Optimization in City Logistics

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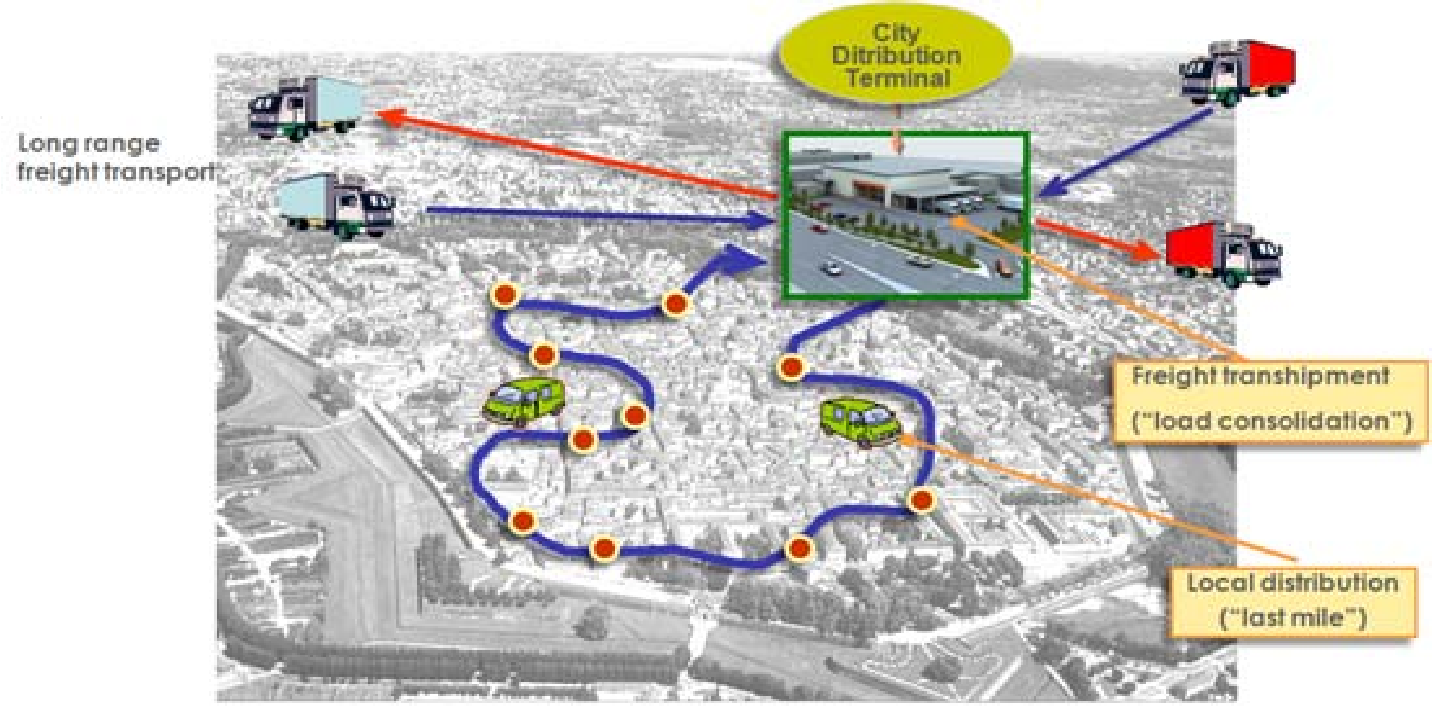
City Logistics

- Optimization of logistics and transport activities by private companies in urban areas
- Target: improving environmental, economic, and social sustainability of urban areas by
  - Reducing the number of vehicles used for freight transport in urban centers
  - Using resources in a smart way (vehicles, capacities, facilities, workers, etc…)
  - Reducing the traffic congestion and pollution emissions…



Optimization problems in city logistics

- Conflicts between public and private stakeholders on resources and profitability.
- Holistic vision but tackled only by decomposition:
  - Urban freight/passenger transportation
  - Distribution Logistics / Demand-responsive Home Delivery Services
  - Dynamic logistics resource allocation
  - Procurement Logistics
  - Sizing /Location of logistics terminals and facilities
  - Green logistics
  - Garbage collection
  - Packing/Loading
  - Multi-commodity multi-modal transshipment
  - Two-Echelon Vehicle Routing and location routing
  - and many more…

GARBAGE COLLECTION

- Collection of waste is an important logistics activity within any city.

