agence de la biomédecine

Using a gravity model for allocation of livers to transplant

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a - Introduction

Study Objectives

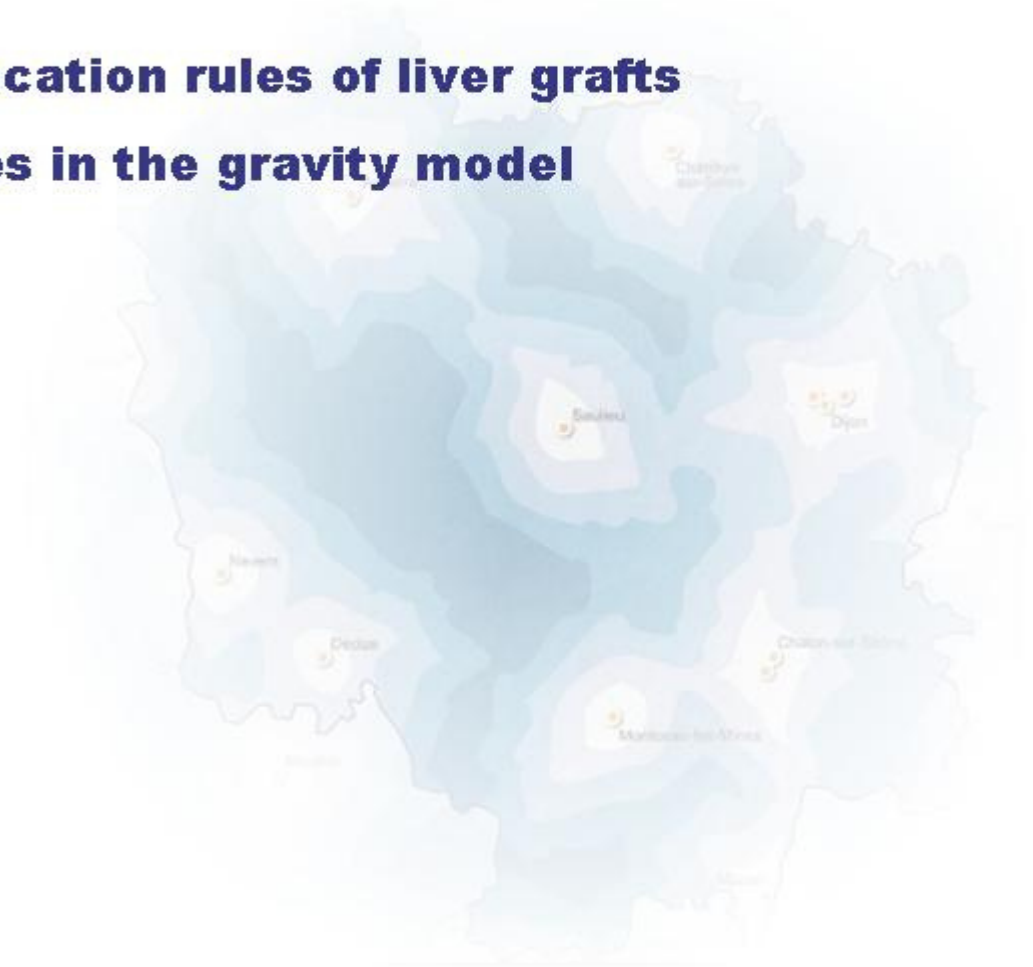
Global context :

- **What can be the contribution of spatial analysis and Geography to improve organ allocation ?**
- **How to improve the liver allocation scheme ?**

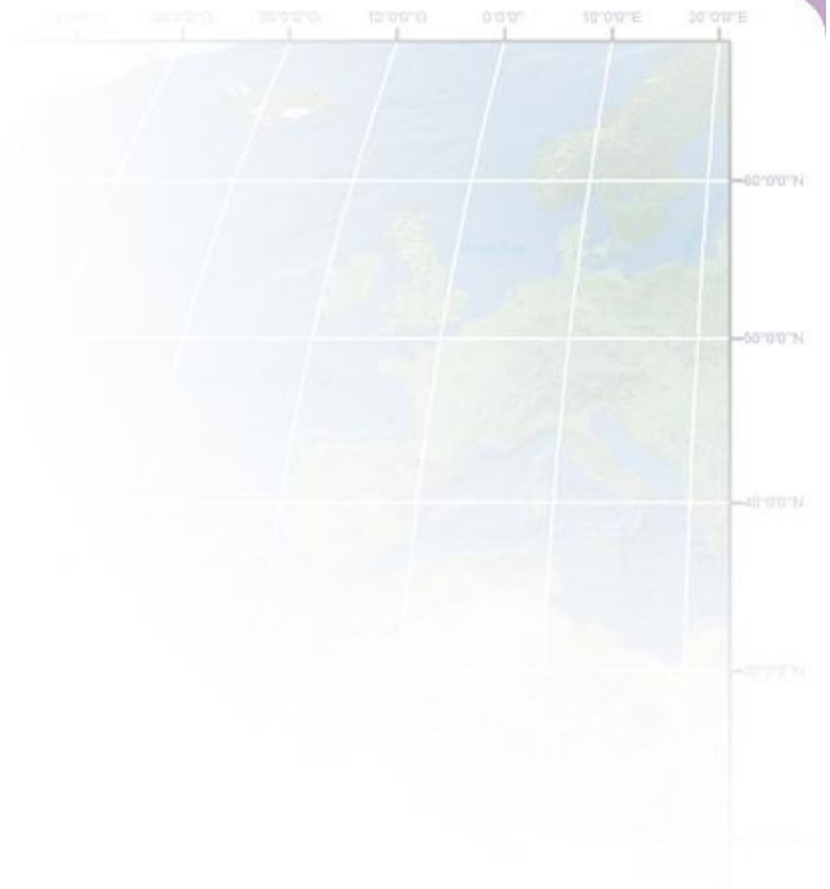
a - Introduction

Contents

1. The context : the french allocation rules of liver grafts
2. The integration of these rules in the gravity model
3. The results
4. Conclusion
5. Future works



