Modelling Home Social Care Services with Non-Loyalty Features

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Home social care service problem

Formal homecare services as meal delivery, activities of the daily living, adult day care, amongst other, started to be provided to persons in need of assisted living support

Caregivers

Home social care service problem

Define a daily work schedule for each caregiver
(**which** patient to visit and **when**)

Caregiver	Mon	Tue	Wed	Thu	Fri
	Patient 1 Patient 4	Patient 4 Patient 9	Patient 1 Patient 4 Patient 7	Patient 4 Patient 9	Patient 1 Patient 4
	Patient 2	Patient 2 Patient 5	Patient 2	Patient 2 Patient 5	Patient 2 Patient 8
	Patient 6 Patient 3 Patient 9	Patient 6 Patient 3	Patient 6 Patient 3 Patient 9	Patient 6 Patient 3	Patient 6 Patient 3 Patient 9

Home social care service problem

<u>Real Case Study: a Portuguese catholic parish</u>

- 66 patients
- Services offered:
  - Meal delivery
  - Activities of the daily living: bathing, dressing, medication assistance, home cleaning
  - Adult day care
  - Transportation to (and from) the day care center
- Patient visit frequency: from three times a day to once a week

Home social care service problem

Real Case Study: a Portuguese catholic parish

Specific Features

Non-Loyalty between Caregiver and Patient

Caregivers must rotate among patients and among teams on a weekly basis

Patients live in two different urban areas

Some patients need to be walked to the Day Care Centre

Home social care service problem

Real Case Study: a Portuguese catholic parish

Specific Features

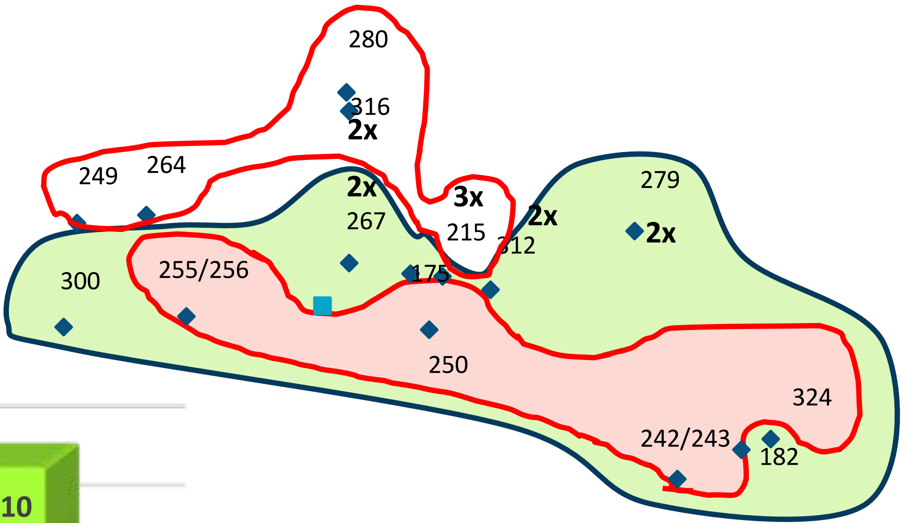
6 caregivers

- Work in teams of 2
- Each team departs from the Day Care Centre and returns at the end of the day
- Lunch-break at 1 p.m. a the Day Care Centre
- One team has to arrive at 12 p.m. to help delivering meals

