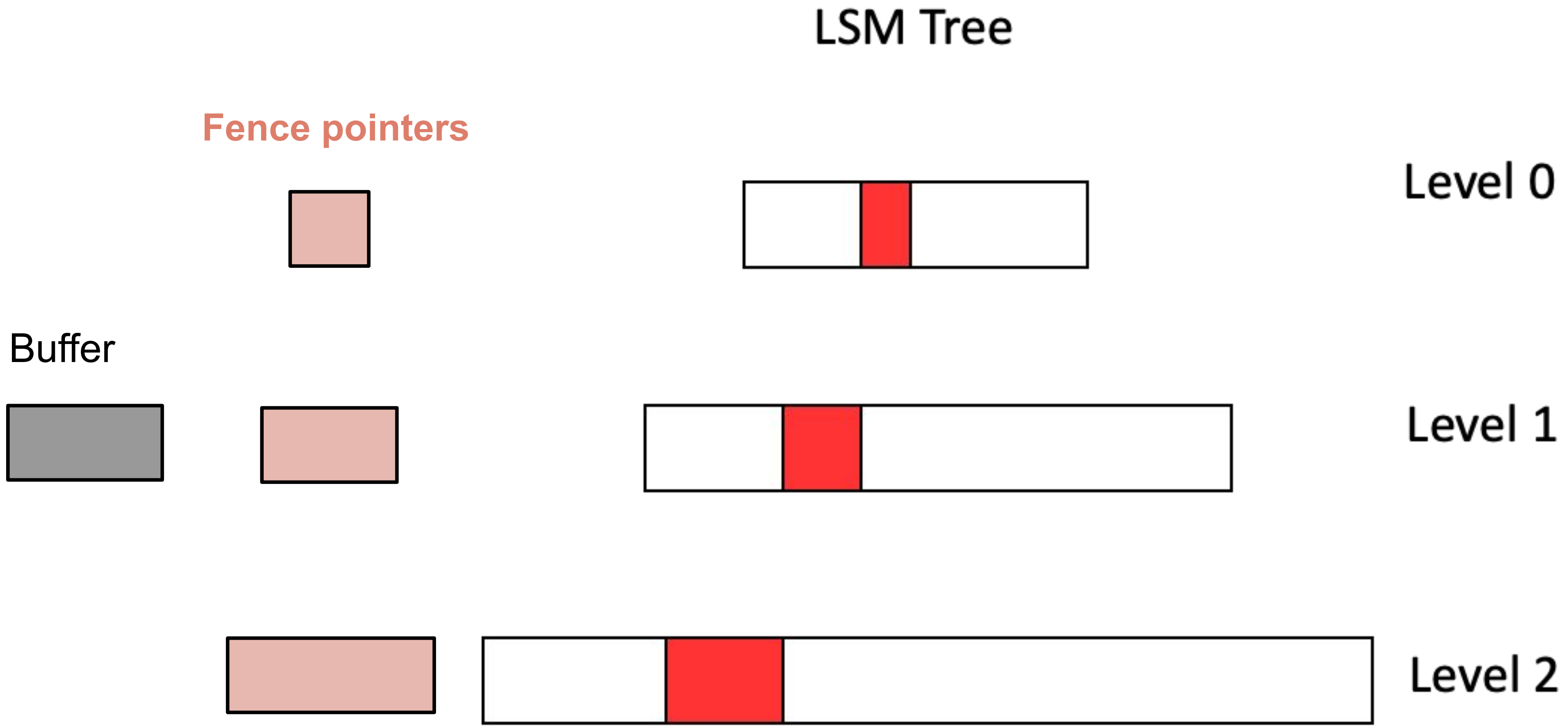
Query-driven compaction in LSM-trees

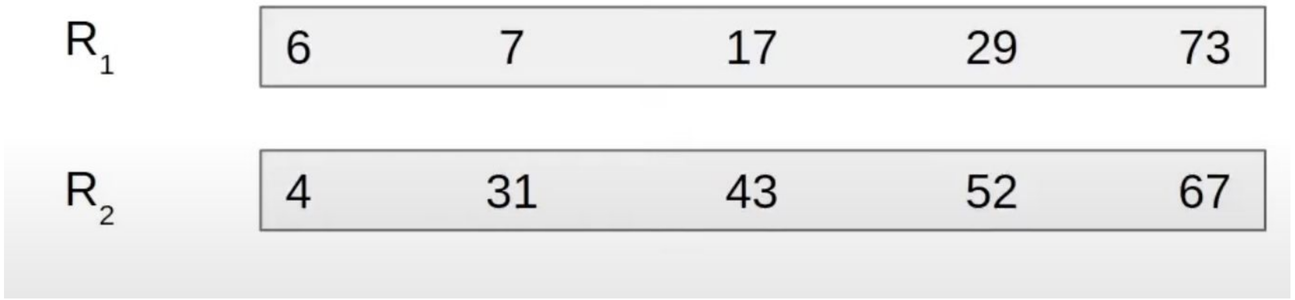
Ye Tian, Peiying Ye, Li Xi

Log-Structured Merge-tree and Range Query



Range Query and its Sorted View

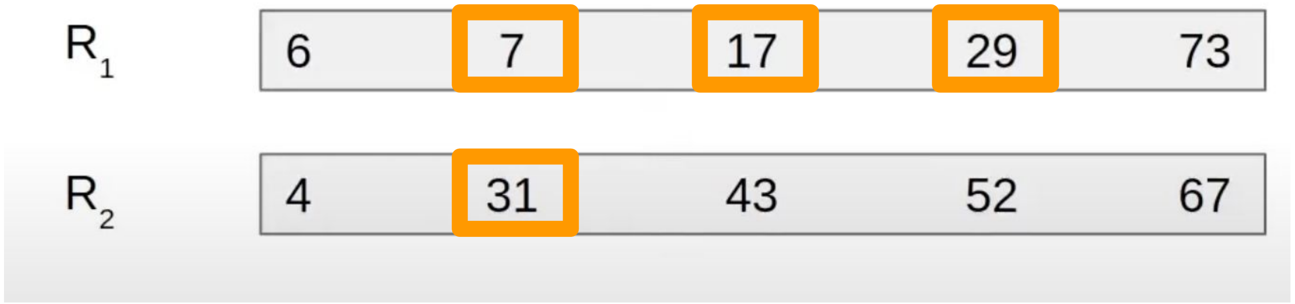
Range query (min = 7, max = 40)



Access each run and find the smallest key >= 7 and <= 40.

Range Query and its Sorted View

Range query (min = 7, max = 40)



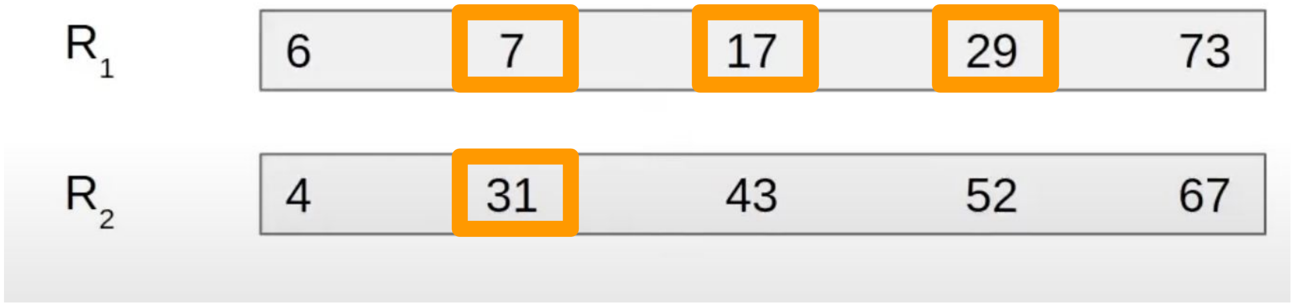
Access each run and find the smallest key >= 7 and <= 40.

→

Compare, build heap, and output the smallest.

Range Query and its Sorted View

Range query (min = 7, max = 40)



Access each run and find the smallest key >= 7 and <= 40.

Compare, build heap, and output the smallest.

Runtime Sort-merge completed.

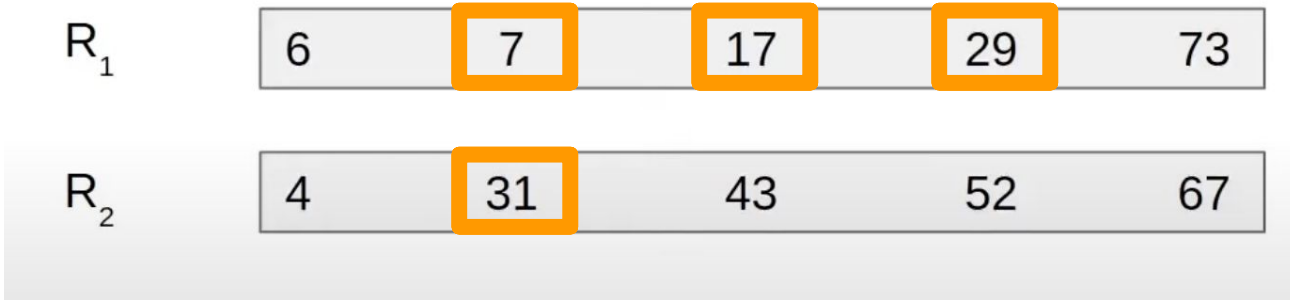
7, 17, 29, 31

Discarded after range query completed.

Duplicate Sort-merge next time!

Research Motivation

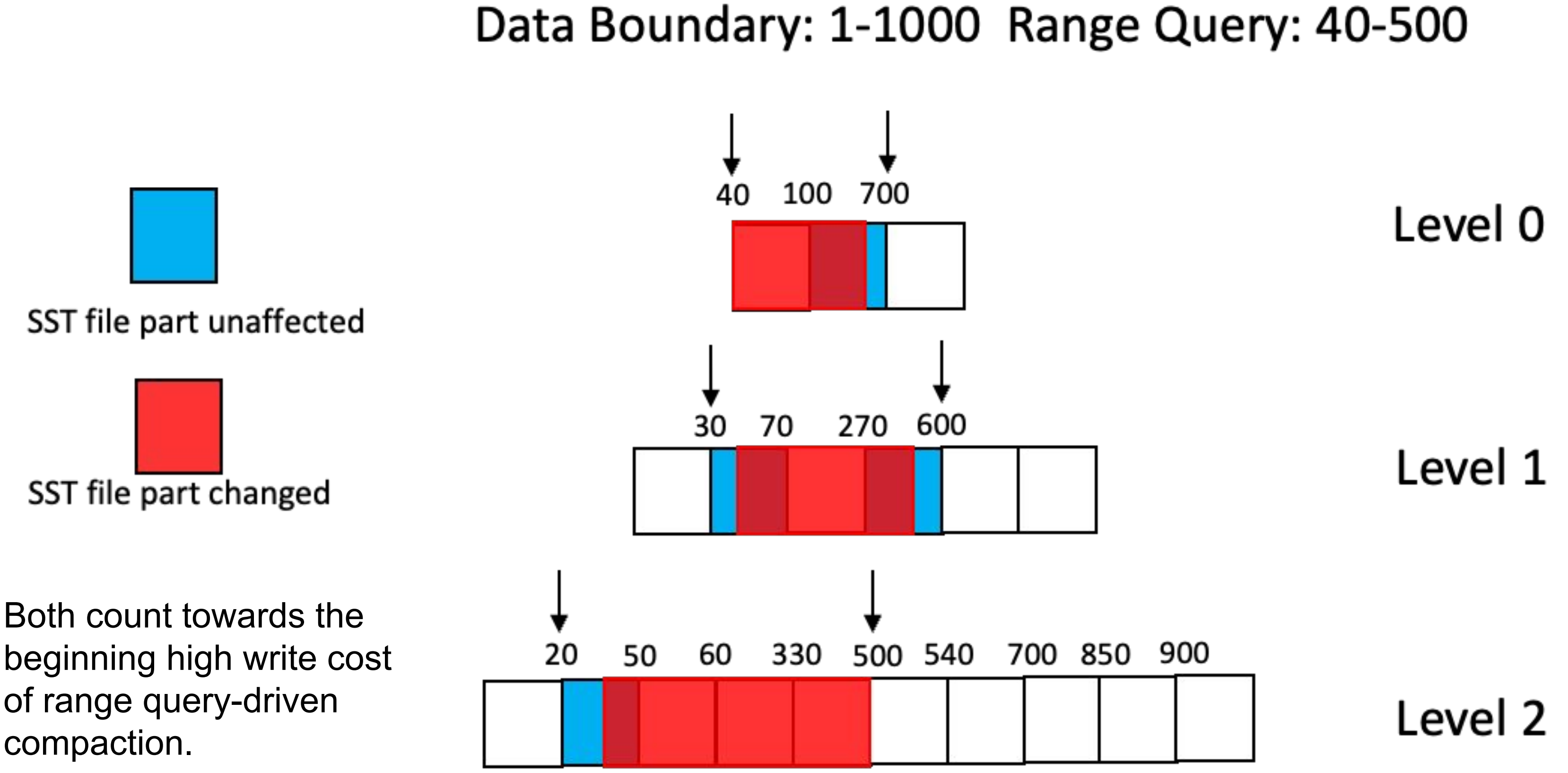
Range query (min = 7, max = 40)



R_1	6	7	17	29	73
R_2	4	31	43	52	67

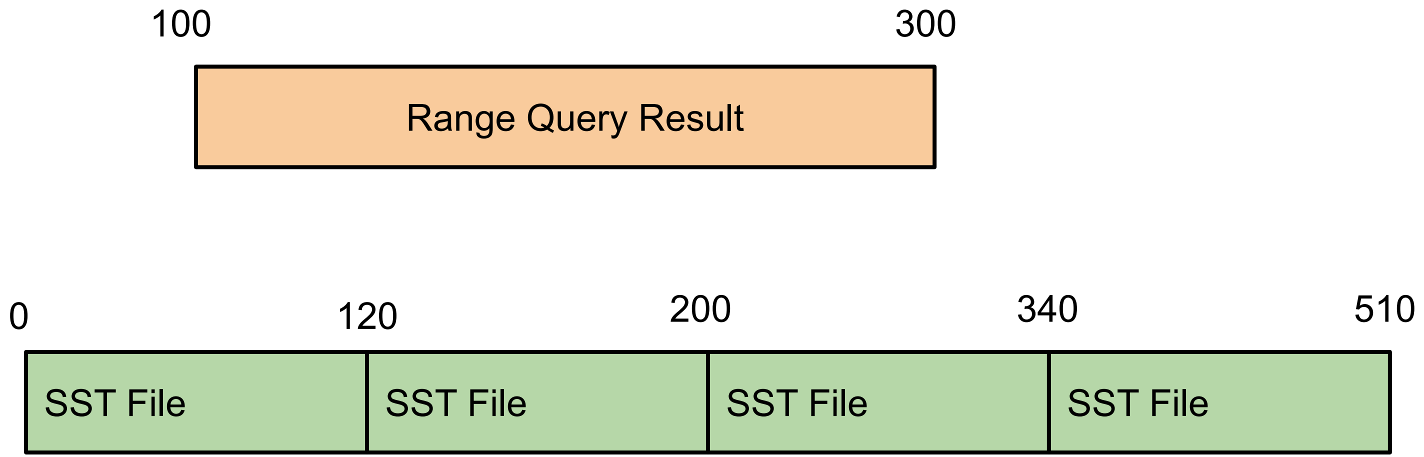
7, 17, 29, 31 → **Duplicate Sort-merge next time!** → **How can we optimize it?**

How does range-query-driven compaction work?

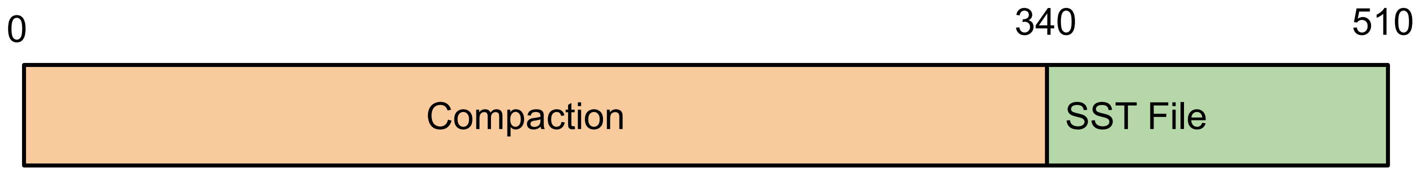


Both count towards the beginning high write cost of range query-driven compaction.

