INSTITUTO
DE INFORMÁTICA
UFRGS

SOLVING THE SINGLE-DAY HOME HEALTH CARE PROBLEM WITH ROUTE INTERDEPENDENCIES

Alberto F. Kummer, Olinto C.B. de Araújo, Luciana S. Buriol, and Mauricio G.C. Resende

EURO 2021H — MD-35 — July 12, 2021

OUTLINE

Introduction

Overview of HHCP

- Studied since 1974
- Traditional systems: patients receive healthcare in *hospitals*
- Home care: patients receive healthcare in their *homes*

Overview of HHCP

- Studied since 1974
- Traditional systems: patients receive healthcare in *hospitals*
- Home care: patients receive healthcare in their *homes*

Ease the access to health and social care services

- More inclusive
- Alternative to nursing homes
- Leverage hospital beds for complex cases

Overview of HHCP

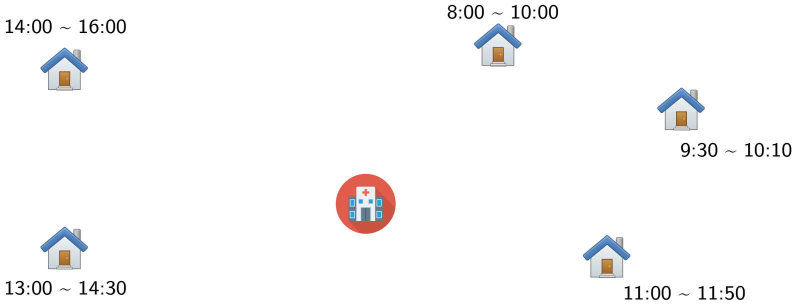
- Studied since 1974
- Traditional systems: patients receive healthcare in *hospitals*
- Home care: patients receive healthcare in their *homes*

Ease the access to health and social care services

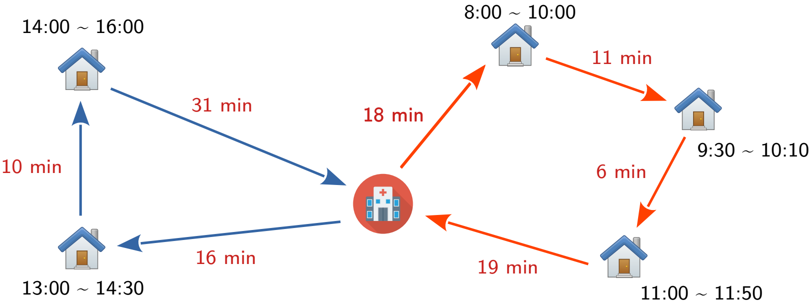
- More inclusive
- Alternative to nursing homes
- Leverage hospital beds for complex cases

Arriving challenge: Efficient routing solution for caregivers to patient locations.

Core of home care problems: A vehicle routing problem with additional constraints.



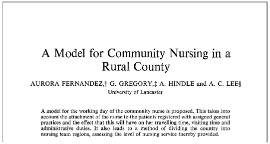
Core of home care problems: A vehicle routing problem with additional constraints.



Related works

Overview of HHCP

- First study from 1974
- Since 2006: +1 new publications per year
- At least three major surveys



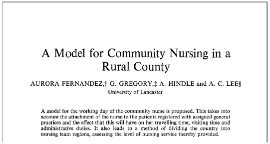
A Model for Community Nursing in a Rural County

AURORA FERNANDEZ,† G. GREGORY,‡ A. HINDLE and A. C. LEE§
University of Lancaster

A model for the working day of the community nurse is proposed. This takes into account the attachment of the nurse to the patients registered with assigned general practices and the effect that this will have on her travelling time, visiting time and administrative duties. It also leads to a method of dividing the country into nursing team regions, assessing the level of nursing service thereby provided.

Overview of HHCP

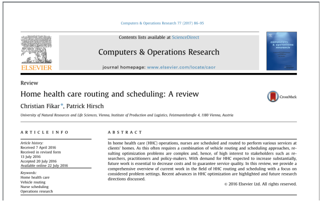
- First study from 1974
- Since 2006: +1 new publications per year
- At least three major surveys



A Model for Community Nursing in a Rural County

AURORA FERNANDEZ,† G. GREGORY,‡ A. HINDLE and A. C. LEE§
University of Lancaster

A model for the working day of the community nurse is proposed. This takes into account the attachment of the nurse to the patients registered with assigned general practices and the effect that this will have on her travelling time, visiting time and administrative duties. It also leads to a method of dividing the country into nursing team regions, assessing the level of nursing service thereby provided.



