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Modeling, Computing and Data Handling Methodologies for Maritime Transportation

Springer

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The vast majority of human beings dislike and even actually dread all notions with which they are not familiar… Hence it comes about that at their first appearance innovators have generally been persecuted, and always derided as fools and madmen.
from “Words of Wisdom” by Aldous Huxley

To our families.

Foreword

Innovation is the keyword that drives and brings together the scientific and commercial world these days. Computer science and technologies are usually hidden beneath the success, especially in the disciplines well established before IT revolution in the end of the last century. This is exactly the case in maritime transportation: Ideas of e-navigation, GPS-based logistics, artificial intelligence in routing, or cost optimization are only mere examples of what can be achieved when traditional transportation approaches are boosted by aptly applied computer technologies. Despite the fact that a significant part of maritime industry has already been somehow IT-supported, there are still issues and aspects waiting to be solved, implemented, deployed, or improved.

A well-known problem of any interdisciplinary research is a lack of common understanding between the specialists. In technical sciences, often there are multiple discipline-specific terms that might be unclear to researches from other fields. An AI solution applied to marine technology may be misunderstood by IT researchers as well as mariners. The former might not be aware of the problem's roots and organizational or legal constraints (e.g., COLREGs), while the latter would be puzzled with terms such as "metaheuristic". Thus, it is crucial to establish a communication platform and knowledge exchange. Any interdisciplinary meeting or publication is a step forward. And this precisely is the root of the "Modeling, Computing and Data Handling Methodologies for Maritime Transportation" volume.

This volume comprises of seven chapters proposing solid IT-based models and systems in various maritime transportation fields, ranging from shipping safety and security issues to maritime logistics optimization. Three of the chapters are extended versions of papers from the 1st Workshop on Modeling, Computing and Data Handling for Marine Transportation (MCDMT 2015) in association with the 6th International Conference on Information, Intelligence, Systems and Applications (IISA 2015), July 6–8, 2015, Corfu, Greece. Such workshops as

MCDMT are great opportunities to fully integrate transportation and computer science worlds and may contribute to innovation breakthrough in the field. I am happy to notice such initiatives and waiting in anticipation what the next edition of the workshop will bring.

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Preface

Maritime transportation is a major conduit of international trade. In terms of cost, maritime transport is very competitive against land and airborne transport, increasing only by a few percent the total product cost. On the other hand, it takes longer and may cause harbor congestion which may further increase the voyage time. Furthermore, there are difficulties in integrating this transportation mode efficiently with other transport or distribution options. On top of these, the safety and the environmental impact of maritime transportation, in particular in the case of sea accidents, are always two challenging issues.

Recent advances on maritime transportation require the synergy of both computer and maritime science. Computational intelligence, data mining and knowledge discovery/representation, risk assessment methodologies, as well as combinatorial optimization are the IT fields that have gained significant interest in maritime studies because of their potential in giving solutions for effective sea transportation. This edited volume focuses on research works related to the latest developments of IT methodologies for maritime transportation, and it comes after the successful organization of the the 1st and 2nd Workshop on Modeling, Computing and Data Handling for Marine Transportation (MCDMT 2015 and MCDMT 2016) which were held in association with the 6th and 7th International Conference on Information, Intelligence, Systems and Applications (IISA 2015 and IISA 2016). Seven chapters describing modeling tools, methodologies, algorithms, and systems comprise this edited volume as follows:

Chapters 1 and 2 consider two important problems in maritime logistics pertaining to quayside operational planning. Quayside problems include the Berth Allocation Problem (BAP) which determines the berths that incoming vessels are assigned to, the Quay Crane Assignment Problem, whereby the required cranes are assigned to each ship, and the Quay Crane Scheduling Problem (QCSP) where scheduling of crane tasks takes place. Chapter 1 considers a variation of BAP, namely the Minimum Cost Hybrid BAP (MCHBAP) with fixed handling times of vessels. The objective function to be minimized includes the cost of positioning, the speeding up or waiting, and the tardiness of completion for all vessels. A number of metaheuristics are surveyed, and a general variable neighborhood search

approach is proposed. The metaheuristics are evaluated on real-life and randomly generated instances. Chapter 2 considers the problem of vessel stability during the process of unloading and/or loading containers onto vessels. The quay crane scheduling process determines the operational profile of each quay crane in terms of the container tasks and timing. The literature on the QCSP and related problems pertaining to quayside operational planning is surveyed considering vessel stability constraints to allow for quay crane schedules that can be used in practice, and directions are provided for future work in the area.

Chapters 3 and 4 focus on maritime routing problems. Specifically, Chap. 3 presents an extensive computational study of simple, but prominent metaheuristics to find high-quality ship schedules and inventory policies for a class of maritime inventory routing problems. Several variants of rolling horizon heuristics, K-opt heuristics, local branching, solution polishing, and hybrid metaheuristics are compared. Many of them substantially outperform the commercial mixed-integer programming solvers. Chapter 4 presents evolutionary algorithms for solving the real-time ship weather routing problem. The objectives to be minimized are the mean total risk and the fuel cost incurred along the obtained route while considering the time-varying sea and weather conditions and also a constraint on the total voyage time. The proposed approaches return only solutions compliant with the guidelines of the International Maritime Organization (IMO) and are tested on real data and also compared with an exact algorithm which solves the same problem.

