Metaheuristic Search Reversion in Forest Planning

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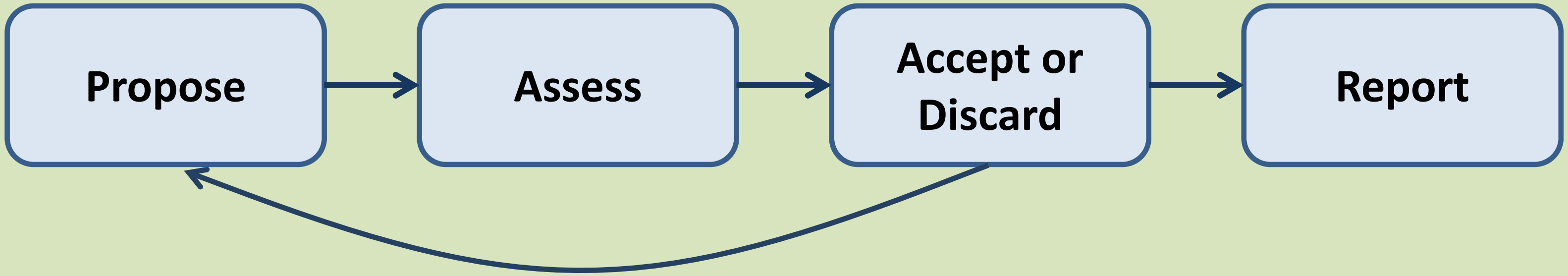
INTRODUCTION

When utilizing a metaheuristic method to develop a feasible and efficient forest plan for a mixed-integer problem, a sequence of events are typically used to explore the solution space.



Often, the sequence of events involves stochastic or deterministic decision choices, guided by logic and perhaps directed by preferences described through probabilities of selection or mutation.

INTRODUCTION

Most of the early work involving forest management problems has consisted of *s*-metaheuristics operating in 1-opt mode, where the status of a single discrete decision variable (management unit or road) is changed and the solution is re-evaluated.

- **Harvest timing of a stand is changed**
- **Management regime of a stand is changed**

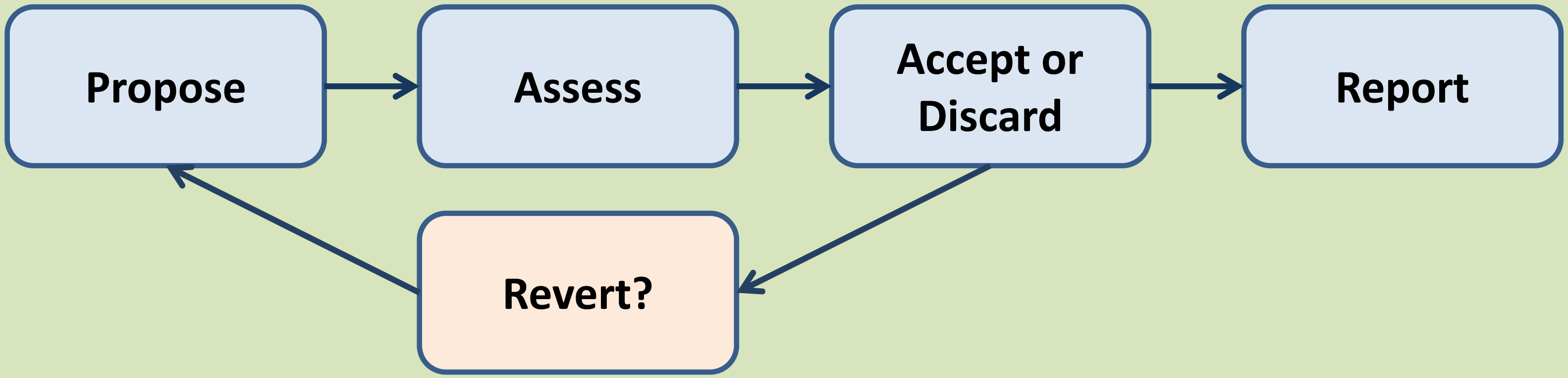
Bettinger et al. (1999, 2002), Caro et al. (2003), and Heinonen and Pukkala (2004) illustrated how 2-opt (or more) moves can be used to intensify a search within high-quality areas of a solution space.

- **Harvest timing of one stand is exchanged with that of another**
- **Management regime of a stand is exchanged with that of another**

INTRODUCTION

Another intensification scheme involves reverting the search to a previously-saved high-quality location in the solution space.

Rarely has a metaheuristic search process involved interrupting the sequence of events and re-initiating the search process with a known, high-quality solution.



In effect, this action can concentrate a search process around desirable areas of the solution space.

The assumption is that better solutions can be found in these areas.

INTRODUCTION

In some heuristic search processes, the chain of events in transforming one solution to another *may technically revert* to the best solution stored in memory, particularly when the probability of acceptance of inferior solutions decreases with search time and the search is designed to revert to the best solution.

