Design of Snow Plowing and Deicing Routes for Urban Winter Viability : Addressing Actual Operational Constraints

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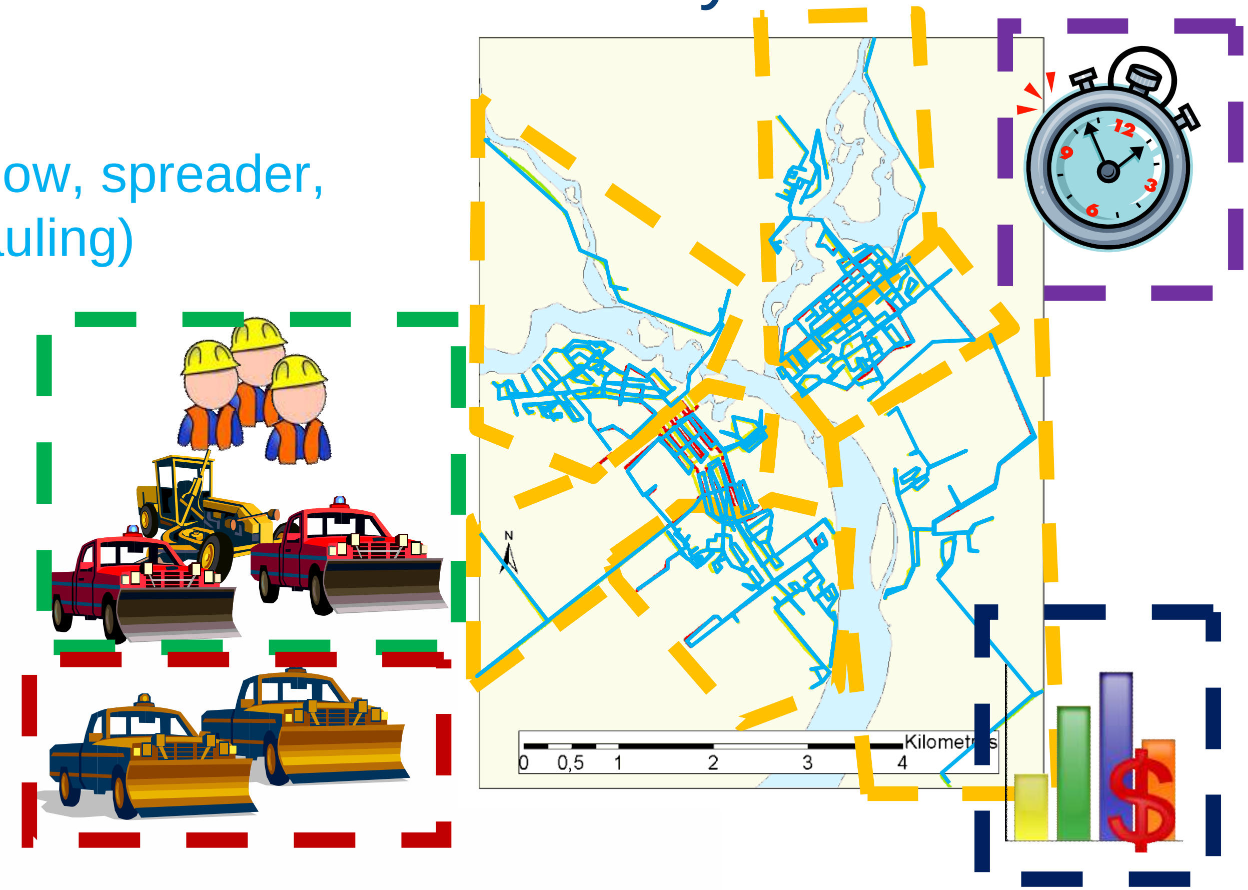
0. CONTENT

Operational Problems in Winter Viability:

- Work sectors design
- Vehicle routing (snow plow, spreader, snow removing, snow hauling)
- Crew and fleet sizing
- Subcontractor
- Budget planning
- Scheduling



1. TYPE OF SOLVING APPROACHES

Approach	References	Characteristics
Simulations	• Tucker and Clohan, 1979	Precise results over time Case specific
Mathematical programming	• Tagmouti et al., 2007	Optimality Small instances
Heuristics	• Lemieux and Campagna, 1984 • Perrier et al., 2008	Quick results Depends on the case
Metaheuristics	• Handa et al., 2005 and 2006 • Omer, 2007 • Tagmouti et al., 2010	Generalist Long development time