VS

Door-to-door waste collection:

ADVANTAGES

- Higher level of selective collection /recovery
- No more containers on the street
- Higher quality of the recovered materials
- Lower disposal costs
- No more putting out waste anonimously
- Enables pay-as-you-throw refuse taxes system

DRAWBACKS

- Higher costs of service collection
- Higher effort for the citizens
- Higher effort for service provider

CASE STUDY I: DOOR TO DOOR GARBAGE COLLECTION IN THE CITY OF BRESCIA

- Brescia is moving from a bins-based system to a door-to-door service

- Municipality needs to:
  - Re-organize the activity of a huge number of trucks and workers
  - Define the routes for the new service and the corresponding schedule

- Optimization models and algorithms allow to define routes that:
  - minimize transportation costs
  - guarantee a fixed schedule for each type of waste
  - reduce the environmental impact

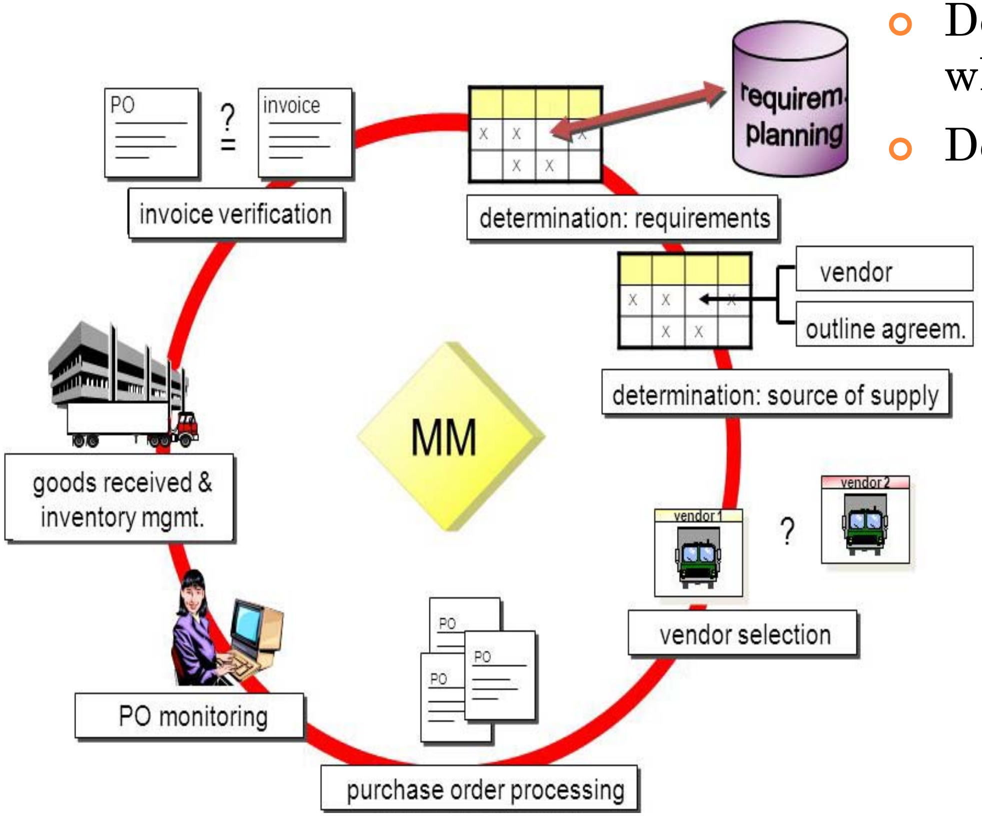
PROJECT I: ORGANIZATION OF GARBAGE COLLECTION ROUTES IN A PILOT AREA OF BRESCIA

- **Goal 1**: Collect and process geo-spatial real data of the pilot zone
- **Goal 2**: Map the problem into graph theory
- **Goal 3**: Solve the problem by using mathematical programming models and algorithms on graphs (Arc Routing optimization)
- **Goal 4**: Implement/visualize the solution

PROCUREMENT LOGISTICS

Many companies face products and/or raw material procurement as three separated problems