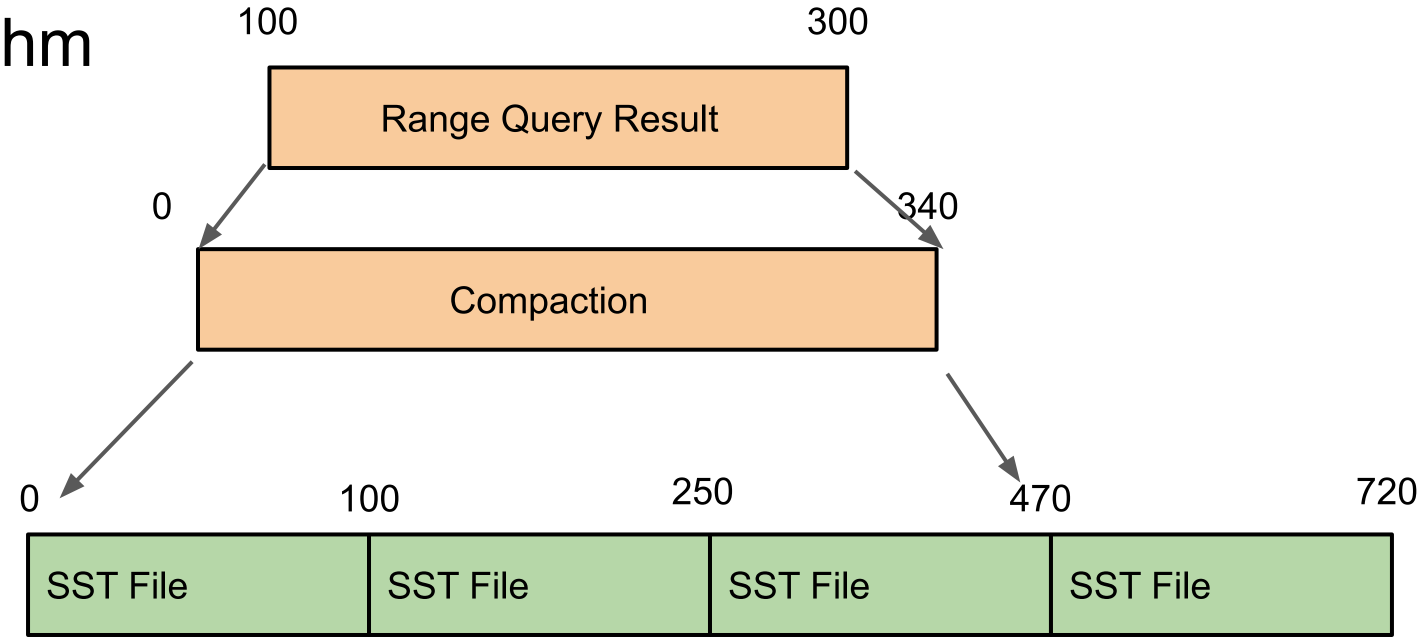
Algorithm


100
300
Range Query Result
0
120
200
340
510
SST File
SST File
SST File
SST File

Algorithm

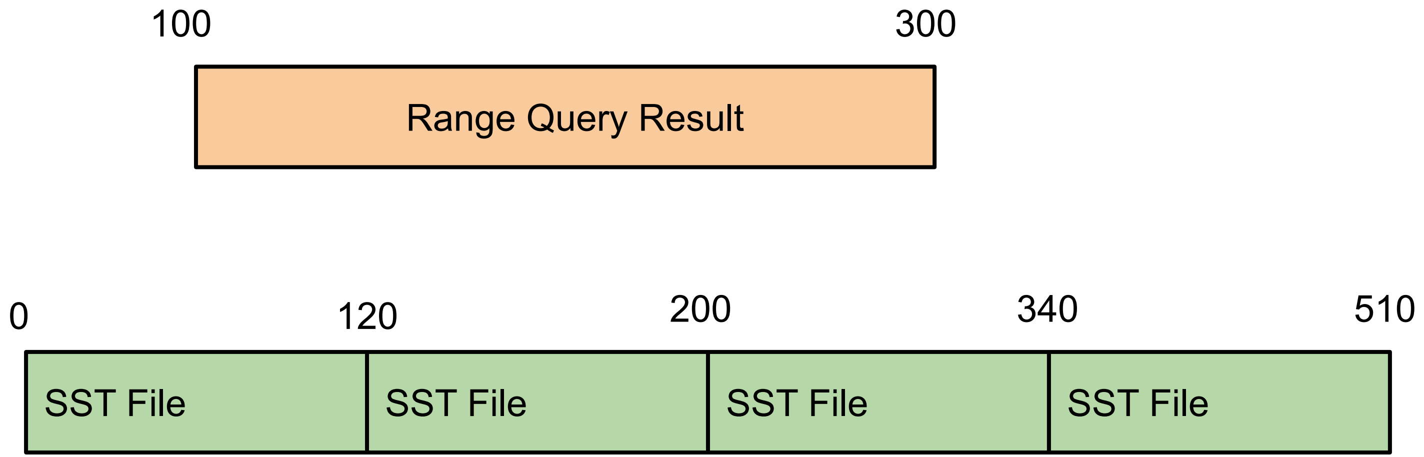


Algorithm



Don’t work for multi-layer compaction
Compaction range keeps growing

Algorithm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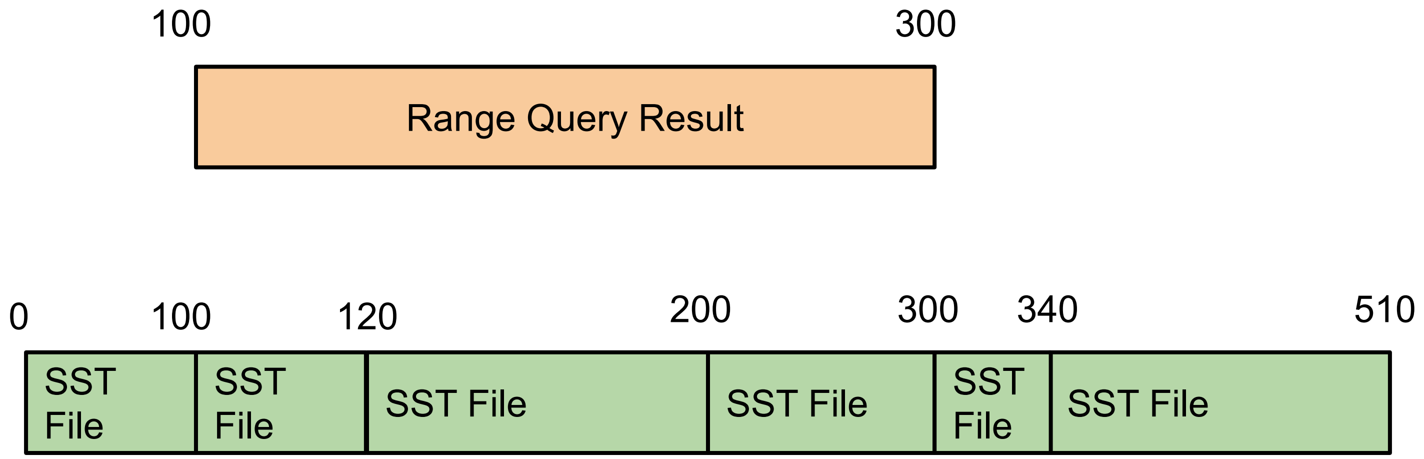
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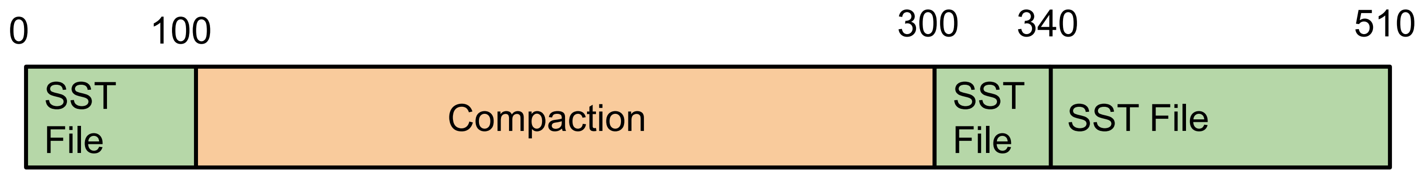
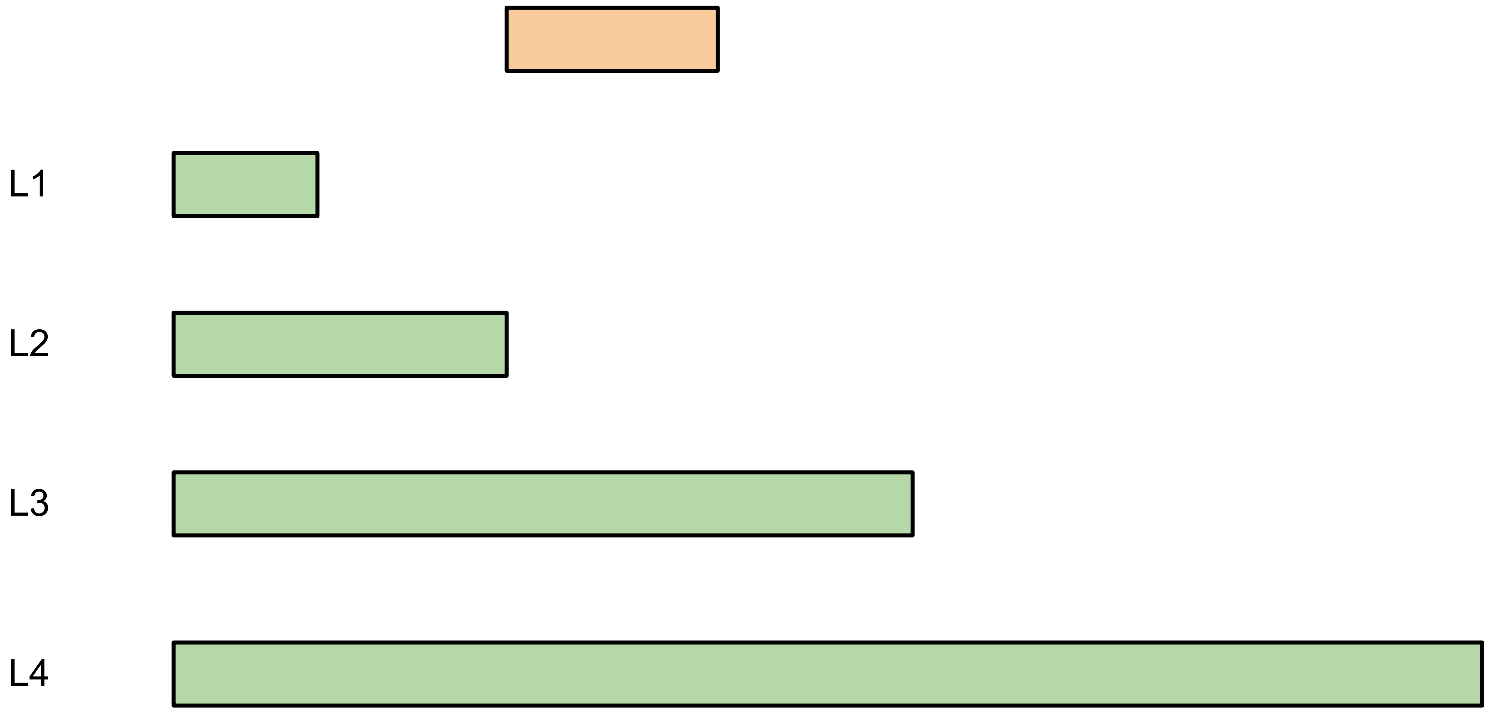
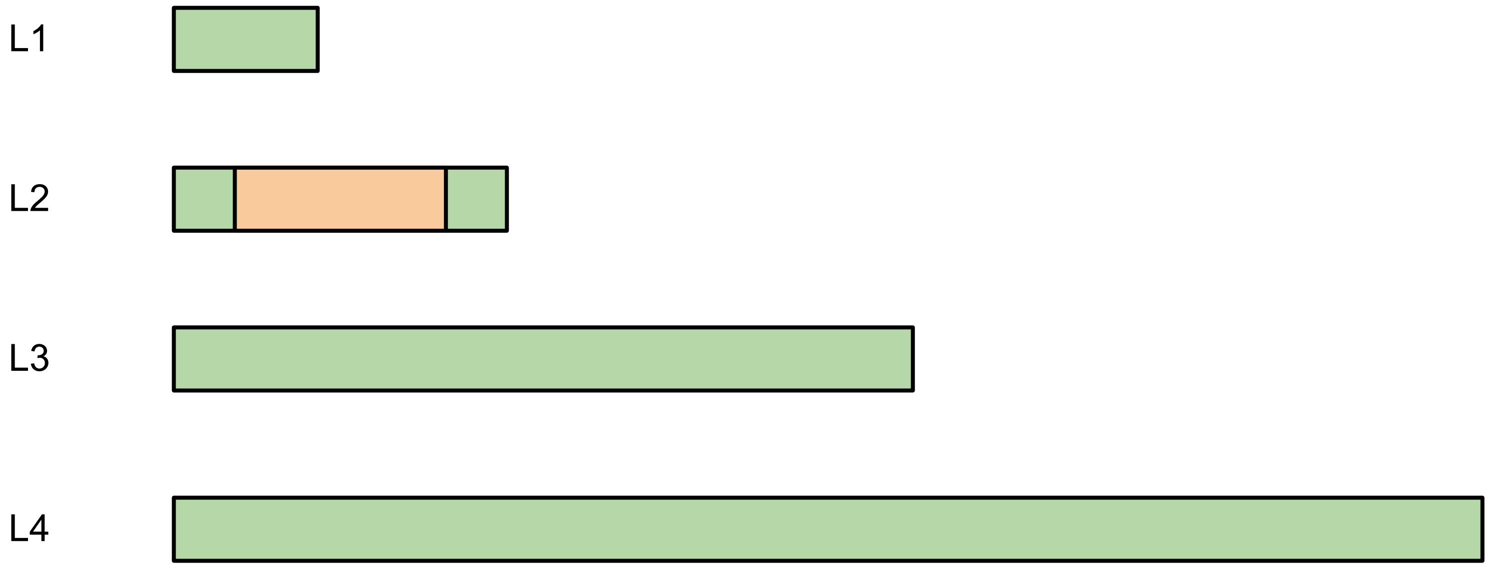
Algorithm



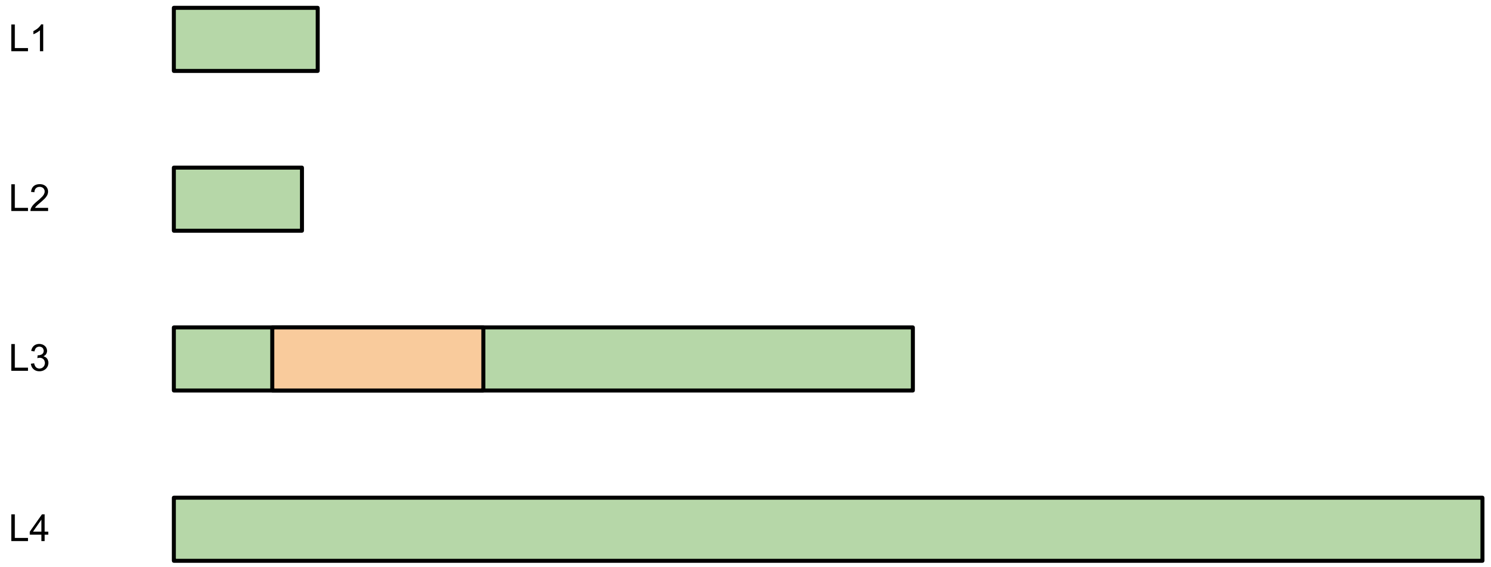
Algorithm



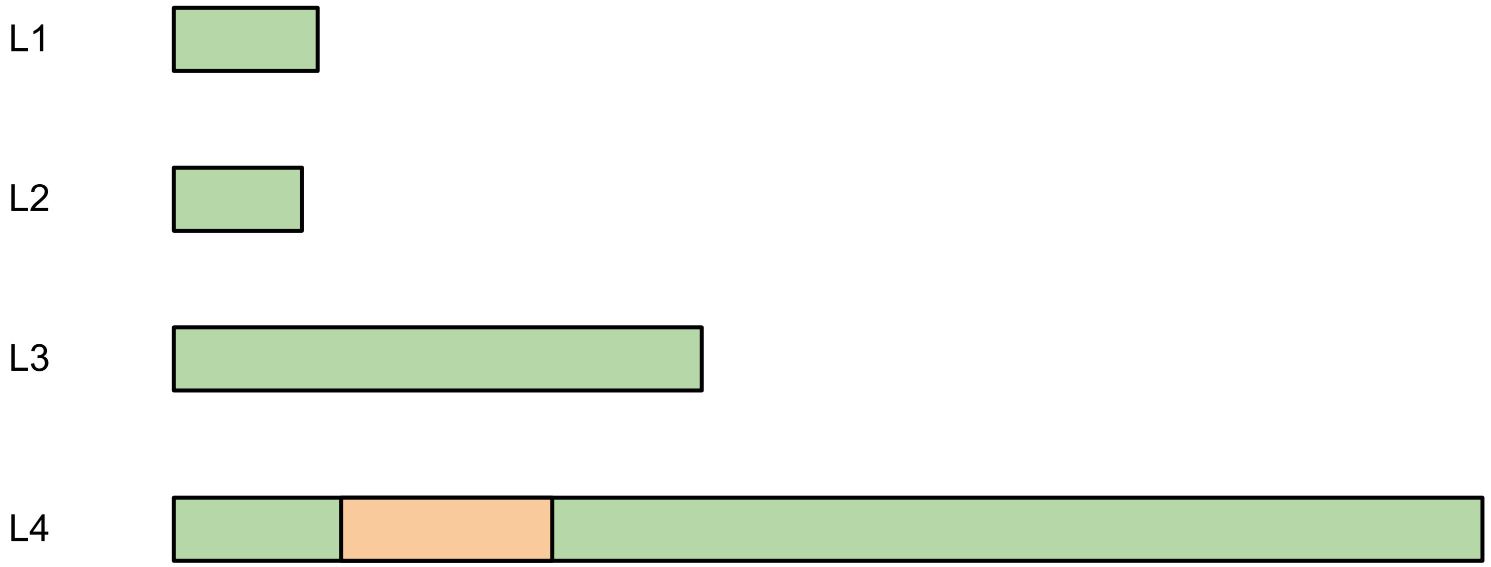
Algorithm



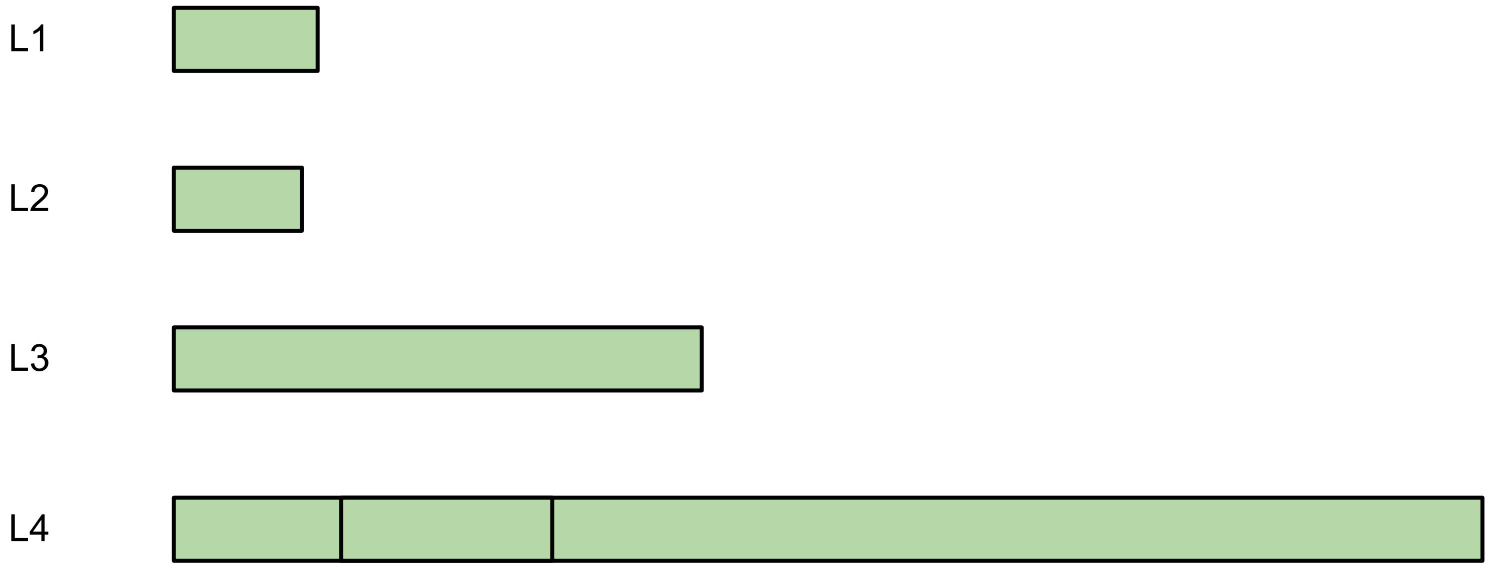
Algorithm



Algorithm

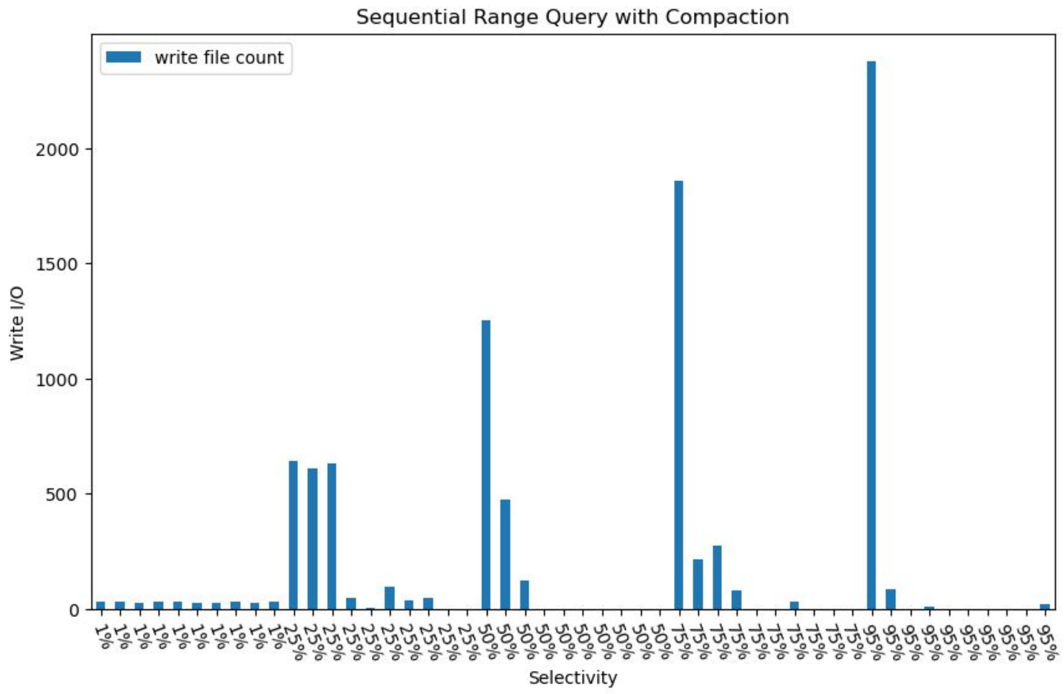


Algorithm

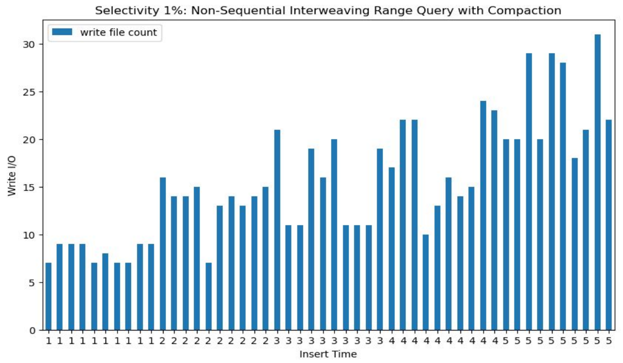


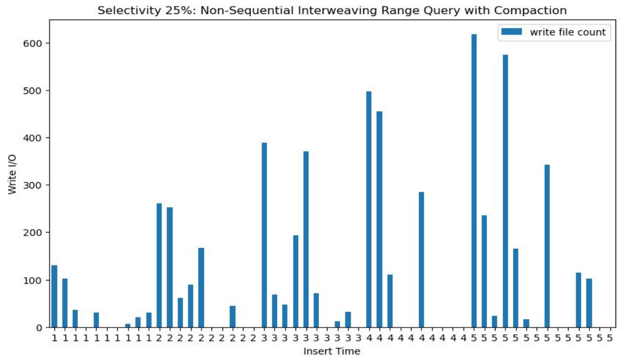
Benchmark Experiments (100k Inserts)