1. TYPE OF SOLVING APPROACHES

Simulations
- Tucker and Clohan, 1979

Precise results over time
Case specific

Mathematical programming
- Tagmouti et al., 2007

Optimality
Small instances

Used to assess the problem

Heuristics
- Lemieux
- Perrier e

Quick results
Depends on the case

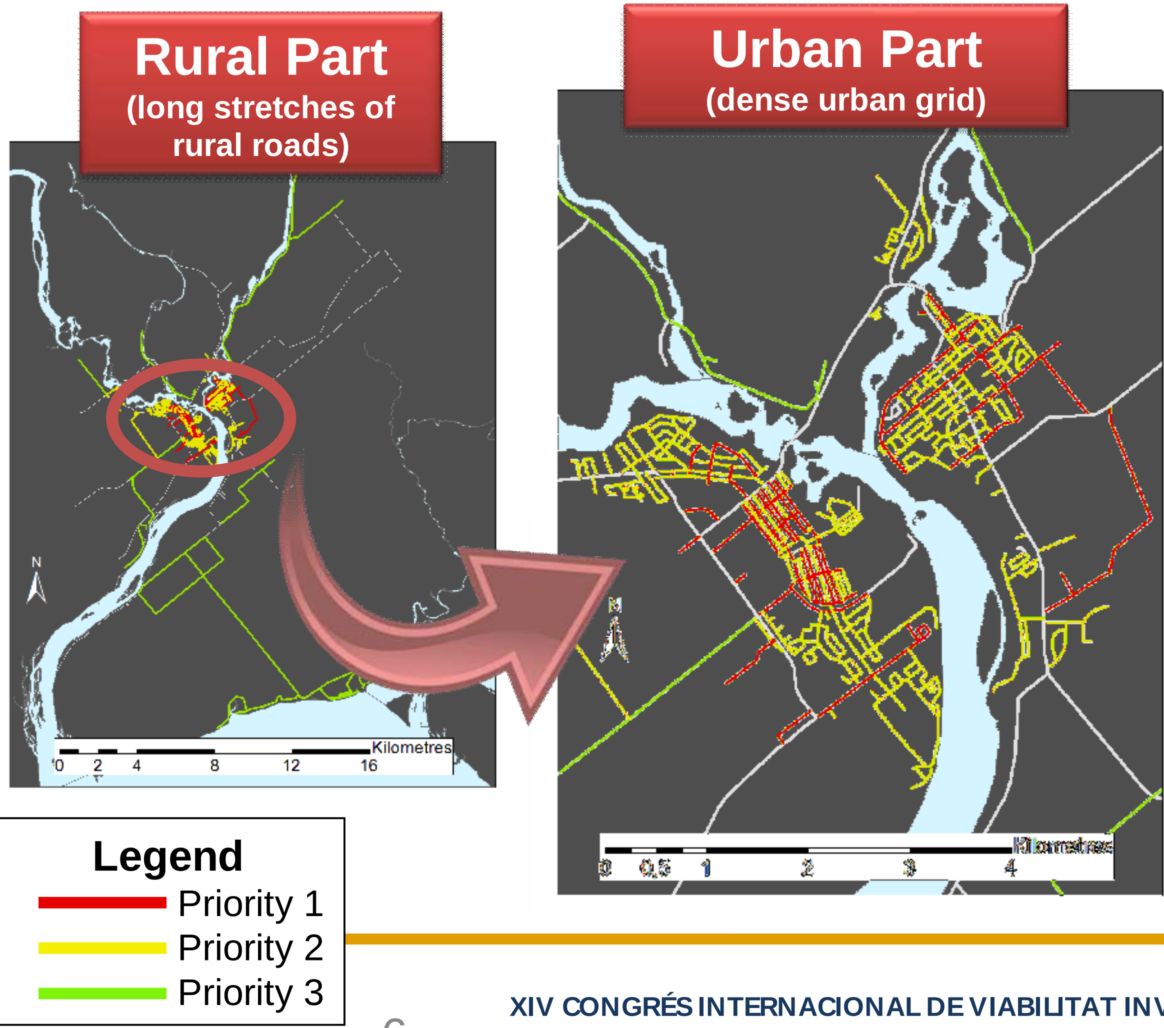
Metaheuristics
- Handa et al., 2005 and 2006
- Omer, 2007
- Tagmouti et al., 2010

Generalist
Long development time

The case of Dolbeau-Mistassini

Small town in northern Quebec :

- 14,000 inhabitants
- 8 vehicles
- 260 km of roadway, 3 classes of priority
- 1880 directed street segments, 44 undirected
- 733 nodes (intersections)



2. CONSTRAINTS RAISED

Workload Balance

Network Hierarchy

Turn Restrictions

Road/Vehicle Dependency

Image source : http://www.flickr.com/photos/jamescastle/4389696603

Partial Area Coverage

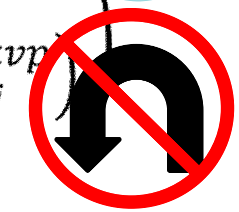
Other constraints not considered for this study :

