Combining distribution and recovery operations in Humanitarian Logistics

F. Liberatore, B. Vitoriano, M.T. Ortuño, G. Tirado, M.P. Scaparra

Universidad Rey Juan Carlos

Kent Business School
UNIVERSITY OF KENT

Introduction

Background and motivation

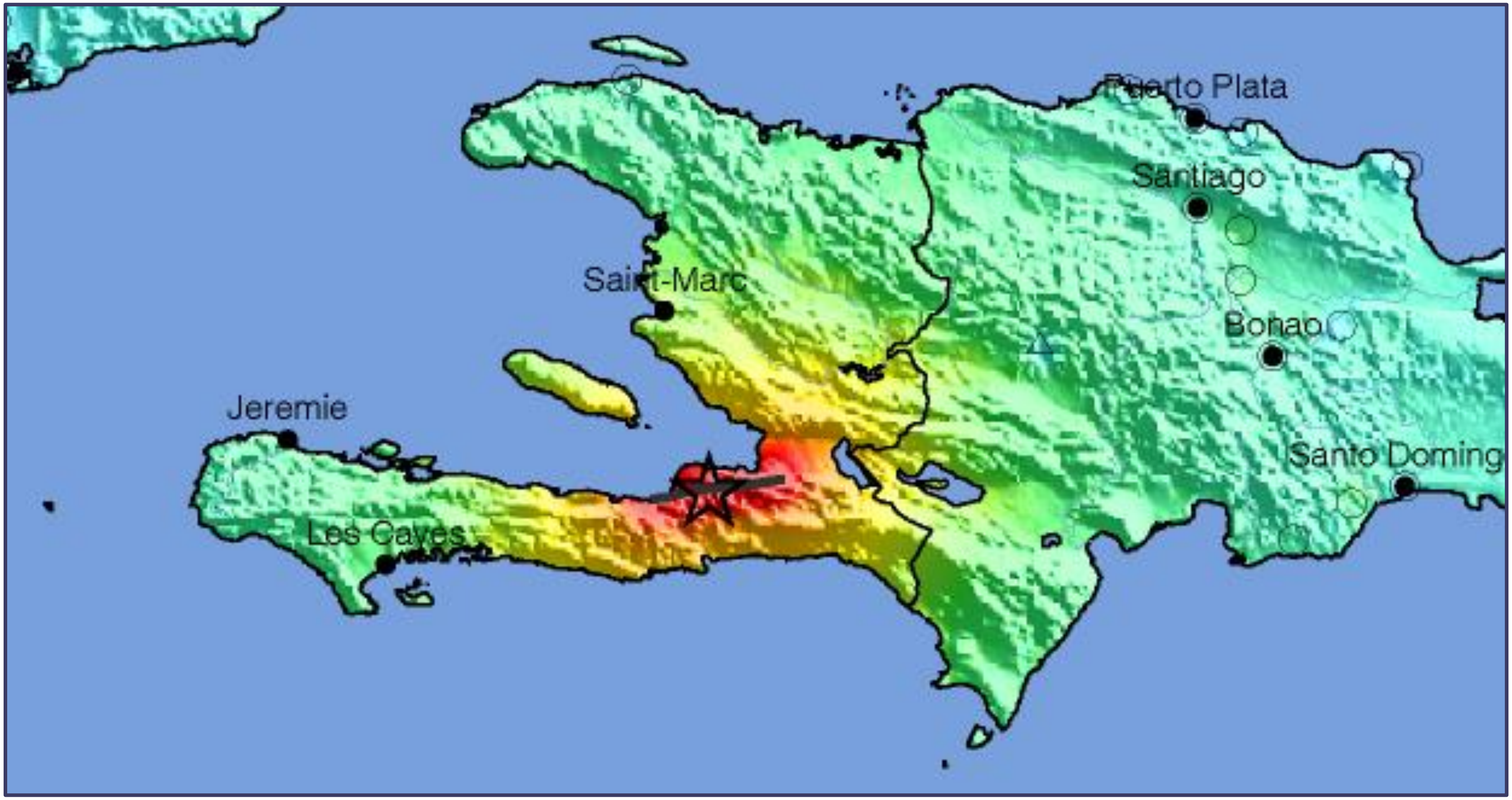
Disasters

- Definition
  - Extraordinary event
  - Resources stressed
  - Non-standard procedures implemented
  - Special authorities invoked
- Emergency Database
  - 7,671 disasters (approx. 2 disasters/day) from 2000 to 2009.

