BUSINESS SCHOOL

Planning the delivery of Home Social Care Services: A Multi-Objective Mathematical Programming-Based Approach

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AGENDA

1. Context
2. Objective
3. Previous Research
4. Structuring the problem
5. Planning Model
6. Multi-objective Approach
7. Case Study
8. Results
9. Conclusions and Future Work

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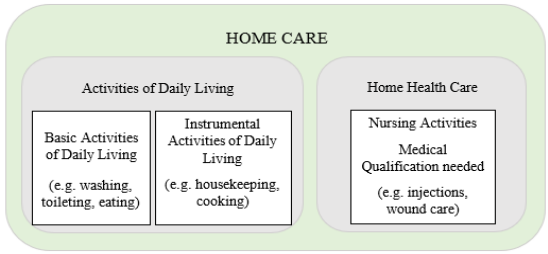
hSNS Workshop

CONTEXT

Population ageing

Elderly people no longer desire institutional care



Source: Adapted from Murray (2008) and WHO (2012)

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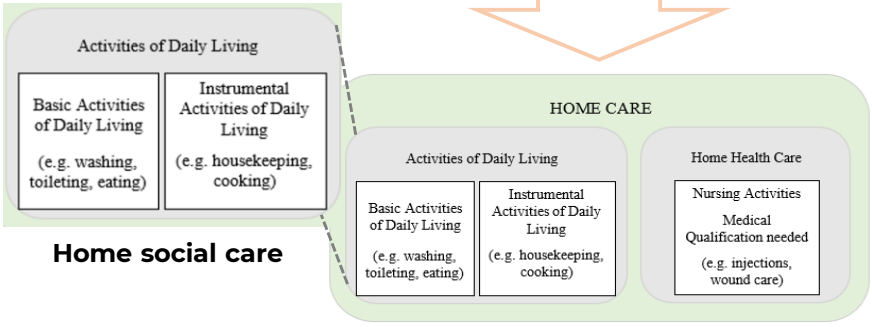

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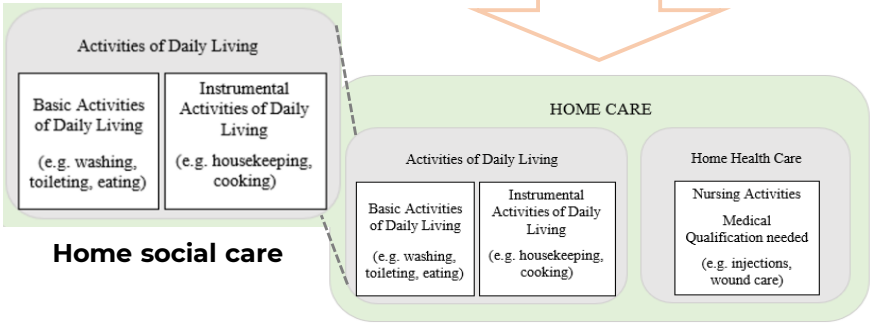

Home social care

Providers in Portugal:

- ✓ Private Institutions of Social Solidarity (IPSS, *Instituições de Solidariedade Social*)
- ✓ Holy Houses of Mercy (*Misericórdias*)

Source: Adapted from Murray (2008) and WHO (2012)

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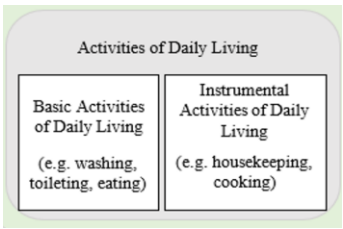
CONTEXT



Home social care

Key challenges in the HSC sector in the Portuguese context:

- ✓ Staff deficit
- ✓ Rising pressure for improved care
- ✓ Limited budget
- ✓ Increasing demand and costs

Tools to support the planning of routes and the scheduling of caregivers' tasks are essential!

Multiple policy objectives

Multiplicity of tasks

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OBJECTIVE

Develop a planning tool to support **routing** and **scheduling** decisions for **Home Social Care (HSC)** providers currently facing a context of **limited resources**...

