

Internet of Things in urban waste collection

Original

Internet of Things in urban waste collection / Fadda, Edoardo; Perboli, Guido; Rosano, Mariangela; Tadei, Roberto. -
ELETTRONICO. - (2017), pp. 10-12. (MIC 2017 - The 12th edition of the Metaheuristics International Conference (MIC
2017) and the XII Metaheurísticas, Algoritmos Evolutivos y Bioinspirados (MAEB 2017) Barcelona July 4-7, 2017).

Availability:

This version is available at: 11583/2681207 since: 2017-09-22T12:37:54Z

Publisher:

Universitat Pompeu Fabra

Published

DOI:

Terms of use:

This article is made available under terms and conditions as specified in the corresponding bibliographic description in
the repository

Publisher copyright

(Article begins on next page)



Welcome

Dear Colleagues and Friends,

Welcome to Barcelona and to the joint MIC'2017/MAEB conferences. It is our great pleasure to have you here and would like to wish you a pleasant stay in this beautiful city and a fruitful conference.

MIC is now in its 12th edition. Since the first unforgettable meeting in Colorado, it has crossed almost all Continents and, in each new edition, has successfully attracted several new researches with extremely interesting research topics. For MIC'2017, we believe that tradition will not change – we will receive again many old friends that have been present in most of this conference's editions, and younger researchers that will continue to explore this topic in the future and show its potential, both from a theoretical and a practical point of view.

MAEB 2017 represents the 12th edition of a Spanish conference devoted to be a forum for the exchange, discussion and knowledge transference of researchers in the area of Metaheuristics and Evolutionary Algorithms. Since the first meeting in 2002, it has crossed almost all Autonomous Communities in Spain, being the witness of the evolution of the research area. MAEB 2017 covers a wide variety of topics, including methodological contributions and applications for problem solving

In MIC 2017/MAEB there will be presentations covering a wide range of subjects – over 200 high quality presentations, enriched by the presence of four keynote speakers: Paola Festa, Rafel Martí, Manuel Laguna, José Andrés Moreno Pérez and a Discussion Panel in Industrial Applications with the collaboration of Mauricio Resende (Amazon), Nuria Oliver (Vodafone), Ricardo Baeza (NTENT), Henning Wagner (Rhenus), Kristof Roomp (Microsoft) and Enrique Alfonseca (Google). We are also very grateful to all authors for contributing to the success of the conferences. We hope that this selection will provide each of you with opportunities to exchange research ideas with other colleagues and to start new collaborations.

Barcelona is a multicultural and cosmopolitan city in the south of Europe. If you enjoy culture, sports, good weather, shopping, gastronomy, etc... Barcelona is the city to visit!

At this moment, we would also like to publicly acknowledge the Program Committee Members and Clusters organizer - the high quality of the programs is also due to their strong engagement in the reviewing process. We are also grateful to all sponsors, for the financial support provided, all members of the organization committee and employees of UPF that without their help will be not possible to organize it, and all colleagues that accept to participate, which greatly enhances the quality of both conferences.

We wish you all a very productive conference and a pleasant and fruitful stay in Barcelona.

Abraham Duarte, Universidad Rey Juan Carlos
Ana Viana, INESC TEC/ISEP, Portugal
Angel Juan, Universitat Oberta de Catalunya
Belén Mélian, Universidad de La Laguna
Helena Ramalhinho, Universitat Pompeu Fabra.



MIC 2017

The 12th edition of the Metaheuristics International Conference (MIC 2017) and the XII Metaheurísticas, Algoritmos Evolutivos y Bioinspirados (MAEB 2017) will be held in Barcelona, Spain, from the 4th to 7th July 2017.

The MIC conference series was established in 1995 and this is its 12th edition. MIC is the main event focusing on the progress of the area of Metaheuristics and their applications. As in previous editions, MIC 2017 will provide an opportunity to the international research community in Metaheuristics to discuss recent research results, to develop new ideas and collaborations, and to meet old and make new friends in a friendly and relaxed atmosphere.

Presentations covering all aspects of Metaheuristic research such as new algorithmic developments, industrial applications, new research challenges, theoretical developments, implementation issues, in-depth experimental studies, hybrid metaheuristics, etc. are welcome.

The MIC 2017 will be organized jointly with the MAEB (Metaheurísticas, Algoritmos Evolutivos y Bioinspirados), the most well-known conference in the area of Metaheuristics, Evolutionary and Bio-Inspired Algorithms.

Topics of Interest

Topics of interest include, but are not limited to:

- **Techniques** such as tabu search, simulated annealing, iterated local search, variable neighborhood search, bio-inspired algorithms, memory-based optimization, evolutionary algorithms, memetic algorithms, ant colony optimization, particle swarm optimization, scatter search, path relinking, hybrid metaheuristics, simheuristics, matheuristics, etc. Including techniques that enhance the usability and increase the potential of metaheuristic algorithms such as parallelization of algorithms, reactive search mechanisms for self-tuning, offline metaheuristic algorithm configuration techniques, algorithm portfolios, etc.
- **Empirical and Theoretical Research** in metaheuristics including large-scale experimental analyses, algorithm comparisons, new experimental methodologies, engineering methodologies for stochastic local search algorithms, search space analysis, theoretical insights into properties of metaheuristic algorithms. Including applications of well-known and classical problems as Traveling Salesman Problem, Vehicle Routing Problems, Scheduling Problems, Location Problems, etc.
- **Industrial Applications** of metaheuristics in fields such as transportation, health care, bioinformatics, data mining, planning and scheduling, production and operations management, economics, marketing, telecommunications, logistics and supply chains, etc. Particularly, it is welcomed are innovative applications of metaheuristics with high impact in real business and organization.
- Contributions on the **Interface of Metaheuristics** with other disciplines, such as agent-based models, integer programming, constraint programming, machine learning, deep learning, etc.
- **Challenging New Problems** such as big data and large-scale optimization problems, multi-objective, stochastic, dynamic problems and new challenge problems.