Altay and Green, EJOR, 2006.

EM-DAT, http://www.emdat.be.

Haiti – January 2010



OR for Humanitarian Logistics

RecHADS

Rationale

- As a consequence of the disaster, parts of the distribution infrastructure can be damaged or destroyed.
- Example: Haiti
  - Airport destroyed, port and roads damaged.
  - Access of international aid to the victims was severely constrained

Van Wassenhove, 2010.

RecHADS

Combining recovery operations and distribution of emergency goods in Humanitarian Logistics

Problem Elements

- Distribution network
  - Nodes
    - Supply
    - Transitional
    - Demand
  - Arcs
    - Length
    - Reliability
    - Security
  - Subset of damaged arcs
    - Recovery cost
- Recovery budget

Distribution

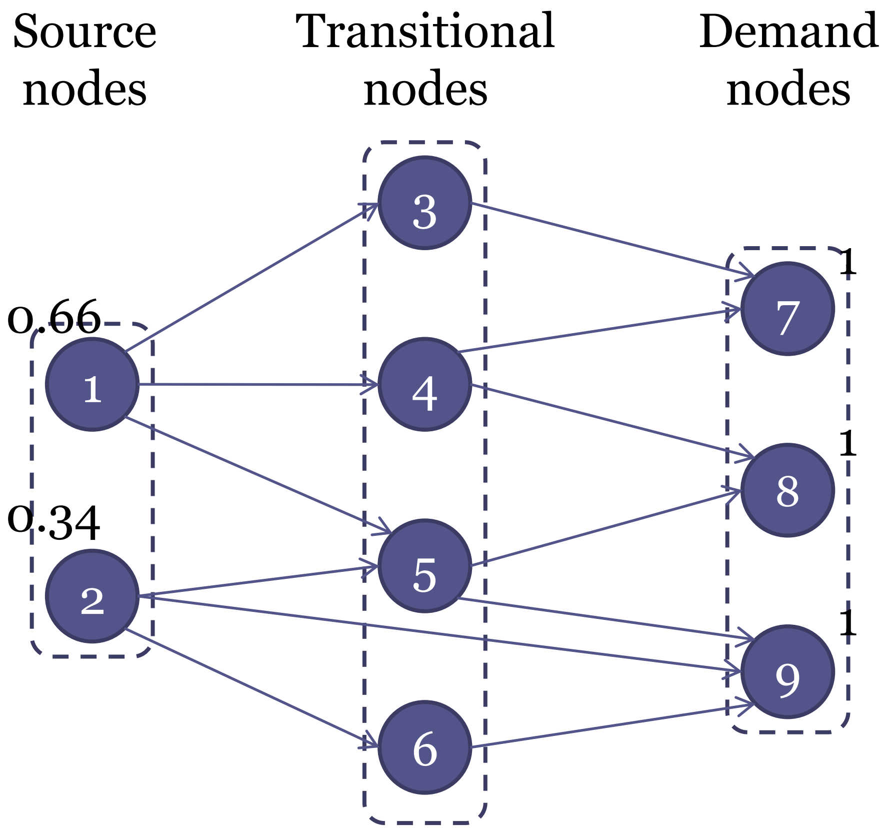
Recovery

Multi-criteria Model

Recovery

- Subset of damaged arcs
  - Cannot be used unless recovered
  - Characterized by recovery cost
- Recovery budget

Distribution



- Transitional nodes
  - No demand
  - No supply
- Demand nodes
  - Characterized by demand
  - Cannot receive more flow than its demand
- Source nodes
  - Supply flow
  - Characterized by *capacity ratio*
    - *Specifies the portion of the total delivered demand that originates from the node*

Attributes - 1

- Equity
  - DG – Total demand satisfied
- Time
  - TX – Maximum node visiting time
- Security
  - PX – Maximum arc ransack probability
  - PG – Global ransack probability
- Reliability
  - RMN – Minimum arc reliability
  - RG – Global reliability measure

Set of attributes V, indexed by v.

