Development Logistics Example

Urban Healthcare: Periodic Location Routing Problem

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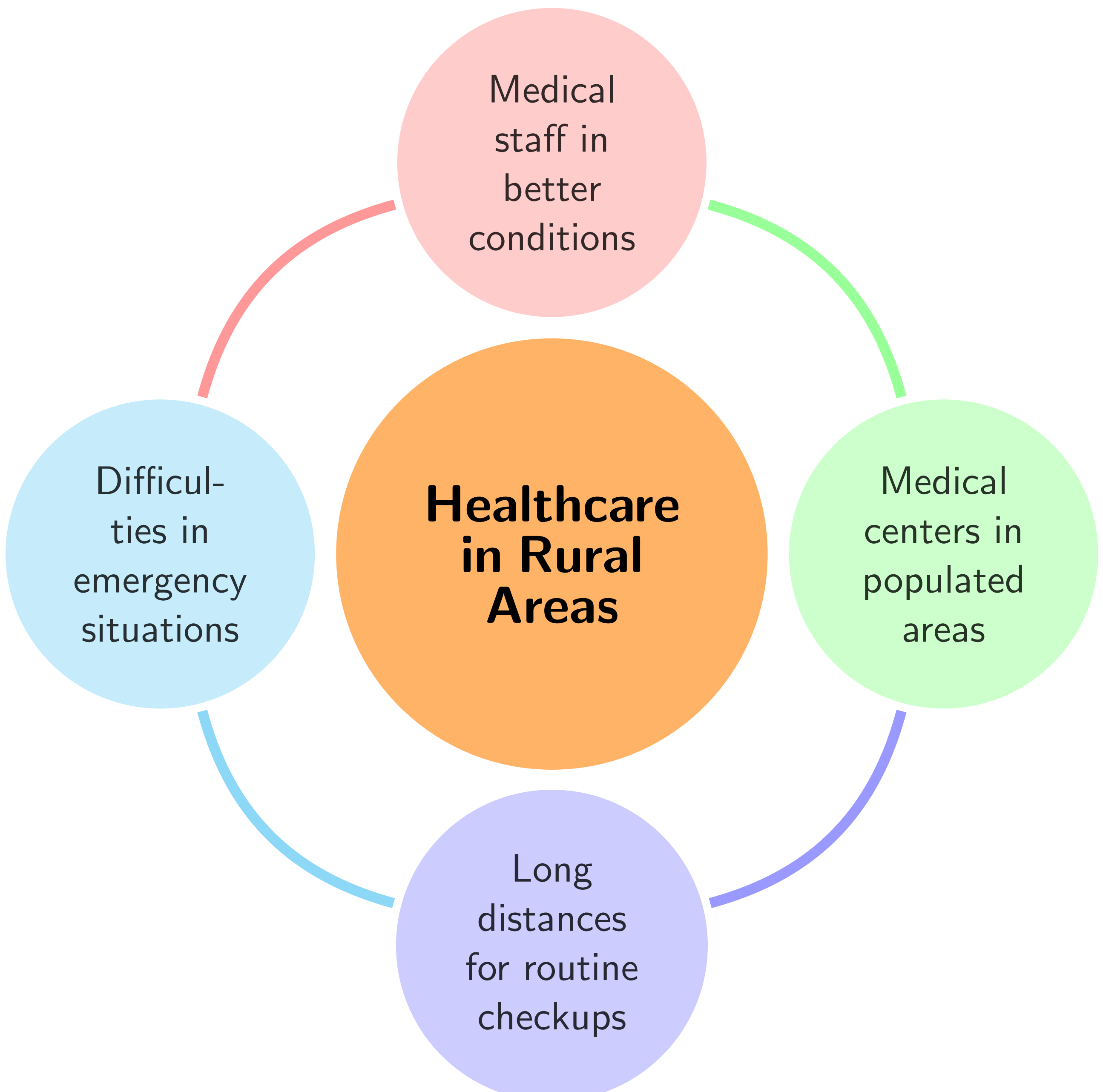
Healthcare in Rural Areas

Lack of sufficient healthcare services in rural areas has been a considerable problem throughout the world.



Healthcare Issues in Turkey

Urban Areas

- Death rate among new born babies: **1.6%**
- Vaccination rate until age of 2: **74%**
- Medical assistance in births: **91%**

Rural Areas

- Death rate among new born babies: **3.9%**
- Vaccination rate until age of 2: **60%**
- Medical assistance in births: **74%**

Mobile Healthcare Services

Possible Solutions

- Encourage doctors with privileges and promotions
- More investments on medical centers
- Mobile healthcare services

Mobile Healthcare Services

↓

Transportation of medical staff to the villages without any medical centers

↓

Applications in the world
Since 2010 in Turkey

↓

10 villages to a family practice center

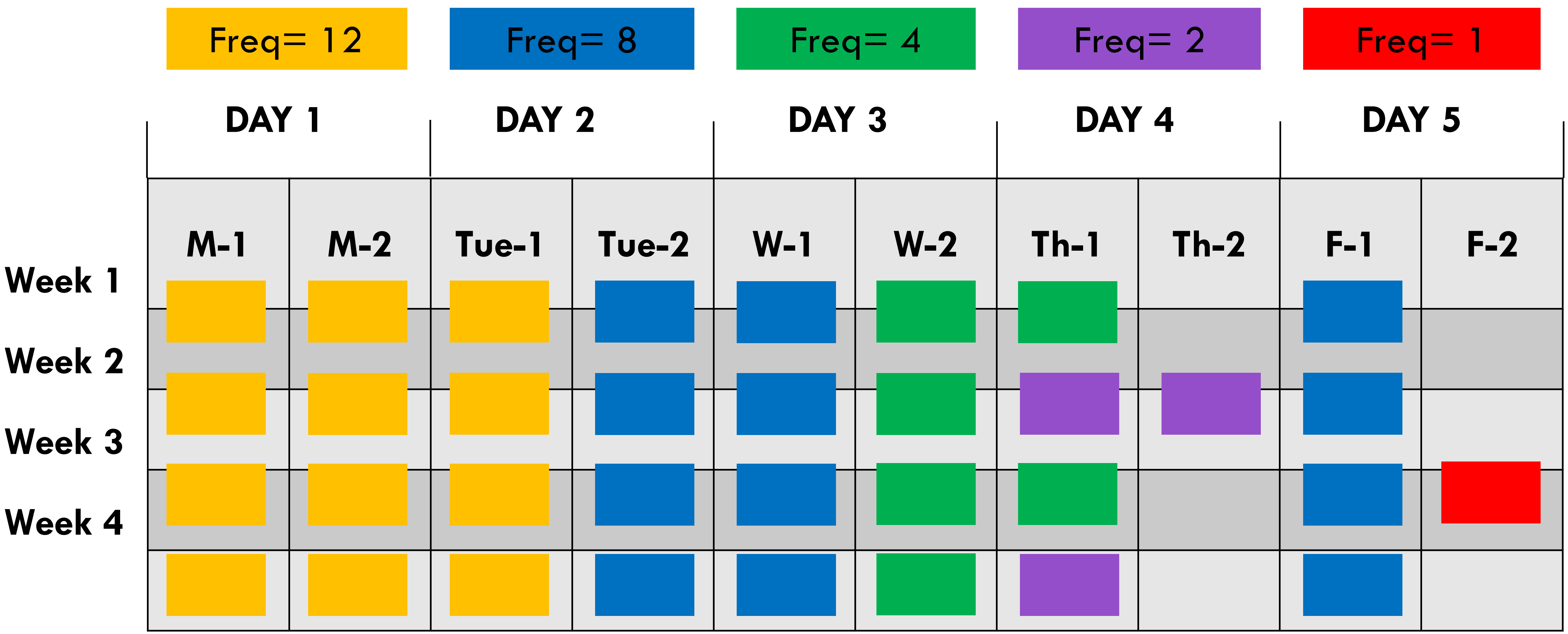
Problem Specific Requirements

- Visiting frequencies depend on the population size.
- There are alternative visiting rules for each frequency level.