MIC 2017

Committee

Steering Committee

Fred Glover, University of Colorado and OptTek Systems, USA
Celso Ribeiro, Universidade Federal Fluminense, Brazil
Éric Taillard, University of Applied Sciences of Western Switzerland, Switzerland
Stefan Voss, University of Hamburg, Germany

Program Committee

Ana Viana (Chair of the Program Committee MIC 2017), INESC TEC/ISEP, Portugal
Abdelkader Sbihi, Ecole de Management de Normandie, France
Abraham Duarte, Universidad Rey Juan Carlos, Spain
Amir Nakib, Université Paris Est, France
Andrea Lodi, Università degli Studi di Bologna, Italy
Andrea Schaerf, Università degli Studi di Udine, Italy
Andreas Reinholz, German Aerospace Center (DLR), Germany
Andrei Tchernykh, CICESE Research Center, Mexico
Angel A. Juan, Open University of Catalonia, Spain
Bruce Golden, University of Maryland, USA
Christine Currie, University of Southampton, UK
Christine Solnon, INSA de Lyon, France
Christoph Laroque, Zwickau University, Germany
Daniel Guimarans, Amsterdam University of Applied Sciences, The Netherlands
Djamila Ouelhadj, University of Portsmouth, United Kingdom
Eduardo Prado, Universidad Politecnica de Madrid, Spain
El-Ghazali Talbi, University of Lille, France
Erwin Pesch, Universität Siegen, Germany
Fabien Lehuédé, École des Mines de Nantes, France
Farouk Yalaoui, Université Technologique de Troyes, France
Francisco Rodriguez, Universidad de Granada, Spain
Geir Hasle, SINTEF, Norway
Graham Kendall, University of Nottingham, United Kingdom
Guenther Raidl, TU Wien, Austria
Helena Ramalinho, Universitat Pompeu Fabra, Spain
Ibrahim Osman, American University of Beirut, Lebanon
Jacek Blazewicz, University of Poznan, Poland
Jacques Teghem, Université de Mons, Belgium
Jairo Montoya-Torres, Universidad de Los Andes, Colombia
Jakob Puchinger, Austrian Institute of Technology, Austria
Javier Faulin, Universidad Pública de Navarra, Spain
Jin-Kao Hao, University of Angers, France
Johann Hurink, University of Twente, Netherlands
Jorge E. Mendoza, Université de Tours, France
José Fernando Oliveira, Universidade do Porto/INESC TEC, Portugal
Karl Dörner, Johannes Kepler University Linz, Austria
Kenneth Sörensen, Universiteit Antwerpen, Belgium
Laetitia Jourdan, University of Lille 1, INRIA Lille, France
Lionel Amodeo, Université Technologique de Troyes, France

Luca Di Gaspero, Università degli Studi di Udine, Italy
Lyes Benyoucef, University of Marseille, France
Marc Sevaux, Université de Bretagne-Sud, France
Marco Caserta, Universität Hamburg, Germany
Marco Chiarandini, Syddansk Universitet, Denmark
Mario Pavone, University of Catania, Italy
Markus Rahe, Technical University Dortmund, Germany
Martin Gomez-Ravetti, Universidade Federal de Minas Gerais, Brazil
Matthias Prandstetter, Austrian Institute of Technology, Austria
Mauricio Resende, Amazon, USA
Mauro Dell'Amico, Università degli Studi di Modena e Reggio Emilia, Italy
Michael Trick, Carnegie Mellon, University USA
Michel Gendreau, École Polytechnique de Montréal, Canada
Mutsunori Yagiura, Nagoya University, Japan
Nenad Mladenovic, LAMIH, University of Valenciennes, France
Nicolas Monmarché, Université de Tours, France
Nicolas Zufferey, University of Geneva, Switzerland
Noureddine Melab, University of Lille, France
Nysret Musliu, Technische Universität Wien, Austria
Paola Festa, Università degli Studi di Napoli, Italy
Paolo Toth, Università degli Studi di Bologna, Italy
Pascal Van Hentenryck, NICTA and University of Melbourne, Australia
Patrick DeCausmaecker, University of Gent, Belgium
Patrick Hirsch, University of Natural Resources and Life Sciences, Austria
Patrick Siarry, Université Paris-Est Créteil, France
Peter Greistorfer, Karl-Franzens-Universität Graz, Austria
Rachid Chelouah, EISTI Cergy-Pontoise, France
Rachid Ellaia, EMI Univeristy Agdal, Morocco
Rafael Martí, Universitat de València, Spain
Rhyd Lewis, Cardiff University, United Kingdom
Richard Hartl, Universität Wien, Austria
Rubén Ruiz, Universidad Politécnica de Valencia, Spain
Silvano Martello, Università degli Studi di Bologna, Italy
Simona Martins, Universidade Federal Fluminense, Brazil
Sophie N. Parragh, Vienna University of Economics and Business, Austria
Thomas Jansen, University College Cork, Ireland
Thomas Stützle, Université Libre de Bruxelles, Belgium
Tommaso Urli, Università degli Studi di Udine, Italy
Vittorio Maniezzo, Università degli Studi di Bologna, Italy
Walter Gutjahr, Universität Wien, Austria

MAEB 2017

XII Congreso Español de Metaheurísticas, Algoritmos Evolutivos y Bioinspirados (MAEB 2017)

El congreso nacional sobre Metaheurísticas, Algoritmos Evolutivos y Bioinspirados (MAEB) pretende ser un foro de encuentro, discusión y transferencia de conocimiento entre investigadores en el campo de las metaheurísticas y los algoritmos bioinspirados, con el fin de presentar e intercambiar experiencias y resultados. La XII edición, MAEB'2017, se celebrará en Barcelona, junto con XII Metaheuristic International Conference (MIC 2017).

Temas

Son trabajos de interés en este congreso los que aborden alguna de las siguientes metodologías de resolución de problemas de optimización (las siglas corresponden a su denominación original en inglés) o sus aplicaciones a la resolución de problemas:

ACO: Algoritmos basados en colonias de hormigas

CE: Entropía cruzada

CLA: Algoritmos de clasificación y aprendizaje

CP: Programación por restricciones

CH: Heurísticas cooperativas

DE: Evolución diferencial

ECO: Computación evolutiva

EDA: Algoritmos basados en estimación de distribuciones

EE: Estrategias evolutivas

EP: Programación evolutiva

FMH: Metaheurísticas basados en lógica difusa

GA: Algoritmos genéticos

GLS: Búsqueda local guiada

GP: Programación genética

GRASP: Procedimientos voraces aleatorizados

HA: Algoritmos híbridos

HH: Hyperheurísticas

ILS: Búsqueda local iterada

IS: Algoritmos basados en el sistema inmunitario

MA: Algoritmos meméticos

MOMH: Metaheurísticas multiobjetivo

MTH: Metaheurísticas

NC: Computación natural

NN: Redes Neuronales

PA: Algoritmos paralelos y distribuidos

PR: Re-encadenamiento de trayectorias

PSO: Algoritmos basados en nubes de partículas

SA: Enfriamiento simulado

SI: Algoritmos basados en sociedades/enjambres

SS: Búsqueda dispersa

TS: Búsqueda tabú

VNS: Búsqueda de entornos variable

MAEB 2017

Committee

Steering Committee

Enrique Alba, Universidad de Málaga
Abraham Duarte, Universidad Rey Juan Carlos
Francisco Fernández, Universidad de Extremadura
José Antonio Gámez, Universidad de Castilla la Mancha
Francisco Herrera, Universidad de Granada
César Hervás, Universidad de Córdoba
J. Ignacio Hidalgo, Universidad Complutense de Madrid
Rafael Martí, Universidad de Valencia
Juan Julián Merelo, Universidad de Granada
José A. Moreno, Universidad de La Laguna
Luciano Sánchez, Universidad de Oviedo

Program Committee

Belén Mélian (Chair of the Program Committee MAEB 2017),
Universidad de La Laguna
Abraham Duarte, Universidad Rey Juan Carlos
Ada Álvarez, Universidad Autónoma de Nuevo León
Alberto Fernández, University of Granada
Alejandro Rosete-Suárez, Instituto Superior Politécnico “José Antonio Echevarría”, CUJAE
Alexander Mendiburu, The University of the Basque Country
Álvaro Rubio-Largo, Universidad de Extremadura
Amelia Zafra, Universidad de Córdoba
Ana Viana, INESC Porto/ISEP
Angel Juan, Open University of Catalonia
Ángel Corberán, Universidad de Valencia
Ángel Udías, Universidad Rey Juan Carlos
Anna Esparcia, Universidad Politécnica de Valencia
Antonio González, Universidad de Granada
Antonio Mora-García, Universidad de Granada
Antonio Peregrín, Universidad de Huelva
Antonio J. Nebro, Universidad de Málaga
Antonio J. Fernández, Universidad de Málaga
Belen Melian, Universidad de La Laguna
Bernabé Dorronsoro, Universidad de Cádiz
Carlos García, Universidad de Córdoba
Carlos Cotta, Universidad de Málaga
Carlos A. Coello, CINVESTAV-IPN
Carlos Andrés Romano, Universidad Politécnica de Valencia
Cesar Hervás, Universidad de Córdoba
Christian Blum, Consejo Superior de Investigaciones Científicas
Christopher Expósito-Izquierdo, Universidad de La Laguna
Daniel Molina, Universidad de Cádiz
Dario Landa-Silva, The University of Nottingham
David Camacho, Universidad Autónoma de Madrid
David Pelta, Universidad de Granada
David L. González-Álvarez, Universidad de Extremadura
Eduardo G. Pardo, Universidad Politécnica de Madrid
Enrique Alba, Universidad de Málaga

first name last name, organization
Francisco Luna, Universidad de Málaga
Francisco Parreño, Universidad de Castilla-La Mancha
Francisco Chicano, Universidad de Málaga
Francisco Chavez, Universidad de Extremadura
Francisco Fernández, Universidad de Extremadura
Francisco Almeida, Universidad de La Laguna
Francisco Herrera, Universidad de Granada
Francisco Javier Elorza, Universidad Politécnica de Madrid
Gabriel Villa, Universidad de Sevilla
Gabriel Winter, Universidad de las Palmas de Gran Canaria
Gabriel J. Luque, Universidad de Málaga
Helena Ramalinho, Universitat Pompeu Fabra
Isaac Triguero, The University of Nottingham
J. Marcos Moreno, Universidad de La Laguna
Jaume Bacardit, The University of Nottingham
Javier Faulin, Universidad Pública de Navarra
Javier Sánchez-Monedero, Universidad de Córdoba
Jesús Sánchez-Oro, Universidad Rey Juan Carlos
Jesús Aguilar, Universidad Pablo de Olavide
Joaquín Pacheco, Universidad de Burgos
Joaquín Bautista, Universitat Politécnica de Catalunya
Jorge Casillas, Universidad de Granada
José Egea, Universidad Politécnica de Cartagena
José Otero, Universidad de Oviedo
José Riquelme, Universidad de Sevilla
Jose A. Lozano, Universidad del País Vasco
José A. Moreno, Universidad de La Laguna
José Antonio Gámez, Universidad de Castilla-La Mancha
José Ignacio Hidalgo, Universidad Complutense de Madrid
Jose Luis Risco-Martín, Universidad Complutense de Madrid
José Luis González-Velarde, Tecnológico de Monterrey
José Luis Verdegay, Universidad de Granada
José M. Granado-Criado, Universidad de Extremadura
José Manuel Cadenas, Universidad de Murcia
José Manuel Colmenar, Universidad Rey Juan Carlos
José Manuel Benítez, Universidad de Granada
José María Luna, Dept. of Computer Science and Numerical Analysis
José Miguel Puerta, Universidad de Castilla-La Mancha
Josep M. Garrell, Universitat Ramon Llull
Juan Lanchares, Universidad Complutense de Madrid
Juan Villegas, Universidad Autónoma Metropolitana
Juan A. Gómez, Universidad de Extremadura
Juan J. Pantrigo, Universidad Rey Juan Carlos
Juan Julián Merelo, Universidad de Granada
Juan R. Rabuñal, Universidade da Coruña
Julián Dorado, Universidade da Coruña
Julián Molina, Universidad de Málaga
Julio Brito, Universidad de La Laguna

Organization Committee

Conference Chairs

Julio Ortega, Universidad de Granada
Julio R. Banga, Consejo Superior de Investigaciones Científicas
Leonardo Trujillo, Instituto Tecnológico de Tijuana
Lourdes Araujo, UNED

Luciano Sánchez, Universidad de Oviedo
Luis de La Ossa, Universidad de Castilla-La Mancha