Computers & Operations Research 77 (2017) 86–95
Contents lists available at ScienceDirect
Computers & Operations Research
journal homepage: www.elsevier.com/locate/caor

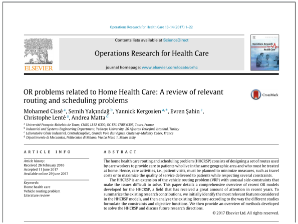
Review

Home health care routing and scheduling: A review

Christian Fikar*, Patrick Hirsch
University of Natural Resources and Life Sciences, Vienna, Institute of Production and Logistics, Feistmantelstraße 4, 1180 Vienna, Austria

ARTICLE INFO
Article history:
Received 7 April 2016
Received in revised form
13 July 2016
Accepted 20 July 2016
Available online 22 July 2016
Keywords:
Home health care
Vehicle routing
Nurse scheduling
Operations research

ABSTRACT
In home health care (HHC) operations, nurses are scheduled and routed to perform various services at clients' homes. As this often requires a combination of vehicle routing and scheduling approaches, resulting optimization problems are complex and, hence, of high interest to stakeholders such as researchers, practitioners and policy-makers. With demand for HHC expected to increase substantially, future work is essential to decrease costs and to guarantee service quality. In this review, we provide a comprehensive overview of current work in the field of HHC routing and scheduling with a focus on considered problem settings. Recent advances in HHC optimization are highlighted and future research directions discussed.



Operations Research for Health Care 13-14 (2017) 1–22
Contents lists available at ScienceDirect
Operations Research for Health Care
journal homepage: www.elsevier.com/locate/orhc

OR problems related to Home Health Care: A review of relevant routing and scheduling problems

Mohamed Cissé[a], Semih Yalçındağ[b], Yannick Kergosien[a,*], Evren Şahin[c], Christophe Lenté[a], Andrea Matta[d]
[a] Université François-Rabelais de Tours, CNRS, LI EA 6300, OC ERL CNRS 6305, Tours, France
[b] Industrial and Systems Engineering Department, Yeditepe University, 26 Ağustos Yerleşimi, Istanbul, Turkey
[c] Laboratoire Génie Industriel, CentraleSupélec, Grande Voie des Vignes, Chatenay-Malabry Cedex, France
[d] Dipartimento di Meccanica, Politecnico di Milano, Via La Masa 1, Milan, Italy

ARTICLE INFO
Article history:
Received 26 February 2016
Accepted 11 June 2017
Available online 29 June 2017
Keywords:
Home health care
Vehicle routing problem
Literature review

ABSTRACT
The home health care routing and scheduling problem (HHCRSP) consists of designing a set of routes used by care workers to provide care to patients who live in the same geographic area and who must be treated at home. Hence, care activities, i.e., patient visits, must be planned to minimize measures, such as travel costs or to maximize the quality of service delivered to patients while respecting several constraints.

The HHCRSP is an extension of the vehicle routing problem (VRP) with unusual side-constraints that make the issues difficult to solve. This paper details a comprehensive overview of recent OR models developed for the HHCRSP, a field that has received a great amount of attention in recent years. To summarize the existing research contributions, we initially identify the most relevant features considered in the HHCRSP models, and then analyze the existing literature according to the way the different studies formulate the constraints and objective functions. We then provide an overview of methods developed to solve the HHCRSP and discuss future research directions.

JOURNAL OF THE OPERATIONAL RESEARCH SOCIETY
https://doi.org/10.1080/01605682.2020.1750311

ORIGINAL ARTICLE

OPEN ACCESS

Operational research applied to decisions in home health care: A systematic literature review

Luca Grieco[a], Martin Utley[b] and Sonya Crowe[a]
[a]University College London, London, UK; [b]Care City, Barking, UK

ABSTRACT
The efficient deployment of resources in home-based care is considered crucial for the sustainability of health and social care systems worldwide. The aim of this study was to identify and review operational research approaches to support decision-making in home health care. We identified a set of linked decisions at different planning levels (strategic, tactical, operational) and conducted a systematic review of operational research approaches used to address these decisions. We also sampled OR literature applied to analogous decisions in other settings. The 77 papers selected focused predominantly on solutions for staff-to-patient allocation, visit scheduling and staff routing, few of which were adopted by organisations. Few studies dealt with tactical decisions of team size and composition or strategic decisions of districting, and we found no studies on contract design for commissioning home health care, on staff role definitions or on reassessment of patient need. Integrative work is scarce and the aspects of system performance considered are variable and diverse. For these reasons the literature does not provide guidance for home health care services aspiring to effective and coherent decisions across planning levels. OR approaches from other areas of application provide some insights for future research aimed at addressing this shortfall.

