“Securing Home Health Care structures facing forecastable natural disasters”

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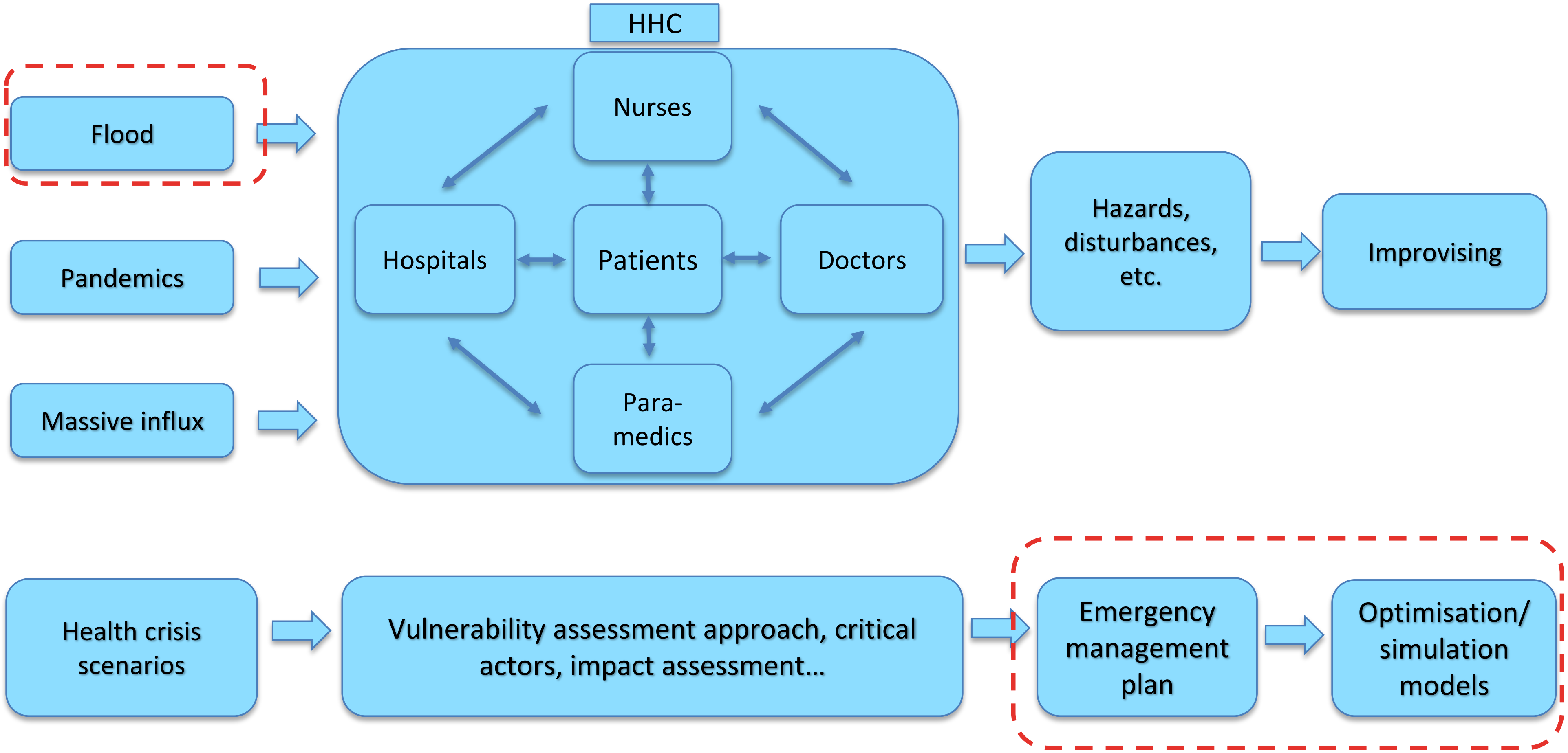
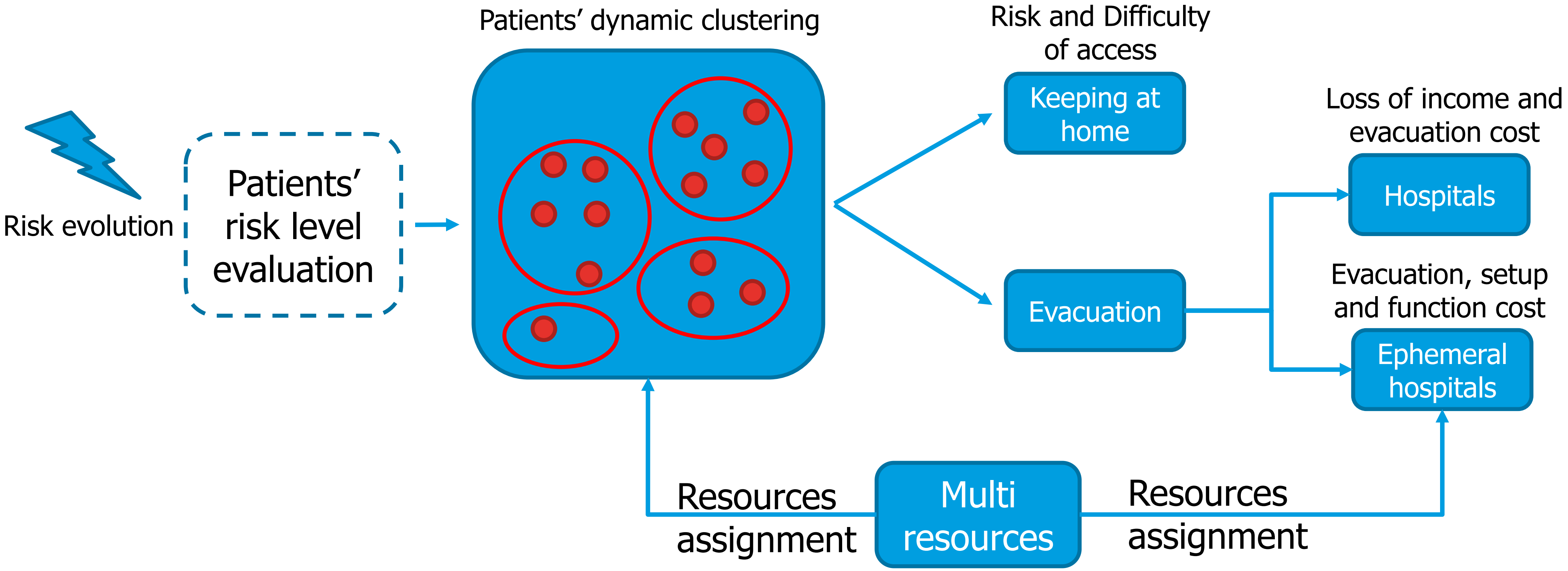
Agenda