- **However, this is not standard in some *s*-metaheuristics.**

Further, in some search processes that resemble Markov chains (e.g., threshold accepting), the typical transformation process for creating solution *j* from solution *i* does not include a phase for re-starting the process or reverting to the best solution.

INTRODUCTION

This study involved the exploration of a reversion technique that was employed during the search process of two *s*-metaheuristics.

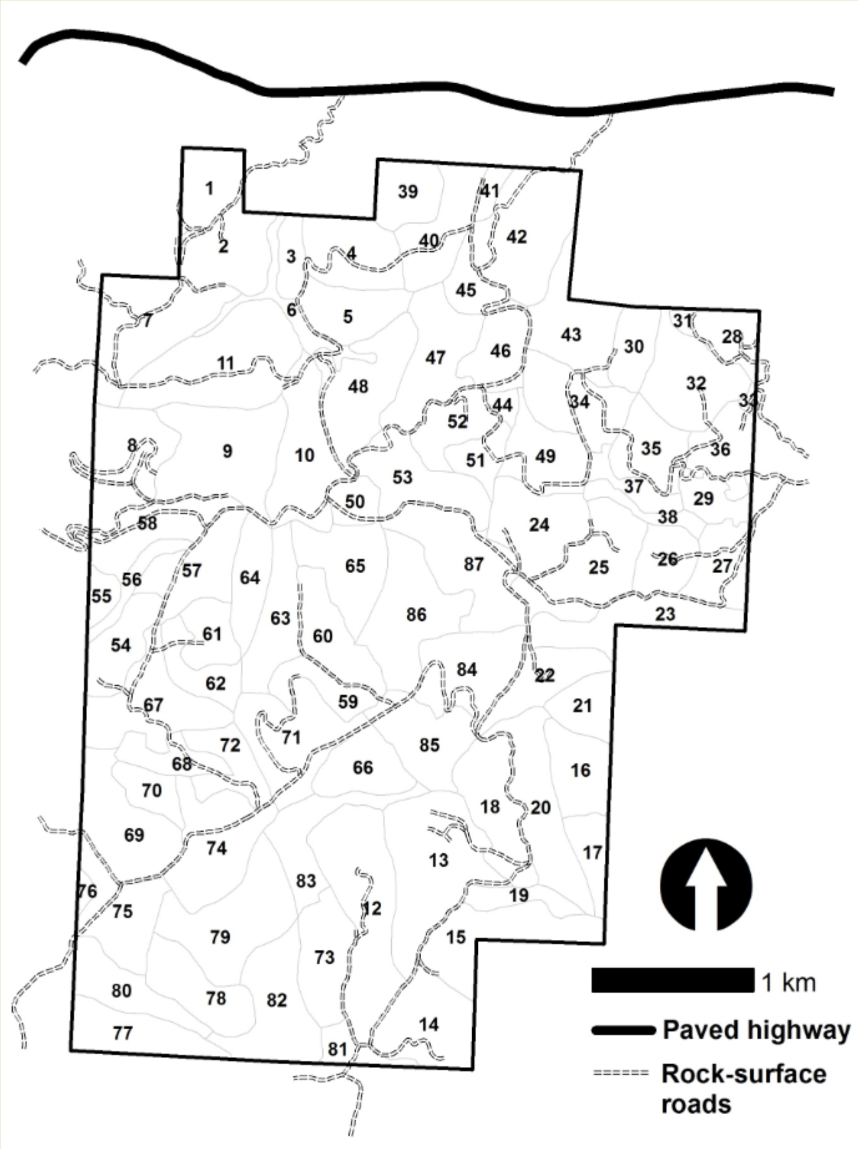
- Tabu search
- Threshold accepting

- **Different reversion rates were explored**
  - No reversion
  - Longer reversion - revert less often
  - Short reversion - revert more often

- **Three types of decision choices:**
  - A change to the harvest timing of a single management unit (1-opt move)
  - The exchange of two management unit's harvest timing (2-opt moves)
  - The exchange of three management unit's harvest timing (3-opt moves)

- **Two types of adjacency constraints:**
  - Unit restriction
  - Area restriction