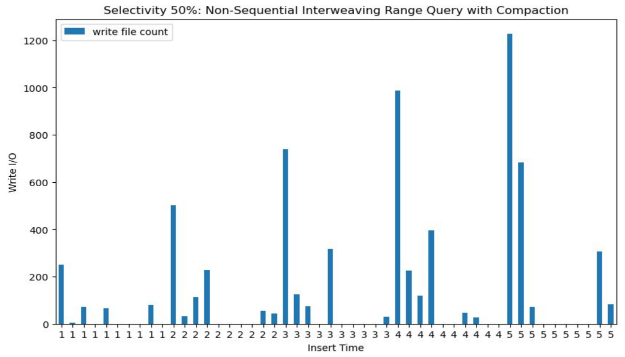
Sequential Workload (50RQ)

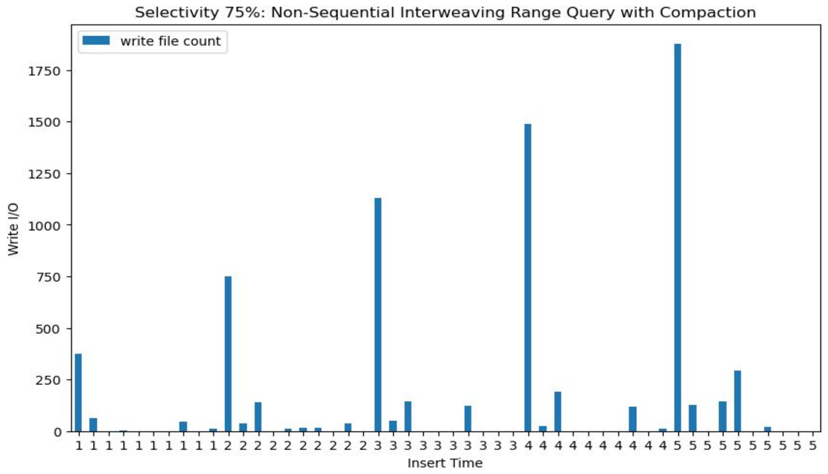


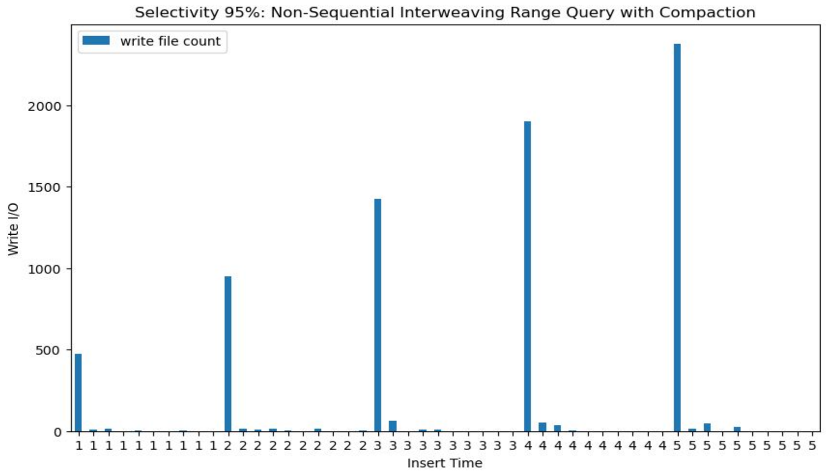
Non-sequential Workload (5 times inserts, 100RQ each time)



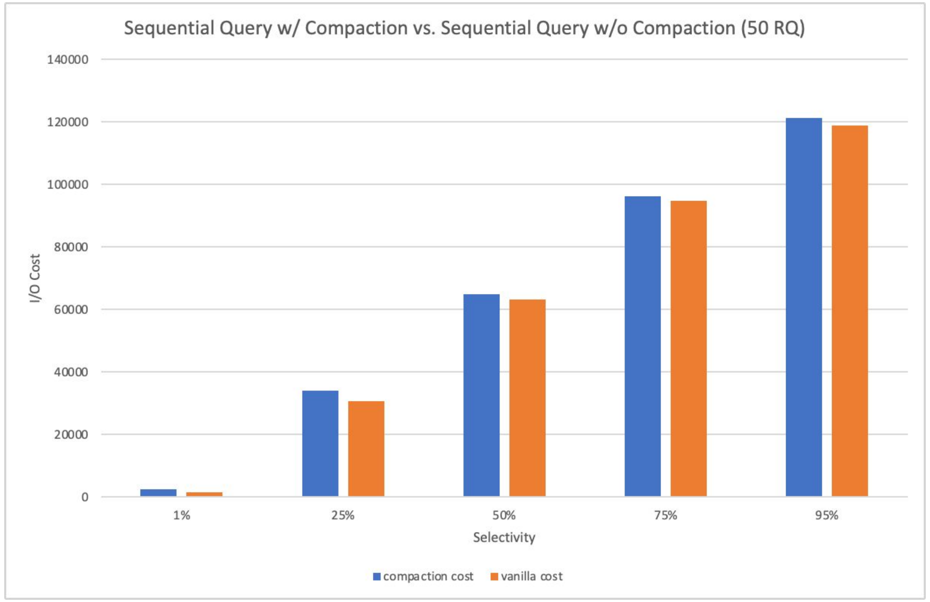


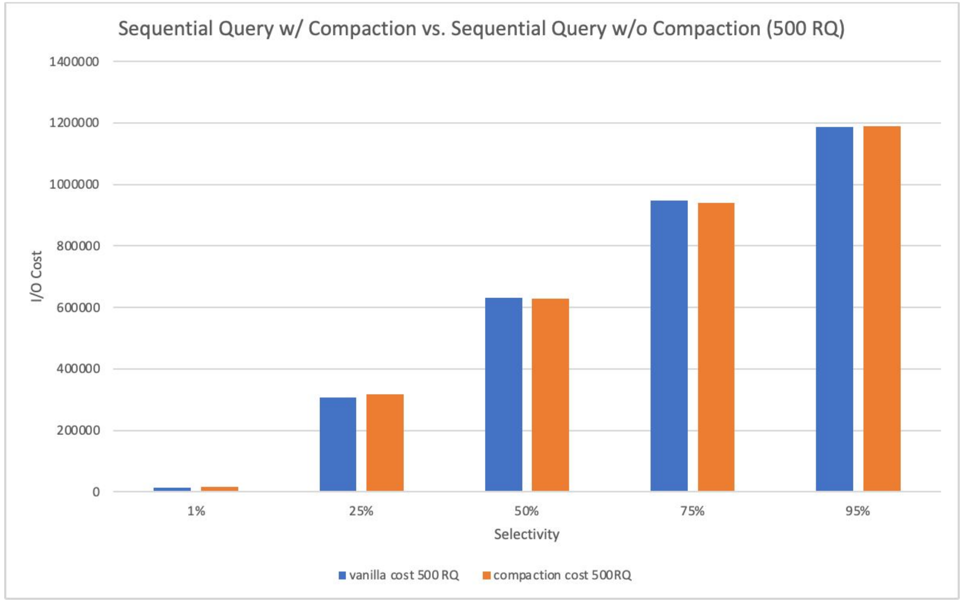






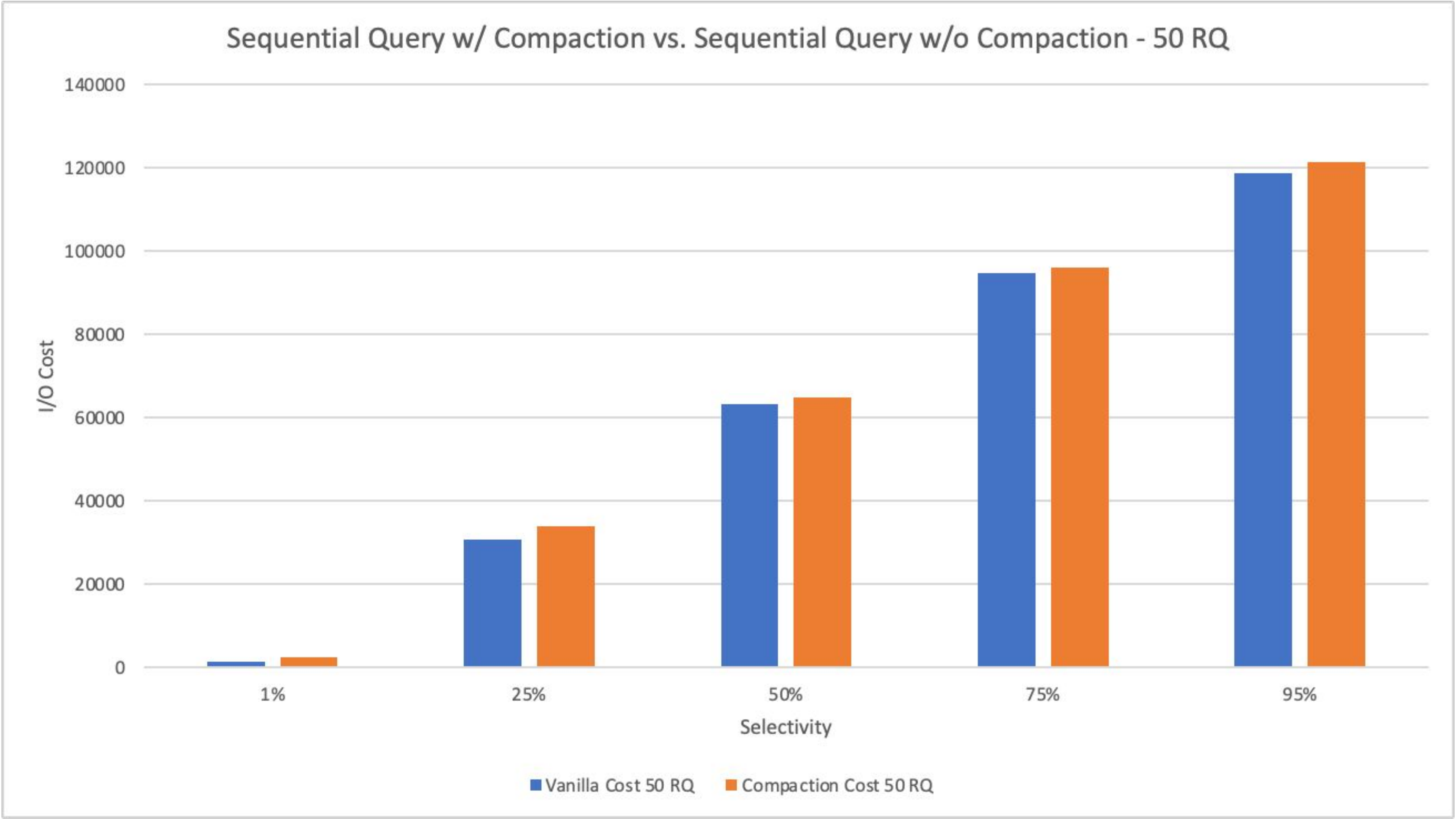
Comparison


Sequential Query w/ Compaction vs. Sequential Query w/o Compaction (50 RQ)
140000
120000
100000
80000
60000
40000
20000
0
I/O Cost
1%
25%
50%
75%
95%
Selectivity
■ compaction cost
■ vanilla cost


Sequential Query w/ Compaction vs. Sequential Query w/o Compaction (500 RQ)
1400000
1200000
1000000
800000
600000
400000
200000
0
I/O Cost
1%
25%
50%
75%
95%
Selectivity
■ vanilla cost 500 RQ
■ compaction cost 500RQ

Challenges and Future Evaluations

- Further experiments on comparing non-sequential workload I/O for vanilla implementation and query-driven-compaction implementation
- Further experiments on ‘QueryDrivenCompactionSelectivity’ to figure out the trend and see if we can find a sweet spot


Sequential Query w/ Compaction vs. Sequential Query w/o Compaction - 50 RQ
140000
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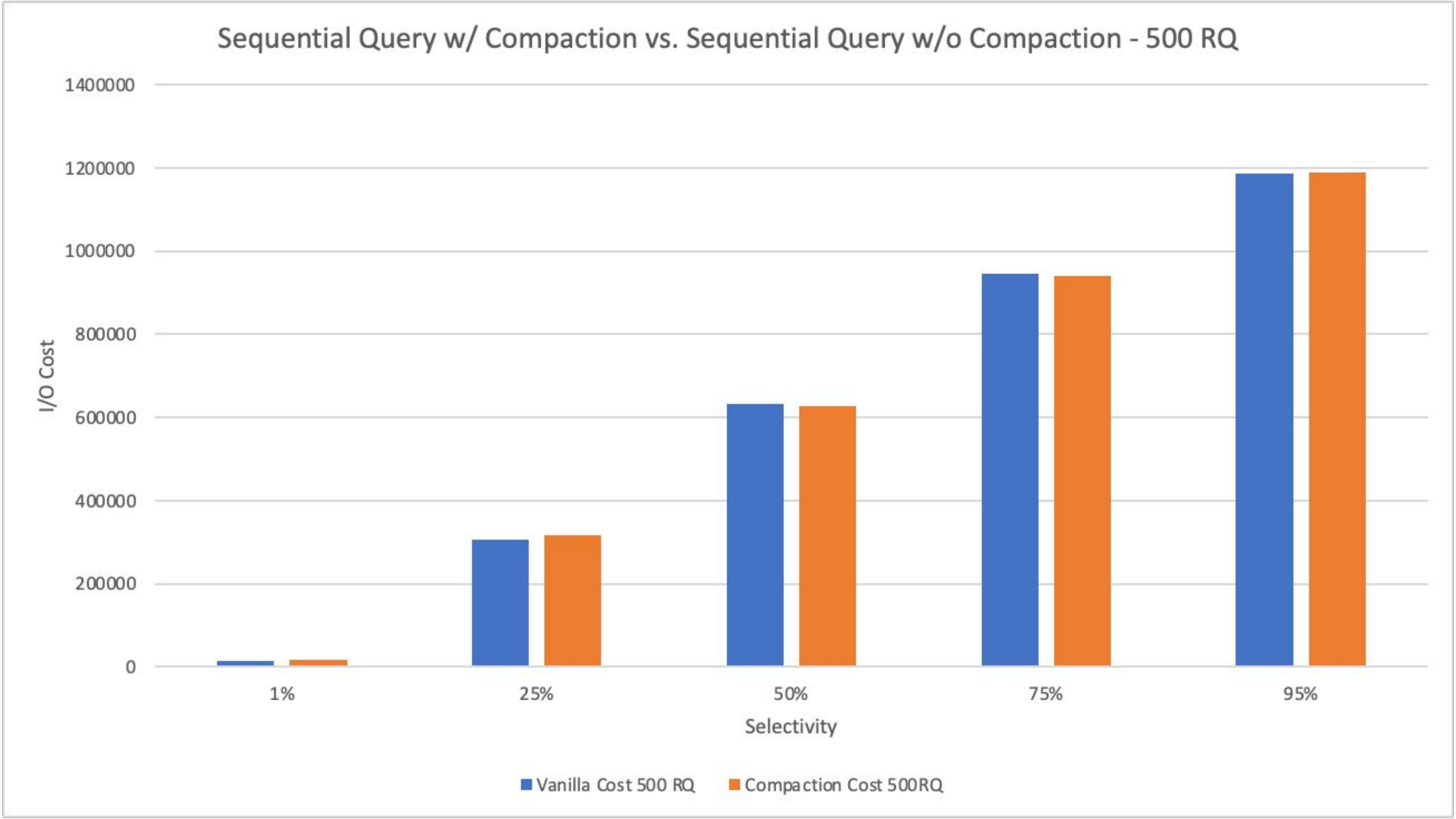
Sequential Query w/ Compaction vs. Sequential Query w/o Compaction - 500 RQ
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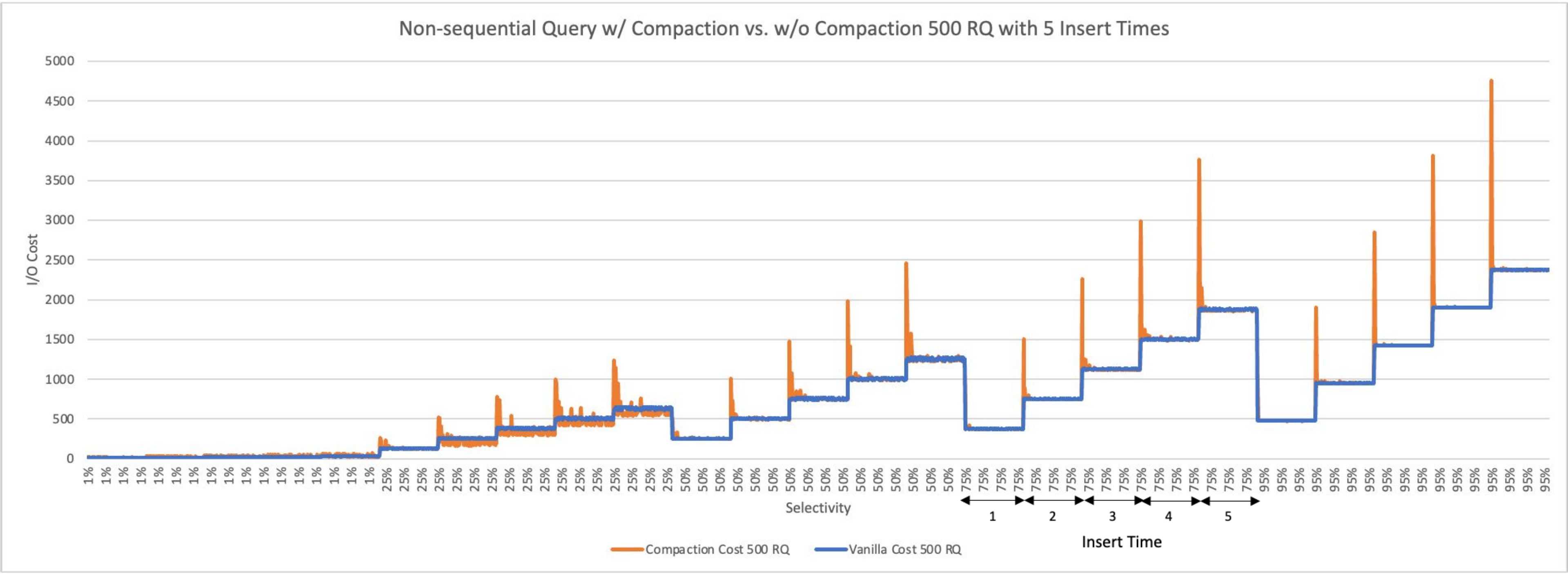
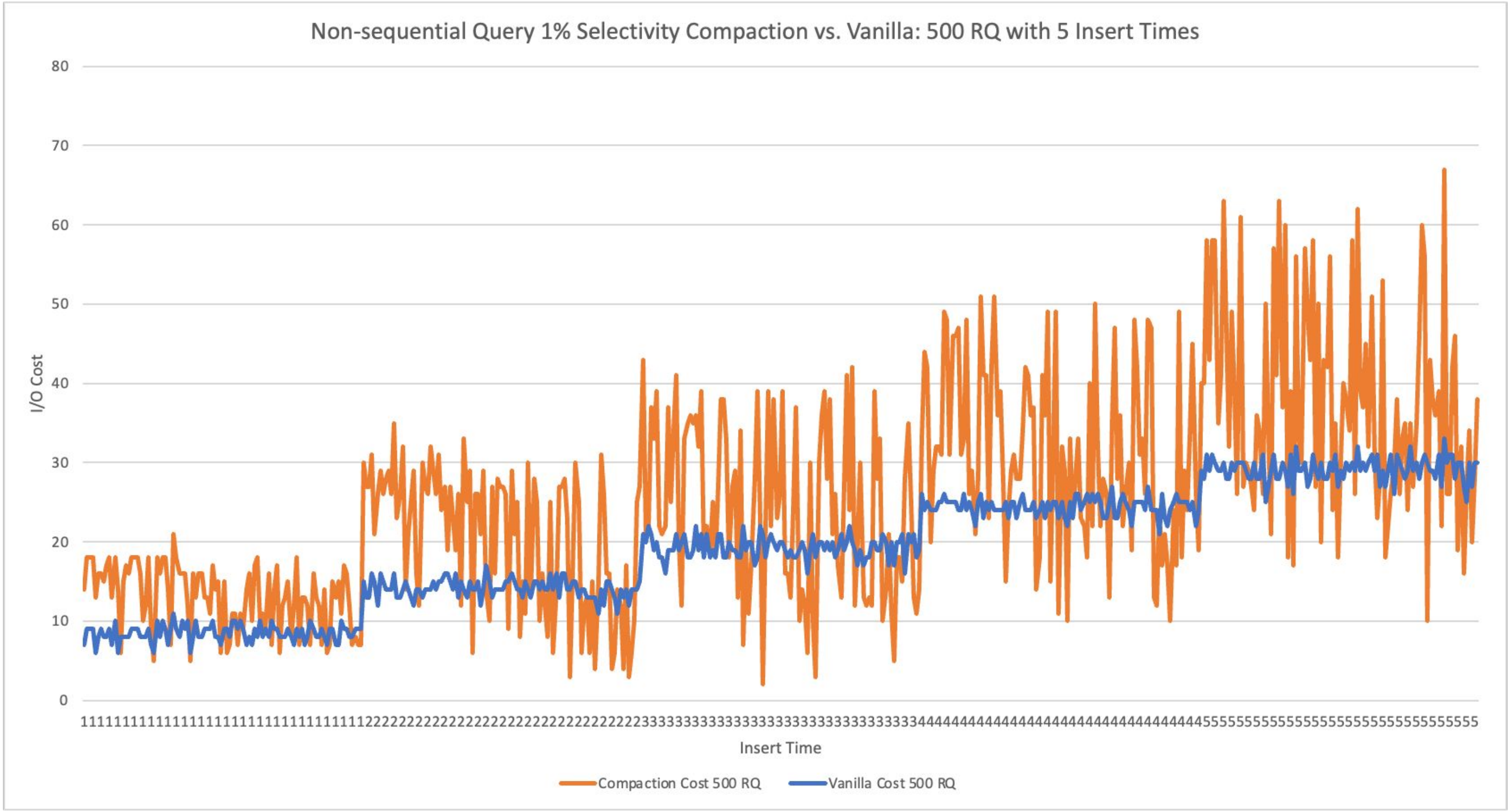
Selectivity
Vanilla Cost 500 RQ
Compaction Cost 500RQ