1 - The context



1 - The context

The biomedecine Agency

- **Born with the bioethics law of August 6, 2004**
- **French public body**
- **Spread of abilities :**

  - organ allocation
  - medical assisted procreation
  - human embryology
  - human genetics

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1 - The context

The biomedecine Agency

Organ allocation rules and the national waiting list are under its responsability :

- **To ensure a fair distribution and seeking the best recipient**
- **To make a compromise between efficiency, equity and feasibility**

In liver transplant, this compromise takes into account :

- **Specific recipient condition (i.e. urgency)**
- **The graft quality/safety**
- **The distance between donor and transplant centres (cold ischemia time)**

1 - The context

Liver Score

The Liver Score was introduced in March 2007

➔ To submit a liver for the best recipient, by a "just-in-time" optimization

1 - The context

Liver Score

Set of function based on :

1. **An estimate of risk to die on waiting list, using the MELD (Model for End-Stage Liver Disease)** (0 - 1000 points)

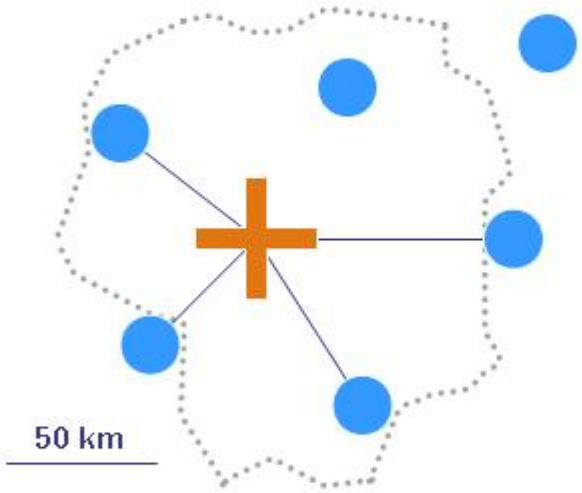
2. **His time spent on the waiting list** (0 - 300 points)

3. **The distance between donor and transplant centres** (0 - 300 points)
   - To reduce teams shipment
   - To reduce cold ischemia
   - To take into account the teams location (frontier effect)

1 - The context

Liver Score application

1/ Local network : choosing help



Organ retrieval team

Transplantation team with n patients on its waiting list

- In 2010, 20 liver's transplantation teams.
- Some are related to local retrieval teams

→Local Network.

- When a graft is available in this network, it is proposed in priority to the local transplantation center
- This team has the choice of the patient. The Liver Score is just a choosing help.

→ The distance doesn't matter in the Liver Score

When a graft is retrieved outside a local network or when the offer is declined by the transplantation team, then the graft is allocated nationally.

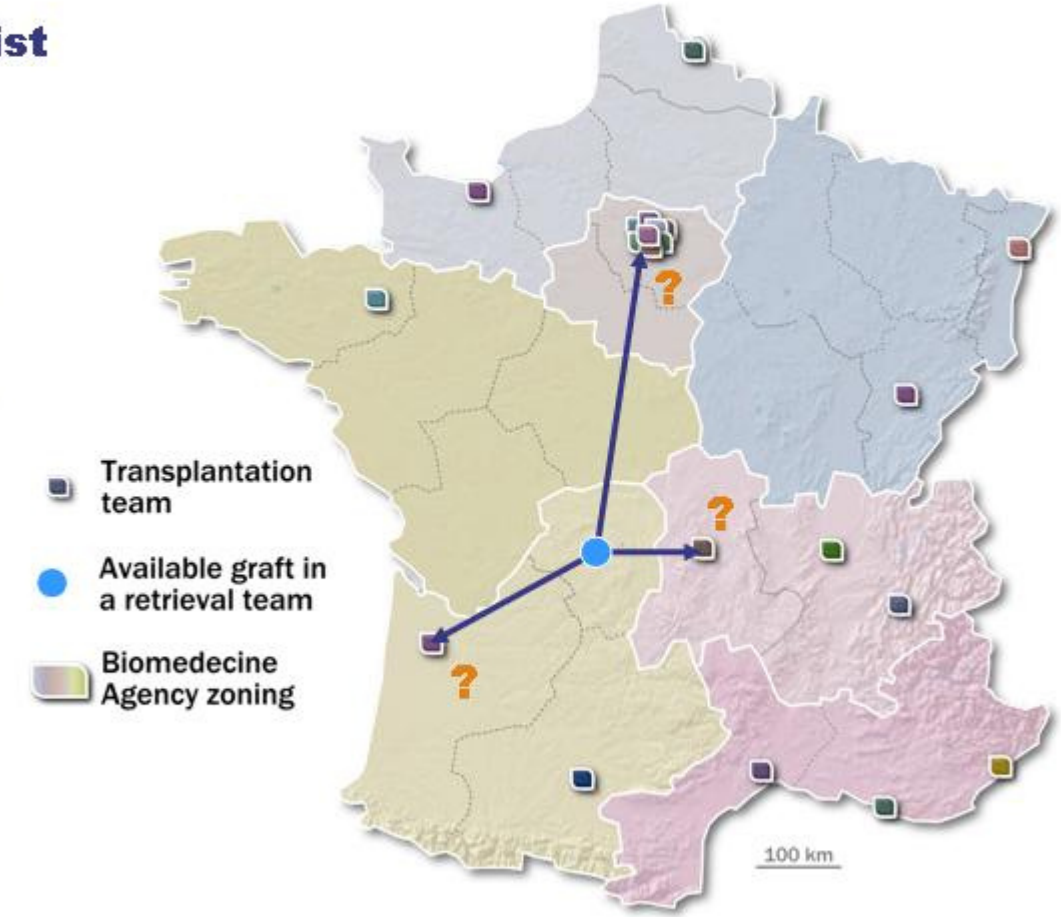
Liver Score application

2/ National : sort of the waiting list

- Where is the higher Liver Score ?
- The Liver Score is used to sort all suitable recipents that are on the waiting list
- Take into account the medical functions and the distance between donor and transplantation teams