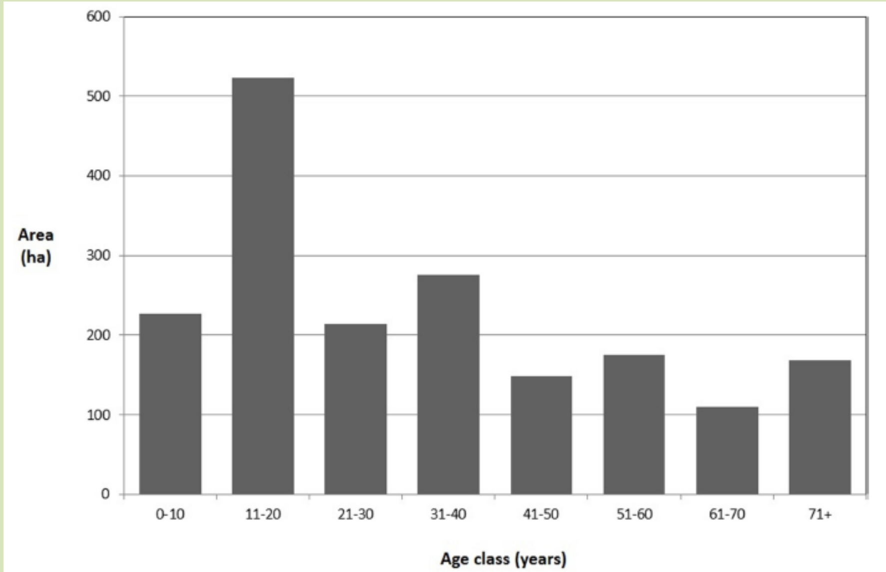
METHODS



Western Oregon

Mainly state-owned land

87 stands, 1841 hectares



30 year time horizon, 6 time periods

Target harvest volume: 13950 MBF

Objective: Min dev. from target volume

URM and ARM adjacency constraints

Minimum harvest age: 30 years

METHODS

Basic process for generalized local search (minimization)

Create an initial solution.

It is the best solution.

It is the current solution.

Perturb the current solution.

If acceptable, keep it.

If better than the best solution, it becomes the best solution.

If time to revert, the current solution is replaced with the best solution in memory.

```
s0 ← initial solution()
s* ← ŝ ← s0
while ¬ termination() do
        s' ← perturb(ŝ)
        if accept(s') then
                ŝ ← s'
                count = count + 1
        end if
        if f(ŝ) < f(s*) then
                s* ← ŝ
        end if
        if count mod reversion interval = 0 then
                ŝ ← s*
        end if
end while
return s*
```