- Vehicle capacity
- Tandem synchronization
- Recurring service

2. MATHEMATICAL FORMULATION

Objective Function

$$Min\left(\begin{array}{c}\sum_{p=1}^{P}(TMAX^{P}M^{P}) + T^{tot}M^{tot} \\ + \sum_{p=1}^{P+1}\sum_{v=1}^{V}\sum_{k=1}^{K}\sum_{i\in A}\sum_{j|x_{ij}^{kvp}\exists} f_{ij}\left(x_{ij}^{kvp} + y_{ij}^{kvp}\right)\end{array}\right)$$



2. MATHEMATICAL PROGRAMMING

Constraints

2. $TMAX^{P} \geq t^{vp}$ $p = \{1 \quad 1\}$

3. $t^{vp} = \sum_{k=1}^{K} \sum_{i \in A} \sum_{j \in A} \left(x_{ij}^{kvp} tp_i^v + y_{ij}^{kvp} ts_i^v \right)$ $p = \{ \quad \}, v = \{1 \ldots V\}$

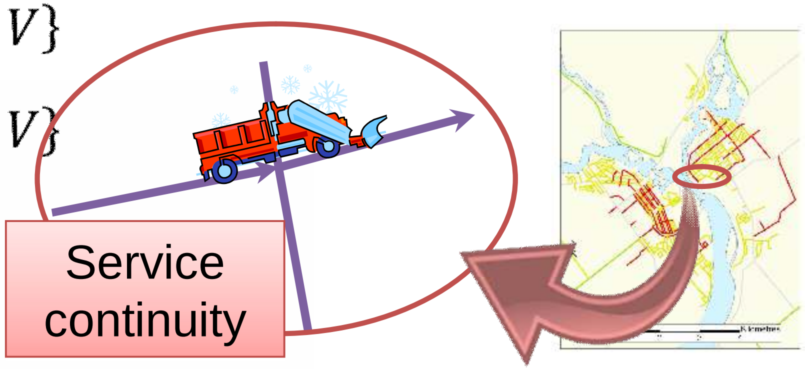
4. $\sum_{p=1}^{P+1} \sum_{j \in A | x_{ij}^{kvp} \exists} \left(x_{ij}^{kvp} + y_{ij}^{kvp} \right) = \sum_{p=1}^{P+1} \sum_{l \in A | x_{li}^{k+1,vp} \exists} (\quad y_{li}^{k+1,vp})$

$k = \{2 \ldots K\}, v = \{1 \ldots V\}, i \in A \cup A_{end} \cup a_{init}$

5. $\sum_{p=1}^{P+1} \sum_{j \in d} x_{ia_{init}}^{1vp} = 1$ $v = \{1 \ldots V\}$

6. $\sum_{p=1}^{P+1} \sum_{i \in A} \sum_{j | x_{ij}^{1vp} \exists} x_{ij}^{1vp} = 0$ $v = \{1 \ldots V\}$

7. $\sum_{k=1}^{K} \sum_{i \in A_{end}} \sum_{j \in A} x_{ij}^{kvP+1} = 1$ $v = \{1 \ldots$



2. MATHEMATICAL PROGRAMMING

Constraints

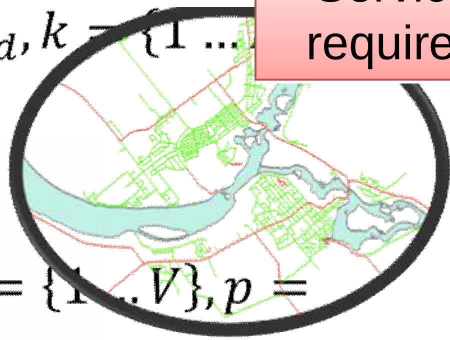
8. $\sum_{j|x_{ij}^{kvp}\exists}\left(x_{ij}^{kvp}+y_{ij}^{kvp}\right)\leq\sum_{p*=p}^{P+1}\sum_{l|x_{li}^{kvp}\exists}\left(x_{li}^{k+1,vp*}+y_{li}^{k+1,vp*}\right)$

$k=\{2\dots K\}, p=\{1\dots P, P+1\}, i\in A\cup a_{init}\cup A_{end}$

Hierarchy

9. $\sum_{k=1}^{K}\sum_{v=1}^{V}\sum_{p*=1}^{p}\sum_{j|y_{ij}^{kvp*}\exists}y_{ij}^{kvp*}=1 \quad i\in A_{ToBeServiced}^{p}, p=\{1\dots P\}$

Service required



10. $x_{ij}^{kvp}\in\{0,1\} \quad i\in A\cup A_{end}, j\in A\cup a_{init}\cup A_{end}, k=\{1\dots$