→ The distance matters

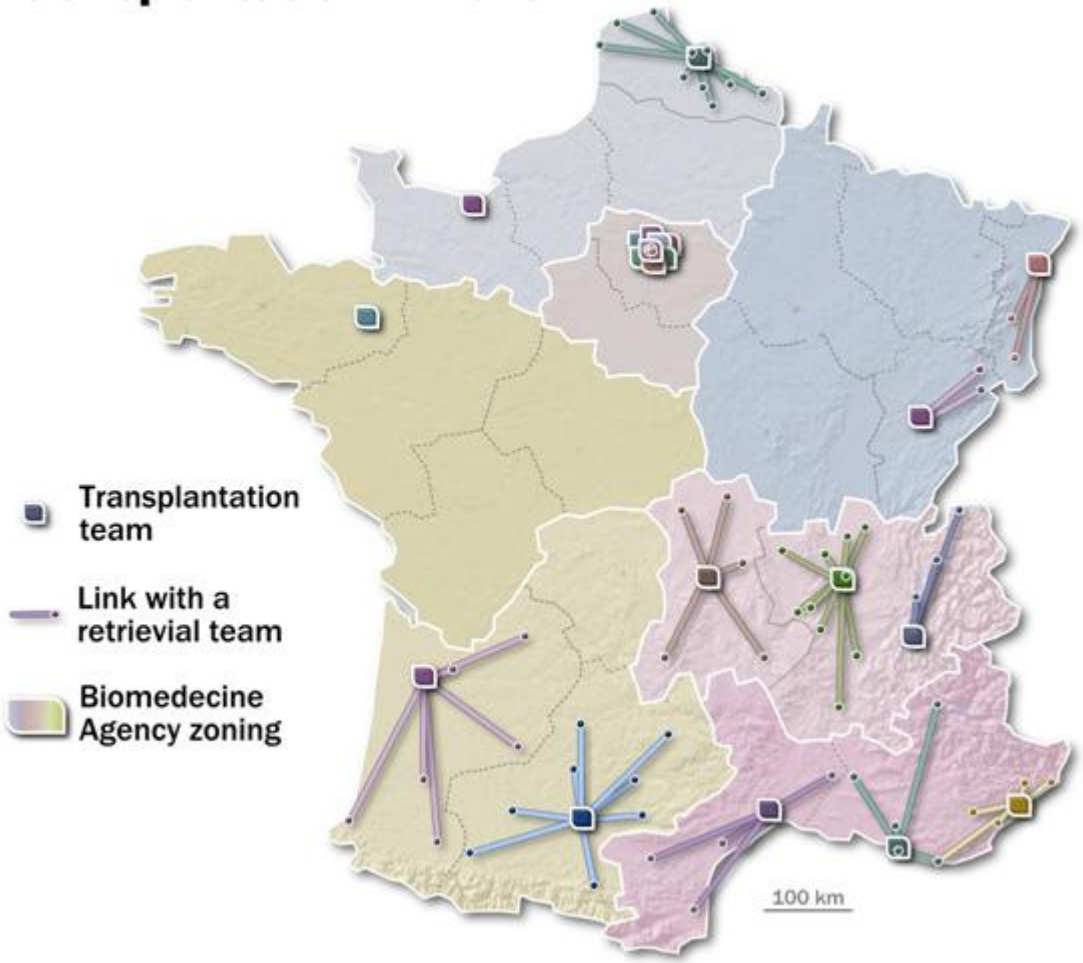
Where is the higher Liver Score ?



