

**AFRL-VA-WP-TM-2006-3002**  
**ROUTING COOPERATING VEHICLES**  
**TO PERFORM PRECEDENCE-LINKED**  
**TASKS**

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**STINFO INTERIM REPORT**

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<b>14. ABSTRACT</b>  The problem of scheduling cooperating vehicles is a generalization of the classical vehicle routing problem where certain tasks are linked by precedence constraints and vehicles have varying constrained resources. We describe a type of roll-out algorithm that finds an approximate solution to the problem in real-time and demonstrate the results of the computational experiments.					
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# Routing Co-operating Vehicles to Perform Precedence-linked Tasks

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# Problem description

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- **Multiple Vehicle Orienteering Problem:**  
Given a set of vehicles and sites with rewards, maximize the total number of rewards collected subject to hard time constraint
  - Closely related to Vehicle Routing Problem (VRP)
- **Co-operating vehicle orienteering problem:**  
Certain sites must be visited multiple times to perform various tasks in given order.

# Applications

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- **Synchronized vehicle dispatch [Rousseau, Gendreau, Pesant, 2002]**
  - Transportation of disabled persons
  - Hardware/software installation
- **Military applications:**
  - Shoot – look – shoot sequence
  - Standoff jamming
- **Problems of real-time nature**

# Solution Methods

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- **Local search techniques**
  - Tabu search
- **Constrained programming**

# Problem Formulation

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- **Given:**
  - **Heterogeneous vehicle fleet.**  
For each vehicle:
    - Initial and terminal positions
    - Time constraint
    - Vehicle type
  - **Site set.**  
For each site:
    - Task sequence and vehicle type per task
    - Travel times to all other sites and initial/terminal vehicle positions per vehicle type
    - Precedence constraint per task pair: (min, max) times between tasks
    - Reward collected by performing each task

# Problem Formulation (cont'd)

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**Maximize:**

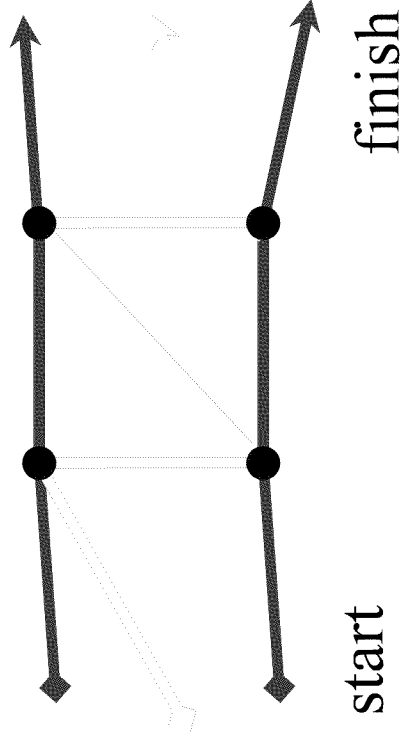
Total collected reward

**Subject to:**

- Initial/terminal positions of the vehicles
- Travel time constraints
- Task precedence

# Example

- Three vehicles to visit four sites, two ordered tasks per site
- Two type I vehicles;  
one type II vehicle