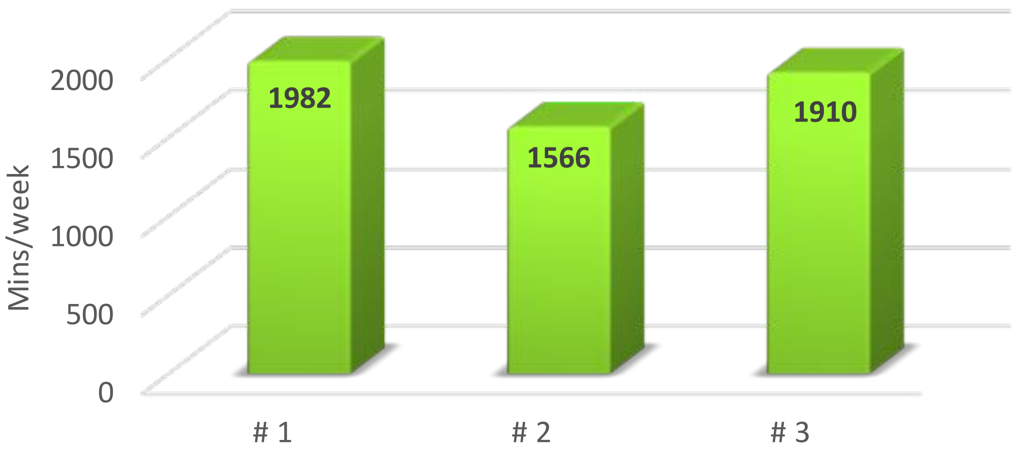
Current planning

66 patients
- 39 patients: only meal delivery
- 17 patients: meal delivery + homecare services

15 homes



Workload



Total Walking Time

924 minutes/week

Modelling approach

Define a daily work schedule for each caregiver

Multi-period Vehicle Routing Problem with Time-Windows	Allocation problem
• Patient visiting time • Sequence of visits	Non-loyalty between caregiver and patient

MPVRPTW: Modelling approach

Vehicle Routing Problem

With Time-Windows

Task/Service?

Patient

Patient 1

1. Bathing (15 min)
2. Dressing (5 min)
3. Medication assistance (5 min)
4. Home cleaning (35 min)

Visit duration 60 minutes

Time-Window [0 min – 240 min]

MPVRPTW: Modelling approach

Patient with more than one visit per day

1. Change a diaper in the morning
2. Change a diaper after lunch
3. Change a diaper in the afternoon

} **Replicas with adequate time-windows**

Lunch Break

Fictitious Patient located at the Day Care Centre

Visit duration 60 minutes	Time-Window [300 min – 300 min]

Walking *transportation* services

Fictitious Patient located at the Day Care Centre that needs to be visited immediately after

MPVRPTW: Modelling approach

Services → **Patients**

Vehicles → **Teams**

Binary variable

x_{ij}^{kt} = 1 if **team** *k* travels from *i* to *j* (immediately) on day *t* ;
0 otherwise

Continuous variable

s_i^{kt} Starting time of **team** *k* to visit patient *i* on day *t*

MPVRPTW: Modelling approach

Objective function

Minimize the total walking time

Constraints

Specific constraints

(1) All request have to be attended
(2) All teams must leave from the depot
(3) All teams must arrive to the depot
(4) Time window constraint
(5) Only one team can visit each patient during the week
(6) The same team has to visit the patient and all the corresponding replicas
(7) Some patients need to be walked to day care center after being visited
(8) All teams have to visit **lunch break node**

MPVRPTW: results

66 patients
- 39 patients: only meal delivery
- 17 patients: meal delivery + homecare services

