MAR
0.42
0.40
0.38
0.36
0.34
0.32
0.30
0.28
0.26
0.24
170
180
190
200
210
220
230
240
250
260
Entry Breakout (days)
40
45
50
55
60
Exit Breakout (days)

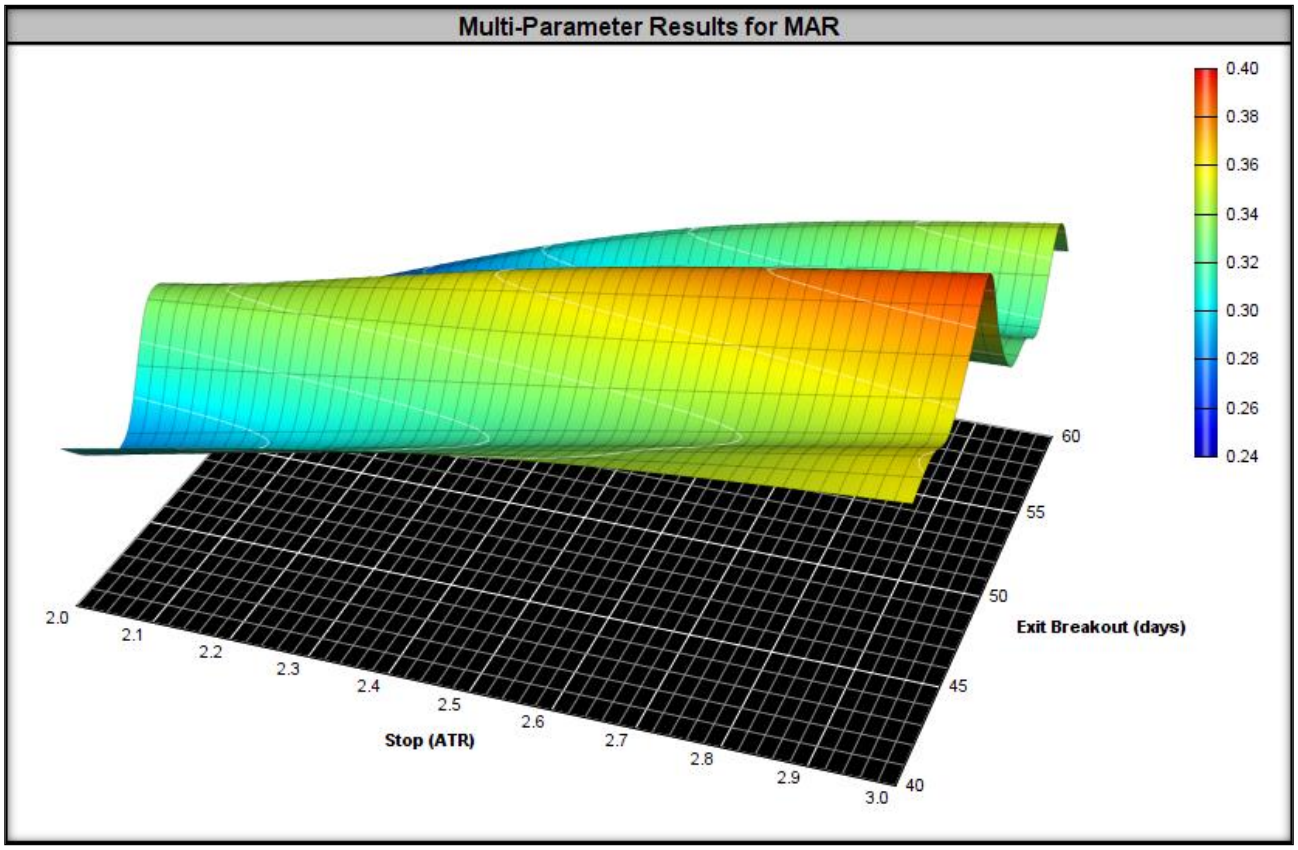

Multi-Parameter Results for MAR
0.38
0.37
0.36
0.35
0.34
0.33
0.32
0.31
0.30
0.29
0.28
0.27
3.00
2.95
2.90
2.85
2.80
2.75
2.70
2.65
2.60
2.55
2.50
2.45
2.40
2.35
2.30
2.25
2.20
2.15
2.10
2.05
2.00
Stop (ATR)
0.50 0.52 0.54 0.56 0.58 0.60 0.62 0.64 0.66 0.68 0.70 0.72 0.74 0.76 0.78 0.80 0.82 0.84 0.86 0.88 0.90 0.92 0.94 0.96 0.98 1.00
Unit Add (ATR)

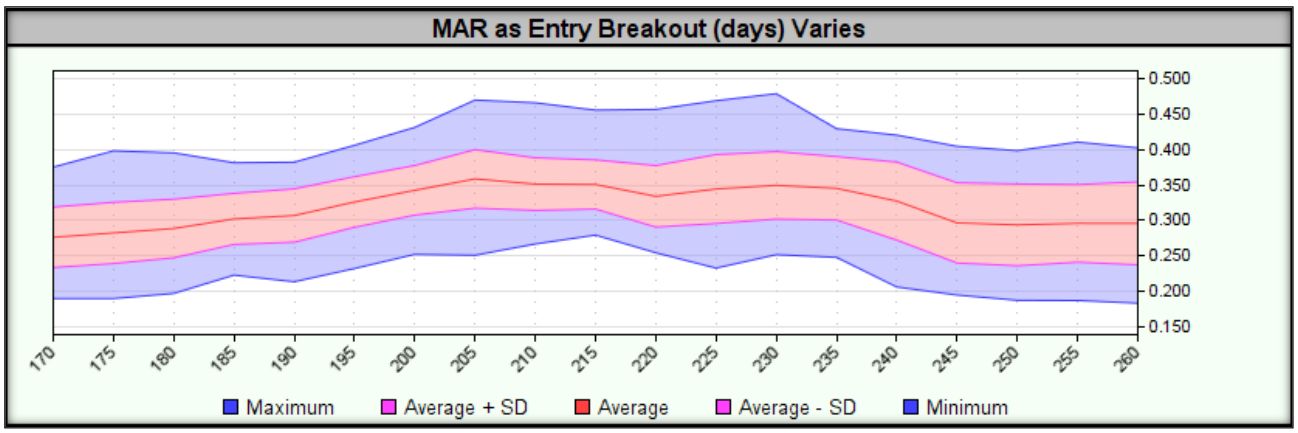

Multi-Parameter Results for MAR
0.38
0.37
0.36
0.35
0.34
0.33
0.32
0.31
0.30
0.29
0.28
0.27
3.0
2.8
2.6
2.4
2.2
2.0
Stop (ATR)
0.50
0.55
0.60
0.65
0.70
0.75
0.80
0.85
0.90
0.95
1.00
Unit Add (ATR)

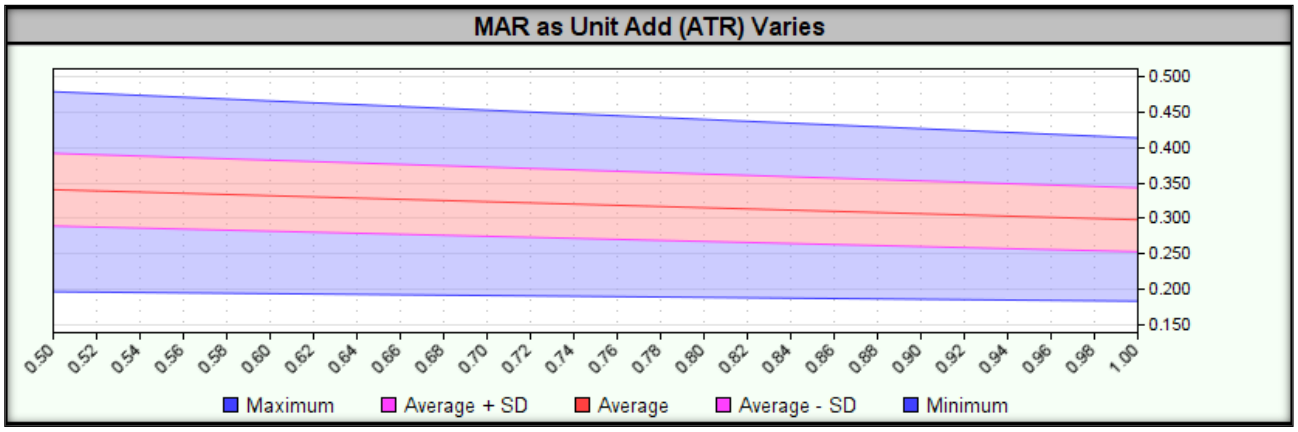

Multi-Parameter Results for MAR
0.40
0.38
0.36
0.34
0.32
0.30
0.28
0.26
60
59
58
57
56
55
54
53
52
51
50
49
48
47
46
45
44
43
42
41
40
Exit Breakout (days)
0.50 0.52 0.54 0.56 0.58 0.60 0.62 0.64 0.66 0.68 0.70 0.72 0.74 0.76 0.78 0.80 0.82 0.84 0.86 0.88 0.90 0.92 0.94 0.96 0.98 1.00
Unit Add (ATR)

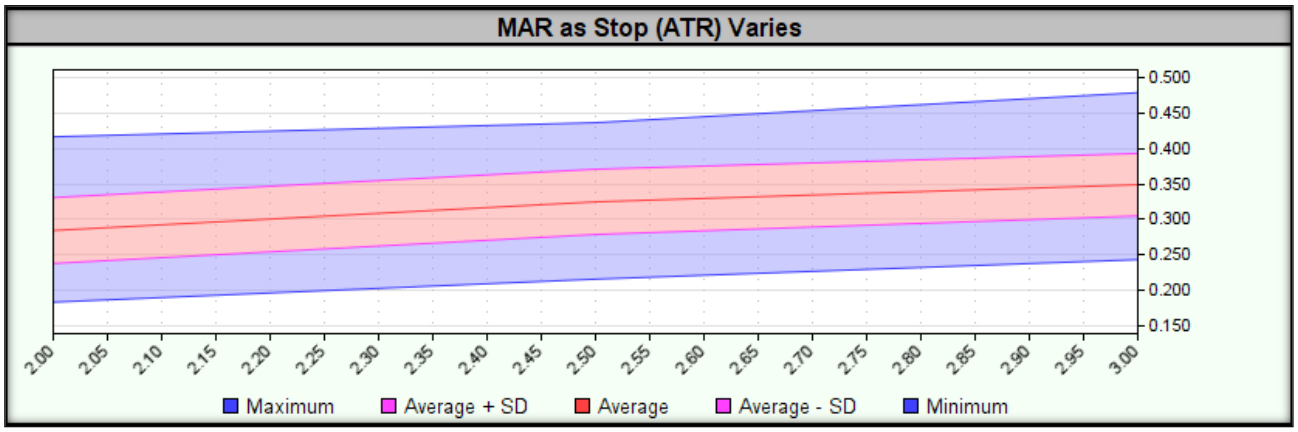

Multi-Parameter Results for MAR
0.39
0.38
0.37
0.36
0.35
0.34
0.33
0.32
0.31
0.30
0.29
0.28
0.27
0.26
0.50
0.55
0.60
0.65
0.70
0.75
0.80
0.85
0.90
0.95
1.00
Unit Add (ATR)
40
45
50
55
60
Exit Breakout (days)