Luis Magdalena, Universidad Politécnica de Madrid

M. Elena Pérez, Universidad de Valladolid

Manuel Laguna, University of Colorado

Manuel Lozano, Universidad de Granada

María Albareda, Universidad Politécnica de Cataluña

María Pérez-Ortíz, Universidad de Córdoba

María Del Carmen Pegalajar, Universidad de Granada

María José Del Jesús, Universidad de Jaén

Mario Garcia, Instituto Tecnológico de Tijuana

Miguel Ángel-Vega, Universidad de Extremadura

Nicolás García, University of Córdoba

Oscar Cordón, Universidad de Granada

Pablo Moscato, The University of Newcastle

Pedro Larrañaga, Universidad Politécnica de Madrid

Pedro González, Universidad de Jaén

Pedro Villar, Universidad de Granada

Pedro A. Castillo, Universidad de Granada

Pedro Antonio Gutiérrez, Universidad de Córdoba

Rafael Martí, Universidad de Valencia

Rafael Caballero, Universidad de Málaga

Rafael M. Luque-Baena, Universidad de Extremadura

Ramón Álvarez-Valdés, Universidad de Valencia

Raúl Giraldez, Universidad Pablo de Olavide

Richard Duro, Universidade da Coruña

Roberto Santana, Universidad del País Vasco

Roger Ríos, Universidad Autónoma de Nuevo León

Rubén Ruiz, Universidad Politécnica de Valencia

Salvador García, Universidad de Granada

Sancho Salcedo, Universidad de Alcalá

Sebastián Ventura, Department of Computer Sciences and Numerical Analysis

Sergio Santander-Jiménez, Universidad de Extremadura

Sergio Damas, European Centre for Soft Computing

Thomas Stützle, Université Libre de Bruxelles (ULB)

Vicente Campos, Universidad de Valencia

Víctor Rivas, Universidad de Jaén

Yago Sáez, Universidad Carlos III de Madrid

Abraham Duarte (URJC – Universidad Rey Juan Carlos)

Angel A. Juan (UOC – Universitat Oberta de Catalunya)

Helena Ramalinho Lourenço (UPF – Universitat Pompeu Fabra)

Local Committee Chairs

Jésica de Armas (UPF – Universitat Pompeu Fabra)

Montserrat Guillem (UB – Universitat de Barcelona)

Special Issues Chair

Christian Blum (CSIC-Spanish National Research Council)

Social Media Chair

Àlex Grasas (EADA Business School)

Vera Pujadas

Proceedings and Posters Chairs

Alejandra Cabañas (UAB – Universitat Autònoma de Barcelona)

Carles Serrat (UPC – Barcelona Tech)

Isabel Serra (CRM – Centre de Recerca Matemàtica)

Maria Albareda (UPC – Barcelona Tech)

Organization Team

Adela Pagés (UdL – Universitat de Lleida)

Carlos Quintero (UOC – Universitat Oberta de Catalunya)

Eduardo García Pardo (UPM – Universidad Politécnica de Madrid)

Eliana González (UOC – Universitat Oberta de Catalunya)

Elisa Alós (UPF – Universitat Pompeu Fabra)

Fatos Xhafa (UPC – Barcelona Tech)

Gema Calleja (UPC – Barcelona Tech)

Javier Panadero (UOC – Universitat Oberta de Catalunya)

Jesús Sánchez-Oro Calvo (URJC – Universidad Rey Juan Carlos)

José Manuel Colmenar Verdugo (URJC – Universidad Rey Juan Carlos)

Laura Calvet (UOC – Universitat Oberta de Catalunya)

Lorena Reyes (UOC – Universitat Oberta de Catalunya)

Marcelus Fabri (UPF – Universitat Pompeu Fabra)

Sara Hatami (UOC – Universitat Oberta de Catalunya)

Stephanie Alvarez (UOC – Universitat Oberta de Catalunya)

Thays Oliveira (UPF – Universitat Pompeu Fabra)

Vitor Coelho (UPF – Universitat Pompeu Fabra)

Metaheuristics: Proceeding of the MIC and MAEB 2017 Conferences

Editors

Abraham Duarte, Universidad Rey Juan Carlos
Ana Viana, INESC TEC/ISEP, Portugal
Angel Juan, Universitat Oberta de Catalunya
Belén Mélian, Universidad de La Laguna
Helena Ramalinho, Universitat Pompeu Fabra

Editorial: Universitat Pompeu Fabra
Barcelona, Spain June 2017
ISBN: 978-84-697-4275-1
Depósito Legal: B 16502-2017
© Universitat Pompeu Fabra

Contents

MIC Submissions	1
1 Industrial Applications	1
1.1 Tabu search and matheuristic algorithms for solving an integrated flow shop and vehicle routing problem	2
2 Metaheuristics in Healthcare	5
2.1 A GRASP algorithm for scheduling emergency room physicians	6
3 Smart Cities	9
3.1 Internet of Things in urban waste collection	10
3.2 Enabling Low Cost Smart Road Traffic Sensing	13
3.3 Travel Assistance Application for Seniors	16
3.4 Beacon-based solution for dynamic traffic light man- agement	24
3.5 Hybrid Metaheuristics for Multiobjective Thermal and Electrical Energy Management in a Smart Home	34
4 Metaheuristics in Cutting and Packing	37
4.1 A heuristic approach for the Pallet Building and Load- ing Problem	38
5 Air Transportation and Airport Logistics	44
5.1 A Simple and Efficient Metaheuristic for the Dynamic Flight Scheduling Problem	45
5.2 A simheuristic approach for solving the Aircraft Re- covery Problem with stochastic delays	48
6 Iterated Local Search	51
6.1 The Graph Edit Distance Problem treated by the Local Branching Heuristic	52
7 Metaheuristics in Education	62
7.1 Introducing Metaheuristics in an e-learning Course on Distributed Systems	63

	7.2	Teaching metaheuristics online: experiences at the Open University of Catalonia	66
8		Ph.D Colloquium	69
	8.1	A neighborhood for the blocking job-shop problem embedded in a simulated annealing	70
	8.2	Routes design from warehouses towards the delivery points	73
	8.3	Scheduling of a line manager using Iterated Local Search	76
	8.4	Cyclic Cutwidth Minimization Problem	79
9		Metaheuristics in Cloud Computing	82
	9.1	Evolutionary planning for IaaS virtual brokering in the cloud	83
	9.2	Evaluating a Two-Phase Virtual Machine Placement Optimization Scheme for Cloud Computing Datacenters	93
	9.3	A Brokering Approach for Multi-Objective Resource Allocation in Cloud Computing	103
10		GRASP	105
	10.1	A GRASP with restarts heuristic for the Steiner traveling salesman problem	106
	10.2	A GRASP for the Max Cut-Clique Problem	116
	10.3	Introducing biased randomization in GRASP	119
	10.4	GRASP for the Weighted Target Set Selection problem	122
	10.5	Generalized GRASP for Mixed-Integer Nonlinear Optimization	132
11		MIC General Session	141
	11.1	Gravitational search algorithm (GSA) with linearly decreasing gravitational constant for parameter estimation of photovoltaic cells	142
	11.2	A mapping technique to improve solutions for a Multi-Objective Resource Constraint Project Scheduling Problem	148
	11.3	An iterative heuristic algorithm for the Aircraft Landing Problem with multiple runways	158
	11.4	A combined approach for analysing heuristic algorithms	161
	11.5	A percentile transition ranking algorithm applied to knapsack problem	164
	11.6	Subdividing Labeling Genetic Algorithm: A New Method for Solving Continuous Nonlinear Optimization Problems	174
	11.7	A local search-based multi-objective metaheuristic for biclustering on heterogeneous data	176