... when considering **multiple policy objectives**

... when considering the **multiplicity of services and tasks** often delivered within the scope of HSC

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PREVIOUS RESEARCH

VEHICLE ROUTING PROBLEM

	Home care domain		Objectives		Constraints				
	HHC	HSC	Operating Costs	Equity	Working Time Regulations	Break Requirements	Shifts	Users' Autonomy	Meals' Distribution
Braekers *et al.* (2016)	X		X		X				
Guericke & Suhl (2017)	X				X	X	X		
Xiao *et al.* (2018)	X		X		X	X			
Gomes & Ramos (2019)		X		X		X			X

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Gomes & Ramos (2019)		X		X		X			X
Our Study		X	X	X	X	X	X	X	X

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PREVIOUS RESEARCH

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Contribute to the literature:

- ✓ It is focused in the **social care component of home care** - not often explored;
- ✓ Simultaneously considers **users' autonomy, work time regulations, caregivers' shifts, break requirements and the need to deliver a multiplicity of services** (such as personal or habitational hygiene, and meals distributions);
- ✓ It accounts for multiple planning objectives, namely, the **minimization of operating costs** and the **maximization of equity**

| Our Study | X | X | X | X | X | X | X | X |

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STRUCTURING THE PROBLEM

Planning Decisions

1: Which should be the routes established by each team of caregivers, i.e., which is the sequence of visits to be followed per day?

2: How should the workload be distributed across caregivers working in different shifts?

Key Objectives

1: Minimization of operational costs - including travel costs and wages

2: Maximization of equity - through the minimization of the differences in the daily working time of different caregivers

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PLANNING MODEL

OBJECTIVES

Objective Function 1: Minimization of operating costs

$$f_1 = min \sum_{k \in K} \sum_{t \in T} (\alpha l_{kt} + \beta dt_{kt}) \quad (1)$$

Fuel costs

Wages

Objective Function 2: Maximization of equity (minimization of the differences in the daily working time of different caregivers)

$$f_2 = min \sum_{k \in K} \sum_{t \in T} l''_t - l_{kt} \quad (2)$$

Daily working time of team $k \in K$ on day $t \in T$

Higher working time for teams working on day $t \in T$

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PLANNING MODEL

CONSTRAINTS

Route-Related Constraints

- Each visit is done exactly once
- Each caregiver visits each node only once, at most
- Flow conservation constraint

Caregivers visiting a node, need to leave that node afterwards

- Subtours prevention

Miller & Zemlin (1960)

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PLANNING MODEL

CONSTRAINTS

Caregivers-Related Constraints

- Number of caregivers leaving the center should not exceed the maximum number of caregivers available to work
- Overtime should be avoided

Meals-Related Constraints

- The last lunch distribution ensured by each team should be concluded earlier than a given hour.

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MULTI-OBJECTIVE APPROACH

ε-constraint methods	Optimization of one of the *m* objectives considering the others *m-1* as constraints
Weighted-sum methods	Optimization of a weighted-sum of the *m* objective functions through the assigning of weighted coefficients
Reference-point based techniques	Minimization of a distance function to a reference point, generally the ideal solution, such as the Manhattan metric or the Chebyshev metric

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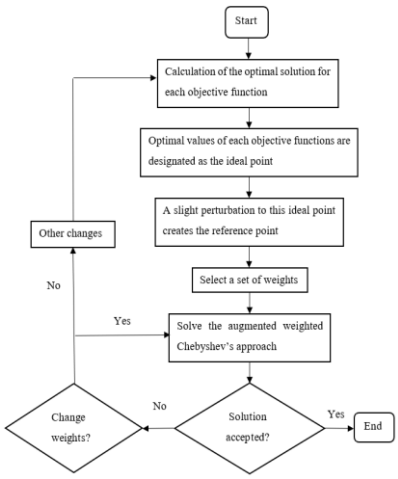
MULTI-OBJECTIVE APPROACH

ε-constraint methods	Optimization of one of the *m* objectives considering the others *m-1* as constraints
Weighted-sum methods	Optimization of a weighted-sum of the *m* objective functions through the assigning of weighted coefficients
Reference-point based techniques	**Chebyshev's method**



Source: Adapted from Pereira et al. (2019)

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CASE STUDY

Centro Social e Paroquial da Póvoa de Santo Adrião

- CSPPSA's Headquarters
- Users' Home in Póvoa de Santo Adrião
- Users' Home in Olival Basto
- Home with two users

Private Institution of Social Solidarity

9 Caregivers

45 Users

Four major groups of services

2 Shifts

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CASE STUDY

Centro Social e Paroquial da Póvoa de Santo Adrião

Personal Hygiene	Habitational Hygiene	Laundry Care	Food
Diaper maintenance	Dusting	Collection	Distribution
Head washing	Floor mopping	Delivery	
Body washing	Vacuuming		
Body hydration	Taking out the trash		
Moisturizing cream	Kitchen		
application	Cleaning		
Nail's cutting	Washing the dishes		
Dressing	Exchange of beds		
Making the bed	sheets		

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(i) Autonomous – Able to perform basic care needs without support from third parties

(ii) Partially Dependent – Needs third party support for personal hygiene and/or movement

(iii) Dependent – Cannot independently perform the tasks essential to the satisfaction of everyday life basic needs

(iv) High level of dependency – Accumulates situations of dependency that characterize dependents, and the user is bedridden or presents severe dementia

One caregiver is assigned in the case of autonomous users
Two caregivers are allocated in the remaining cases ((ii)-(iv)).