Population Size	Minimum Visiting Hours (per month)	Frequencies (half-day/month)	Visiting Rule Alternatives
≤ 100	4	1	1 half-day in a month
≤ 300	8	2	1 day in a month 1 half-day in each two weeks
≤ 750	16	4	1 day in each two weeks 1 half-day in each week
≤ 1000	32	8	1 day in each week 1 half-day in each 2.5 days
> 1000	48	12	1.5 days in each week

Requirements of the Problem

- Services must be provided at the same slot each week.



Problem Definition

- Generate monthly service schedules for the practitioners to travel the villages,
- Determine their base hospitals,
- While satisfying problem specific requirements.
  1. Visiting frequencies depend on the population size.
  2. There are alternative visiting rules for each frequency level.
  3. Services must be provided at the same slot each week.
  4. Doctors are dedicated to the villages.
  5. Base hospitals for each doctor must be selected (where they start their tour from on Monday morning and end them on Friday afternoon)

Variations of Classical Routing Problems

- Distance Constrained
- Time Windowed
- Multi-depot
- Split Delivery
- Heterogenous Fleet
- Pick-up and delivery together
- Periodic
- ...

Periodic Location and Routing Problem (PLRP)

Location(s) of the depot fixed or to be determined

Periodic Location and Routing Problem

- Determine periodic routes
- Determine the location of the depot

- The literature on PLRP is scarce

- Visit the Periodic Vehicle Routing Problem literature
  - Depot location is fixed

Mathematical Model

Sets:

N	Set of all nodes, $N = I \cup H$.
I	Set of villages.
$I2, I4, I8, I12$	Set of villages with frequency 2, 4, 8, 12, respectively.
H	Set of hospitals.
D	Set of doctors (practitioners).
T	Set of time periods.
$NT1$	Set of time periods consisting of $\{11, 21, 31\}$
$NT01$	Set of time periods consisting of $\{10, 11, 20, 21, 30, 31\}$

Parameters:

$DIST_{nm}$:	distance between nodes $n \in N$ and $m \in N$.
DEM_i:	visiting frequency of village $i \in I$.
CAP:	maximum working time of doctors.
p:	number of base hospitals to be selected.

Mathematical Model

- Decision Variables

$$x_{nm}^{dt} = \begin{cases} 1, & \text{if doctor } d \in D \text{ travels from node } n \in N \text{ to } m \in N \text{ at time period} \\ & t \in T, \\ 0, & \text{otherwise.} \end{cases}$$

$$y_i^{dt} = \begin{cases} 1, & \text{if doctor } d \in D \text{ visits village } i \in I \text{ at time period } t \in T, \\ 0, & \text{otherwise.} \end{cases}$$

$$u_n^d = \begin{cases} 1, & \text{if node } n \in N \text{ is assigned to doctor } d \in D, \\ 0, & \text{otherwise.} \end{cases}$$

$$z_h = \begin{cases} 1, & \text{if a hospital at } h \in H \text{ is selected as a base hospital,} \\ 0, & \text{otherwise.} \end{cases}$$

$$k_{ih}^{dt} = \begin{cases} 1, & \text{if doctor } d \in D \text{ who is assigned to the hospital at point } h \in H \\ & \text{is present at village } i \in I \text{ at time period } t \in T, \\ 0, & \text{otherwise.} \end{cases}$$

Mathematical Model (Routing Decisions)

$$\text{minimize} \quad \sum_{n\in N}\sum_{m\in N}\sum_{d\in D}\sum_{t\in T} x_{nm}^{dt}\cdot DIST_{nm} - \sum_{n\in N}\sum_{m\in N}\sum_{d\in D}\sum_{t\in NT1} x_{nm}^{dt}\cdot DIST_{nm} + \sum_{i\in I}\sum_{h\in H}\sum_{d\in D}\sum_{t\in NT01} k_{ih}^{dt}\cdot DIST_{ih}, \tag{1}$$

subject to

$$\sum_{i\in I}\sum_{h\in H} x_{hi}^{d1} = 1, \qquad d\in D \tag{2}$$

$$\sum_{d\in D}\sum_{t\leq 40} y_i^{dt} = DEM_i, \qquad i\in I \tag{3}$$

$$\sum_{n\in N} x_{ni}^{dt} = y_i^{dt}, \qquad i\in I,\ d\in D,\ t\leq 40 \tag{4}$$

$$\sum_{n\in N} x_{in}^{dt+1} = y_i^{dt}, \qquad i\in I,\ d\in D,\ t\leq 40 \tag{5}$$

$$y_i^{dt} \leq u_i^d, \qquad i\in I,\ d\in D,\ t\leq 40 \tag{6}$$

$$\sum_{d\in D} u_i^d = 1, \qquad i\in I \tag{7}$$

Mathematical Model (Routing Decisions)

$$\sum_{i \in I} y_i^{dt} \leq 1, \qquad d \in D,\ t \leq 40 \qquad (8)$$

$$\sum_{n \in N} \sum_{m \in M} x_{nm}^{dt} \leq 1, \qquad d \in D,\ t \in T, \qquad (9)$$

$$\sum_{i \in I} \sum_{t \leq 40} y_i^{dt} \leq CAP, \qquad d \in D \qquad (10)$$

$$\sum_{i \in I} \sum_{h \in H} \sum_{t \in T} x_{ih}^{dt} = 1, \qquad d \in D \qquad (11)$$

$$y_i^{d41} = 0, \qquad i \in I,\ d \in D \qquad (12)$$

$$k_{ih}^{dt} \leq \frac{y_i^{dt} + u_h^d}{2}, \qquad i \in I,\ h \in H,\ d \in D,\ t \in T \qquad (13)$$

$$k_{ih}^{dt} \geq y_i^{dt} + u_h^d - 1, \qquad i \in I,\ h \in H,\ d \in D,\ t \in T, \qquad (14)$$

Mathematical Model (Location Decisions)

$$\sum_{h \in H} z_h = p \qquad (15)$$

$$\sum_{h \in H} u_h^d = 1, \qquad d \in D \qquad (16)$$

$$x_{hi}^{dt} \leq u_h^d, \qquad i \in I,\ h \in H,\ d \in D,\ t \in T \qquad (17)$$

