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Computational Intelligence in Logistics and Supply Chain Management

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Preface

Over the last decades, logistics and supply chain management (SCM) have become one of the most often and intensively discussed fields in management and economics. Although many ideas and concepts used in logistics and SCM are reasonably old, much effort has been undertaken to transfer them into practice and to improve them further. Many publications, in academia as well as in application-oriented literature, have appeared. Logistics and SCM have become fields which are rich in terms of innovation and progress.

Despite these promising developments, there are still obstacles to bring advanced visions of improved planning and cooperation along logistics processes and supply chains into reality. On the one hand, there are many practical issues such as the availability and transparent processing of information, difficulties in establishing cooperation, or because of an increasingly uncertain or rapidly changing planning environment. On the other hand, it has become more and more apparent that the underlying planning problems are very complex and hard to solve even in the case that respective data is fully retrievable and complete.

From a computational point of view, many of these problems can be characterized as NP-hard, which means that the number of possible solutions is increasing exponentially with the problem size and that presumably no algorithms exist, which can solve them exactly within acceptable time limits—at least when the problems are "rather large." Unfortunately, most real-world problems can be considered rather large.

Especially during the last 20 years, these problems have been investigated intensively in the academic literature, and many suitable solution approaches have been suggested. As the problems usually cannot be solved exactly within an acceptable time, these methods allow to find sufficiently good, although not necessarily, optimal solutions.

One of the still growing streams of methods belongs to the field of computational intelligence (CI), which comprises mostly approaches inspired by concepts found in nature, e.g., the natural evolution or the behavior of swarms. These methods are based on general heuristic ideas and concepts for problem solving, which can—with some adaptations—be applied to a wide range of problems. To distinguish these methods from simple heuristics, which are often very specific to a single type of problem, they are also denoted as metaheuristics.

Although the respective computational intelligence methods have been studied in numerous applications related to logistics and supply chain management, they are hardly discussed in general textbooks in these fields. Often, the treatment of formal planning problems in these books does not go much beyond some rather simple and general results, which are often not applicable in real-world settings, for instance, the more than 100-year-old equation for calculating economic order quantities.

The book is intended to reduce this gap between general textbooks in logistics and supply chain management and recent research in formal planning problems and respective algorithms. It focuses on approaches from the area of computational intelligence and other metaheuristics for solving the complex operational and strategic problems in these fields.

Thus, the book is intended for readers who want to proceed from introductory texts about logistics and supply chain management to the scientific literature, which deals with the usage of advanced methods. For doing so, state-of-the-art descriptions of the corresponding problems and suitable methods for solving them are provided. The book mainly addresses students and practitioners as potential readers. It can be used as additional reference for undergraduate courses in logistics, supply chain management, operations research, or computational intelligence or as a main teaching reference for a corresponding postgraduate level course. Practitioners may read the book to become familiar with advanced methods that may be used in their area of work. For a reader, a basic understanding of mathematical notation and algebra is suggested as well as introductory knowledge on operations research (e.g., on the simplex algorithm or graphs).

The book is organized as follows: The first two chapters provide general introductions to logistics and supply chain management on the one hand and to computational intelligence on the other hand. The subsequent chapters cover specific fields in logistics and supply chain management, work out the most relevant problems found in those fields, and discuss approaches for solving them. In Chap. 3, problems in transportation planning such as different types of vehicle routing problems are considered. Chapter 4 discusses problems in the field of production and inventory management. Chapter 5 considers planning activities on a finer level of granularity, which is usually denoted as scheduling. While Chaps. 3 to 5 rather discuss planning problems, which appear on an operative level, Chap. 6 discusses the strategic problems with respect to the design of a supply chain or network. The final chapter provides an overview of academic and commercial software and information systems for the discussed applications.

We hope to provide the readers a comprehensive overview with specific details about using computational intelligence in logistics and supply chain management.

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Our deep gratitude goes to our beloved families, i.e., our wives and children. As professors who are active in research and teaching, with Rolf additionally being head of the institute and Thomas being head of one of its competence centers, we spend so much time with working issues that we always feel that our families are missing out. Therefore, we wish to express to them our highest thanks for their great understanding and their never-ending support! Thomas additionally thanks his wife Doris for proofreading some of the chapters, for discussion of some contents, and for support with the lists of symbols and acronyms.

Contents

List of Symbols

λ	Number of offspring (parameter of an evolution strategy)
π	Permutation
$\mathfrak{R}$	Set of real numbers
ρ	Number of recombined parents (parameter of an evolution strategy)
σ	Standard deviation, prediction error
σ_{d}	Standard deviation for demand
σ_{LT}	Standard deviation for lead time
μ	Number of parents (parameter of an evolution strategy)
A	(Feasible) set of alternatives, search space
A, B	Start and destination location of a transport
a	Capacity requirement per unit
a_i	Capacity requirement at location i
(a_{i1}, a_{i2})	Coordinates of customer i
a_{ij}	Influence factors (in particle swarm optimization)
a_p	Capacity requirement per unit of item p
at_i	Arrival time of job i
b	Capacity requirement per setup
C, C_i	Completion time (of job i)
c, c_t	Costs, unit costs
c_i^{best}, c_i^{global}	Acceleration factors (in particle swarm optimization)
c_{ij}	Transport costs (between i and j)
C_{max}	Makespan
D	Total required quantity (in the time horizon)
$d(.,.)$	Distance function
dd_i	Due date of job i
d_{ij}	Distance between i and j
dl_i	Deadline of job i
d_p	Demand of item p
d_t	Demand in t