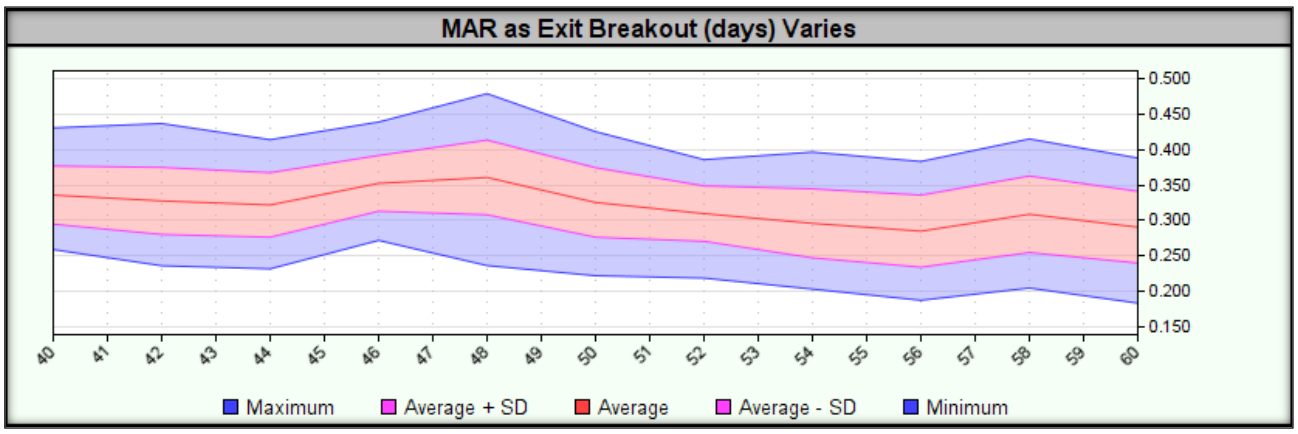

Multi-Parameter Results for MAR
0.40
0.38
0.36
0.34
0.32
0.30
0.28
0.26
0.24
60
59
58
57
56
55
54
53
52
51
50
49
48
47
46
45
44
43
42
41
40
Exit Breakout (days)
2.00
2.05
2.10
2.15
2.20
2.25
2.30
2.35
2.40
2.45
2.50
2.55
2.60
2.65
2.70
2.75
2.80
2.85
2.90
2.95
3.00
Stop (ATR)


Multi-Parameter Results for MAR
0.40
0.38
0.36
0.34
0.32
0.30
0.28
0.26
0.24
2.0
2.1
2.2
2.3
2.4
2.5
2.6
2.7
2.8
2.9
3.0
Stop (ATR)
40
45
50
55
60
Exit Breakout (days)


MAR as Entry Breakout (days) Varies
0.500
0.450
0.400
0.350
0.300
0.250
0.200
0.150
170
175
180
185
190
195
200
205
210
215
220
225
230
235
240
245
250
255
260
Maximum
Average + SD
Average
Average - SD
Minimum







After passing the stability tests on **in-sample data,** it is time perform the same procedure on **out-of-sample data.** For this purpose, we use **the same range of parameters** as on in-sample data:

- **Entry Breakout (days):** range **170-260 (step: 5);**
- **Unit Add (ATR):** range **0.5-1.0 (step: 0.5);**
- **Stop (ATR):** range **2.0-3.0 (step: 0.5);**
- **Exit Breakout (days):** range **40-60 (step: 2).**

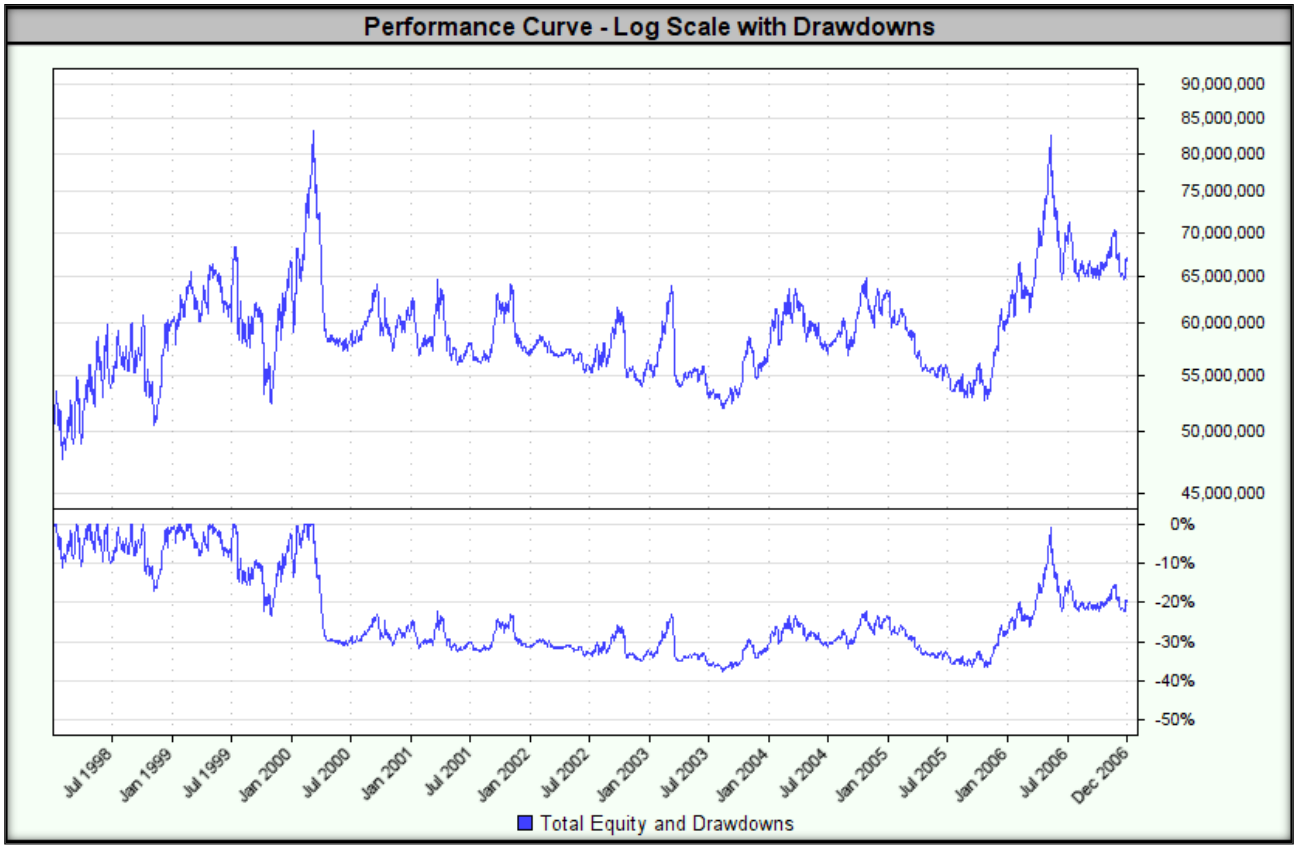
Other parameters remain unchanged.

The lowest MAR value of 0.09 was achieved for the following parameters:

- **Entry Breakout (days):** 190;
- **Unit Add (ATR):** 1.0;
- **Alloy (ATR):** 2.0;
- **Exit Breakout (days):** 42.

Test	Entry Breakout (days)	Unit Add (ATR)	Stop (ATR)	Exit Breakout (days)	End Balance	CAGR%	MAR	Sharpe	Ann. Sharpe	Max TE DD	Longest DD	Trades	R3	RAR [%]
299	190	1.0	2.0	42	$66,639,559.54	3.25%	0.09	0.26	0.36	37.5%	81.7	1010	0.02	0.75
365	195	1.0	2.0	42	$66,417,647.70	3.21%	0.09	0.26	0.35	36.7%	81.7	999	0.02	0.77
233	185	1.0	2.0	42	$68,375,555.65	3.54%	0.09	0.28	0.38	37.8%	81.7	1018	0.02	0.76
431	200	1.0	2.0	42	$69,070,172.92	3.66%	0.10	0.28	0.38	36.2%	74.0	980	0.04	1.28
497	205	1.0	2.0	42	$70,093,584.91	3.83%	0.11	0.29	0.41	35.5%	74.0	972	0.04	1.37
167	180	1.0	2.0	42	$72,939,995.72	4.29%	0.11	0.31	0.38	38.2%	81.7	1018	0.03	0.97
298	190	1.0	2.0	40	$72,826,292.48	4.27%	0.12	0.31	0.45	35.3%	74.0	1011	0.05	1.58
563	210	1.0	2.0	42	$72,938,648.55	4.29%	0.13	0.31	0.46	34.3%	73.8	958	0.06	1.98
101	175	1.0	2.0	42	$75,036,254.55	4.62%	0.13	0.33	0.48	35.2%	73.9	1015	0.04	1.60
232	185	1.0	2.0	40	$75,272,422.62	4.66%	0.13	0.33	0.47	35.5%	74.0	1019	0.05	1.64
364	195	1.0	2.0	40	$74,378,719.11	4.52%	0.13	0.32	0.48	34.0%	73.9	1000	0.05	1.86
166	180	1.0	2.0	40	$76,341,956.99	4.82%	0.13	0.34	0.46	36.3%	74.0	1022	0.05	1.61
369	195	1.0	2.0	50	$79,091,343.74	5.23%	0.13	0.35	0.41	39.3%	74.1	946	0.09	3.03
303	190	1.0	2.0	50	$80,651,372.85	5.46%	0.13	0.36	0.40	40.7%	81.7	957	0.10	3.07
376	195	1.0	2.5	42	$70,720,392.00	3.93%	0.14	0.30	0.45	29.1%	73.4	888	0.05	1.61

Below is a graph of the equity curve for **the strategy with the lowest MAR.**



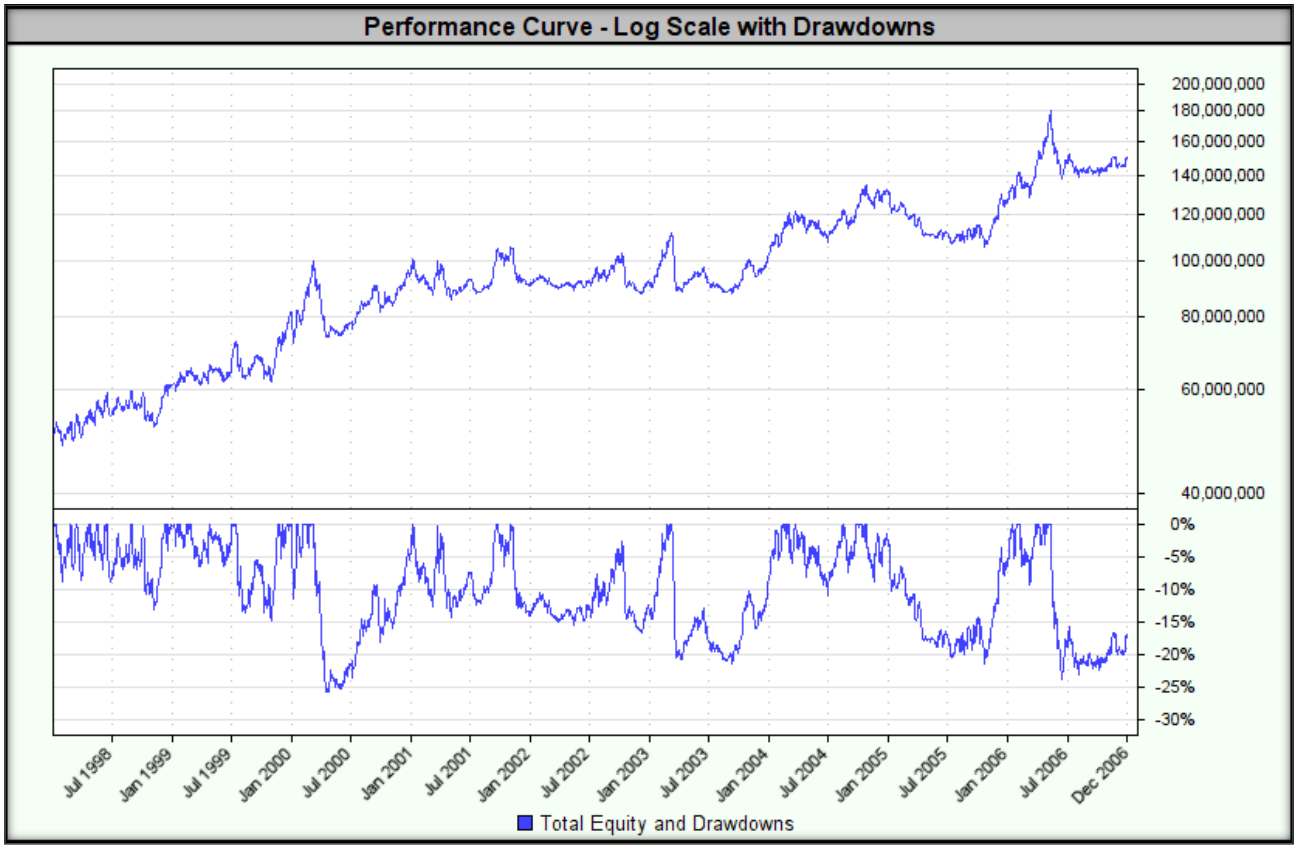
The highest MAR value of 0.50 was achieved for the following parameters:

- **Entry Breakout (days):** 260;
- **Unit Add (ATR):** 1.0;
- **Alloy (ATR):** 2.5;
- **Exit Breakout (days):** 46.