s_0 = the initial feasible solution generated

$\hat{s}$ = the current feasible solution

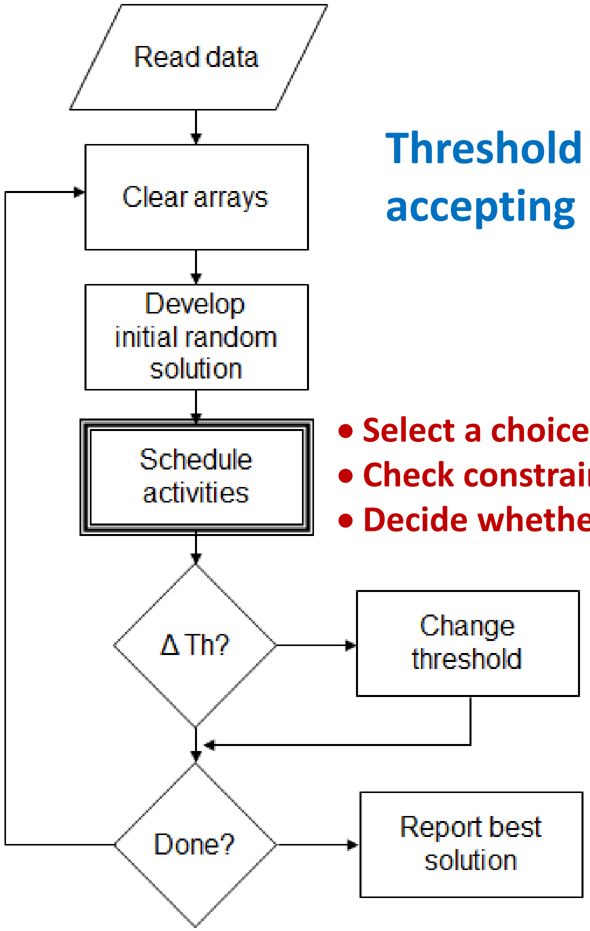
s' = a proposed new feasible solution

s^* = the best feasible solution

METHODS

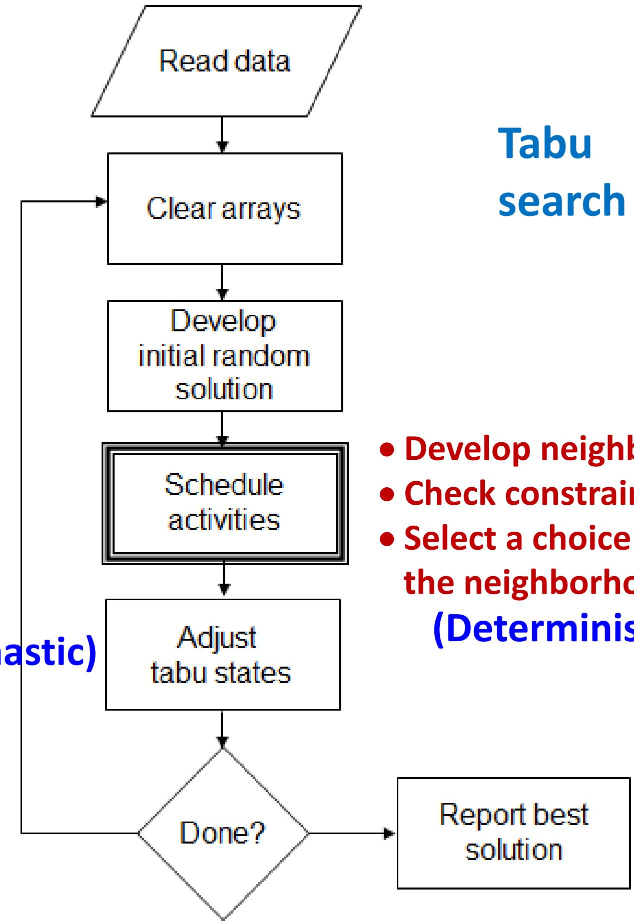
Each metaheuristic has a general behavior (stochastic, deterministic, or both) with regard to how it explores the solution space in search of the optimal solution to a problem.

Threshold accepting



- **Select a choice** **(Stochastic)**
- **Check constraints**
- **Decide whether to keep**

Tabu search



(Stochastic)

- **Develop neighborhood**
- **Check constraints**
- **Select a choice from the neighborhood**

(Deterministic)

RESULTS

Threshold Accepting - URM adjacency model

Decision choices	Reversion	Best	Average	Std. dev.
1-opt	none	1,340	69,347	372,257
	long	228	3,976	6,663
	medium	347	3,471	3,082
	short	201	4,152	6,665
1-opt, 2-opt	none	2,358	11,299	4,697
	long	178	1,256	1,004
	medium	58	1,105	980
	short	36	723	767
1-opt, 2-opt, 3-opt	none	1,782	12,366	7,142
	long	39	1,621	1,611
	medium	59	1,363	1,201
	short	31	898	981

RESULTS

Tabu Search - URM adjacency model

Decision choices	Reversion	Best	Average	Std. dev.
1-opt	none	174	3,716	11,343
	long	4	208	373
	medium	1	5,957	42,904
	short	39	13,186	58,131
1-opt, 2-opt	none	5	59	25
	long	-	4	10
	medium	-	8	20
	short	1	37	89
1-opt, 2-opt, 3-opt	none	4	58	26
	long	-	4	9
	medium	-	7	14
	short	1	40	107

RESULTS

Threshold Accepting - ARM adjacency model

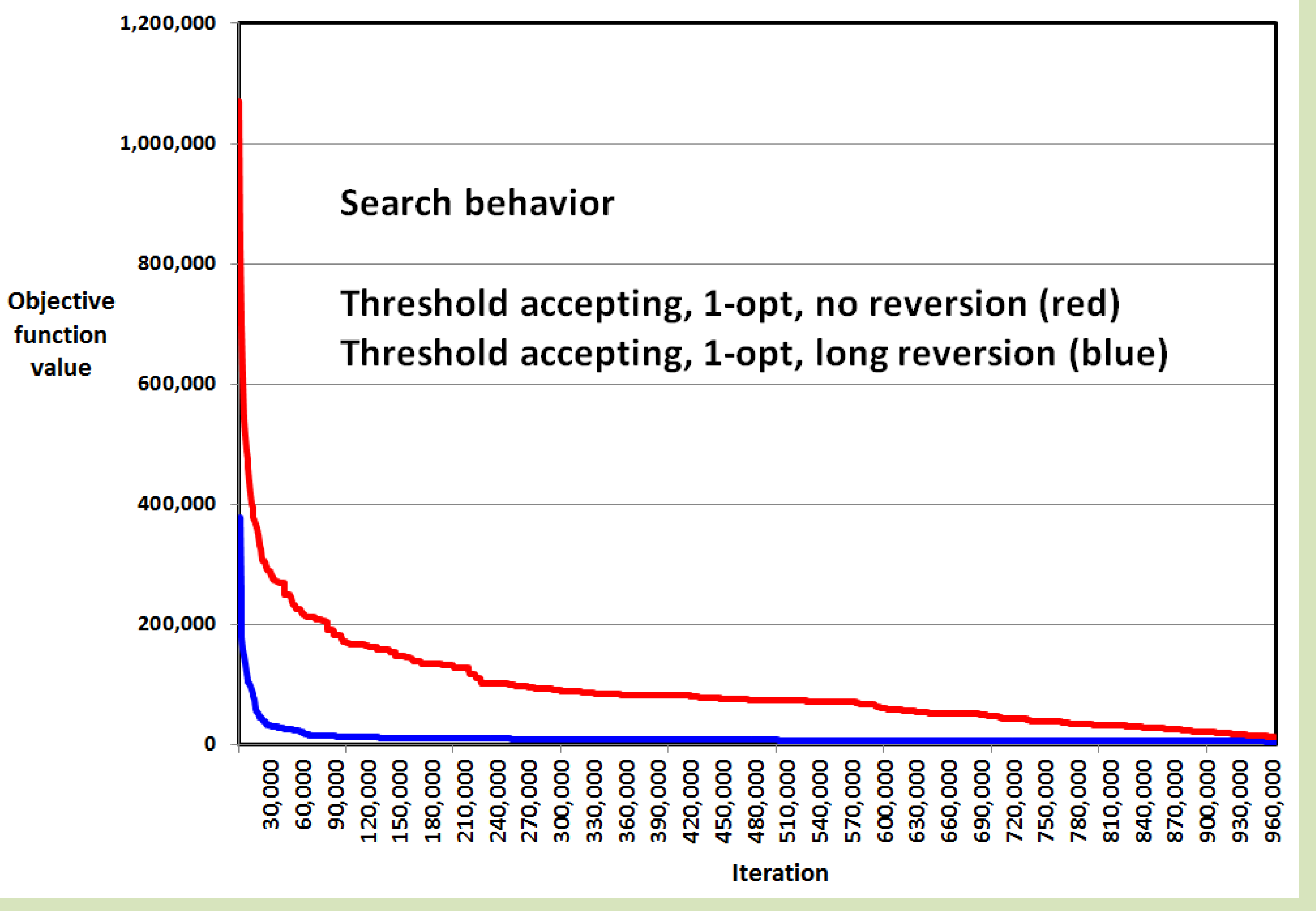
Decision choices	Reversion	Best	Average	Std. dev.
1-opt	none	1,525	63,549	305,728
	long	206	6,053	36,907
	medium	369	3,886	6,831
	short	136	6,470	29,916
1-opt, 2-opt	none	1,030	8,566	3,690
	long	85	1,165	1,243
	medium	40	928	759
	short	27	1,050	4,931
1-opt, 2-opt, 3-opt	none	2,466	8,023	3,636
	long	76	1,092	1,187
	medium	42	825	924
	short	69	618	579