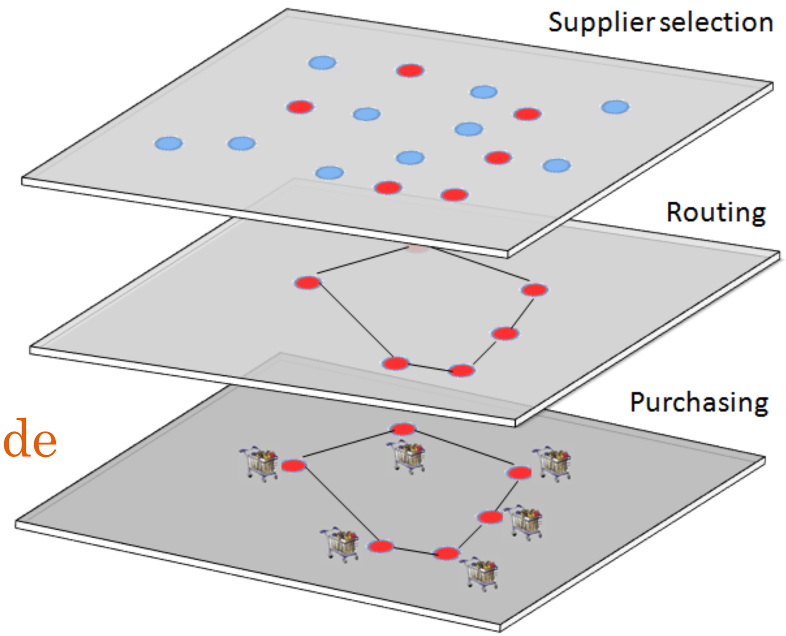
- Identify the best suppliers
- Decide which products to buy from whom
- Define routes to visit selected suppliers



CASE STUDY II: MANAGEMENT OF COMPLEX OPERATIONS IN PROCUREMENT LOGISTICS

Solve a real case problem where the three stages are jointly optimized

- Optimal suppliers selection
- Optimal routing
- Optimal purchase planning

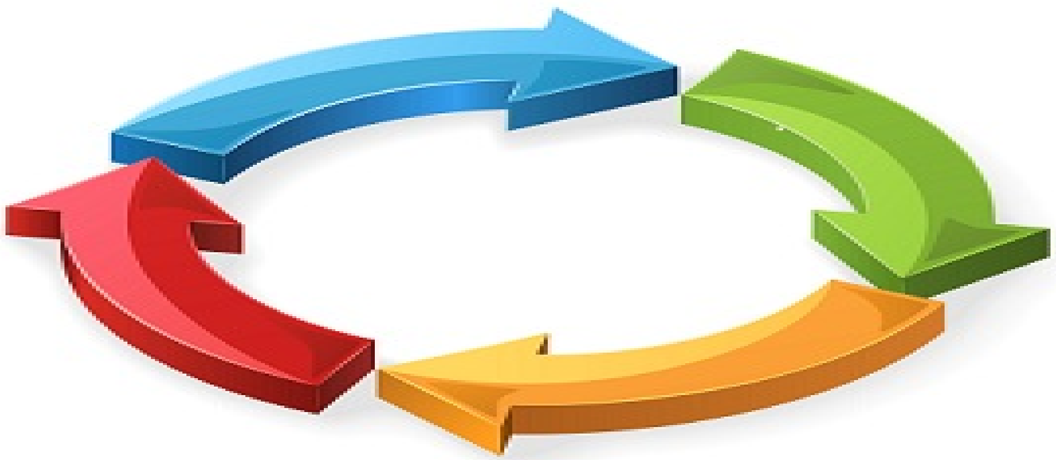


Problem is further complicated by side constraints:

- restrictions on vehicle capacity
- incompatibilities among products loaded on the same vehicle

PROJECT II: SELECTION OF SUPPLIERS AND PROCUREMENT OPTIMIZATION

- **Goal 1**: Provide alternative mathematical models
- **Goal 2**: Solve the problem by using mathematical programming and advanced optimization algorithms
- **Goal 3:** Compare solutions and computational complexity
- **Goal 4**: Implement/visualize the solution



Schedule of the week:

		05/09/2016	06/09/2016	07/09/2016	08/09/2016	09/09/2016
		MON	TUE	WED	THU	FRI
09:00	09:30		Lecture: Arc Routing	Lecture: Algorithms on graph	Lecture: Branch&Cut	Lab project
09:30	10:00					
10:00	10:30					
10:30	11:00					
11:00	11:30		Lecture: RPP	Lecture: TPP	Lecture: Algorithms on graph	Lab project
11:30	12:00					
12:00	12:30					
12:30	13:00					
13:00	13:30					
13:30	14:00					
14:00	14:30		Lab lecture: QGIS	Lab lecture: CPLEX	Lab lecture: B&C	Lab project
14:30	15:00	Lecture: MP/LP/ILP				
15:00	15:30				Lab project	
15:30	16:00					
16:00	16:30					
16:30	17:00					
17:00	17:30	Lab lecture: MPL	Lab project	Lab project	Lab project	Lab project
17:30	18:00					
18:00	18:30					
18:30	19:00					

Lecturer: Prof R. Mansini
Lecturer: Prof. R. Rizzi
Lecturer: D. Manerba, Ph.D.
Supervision of all the instructors

LECTURE TOPIC: MATHEMATICAL PROGRAMMING (MP)

- Basics of
  - Linear Programming (LP)
  - Integer Linear Programming (ILP)

Linear Programming Problem (1/4)

Objective function and constraints are linear function in x:

$$MIN \quad c_1x_1 + \; c_2x_2 \; + \cdots + \; c_nx_n$$

constraints

$$\begin{array}{ccccccc} a_{11}x_1 & + & a_{12}x_1 & + & \cdots & + & a_{1n}x_n \\ a_{21}x_1 & + & a_{22}x_2 & + & \cdots & + & a_{2n}x_n \\ \vdots & & \vdots & & & & \vdots \\ a_{m1}x_1 & + & a_{m2}x_2 & + & \cdots & + & a_{mn}x_n \end{array}$$

non negativity $\quad x_1, \quad x_2, \quad \cdots \quad x_n \quad \geq \quad 0$

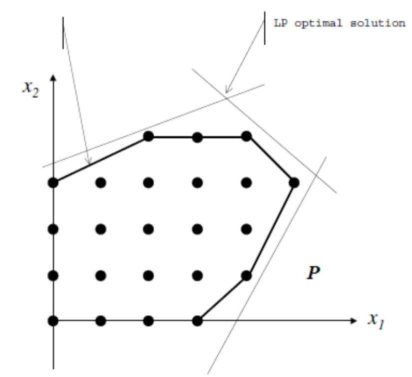
Integer Linear Programming Problem

Feasible region of the ILP problem:

$$X = P \cap Z^n$$

Feasible region of the LP relaxation problem:

$$P = \{\mathrm{x} \geq 0 : A\mathrm{x} \geq \mathrm{b}\}$$



LECTURE TOPIC: ROUTING OPTMIZATION

- Basics of Graph Theory
- Arc Routing Problems
- Node Routing Problems

Example: Undirected CPP (3/4)

Possible matchings:

- $(1,3),(4,6) \rightarrow cost: 7;$
- $(1,4),(3,6) \rightarrow cost: 6;$
- $(1,6),(3,4) \rightarrow cost: 5.$

Optimal Perfect Matching:

- $(1,6),(3,4) \rightarrow cost: 5.$

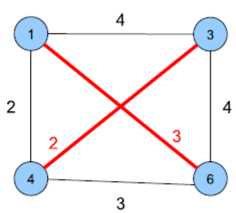


Figure: Graph $\bar{G}$.

Basic Definitions: Hamiltonian Graphs and Cycles

- A cycle is **Hamiltonian** if it traverses each node of the graph once and only once (with the only exception of the initial node and the terminal one that, by definition, have to coincide);
- A graph is said to be **Hamiltonian** when it is possible to identify an Hamiltonian cycle in it.

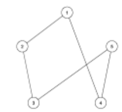
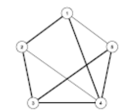


Figure: Hamiltonian Cycle



...onian Graph

Asymmetric TPP (2/3)

$$(ATPP) \quad \min \sum_{(i,j)\in A} c_{ij}x_{ij} + \sum_{k\in K}\sum_{i\in M_k} p_{ik}z_{ik} \quad (1)$$

$$\text{subject to} \quad \sum_{i\in M_k} z_{ik} = d_k \qquad k \in K \quad (2)$$

$$z_{ik} \leq q_{ik}y_i \qquad k \in K, i \in M_k \quad (3)$$

$$\sum_{(i,j)\in\delta^+(\{h\})} x_{ij} = \sum_{(i,j)\in\delta^-(\{h\})} x_{ij} = y_h \qquad h \in V \quad (4)$$