The highest MAR value was accompanied by **a drawdown of 25.8%.**

Test	Entry Breakout (days)	Unit Add (ATR)	Stop (ATR)	Exit Breakout (days)	End Balance	CAGR%	MAR	Sharpe	Ann. Sharpe	Max TE DD	Longest DD	Trades	R3	RAR [%]
1236	260	1.0	2.5	46	$148,977,868.29	12.91%	0.50	0.69	1.02	25.8%	15.7	714	0.50	10.93
1247	260	1.0	3.0	46	$135,391,739.65	11.72%	0.50	0.70	1.11	23.5%	17.0	653	0.53	10.75
1104	250	1.0	2.5	46	$148,116,280.00	12.84%	0.50	0.68	1.01	25.9%	15.7	731	0.49	10.68
1248	260	1.0	3.0	48	$134,221,049.79	11.61%	0.49	0.69	1.09	23.7%	17.0	644	0.51	10.51
1170	255	1.0	2.5	46	$143,513,725.68	12.44%	0.48	0.67	1.00	25.8%	15.7	725	0.47	10.34
1038	245	1.0	2.5	46	$143,493,985.41	12.44%	0.48	0.67	0.96	25.9%	15.7	737	0.47	10.32
1254	260	1.0	3.0	60	$139,043,889.48	12.05%	0.48	0.70	1.03	25.2%	17.1	604	0.49	10.70
1181	255	1.0	3.0	46	$129,957,160.46	11.21%	0.48	0.67	1.07	23.6%	17.0	666	0.48	10.05
774	225	1.0	2.5	46	$141,669,223.53	12.28%	0.47	0.65	0.99	25.9%	15.1	762	0.49	10.10
1115	250	1.0	3.0	46	$129,287,875.33	11.14%	0.47	0.67	1.05	23.6%	17.0	674	0.48	9.91
785	225	1.0	3.0	46	$128,973,456.92	11.11%	0.47	0.66	1.08	23.6%	17.0	702	0.50	9.66
59	170	1.0	3.0	46	$136,552,512.25	11.82%	0.47	0.67	1.16	25.3%	15.2	785	0.54	10.57
1049	245	1.0	3.0	46	$127,560,192.46	10.98%	0.47	0.66	1.03	23.6%	17.0	680	0.46	9.70
1237	260	1.0	2.5	48	$138,925,968.59	12.04%	0.46	0.66	0.91	26.0%	18.4	708	0.38	9.69
840	230	1.0	2.5	46	$138,791,163.35	12.02%	0.46	0.64	0.95	26.0%	15.1	763	0.47	9.72

Below is a graph of the equity curve for **the strategy with the highest MAR.**



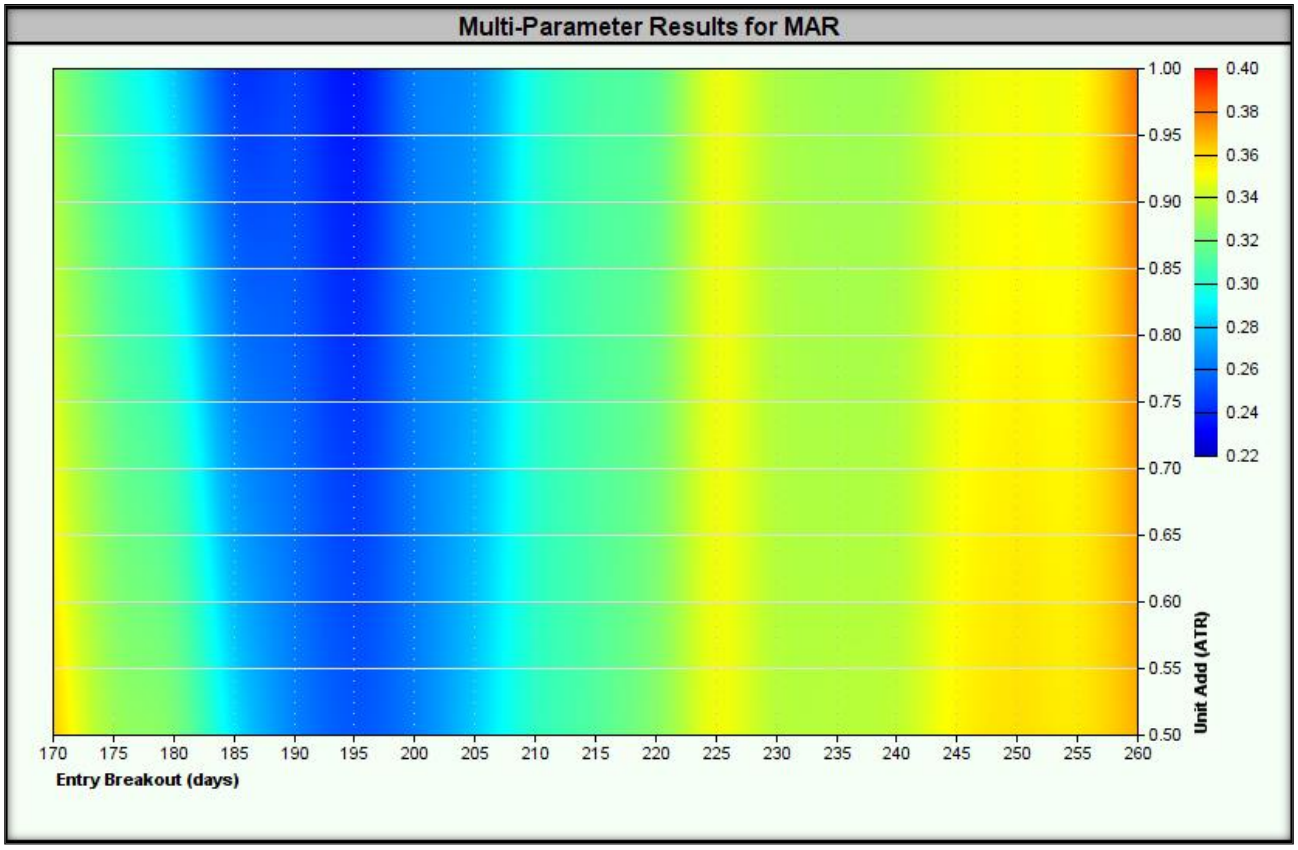
For all combinations of tested parameter ranges, **the highest drawdown was 42.9%.**

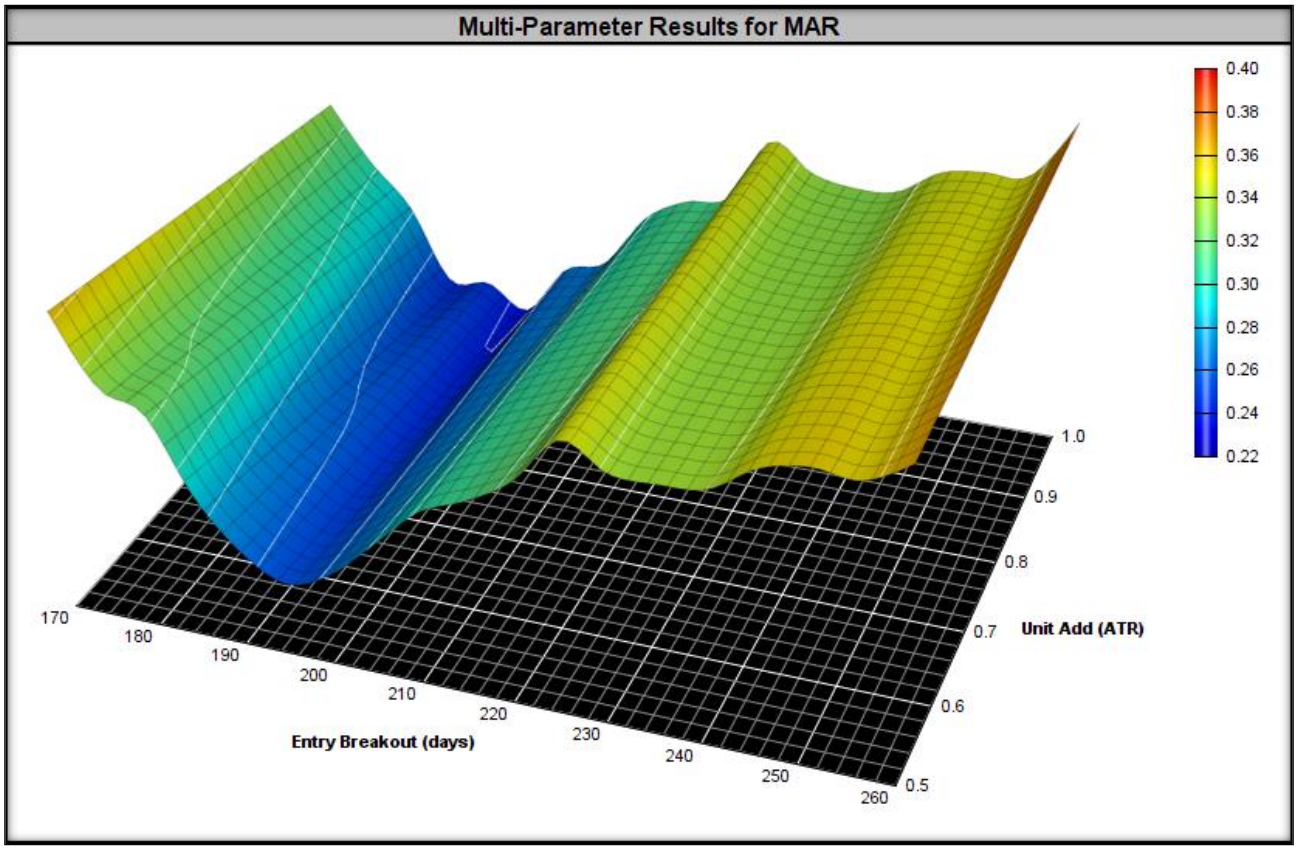
Test	Entry Breakout (days)	Unit Add (ATR)	Stop (ATR)	Exit Breakout (days)	End Balance	CAGR%	MAR	Sharpe	Ann. Sharpe	Max TE DD	Longest DD	Trades	R3	RAR [%]
240	185	1.0	2.0	56	$85,086,824.56	6.09%	0.14	0.39	0.34	42.9%	81.7	942	0.09	2.76
241	185	1.0	2.0	58	$85,894,493.09	6.20%	0.14	0.39	0.35	42.8%	81.7	938	0.09	2.91
307	190	1.0	2.0	58	$85,353,627.93	6.13%	0.14	0.39	0.35	42.6%	81.7	930	0.10	3.03
175	180	1.0	2.0	58	$92,894,157.72	7.13%	0.17	0.43	0.37	42.5%	81.7	935	0.10	3.27
174	180	1.0	2.0	56	$93,712,456.72	7.24%	0.17	0.44	0.38	42.3%	81.7	939	0.11	3.31
306	190	1.0	2.0	56	$86,084,587.48	6.23%	0.15	0.39	0.35	42.3%	81.7	934	0.10	3.06
239	185	1.0	2.0	54	$86,311,850.77	6.26%	0.15	0.40	0.37	41.9%	81.7	948	0.10	3.08
173	180	1.0	2.0	54	$92,194,542.16	7.04%	0.17	0.43	0.40	41.6%	81.7	945	0.11	3.34
305	190	1.0	2.0	54	$86,054,112.17	6.22%	0.15	0.39	0.38	41.5%	81.7	940	0.10	3.22
238	185	1.0	2.0	52	$85,229,238.34	6.11%	0.15	0.39	0.40	41.5%	81.7	961	0.10	3.30
172	180	1.0	2.0	52	$91,214,104.39	6.92%	0.17	0.42	0.42	41.2%	81.7	958	0.11	3.57
304	190	1.0	2.0	52	$82,707,770.75	5.76%	0.14	0.37	0.39	41.1%	81.7	953	0.10	3.20
372	195	1.0	2.0	56	$83,855,900.47	5.92%	0.14	0.38	0.35	41.0%	81.7	923	0.09	2.80
237	185	1.0	2.0	50	$82,815,753.17	5.77%	0.14	0.37	0.41	40.9%	81.7	965	0.10	3.12
373	195	1.0	2.0	58	$84,167,667.22	5.96%	0.15	0.38	0.35	40.9%	81.7	919	0.09	2.90