15 homes → 21 nodes to visit + lunch break node

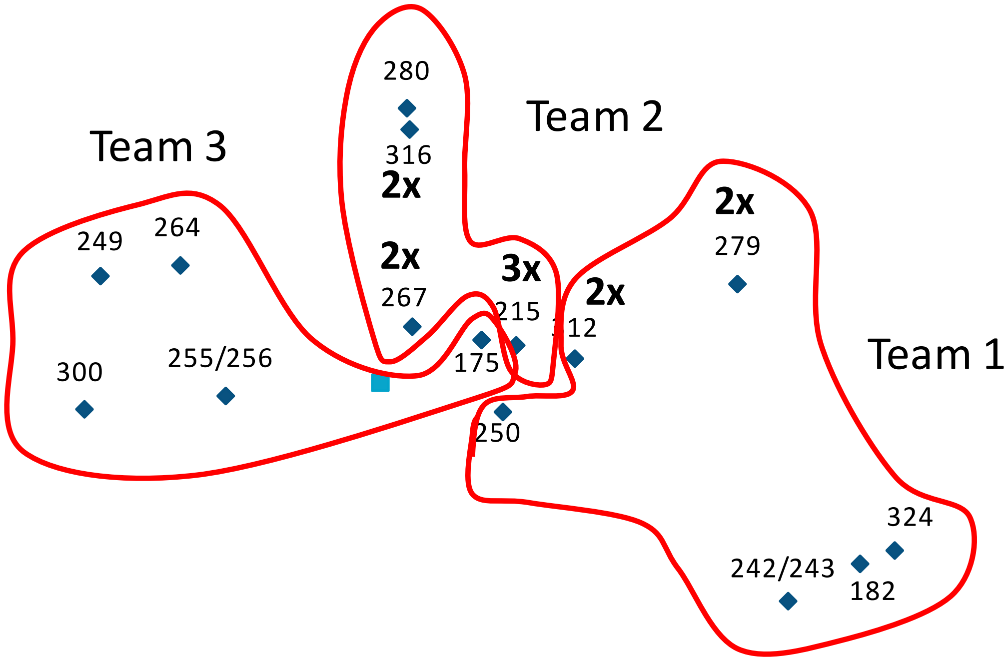
Walking time

797 minutes

~ 14% ↓

Current Walking Time

924 minutes/week



MPVRPTW: results

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Walking time

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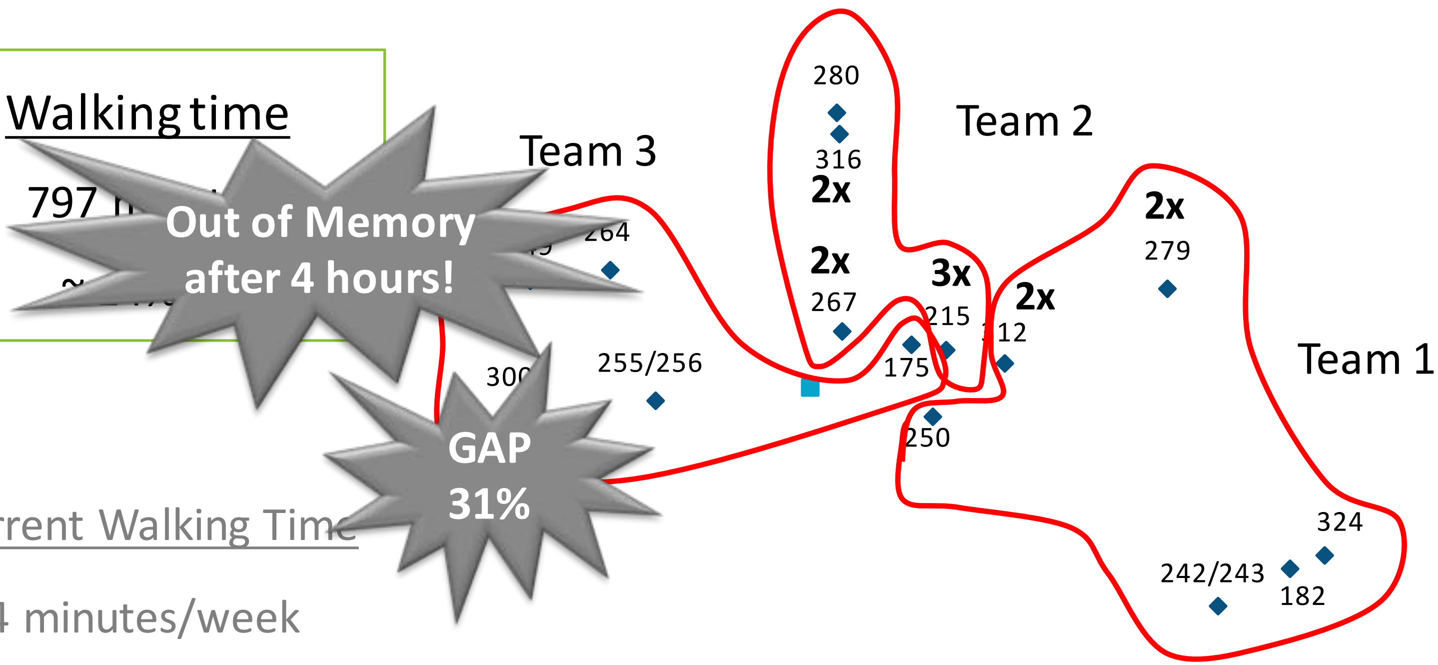


Current Walking Time

924 minutes/week

MPVRPTW: Solution approach

1. Sort the week days by according to the number of patients to visit
2. Solve single day MILP model for day t_1
   - Each patient with a visit at $t=t_1$ is assigned to a team
3. Solve single day MILP model for day t_2 and fixed assignment for t_1 patients
4. Repeat step 3 until all week days are solved