- Context
- State of the art
- Model description
- Results
- Prospects

Context


HHC
Flood
Pandemics
Massive influx
Nurses
Hospitals
Patients
Doctors
Para-
medics
Hazards,
disturbances,
etc.
Improvising
Health crisis
scenarios
Vulnerability assessment approach, critical
actors, impact assessment...
Emergency
management
plan
Optimisation/
simulation
models

Problem description



➔ Dynamic Partitioning Problem combined with an assignment problem

State of the art

Evacuation problem

Optimization models

Macroscopic evacuation:
Endangered area evacuation,
location-allocation, BEP,etc.
Song et al. (2009), Tayfur and
Taaffe (2009), etc.

Simulation models

Microscopic evacuation:
evacuation of buildings

(Pelechano and Malkawi, 2008), (Kaup and al. 2002), etc.

➔ the optimization models are the most suitable when considering evacuation problem with resource distribution.

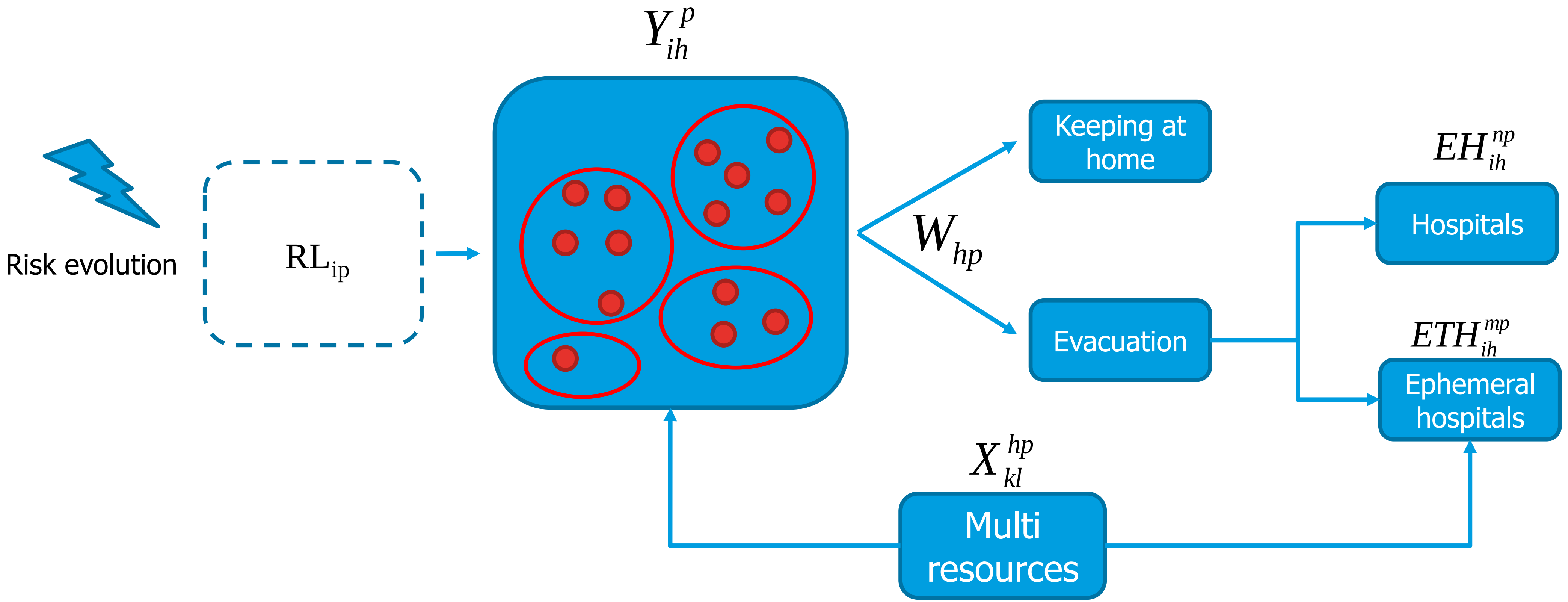
Model description

- **Inputs**
  - Distance between different patients.
  - Distance between patients and regular /temporary hospitals.
  - Risk level evolution over time of each patient.
  - Important parameters: *α, Tmax, capevac, LPevac*

- **Outputs**
  - Patients' partitioning per period.
  - Which patients should be kept at home and which patients should be evacuated and where?
  - How many resources must be assigned to the non-evacuated areas?
  - How many resources must be assigned to the temporary hospitals?