Attributes - 2

- Used to define criteria
- Decision-maker can specify preference among the criteria by using weights α

Multi-criteria Model - 1

- Hierarchical (lexicographic) model

1. Maximize Equity
   - Maximize the quantity of aid delivered DG (i.e., recover arcs so that the maximum demand is reached)
   - Fix the quantity of aid delivered
   - Calculate Ideal (Z^+) and Anti-ideal (Z^-) values for each attribute

Multi-criteria Model - 2

2. Minimize infinity norm
   - Minimize maximum distance of an attribute to Ideal

$$\min D^{\infty} = \max_{v \in V / \{B, G\}} \left\{ \alpha_v \frac{Z_v^+ - Z_v}{Z_v^+ - Z_v^-} \right\}$$

Multi-criteria Model - 3

3. Minimize norm one
   - Minimize sum of distances of the attributes to Ideal

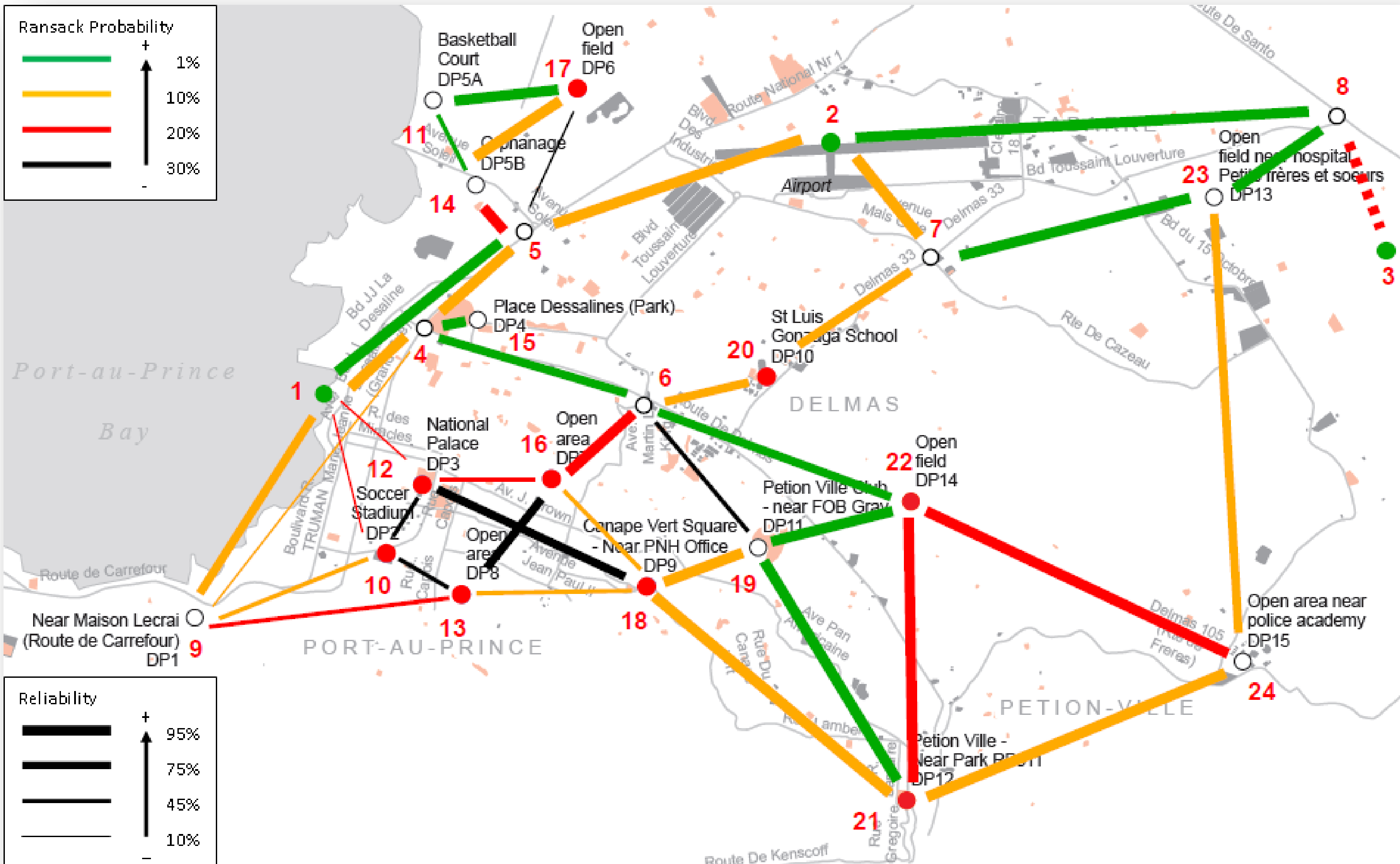
$$\min D^1 = \sum_{v \in V} \alpha_v \frac{Z_v^+ - Z_v}{Z_v^+ - Z_v^-}$$

