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Decision Support System for carpooling to reduce car traffic in Grenoble area

Romain NAVARRO
June, 29th 2018

Supervisor:	Prof.	Van-Dat CUNG, G-SCOP & UGA
Jury members:	Prof.	Nadia BRAUNER
	Prof.	Van-Dat CUNG
	Dr.	Vassilissa LEHOUX
	Prof.	Matej STEHLIK

Outline

Goal

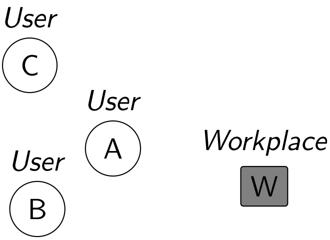
Satisfaction of the users

- Flexibility
- Schedules
- Detours

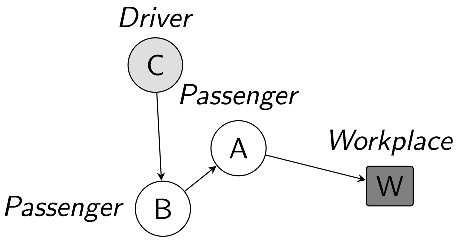
[0] references in the report

Outline

Presentation of the problem



(a) User requests



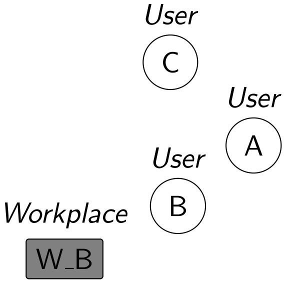
(b) A solution

Figure: Same workplace

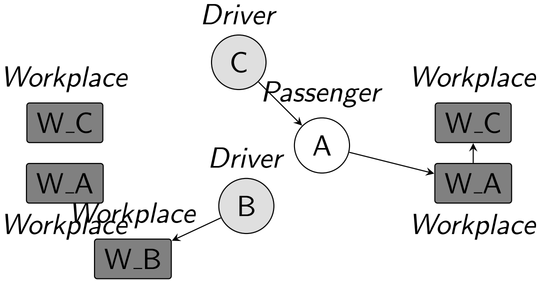
Outline

2. Problem's presentation
   - Different workplaces
   - Time windows
   - Objective
   - NP Completeness

Presentation of the problem
Different workplaces



(a) User requests



(b) A solution

Figure: Different workplaces

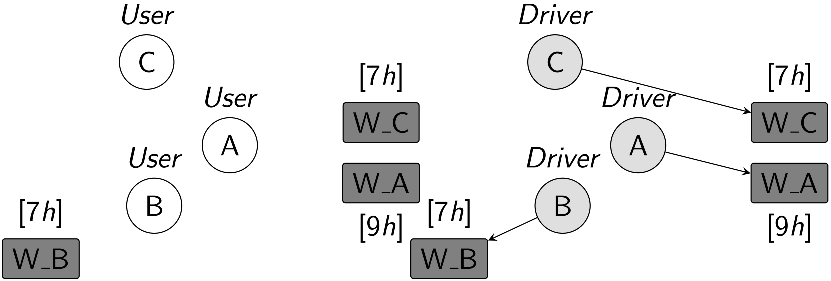
Outline

2 Problem's presentation

- Different workplaces
- Time windows
- Objective
- NP Completeness

Presentation of the problem

Time windows



(a) User requests (b) A solution

Figure: Different time windows

Outline

2 Problem's presentation
- Different workplaces
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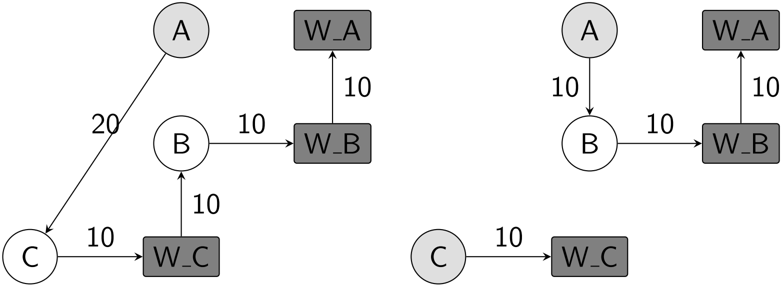
- Objective
- NP Completeness