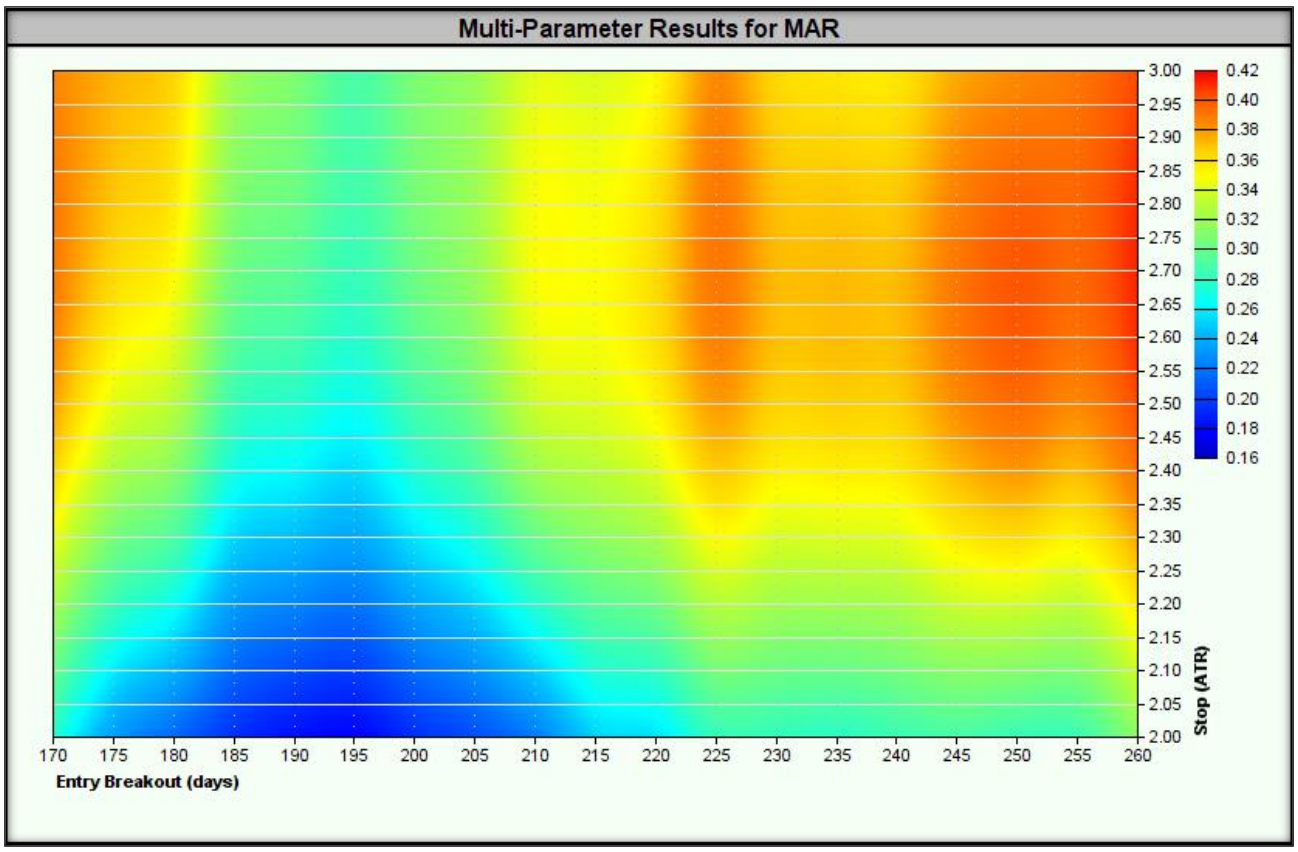
In summary, the strategy **passed the stability test** over a wide range of optimized parameters on out-of-sample data because:

- **All test results showed a positive MAR value** – which indicates the stability of the strategy in various market conditions.
- **The maximum drawdown on out-of-sample data did not exceed 150% of the maximum drawdown value** on **in-sample data (42.9% vs. 39.5%)** – which means an acceptable risk of capital drawdown.
- **The decrease in the maximum MAR value on out-of-sample data was less than 50% compared to the in-sample test results (0.50 vs. 0.48)** – indicating that the strategy can achieve good results in a variety of market conditions.

Heatmaps for the tested ranges are shown below.







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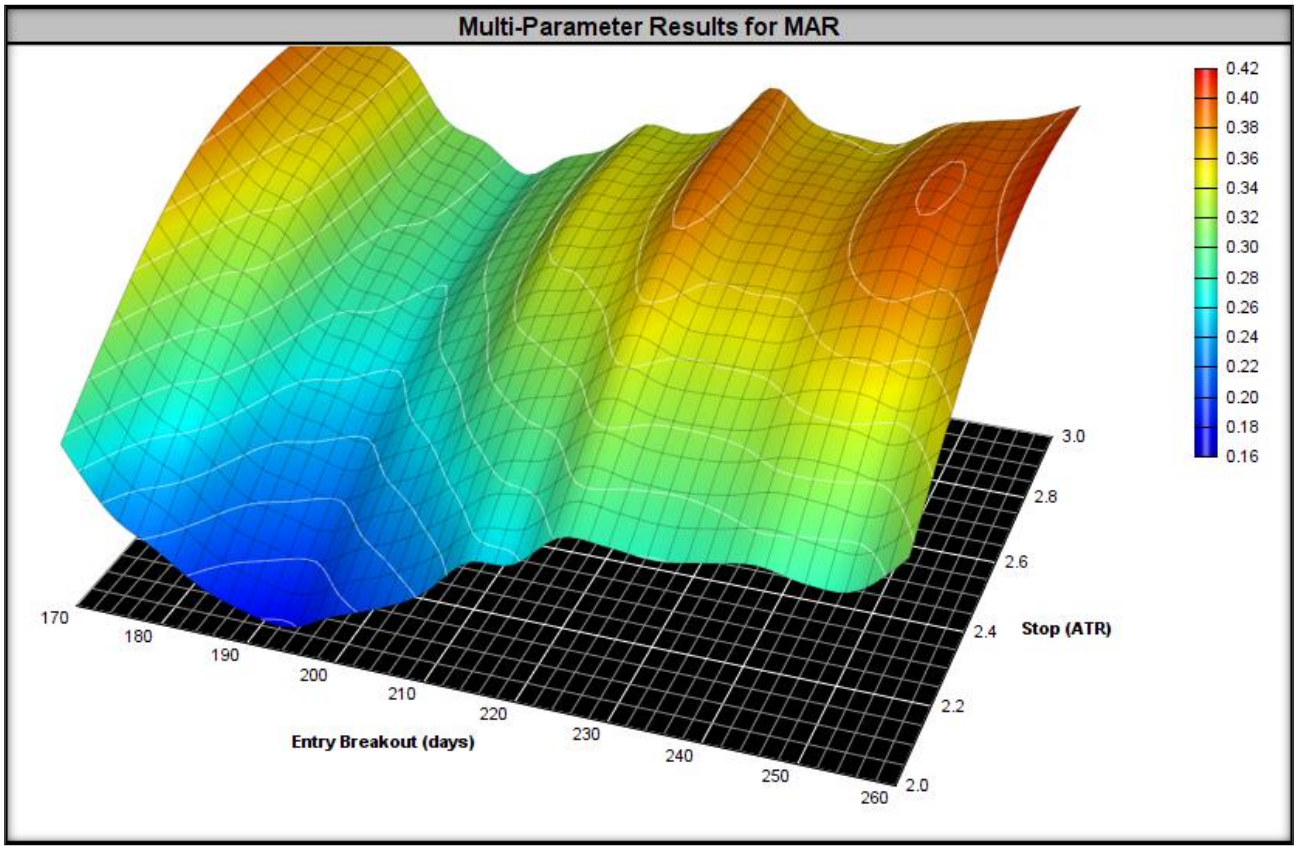
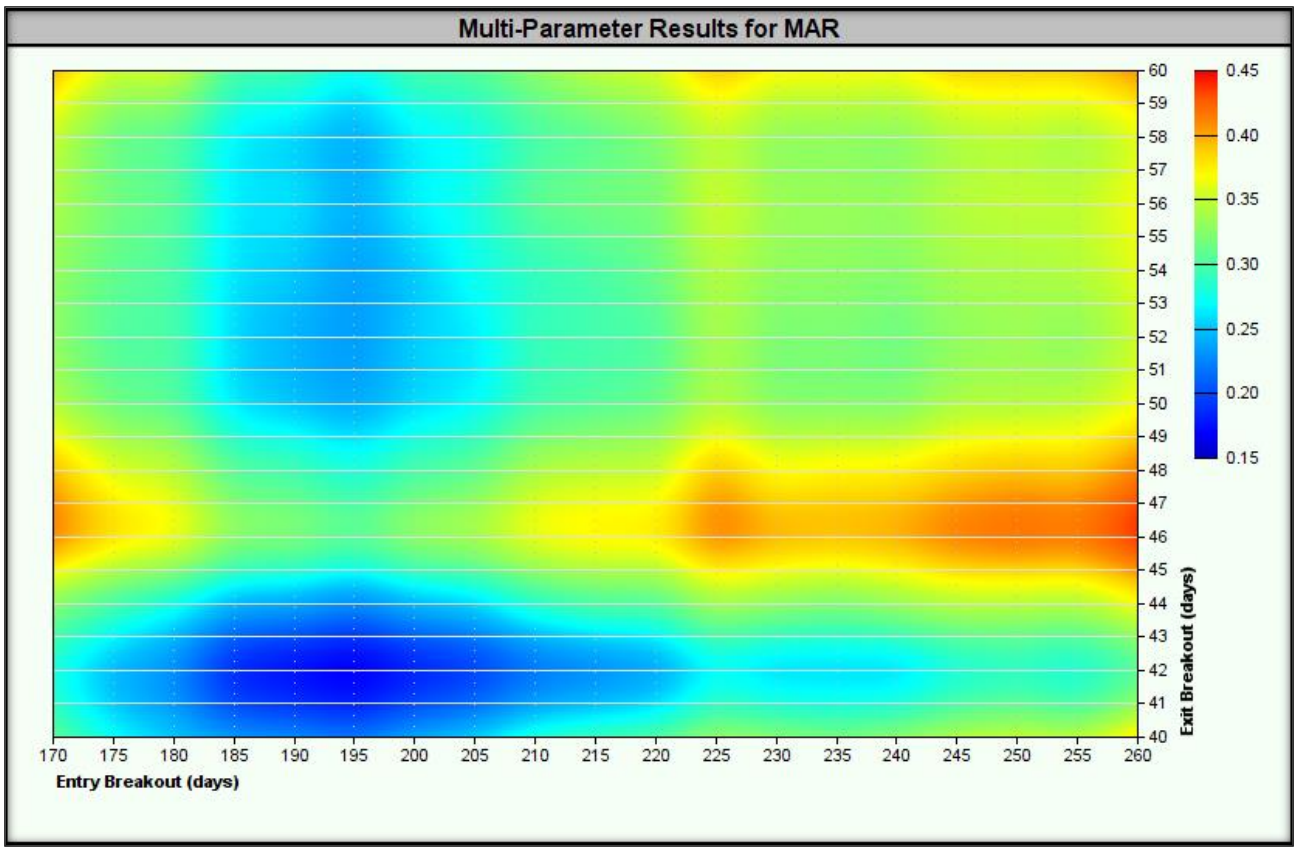