Bayer Florian
Source : Agence de la biomédecine 2010

1 - The context

Disparity of local networks in hepatic transplantation in 2010

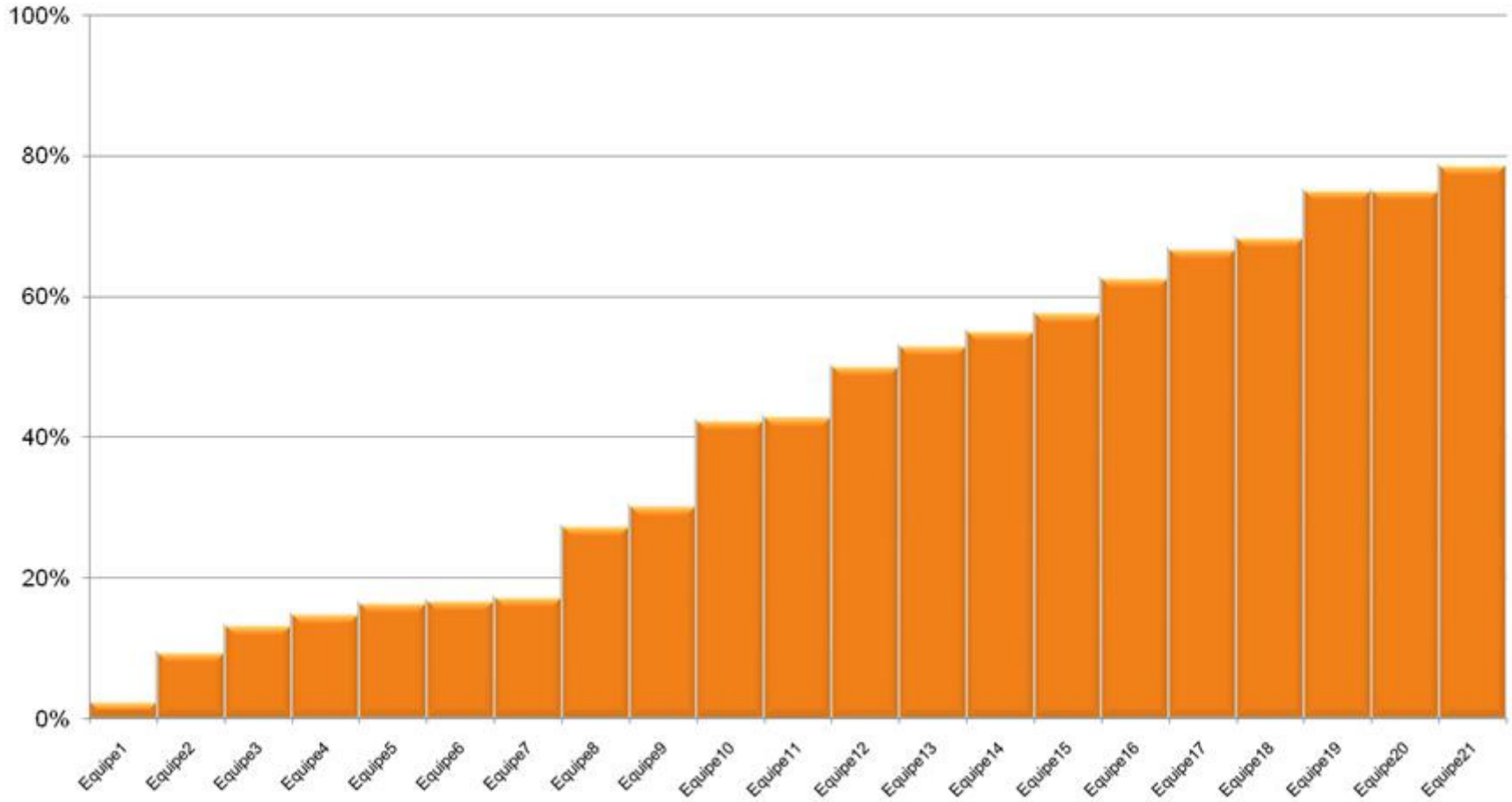


Bayer Florian
Source : Agence de la biomédecine 2010

Some of the transplantation teams have large regional network.

The others have only one member (themselves)

Percentage of transplantation issued from a local network, by team
2007-2008



1 - The context

The distance in the Liver Score

It fulfilled its role by limiting the teams movement and cold ischemia time.

This model continues to favoured local network, but we face big discrepancies between teams.

Sicker patients but more distant from the graft or out of these networks could benefit from it, but they don't.

- The just-in-time principle of the Liver Score is only partial
- Equity problem

1 - The context

Objectives

1. **Optimizing the distance function in the current Liver Score by linking the key decision factors of liver transplant :**

   - The distance between donor and transplant team
   - The recipient health
   - The graft quality

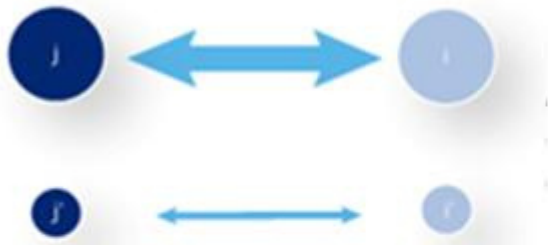
2. **To show that an alternative to local network is conceivable**

Without reducing the organ retrievment and transplant activity

2 - The integration of these rules in the gravity model

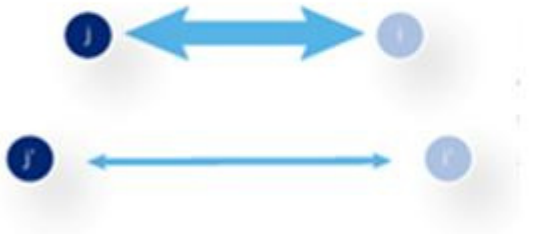
2 - The integration of these rules in the gravity model

The principles of spatial interaction



1st : size effect

At equal distance, the importance of relations between two places is equal to their ability to transmit and receive