MPVRPTW: Solution approach

Monday and Thursday

145 minutes x 2 days

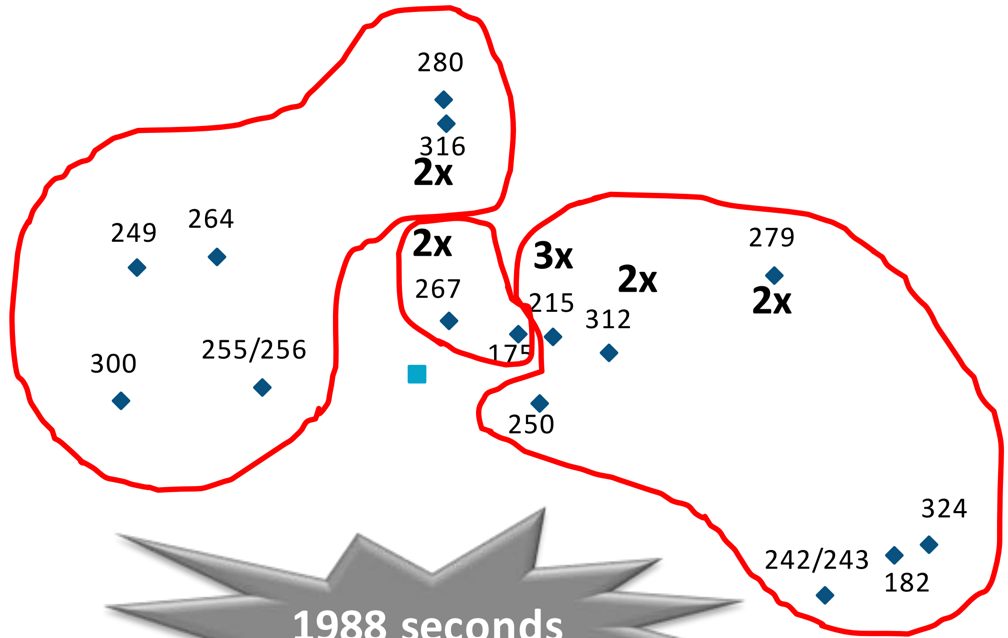
Tuesday, Wednesday, Friday

141 minutes x 3 days

Walking time

713 minutes

~ 23% ↓



1988 seconds

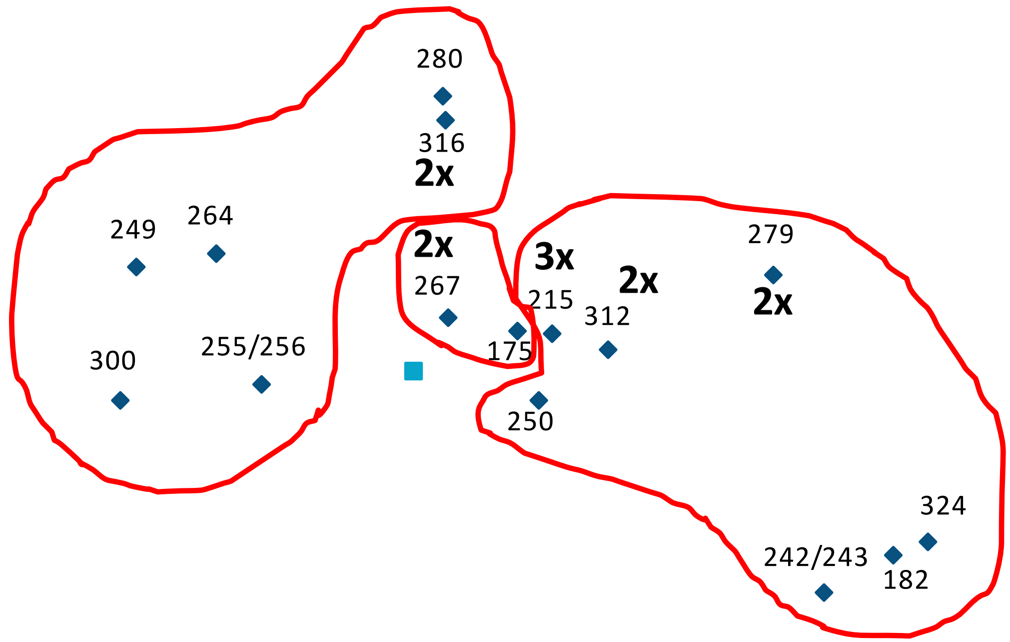
GAP 0%

MPVRPTW: Solution approach

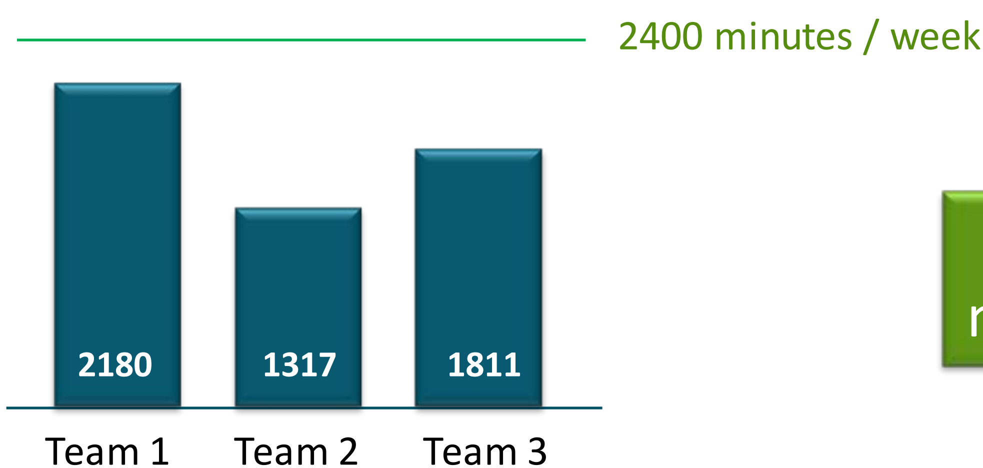
Walking time

713 minutes

~ 23% ↓

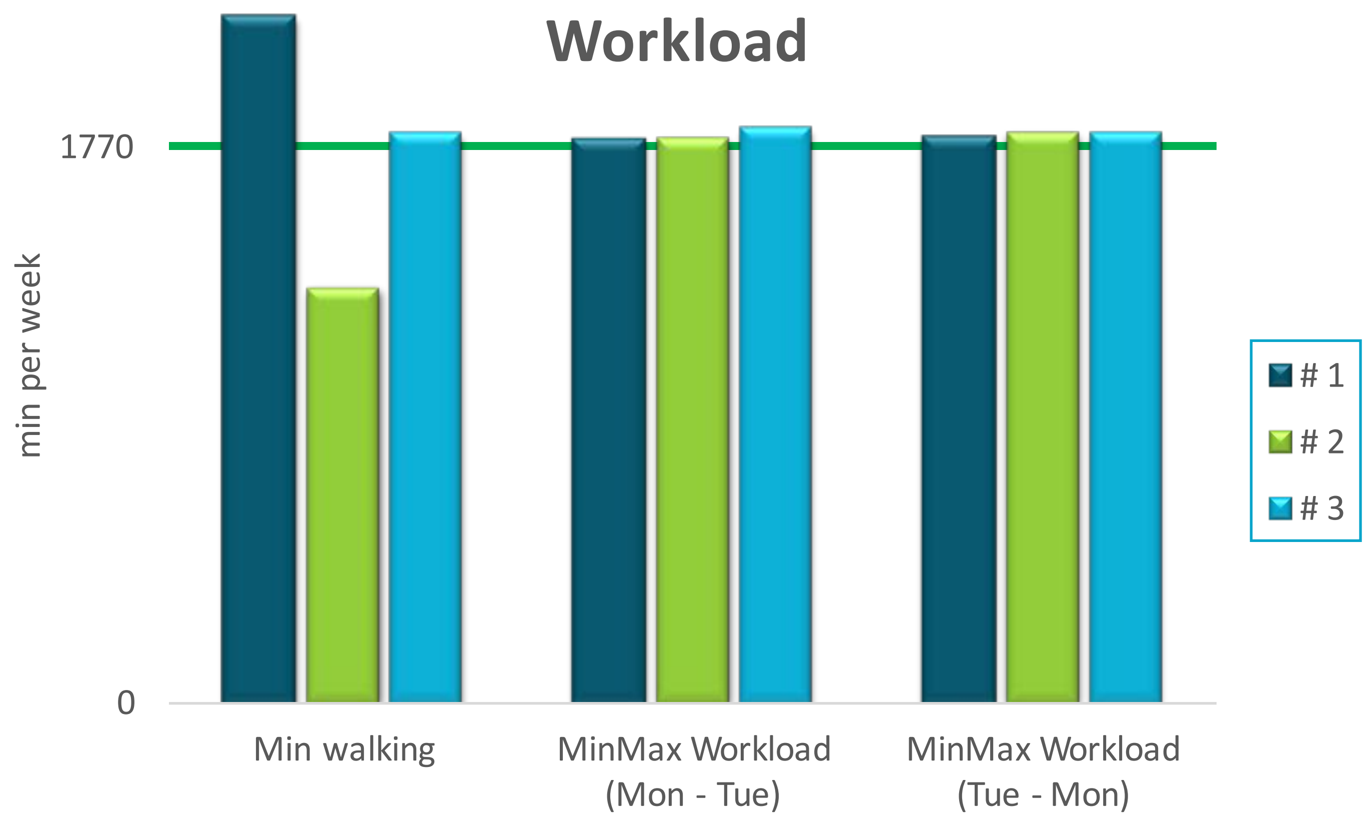


Workload

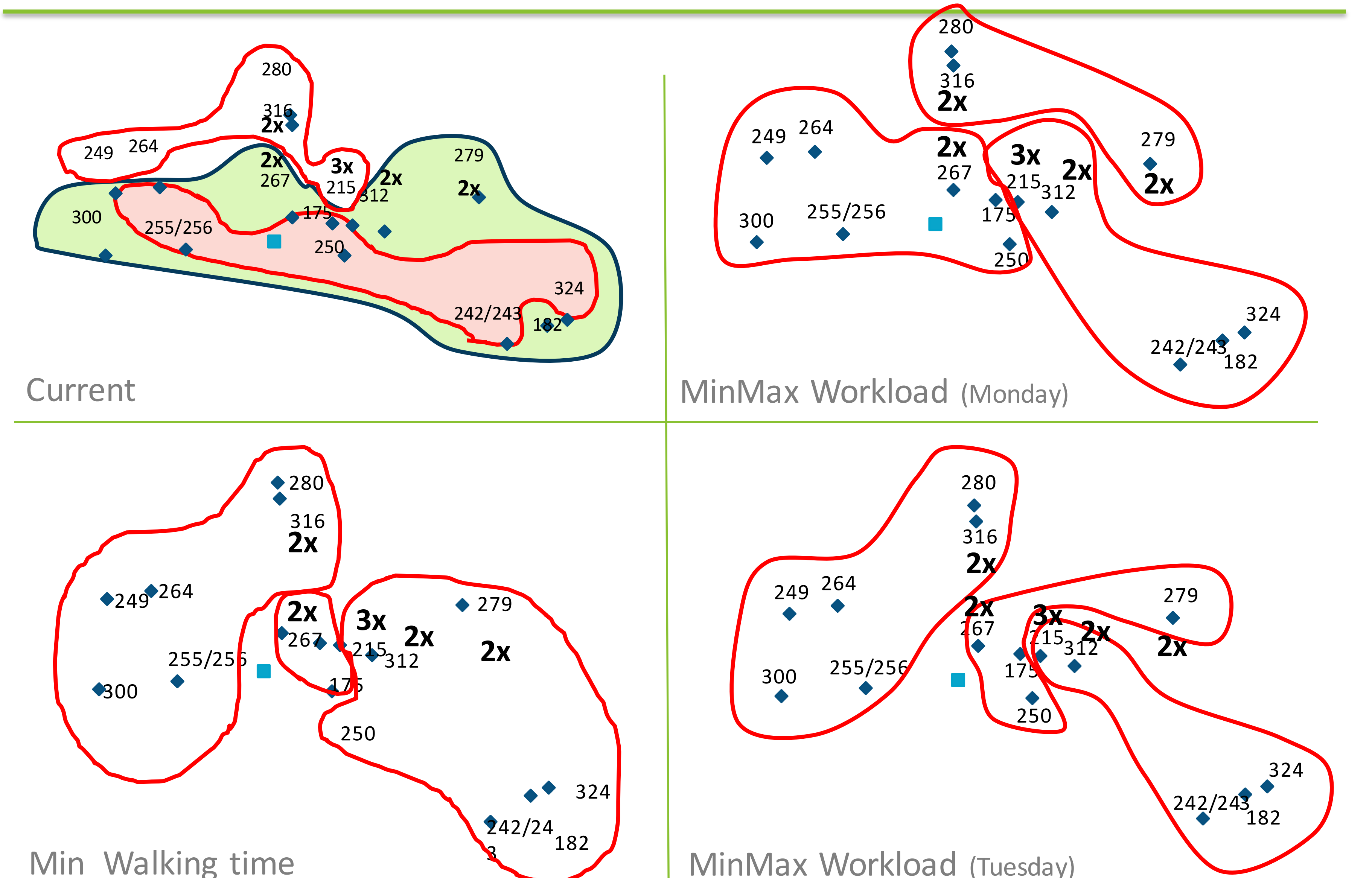


Minimize the maximum workload

Min Max Workload: results



Teams working areas



Allocation problem: modelling

We want to design **week schedule** **such that**:

- Each caregiver belongs to only one team
- All teams have two caregivers
- All teams work every week

Specific constraints

- All caregivers should visit all patients
- All caregivers have to work with each other