11.8	A metaheuristic algorithm using chaotic neurodynamics with degree information for the dynamic combinatorial optimization problem: a packet routing problem	186
11.9	A Population-Based Iterated Greedy Algorithm for the Knapsack Problem with Setup	189
11.10	A differential evolution algorithm for single model U-type assembly line balancing problem	197
11.11	Identifying the critical needs of production and maintenance as integrated systems, in order to build a management tool	206
11.12	Strategic planning of maintenance work of a large-scale tramway network	212
11.13	Grid-Based Parameter Adaptation in Particle Swarm Optimization	215
11.14	Optil.io Platform: Evaluation as a Service for Metaheuristics	225
11.15	Extending time-to-target plots to multiple instances and targets: mttt-plots	228
11.16	TSP Neighbourhood Reduction with POPMUSIC	237
11.17	Minimum Labelling bi-Connectivity	241
11.18	On the minimum quartet tree cost problem	244
11.19	Hybridizing Particle Swarm Optimization Variants on Continuous Optimization Functions	247
11.20	An Investigation of the Generalized Assignment Problem from the Perspective of Generalized Optimization	257
11.21	Computing Short Edge-Flipping Sequences Between Triangulations: a Heuristic Approach	267
11.22	A hybrid algorithm based on Particle Swarm Optimization and Tabu Search for the Maximum Diversity Problem	276
11.23	Can single-objective metaheuristics efficiently solve multi-objective problems?	286
11.24	An $O(E)$ -linear Model for the Maxcut Problem	289
11.25	Optimization of dynamic pricing issues in manufacturing industry: coordination of pricing and production decisions	302
11.26	On the comparison of CMSA versus LNS for solving Combinatorial Optimization problems with different solution sizes	307
11.27	A Hybrid Random Key Symbiotic Organism Search Algorithm for the Quadratic Assignment Problem	310

11.28	A Multi-Start Algorithm with Intelligent Neighborhood Selection	317
11.29	Tabu search for the RNA partial degradation problem .	320
11.30	Heuristics for the Dynamic Bipartite Drawing Problem	333
12	Sports and Metaheuristics	336
12.1	Referee Assignment for a Basketball League with Multiple Divisions using Local Search	337
13	Finance	340
13.1	A Simulation-enriched Variable Neighborhood Search for the Stochastic Project Portfolio Selection Problem .	341
13.2	An improved Cuckoo Search Algorithm for the cardinality constraint portfolio optimization problem	344
14	Variable Neighborhood Search	353
14.1	Solving the Steiner Tree Problem in graphs with Variable Neighborhood Descent	354
14.2	A variable neighborhood search for single machine scheduling problem with time restrictions	363
14.3	Online Order Batching Problem	366
14.4	A Parallel Variable Neighborhood Search Approach for the Obnoxious p-Median Problem	369
15	Metaheuristics in Nonsmooth Nonconvex Optimization and Applications	372
16	Metaheuristics in Retail Operations	372
16.1	An ALNS for solving the MCVRP with Product-Specific Time-Windows Assignment	373
16.2	Solution Approaches for the Consideration of Loading Constraints for MCVRP	376
17	Tabu Search	379
17.1	A tabu search algorithm for the multi-vehicle covering tour problem	380
17.2	Tabu Search with Path-Relinking for the Quadratic Assignment Problem	383
17.3	Dynamic Scalable Models in Simulation Optimization: Optimizing Heliostat Positions for Solar Power Tower Plants	386
17.4	Variable neighborhood tabu search for the vertex bisection minimization problem	389
17.5	Unrelated Parallel Machine Selection and Job Scheduling with the Objective of Minimizing Total Workload and Machine Fixed Costs, in Presence of Outsourcing .	392

17.6	A Simple Multi-Wave Algorithm for the Uncapacitated Facility Location Problem	395
17.7	Probabilistic Tabu Search for the Cross-Docking Assignment Problem	398
18	Metaheuristics and Machine Learning	401
18.1	Setting the Number of Simulation Runs in a Simheuristic Algorithm: a statistical-based approach	402
19	Scheduling	411
19.1	An efficient algorithm based on metaheuristic for the no-wait flowshop scheduling problem	412
19.2	An efficient algorithm based on metaheuristic for the permutation flowshop scheduling problem	422
19.3	An Iterated Greedy-based Approach Exploiting Promising Sub-Sequences of Jobs to solve the No-Wait Flowshop Scheduling Problem	432
19.4	Artificial Immune Systems based Astronomy Scheduling	442
19.5	A new migrating birds optimization algorithm to solve a permutation flowshop problem	452
19.6	A Metaheuristic Approach for Scheduling Steelmaking and Casting Plants	460
19.7	An Enhanced Iterated Greedy Metaheuristic for the Particle Therapy Patient Scheduling Problem	463
19.8	A hybrid memetic algorithm for parallel machine scheduling problems with deteriorating effects	473
19.9	Algoritmos Constructivos Metaheurísticos para Solucionar el Problema de Programación de Vehículos de Transporte Público de Pasajeros con Múltiples Depósitos	476
19.10	A Hybrid Differential Particle Swarm Optimization Approach for Multi-objective Parallel Machine Scheduling Problem	489
19.11	Predictive baseline schedule for electrical vehicles charging in dedicated residential zone parking	499
19.12	Applying the Corridor Method to the Multi-Mode Resource-Constrained Project Scheduling Problem	508
19.13	Metaheuristics for non-renewable resources constraints flow shop scheduling problems	511
19.14	Multi-objective Model and Iterated Greedy Algorithm for Robust Permutation Flow Shop Scheduling in the presence of uncertainties	521
19.15	Revisiting the Distributed Permutation Flowshop Problem	530