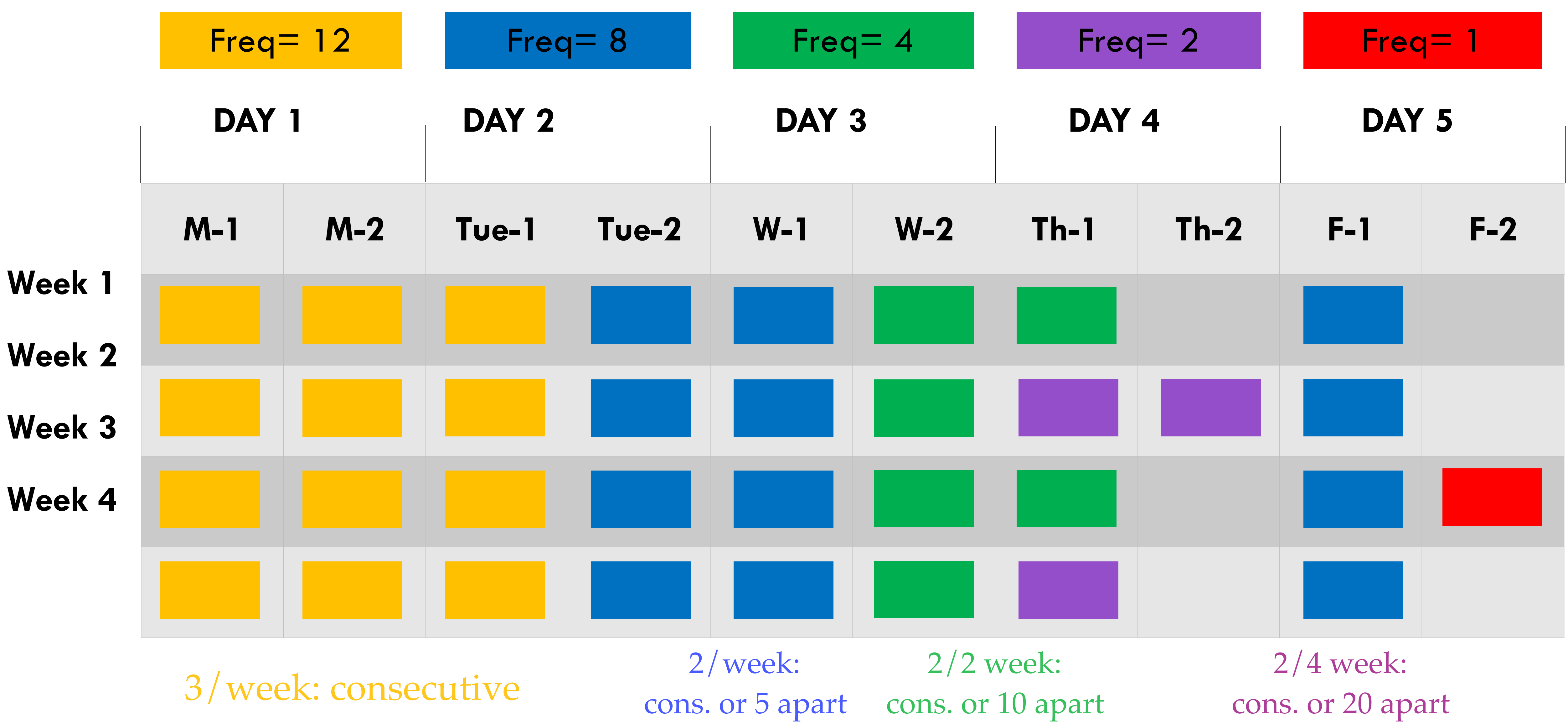
$$x_{ih}^{dt} \leq u_h^d, \qquad i \in I,\ h \in H,\ d \in D,\ t \in T \qquad (18)$$

$$u_h^d \leq z_h, \qquad h \in H,\ d \in D \qquad (19)$$

Mathematical Model: Scheduling Decisions

Requirements of the Problem

2) The time intervals between the visits are fixed (services must be provided at the same slot each week)



Scheduling Decisions

Frequency	Doctor repeats the same tour every	
12	week	3 slots/week: consecutive
8	week	2 slots/week: either consecutive or 5 slots apart
4	two weeks	2 slots/2 weeks: either consecutive or 10 slots apart
2	-	2 slots / 4 weeks: either consecutive or 20 slots apart
1	-	1 slot / 4 weeks

Mathematical Model: Scheduling Decisions

Frequency of 2: 2 slots / 4 weeks: either consecutive or 20 slots apart

$$y_i^{d2} + y_i^{d21} \geq y_i^{d1}, \qquad i \in I2,\ d \in D \qquad (5.20)$$

$$y_i^{dt+1} + y_i^{dt-1} + y_i^{dt+20} \geq y_i^{dt}, \qquad i \in I2,\ d \in D, t \leq 20 : t \neq \{1, 10\} \qquad (5.21)$$

$$y_i^{dt-1} + y_i^{dt+20} \geq y_i^{dt}, \qquad i \in I2,\ d \in D,\ t = \{10, 20\} \qquad (5.22)$$

$$y_i^{dt+1} + y_i^{dt-1} + y_i^{dt-20} \geq y_i^{dt}, \qquad i \in I2,\ d \in D,\ 21 \leq t \leq 39, \qquad (5.23)$$

$$y_i^{dt-1} + y_i^{dt-20} \geq y_i^{dt}, \qquad i \in I2,\ d \in D,\ t = \{30, 40\} \qquad (5.24)$$

Frequency of 4: 2 slots/2 weeks: either consecutive or 10 slots apart

$$\sum_{t \leq 20} y_i^{dt} \geq 2 \cdot u_i^d, \qquad i \in I4,\ d \in D, \qquad (5.25)$$

$$y_i^{d2} + y_i^{d11} \geq y_i^{d1}, \qquad i \in I4,\ d \in D, \qquad (5.26)$$

$$y_i^{dt+1} + y_i^{dt-1} + y_i^{dt+10} \geq y_i^{dt}, \qquad i \in I4,\ d \in D,\ 2 \leq t \leq 20, \qquad (5.27)$$

$$y_i^{dt+20} + y_i^{dt+30} \geq y_i^{dt} + y_i^{dt+10}, \qquad i \in I4,\ d \in D,\ 1 \leq t \leq 10, \qquad (5.28)$$

$$y_i^{dt+20} + y_i^{dt+21} \geq y_i^{dt} + y_i^{dt+1}, \qquad i \in I4,\ d \in D, 1 \leq t \leq 19 : t \neq 10, \qquad (5.29)$$

Mathematical Model: Scheduling Decisions

Frequency of 8: 2 slots / week: either consecutive or 5 slots apart

$$\sum_{t \le 10} y_i^{dt} \ge 2 \cdot u_i^d, \qquad i \in I8,\ d \in D, \qquad (5.30)$$

$$y_i^{d2} + y_i^{d6} \ge y_i^{d1}, \qquad i \in I8,\ d \in D, \qquad (5.31)$$

$$y_i^{dt+1} + y_i^{dt-1} + y_i^{dt+5} \ge y_i^{dt}, \qquad i \in I8,\ d \in D,\ 2 \le t \le 5, \qquad (5.32)$$

$$y_i^{dt+1} + y_i^{dt-1} + y_i^{dt-5} \ge y_i^{dt}, \qquad i \in I8,\ d \in D,\ 6 \le t \le 10, \qquad (5.33)$$

$$y_i^{dt+10} \ge y_i^{dt}, \qquad i \in I8,\ d \in D, 1 \le t \le 30, \qquad (5.34)$$