Presentation of the problem
Objective



(a) Total cost = 60 (b) Total cost = 40

Figure: Minimization of the costs

Outline

2. Problem's presentation
   - Different workplaces
   - Time windows
   - Objective
   - NP Completeness

Presentation of the problem

NP Completeness

A NP-hard problem
Yes-Certificate from the Hamiltonian Path Problem with polynomial time = This is a NP problem
Being NP and NP-hard, the problem is therefore NP-complete

[0] NP-hard part of the report

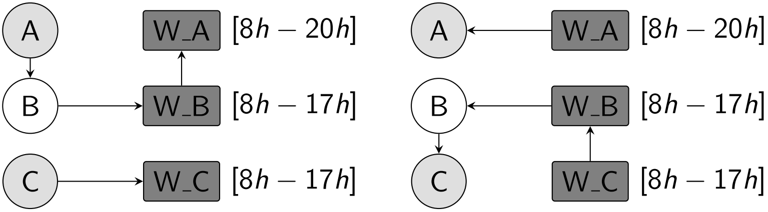
[0] Proof that Hamiltonian Path is NP-Complete - https://www.geeksforgeeks.org/

Outline

Outline

3 Originalities
- Return management
- Multiple places
- Waiting time management
- The case of Grenoble

Originalities
Return management



(a) Home-to-work trip (b) Return trip

Figure: Return management

Outline

3 Originalities
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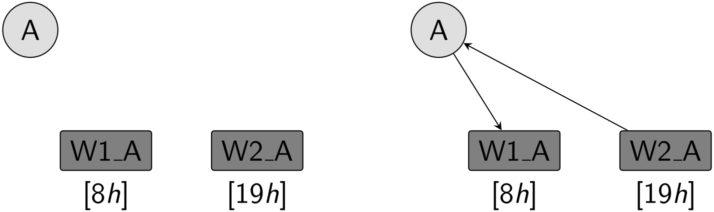
Originalities
Multiple places



(a) Data (b) Solution

Figure: Multiple workplaces

Outline

3 Originalities
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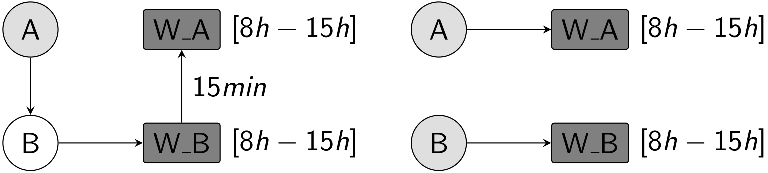
Originalities