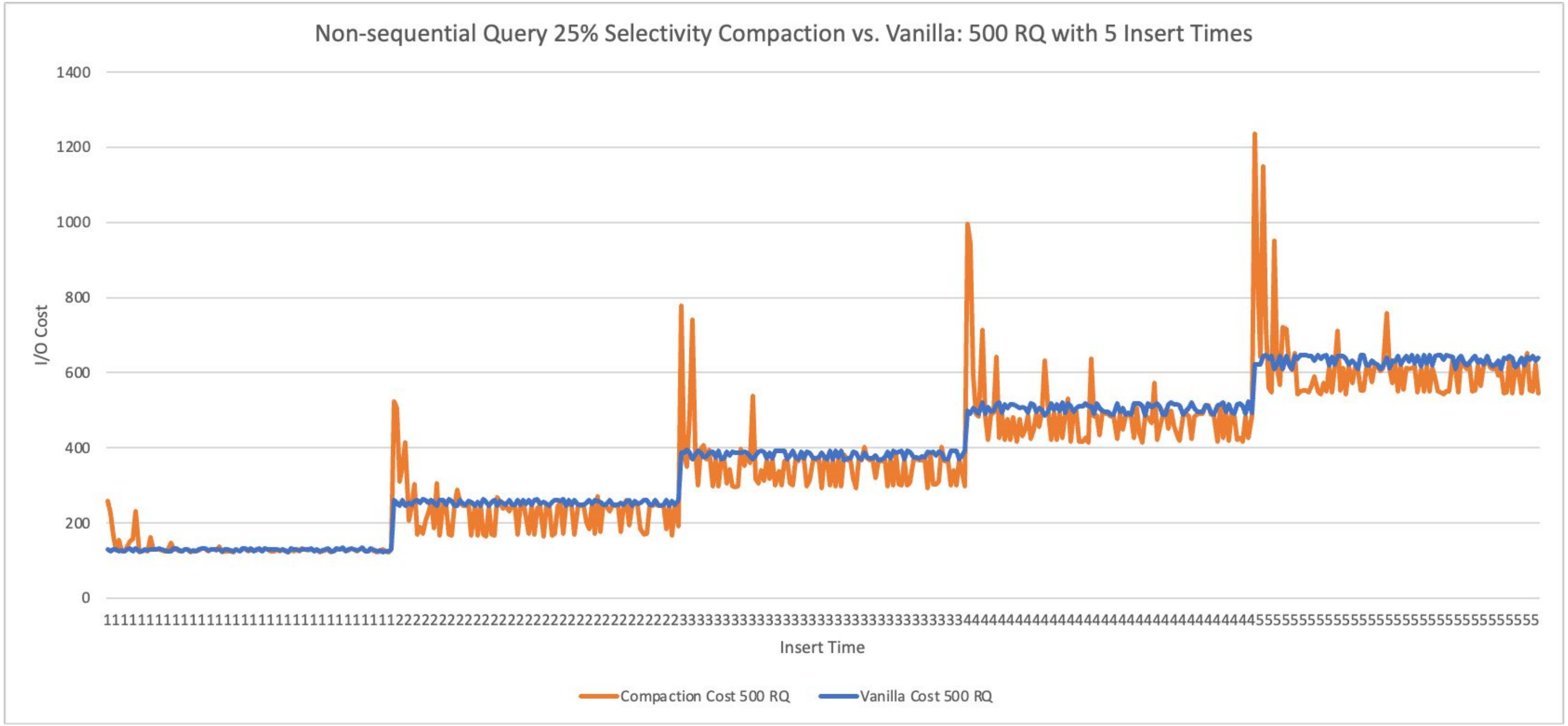
Non-sequential Query: 500 RQ, 5 times insert



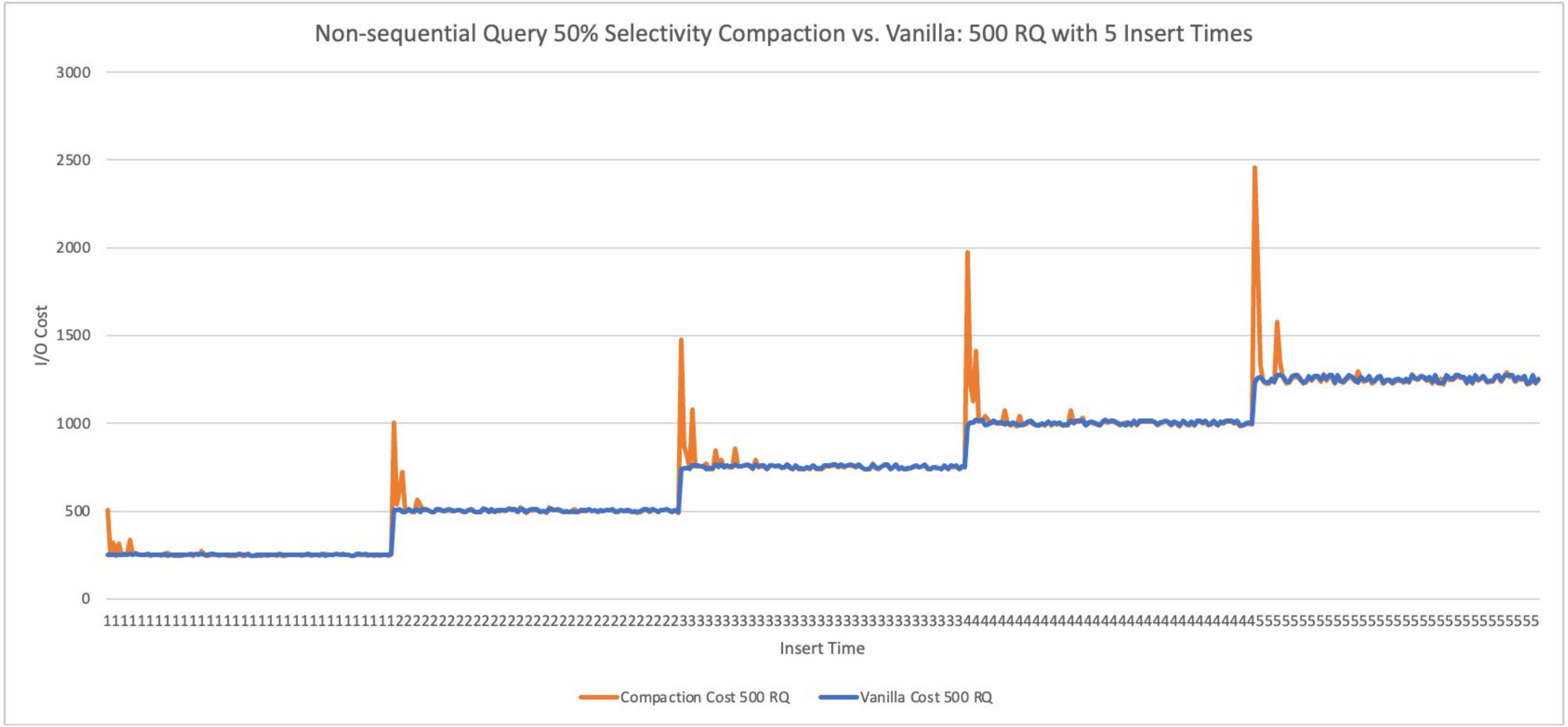
Non-sequential Query: 500 RQ, 5 times insert -1% Selectivity



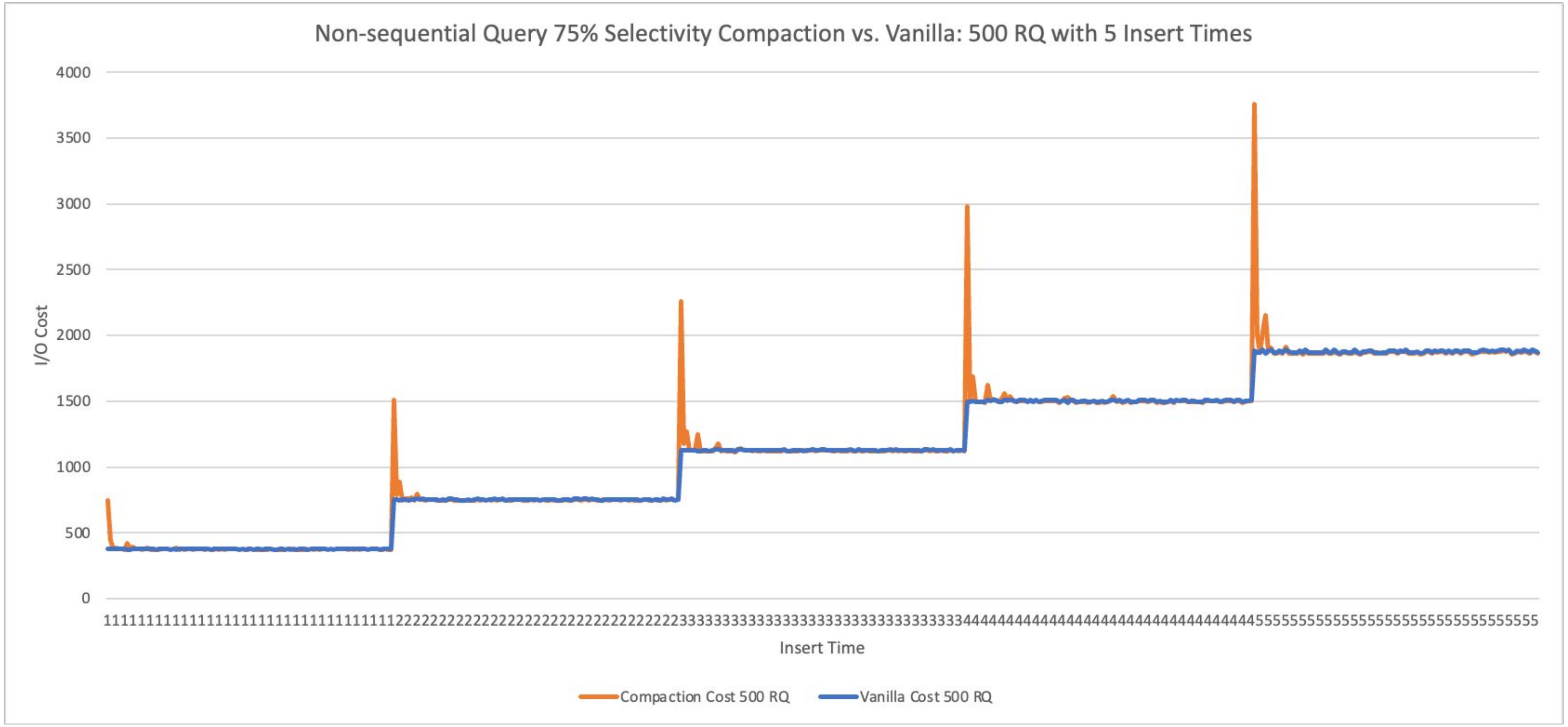
Non-sequential Query: 500 RQ, 5 times insert -25% Selectivity



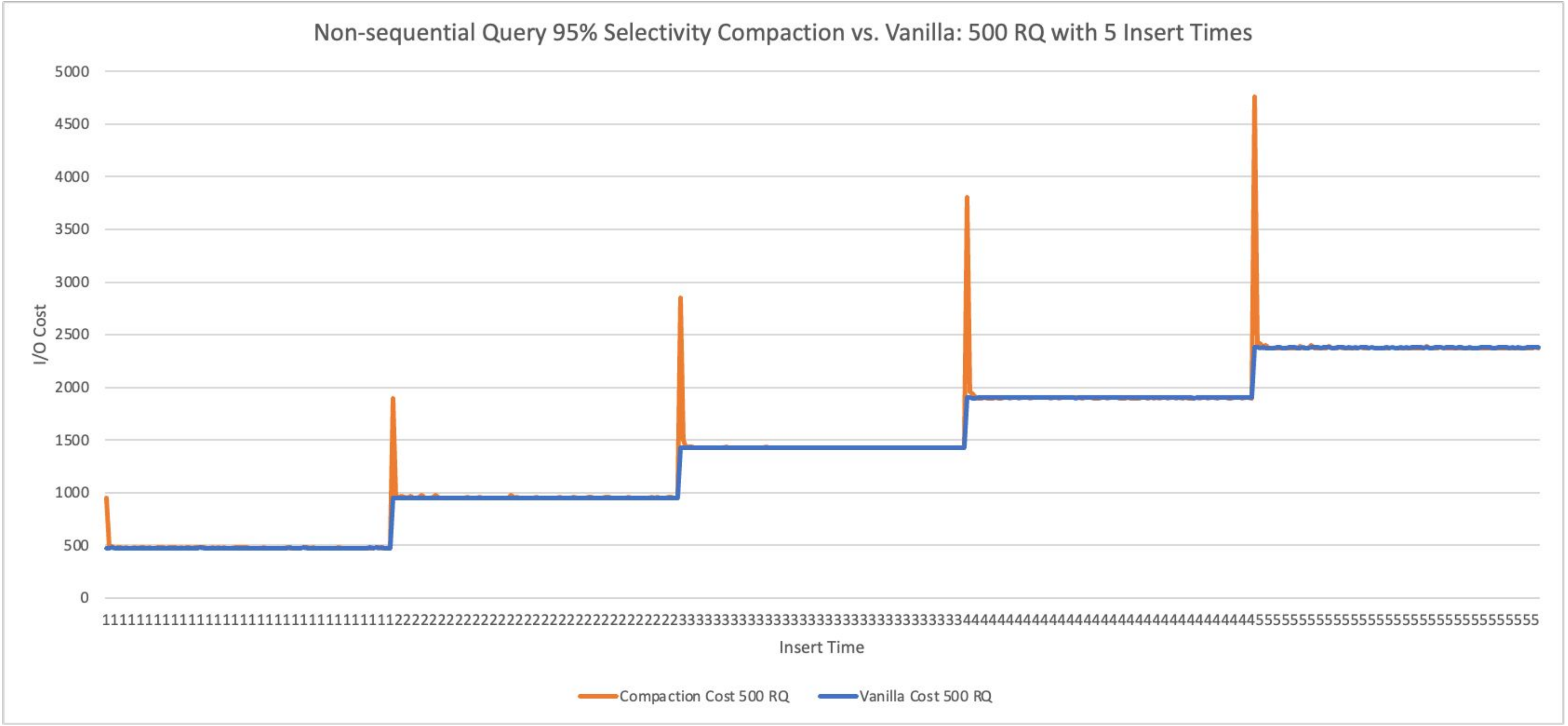
Non-sequential Query: 500 RQ, 5 times insert -50% Selectivity



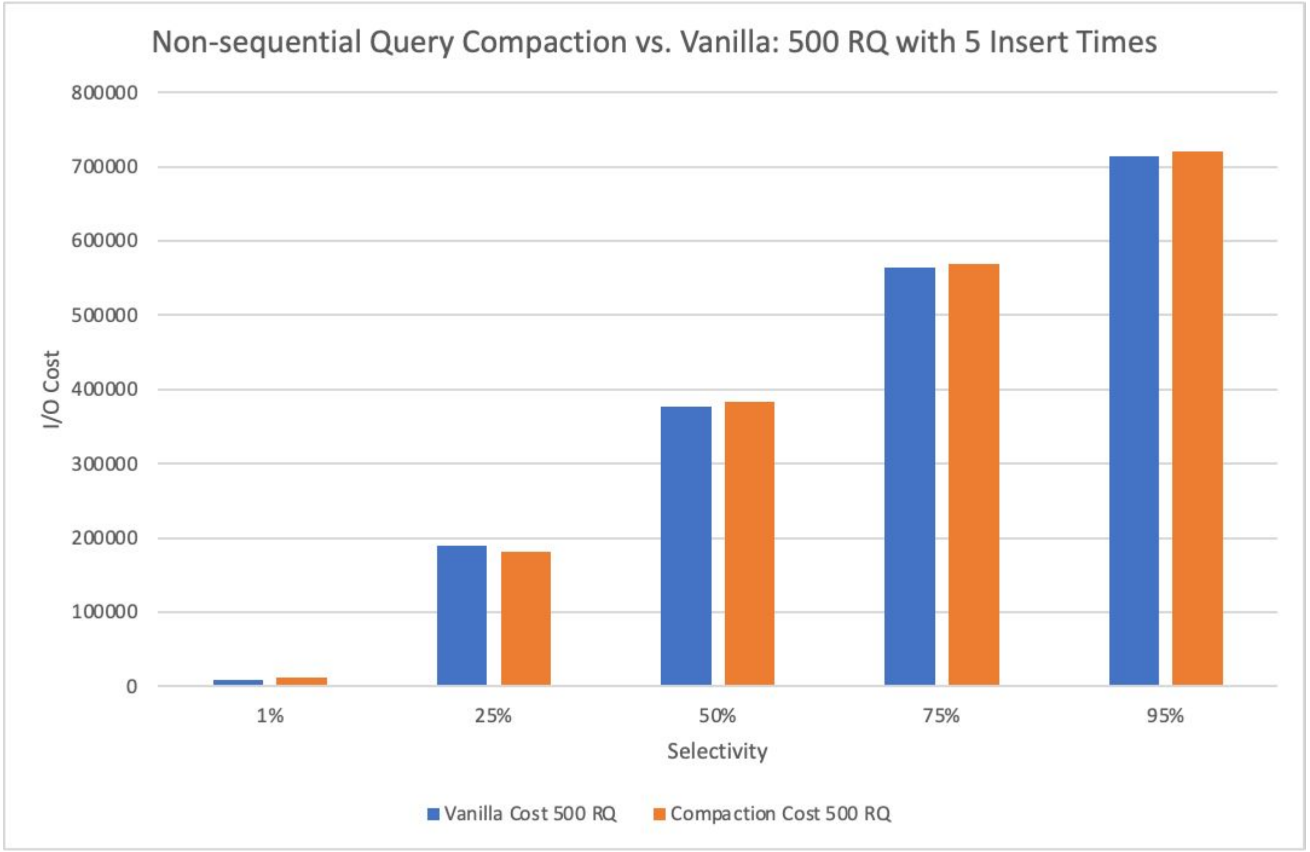
Non-sequential Query: 500 RQ, 5 times insert -75% Selectivity



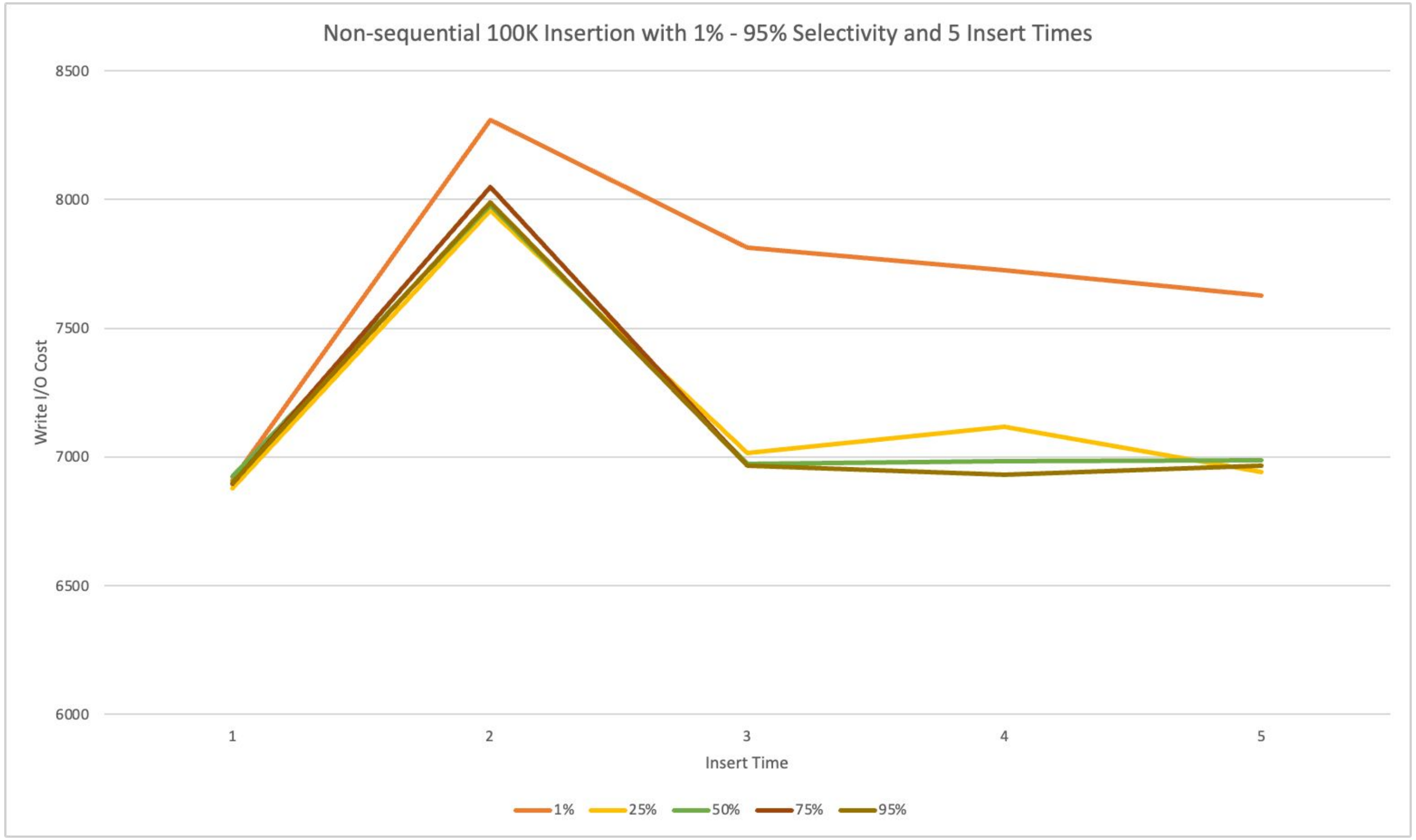
Non-sequential Query: 500 RQ, 5 times insert -95% Selectivity