RESULTS

Tabu Search - ARM adjacency model

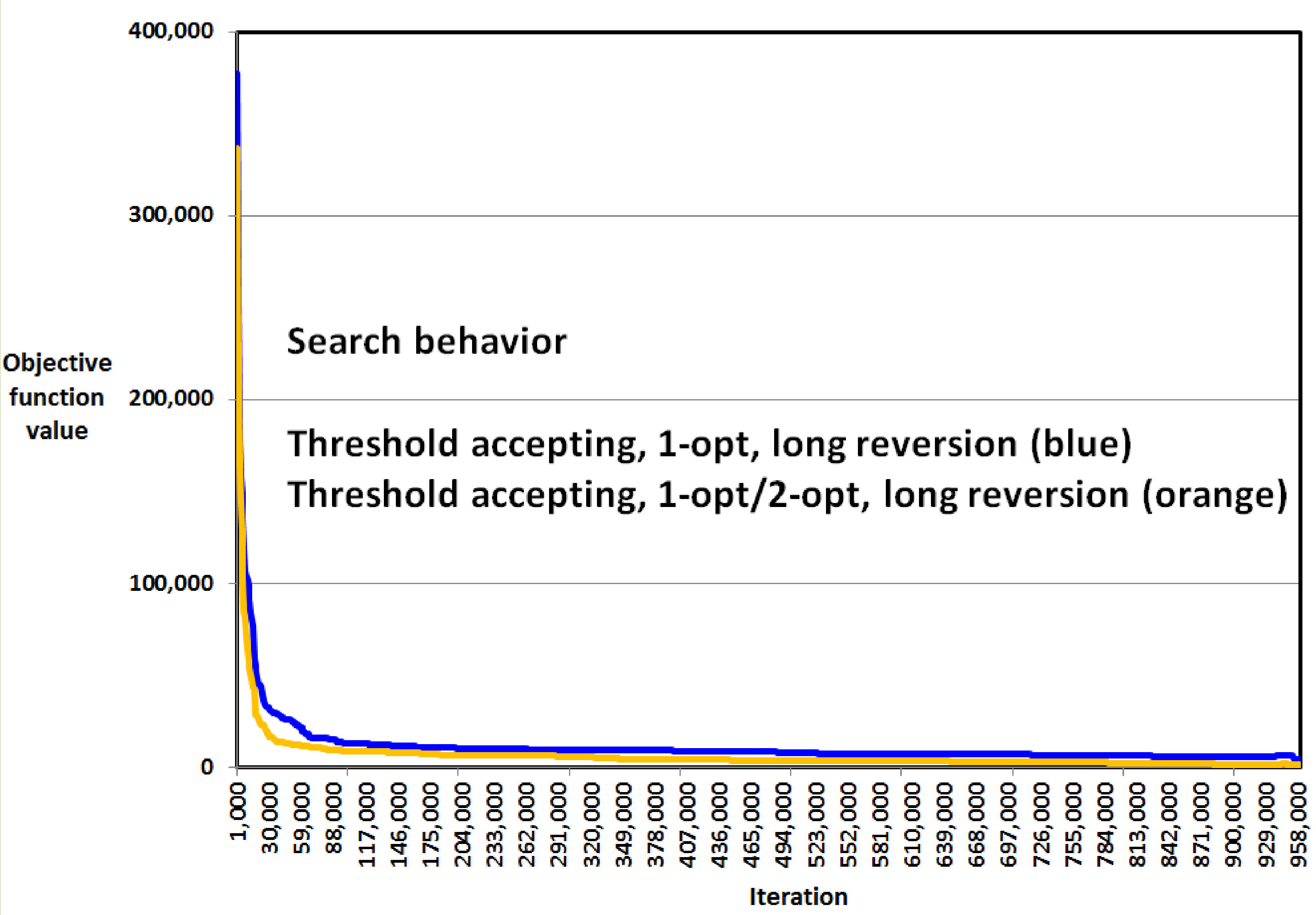
Decision choices	Reversion	Best	Average	Std. dev.
1-opt	none	291	2,274	10,628
	long	1	5,095	25,254
	medium	1	7,509	44,080
	short	19	18,120	67,863
1-opt, 2-opt	none	8	47	19
	long	-	1	2
	medium	-	3	7
	short	-	17	49
1-opt, 2-opt, 3-opt	none	6	33	14
	long	-	2	4
	medium	-	2	3
	short	-	26	90