Waiting time management



(a) Allowed advance waiting time = 20 min

(b) Allowed advance waiting time = 10 min

Figure: Arrival to work waiting time

Outline

3. Originalities
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Originalities
The case of Grenoble

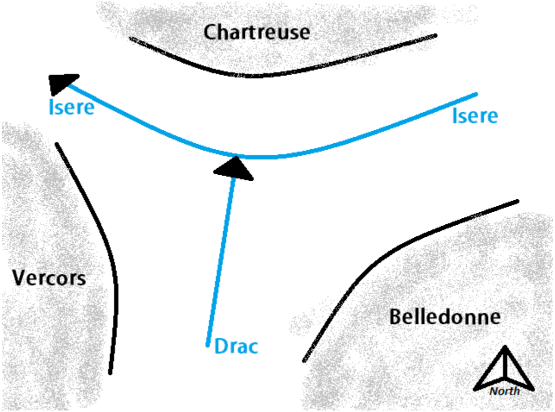


Figure: Mountains around Grenoble city

Outline

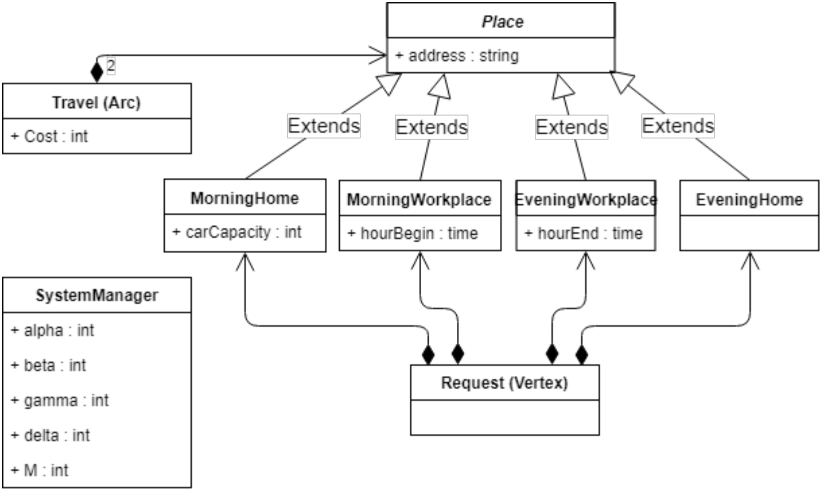
Outline

4. Modeling
   - Data
   - Decision variables
   - Scheduling
   - Resolution process

Modeling
Data

- $\forall i, j \in V, C_{ij}$ Cost matrices for commuting $arc(i, j)$.
- $\forall n \in O, Q_n$ Car's capacity of the user n.
- $\forall v \in D, B_v$ Hour: Beginning of work for the user n.
- $\forall v \in K, E_v$ Hour: End of work for the user n.
- γ Percentage of the initial travel time added.
- δ Constant value added to the max travel time.
- α Allowed waiting time to get to work early.
- β Allowed waiting time to leave work.
- M A large enough constant.

Modeling
Data



Outline

4 Modeling
- Data
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Modeling

Decision variables

- $\forall k \in O, \forall i, j \in V, x_{ij}^k = 1$ if the travel of the $arc(i, j)$ is deserved by the driver k.
- $\forall k \in O, y^k = 1$ if the user k is a driver.
- $\forall k \in O, \forall v \in V, z_v^k = 1$ if the user k is picking or delivering the vertex v.
- $\forall k \in O, \forall v \in V, b_v^k$ Estimated passage time of the driver k to the vertex v.
- $\forall k \in O, \forall v \in V, q_v^k$ Number of persons in the car k at the vertex v.

Outline

4. Modeling
   - Data
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   - Resolution process

Modeling
Scheduling

Sequencing the hours of passages.

$$b_j^k \geq b_i^k - B_{k+n} + (C_{ij} + B_{k+n}) \times x_{ij}^k + (B_{k+n} - C_{ij}) \times x_{ji}^k$$

$$b_j^k \geq b_i^k - M + (C_{i-2n,j-2n} + M) \times x_{ij}^k + (M - C_{i-2n,j-2n}) \times x_{ji}^k$$

[0] Ismail Karaoglan and Fulya Altiparmak. A memetic algorithm for the capacitated location-routing problem with mixed backhauls. Computers & Operations Research, 55:200216, March 2015.

[0] Hossein Karimi. The capacitated hub covering location-routing problem for simultaneous pickup and delivery systems. Computers & Industrial Engineering, 116:4758, February 2018.

Outline

4 Modeling
- Data
- Decision variables
- Scheduling
- Resolution process

Modeling
Resolution process

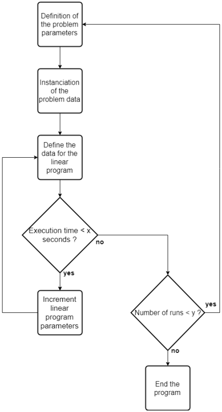

Figure: Flowchart of the LP's parameters variations

Outline

Outline

5. Experiments
   - Experimental protocol
   - Generator
   - Limits of the model
   - Same and different user pool
   - The case of Grenoble

Experiments
Experimental protocol

The PC used for the experiments:

- Operating System: **Windows 10 Professional 64-bit version**.
- Code language: **JAVA**
- Solver: **CPLEX**
- RAM quantity: **8GB**
- CPU: **Intel Core i5-4690 CPU 3.50 GHz**

All available at the following web address:
`https://github.com/NeoKa4ra/CarPoolingInternship`

Outline

5 Experiments
- Experimental protocol
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Experiments

Generator

Allowed advance to work: 30 minutes
Allowed waiting time after job: 15 minutes
Allowed travel time: $+ = 5 + 20\%$ of the direct trip

Outline

5 Experiments

- Experimental protocol
- Generator
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Experiments

Limits of the model

Working hours randomly generated from 8:00 to 9:00 and from 16:00 to 21:00

Less than 2% of GAP on 1 hour for 25 users.