$\hat{d}_t$	Predicted demand in t
$\overline{d}$	Average demand
E	Set of edges (arcs) of a graph
ea	Earliness
e_i	Edge of a graph
$f(.)$	Objective function
f_i	Finishing time
f_j	Setup costs of facility j
$G=(V,E)$	Graph
$G=(V,E,c)$	Graph with weights (which correspond to costs)
h, h_t, h_p	(Unit) holding costs
h^r	Holding cost rate
i_{pt}	Inventory of product p in t
i_{pt}^A, i_{pt}^B	Inventory of product p at location A (B) in t
i_t	Inventory in t
L	Set of locations
L^C	Set of customer locations
L^D	Set of depot locations
LT	Lead time
$\overline{LT}$	Average lead time
la	Lateness
l_i	Location
l_j^C	Customer location
l_i^D	Depot location
M	Large constant number
m	Number of neurons
$N(0, \sigma)$	Normal distribution with expected value 0 and standard deviation σ
n	Number of variables (e.g., locations in a tour)
$n!$	Factorial function of n
$O(.)$	Run time complexity of an algorithm (big O notation)
P	Subset of locations
p	Price per unit
p	Number of facilities to open in a p-median problem
p^{global}	Global best position of a particle (in particle swarm optimization)
p_i	Particle i (in particle swarm optimization)
p_i^{best}	Best previous position of particle i (in particle swarm optimization)
p_{ij}	Processing time of job i (on machine j)
q, q_j	Capacity (e.g., of a vehicle or a facility)
q_{ij}	Transported quantity between two locations
RP	Reorder point
r_i^{best}, r_i^{global}	Random coefficients (in particle swarm optimization)
S	Set of facility locations
SS	Safety stock
s_i	Start time of job i

s_{ik}	Arrival time of vehicle k at location i
s_i^{max}	Latest arrival time at location i (with specified time window)
s_i^{min}	Earliest arrival time at location i (with specified time window)
T	Planning horizon, time horizon, total number of periods
t_{ij}	Travel time from i to j
u, u_t, u_p	Fixed costs per order, setup costs of a production process
U_i	Order-up-to level quantity of product i
V	Set of vertices (nodes) of a graph, set of vehicles
v_i	Vertex (node) of a graph, velocity vector of a particle (in particle swarm optimization)
w_i	Inertia weight (in particle swarm optimization)
w_L, w_E	Weights (for lateness and earliness)
w_t	Production capacity in period t
$x, x_{ij}, x_{ijk}, x_{pt}$	Decision variables
x_o	Economic order quantity
x_t	Production quantities in t
y_t, y_{pt}	Binary decision variables
Z	Service level
z	Auxiliary variable for objective function values
z_{it}	Binary variables (denoting whether node i is visited at time t)

List of Abbreviations and Acronyms

2E-VRP	Two-echelon vehicle routing problem
ABC	Artificial bee colony
ACO	Ant colony optimization
AGV	Automated guided vehicles
AI	Artificial intelligence
AIMMS	Advanced interactive multidimensional modeling system
AIS	Artificial immune system
AMPL	A mathematical programming language
ANN	Artificial neural network
AP	Alternating position crossover
APS	Advanced planning systems or advanced planning and scheduling
AS/RS	Automated storage/retrieval system
ATP	Available-to-promise (functionality used in APS for supporting order promising and fulfillment)
BA	Bees algorithm
BE	Bionic engineering
BOM	Bill of materials
CCLSP	Coordinated capacitated lot-sizing problem
CFLP	Capacitated facility location problem
CI	Computational intelligence
CMA	Covariance matrix adaption
CMA-ES	Evolution strategy with covariance matrix adaptation
CMWP	Capacitated multi-facility Weber problem
COI	Cube-per-order index
CS	Cuckoo search
CSCMP	Council of supply chain management professionals
CULSP	Coordinated uncapacitated lot-sizing problem
CVRP	Capacitated vehicle routing problem
CX	Cycle crossover

DE	Differential evolution
DLL	Dynamic linked library
DPSO	Discrete particle swarm optimization
DPX	Distance-preserving crossover
EA	Evolutionary algorithm
EC	Evolutionary computation
ELS	Economic lot size
EOQ	Economic order quantity
EP	Evolutionary programming
ER	Genetic edge recombination crossover
ERP	Enterprise resource planning
ERX	Edge recombination crossover
ES	Evolution strategy
FA	Firefly algorithm
FIFO	First-in first-out
FL	Fuzzy logic
FNN	Feedforward neural network
GA	Genetic algorithm
GAMS	General algebraic modeling system
GCLSP	General capacitated lot-sizing problem
GDP	Gross domestic product
GE	Grammatical evolution
GEP	Gene expression programming
GIS	Geographic information systems
GNX	Generalized n-point crossover
GP	Genetic programming
GPS	Global Positioning System
GRASP	Greedy randomized adaptive search procedure
GSO	Glowworm swarm optimization
HNN	Hopfield neural networks
HS	Harmony search
IEEE	Institute of Electrical and Electronics Engineers
ILS	Iterated local search
ILS-FDD	Iterated local search with fitness-distance-based diversification
JiT	Just-in-time
LCS	Learning classifier systems
LGP	Linear genetic programming
LOX	Linear order crossover
LSAP	Linear sum assignment problem
MA	Memetic algorithms
MACS	Multiple ant colony system
MCFP	Multicommodity-flow problem
MCLC	Maximal covering location criterion
MGP	Metagenetic programming