RESULTS



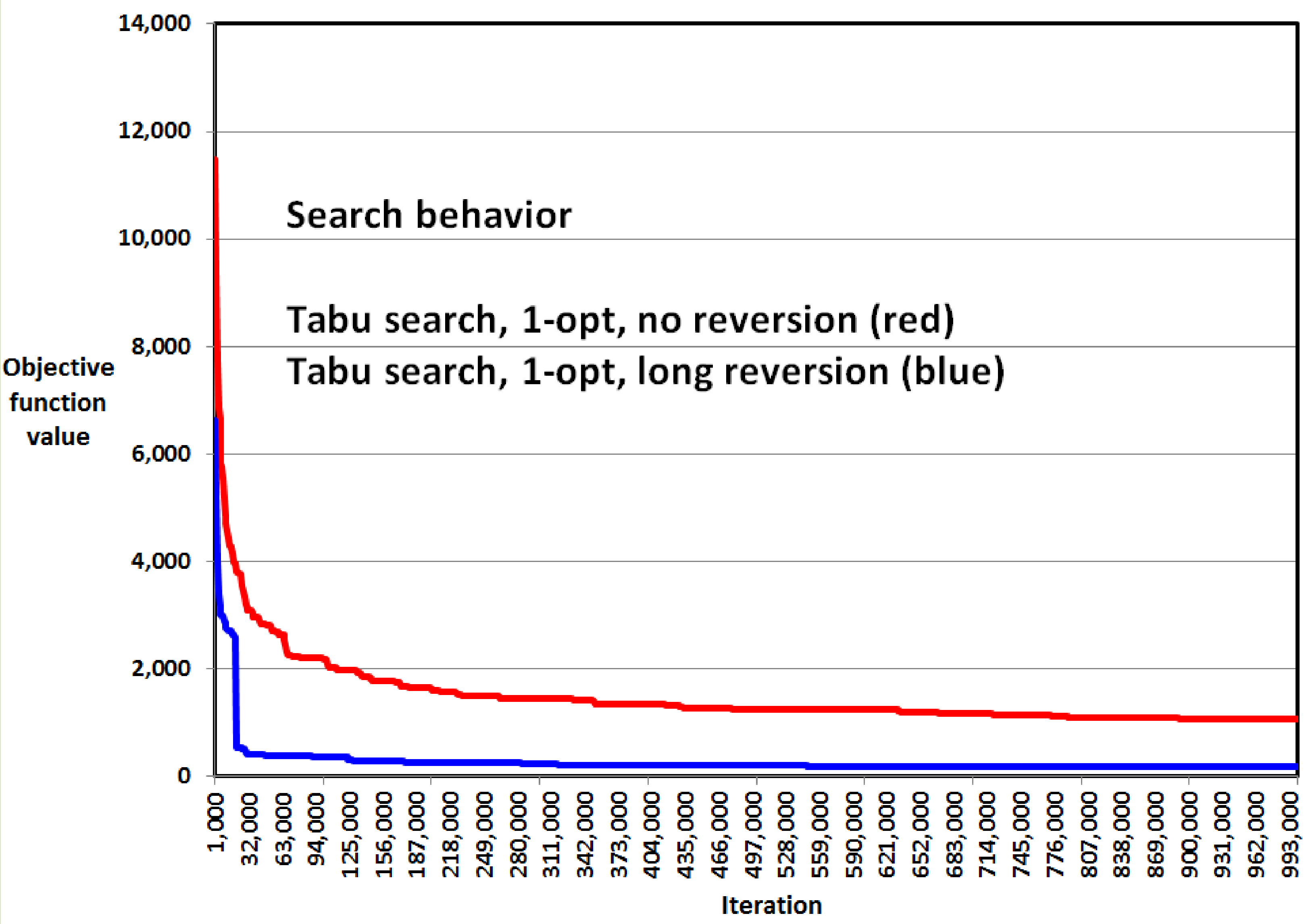
Search behavior
Threshold accepting, 1-opt, no reversion (red)
Threshold accepting, 1-opt, long reversion (blue)
Objective function value
1,200,000
1,000,000
800,000
600,000
400,000
200,000
0
30,000
60,000
90,000
120,000
150,000
180,000
210,000
240,000
270,000
300,000
330,000
360,000
390,000
420,000
450,000
480,000
510,000
540,000
570,000
600,000
630,000
660,000
690,000
720,000
750,000
780,000
810,000
840,000
870,000
900,000
930,000
960,000
Iteration