Chapters 5 and 6 present decision support systems for safe shipping and seaport's security. In particular, Chap. 5 describes a decision support tool for environmentally safe shipping focusing on extracting aggregated statistics using spatial analysis of multilayer information, namely vessel trajectories, vessel data, and information regarding environmentally important areas. The proposed system includes preprocessing, clustering of trajectories based on their spatial similarity, and risk assessment employing probabilistic models. Applications are presented in areas such as queries in protected areas and marine traffic monitoring for environmental safety. Chapter 6 presents a decision support system for the assessment of seaports' security employing a flexible approach to evaluate the performance of security measures. A fuzzy analytical hierarchy process is utilized to analyze the complex structure of a seaport system and determine the weights of security measures while evidential reasoning is used to synthesize the risk analysis. The approach may provide analysts with a flexible tool to develop and employ robust resilience strategies aimed at enhancing seaport security in a systematic manner.

Finally, Chap. 7 presents a step-by-step development of a model which simulates maritime traffic in Bosporus, Turkey. The model demonstrates the relationships between sea traffic rules, number of pilots, and waiting times. It is expected that the presentation of the process for building a simulation model will be a useful guide for model builders in the maritime transportation domain.

From our position, we wish to thank Prof. George Tsichritzis for his constant support and help during the preparation of this volume. We would also like to thank all the authors for their contributions and the reviewers for their assessment of the chapters. We hope that the readers will find the contents of this edited volume interesting and useful.

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Abbreviations

ADP	Approximate Dynamic Programming
AHP	Analytical Hierarchy Process
AIS	Automatic Identification System
B&P	Branch and Price
BAP	Berth Allocation Problem
BCO	Bee Colony Optimization
BPGS	Branch-and-Price Guided Search
CBP	Customs and Border Protection agency
CDDA	Common Database on Designated Area
CMI	Critical Maritime Infrastructure
COTS	Commercials Off the Shelf
CRP	Container Relocation Problem
CSI	Container Security Initiative
CSO	Company Security Officer
CTOS	Container Terminal Operating System
C-TPAT	Customs-Trade Partnership Against Terrorism Initiative
DBAP	Discrete Case Berth Allocation Problem
DES	Discrete Event Simulation
DNV	Det Norske Veritas
DTED	Digital Terrain Elevation Data
EA	Evolutionary Algorithm
EDI	Electronic Data Interchange
ER	Evidential Reasoning
ES	Event Scheduling
ETA	Event Tree Analysis
FAHP	Fuzzy Analytical Hierarchy Process
FSA	Formal Safety Assessment
FTA	Fault Tree Analysis
GA	Genetic Algorithm
GIS	Geographical Information System

GVNS	General Variable Neighborhood Search
HBAP	Hybrid layout Berth Allocation Problem
IAT	Inter-Arrival Time
IED	Improvised Explosive Device
IMO	International Maritime Organization
IMTS	Index of Maritime Traffic Situation
IPT	Inter-Ping Time
IRP	Inventory Routing Problem
ISF	Importer Security Filing
ISPS	International Shipboard and Port Facility Security
KML	Keyhole Markup Language
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
LRIT	Long-Range Identification and Tracking System
MADA	Multiple Attribute Decision Analysis
MaritimeSim	Maritime Simulation Model
MCHBAP	Minimum Cost Hybrid Berth Allocation Problem
MILP	Mixed-Integer Linear Programming
MIP	Mixed-Integer Program
MIRP	Maritime Inventory Routing Problem
MIRPLib	Maritime Inventory Routing Problem Library
MOGA	Multi-Objective Genetic Algorithm
MSRAM	Maritime Security Risk Analysis Model
MT	Maritime Transportation
MTSA	Maritime Transportation Security Act
MTSS	Maritime Traffic Simulation System
NII	Non-Intrusive Inspection
NSGA	Non-dominated Sorting Genetic Algorithm
OR/MS	Operational Research/Management Science
OVCF	Ocean Vessel Carrier Filing
PFSO	Port Facilities Security Officer
PRA	Probabilistic Risk Analysis
QC	Quay Crane
QCAP	Quay Crane Assignment Problem
QCASP	Quay Crane Assignment and Scheduling Problem
QCSP	Quay Crane Scheduling Problem
RFID	Radio Frequency Identification
RHH	Rolling Horizon Heuristic
SC	Straddle Carrier
SPEA	Strength Pareto Evolutionary Algorithm
TFN	Triangular Fuzzy Number
TSS	Traffic Separation Scheme
TSVTS	Turkish Strait Vessel Traffic Service
VGO	Vacuum Gas Oil
VMI	Vendor-Managed Inventory

VND	Variable Neighborhood Descent
VTIS	Vessel Tracking and Information System
VTMIS	Vessel Traffic Management and Information System
WMD	Weapons of Mass Destruction