# Roll-out Algorithm

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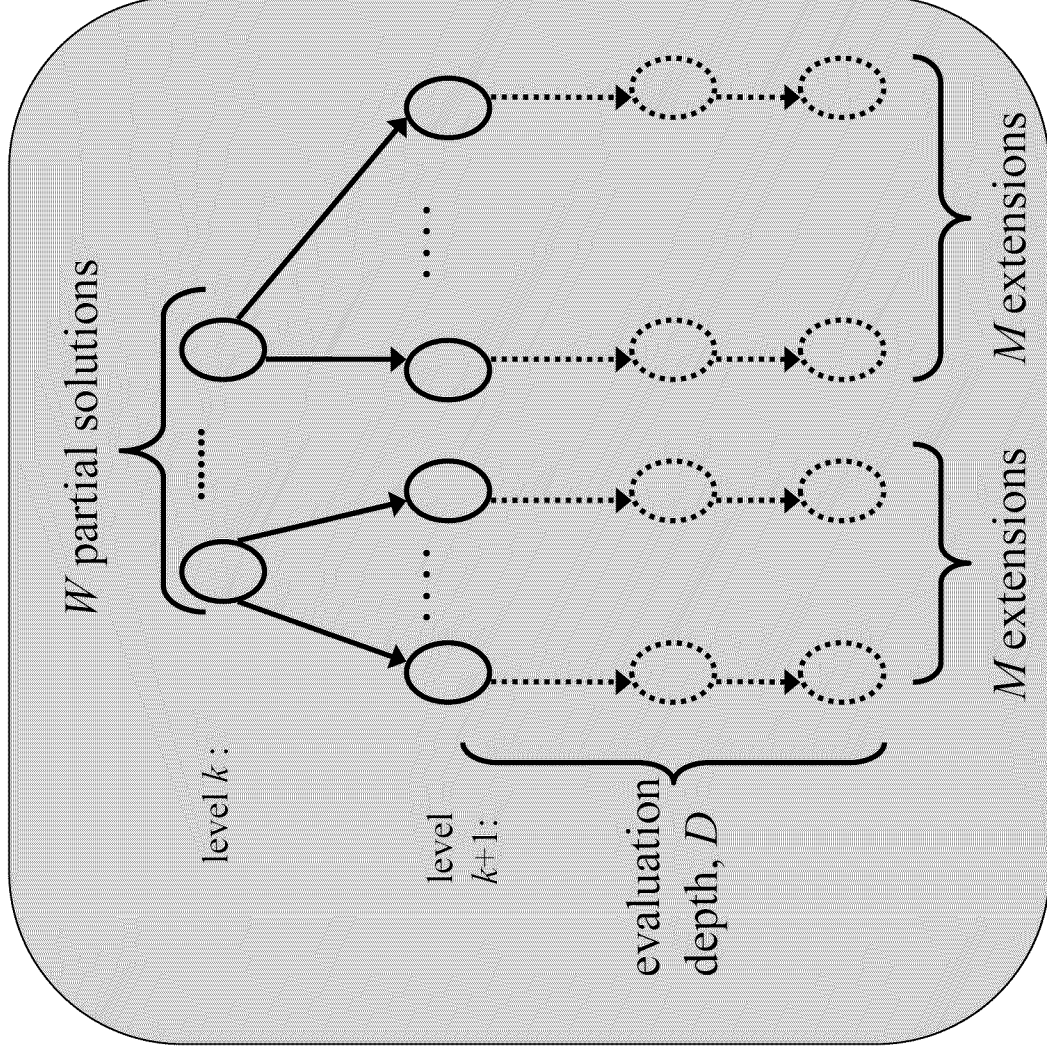
- Heuristic tree search using so-called “base heuristic”
- Start with an empty partial solution
- At each iteration:
  - Given a partial solution
  - Construct  $M$  candidate extensions of a partial solution
  - Roll-out move:
    - Evaluate each candidate extension by applying the base heuristic
  - Select the best candidate and re-iterate
- Stop when a complete solution is obtained
- Variation: At each iteration use  $W$  partial solutions to extend