19.16	A biased random-key genetic algorithm for the Multi-period, Multi-rate and Multi-channels with variable bandwidth Scheduling Problem	533
19.17	A Genetic Algorithm for the Flexible Open Shop Scheduling Problem with Setup and Transportation Times . .	543
19.18	Exploring Automatic Algorithm Design for the Hybrid Flowshop Problem	546
19.19	Heuristics for the parallel machines scheduling problem with additional resources	549
19.20	An ILS heuristic for a real-life ship scheduling problem	552
19.21	A Comparison of Genetic Algorithm and Local Search Based Algorithms for Scheduling Recurring Radiotherapy Treatment Activities with Time Window Constraints and Optional Activities	555
19.22	Scheduling for the Growing of Crops to Meet Demand .	558
19.23	A CLONALG-inspired algorithm with adaptive large neighborhood search for the multi-mode resource-constrained project scheduling problem	561
19.24	HyperSpark: A Software Engineering Approach to Parallel Metaheuristics	571
20	Timetabling	581
20.1	A clique-based approach for the course timetabling problem	582
21	Automated Algorithm Design	585
21.1	AMH: a new Framework to Design Adaptive Metaheuristics	586
21.2	Revisiting Simulated Annealing: From a Component-Based Analysis to an Automated Design of Simulated Annealing Algorithms	589
21.3	ADVISER+: Toward a Usable Web-based Algorithm Portfolio Deviser	592
22	Transportation	600
22.1	A parallel matheuristic for the technician routing problem with conventional and electric vehicles	601
22.2	The two clustered multi depot pick up and delivery problem with time windows	604
22.3	A Hybrid Heuristic for a Balanced Vehicle Routing Problem with Time Windows and Loading Constraints	607
22.4	Combining real-time information with a variable neighborhood search metaheuristic for the inventory routing problem: a case study at UBIKWA systems	617

22.5	A dual hub-and-spoke problem with fixed and flexible long-hauls	620
22.6	A Large Neighborhood Search for a Rich Vehicle Routing Problem arising in the Steel Industry	623
22.7	Comparison of trajectory-based metaheuristics for the Electric Vehicle Routing Problem	626
22.8	Tactical Time Slot Management Problem with Split Deliveries	629
22.9	An Adaptive Large Neighborhood Search for Relocating Vehicles in Electric Carsharing Services	632
22.10	A biased random-key genetic algorithm for the car rental vehicle-reservation assignment problem	635
22.11	A GRASP for the Tourist Trip Design with Clustered POIs	645
22.12	Solving Multi-trip Vehicle Routing Problems with Back-hauls, Time Windows, and Release Dates	648
22.13	Scheduling a large fleet of rental vehicles using multi-neighbourhood local search	651
22.14	An Adaptive Large Neighborhood Search for the Consistent Inventory Routing Problem	661
22.15	Evolutionary Multi-Objective Optimization for the Multimodal Transport Problem	664
22.16	Size Limited Iterative Method (SLIM) for Train Unit Scheduling	674
22.17	Clustering is the key to security related routing problems	677
22.18	Sustainable Urban Freight Transport Considering Multiple Capacitated Depots	680
22.19	A Heuristic for the Period Vehicle Routing Problem with Inventory	683
22.20	Simheuristics-based selection of the optimal production strategy for a manufacturing facility under the influence of corrective maintenance operations	686
23	Logistics and Supply Chain Management	689
23.1	The Vehicle Routing Problem with Private fleet and multiple common Carriers: solution with hybrid metaheuristic algorithm	690
23.2	Metaheuristics for the vehicle routing problem with time windows	701
23.3	A mathematical programming approach to support proactive routing on the emergency dispatching problem	711

23.4	Green Heterogeneous Vehicle Routing Problem with Multiple Driving Ranges	714
23.5	Heuristic solutions to the Probabilistic p-Center Problem	717
23.6	Combining DES with metaheuristics to improve scheduling and workloads in parcel transshipment terminals .	720
23.7	Solving a supply chain design problem by the krill herd algorithm	730
23.8	A hybrid metaheuristic approach for the two-dimensional loading vehicle routing problem with heterogeneous fleet (2L-HFVRP)	737
23.9	An iterated local search procedure for the green vehicle routing problem with heterogeneous fleet and time windows	740
24	Simheuristics	743
24.1	A simheuristic for bi-objective permutation flow shop problem with stochastic processing times	744
24.2	A Concept to Combine PSO with Industrial Tooling Machine Setup Issues as Practical Approach for Simulation Based Optimization	753
24.3	A Simheuristic Algorithm for the Uncapacitated and Stochastic Hub Location Problem	756
24.4	Simulation-based headway optimization of the Vietnamese urban subway network	759
24.5	A simulation-optimization approach for the single-period inventory routing problem with stochastic demands . .	762
24.6	Combining a Discrete-event Simulation Model of a Logistics Network with Deep Reinforcement Learning . .	765
25	Metaheuristics in Agriculture and Forest Management	775
25.1	Optimal scheduling of production tasks in an animal feed mill	776
26	Matheuristics	780
26.1	A Matheuristic for the Swap-body Vehicle Routing Problem	781
26.2	A Large Neighborhood Search Matheuristic for Tourist Trip Design Problems	785
26.3	A Hybrid Method for Multi-Product Continuous Plant Scheduling	788
26.4	Client-side combinatorial optimization	791
26.5	An evolutionary algorithm for harmonic music composition	794

26.6	Using mixed integer programming techniques within a large neighborhood search as a hybrid metaheuristic for the multi-mode resource investment problem	804
26.7	Matheuristics for a VRPTW with competence constraints	807
26.8	Matheuristics for the problem of pre-positioning emergency supplies	811
26.9	Solving the Steiner Tree Problem in Graphs by Chaotic Neural Network using Key Path Neighborhood	814
26.10	Meta- and Matheuristic Approaches for the Symmetric Quadratic Traveling Salesman Problem	817
26.11	Programación de un sistema portuario implementando algoritmos genéticos con un modelo de simulación . . .	820
MAEB Submissions		823
1	Bioinformática usando Metaheurísticas, Algoritmos Evolutivos y Bioinspirados	823
1.1	Integrando Paralelismo en la Metaheurística Indicator-Based Multiobjective Bat Algorithm para Reconstrucción Filogenética	824
1.2	Inteligencia Colectiva de Abejas Multiobjetivo para Alinear Múltiples Secuencias Biológicas	834
1.3	Optimización Multiobjetivo para el Estudio de Asociaciones Genéticas	844
2	MHs en Ciencia de Datos y Aprendizaje Automático	854
2.1	Propuesta de cooperación en redes Ad hoc utilizando agentes inteligentes	855
2.2	Análisis de Diferentes Tipos de Reglas en Sistemas Difusos Evolutivos para Minería de Patrones Emergentes	864
2.3	Uso de Metaheurísticas Locales para Mejora de Rendimiento del Algoritmo GES en el Aprendizaje Estructural de Redes Bayesianas	874
3	General	877
3.1	Un algoritmo de programación genética multivista para inducir clasificadores basados en reglas en contextos semi-supervisados	878
3.2	¿Existe una mejora continua entre los algoritmos ganadores de las competiciones de optimización real del IEEE CEC?888	
3.3	A Fractal-based Mutation Operator from Iterated Function Systems	898