Problem description

- Decision Variables



Model description

- Objective function

$$Min(Z) =$$

$$\sum_{l=1}^{Ntype}\sum_{k=1}^{Nres(l)}\sum_{h=1}^{M+NTH}\sum_{p=1}^{T}(X_{kl}^{hp} * R\cos t_{kl})$$

The employment cost of resources

$$+\sum_{m=1}^{NTH}(THO_m * THO\cos t) + \sum_{m=1}^{NTH}\sum_{p=1}^{T}(TH_m^p * FuncTH)$$

the setup and function cost of temporary hospitals

$$+\sum_{i=1}^{NP}\sum_{h=1}^{M}\sum_{n=1}^{NH}\sum_{p=1}^{T}(EH_{ih}^{np} * (2 * \alpha * RL_{ip} * \frac{DPH_{in}}{V_{hp}} * Eva\cos t + Loss * (T - p + 1))$$

the evacuation cost to hospitals and the loss of income

$$+\sum_{i=1}^{NP}\sum_{h=1}^{M}\sum_{m=1}^{NTH}\sum_{p=1}^{T}(2 * \alpha * RL_{ip} * \frac{DPTH_{im}}{V_{hp}} * ETH_{ih}^{mp} * Eva\cos t)$$

the evacuation to temporary hospitals

$$+\sum_{i=1}^{NP}\sum_{h=1}^{M}\sum_{p=1}^{T}((\rho(RL_{ip}) * \beta * (Y_{ih}^{p} - (\sum_{n=1}^{NH} EH_{ih}^{np} + \sum_{m=1}^{NTH} ETH_{ih}^{mp}))$$

risk cost (penalties) related to non-evacuated patients

- Constraints: grouping aspect (clustering)

$$\sum_{h=1}^{M} Y_{ih}^{1} = 1; \forall i$$ p=1

$$\sum_{h=1}^{M} Y_{ih}^{p} = 1 - (\sum_{h=1}^{M}\sum_{n=1}^{NH}\sum_{q=1}^{p-1} EH_{ih}^{nq} + \sum_{h=1}^{M}\sum_{m=1}^{NTH}\sum_{q=1}^{p-1} ETH_{ih}^{mq}); \forall i, \forall p = 2..T$$ P>=2

$$\alpha * RL_{ip} * \frac{D_{ij}}{V_{hp}} * (Y_{ih}^{p} + Y_{jh}^{p} + RLC_{ij}^{p} - 2) \leq T_{\max}; \forall i, \forall j, \forall h, \forall p$$ Proximity <= Tmax, same risk level

Model description

- Constraints: evacuation aspect

$$\sum_{h=1}^{M}\sum_{n=1}^{NH}\sum_{p=1}^{T} EH_{ih}^{np} + \sum_{h=1}^{M}\sum_{m=1}^{NTH}\sum_{p=1}^{T} ETH_{ih}^{mp} \leq 1; \forall i$$

No return is allowed

$$\sum_{n=1}^{NH} EH_{ih}^{np} + \sum_{m=1}^{NTH} ETH_{ih}^{mp} \leq Y_{ih}^{p}; \forall i, \forall h, \forall p$$

Patients are evacuated from the area where they are located

$$W_{hp} \leq \sum_{i=1}^{NP} Y_{ih}^{p}; \forall h, \forall p$$

The group must contain at least one patient to be evacuated

$$\sum_{i=1}^{NP}\sum_{n=1}^{NH} EH_{ih}^{np} + \sum_{i=1}^{NP}\sum_{m=1}^{NTH} ETH_{ih}^{mp} \leq W_{hp} * HV; \forall h, \forall p$$

Assignment to hospitals and temporary hospitals

$$\sum_{i=1}^{NP}\sum_{n=1}^{NH} EH_{ih}^{np} + \sum_{i=1}^{NP}\sum_{m=1}^{NTH} ETH_{ih}^{mp} \geq (W_{hp} - 1) * HV + \sum_{i=1}^{NP} Y_{ih}^{p}; \forall h, \forall p$$

Unity of the group, split evacuation is authorized

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Model description

- Constraints: temporary hospitals management

$$\sum_{p=1}^{T} TH_{mp} \le THO_m * T; \forall m$$

Preparation of temporary hospitals before their opening

$$\sum_{q=p}^{T} TH_{mq} \le TH_{mp} * (T - p + 1); \forall m, \forall p$$

No return is allowed

$$\sum_{i=1}^{NP} \sum_{h=1}^{M} ETH_{ih}^{mp} \le TH_{mp} * HV; \forall m, \forall p$$