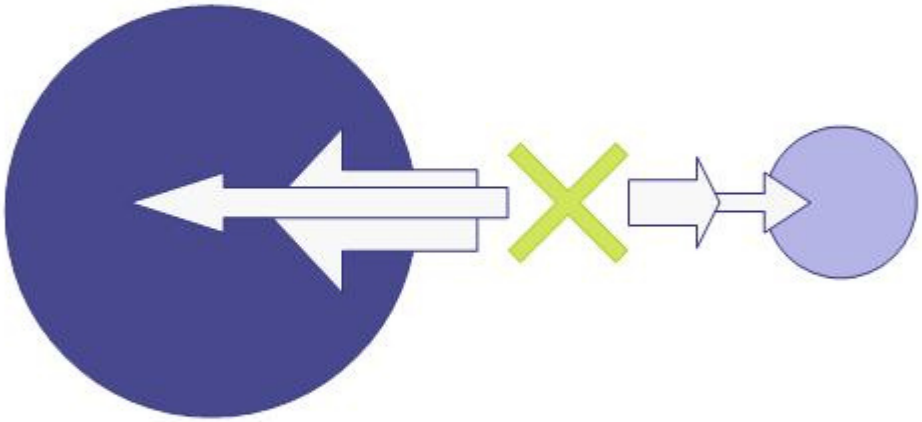
2nd : distance effect

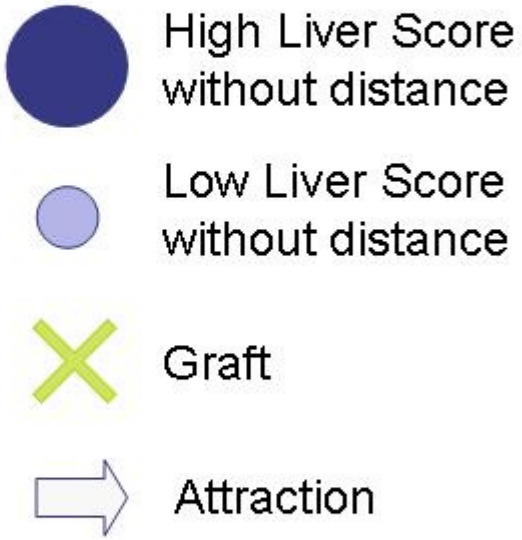
At equal weight, the importance of relations between two places is inversely proportional to their distance

Source : Claude Grasland

2 - The integration of these rules in the gravity model

Some principles of spatial interaction





Objective : measure this attraction

2 - The integration of these rules in the gravity model

The « basic » model

$$Aij = Mj \times Mi / Dij^{\alpha}$$

Mj the mass of the patient on the waiting list → Liver Score without distance component

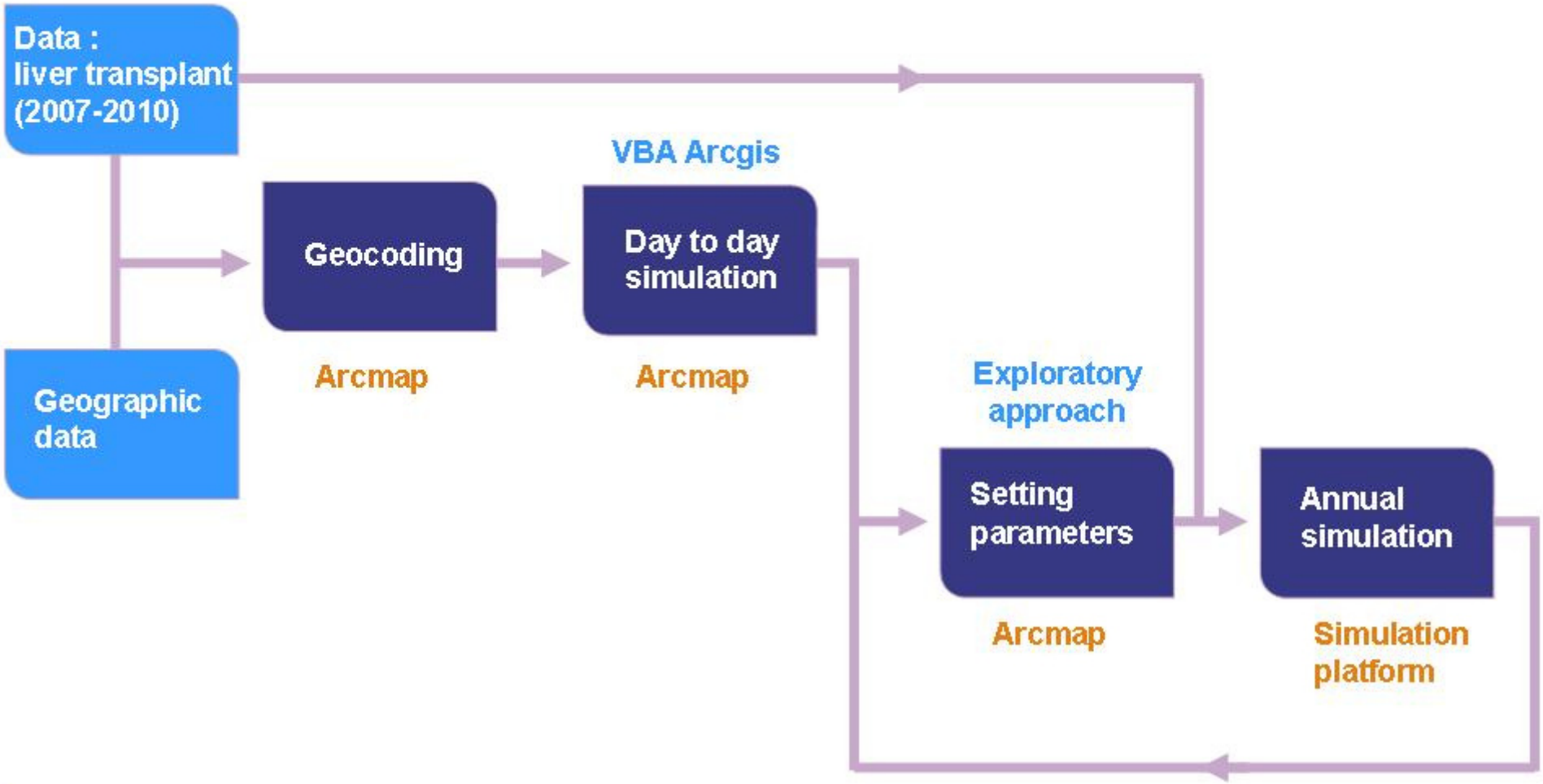
Mi the mass of the graft status → At this time, no consensus for its evaluation. Mi = 1

Distant Dij between i et j → Euclidean metric in an isotropic area

The last parameter is α, the distance decay (entropy).
It has to be calibrated and a VBA tool has been developped for the day-to-day simulation.