# Roll-out approach: a single iteration

- Base heuristic: generate  $D$  sequential greedy solution extensions

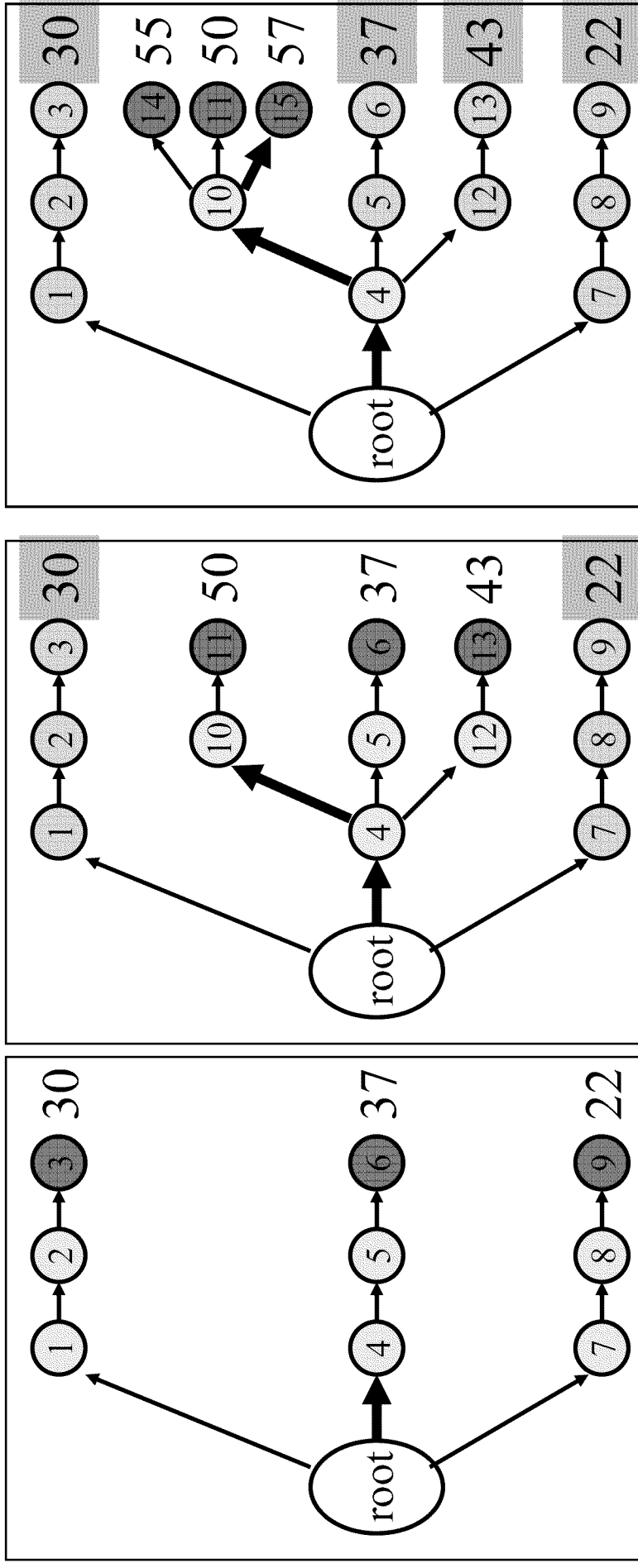
- Algorithm running time:  $O(WMDT(GH))$

where  $T(GH)$  is the time spent on a single greedy extension



# Roll-out approach: Limited Tree Search

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Complete Solution  
solutions: values:

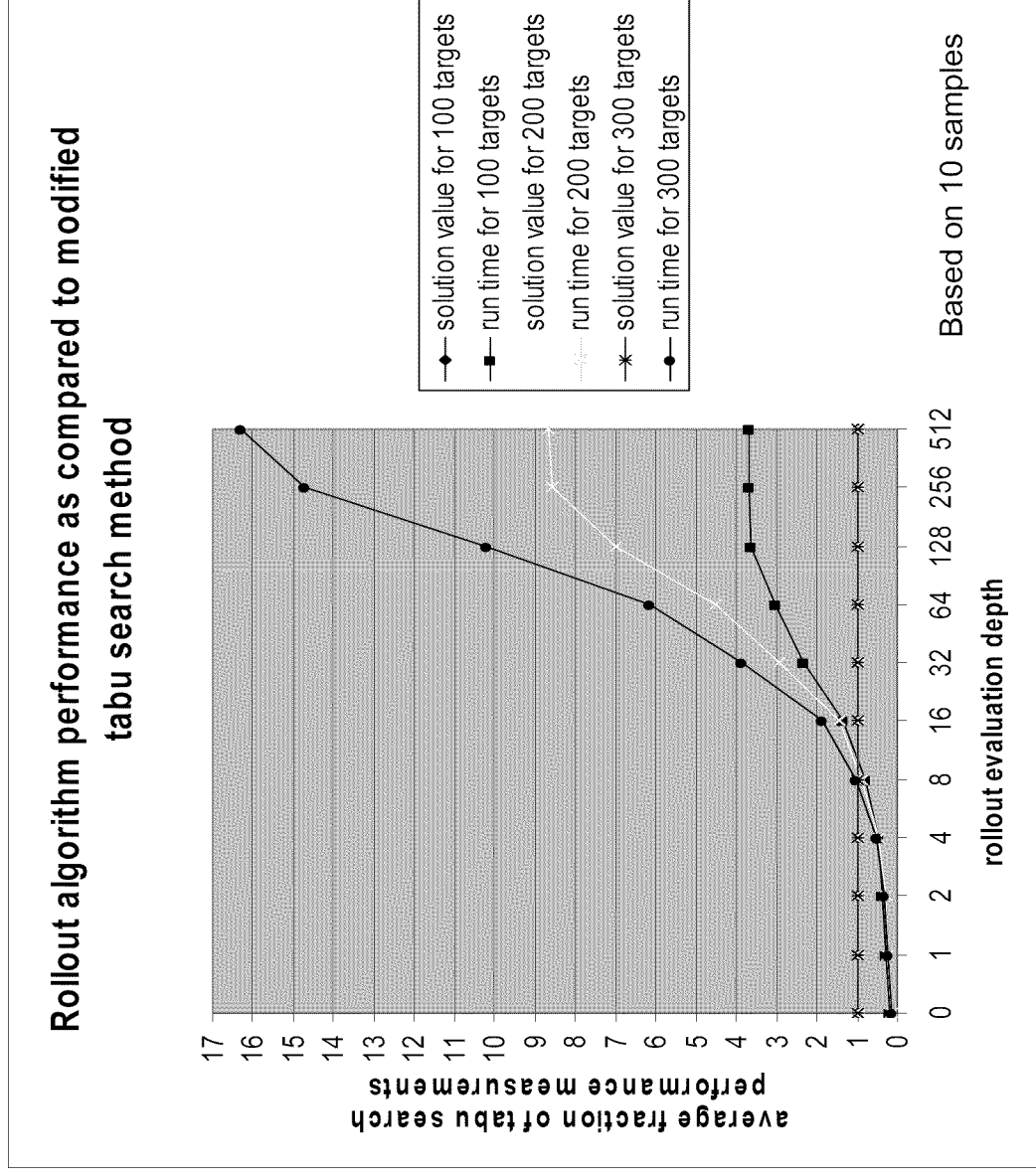
Numbers inside the circles indicate the order, in which the corresponding nodes are generated