Frequency of 12: 3 slots / week: consecutive

$$\sum_{t \le 10} y_i^{dt} \ge 3 \cdot u_i^d, \qquad i \in I12,\ d \in D, \qquad (5.35)$$

$$y_i^{d2} + y_i^{d3} \ge 2 \cdot y_i^{d1}, \qquad i \in I12,\ d \in D, \qquad (5.36)$$

$$y_i^{d1} + y_i^{d3} + y_i^{d4} \ge 2 \cdot y_i^{d2}, \qquad i \in I12,\ d \in D, \qquad (5.37)$$

$$y_i^{dt-2} + y_i^{dt-1} + y_i^{dt+1} + y_i^{dt+2} \ge 2y_i^{dt} \qquad i \in I12,\ d \in D,\ 3 \le t \le 8 \qquad (5.38)$$

$$y_i^{d7} + y_i^{d8} + y_i^{d10} \ge 2 \cdot y_i^{d9}, \qquad i \in I12,\ d \in D, \qquad (5.39)$$

$$y_i^{d8} + y_i^{d9} \ge 2 \cdot y_i^{d10}, \qquad i \in I12,\ d \in D, \qquad (5.40)$$

$$y_i^{dt+10} \ge y_i^{dt}, \qquad i \in I12,\ d \in D, 1 \le t \le 30, \qquad (5.41)$$

Mathematical Model

Valid Inequalities

$$\sum_{i \in I12} u_i^d + \sum_{i \in I8} u_i^d \leq 5, \qquad d \in D \tag{43}$$

$$\sum_{i \in I12} u_i^d \leq 3, \qquad d \in D \tag{44}$$

$$\sum_{i \in I} u_i^d \cdot DEM_i \leq CAP, \quad d \in D \tag{45}$$

$$x_{ij}^{dt} \leq u_i^d, \qquad i \in I,\ j \in I,\ d \in D,\ t \in T \tag{46}$$

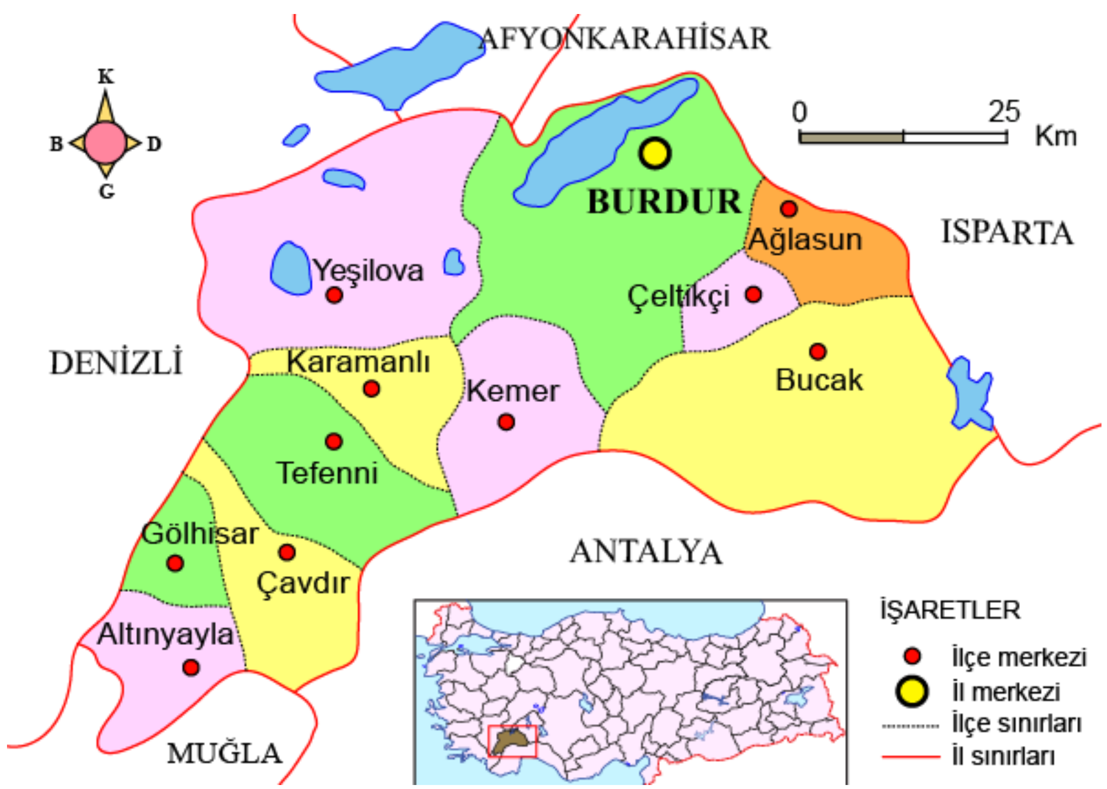
Domain Constraints

$$x_{nm}^{dt}, y_i^{dt}, u_n^d, z_h, k_{ih}^{dt} \in \{0,1\},$$

$$n, m \in N,\ h \in H,\ d \in D, t \in T,$$

Data: City of Burdur

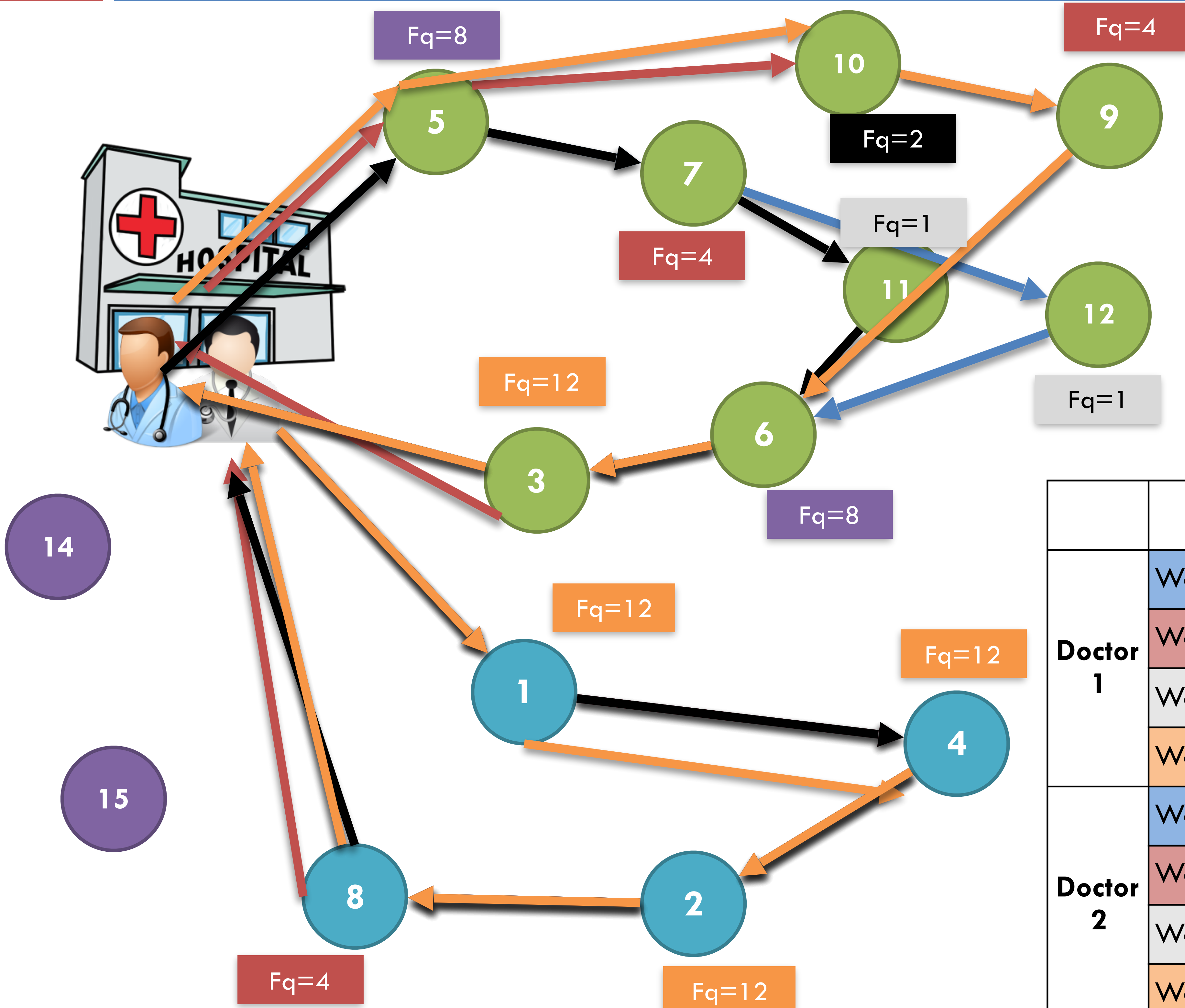
Burdur data set is used for computational analysis.