Computational Experiments

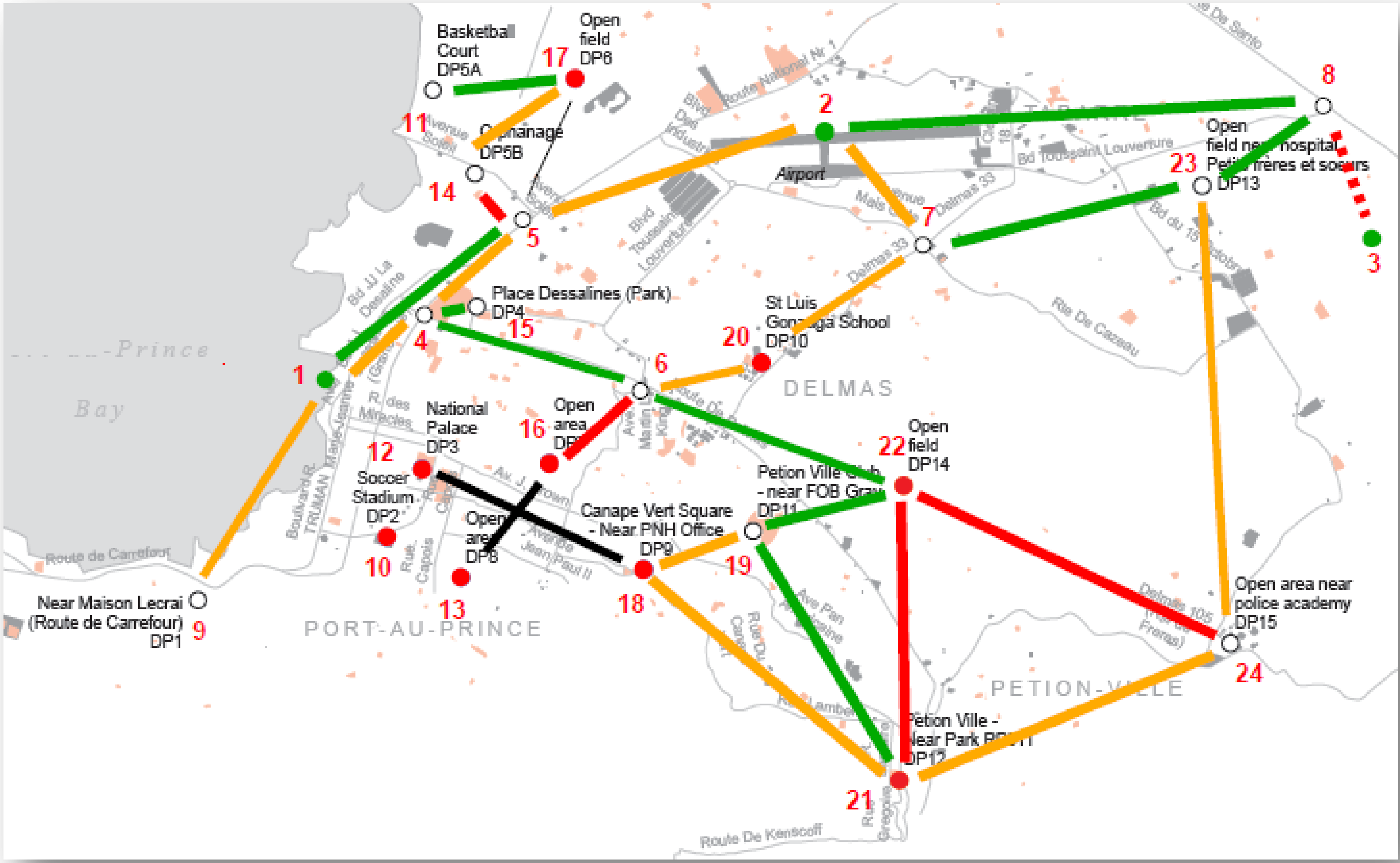
Dataset - 1

OCHA, http://ochaonline.un.org/.

RED HUM, http://www.redhum.org/.



Dataset - 2



Basketball Court DP5A
Open field DP6
17
Orphanage DP5B
11
14
5
2
Airport
8
Open field near hospital Petits frères et soeurs DP13
23
3
7
Place Dessalines (Park) DP4
15
4
1
St Luis Gonzaga School DP10
20
6
DELMAS
National Palace DP3
Open area
16
12
Open field DP14
22
Petion Ville Club - near FOB Gray DP11
Soccer Stadium DP2
10
13
Canape Vert Square - Near PNH Office DP9
19
18
Near Maison Lecrai (Route de Carrefour) DP1
9
PORT-AU-PRINCE
Open area near police academy DP15