# Roll-out algorithm application to routing co-operating vehicles

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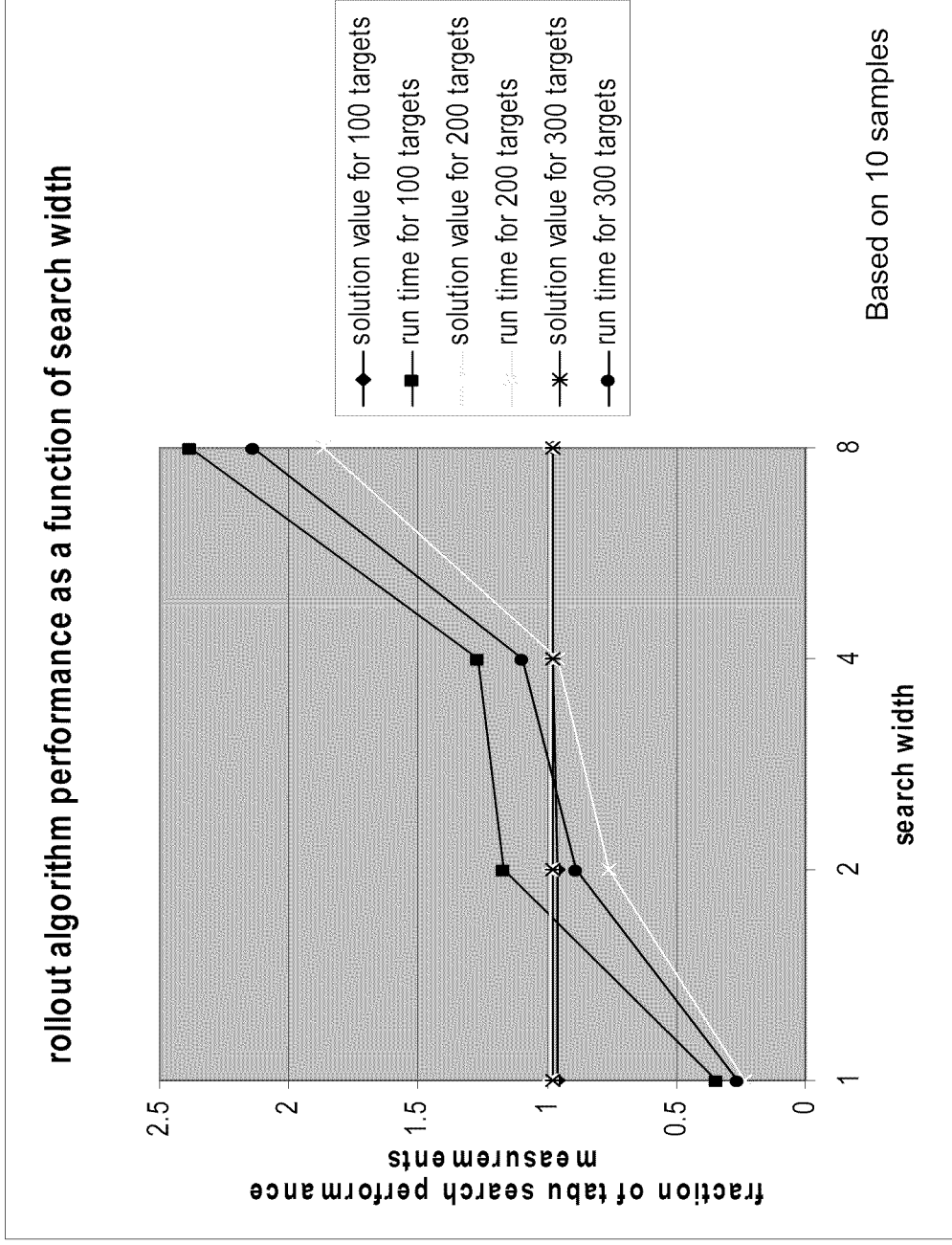
- **Partial solution:**
  - Sequence of site visits per vehicle subject to precedence and time constraints and terminal position reachability
  - At least one task can be added to at least one vehicle
- **Task availability:**
  - Given a partial solution, task is available if adding it does not violate precedence/time constraints
- **Solution extension:**
  - One available task is added to one vehicle
- **Base heuristic:**
  - Select an available task to maximize reward per travel time