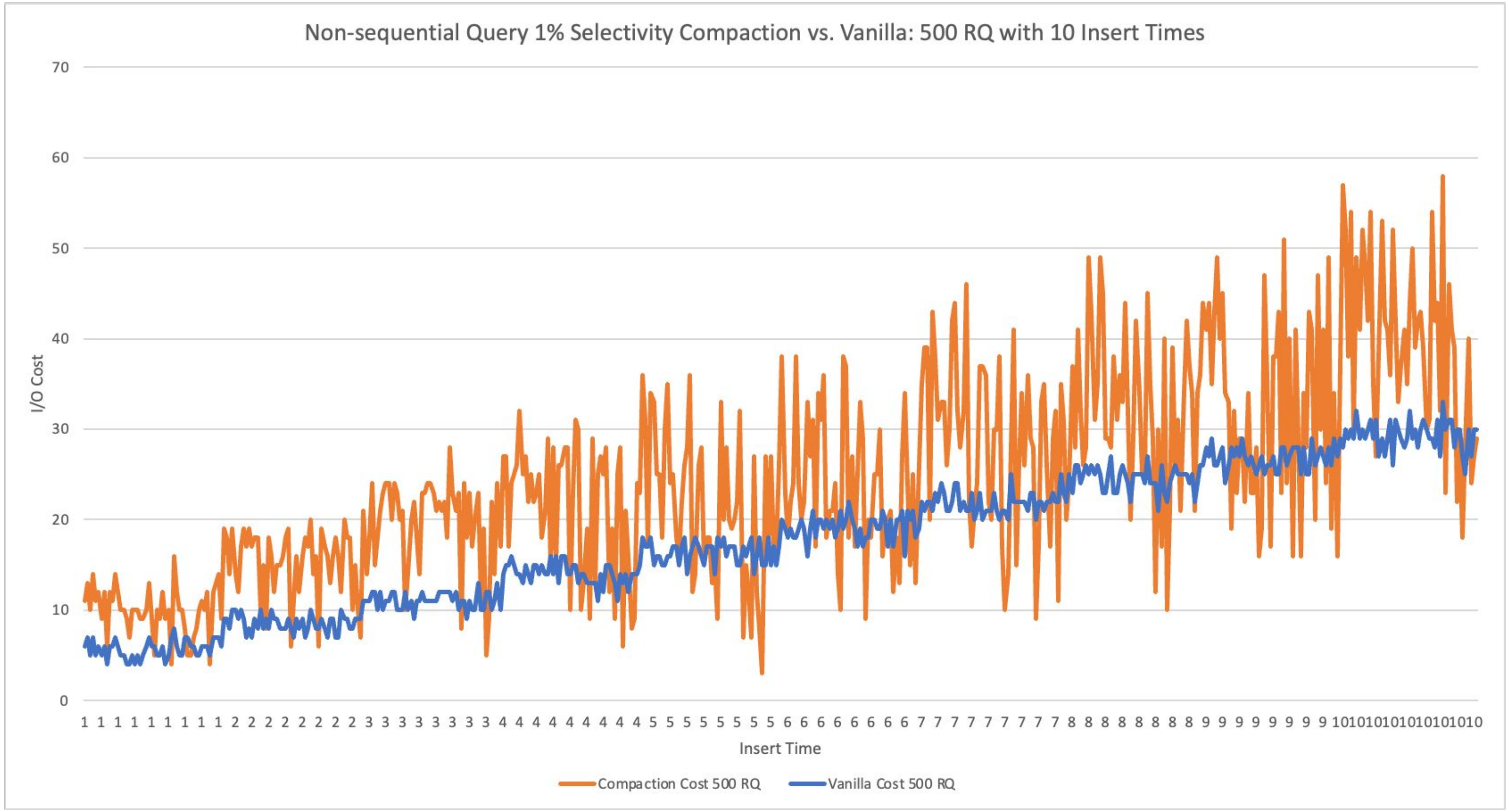
Non-sequential Query: 500 RQ, 5 times insert - Sum i/o



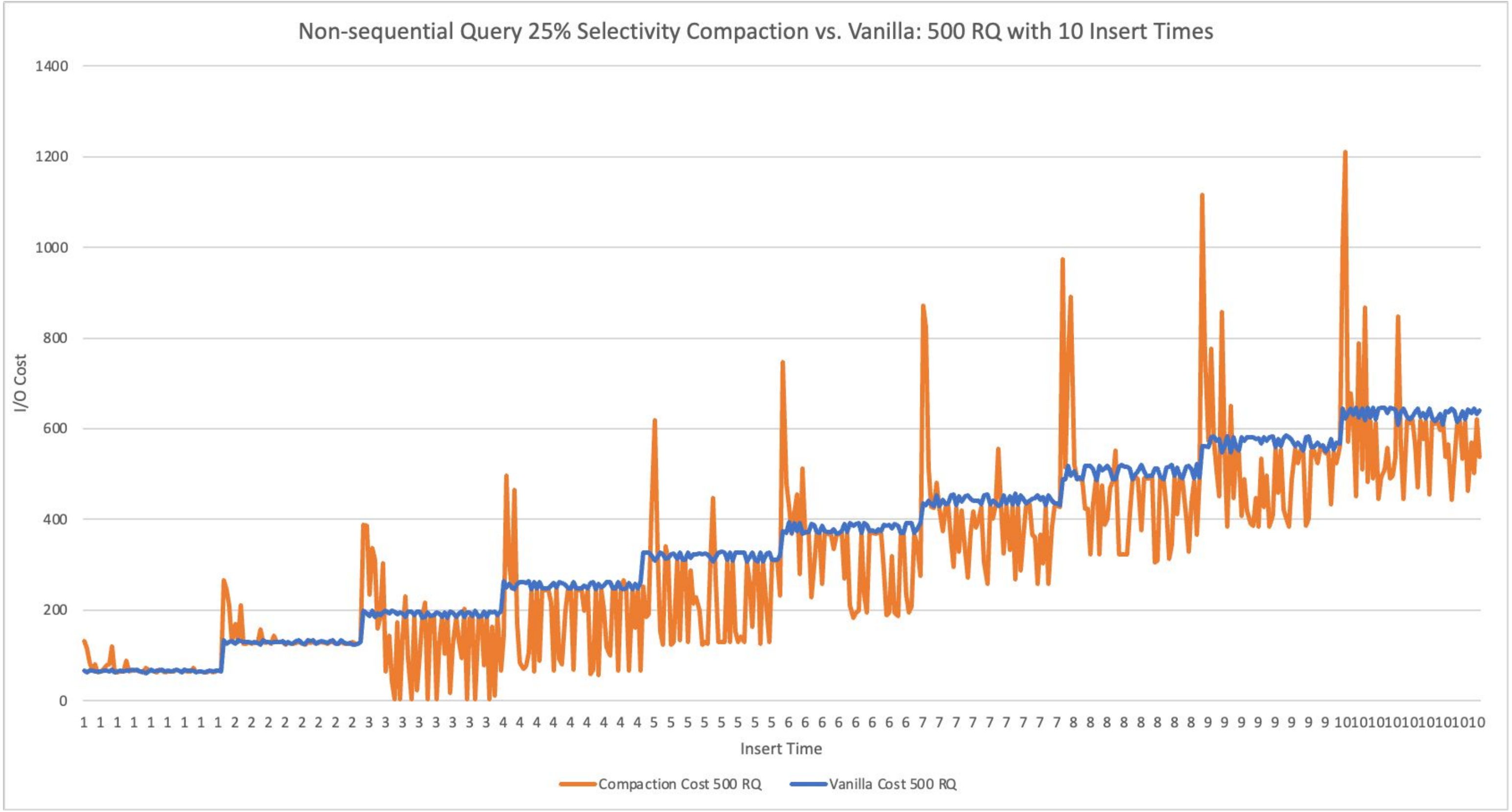
Non-sequential Query: 500 RQ, 5 times insert - Insertion



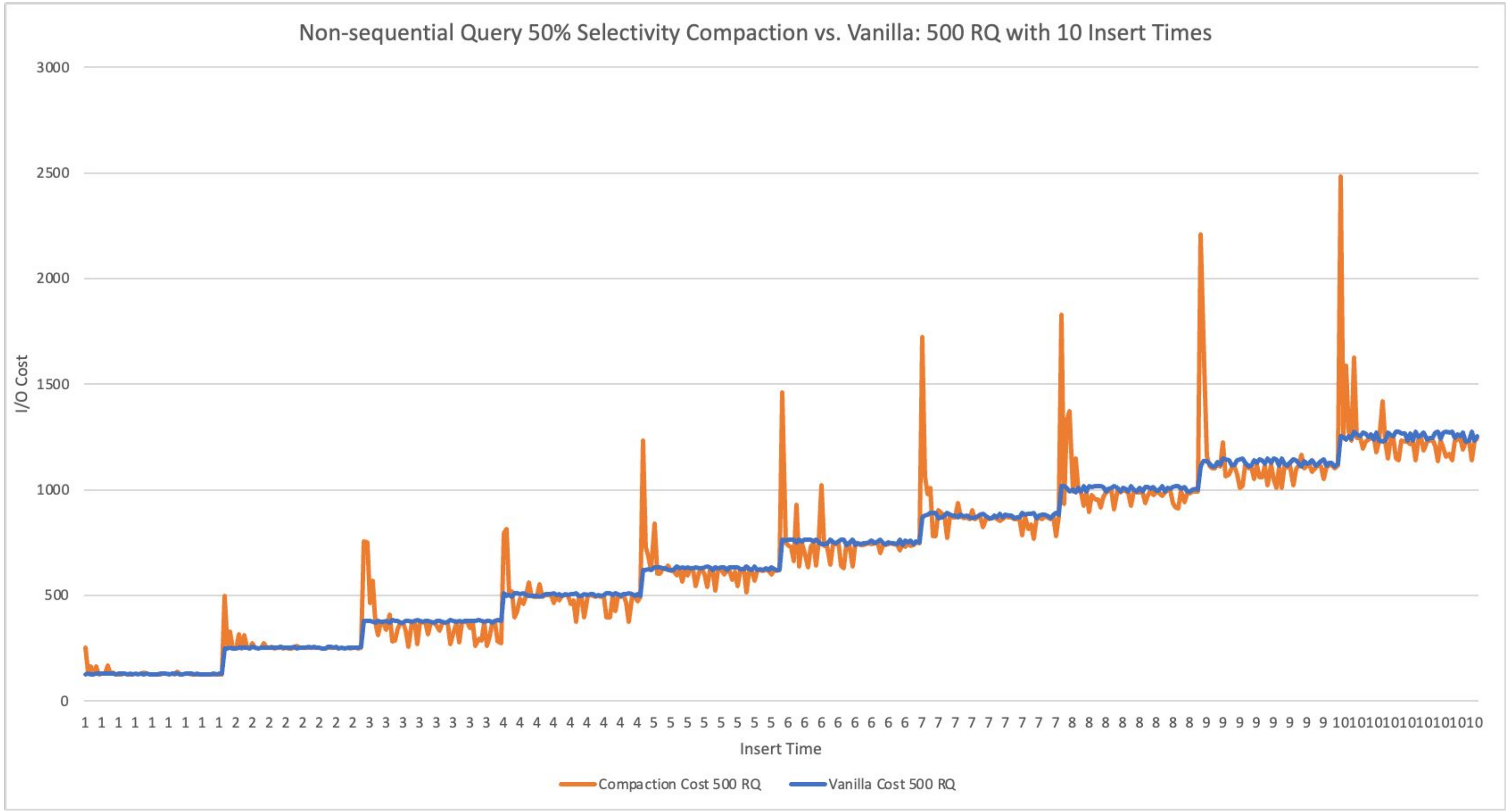
Non-sequential Query: 500 RQ, 10 times insert -1% Selectivity



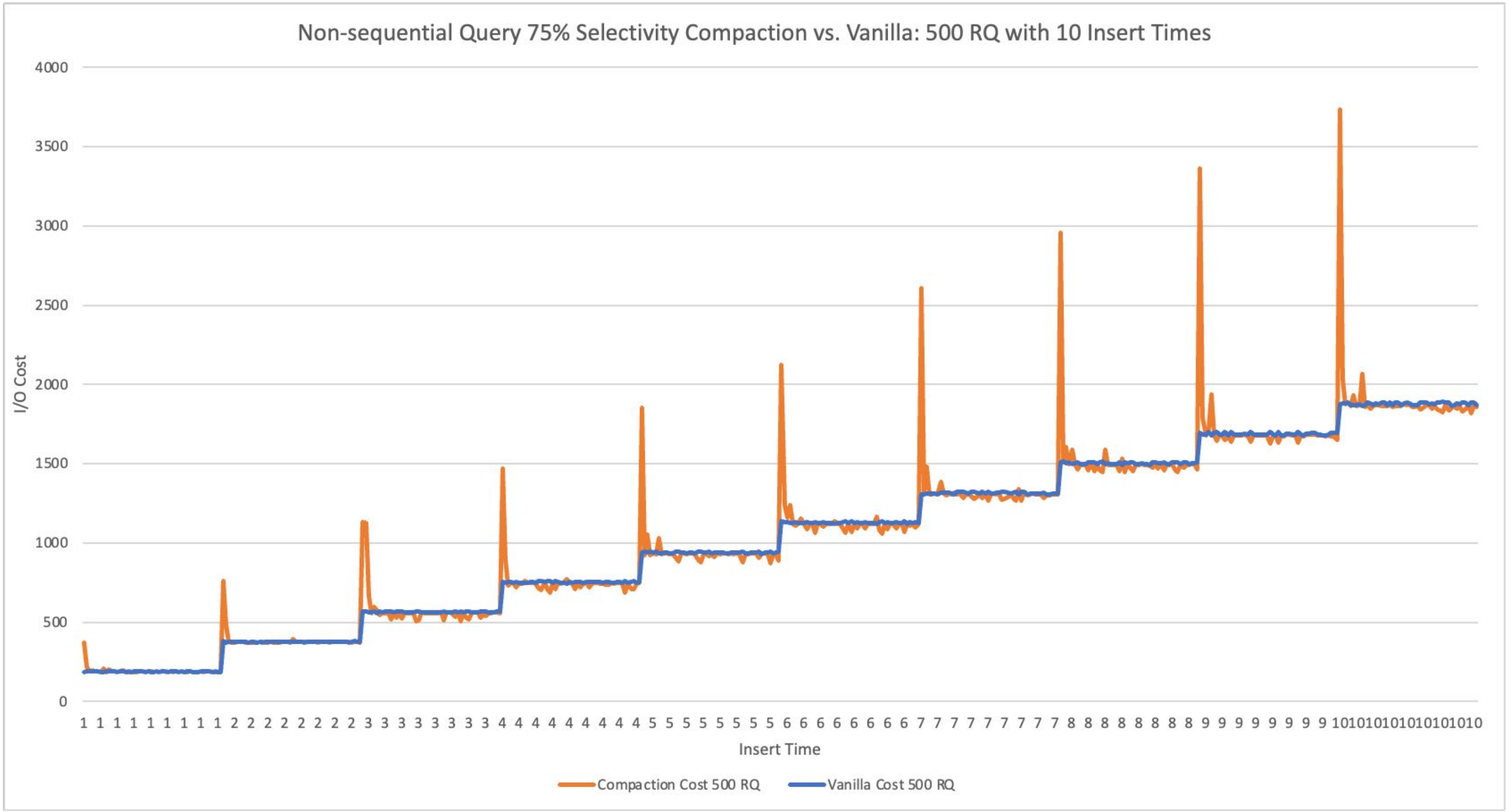
Non-sequential Query: 500 RQ, 10 times insert -25% Selectivity



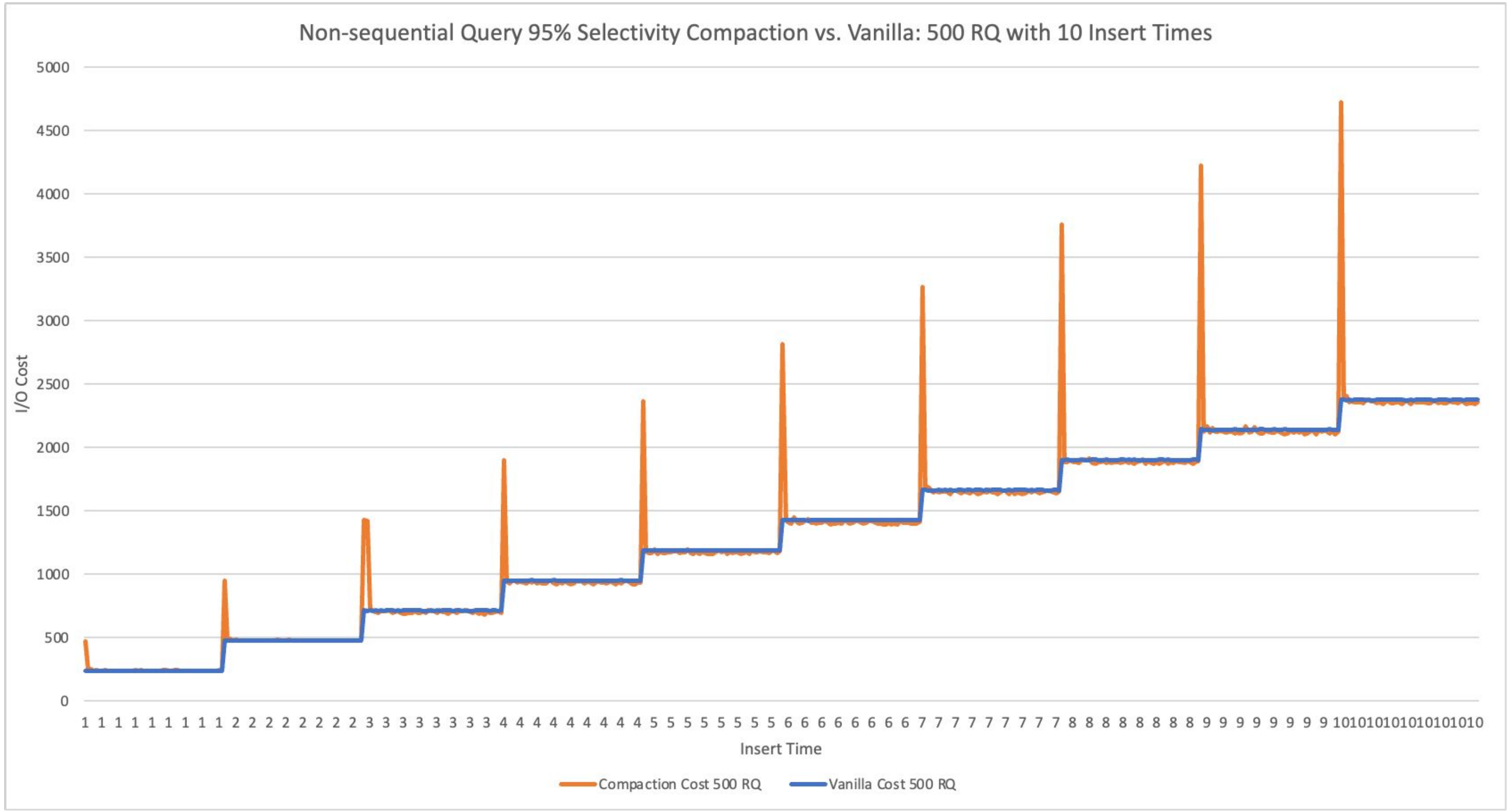
Non-sequential Query: 500 RQ, 10 times insert -50% Selectivity