24
Petion Ville - Near Park DP12
21
Bay
Route de Carrefour
Route De Kenscoff

Dataset – 3

- 24 nodes
  - 3 supply nodes
  - 9 demand nodes
- 42 arcs
  - 12 damaged arcs with recovery cost 1
- Recovery budget ranging from 0 to 12
- Unitary preference weights: $\alpha_v = 1$

- Average solution time ~70 sec

Coordinated VS. Sequential - 1

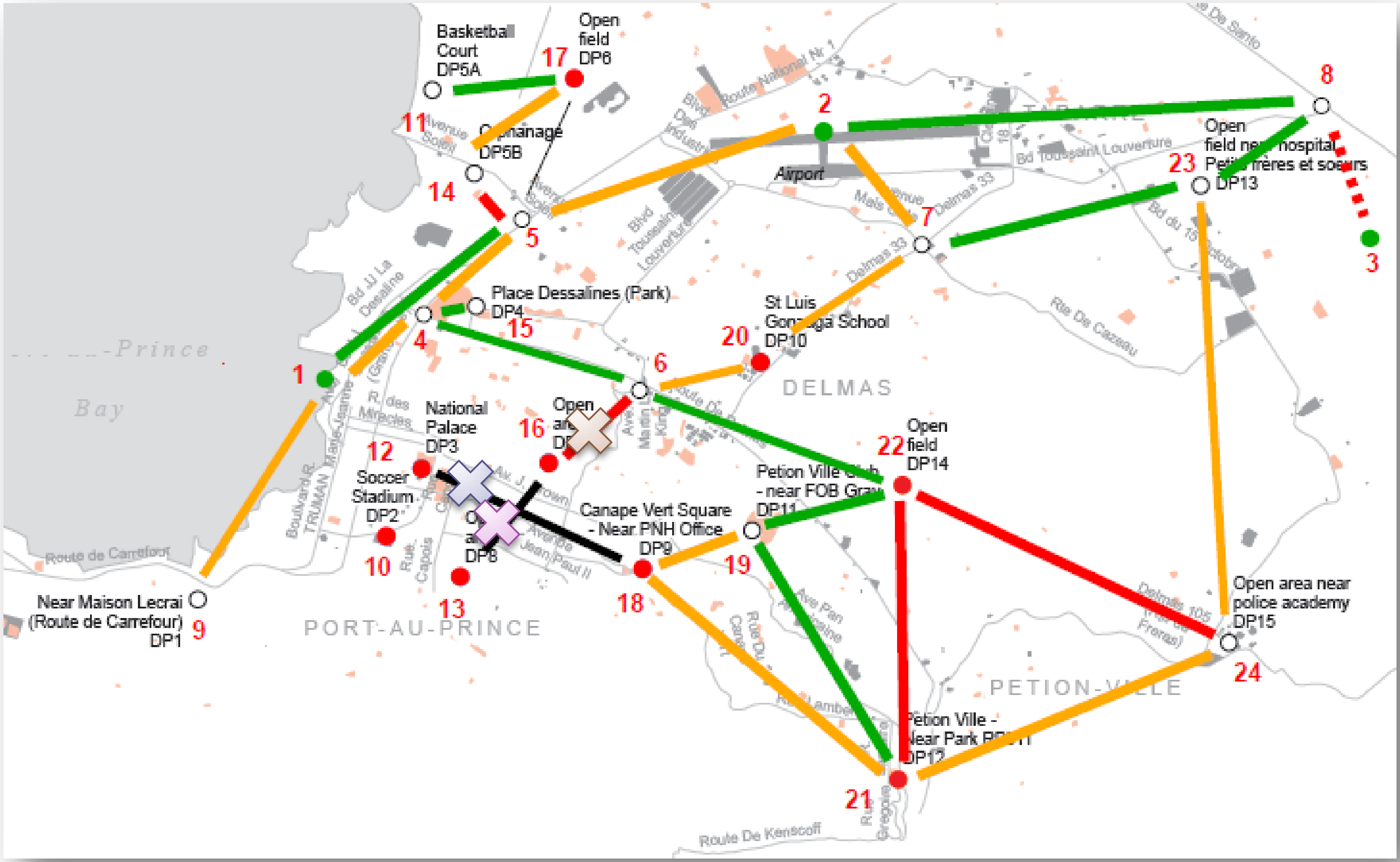
- How useful is to jointly optimize recovery and distribution operations?
- Sequential Model:
  1. Maximize delivered demand and fix arcs recovered
  2. Compute distribution plan that minimizes infinity norm distance and norm one distance