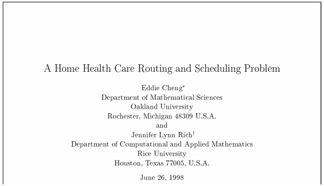
ARTICLE HISTORY
Received 24 July 2019
Accepted 30 March 2020
KEYWORDS
OR in health services; home health care; systematic literature review

In general

- Most publications approach *only* the routing problem
- Focuses on **home hospitalization**
  - Survey: Fikar and Hirsch (2017)
  - Survey: Cissé et al. (2017)
- Other formats: first care, social care

We also approach the operational planning

- Basic VRPTW model (Cheng and Rich, 1998)
- But no consensus regarding a *standard* problem
- No standard dataset



A Home Health Care Routing and Scheduling Problem

Eddie Cheng[*]
Department of Mathematical Sciences
Oakland University
Rochester, Michigan 48309 U.S.A.
and
Jennifer Lynn Rich[†]
Department of Computational and Applied Mathematics
Rice University
Houston, Texas 77005, U.S.A.

June 26, 1998

Problem definition

Pilot program "Better in Home"

- Program started in 2011
- Implemented in some big Brazilian cities

Source: DATASUS (2021)

3

PROBLEM DEFINITION

HOME CARE IN BRAZIL

Motivation: Solve a real problem in Porto Alegre

- Provides home hospitalization
- Opportunity for **knowledge transfer**
  - E.g. São Paulo e Rio de Janeiro

Melhor em Casa
A SEGURANÇA DO HOSPITAL NO CONFORTO DO SEU LAR

Source: DATASUS (2021)

The sizes of the problem

- 19 caregivers
- 300 patients visited per week
- Most of the **planning is manual**, daily basis

Three-step manual approach

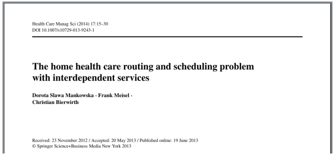
- One experienced caregiver
- Step 1: chooses the patient of the day
- Step 2: assign the patients to the caregivers
- Step 3: individual routing of the caregivers
  - Done by the vehicle drive
  - Mostly a "nearest neighbor" strategy

Our methodology

- Find a *core* optimization problem
- Complex enough
  - Valuable for the practitioner
  - Interesting from the scientific perspective

Our methodology

- Find a *core* optimization problem
- Complex enough
  - Valuable for the practitioner
  - Interesting from the scientific perspective


Health Care Manag Sci (2014) 17:15–30
DOI 10.1007/s10729-013-9243-1

The home health care routing and scheduling problem with interdependent services

Dorota Slawa Mankowska · Frank Meisel · Christian Bierwirth

Received: 23 November 2012 / Accepted: 20 May 2013 / Published online: 19 June 2013
© Springer Science+Business Media New York 2013

Mankowska et al. (2014)

Problem of choice: The Home Health Care Routing and Scheduling Problem (HHCRSP)

The home health care routing and scheduling problem

- Routing (caregivers) and scheduling (patient visit times)
- A model, and heuristics
- A public standard benchmark dataset

Main characteristics

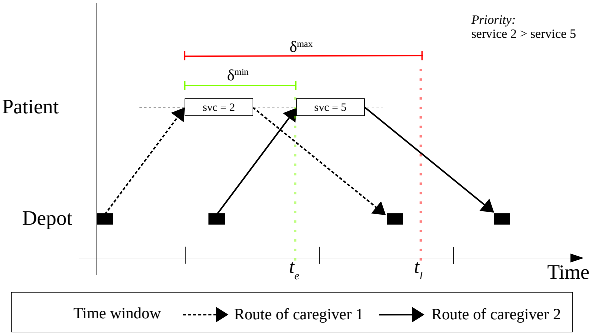
1. Routing components
2. Patient time-window
3. Covered service types
4. Operations synchronization on multiple visits