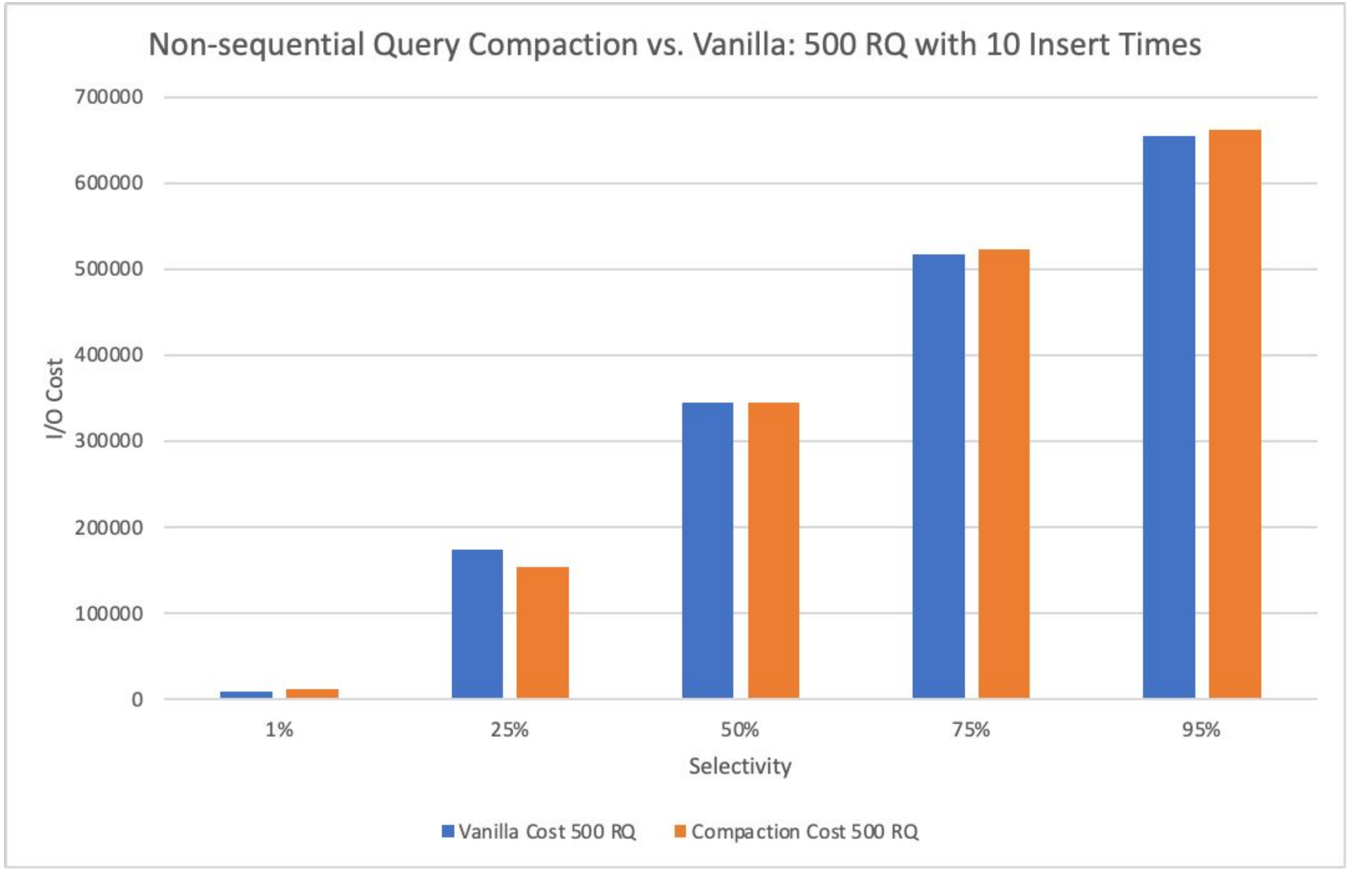
Non-sequential Query: 500 RQ, 10 times insert -75% Selectivity



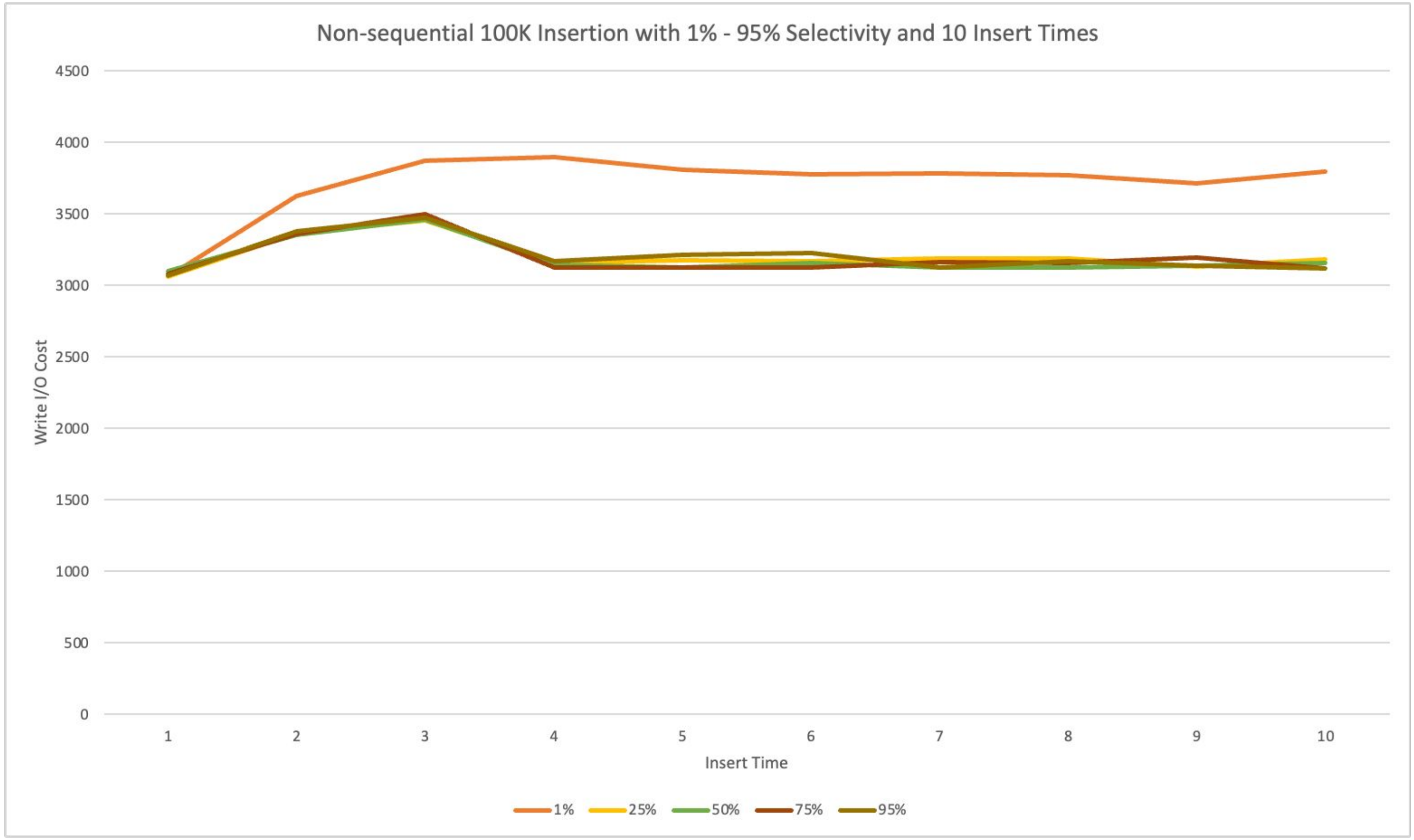
Non-sequential Query: 500 RQ, 10 times insert -95% Selectivity



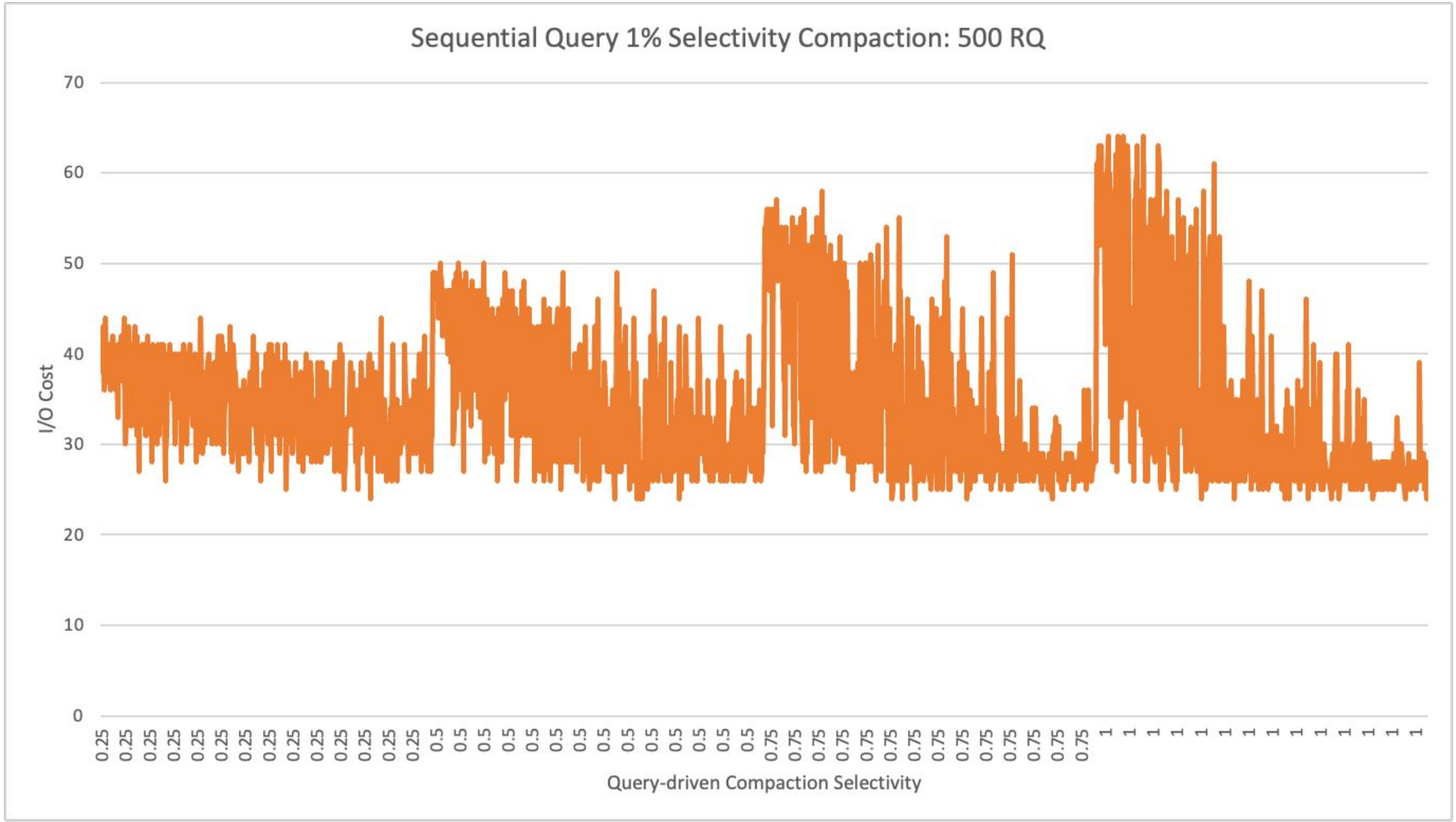
Non-sequential Query: 500 RQ, 10 times insert - Sum i/o



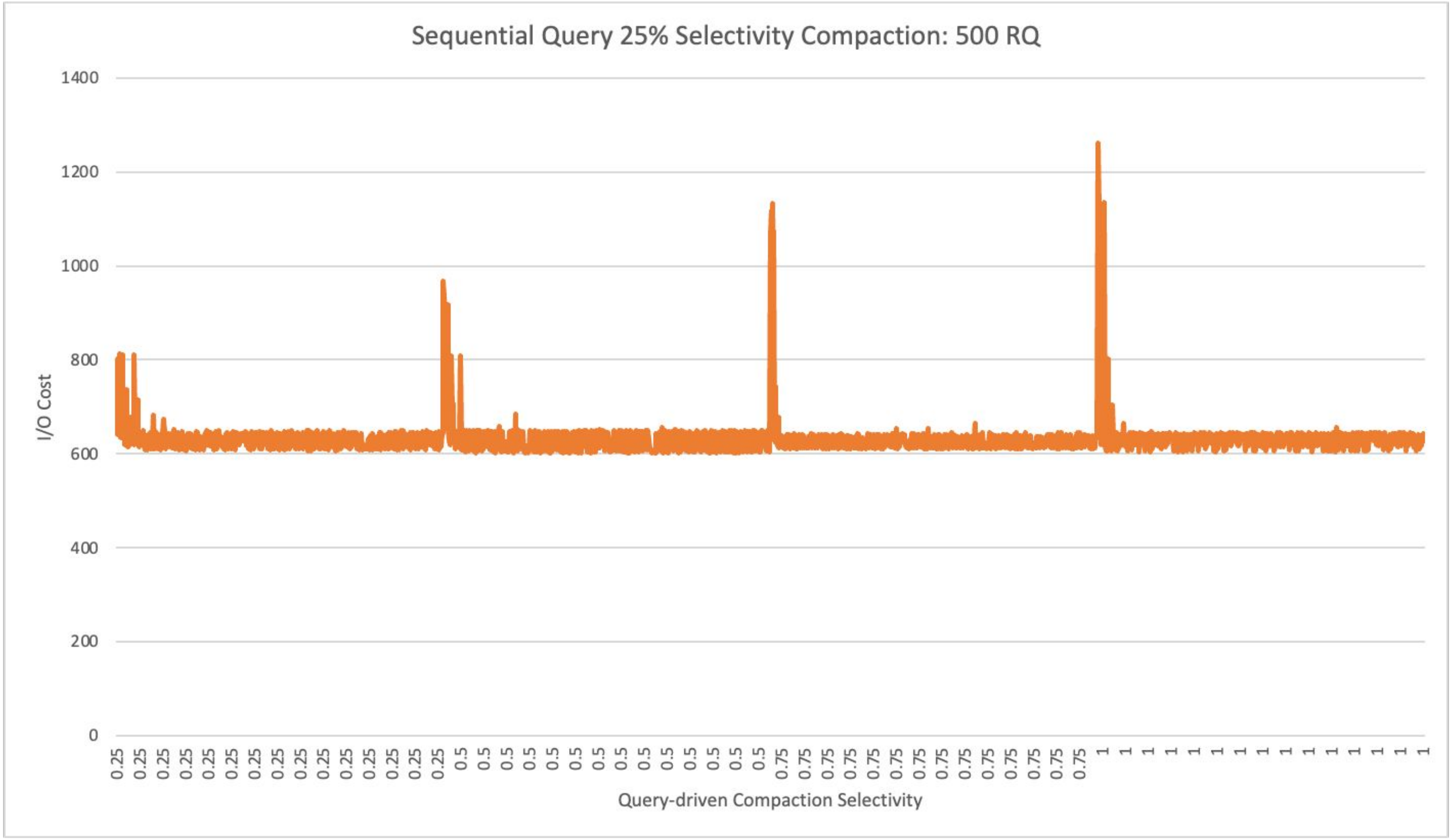
Non-sequential Query: 500 RQ, 10 times insert - Insertion



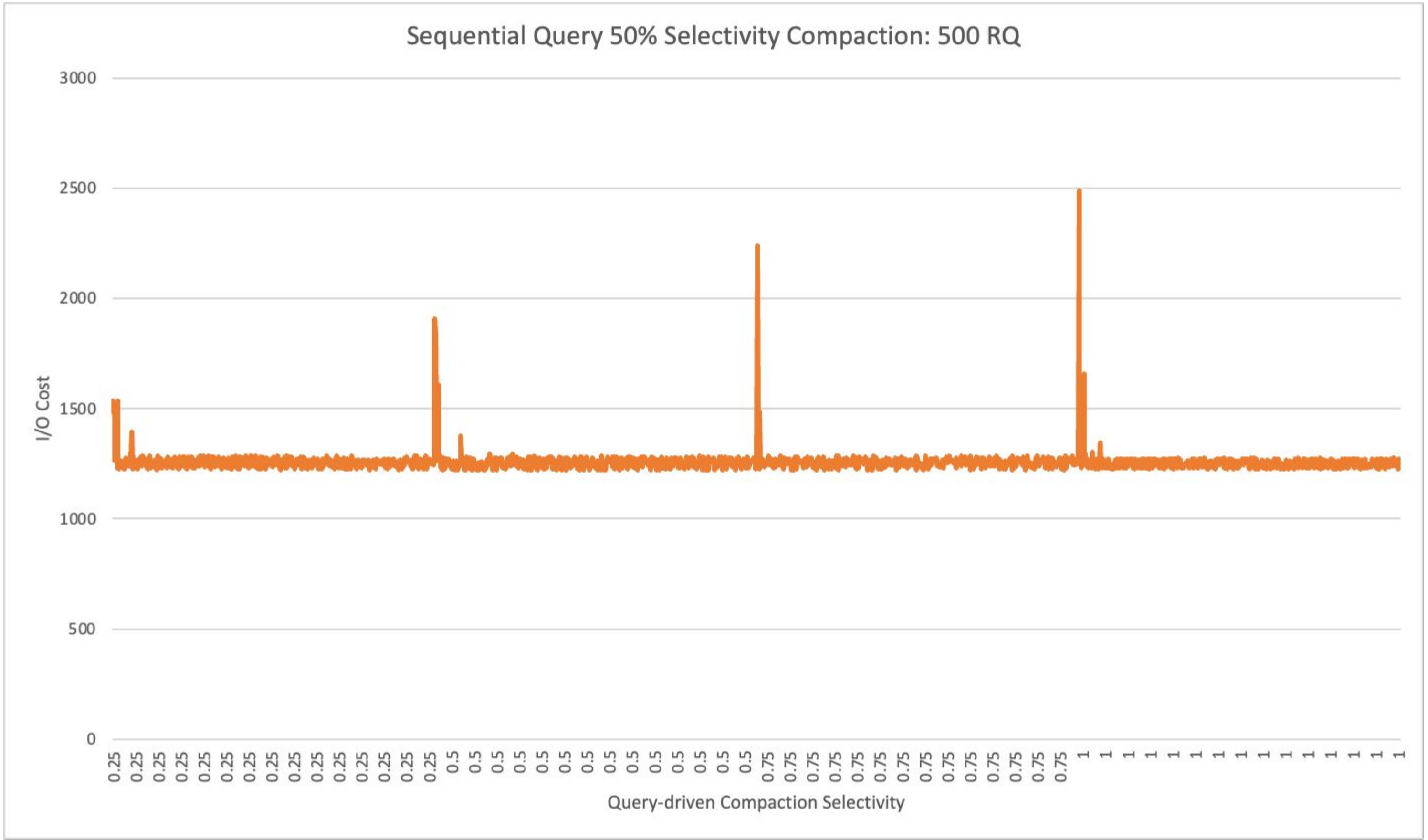
Compaction Selectivity: Sequential Query 1% - 500 RQ



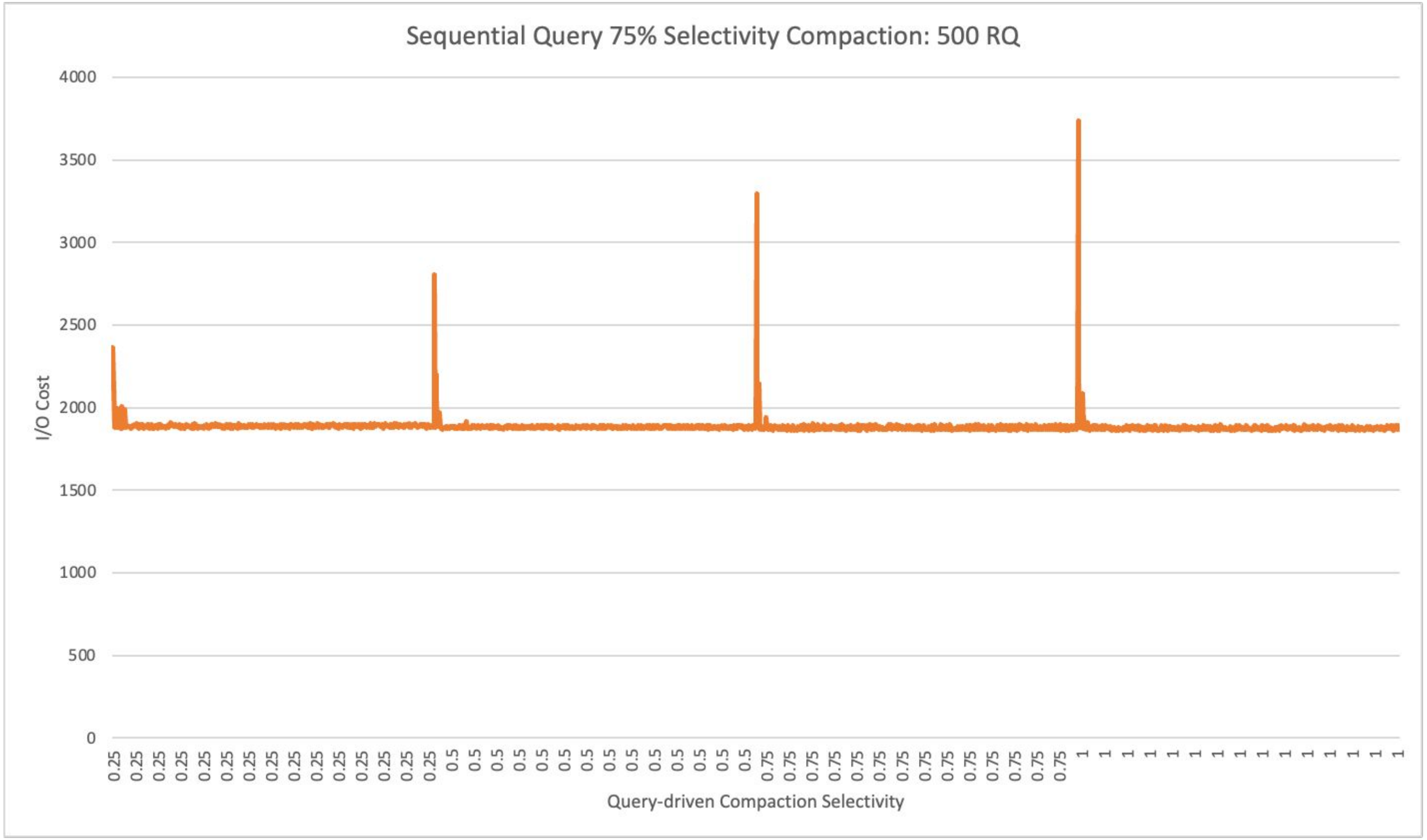
Compaction Selectivity: Sequential Query 25% - 500 RQ