- Scheduling must allow a *rolling horizon*
- No caregiver can stay in a team more than *n* weeks in a row
- **One, and only one,** caregiver have to stay in the team at least 2 consecutive weeks

Allocation problem: modelling

Decision Variables

x_{ij}^{kt} = 1 if a pair of caregivers *(i,j)* is assigned to team *k* at week *t*

y_{i}^{kt} = 1 if caregiver *i* is assigned to team *k* at week *t*

Objective Function

Min "Dummy" Variable

We only need a feasible solution!

Allocation problem: modelling

We want to design **week schedule** **such that**:

- Each caregiver belongs to only one team
- All teams have two caregivers
- All teams work each week

$$\sum_{k} y_i^{kt} = 1, \qquad \forall_{i,t}$$

$$\sum_{i,j:i\neq j} x_{ij}^{kt} = 1, \qquad \forall_{k,t}$$

$$x_{ij}^{kt} \leq y_i^{kt} \text{ e } x_{ij}^{kt} \leq y_j^{kt}, \qquad \forall_{k,t,i,j:i\neq j}$$

Allocation problem: modelling

We want to design week schedule such that:

- Each caregiver belongs to only one team,
- All teams have two caregivers,
- All teams work each week
- All caregivers should visit all patients
- All caregivers have to work with each others

$$\sum_{t} y_i^{kt} \geq 1, \qquad \forall_{i,k}$$

$$\sum_{k,t} x_{ij}^{kt} \geq 1, \qquad \forall_{i,j:i \neq j}$$

Allocation problem: modelling

We want to design week schedule **such that**:

- Each caregiver belongs to only one team
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- All caregivers should visit all patients
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- No caregiver can stay in a team more than *n* weeks in a row

$$\sum_{\tau=0}^{n} y_i^{k(t++\tau)} \leq n, \qquad \forall_{i,k,t}$$

Allocation problem: modelling

We want to design week schedule such that:

- One, and only one, caregiver has to stay in the team at least 2 consecutive weeks

$$x_{ij}^{kt} + x_{ij}^{k(t++1)} \leq 1, \qquad \forall_{k,t,i,j:i\neq j}$$

$$y_i^{kt} + y_j^{kt} \geq x_{ij}^{kt}, \qquad \forall_{k,t,i,j:i\neq j}$$

$$y_i^{kt} + y_j^{k(t++1)} \geq x_{ij}^{kt}, \qquad \forall_{k,t,i,j:i\neq j}$$

$$y_i^{k(t++1)} + y_j^{kt} \geq x_{ij}^{kt}, \qquad \forall_{k,t,i,j:i\neq j}$$

$$y_i^{k(t++1)} + y_j^{k(t++1)} \geq x_{ij}^{kt}, \qquad \forall_{k,t,i,j:i\neq j}$$

Allocation problem: results

6 caregivers
2 caregivers/team

15 different pairs of caregivers

Weekly schedule for each Caregiver

	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
Team 1	(2,1)	(6,2)	(6,4)	(6,1)	(3,1)	(5,3)	(5,4)	(4,2)
Team 2	(4,3)	(4,1)	(5,1)	(5,2)	(6,5)	(6,2)	(3,2)	(6,3)
Team 3	(6,5)	(5,3)	(3,2)	(4,3)	(4,2)	(4,1)	(6,1)	(5,1)