Main characteristics

1. Routing components
2. Patient time-window
3. Covered service types
4. Operations synchronization on multiple visits

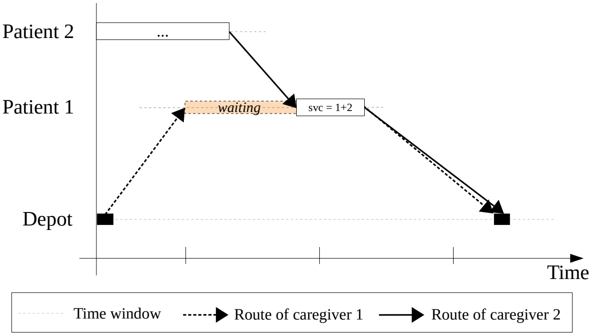
Double service: precedence order

- Service precedence: $2 > 5$
- $(\delta^{\min})$ and $(\delta^{\max})$: separation time



Double service: parallel attendance

- Services must start simultaneously



Objective function

$$\text{Minimize } \lambda_1 D + \lambda_2 T + \lambda_3 T^{max}$$

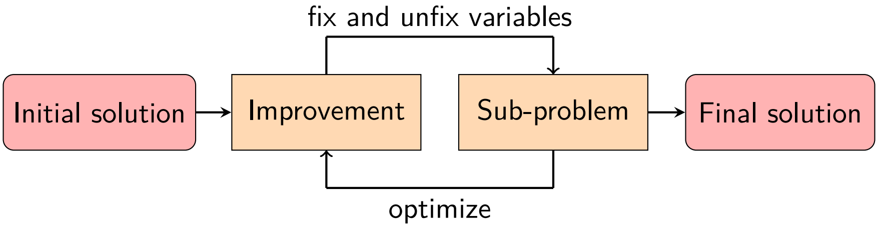
Components

- D: Sum of traveled distance
- T: Sum of tardiness
- $T^{\max}$: Maximum tardiness

Proposed methods

Fix and optimize matheuristic

- Initial solution: constructive heuristic (Mankowska et al., 2014)
- Each iteration: optimizes pair of routes
- Stop criteria: # iterations without improvement



INDIRECT SEARCH METHODS

Local search-based methods can be expensive

- Tricks from VRPTW literature reduce effort of evaluating moves
- But the synchronization constraints are too impacting
- Requires updating large chunks of the solution

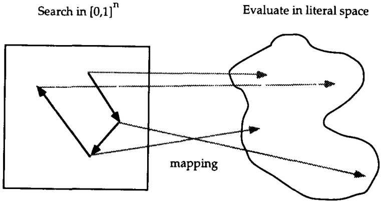
Our proposal: indirect search (Drexl, 2012)

BRKGA

- Main concept by Bean (1994)
- Most popular version by Gonçalves and Resende (2011)

Intensification components (BRKGA-IC)

- Island model (also in Toso and Resende (2015))
- Multi-parent mating
- Implicit path relinking on random keys space
- Proposed by Andrade et al. (2021)



Experimental results

Mankowska et al. (2014) dataset

Instance subset	# Caregivers	# Patients	Avg. cols (MIP)
A	3	10	2,445
B	5	25	21,219
C	10	50	159,429
D	15	75	527,139
E	20	100	1,236,846
F	30	200	7,309,566
G	40	300	21,818,286
Total of instances: 70			

Ten instances for each subset.

Fix and optimize (Kummer et al., 2019)

Instance		Mankowska		Lasfargeas		Fix and optimize		
Subset	# patients	Cost	Time	Cost	Time	Initial	Cost	Time
A	10	**225.19**	5.2	**225.19**	<1	275.75	**225.19**	0.54
B	25	445.36	<1	411.18	48.01	936.38	**407.43**	114.32
C	50	713.24	<1	636.2	109.02	1705.86	**622.12**	532.42
D	75	930.32	6	854.02	156.75	1891.81	**785.51**	1475.85
E	100	1057.62	33	–	–	1856.64	**863.74**	4643.83
F	200	**1587.96**	1115	–	–	2524.49	2454.97	5501.20
G	300	**2161.24**	7133	–	–	4278.32	4278.32	4301.84

Genetic Algorithm (Kummer et al., 2020)