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CASE STUDY

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Key Challenges

Manual Planning	Some visits are not considered in the planning	Disregard for laundry tasks	Delays	Inneficiences in scheduling construction

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CASE STUDY

MULTI-OBJECTIVE SCENARIOS

	MULTI 1 (Scenario 1)	**MULTI 2** (Scenario 2)	**MULTI 3** (Scenario 3)
λ_1 (cost)	0,7	0,5	0,3
λ_2 (equity)	0,3	0,5	0,7

$$\min_{x \in X} \left\{ \max_{i=1,\dots,n} \lambda_i [f_i(x) - z_i^*] - \sum_{i=1}^{n} \rho_i f_i(x) \right\}, \lambda \geq 0$$

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RESULTS

When the CSPPSA is more concerned with equity among caregivers, it can achieve an improvement in equity of around 37,4%, but with an associated increase in operational costs of around 22,4%.

Operational Costs (in euros per day) & Equity (in minutes) [results obtained when planning the activity for Monday]

	MULTI 1	**MULTI 2**	**MULTI 3**
Costs	234,64	305,93	374,34
Equity	147	123	77

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Operational Costs (in euros per day) & Equity (in minutes) [results obtained when planning the activity for Monday]

	MULTI 1	MULTI 2	MULTI 3
Costs	234,64	305,93	374,34
Equity	147	123	77

When the CSPPSA is more concerned with the minimization of costs, it can achieve a reduction in costs of around 23,3%, but with an increase in the inequality between caregivers in the order of 19,5%.

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RESULTS

CSPPSA is more concerned with the minimization of costs

CSPPSA is more concerned with equity among caregivers

	MULTI 1			MULTI 2			MULTI 3			
	k11	k21	k32	k11	k21	k32	k11	k21	k32	k42
Number of visits per team	29	30	32	28	32	31	22	20	18	35
Daily working time (in min.)	**559**	520	**451**	**554**	530	**455**	503	**506**	470	**468**
Total travel distance (in meters)	20593	14625	18298	24967	20125	26097	20052	31056	32480	36540

Legend: kij – Team *i* working in shift *j*
Results obtained when planning the activity for Monday

Four teams are required so as to achieve a more equitable distribution of working time

38 minutes is the maximum difference between teams in this planning solution, whereas **99** and **108 minutes** is the maximum difference found when a higher concern in devoted to costs

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RESULTS

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Results obtained when planning the activity for Monday

Although it is the most balanced planning solution in terms of daily working time, it is also the most unbalanced in terms of number of visits

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Legend: kij – Team *i* working in shift *j*
Results obtained when planning the activity for Monday

Planning solution with the highest total travelling distance and daily working time, thus translating into the highest operational costs

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RESULTS

COMPUTATIONAL RESULTS

	Execution Time (seconds)	Gap	Iterations	Single Equations	Integer Variables	Variables
MULTI 1	28800	19,4%	18299831	58681	29380	29490
MULTI 2	28800	23,6%	9835487	58681	29380	29490
MULTI 3	28800	29,2%	15856393	58681	29380	29490

Results obtained when running the model for monday

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CONCLUSIONS AND FUTURE WORK

- ✓ Development of a generic model than can be used in real practice to support planning decisions in the home social care sector
- ✓ The model avoids the need for a manual and time consuming planning
- ✓ The proposed model allows to:

  i. Obtain planning solutions translating the real concerns of planners – more focused on the minimization of costs or on the maximization of equity between caregivers;

  ii. Plan the delivery of a diversity of tasks;

  iii. Take into account the different levels of autonomy of users;

  iv. Plan the activity of caregivers working in different shifts.

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CONCLUSIONS AND FUTURE WORK

- ✓ Consider the time-windows restrictions on the delivery of meals
- ✓ Explore alternative equity measures – e.g., not only for caregivers, but also for users and their families
- ✓ Introduce preferences of users – in the form of constraints or additional objectives
- ✓ Develop an easy-to-use tool that integrates the developed model with userfriendly interfaces

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Thank you for listening!

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