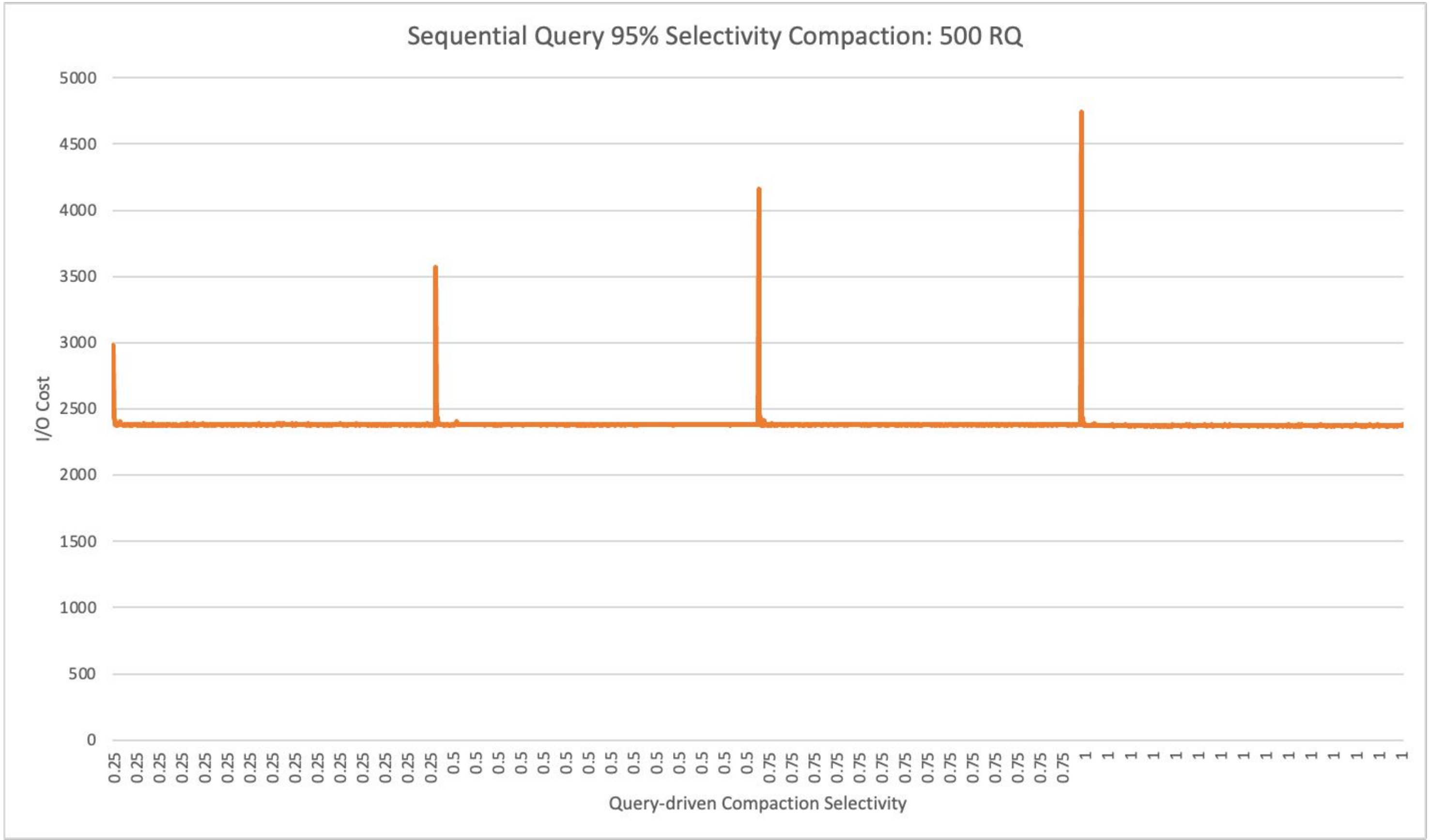
Compaction Selectivity: Sequential Query 50% - 500 RQ



Compaction Selectivity: Sequential Query 75% - 500 RQ



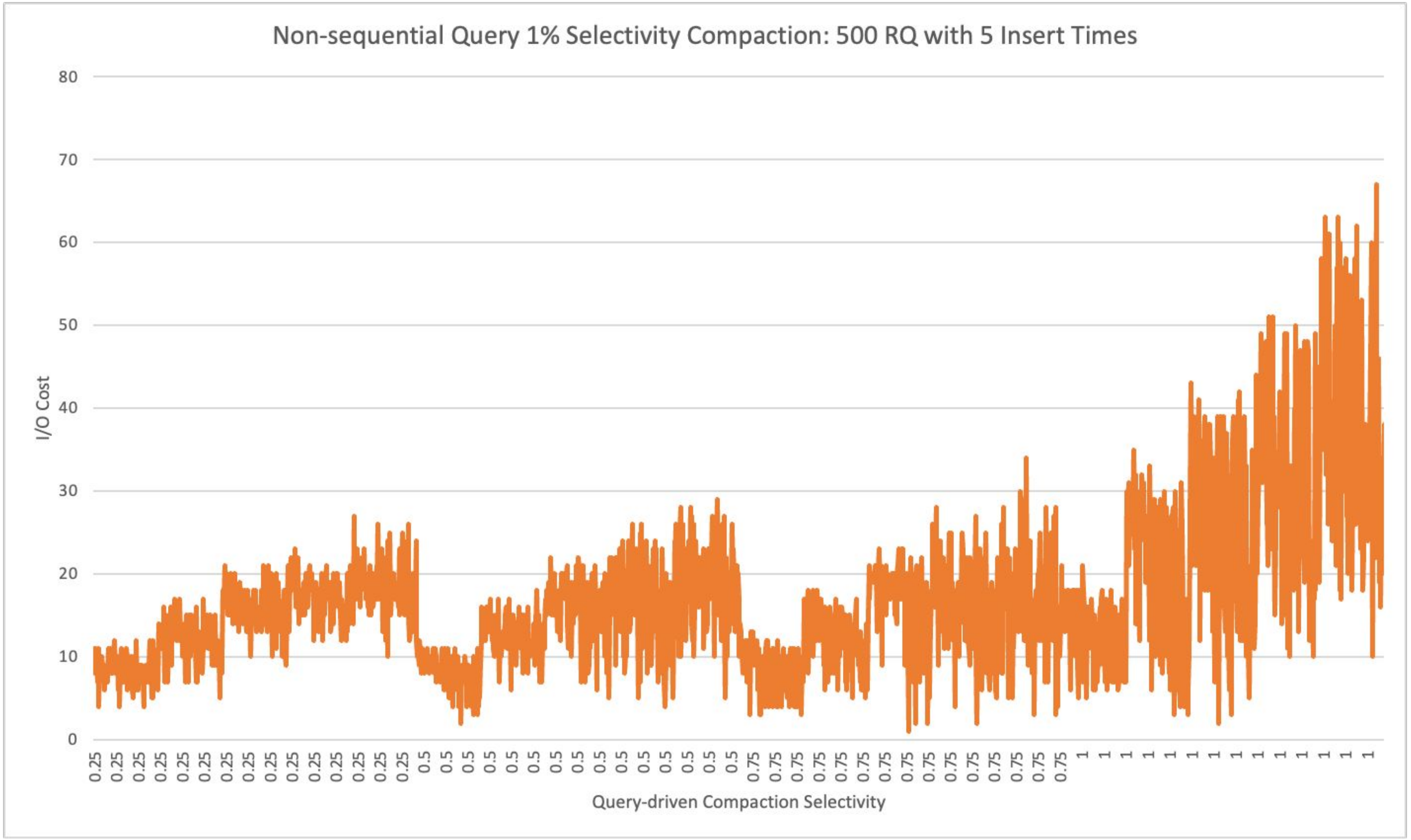
Compaction Selectivity: Sequential Query 95% - 500 RQ



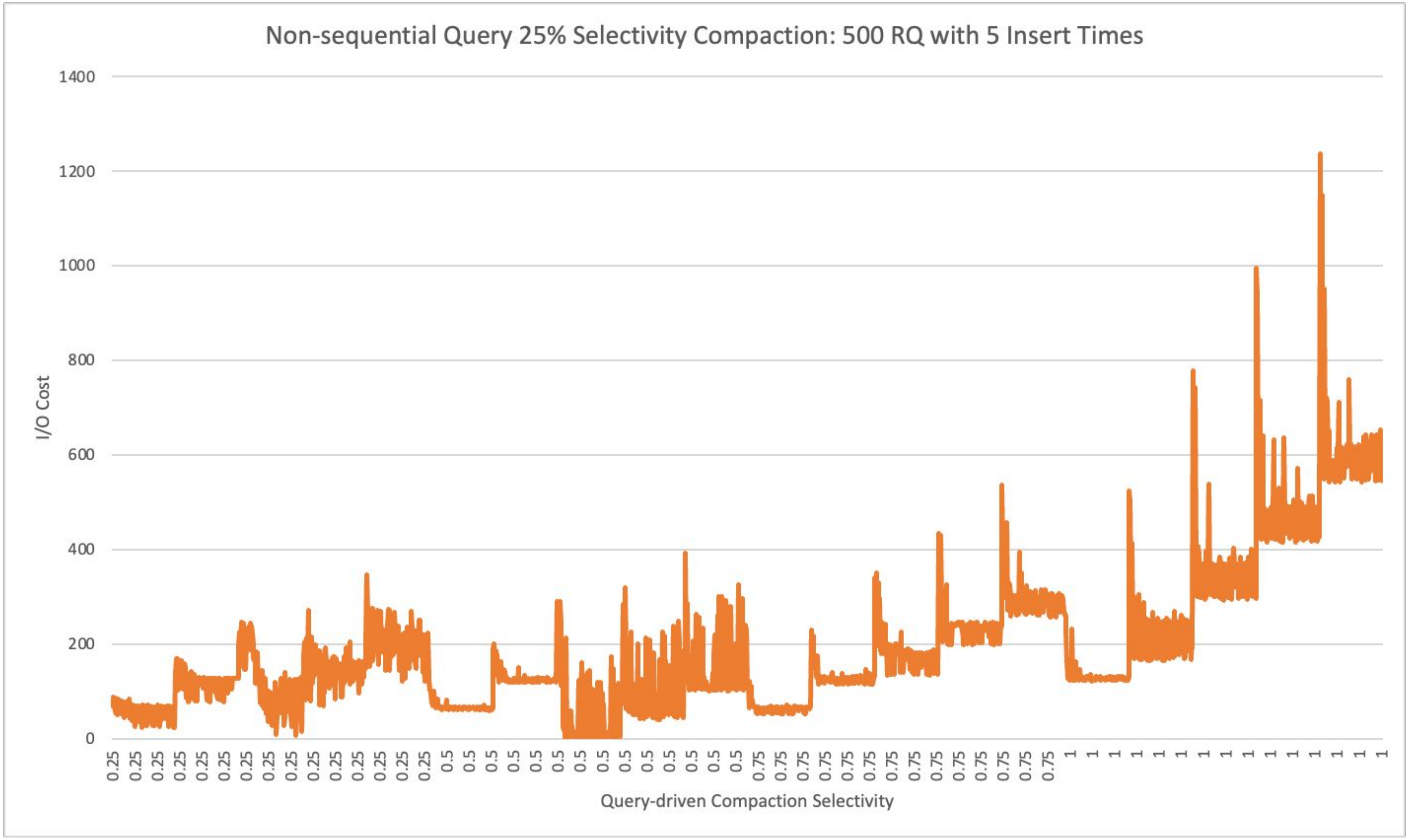
Compaction Selectivity: Sequential Query: 500 RQ - Sum i/o

No vanilla data

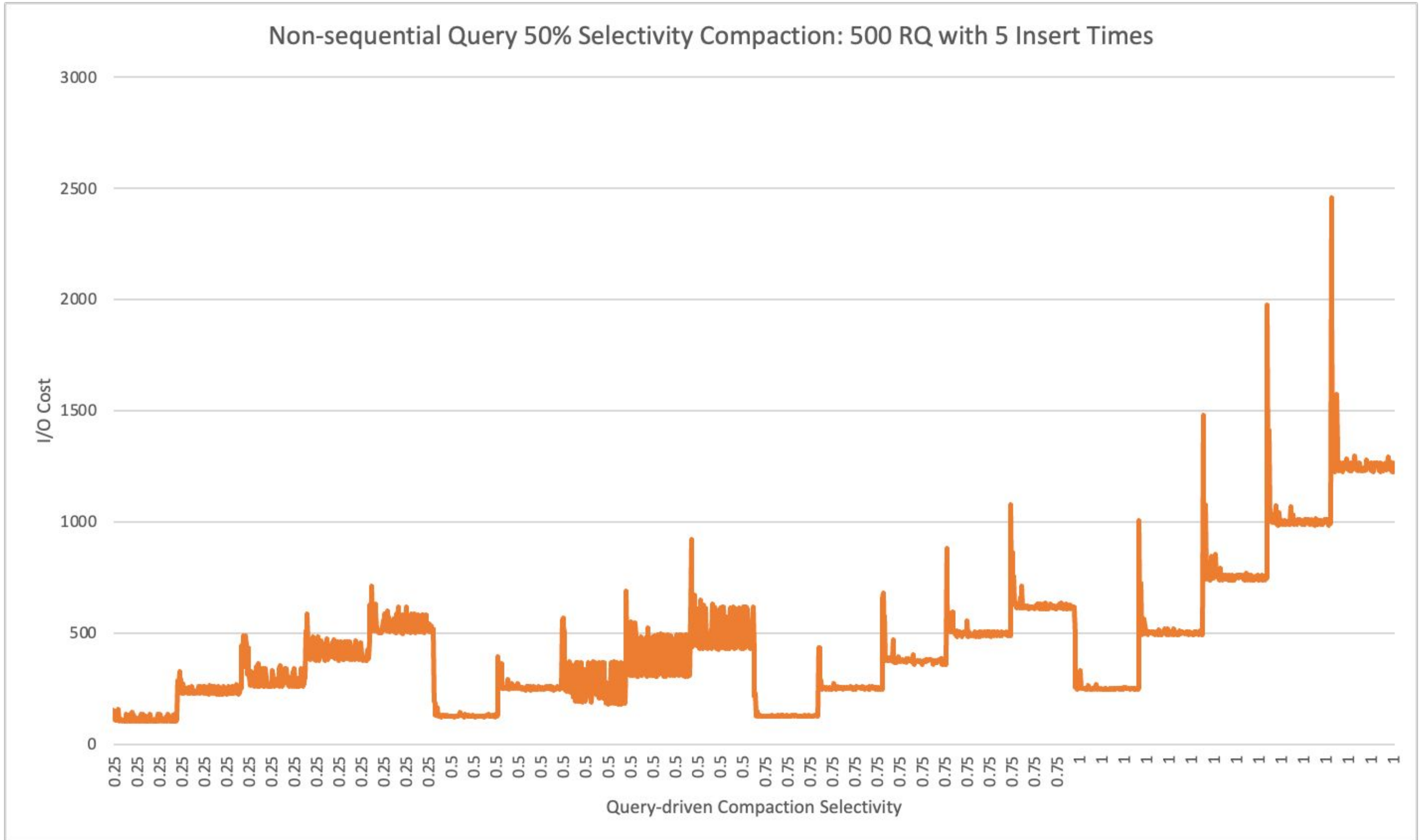
Compaction Selectivity: Non-sequential Query 1% - 500 RQ - 5 Times



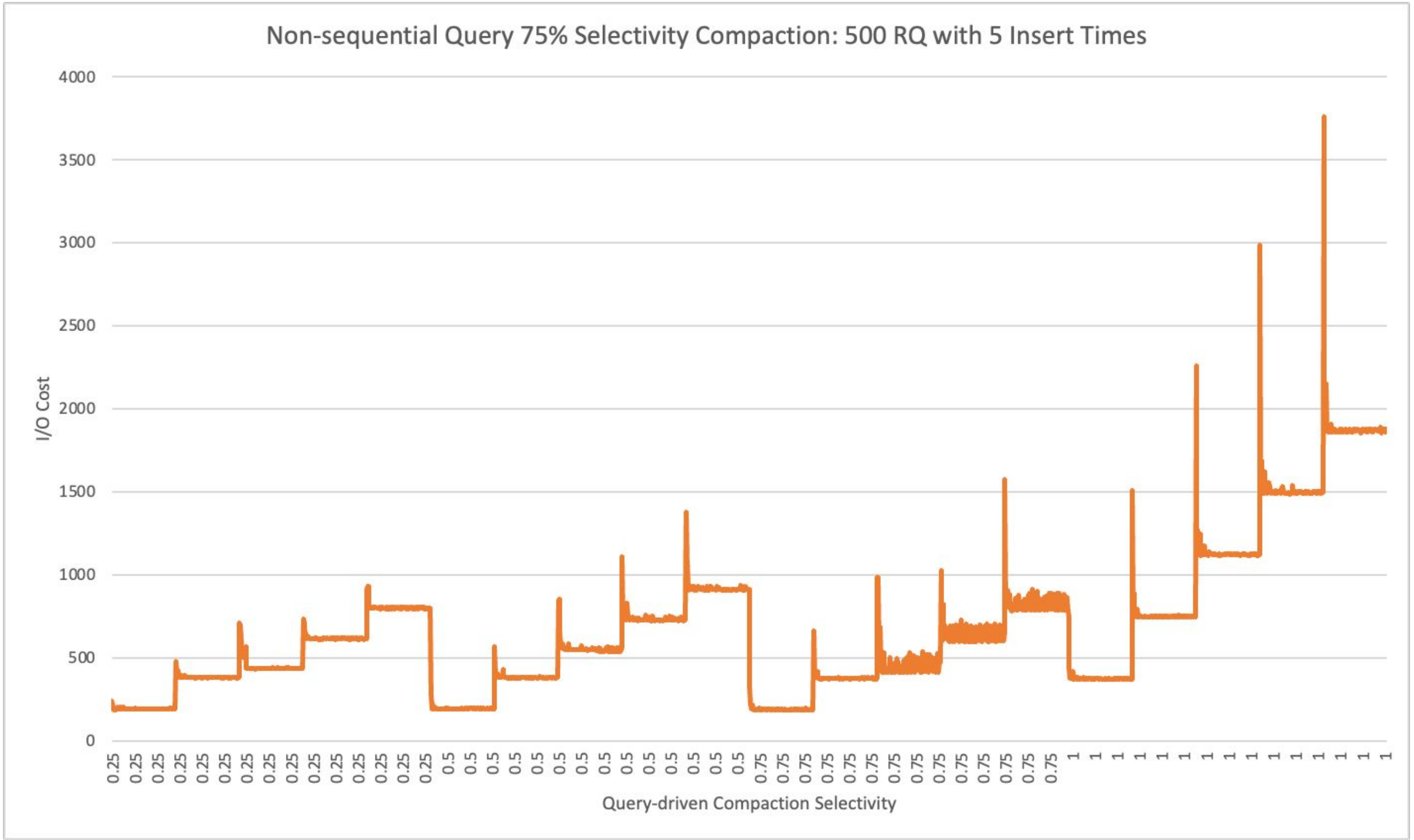
Compaction Selectivity: Non-sequential Query 25% - 500 RQ - 5 Times