Parameters

- Coordinates $\rightarrow$ Distances
- Population $\rightarrow$ Frequencies
- Capacity $=$ 40 slots
- Number of base hospitals: varied over instances

Sample Result



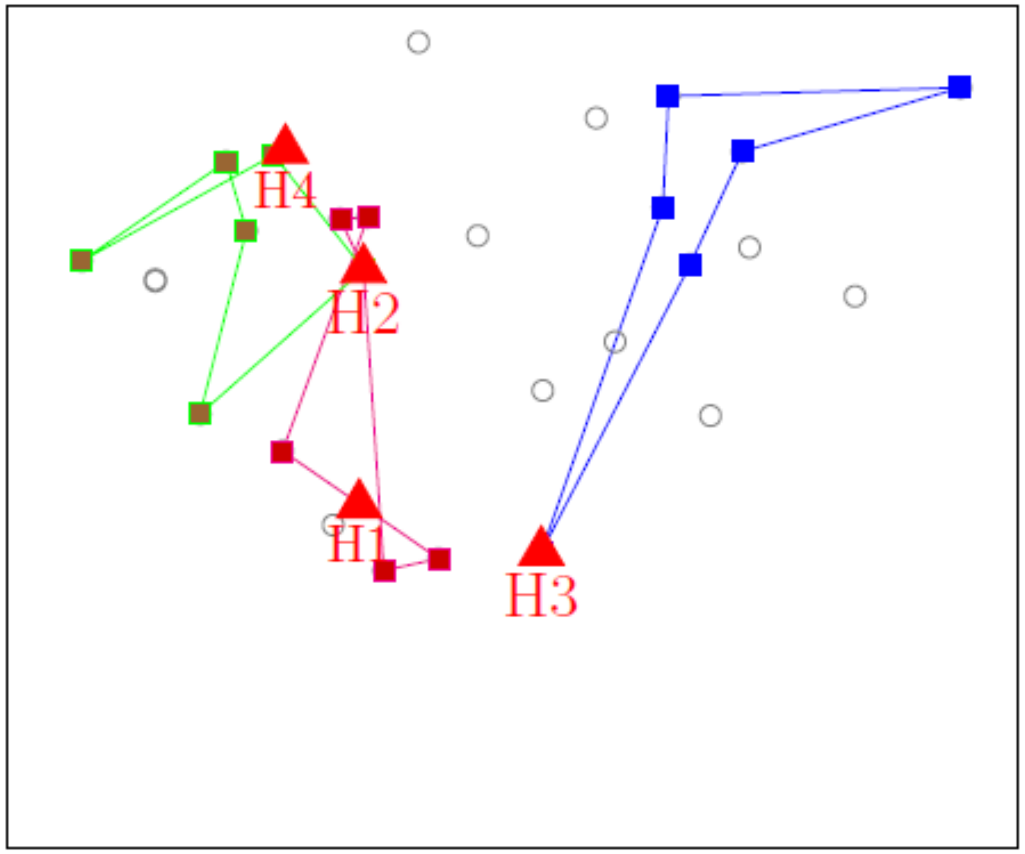
		M 1	M 2	T1	T2	W1	W2	Th 1	Th 2	F1	F2
Doctor 1	Week 1	5	5	7	7	12	6	6	3	3	3
	Week 2	5	5	10	9	9	6	6	3	3	3
	Week 3	5	5	7	7	11	6	6	3	3	3
	Week 4	5	5	10	9	9	6	6	3	3	3
Doctor 2	Week 1	1	1	1	4	4	4	2	2	2	8
	Week 2	1	1	1	4	4	4	2	2	2	8
	Week 3	1	1	1	4	4	4	2	2	2	8
	Week 4	1	1	1	4	4	4	2	2	2	8

Sample Schedule for 3 doctors

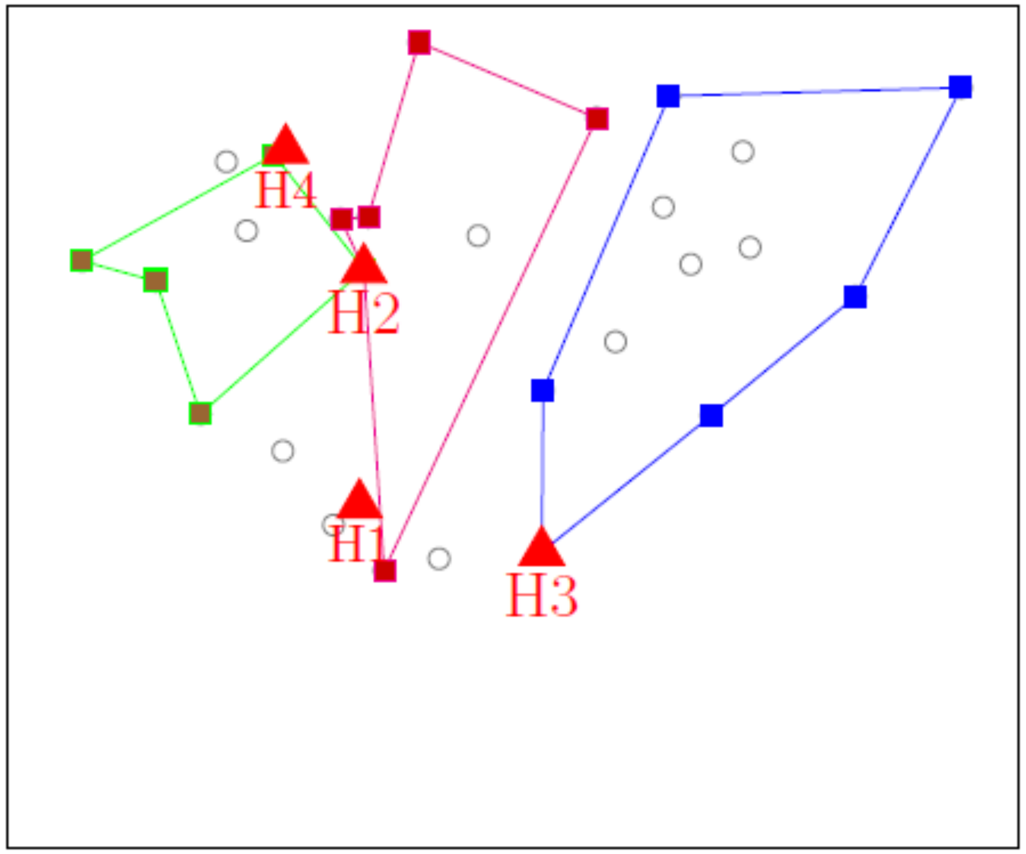
	Mon-1	Mon-2	Tue-1	Tue-2	Wed-1	Wed-2	Thu-1	Thu-2	Fri-1	Fri-2
Week-1	1	1	1	3	12	12	2	2	16	16
Week-2	1	1	1	8	8	15	2	2	16	16
Week-3	1	1	1	7	12	12	2	2	16	16
Week-4	1	1	1	8	8	15	2	2	16	16