3.4	Análisis de algoritmos de evolución gramatical en problemas de regresión simbólica	901
3.5	Project Portfolio Selection with Stochastic Inputs - A Simheuristic VNS Approach	911
3.6	Multi-Start Methods for the Capacitated Clustering Problem	914
3.7	Nuevas heurísticas de construcción para el problema del ordenamiento óptimo de buckets	917
3.8	Multiobjective time series segmentation by improving clustering quality and reducing approximation error . .	920
3.9	Un GRASP/VNS para un problema de recogida de leche modelado como PVRPTW	923
3.10	An Alternative ILP Model and Algorithmic Ideas for the Maximum Edge-Disjoint Paths Problem	926
3.11	Scatter search para el problema multi-objetivo p-median y p-dispersion.	929
4	Metaheurísticas en Producción	932
4.1	Aplicación de algoritmos RRT en la planificación de movimientos óptimos en robótica	933
4.2	Minimizing the ergonomic risk and its dispersion in a mixed model assembly line using GRASP	943
4.3	Exploración de vecindarios mediante búsqueda ramificada para un problema bicriterio con elegibilidad en máquinas paralelas	953
4.4	Non-dominated solutions visualization in multiobjective optimization: application to assembly line balancing	963
4.5	GRASP para secuencias regulares de modelos mixtos con sobrecarga mínima e interrupción forzada de operaciones	973
4.6	Un algoritmo genético para resolver el problema de secuenciación en carruseles con huecos	983
5	Metaheuristics in Port Logistics and Related Problems	986
5.1	Heuristic and metaheuristic algorithms for a multi-port container ship stowage problem	987
5.2	A GRASP algorithm for the container stowage slot planning problem	990
5.3	A Biased Random-Key Genetic Algorithm for the Berth Allocation and Quay Crane Assignment Problem . . .	1012
5.4	Programación de un sistema portuario implementando algoritmos genéticos con un modelo de simulación . . .	1015

5.5	Multi-agent based Model for the Simulation of Yard Crane Operations at Maritime Container Terminals . .	1017
5.6	A General Framework for Handling Synchronization when Scheduling Automated Guided Vehicles	1020
5.7	Artificial Intelligence System for supporting the man- agement of berthing operations	1023

Internet of Things in urban waste collection

Edoardo Fadda¹, Guido Perboli^{1,2}, Mariangela Rosano¹, Roberto Tadei¹

¹ Department of Control and Computer Engineering - Politecnico di Torino
Corso Duca degli Abruzzi, 24, 10129, Turin, Italy

² CIRRELT - Montreal, Canada

edoardo.fadda@polito.it, guido.perboli@polito.it, mariangela.rosano@polito.it, roberto.tadei@polito.it

Abstract

Nowadays, the waste collection management has an important role in urban areas. This paper faces this issue and proposes the application of a metaheuristic for the optimization of a weekly schedule and routing of the waste collection activities in an urban area. Differently to several contributions in literature, fixed periodic routes are not imposed. The results significantly improve the performance of the company involved, both in terms of resources used and costs saving.

1 Introduction and research challenge

As urbanization and demographic growth increase, according to the expected results provided by a World Bank report [6], global solid waste generation will increase by nearly 50% over the next decade. In this context, the adoption of innovative technologies and the optimization of waste collection management generate gains for local administrations and the whole community. This paper addresses this issue by proposing the solution developed under the Optimization Networked Data in Environmental Urban Waste Collection (ONDE-UWC) project, funded by the Regional Council of Piedmont (Italy). The project involved the Department of Control and Computer Engineering of the Politecnico of Torino, CIDIU S.p.A., a company that manages the waste collection in the urban area near the city of Turin (Italy), and other technological partners. The main goal of the project was to minimize the operational costs i.e. the total costs of all the time shifts used. The company divides the day in three time shifts, the first two are basically equal, while the third one is more expensive. The main characteristic of this project is the application of the Internet of Things (IoT) paradigm to the waste collection. In fact, sensors installed on dumpsters and vehicles share data concerning the number of users' accesses, the waste weight and volume, which are then used as input of a heuristic for the scheduling and routing of weekly waste collection activities. Differently from several approaches in the literature, as [2, 3, 5], our approach does not impose fixed periodic routes. This innovative solution has the aim of increasing the efficiency of the whole process, with the consequent reduction of the total operating and environmental costs.

2 The Metaheuristic

As above introduced, data gathered from the sensor network and on-vehicle weight system are processed by a metaheuristic optimization algorithm, which dynamically provides an efficient schedule. The optimization problem is described by means of a mixed integer linear program (MILP). For a more detailed discussion about the model, the reader can refer to [4]. Due to the high number of variables, on the order of $\mathcal{O}(2^{IJ^2T})$, where I , J and T are respectively the number of vehicles, dumpsters and time steps to plan, the model becomes computationally hard to solve, even for small size instances. This complexity led us to choose a metaheuristic composed by four phases: Clusterization, Exact Optimization, Improvement, and finally Post-Optimization. In the first phase, the *Clusterization*, single dumpsters of each city are grouped into clusters (i.e. we obtain 10 big clusters that are statically created and are considered fixed during the algorithm execution). This choice is inspired by the strategy of CIDIU S.p.A to collect waste from all dumpsters located in the same city. Moreover, this aggregation allows us to reduce the size of the problem, defining a set of clusters \mathcal{C} (with cardinality C). Thus, we define $d_{c_1c_2}$ the distance between cluster c_1 and cluster c_2 , whose value is equal to the length of the shortest edge that connects a dumpster