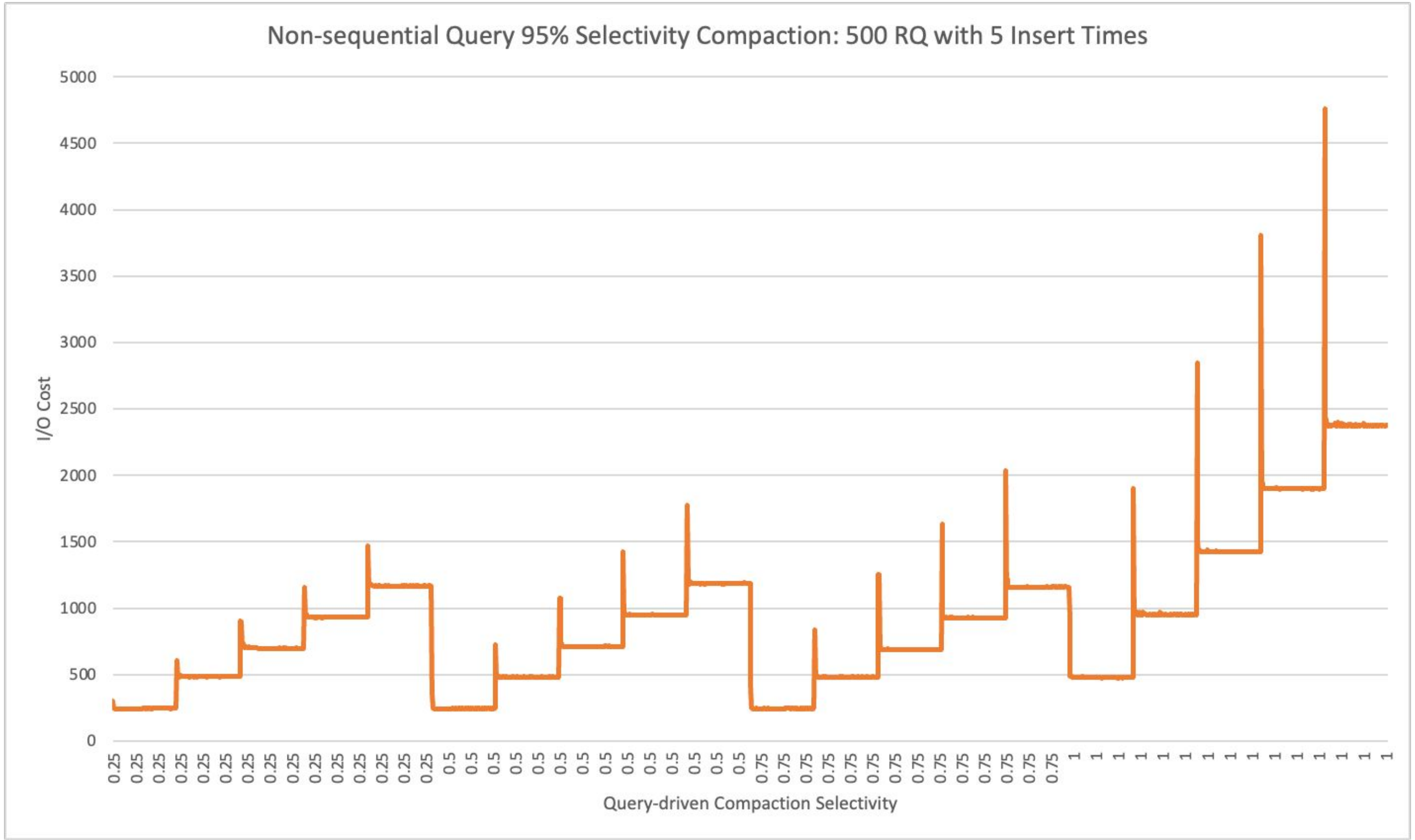
Compaction Selectivity: Non-sequential Query 50% - 500 RQ - 5 Times



Compaction Selectivity: Non-sequential Query 75% - 500 RQ - 5 Times

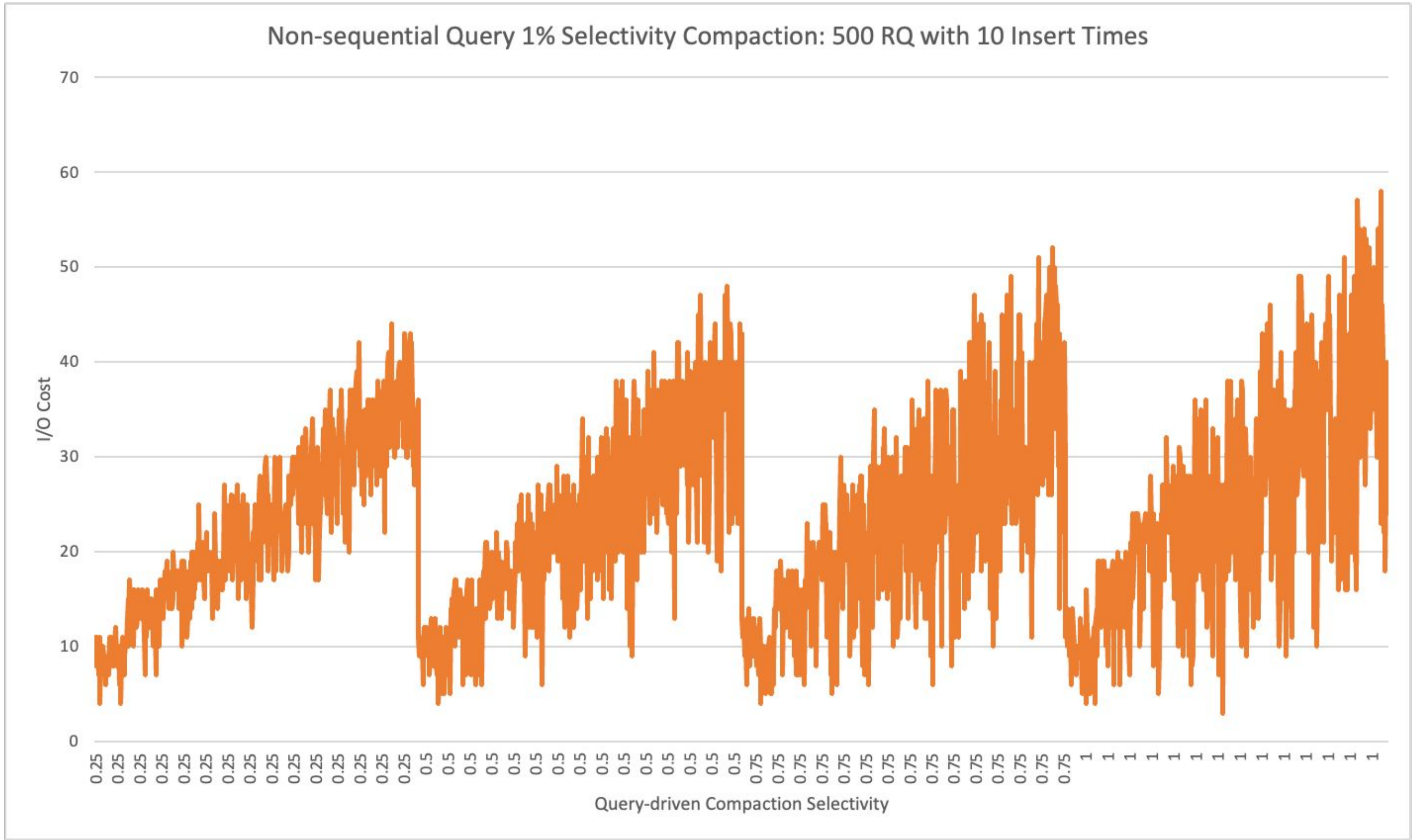


Compaction Selectivity: Non-sequential Query 95% - 500 RQ - 5 Times

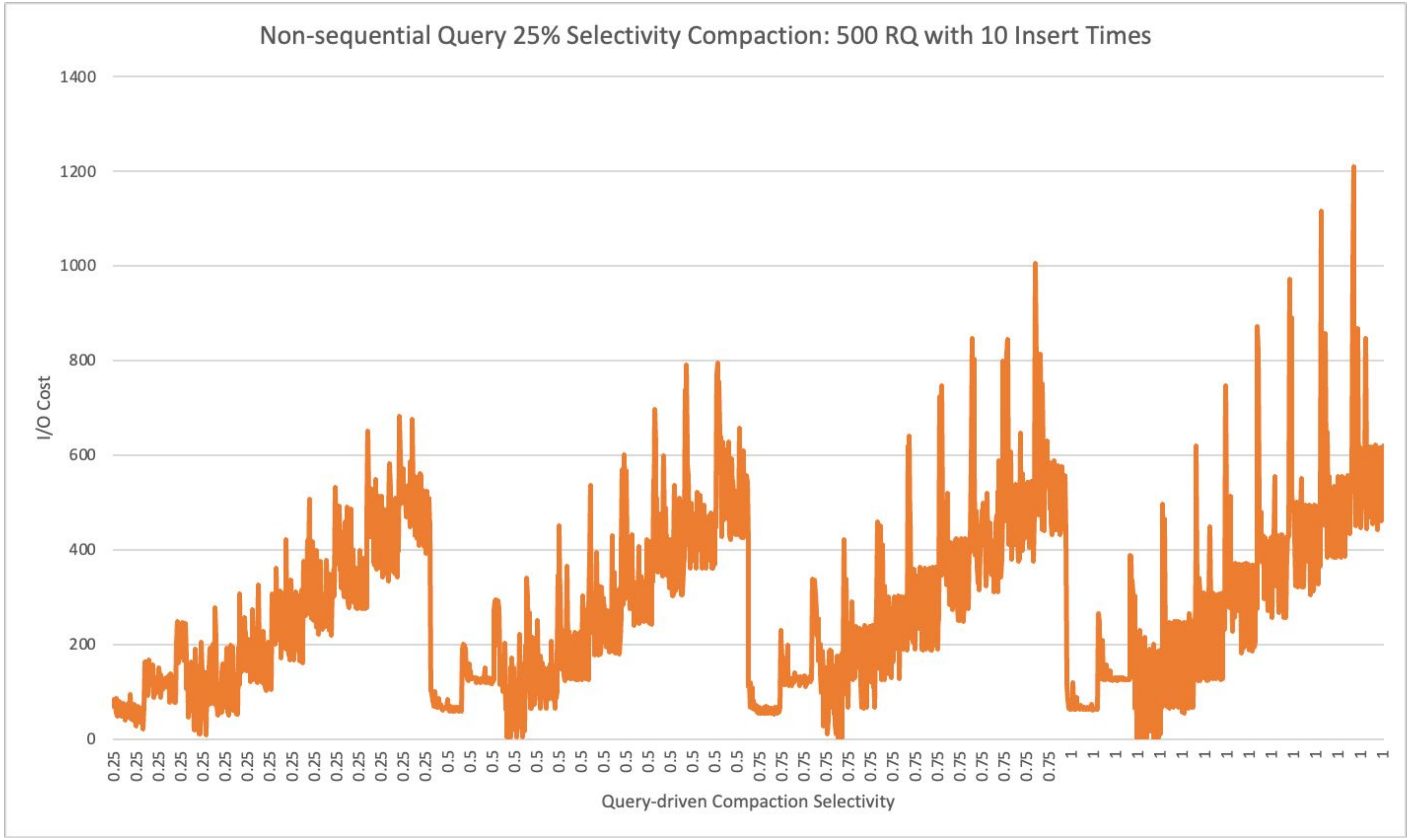


Compaction Selectivity: Non-sequential Query: 500 RQ - 5 Insert - Sum i/o

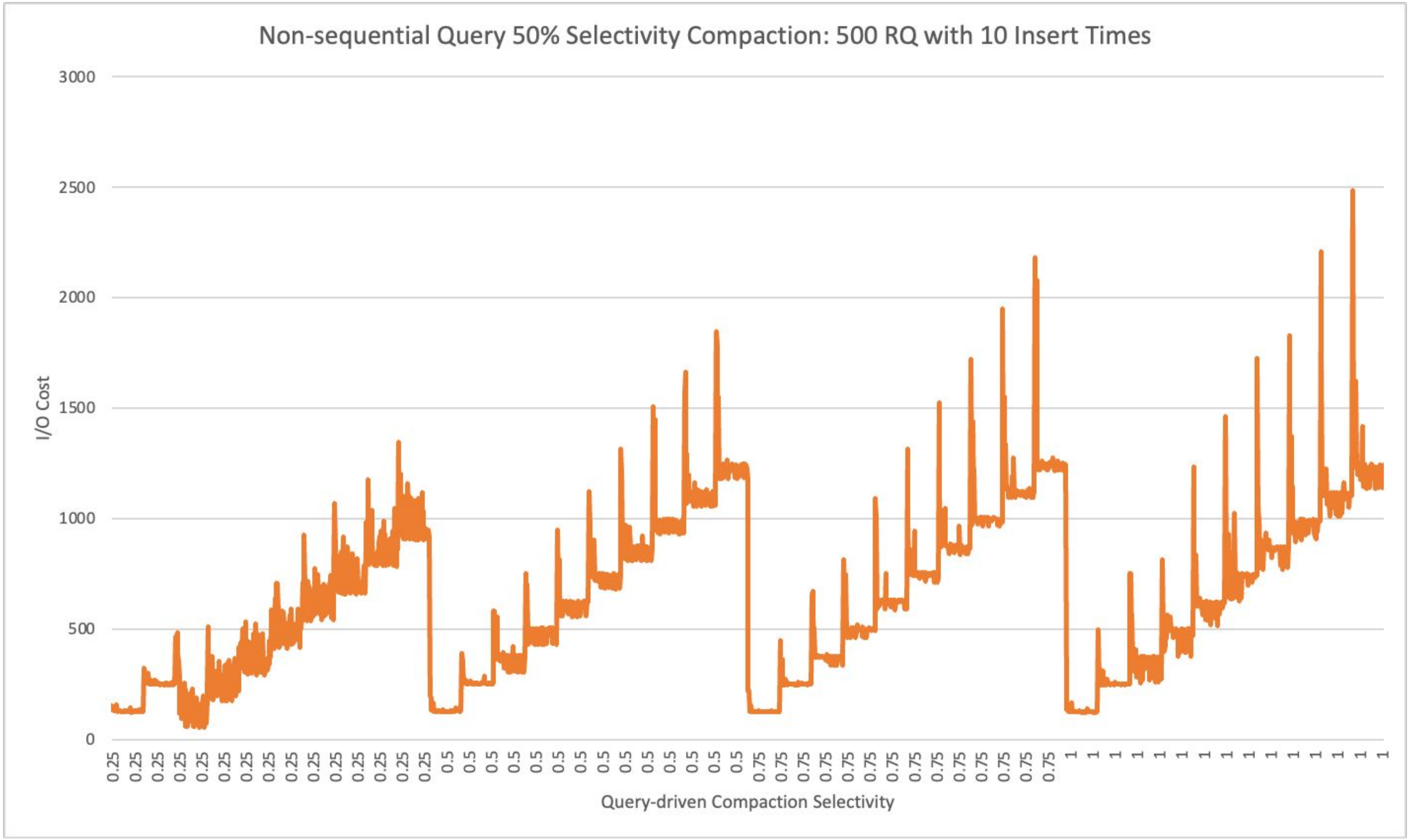
Compaction Selectivity: Non-sequential Query 1% - 500 RQ - 10 Times



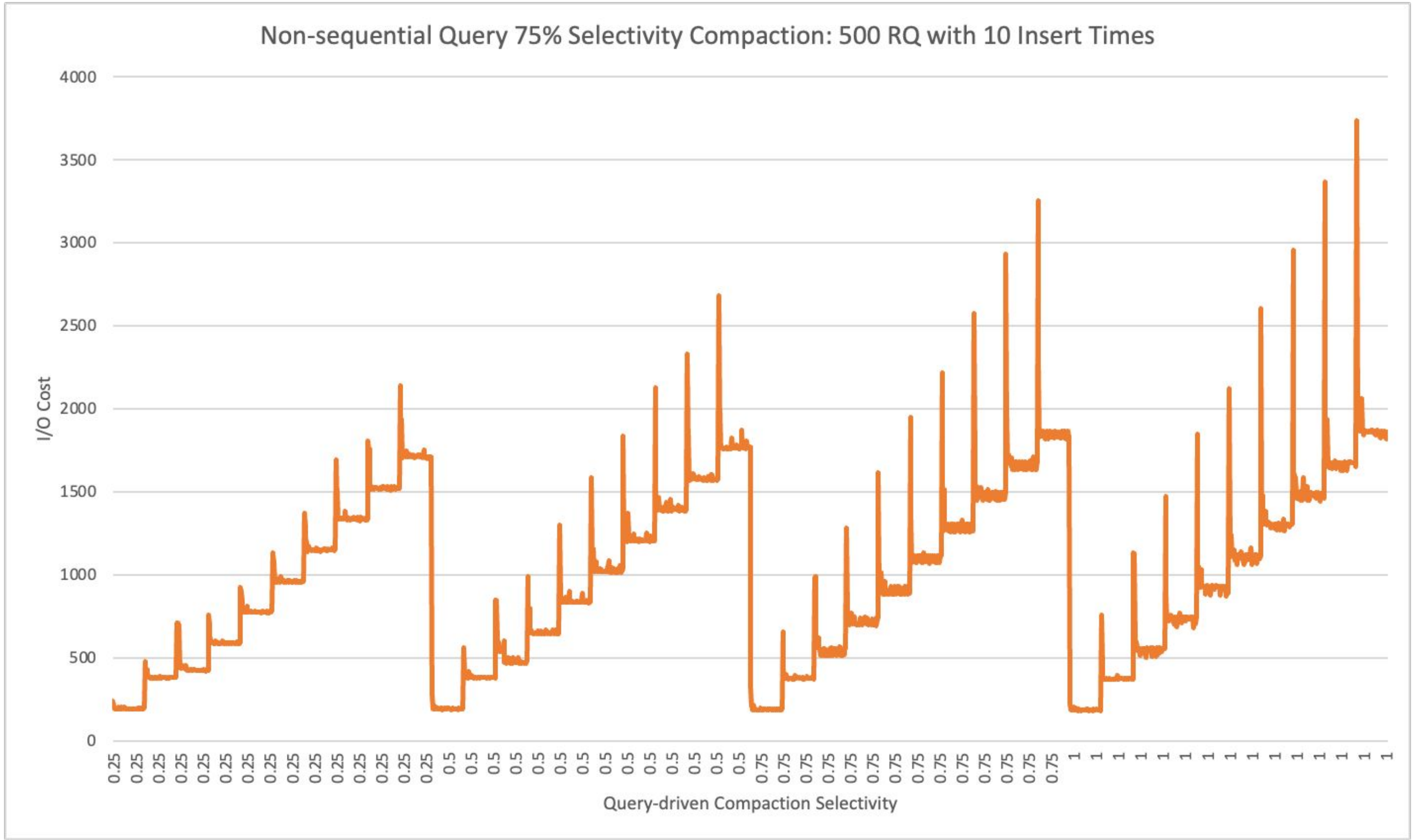
Compaction Selectivity: Non-sequential Query 25% - 500 RQ - 10 Times



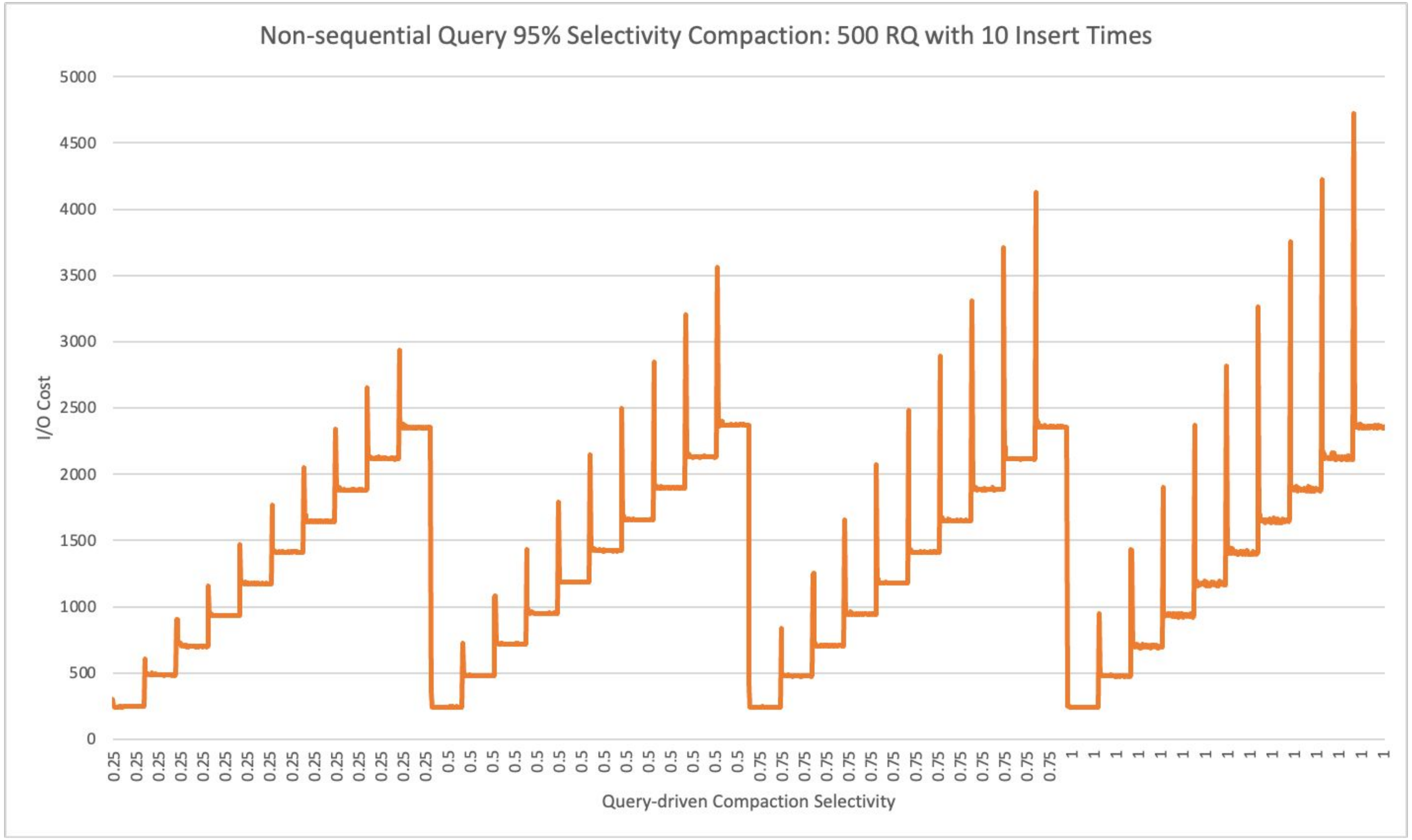
Compaction Selectivity: Non-sequential Query 50% - 500 RQ - 10 Times



Compaction Selectivity: Non-sequential Query 75% - 500 RQ - 10 Times



Compaction Selectivity: Non-sequential Query 95% - 500 RQ - 10 Times



Compaction Selectivity: Non-sequential Query: 500 RQ - 10 Insert - Sum i/o

No vanilla data

Sequential Query: 500 Point Query

No compaction data