RESULTS



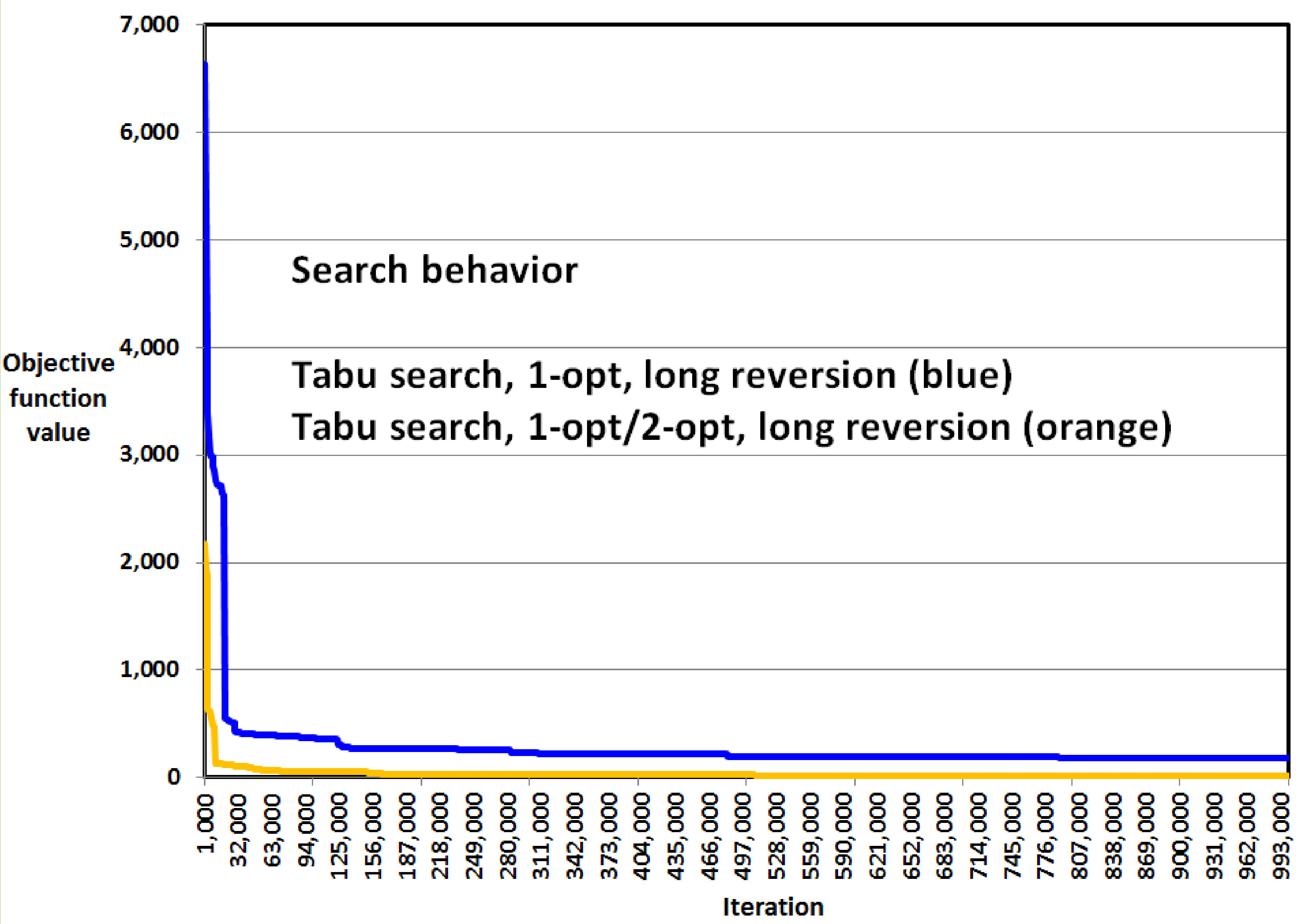
400,000
300,000
200,000
100,000
0
Objective function value
Search behavior
Threshold accepting, 1-opt, long reversion (blue)
Threshold accepting, 1-opt/2-opt, long reversion (orange)
1,000
30,000
59,000
88,000
117,000
146,000
175,000
204,000
233,000
262,000
291,000
320,000
349,000
378,000
407,000
436,000
465,000
494,000
523,000
552,000
581,000
610,000
639,000
668,000
697,000
726,000
755,000
784,000
813,000
842,000
871,000
900,000
929,000
958,000
Iteration