	Mon-1	Mon-2	Tue-1	Tue-2	Wed-1	Wed-2	Thu-1	Thu-2	Fri-1	Fri-2
Week-1	25	25	25	13	13	22	11	11	5	5
Week-2	25	25	25	21	21	20	11	11	5	5
Week-3	25	25	25	13	13	22	11	11	5	5
Week-4	25	25	25	21	21	20	11	11	5	5

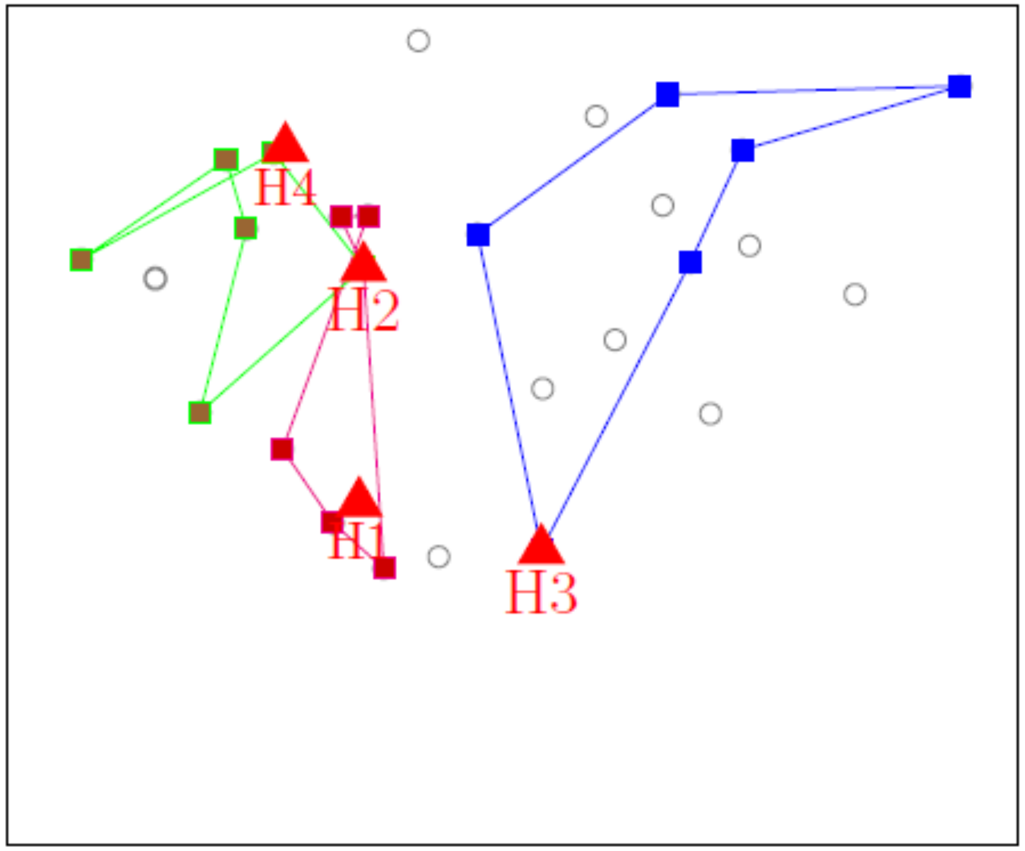
	Mon-1	Mon-2	Tue-1	Tue-2	Wed-1	Wed-2	Thu-1	Thu-2	Fri-1	Fri-2
Week-1	6	6	18	18	24	24	19	19	19	17
Week-2	10	10	23	23	24	24	19	19	19	4
Week-3	6	6	18	18	24	24	19	19	19	26
Week-4	10	10	9	14	24	24	19	19	19	4