Opening of temporary hospitals before patients evacuation

Model description

- Constraints: capacity aspect

$$\sum_{i=1}^{NP}\sum_{h=1}^{M}\sum_{p=1}^{T} ETH_{ih}^{mp} \leq Nbeds\_TH_m ; \forall m$$

Number of beds of temporary hospitals

$$\sum_{i=1}^{NP}\sum_{h=1}^{M}\sum_{p=1}^{T} EH_{ih}^{np} \leq Nbeds\_H_n ; \forall n$$

Number of beds of hospitals

$$\sum_{h=1}^{M+NTH} X_{kl}^{hp} \leq Cap_{kl} ; \forall k, \forall l, \forall p$$

Working hours of nurses, doctors, etc,

$$\sum_{i=1}^{NP}\sum_{h=1}^{M}\sum_{n=1}^{NH}(2*\alpha*RL_{ip}*\frac{DPH_{in}}{V_{hp}}*EH_{ih}^{np})+\sum_{i=1}^{NP}\sum_{h=1}^{M}\sum_{m=1}^{NTH}(2*\alpha*RL_{ip}*\frac{DPTH_{im}}{V_{hp}}*ETH_{ih}^{mp}) \leq Capevac; \forall p$$

Working hours of evacuation resources

Model description

- Constraints: resources' assignment

$$\sum_{k=1}^{Nres(l)} X_{kl}^{hp} \geq \sum_{i=1}^{NP} (\alpha * RL_{ip} * Y_{ih}^{p}) - W_{hp} * HV; \forall l, \forall h, \forall p$$

Regulation between evacuation and home support

$$\sum_{k=1}^{Nres(l)} X_{kl}^{mp} \leq TH_{mp} * HV; \forall l, \forall p, \forall m = M + 1..NTH + M$$

We do not assign resources to closed temporary hospitals.

$$\sum_{k=1}^{Nres(l)} X_{kl}^{mp} \geq \sum_{i=1}^{NP} \sum_{h=1}^{M} \sum_{q=1}^{p} ETH_{ih}^{mq}; \forall l, \forall p, \forall m = M + 1..M + NTH$$

assignment of resources to temporary hospitals

- Constraints: risk management aspect

$$RL_{ip} - 2 \leq \sum_{n=1}^{NH} \sum_{h=1}^{M} \sum_{q=1}^{p} (EH_{ih}^{nq}) + \sum_{m=1}^{NTH} \sum_{h=1}^{M} \sum_{q=1}^{p} (ETH_{ih}^{mq}); \forall i, \forall p$$

Patients with high risk-level must be evacuated

Dimension the minimum capacity of the temporary hospitals

Results

- Results for different "*capevac*" values for 65 patients, *Tmax*=0,5

Capevac (hours)	Penalty Cost	Other costs	Total cost	*LPevac*
8	INF*	INF*	INF*	INF*
16	1960000	498335	2458335	5
24	1120000	499222	1619222	4
32	1120000	502531	1622531	3
40	1120000	501701	1621701	3

Results

- Impact of Tmax and α on the objective function

α\Tmax	0,2	0,3	0,4	0,5
1	1684580	1619222	1621759	1621759
1,25	1975469	1971502	2035737	1975342
1,5	2463680	2394439	2394781	2392318
1,75	2891269	2796361	2815433	2815433
2	3519565	3446098	3375698	3445771

Conclusion and prospects

- Our model is based on a real life scenario which has been defined with our partner: Soins et Santé. Therefore the model is well suited to the Home Health care practices.

- The improvement methods that we propose can be easily applied in the field.

- We take into account, the grouping, the location-allocation, assignment aspects in the same framework.

- Take into account the routing aspect within each group of patient.

- Consider other criteria than the distance in the selection of temporary hospitals .

Thank you!

Do you have any questions?