Coordinated VS. Sequential - 2

- Compare distribution plans found by RecHADS and sequential model.
- Node 10 isolated

Recovery Budget	Time	Max Security	Global Security	Min Reliability	Global Reliability	Average
1	3.64%	0.00%	4.41%	0.00%	0.00%	1.61%

Coordinated VS. Sequential - 3



Coordinated VS. Sequential - 4

- Removing arc (12,18)
- Nodes 10, 12 isolated

Recovery Budget	Time	Max Security	Global Security	Min Reliability	Global Reliability	Average
1	0.92%	0.00%	8.33%	0.00%	0.00%	1.85%
2	0.00%	0.00%	6.81%	0.00%	0.00%	1.36%

Coordinated VS. Sequential - 5

- Removing arcs (12,18), (13,16)
- Nodes 10, 12, 13 isolated

Recovery Budget	Time	Max Security	Global Security	Min Reliability	Global Reliability	Sum
1	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
2	0.88%	50.00%	18.79%	0.00%	-3.50%	13.24%
3	-2.65%	50.00%	19.88%	0.00%	19.58%	17.36%

Coordinated VS. Sequential - 6

- Removing arcs (12,18), (13,16), (16,6)
- Nodes 10, 12, 13, 16 isolated

Recovery Budget	Time	Max Security	Global Security	Min Reliability	Global Reliability	Sum
1	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
2	7.62%	0.00%	7.81%	0.00%	15.97%	13.24%
3	7.62%	0.00%	7.97%	0.00%	15.97%	17.36%
4	7.62%	50.00%	26.09%	0.00%	20.17%	**20.77%**

Conclusions & Future research

Conclusions

- RecHADS, model for coordinated optimization of
  - Recovery operations of elements of the transportation network
  - Distribution planning of emergency aid goods
- Applications
  - Response phase during an emergency
  - Recovery phase after an emergency
- Usefulness
  - Sequential model maximum average deviation: 20.77%

Future Research

- Collaborating with an international NGO to devise recovery operations in Jipijapa, Ecuador.
- Extending RecHADS to capture other complex features arising from the necessities of the case considered.
- Model for the enhancement of network elements prior to disaster.
  - Mitigation: reduce probability of occurrence and impact of a disaster.