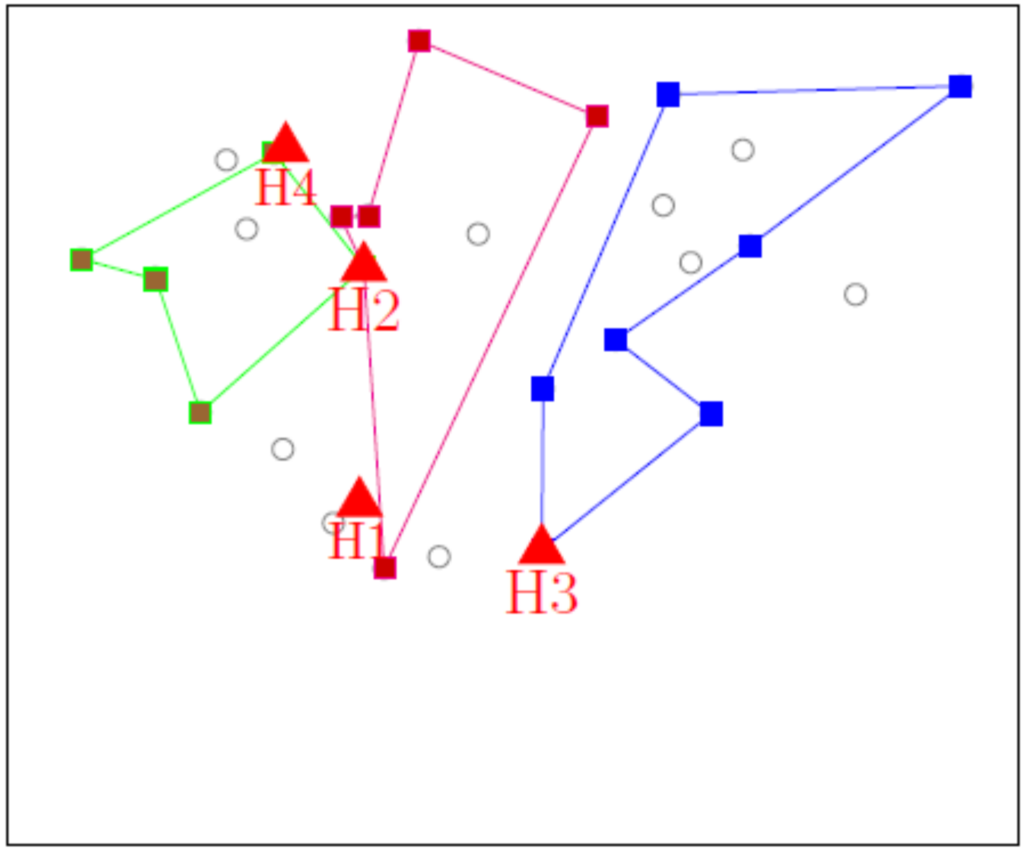
(a) Week 1 Routes



(b) Week 2 Routes



(c) Week 3 Routes



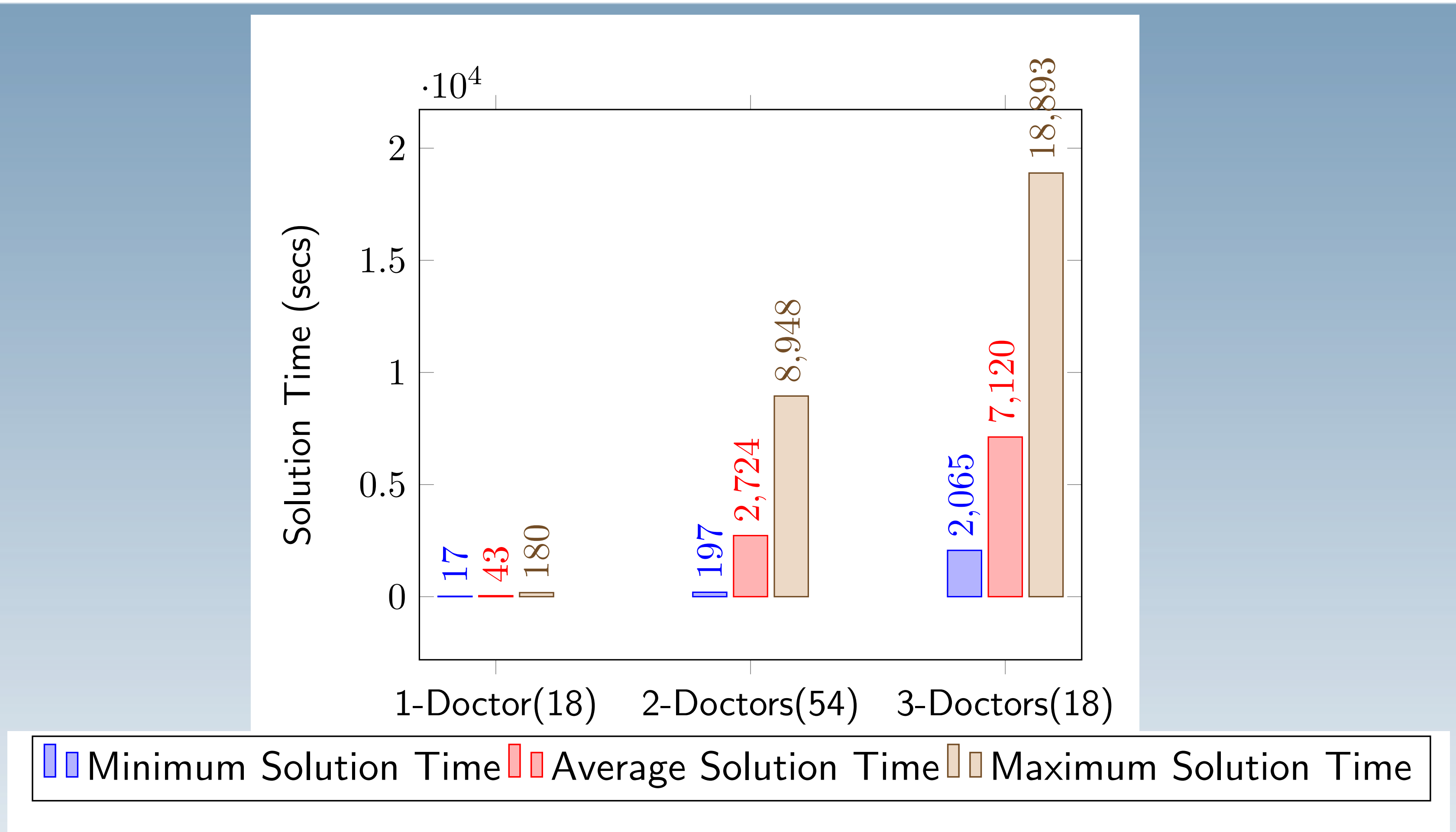
(d) Week 4 Routes

Analysis on the Problem Parameters

Effects of:

1. Number of doctors
2. Number of base hospitals
3. Frequency distribution

Number of doctors on solution times



Increasing number of doctors increase the complexity of problem, thus, solution times increase.

Number of base hospitals on solution times

Number of Doctors	Number of Base Hospitals	Number of Instances	Minimum Solution Time (sec)	Average Solution Time (sec)	Maximum Solution Time (sec)
1	1	18	17	43	180
2	1	30	197	2,579	8,948
2	2	24	210	2,905	5,679
3	1	6	2,065	5798	10,933
3	2	6	3,989	6,917	12,850
3	3	6	3,878	8,645	18,893

Selecting less base hospitals with the same number of doctors results in shorter solution times.

Frequency distribution on solution times

Majority of Frequency	Instance Number	Average Solution Time (sec)
12	Instance 6	2,670
	Instance 7	8,926
	Instance 10	6,549
	Instance 11	7,642
	Instance 14	7,283
	Instance 15	9,647
8	Instance 16	3,046
	Instance 17	3,272
	Instance 18	2,130
	Instance 19	2,325
	Instance 20	4,597
4	Instance 1	4,478
	Instance 21	4,247
	Instance 22	2,077
	Instance 23	3,574
	Instance 24	8,921

Majority of Frequency	Instance Number	Average Solution Time (sec)
2	Instance 25	29
	Instance 26	86
	Instance 27	80
1	Instance 28	24
	Instance 29	18
	Instance 30	22
Evenly Distributed	Instance 2	299
	Instance 3	2,062
	Instance 4	310
	Instance 5	2,150
	Instance 8	298
	Instance 9	4,417
	Instance 12	258
	Instance 13	1,186

- Dominance of frequency 1 or 2 decreases solution time.
- Majority of frequency 12 increases solution time.
- More even frequency distributions (no dominance), especially with selection of less base hospitals, result in shorter computational times.

Heuristic Algorithm

Necessity of an efficient algorithm:

- High solution times for medium/large data sets.
- Large optimality gaps at the end of time limits.

An iterative Cluster First, Route Second based approach

Construction Phase

- Determine cluster (doctor's assignments) via p-median based IP
- Route each doctor separately via adjusted PLRP model
- Add up each doctor's distance

Improvement Phase (Iterative)

- Determine next best cluster with an additional constraint to the IP
- Route each doctor separately via adjusted PLRP model
- Add up each doctor's distance
- Determine the minimum distance value among all iterations

Construction Phase

Same Parameters and Decision Variables:

set of villages I, set of base hospitals H, $DIST_{ij}$, DEM_i, CAP, p, z_h

Additional Parameters and Decision Variables:

$cluster$: number of clusters, i.e. number of doctors

$$x_j = \begin{cases} 1, & \text{if village } j \in I \text{ is selected as a cluster origin,} \\ 0, & \text{otherwise.} \end{cases}$$

$$y_{ij} = \begin{cases} 1, & \text{if village } i \in I \text{ is assigned to cluster origin } j \in I, \\ 0, & \text{otherwise.} \end{cases}$$

$$\text{minimize} \quad \sum_{i \in I} \sum_{j \in I} DIST_{ij} \cdot DEM_i \cdot y_{ij} \tag{7.1}$$

$$\sum_{j \in I} x_j = cluster, \tag{7.2}$$

$$\sum_{j \in I} y_{ij} = 1, \qquad i \in I, \tag{7.3}$$

$$\sum_{i \in I} DEM_i \cdot y_{ij} \leq CAP, \qquad j \in I \tag{7.4}$$

$$y_{ij} \leq x_j, \qquad i \in I,\ j \in I, \tag{7.5}$$

$$x_j \leq y_{jj}, \qquad j \in I, \tag{7.6}$$

$$\sum_{h \in H} z_h = p, \tag{7.7}$$

$$\sum_{h \in H} y_{hj} = x_j, \qquad j \in I \tag{7.8}$$

$$y_{hj} \leq z_j, \qquad j \in I,\ h \in H, \tag{7.9}$$

$$x_j, y_{ij}, z_h, \in \{0, 1\}, \qquad i, j \in I,\ h \in H, \tag{7.10}$$

- $\forall j \in J, y_{ij} = 1$ are determined.
- Each j corresponds to a doctor.
- For each j, set I consists of i's s.t. $y_{ij} = 1$
- Index d and location decisions are removed from the PLRP model.
- For each doctor, schedules are determined via the updated model.
- Total distance is found by adding up the results of each doctor.