RESULTS



Search behavior
Tabu search, 1-opt, no reversion (red)
Tabu search, 1-opt, long reversion (blue)
Objective function value
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1,000
32,000
63,000
94,000
125,000
156,000
187,000
218,000
249,000
280,000
311,000
342,000
373,000
404,000
435,000
466,000
497,000
528,000
559,000
590,000
621,000
652,000
683,000
714,000
745,000
776,000
807,000
838,000
869,000
900,000
931,000
962,000
993,000
Iteration

RESULTS



Search behavior
Tabu search, 1-opt, long reversion (blue)
Tabu search, 1-opt/2-opt, long reversion (orange)
Objective function value
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
1,000
32,000
63,000
94,000
125,000
156,000
187,000
218,000
249,000
280,000
311,000
342,000
373,000
404,000
435,000
466,000
497,000
528,000
559,000
590,000
621,000
652,000
683,000
714,000
745,000
776,000
807,000
838,000
869,000
900,000
931,000
962,000
993,000
Iteration

Discussion

Reversion is an intensification of the search process around high-quality solutions within the solution space.

It was facilitated by the stochastic nature of choices within threshold accepting and a stochastically-determined tabu state in tabu search.

Results suggested that for the problem to which they were applied, although not standard aspects of the *s*-metaheuristics studied,

→ 2-opt decision choices were necessary
→ Reversion was necessary

Discussion

However, universal application of one or both of these search features needs to be considered carefully.

→ 2-opt decision choices were necessary

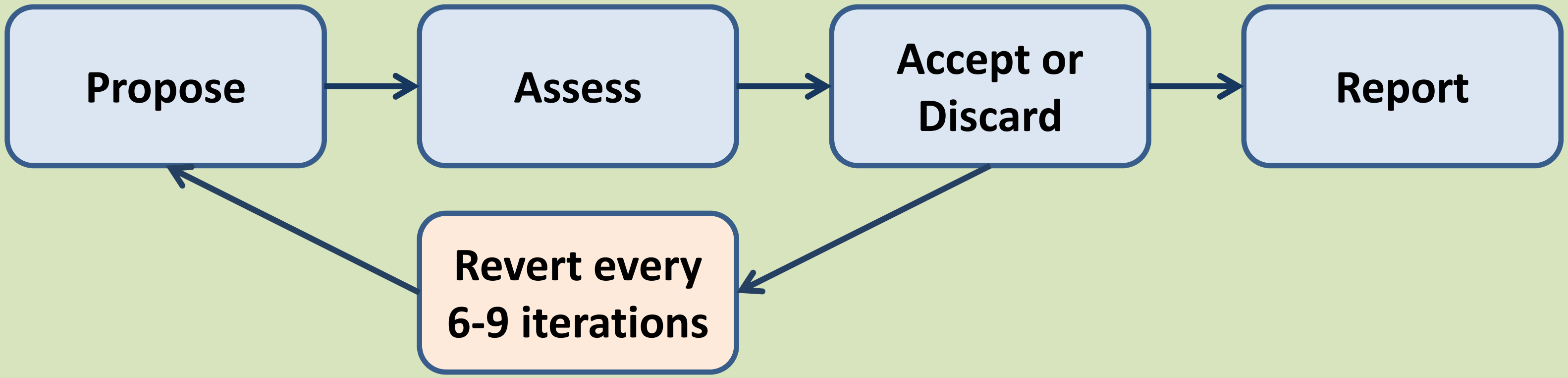
Depending on the type of 2-opt choices employed, 1-opt choices may also be necessary.

→ Reversion was necessary

Tabu search with 1-opt moves alone, and reversion, produced poor results 3-6% of the time. These searches reverted more often to poorer areas of the solution space.

Conclusions

Results suggested that a medium-long interval of iterations for the reversion employed within the *s*-metaheuristics studied could improve the quality of the forest plans generated.



The unit restriction model (URM) results are provided in...

Bettinger, P., M. Demirci, and K. Boston. 2015. Search reversion within *s*-metaheuristics: Impacts illustrated with a forest planning problem. Silva Fennica. 49(2): article id 1232.

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