2 - The integration of these rules in the gravity model

Methodology



3 - The results and improvement

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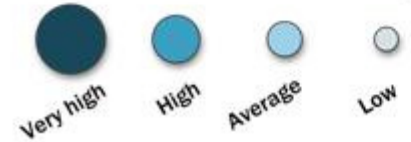
Results : day to day

Fictive patients waiting list for a liver transplantation by team

Liver Score without distance component



Patient Rank	Liver score without distance	Actual Liver Score	Gravity model
1	Bordeaux	Bordeaux	Bordeaux
2	Paris 1	Paris 1	Paris 1
3	Paris 2	Paris 2	Paris 2
4	Marseille	Rennes	Rennes
5	Lyon 1	Caen	Marseille
6	Rennes	Paris 3	Lyon 1
7	Toulouse	Marseille	Paris 3
8	Paris 3	Besançon	Caen
9	Besançon	Toulouse	Toulouse
10	Caen	Lyon 1	Besançon
11	Strasbourg	Strasbourg	Strasbourg
12	Montpellier	Montpellier	Lyon 2
13	Lyon 2	Lyon 2	Montpellier

Bayer Florian *Sources : Agence de la biomédecine, 2009*

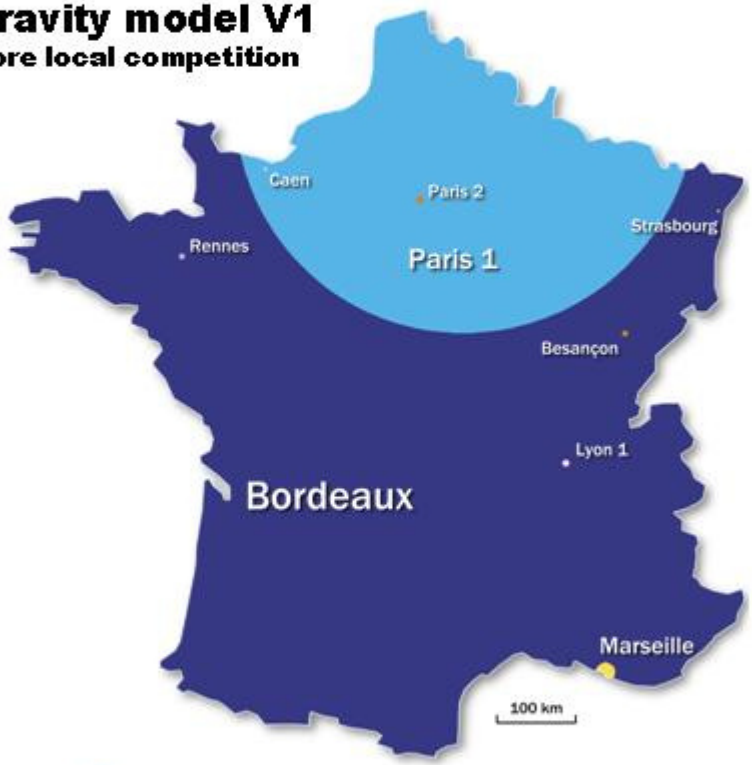
3 - The results and improvement

Area of certitude to be the first on the waiting list, for each patient according to its severity score and the model used (same list as before)

Current Liver Score

Patient area of certitude to get the graft (2 areas)

Gravity model V1
more local competition



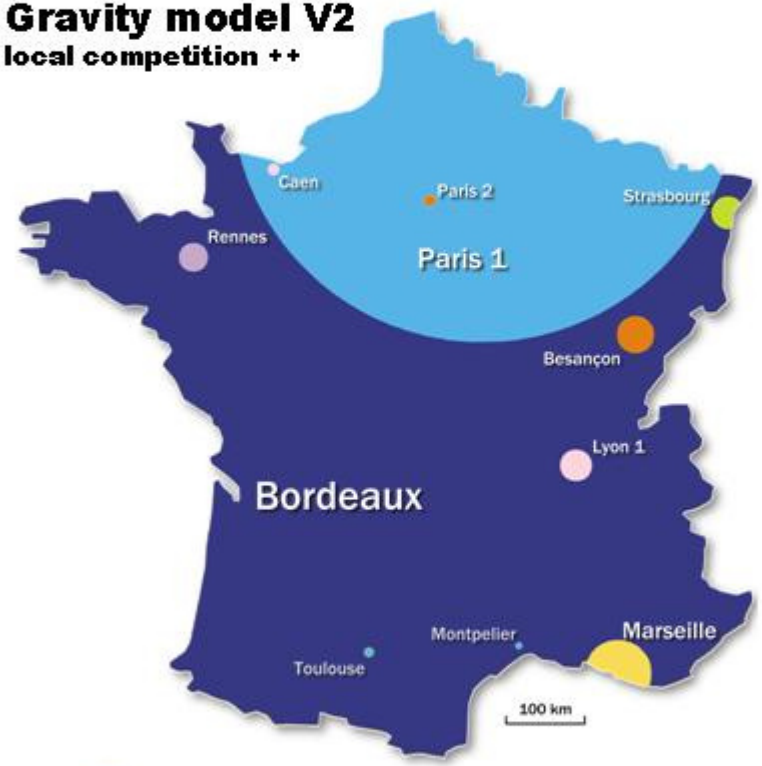
Patient area of certitude to get the graft (9 areas)

