# Advanced Heuristics in Transportation and Logistics

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You're required to plan the routes of your company's 250 delivery trucks from 12 depots to the city's 5,000 vendor locations. Traffic patterns, accidents and breakdowns, vendor-specified delivery time windows, perishable goods, returned empty packages, and product shortages at specific depots further complicate the picture. And, by the way, yesterday's plan is no longer applicable because heavy overnight snowfall has



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invalidated your estimations of the trucks' speeds; you need a new plan by daybreak, in two hours. Where do you start?

In today's global transportation and logistics environment, industries require computational and simulation-based methods that will lead to faster transactions, reduced operating costs, and improved performance and customer service. They also want methods and tools that provide more control and flexibility in their operations, such as production and location planning, warehousing, distribution, and transportation.

Transportation and logistics organizations often face large-scale combinatorial problems on both operational and strategic levels. In such problems, you must examine all possible combinations of decisions and variables to find a solution; consequently, no partial-enumeration-based exact algorithm can consistently solve them. This occurs because sharp lower bounds on the objective value are hard to derive, causing a slow convergence rate.[1] By exploiting problem-specific characteristics, classical heuristic methods—such as constructive and iterative local-search methods—aim at a relatively limited exploration of the search space, thereby producing acceptable-quality solutions in modest computing times.

As a major departure from a classical heuristic, a metaheuristic method implies a higher-level strategy controlling a lower-level heuristic method. Metaheuristics exploit not only the problem characteristics but also ideas based on artificial intelligence methodologies, such as different types of memory structures and learning mechanisms, as well as analogies with optimization methods found in nature. Solutions produced by metaheuristics typically are of a much higher quality than those obtained with classical heuristic approaches. Their swift execution speed allows their use in combinatorial problems where a complete enumeration would be totally impractical. Evidently, metaheuristic approaches succeed by intelligently exploiting the problem structure and obtaining insight from the effective interplay between *intensification* (concentrating the search into a specific region of the search space) and *diversification* (elaborating different regions in the solution space) mechanisms.

## Metaheuristic methods

We can classify metaheuristic algorithms using several different criteria.[2] A classification can be based on whether the algorithm works on

- a population of solutions at each iteration, such as evolutionary algorithms (EAs)[3] and adaptive-memory procedures (AMPs);[4]
- a single solution, such as annealing-based algorithms (AbAs),[5] tabu search (TS),[6] the greedy randomized adaptive search procedure (Grasp),[7] iterated local search (ILS),[8] and variable-neighborhood search (VNS);[9] or
- a learning mechanism, such as neural networks[10] and ant algorithms (AAs).[11]

Alternatively, we might classify metaheuristic algorithm on the basis of their origins. This classification includes nature-inspired metaheuristics such as EAs, AAs, and AbAs and non-nature-inspired algorithms such as TS, ILS, VNS, and Grasp. Another classification might consider whether the algorithm employs a static or dynamic objective function, such as guided local search.[1] A metaheuristic algorithm can also use one or various neighbor structures during the search process. A classification might also consider whether the metaheuristic uses memory (such as TS, AMPs, and AAs) or not (such as AbAs or VNS). Or, we could create a general classification based on whether the method is a state-of-the-art metaheuristic algorithm or a sophisticated combination of different metaheuristic concepts, a *hybrid metaheuristic algorithm*.[12]

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## This issue's articles

We were extremely fortunate to receive 62 submissions for this special issue. At the least, this high number demonstrates the amount of active, high-quality research taking place worldwide in this area. By the end, we had enough material for at least three special issues. As a result, the articles selected to appear in this issue only represent a sample of the metaheuristic strategies for transportation and logistics.

The articles begin with "A Guided Cooperative Search for the Vehicle Routing Problem with Time Windows" by Alexandre Le Bouthillier, Teodor Crainic, and Peter Kropf. This article is a valuable contribution to the combinatorial optimization solution methodologies for solving this problem. Results from an extended set of benchmark problem sets confirm the proposed methodology's computational effectiveness.

"Case Study: An Intelligent Decision-Support System," by Zbigniew Michalewicz, Martin Schmidt, Matthew Michalewicz, and Constantin Chiriac, discusses the design and implementation of a decision-support system for a leading car manufacturer. The system determines an optimal distribution of lease-return vehicles to US car auction sites. It has generated profits in excess of US$200 million per year by detecting data trends in a dynamic environment and employing sophisticated optimization and self-learning techniques.

Pierpaolo Caricato and Antonio Grieco, in "Using Simulated Annealing to Design a Material-Handling System," present a simulated-annealing algorithm to solve the problem of designing a realistic guide path configuration for an automated-guided-vehicle-based material-handling system. Experimental results substantiate the proposed metaheuristic approach's efficiency.

"A Hybrid Algorithm for Distribution Problems," by David Bredström, Dick Carlsson, and Mikael Rönnqvist, presents a hybrid genetic algorithm that helps minimize distribution costs for a large Scandinavian pulp producer. The algorithm uses two linear-programming models. One optimizes all transport flows over a time horizon to minimize a given schedule's total cost; the other approximates a schedule's performance and selects the fittest one. The authors performed computational experiments using real-world data instances and compare the results with a mixed-integer-programming approach.

Ana Moura and José Fernando Oliveira, in "A Grasp Approach to the Container-Loading Problem," discuss logistics decisions related to packing a set of boxes into a container to minimize wasted space. To solve this critical logistics problem, they develop a new Grasp algorithm, which they compare with other effective approaches. The computational results show that the proposed metaheuristic methodology can produce high-quality solutions.

"A Hybrid Approach to Designing Inbound Resupply Strategies," by Wout Dullaert, Birger Raa, Bert Vernimmen, and Frank Witlox, examines how to find the best combination of sourcing alternatives to minimize the total product costs (including product price and order, transportation, and inventory costs) when transporting goods from a supplier to a receiver. The integration of discrete event simulation within an evolutionary methodology models the problem's stochastic-natured variables and efficiently determines the reorder point. The authors also apply the proposed methodology to a real-world case.

Finally, "Sequential and Parallel Path-Relinking Algorithms for the Quadratic Assignment Problem," by Tabitha James, Cesar Rego, and Fred Glover, examines the challenging logistics problem of assigning a set of facilities to a set of locations, given the distances between locations and the flow between facilities. To solve this problem, the authors develop both sequential and parallel versions of a simplified yet effective path-relinking algorithm. They test the proposed metaheuristic approach on well-known benchmark instances, producing promising results. ■

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