Less than 10% of GAP on 1 hour for 30 users.

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Experiments

Difference between same and different user pool

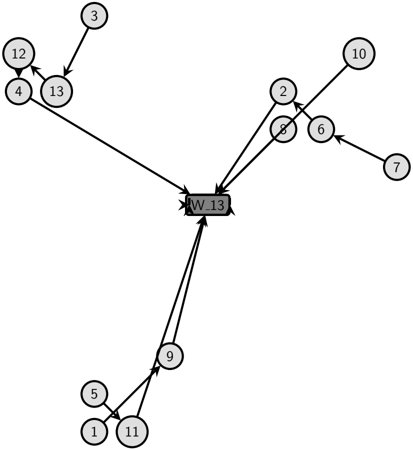

Figure: The same user pool makes the trip to work

Experiments

Difference between same and different user pool

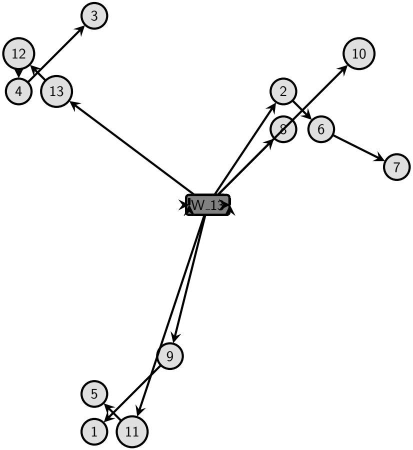

Figure: The same user pool makes the return trip

Experiments

Difference between same and different user pool

Much higher execution time without the same pool.
5 users : 2.20% difference ; 10 users : 7.5% difference.

Table: Objective value with 5 users

Name of the data	LP	LPSP
Mean	48.96	50.04
Standard deviation	15.26	15.32
Median	48.5	50.5

Table: Objective value with 10 users

Name of the data	LP	LPSP
Mean	92.00	98.90
Standard deviation	19.32	20.58
Median	88.00	95.5

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Experiments
The case of Grenoble

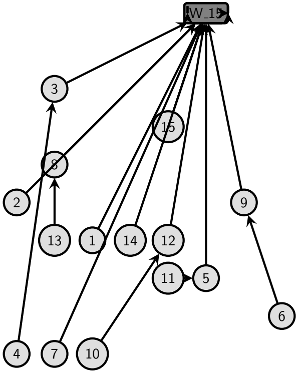

Figure: Home-to-work: VIZILLE PONT-DE-CLAIX VIF

Experiments
The case of Grenoble

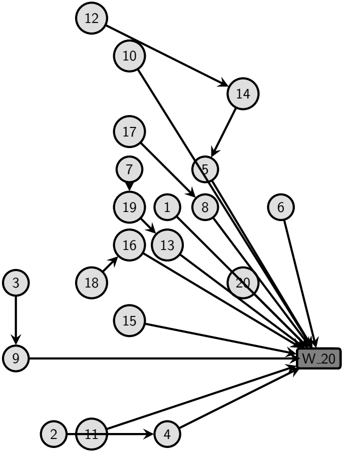

Figure: Home-to-work: VOIRON VINAY SAINT-LAURENT-DU-PONT

Experiments
The case of Grenoble

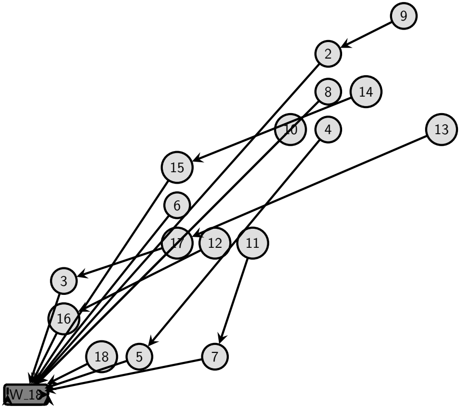

Figure: Home-to-work: PONTCHARRA LE-TOUVET CROLLES

Conclusion

Thank you for listening