Florian Bayer, Source : Agence de la biomédecine 2009

3 - The results and improvement

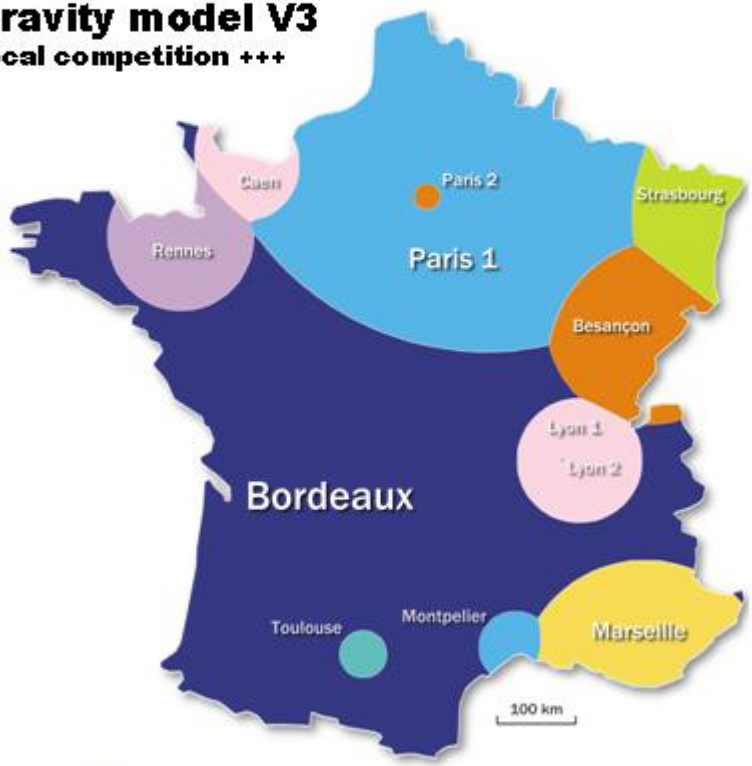
Area of certitude to be the first on the waiting list, for each patient according to its severity score and the model used (same list as before)

Gravity model V2
local competition ++



Patient area of certitude to get the graft (11 areas)

Gravity model V3
local competition +++

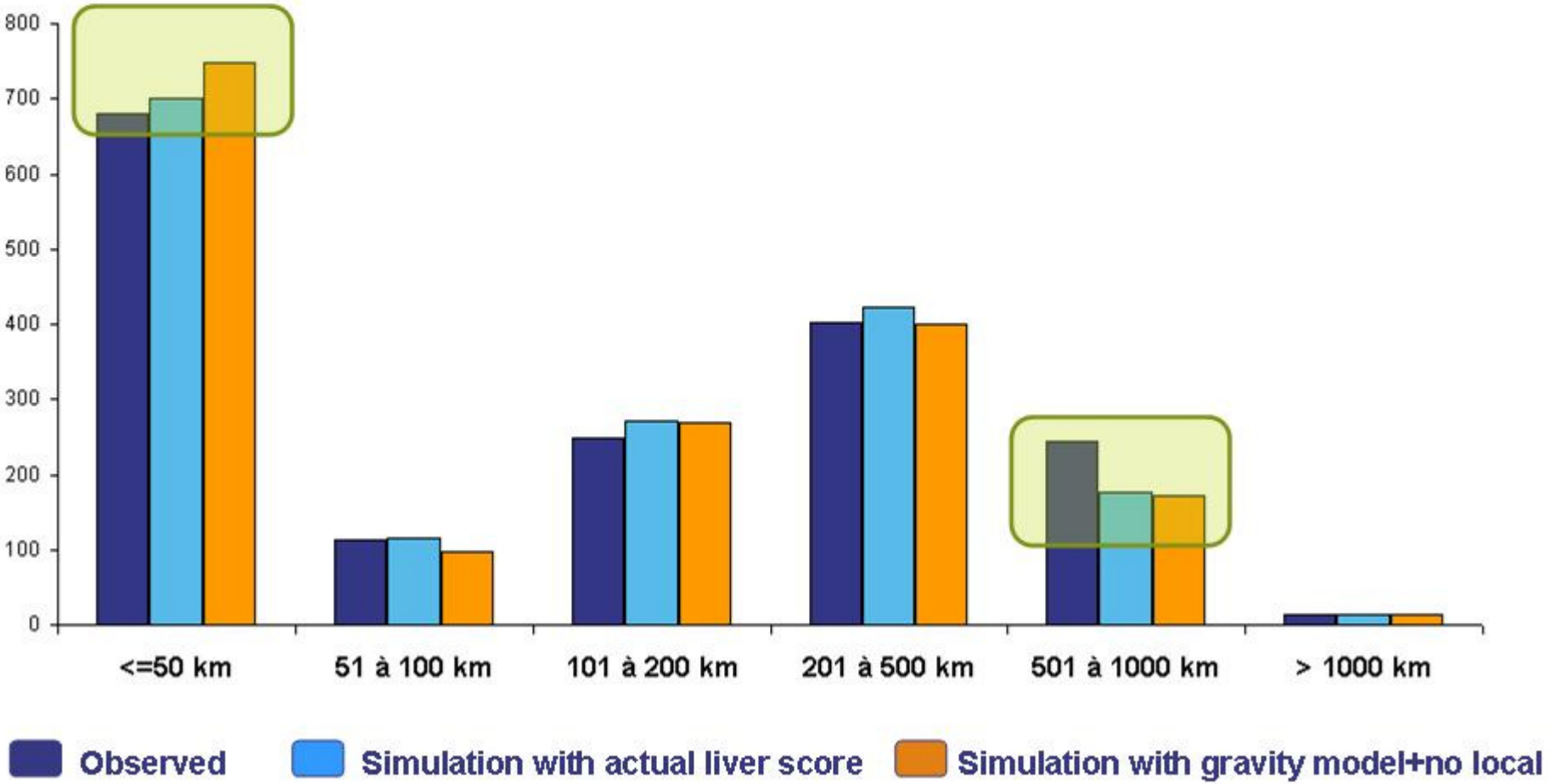


Patient area of certitude to get the graft (12 areas)