Improvement Phase

Find next best cluster with:

$$\sum_{i\in I}\sum_{j\in I} DIST_{ij}\cdot DEM_i\cdot y_{ij} \geq PrevIter+k \qquad (7.11)$$

Eliminating same clusters at each iteration:

$$\sum_{s\in S} y_{sj} \leq |S|-1, \qquad S=\{i\in I : y_{i1}=1\} \qquad (7.12)$$

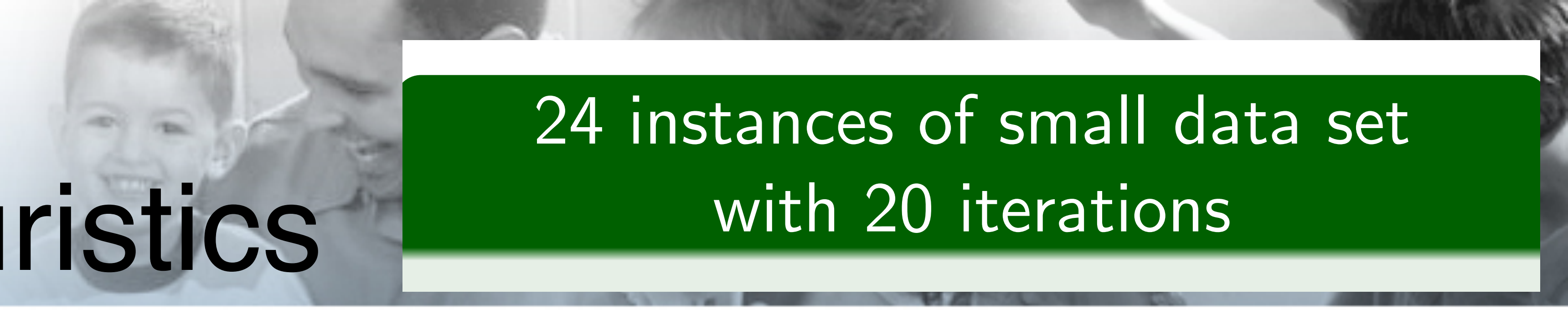
Heuristic-1: with (7.12)
Heuristic-2: without (7.12)

Algorithm 1 Heuristic Approach for PLRP

Require: $iter$: Number of predetermined iterations
p-median($prevIter$): The IP formulation explained in Chapter 7.
routing(D_j): The IP formulation explained in Chapter 5.

for $i = 1 : iter$ **do**
  if i=1 **then**
    $prevIter = 0$
  else
    $prevIter = solution$
  end if
  Solve p-median($prevIter$)
  $solution$ = p-median($prevIter$).objective
  Add new constraint (7.12)
  $size$ = number of clusters (i.e. number of doctors)
  Record clusters in $Doctors(size)$
  for $j = 1 : size$ **do**
    Solve routing($Doctors_j$)
    $distance_j$ = routing($Doctors_j$).objective
    $j = j + 1$
  end for
  $Sum(i) = \sum_{j=1}^{size} distance_j$
  $i = i + 1$
end for
$Result = \min_{i=1..iter} Sum(i)$

Results of Heuristics



24 instances of small data set with 20 iterations

	Mathematical Model		Heuristic-1				Heuristic-2			
	Obj. Value	Solution Time (sec)	Obj. Value	Itera-tion	Solution Time (sec)	Gap (%)	Obj. Value	Itera-tion	Solution Time (sec)	Gap (%)
Ins 1	5,281.18	6,684	5,281.18	4	179	0.00%	5,281.18	7	219	0.00%
Ins 2	4,943.81	357	4,943.81	1	106	0.00%	4,943.81	1	124	0.00%
Ins 3	4,491.33	1,180	4,491.33	1	104	0.00%	4,491.33	1	122	0.00%
Ins 4	4,805.67	344	4,805.67	1	95	0.00%	4,805.67	1	130	0.00%
Ins 5	4,876.04	2,677	4,876.04	2	140	0.00%	4,876.04	2	173	0.00%
Ins 6	7,885.68	2,989	7,908.40	2	94	0.29%	7,908.40	2	119	0.29%
Ins 7	7,908.40	6,773	7,908.40	1	93	0.00%	7,908.40	1	106	0.00%
Ins 8	6,053.13	303	6,053.13	1	120	0.00%	6,053.13	1	121	0.00%
Ins 9	4,856.33	5,483	4,856.33	1	122	0.00%	4,856.33	1	118	0.00%
Ins 10	6,097.48	5,926	6,097.48	2	80	0.00%	6,097.48	3	116	0.00%
Ins 11	6,012.08	12,742	6,012.08	2	78	0.00%	6,012.08	3	119	0.00%
Ins 12	5,551.66	197	5,551.66	14	102	0.00%	5,635.70	1	124	1.51%
Ins 13	4,235.74	210	4,235.74	1	108	0.00%	4,235.74	1	126	0.00%
Ins 14	5,594.12	3,989	5,594.12	16	78	0.00%	5,978.96	1	115	6.88%
Ins 15	5,179.78	3,878	5,179.78	5	80	0.00%	5,196.60	17	99	0.32%
Ins 16	5,310.06	3,259	5,447.26	1	166	2.58%	5,447.26	1	195	2.58%
Ins 17	4,863.60	3,381	4,926.29	1	158	1.29%	4,926.29	1	214	1.29%
Ins 18	5,002.72	2,569	5,002.72	3	148	0.00%	5,002.72	4	206	0.00%
Ins 19	4,663.24	3,669	4,724.97	3	152	1.32%	4,663.24	10	195	0.00%
Ins 20	5,310.06	2,890	5,310.06	6	173	0.00%	5,310.06	14	203	0.00%
Ins 21	4,895.42	5,071	4,895.42	1	153	0.00%	4,895.42	1	193	0.00%
Ins 22	3,059.73	1,494	3,353.17	2	198	9.59%	3,287.80	6	225	7.45%
Ins 23	2,601.60	1,127	2,601.60	1	214	0.00%	2,601.60	1	228	0.00%
Ins 24	2,984.28	6,978	3,103.14	17	242	3.98%	3,179.24	17	315	6.53%
		3507			**132**	**18 opt 0.79%**			**162**	**16 opt 1.12%**

Conclusions

Conclusions:

1. An IP for PLRP is developed which determines the schedules via its constraints, satisfies certain visiting alternatives, dedicates each doctor to the villages and selects base hospitals.
2. Computational studies indicated small instances can be solved in reasonable times; however, this is not valid for medium and large ones.
   - Higher number of doctors result in higher solution times.
   - The lower number of base hospitals to select, the less solution times.
   - Even frequency distributions shorten the computational times.
3. Iterative heuristic methodology based on a "Cluster First, Route Second" approach determines optimal or near-optimal solutions in shorter times.
   - Both variants have their own disadvantages.
   - Heuristic-1 always provides solutions in shorter times.
   - Heuristic-1 provides lower distance values in the majority of the cases.

Other applications

- Specialists services
- Follow up patients
- Healthcare services for refugee camps!
- COVID-19 test booths….