Instance	Mankowska		Lasfargeas		Fix and optimize		BRKGA		BRKGA-IC	
	Cost	Time	Cost	Time	Cost	Time	Cost	Time	Cost	Time
A	**225.19**	5.2	**225.19**	<1	**225.19**	0.54	227.51	0.72	227.511	97.18
B	445.36	<1	411.18	48.01	**407.43**	114.32	413.86	1.92	413.86	104.78
C	713.24	<1	636.2	109.02	**622.12**	532.42	629.05	5.87	625.88	129.37
D	930.32	6	854.02	156.75	785.51	1475.85	791.55	13.20	**783.06**	164.34
E	1057.62	33	–	–	863.74	4643.83	845.50	23.94	**828.74**	217.80
F	1587.96	1115	–	–	2454.97	5501.20	1271.24	97.74	**1231.54**	569.20
G	2161.24	7133	–	–	4278.32	4301.84	1709.28	229.20	**1629.92**	1209.60

Conclusion

F&O matheuristic

- Flexible
- Works well on instances up to 50 patients
- Time-consuming
- Requires a good MIP solver

F&O matheuristic

- Flexible
- Works well on instances up to 50 patients
- Time-consuming
- Requires a good MIP solver

BRKGA

- Also flexible
- Interesting on instances with 75+ patients
- Relatively fast
- Intensification components are effective

Important research topic

- Complex and interesting problems
- In Porto Alegre: large room of improvement
- Current status: generate realistic instances

FUTURE WORKS

- Improve the GA decoder
- Model other practical requirements
- Re-scheduling methods

References

BIBLIOGRAPHY I

Carlos E. Andrade, Rodrigo F. Toso, José F. Gonçalves, and Mauricio G.C. Resende. The multi-parent biased random-key genetic algorithm with implicit path-relinking and its real-world applications. *European Journal of Operational Research*, 289(1):17–30, 2021. ISSN 0377-2217.

James C. Bean. Genetic algorithms and random keys for sequencing and optimization. *ORSA journal on Computing*, 6(2):154–160, 1994.

Eddie Cheng and Jennifer Lynn Rich. A home health care routing and scheduling problem. Technical report, Computational and Applied Mathematics (CAAM) Technical Reports–Rice University, 1998. Available in `https://hdl.handle.net/1911/101899`.

Mohamed Cissé, Semih Yalçındağ, Yannick Kergosien, Evren Şahin, Christophe Lenté, and Andrea Matta. Or problems related to home health care: A review of relevant routing and scheduling problems. *Operations Research for Health Care*, 13:1–22, 2017.

Michael Drexl. Synchronization in vehicle routing—a survey of vrps with multiple synchronization constraints. *Transportation Science*, 46(3):297–316, 2012.

Aurora Fernandez, G Gregory, A Hindle, and AC Lee. A model for community nursing in a rural county. *Journal of the Operational Research Society*, 25(2):231–239, 1974.

Christian Fikar and Patrick Hirsch. Home health care routing and scheduling: A review. *Computers & Operations Research*, 77:86–95, 2017.

BIBLIOGRAPHY II

José Fernando Gonçalves and Mauricio GC Resende. Biased random-key genetic algorithms for combinatorial optimization. *Journal of Heuristics*, 17(5):487–525, 2011.

Alberto F Kummer, Luciana S Buriol, and Olinto CB de Araújo. A matheuristic algorithm applied to the home health care problem. In *Eletronic Proceedings of the LI Brazilian Operational Research Symposium*, volume 2, 2019. Available in `https://proceedings.science/sbpo-2019/papers/a-matheuristic-algorithm-applied-to-the-home-health-care-problem?lang=en`.

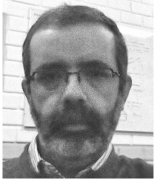
Alberto F Kummer, Luciana S Buriol, and Olinto CB de Araújo. A biased random key genetic algorithm applied to the vrptw with skill requirements and synchronization constraints. In *Proceedings of the 2020 Genetic and Evolutionary Computation Conference*, pages 717–724, 2020.

Dorota Slawa Mankowska, Frank Meisel, and Christian Bierwirth. The home health care routing and scheduling problem with interdependent services. *Health care management science*, 17(1):15–30, 2014.

Rodrigo F Toso and Mauricio GC Resende. A c++ application programming interface for biased random-key genetic algorithms. *Optimization Methods and Software*, 30(1):81–93, 2015.

THANK YOU!



Alberto F. Kummer[1], **Olinto C.B. de Araújo**[2], **Luciana S. Buriol**[1,4], **and Mauricio, G.C. Resende**[3,4]

[1]Federal University of Rio Grande do Sul
{afkneto,buriol}@inf.ufrgs.br

[2]Federal University of Santa Maria
olinto@ctism.ufsm.br

[3]University of Washington
mgcr@berkeley.edu

[4]Amazon.com, Inc.