Multi-Parameter Results for MAR
0.42
0.40
0.38
0.36
0.34
0.32
0.30
0.28
0.26
0.24
0.22
0.20
0.18
0.16
3.0
2.8
2.6
2.4
2.2
2.0
Stop (ATR)
170
180
190
200
210
220
230
240
250
260
Entry Breakout (days)


Multi-Parameter Results for MAR
0.45
0.40
0.35
0.30
0.25
0.20
0.15
60
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52
51
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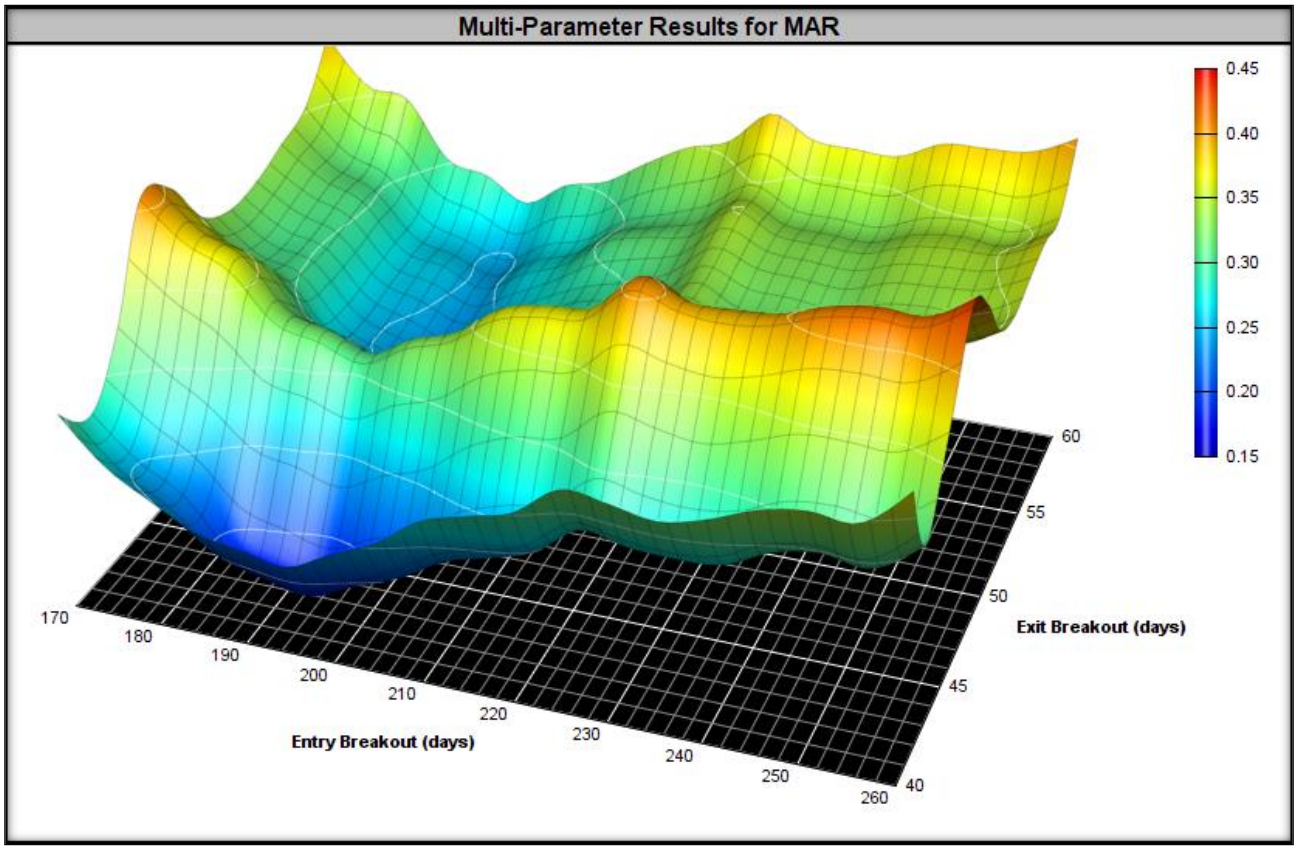
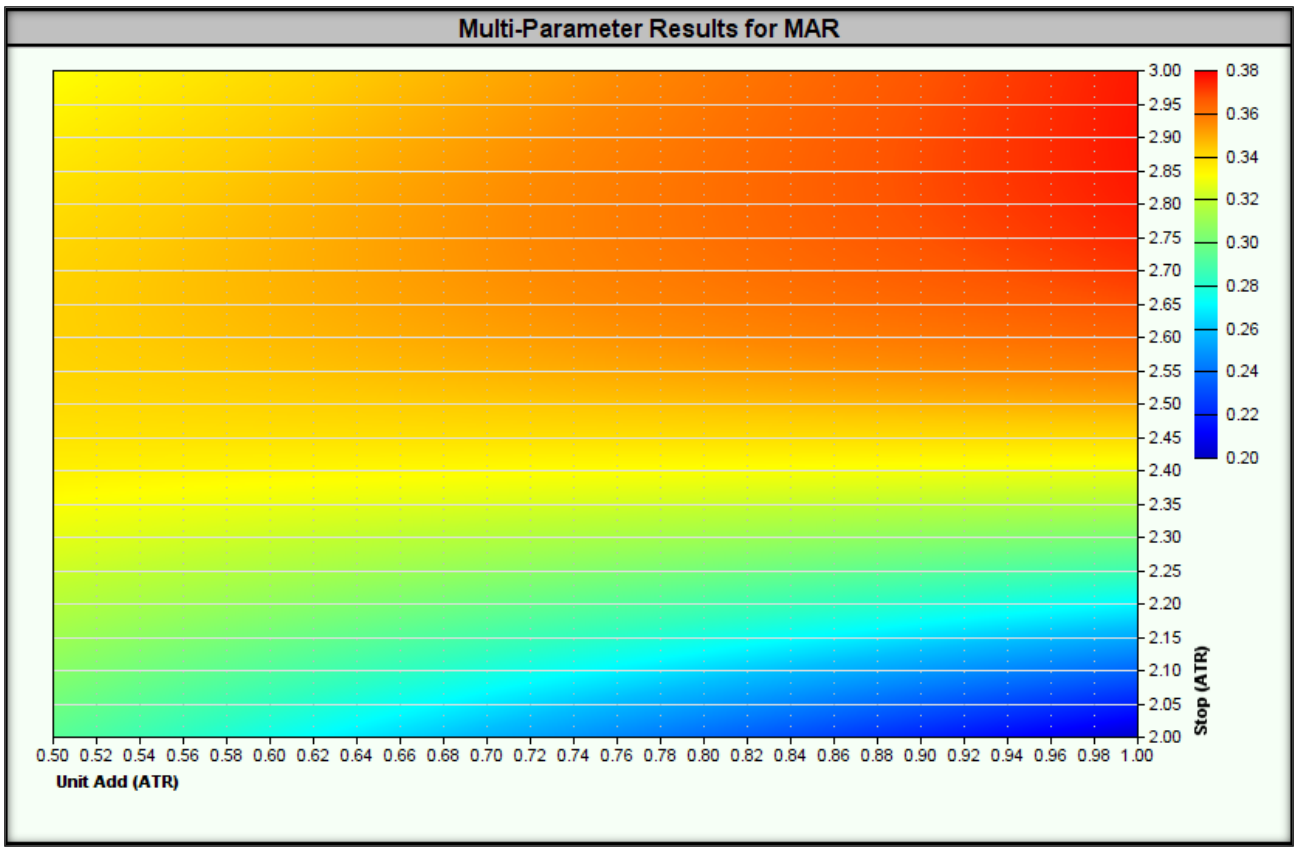
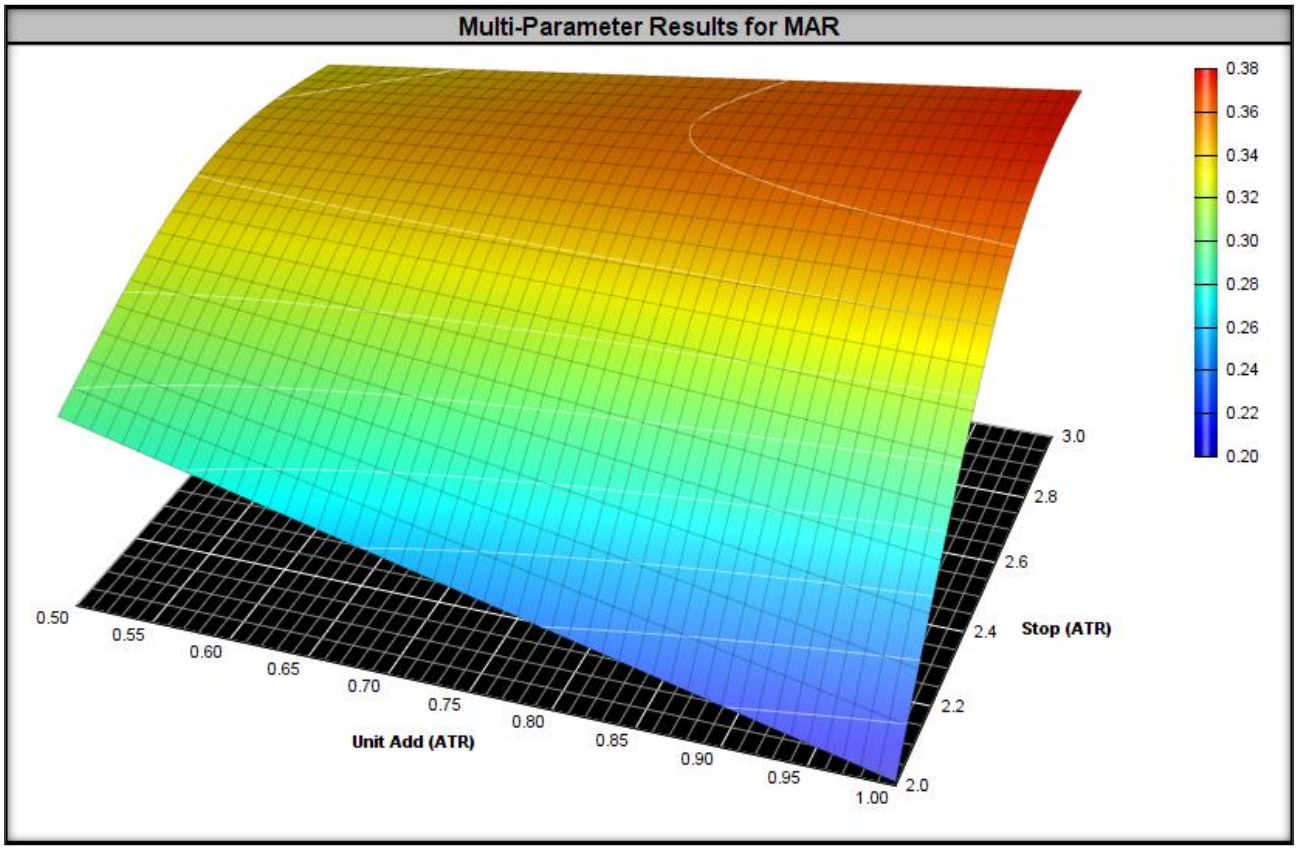
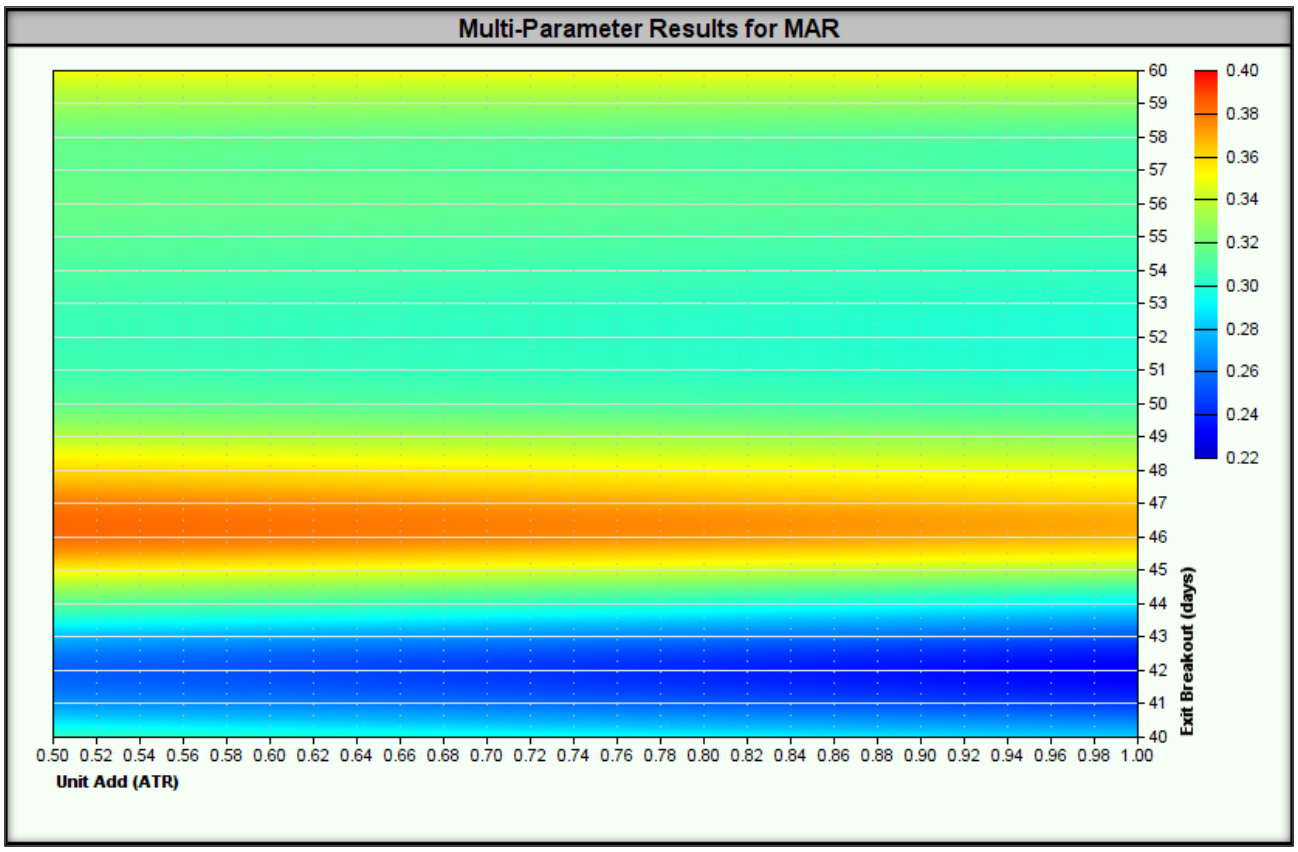
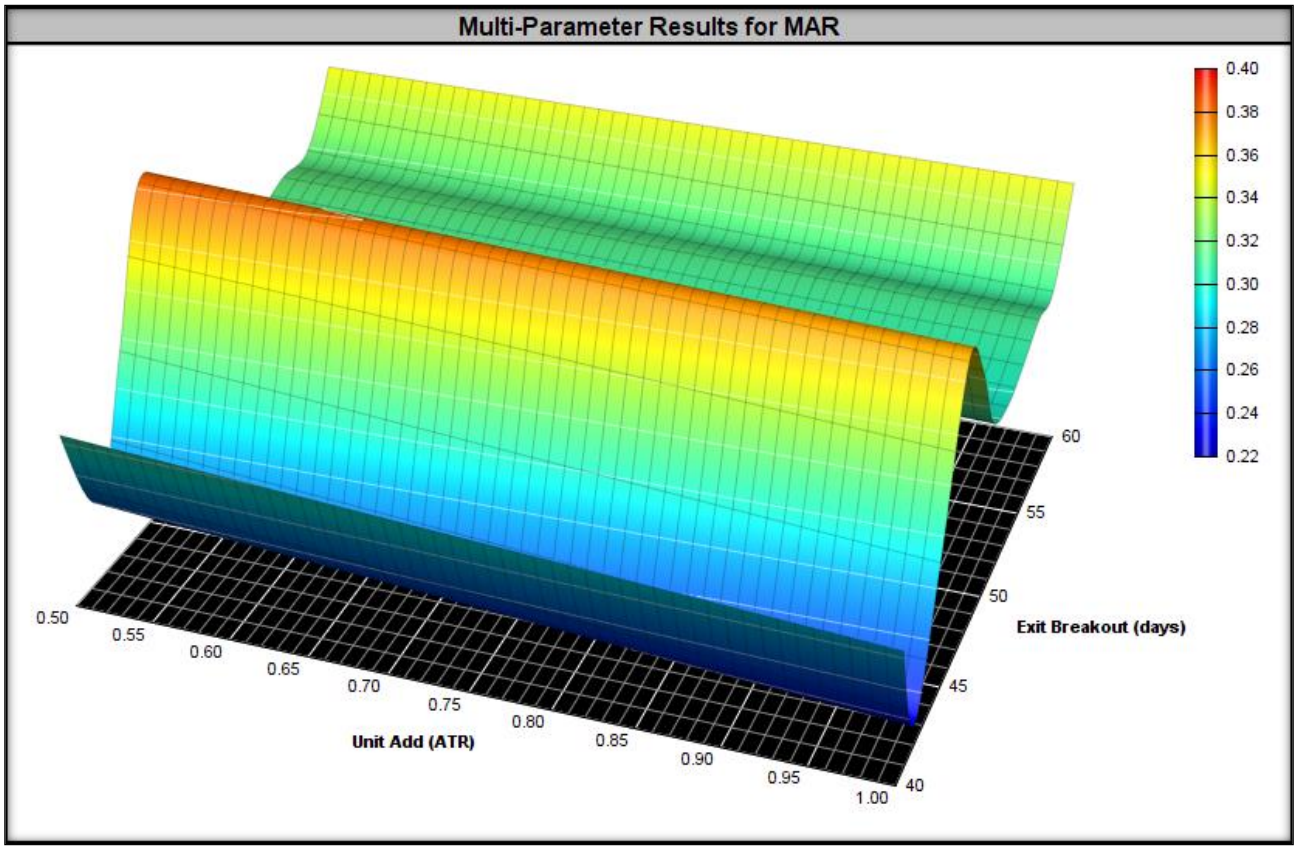
49
48
47
46
45
44
43
42
41
40
Exit Breakout (days)
170
175
180
185
190
195
200
205
210
215
220
225
230
235
240
245
250
255
260
Entry Breakout (days)