Florian Bayer, Source : Agence de la biomédecine 2009

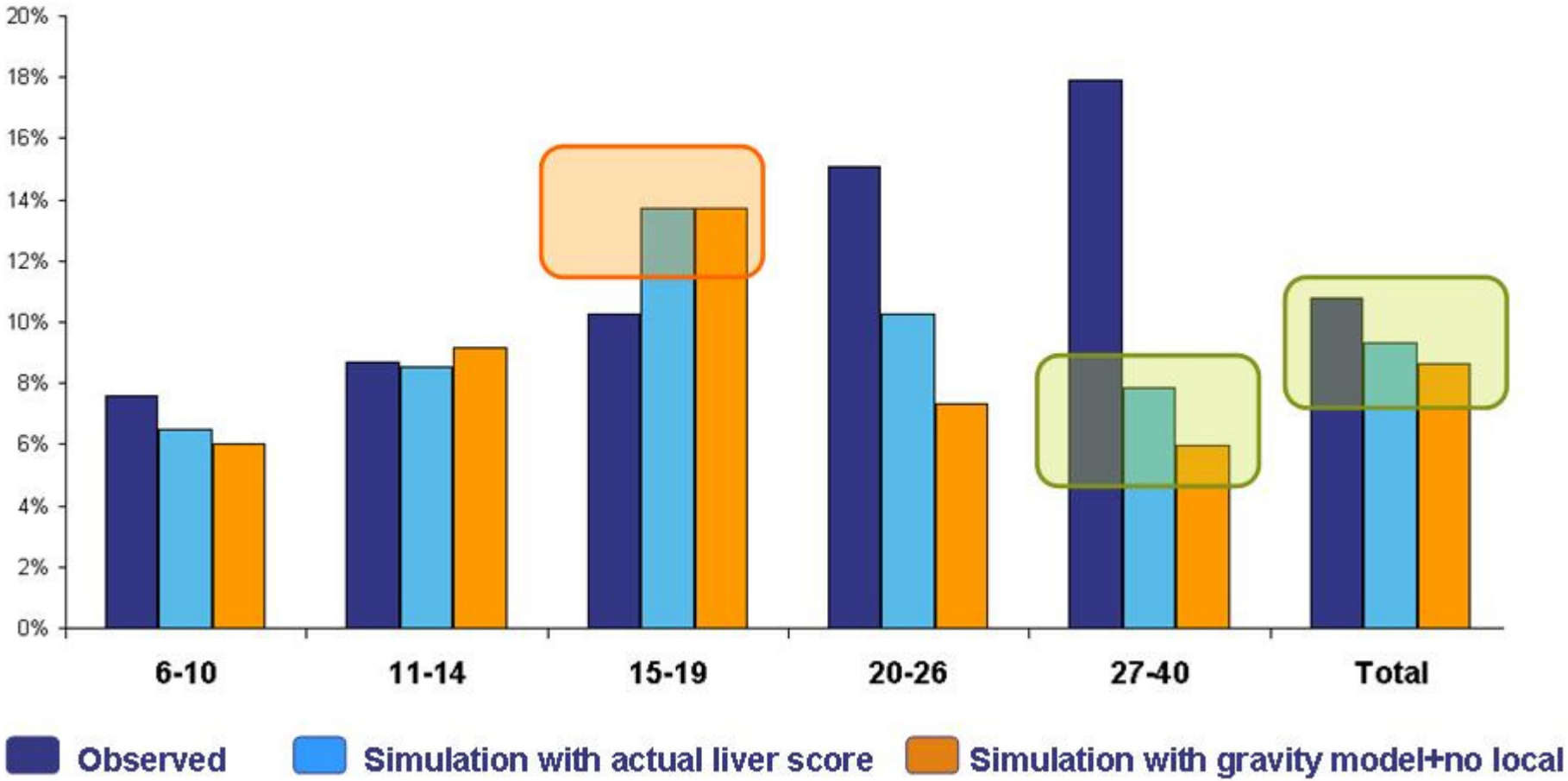
3 - The results and improvement

Distribution of the distance between donor and transplant team
(March, 6th 2007-2008)



3 - The results and improvement

Too-sick or dead patient delisting rate by MELD class (2008-2009)



4 - Conclusion

4 - Conclusion

Summary

- Currently local networks can favored patients whose health is less "urgent" than other outside these networks
- Applying the gravity model allows slightly improving access to transplantation for the most urgent patients
- Better compromise between distance and urgency
- The integration of this gravity model in the Liver Score shows that the principle of local priority can be circumvented : simulate a local network for the sufficiently critical patient

4 - Conclusion

Limits

- **Readability by physicians/clinicians**

Advantages

- **Optimization of the liver graft allocation**
- **Scalability of the number of liver transplantation performed from close donors**
- **Increase grafts pooling for a better just-in-time distribution**
- **Reducing of 15% the too-sick or dead patient delisting rate**

5 - Future works

1/ Integrate the health of the donor

2/ Varying the model parameters depending on the distance

- **Others distance functions (at present time : negative exponential. Test with gaussian function ?)**
- **Relativist models**

→To find the optimal function

3/ Integrate this model (2010 ?)

Thank you for your attention