$\{1\dots V\}$, p $=\{1\dots P, P+1\}$

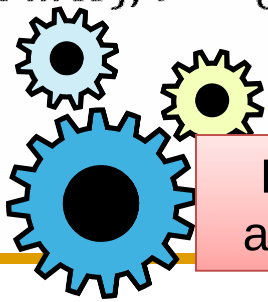
11. $y_{ij}^{kvp}\in\{0,1\}$

$i\in A\cup A_{end}, j\in A\cup a_{init}\cup A_{fin}, k=\{1\dots K\}, v=\{1\dots V\}, p=$

$\{1\dots P, P+1\}$

12. $t^{vp}\geq 0 \; v=\{1\dots V\}, p=\{1\dots P, P+1\}$

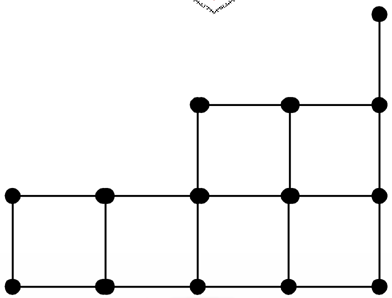
13. $TMAX^{p}\geq 0 \quad p=\{1\dots P, P+1\}$



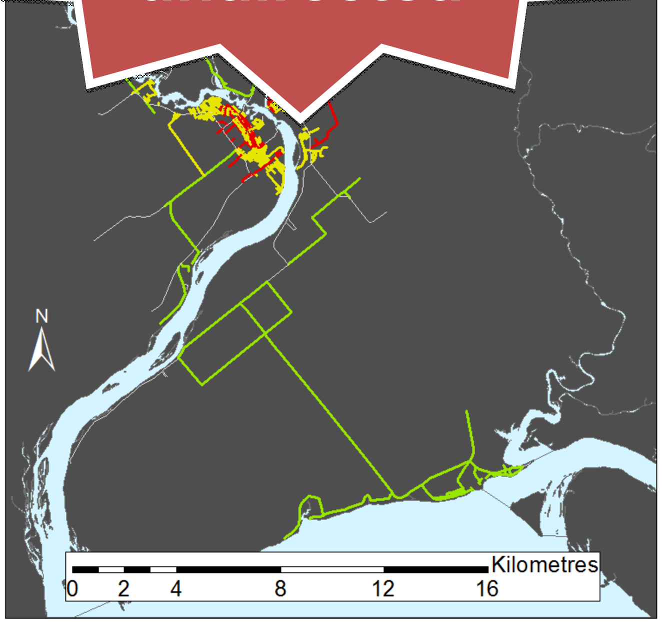
Positivity and binary

3. SOLVING THE MATHEMATICAL FORMULATION

56 directed street segments



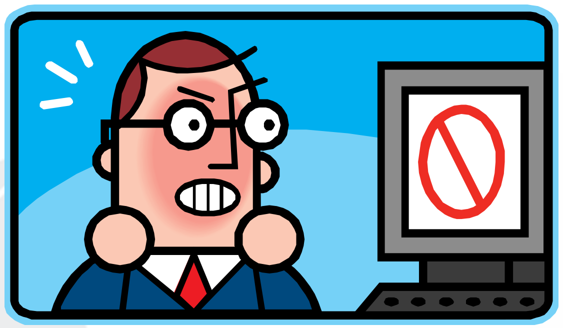
1880 directed street segments, 44 undirected



3. SOLVING REAL CASE STUDIES

Mathematical formulation

- Long solving time
- Limited to 28 street segments

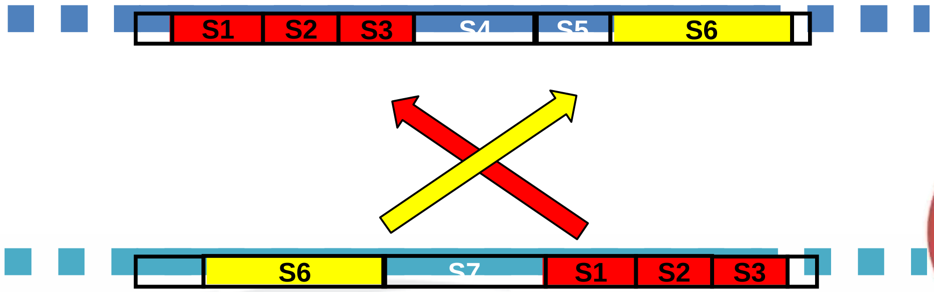


Metaheuristic

- Relatively short solving time (few hours)
- Big instances

4. Metaheuristic

<u>Metaheuristic</u> : search process guided by an objective function that uses simple arc exchanges (operators) in order to improve the global solution.



The improvement of the solution is measured with the objective function

4. Acknowledgments

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