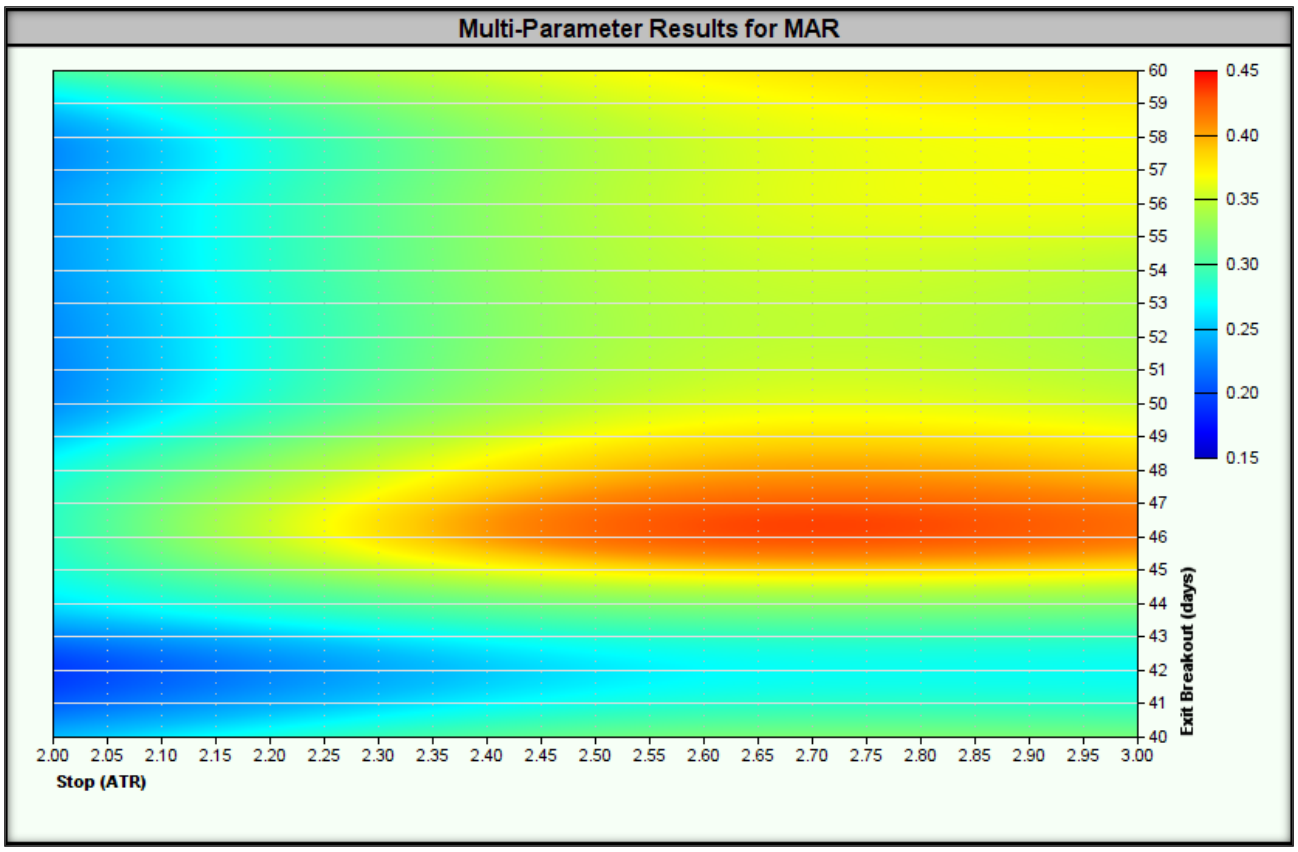

Multi-Parameter Results for MAR
0.45
0.40
0.35
0.30
0.25
0.20
0.15
170
180
190
200
210
220
230
240
250
260
Entry Breakout (days)
40
45
50
55
60
Exit Breakout (days)