# Experimental results: evaluation depth, $D$



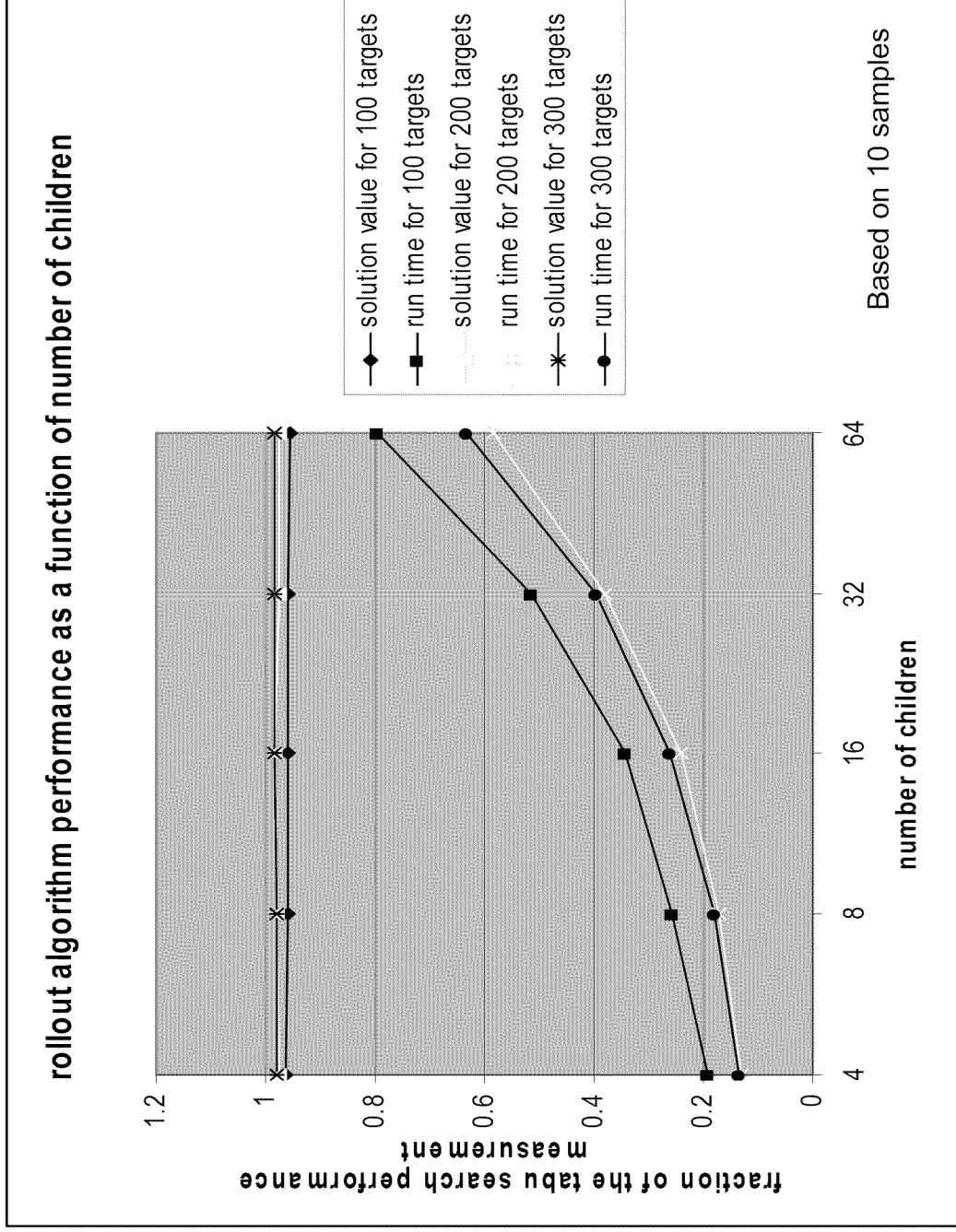
# Experimental results: search width, $W$

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# Experimental results: number of candidate extensions, $M$

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# Conclusion

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- **High-quality solution as compared with tabu search**
- **Scalable algorithm**
- **Applicable to real-time scheduling by adjusting parameters to speed-up computation**
- **Applicable to limited-horizon routing under uncertainty in fast changing environment**