Allocation problem: results

6 caregivers
2 caregivers/team

15 different pairs of caregivers

Weekly schedule for each Caregiver

	Week 1	**Week 2**	**Week 3**	**Week 4**	**Week 5**	**Week 6**	**Week 7**	**Week 8**
Team 1	(2,1)	(6,2)	(6,4)	(6,1)	(3,1)	(5,3)	(5,4)	(4,2)
Team 2	(4,3)	(4,1)	(5,1)	(5,2)	(6,5)	(6,2)	(3,2)	(6,3)
Team 3	(6,5)	(5,3)	(3,2)	(4,3)	(4,2)	(4,1)	(6,1)	(5,1)

Allocation problem: results

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15 different pairs of caregivers

Weekly schedule for each Caregiver

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Team 2	(4,3)	(4,1)	(5,1)	(5,2)	(6,5)	(6,2)	(3,2)	(6,3)
Team 3	(6,5)	(5,3)	(3,2)	(4,3)	(4,2)	(4,1)	(6,1)	(5,1)

Conclusions

- Home Social Care Services with Non-Loyalty between Caregiver and Patient
- Modelling approach

Multi-Period VRP with Time-Windows

MILP Model

NP-Hard!!

Solution Method

Allocation Problem

MILP Model

Further Work

- Develop different solution approaches

- Non-daily patients: given the frequency, decide patient visiting days

- Apply the model to a larger case-study

- Extend the model to accommodate the entrance of new patients and the exiting of actual patients while minimize the changes in a existent work schedule

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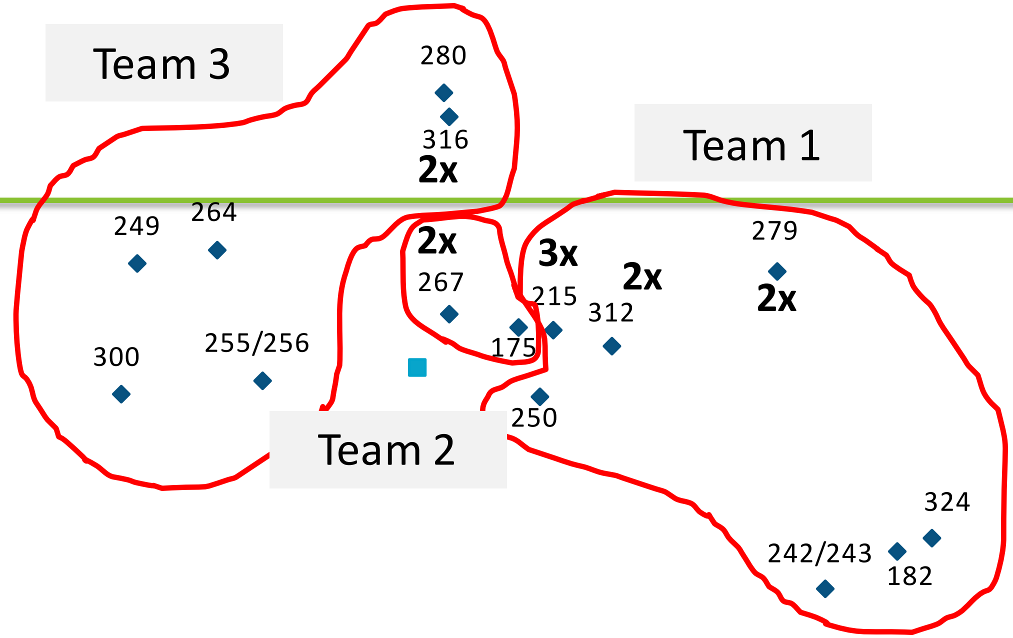
Minimize Walking Time (heuristic)



- **Team 1** Monday and Thursday

Depot – 215 – 312 – 279 – 242 – **182** – 324 – 215´ – Lunch – 215’’ – 279’ – 312’ – **250** – Depot

Tuesday, Wednesday and Friday

Depot – 215 – 312 – 242 – 324 – 279 – 215´ – Lunch – 312’ – 279’ – 215’ – Depot

- **Team 2** Monday, Tuesday, Wednesday, Thursday and Friday

Depot – 267 – 175 – Transport – Lunch Delivery – Lunch – 267’ – Depot

- **Team 3** Monday, Tuesday, Wednesday, Thursday and Friday

Depot – 316 – 280 – 264 – 249 – 300 – 255 – Lunch – 316’ – Depot