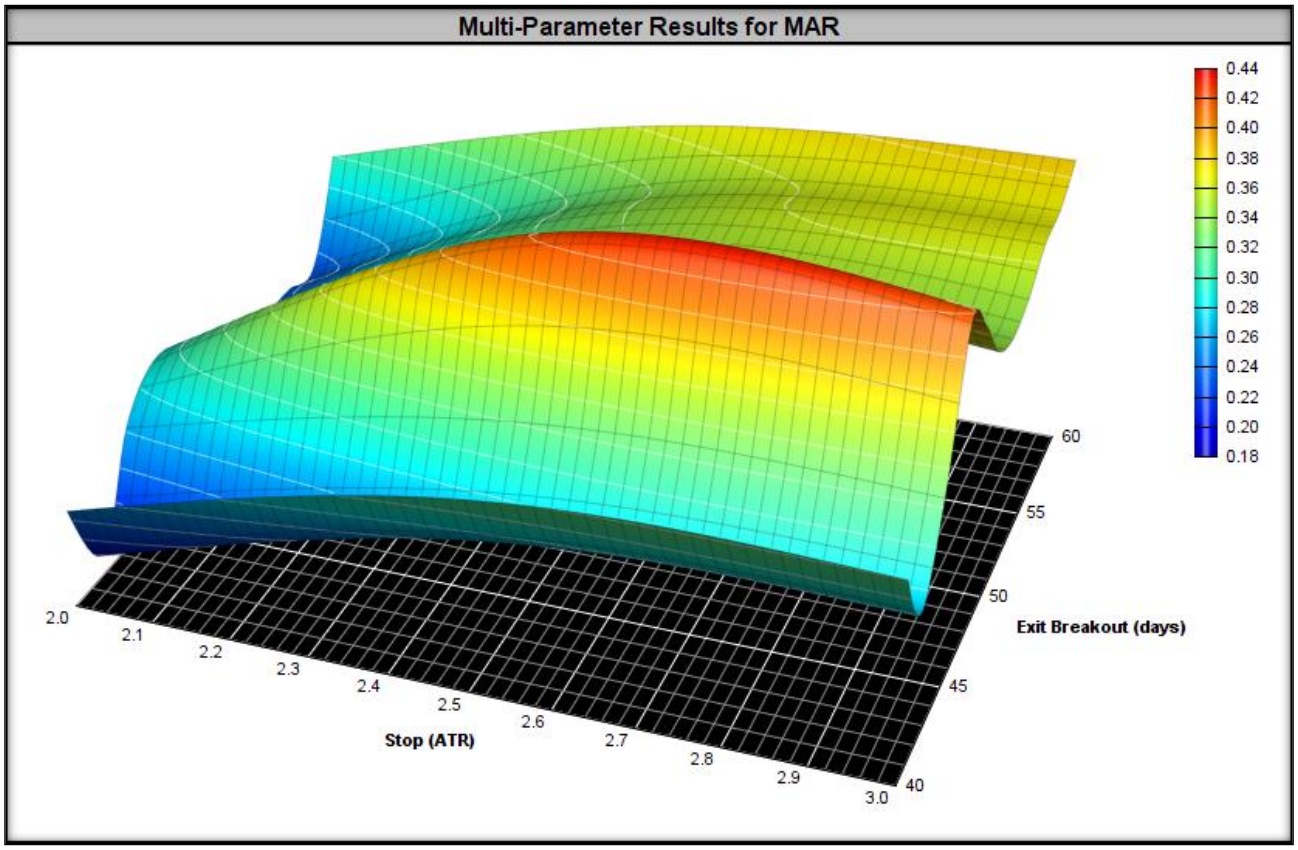

Multi-Parameter Results for MAR
0.38
0.36
0.34
0.32
0.30
0.28
0.26
0.24
0.22
0.20
3.00
2.95
2.90
2.85
2.80
2.75
2.70
2.65
2.60
2.55
2.50
2.45
2.40
2.35
2.30
2.25
2.20
2.15
2.10
2.05
2.00
Stop (ATR)
0.50 0.52 0.54 0.56 0.58 0.60 0.62 0.64 0.66 0.68 0.70 0.72 0.74 0.76 0.78 0.80 0.82 0.84 0.86 0.88 0.90 0.92 0.94 0.96 0.98 1.00
Unit Add (ATR)

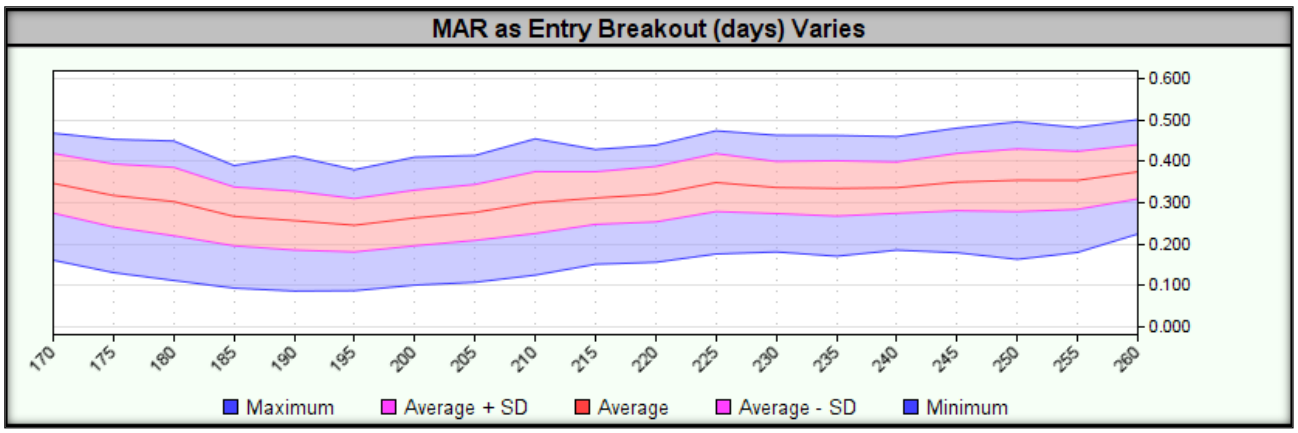

Multi-Parameter Results for MAR
0.38
0.36
0.34
0.32
0.30
0.28
0.26
0.24
0.22
0.20
3.0
2.8
2.6
2.4
2.2
2.0
Stop (ATR)
0.50
0.55
0.60
0.65
0.70
0.75
0.80
0.85
0.90
0.95
1.00
Unit Add (ATR)

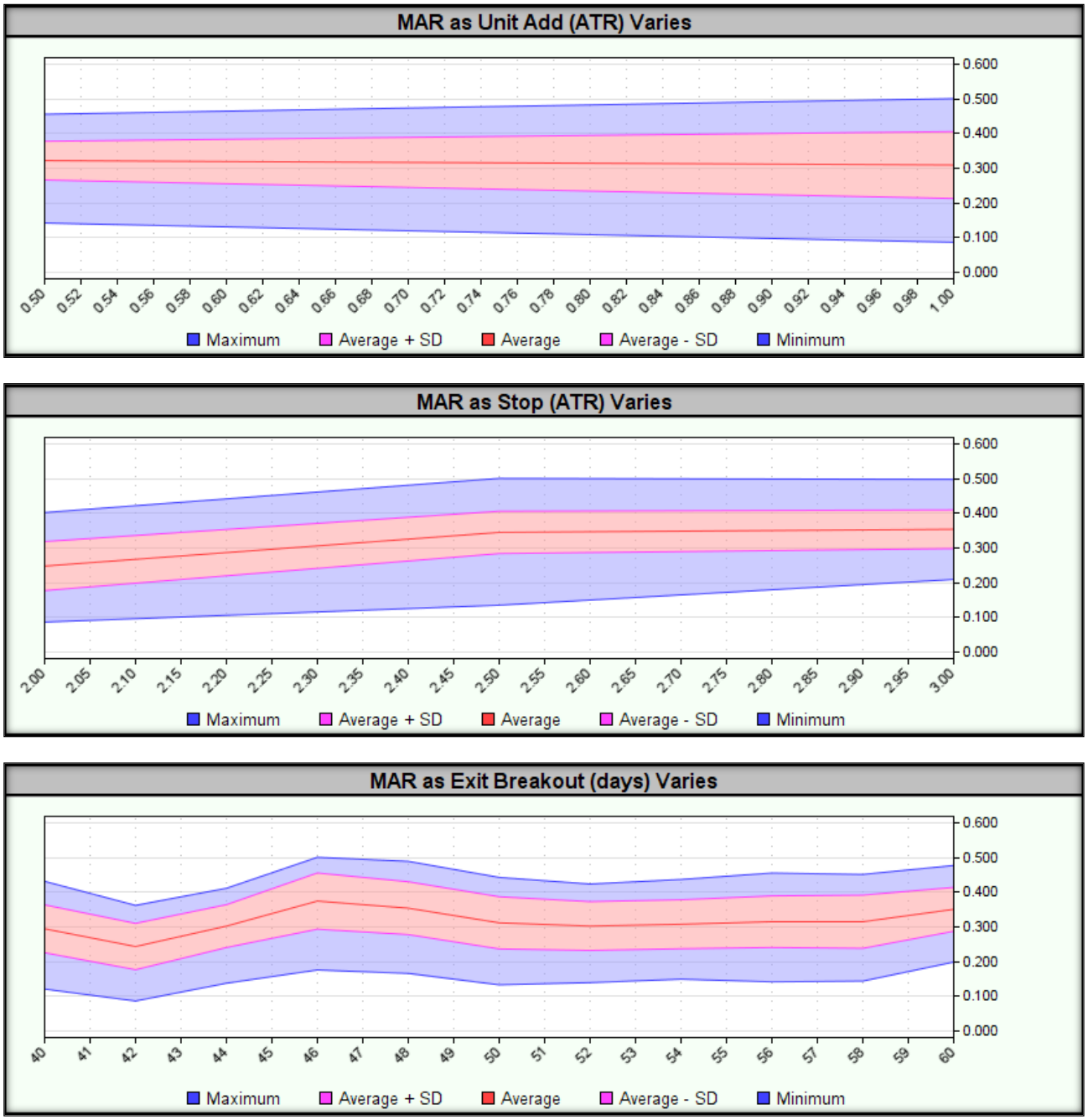

Multi-Parameter Results for MAR
0.40
0.38
0.36
0.34
0.32
0.30
0.28
0.26
0.24
0.22
60
59
58
57
56
55
54
53
52
51
50
49
48
47
46
45
44
43
42
41
40
Exit Breakout (days)
0.50 0.52 0.54 0.56 0.58 0.60 0.62 0.64 0.66 0.68 0.70 0.72 0.74 0.76 0.78 0.80 0.82 0.84 0.86 0.88 0.90 0.92 0.94 0.96 0.98 1.00
Unit Add (ATR)


Multi-Parameter Results for MAR
0.40
0.38
0.36
0.34
0.32
0.30
0.28
0.26
0.24
0.22
60
55
50
45
40
Exit Breakout (days)
0.50
0.55
0.60
0.65
0.70
0.75
0.80
0.85
0.90
0.95
1.00
Unit Add (ATR)


Multi-Parameter Results for MAR
0.45
0.40
0.35
0.30
0.25
0.20
0.15
60
59
58
57
56
55
54
53
52
51
50
49
48
47
46
45
44
43
42
41
40
Exit Breakout (days)
2.00
2.05
2.10
2.15
2.20
2.25
2.30
2.35
2.40
2.45
2.50
2.55
2.60
2.65
2.70
2.75
2.80
2.85
2.90
2.95
3.00
Stop (ATR)


Multi-Parameter Results for MAR
0.44
0.42
0.40
0.38
0.36
0.34
0.32
0.30
0.28
0.26
0.24
0.22
0.20
0.18
2.0
2.1
2.2
2.3
2.4
2.5
2.6
2.7
2.8
2.9
3.0
Stop (ATR)
60
55
50
45
40
Exit Breakout (days)


MAR as Entry Breakout (days) Varies
0.600
0.500
0.400
0.300
0.200
0.100
0.000
170
175
180
185
190
195
200
205
210
215
220
225
230
235
240
245
250
255
260
Maximum
Average + SD
Average
Average - SD
Minimum



Once **the stability test has passed across a wide range of optimized parameters,** we can proceed to **stability testing using Monte Carlo simulation.** The conditions for passing this test are similar to those required in the step above.