Barcelona, July 4-7, 2017

in c_1 and a dumpster in c_2 . For example, if $d_{j_1 j_2}$ is the distance between dumpster j_1 and dumpster j_2 , the distance between clusters will be $d_{c_1 c_2} = \min_{j_1 \in c_1, j_2 \in c_2} d_{j_1 j_2}$. Furthermore, we define Θ_{ct} as the volume of waste that arrives to the cluster in time period t . Since the model in [4] requires this quantity to be expressed as a percentage of the total volume of the cluster, we set Θ_{ct} equal to the maximum growth rate of the dumpsters in the cluster. If we call Θ_{jt} the volume of waste that arrives to dumpster j in time period t , then $\Theta_{ct} = \max_{j \in c} \Theta_{jt}$. Moreover, we have to define the maximum capacity of the cluster V_c as equal to the sum of the capacities of all the dumpsters $V_c = \sum_{j \in c} V_j$. Finally, we denote \hat{a} the time spent to empty a cluster. It is equal to the sum of the emptying times of all the dumpsters, plus the time of a tour between all the dumpsters in the cluster. Once we have defined the clusters, in the *Optimization* phase we solve the MILP problem by considering clusters instead of dumpsters. Due to the transition from single dumpsters to clusters, we have to remove the constraints which impose that only one vehicle can void a dumpster in each time shift.

Taking into account the solution obtained by the Optimization, during the phase *Improvement*, a feasible solution of the problem with the single dumpsters is obtained. The procedure, for each vehicle used in the solution of the cluster problem, creates *list0* (the list with all the non empty dumpsters in each cluster visited by the vehicle). Then, it sorts *list0* in decreasing order of quantity of waste and after that, it creates *list1*: the list of all the dumpsters that the vehicle will void. Next, it adds all the dumpsters of *list0*, one by one, into *list1* until the vehicle is full or until the limit of the time shift is reached. Finally, it sets to zero the percentage of volume occupied by the waste in each dumpster in *list1*. This procedure is repeated for all vehicles. By using this algorithm we ensure that the vehicles do not visit the same dumpsters more times nor they visit nearly empty dumpsters.

Then, the algorithm applies a Tabu search by considering as starting solution the one obtained and it completes the computation by the *Post-Optimization* phase. In this phase, the feasible solution of the original problem is refined solving a TSP problem, according to [1].

3 Results

In order to evaluate the solution, computational tests and simulations are conducted using real data provided by CIDIU S.p.A. The problem considers 525 dumpsters, 8 vehicles, and a week of company activity (i.e., 3 time shifts for 6 days). In particular, we conduct a comparative analysis, between a real month of CIDIU S.p.A activity before the introduction of the heuristic and a simulated month (by using statistical model of the production computed from historical data) with the use of our heuristic, calculating the following three key performance indicators (KPIs):

- the average number of third shifts during a week of activity (nTS);
- the average number of vehicles used daily (nV), calculated as the number of vehicles used during one month of activity, divided by the number of shifts;
- the average percentage of waste volume that a dumpster contains at the moment of collection (WV%). When a vehicle voids a dumpster, an on-board probe records the volume occupied by the waste. If we divide this value by the volume of the dumpster, then we compute a percentage that indicates how much the dumpster is full. We obtain this KPI by taking the average over all the collections and all the dumpsters.

Due to the originality of the problem, we did not find any benchmark algorithm in the literature to compare with our algorithm.

The main finding is an improvement regarding all the KPIs, as illustrated in the Table 1. In particular, although the initial difficult planning based on aperiodic time shifts rather than the periodic ones, the inefficiency of the overestimated waste production forecasts led the CIDIU S.p.A management to consider a change of the operative strategy in order to adopt the proposed solution, justified by the good performance of the algorithm. In fact, CIDIU S.p.A no longer had recourse to a third shift, and the percentage of vehicles used decreased by 33% in the time window considered. On the one hand, this has a positive

Table 1: KPIs before and after the optimization

KPIs	CIDIU S.p.A solution	Simulated solution
nTS	1.44	0
nV	3	2
WV%	0.28	0.70

impact on the work conditions of the technical staff, particularly of the drivers. Indeed, they will not have to work during night and will also gain a more balanced work load. On the other hand, CIDIU S.p.A obtains a reduction of the operational costs and free resources to invest in offering new services to the citizens, relevant for its competitiveness. Moreover, another important result of the metaheuristic is its lower computational time, providing a good solution in less than one hour. For this reason, the algorithm can be run several times during the day, allowing the plan to be adjusted, and it is possible to account for missed operations (e.g., when the vehicle cannot collect the waste, due to the presence of a parked car that blocks the operation). These important results are leading the partners to continue in the same direction by focusing their research efforts on the "Project on Innovative Environmental Health for the recovery of solid waste based on optimization methods of waste collection cycles and accurate pricing" (PAIRUMA) project. Starting from the previous initiative ONDE-UWC, this new project has the aim of refining the mechanism of optimization of waste collection activities, in order to extend it as a best practice, also in similar territorial contexts. Moreover, PAIRUMA addresses the integration of the operational perspective of the topic, with the implementation of a new paradigm for the accurate pricing. In particular, the data obtained from sensors on dumpsters will provide the indication of parameters useful to define the right tariff and rewarding mechanism for the final users.

References

- [1] D. Applegate, W. Cook, and A. Rohe. Chained lin-kernighan for large traveling salesman problems. *INFORMS Journal on Computing*, 15(1):82 – 92, 2003.
- [2] F. Chu, N. Labadi, and C. Prins. A scatter search for the periodic capacitated arc routing problem. *European Journal of Operational Research*, 169(2):586 – 605, 2006.
- [3] S. Das and Bidyut Kr. Bhattacharyya. Optimization of municipal solid waste collection and transportation routes. *Waste Management*, 43:9 – 18, 2015.
- [4] E. Fadda, L. Gobbato, G. Perboli, M. Rosano, and R. Tadei. ONDE UWC mathematical model. *DAUIN internal report*, 2015.
- [5] V. C. Hemmelmayr, K. F. Doerner, R. F. Hartl, and D. Vigo. Models and algorithms for the integrated planning of bin allocation and vehicle routing in solid waste management. *INFORMS Transportation Science*, 48(1):103 – 120, 2013.
- [6] D. Hoornweg and P. Bhada-Tata. What a waste: A global review of solid waste management. *World Bank*, 2012.