2. Monte Carlo simulation

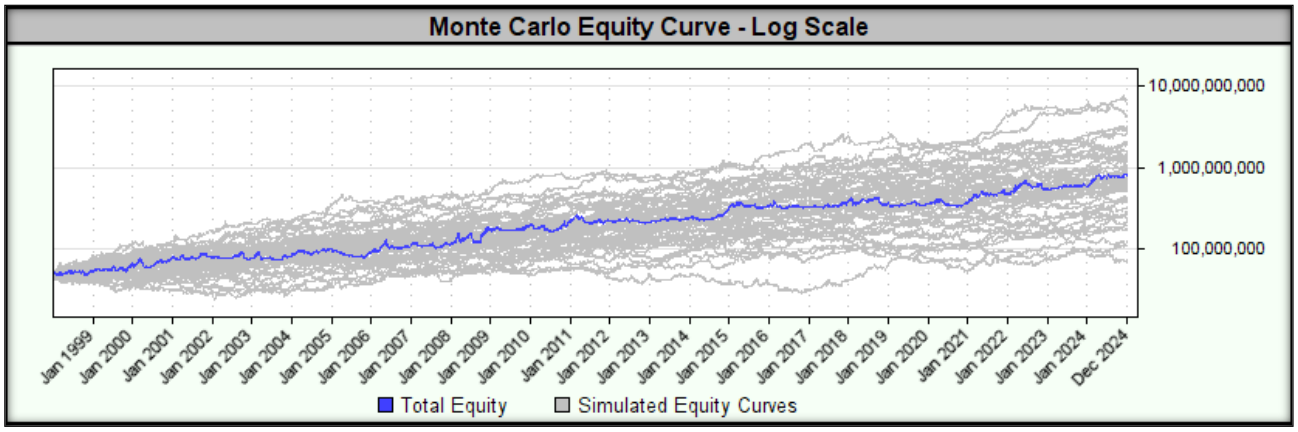
Monte Carlo simulation involves running multiple simulations to examine how a strategy might perform under various market scenarios. A key goal of this method is to assess the potential **drawdown** of an optimized strategy. **Monte Carlo simulation** better reflects possible equity curve fluctuations and the depth of potential **drawdown,** allowing for a more realistic risk assessment. It also provides an ideal opportunity to

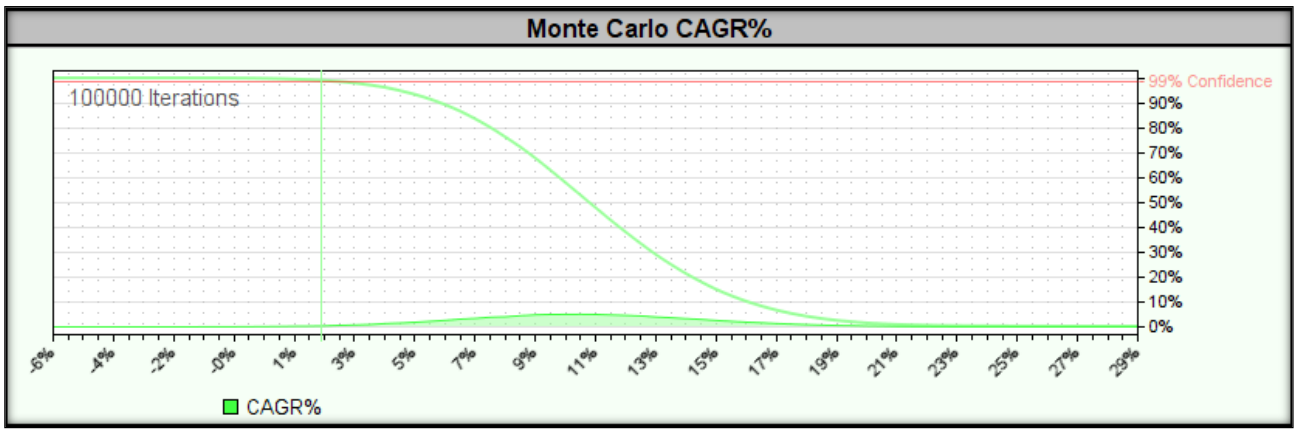
compare **the drawdown** obtained in tests on optimized parameter ranges with the results of **the Monte Carlo simulation,** using **a 99% confidence interval.**

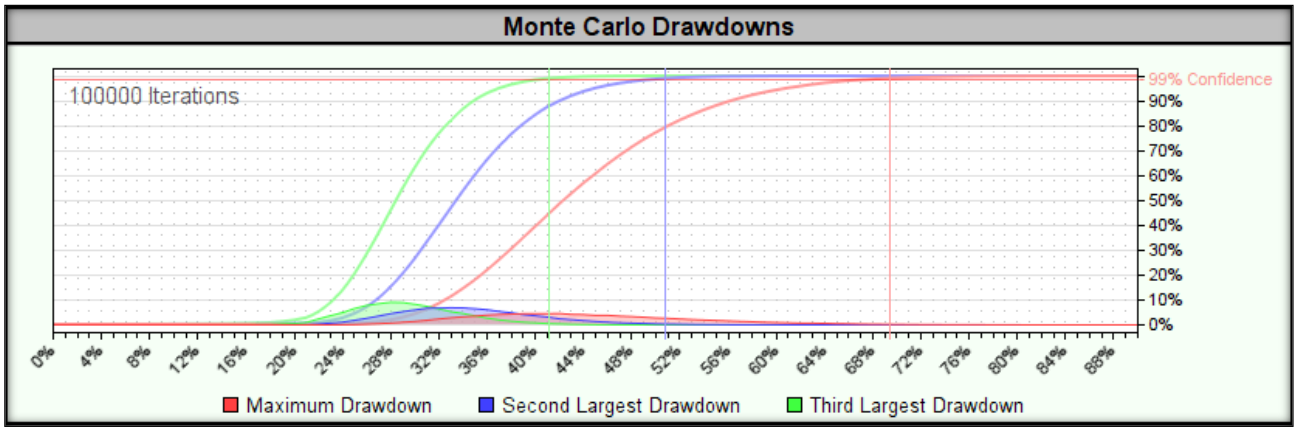
A strategy considered to be **stable (robust) should** achieve **a drawdown** in **a Monte Carlo simulation** that does not exceed **250% of the drawdown** size **from total tests in-sample and out-of-sample** (for parameters optimized on IS data). Furthermore, the **MAR indicator** should remain positive within the chosen confidence interval.

For data covering the period from **January 1, 1998 to December 31, 2024, a Monte Carlo simulation** was performed using **optimal strategy parameters.** The Monte Carlo simulation was performed **100,000 times,** testing **the variant with replacement (more conservative),** and **the confidence interval was set to 99%.**

The sample-replacement simulation are presented below.







- **CAGR%** – In 99% of simulations achieved **a rate of return equal to or higher than 2%.**
- **Drawdown** – 99% of simulations achieved **a drawdown of 69.5% or less.** For parameters optimized on in-sample data, the drawdown was 24.3%.

The strategy stability criteria **were not met** because **the drawdown In Monte Carlo simulation exceeded 250% values drawdown from tests on optimized parameters.** Therefore, **further testing of the strategy is not justified,** as its use in real transactions **is highly doubtful.**

3. **Stability over a moving time window**

The step was omitted due to **failure of previous stability tests.**

4. **Long/short stability**

The step was omitted due to **failure of previous stability tests.**

5. **Stability in the portfolio of financial instruments**

The step was omitted due to **failure of previous stability tests.**

6. **Money Management (Position Sizing)**

The step was omitted due to **failure of previous stability tests.**

7. **Strategy Risk Management**

The step was omitted due to **failure of previous stability tests.**

Step 5: Walk-Forward Analysis

Walk-Forward Analysis (WFA) is a key tool for assessing **a strategy's ability to perform in real-world market conditions.** It provides **reliable measures of reward and risk** after the optimization process and allows you to answer several key questions:

1. **What rate of return can you expect from the strategy?**
    - The optimization result often overstates the expected rate of return, which can lead to unrealistic forecasts.
    - WFA provides more **reliable and realistic measures of return** by minimizing the impact of overfitting to historical data.
2. **What set of parameters should be used in the next period?**
    - Thanks to **WFA,** it is possible **to dynamically adjust the strategy parameters** to **the latest market changes,** increasing its adaptability.

WFA tests the strategy over multiple time periods, minimizing **the risk of overfitting** (overfitting the strategy to historical data). The WFA process consists of **two repeated steps:**

1. **Optimization (In-Sample):**
    - The strategy is optimized over a specific **training period** (**in-sample)**.
    - This step adjusts the parameters to obtain **the best results.**
2. **Testing (Out-of-Sample):**
    - The strategy, using **the parameters optimized in step 1,** is tested on **a test period** (**out-of-sample)**.
    - This stage verifies the effectiveness of the strategy in new market conditions that **were not used** during optimization.

Walk-Forward Efficiency (WFE) is a key metric that assesses a strategy's potential to perform under real-world market conditions. WFE compares:

- **The rate of return achieved in the in-sample window** (where parameters were optimized)
- **Rate of return in the out-of-sample window** (where the strategy was running on unknown data)

Similarly, **for the drawdown value,** WFE checks whether the strategy does not lose significant stability outside the optimization period.

A strategy considered **stable (robust) should meet the following conditions:**

- **WFE ≥ 50% for the rate of return** – means that the strategy retains at least half of its effectiveness beyond the optimization period.
- **WFE ≤ 150% for drawdown** – means that the drawdown outside the optimization period is not significantly higher than during the optimization period.

The step was omitted due to **failure of previous stability tests.**

Step 6: Using the strategy in real time

After **extensive testing,** implementing a **real-time investment strategy** becomes **relatively simple. Buy/sell signals and stop-loss orders are automatically generated** by the computer based on pre-established rules and formulas.

The most important element **of strategy execution** is **consistent execution of all signals, without exception. As Larry Williams noted:** *"Trading strategies work. Traders do not."*

Before making **a final decision to implement a strategy,** it's important to verify **whether it actually adds value** to the overall portfolio performance. It doesn't make sense to implement a strategy that **generates similar signals** or **has a similar equity curve.**

Key criteria for evaluating strategies before implementation:

1. **Daily return correlation**
   - The **lower the correlation** with other strategies, the better.
   - **Optimal values:** Correlation **close to zero or negative.**
2. **Reducing maximum drawdown**
   - If adding a strategy to a portfolio results in **a lower maximum drawdown,** this is **a strong positive signal.**
3. **Objective Function Improvement (MAR)**
   - If adding a strategy causes **the MAR to increase,** this indicates that **it has added value** to the portfolio.
4. **Better results in Monte Carlo simulation**
   - Monte Carlo simulation determines the potential **maximum drawdown.**
   - If Monte Carlo results **improve** after adding a strategy, this is **a strong positive signal.**

The above elements are often interrelated – usually all or **none of them are met.**

Once you decide to add a strategy to your portfolio, **the question arises:** *Should you implement the strategy immediately or is it better to wait?*

Some studies suggest **an incubation period** of **3-6 months,** during which:

- The strategy is **monitored** but **does not execute real transactions.**
- **Generated signals, positions and results** are observed to detect **potential anomalies.**

In our case, **the incubation period** lasts from the moment **the strategy is launched in a live environment** until **a drawdown occurs at approximately half the maximum drawdown** observed in historical data. **Only after this threshold is reached does the strategy begin to be used with real funds.**

Thanks to this:

- **We avoid investing real money in an untested environment.**

- **We wait for a drawdown to occur** before launching the strategy, which **reduces the risk of starting at an unfavorable moment.**

The final decision on its full implementation should be based on **thorough testing and analysis of the value added to the portfolio,** so that the strategy actually supports long-term investment goals and does not increase unnecessary risk.