$$\sum_{(i,j)\in\delta^-(S)} x_{ij} \geq y_h \qquad S \subseteq M, h \in S \quad (5)$$

$$x_{ij} \in \{0,1\} \qquad (i,j) \in A \quad (6)$$

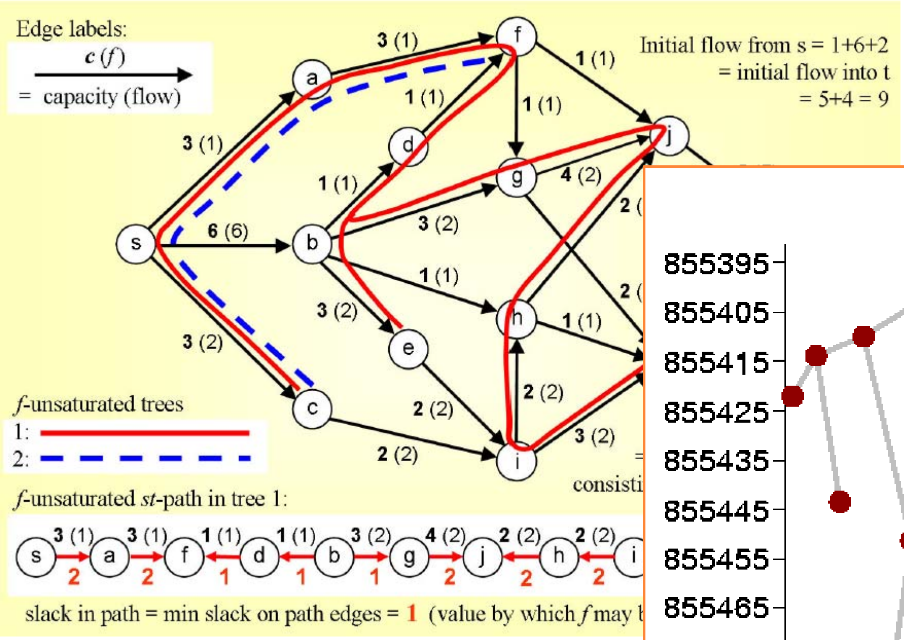
$$y_i \in \{0,1\} \qquad i \in M \quad (7)$$

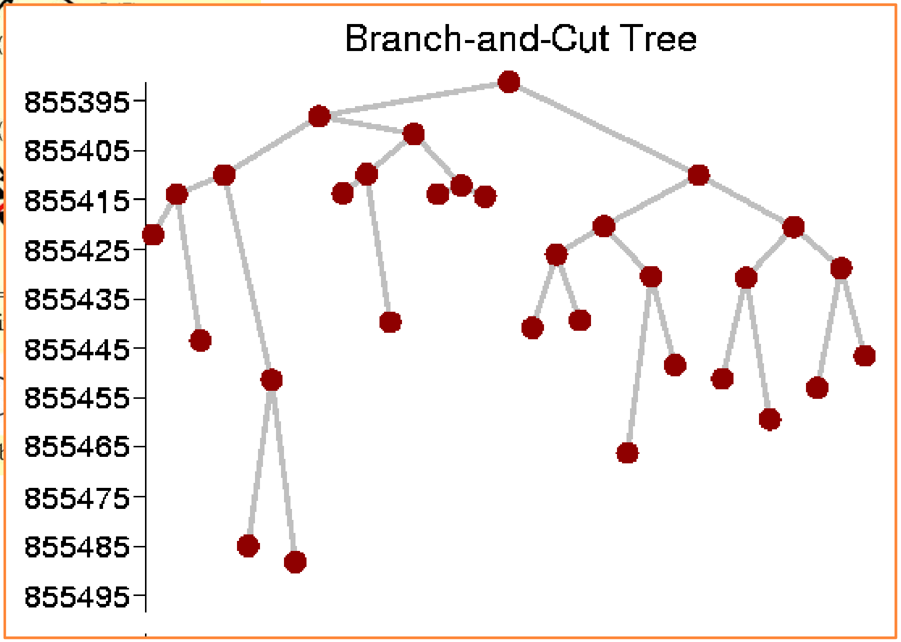
$$y_i = 1 \qquad i = 0 \quad (8)$$

$$z_{ik} \geq 0 \qquad k \in K, i \in M_k. \quad (9)$$

LECTURE TOPIC: SOLUTION METHODS

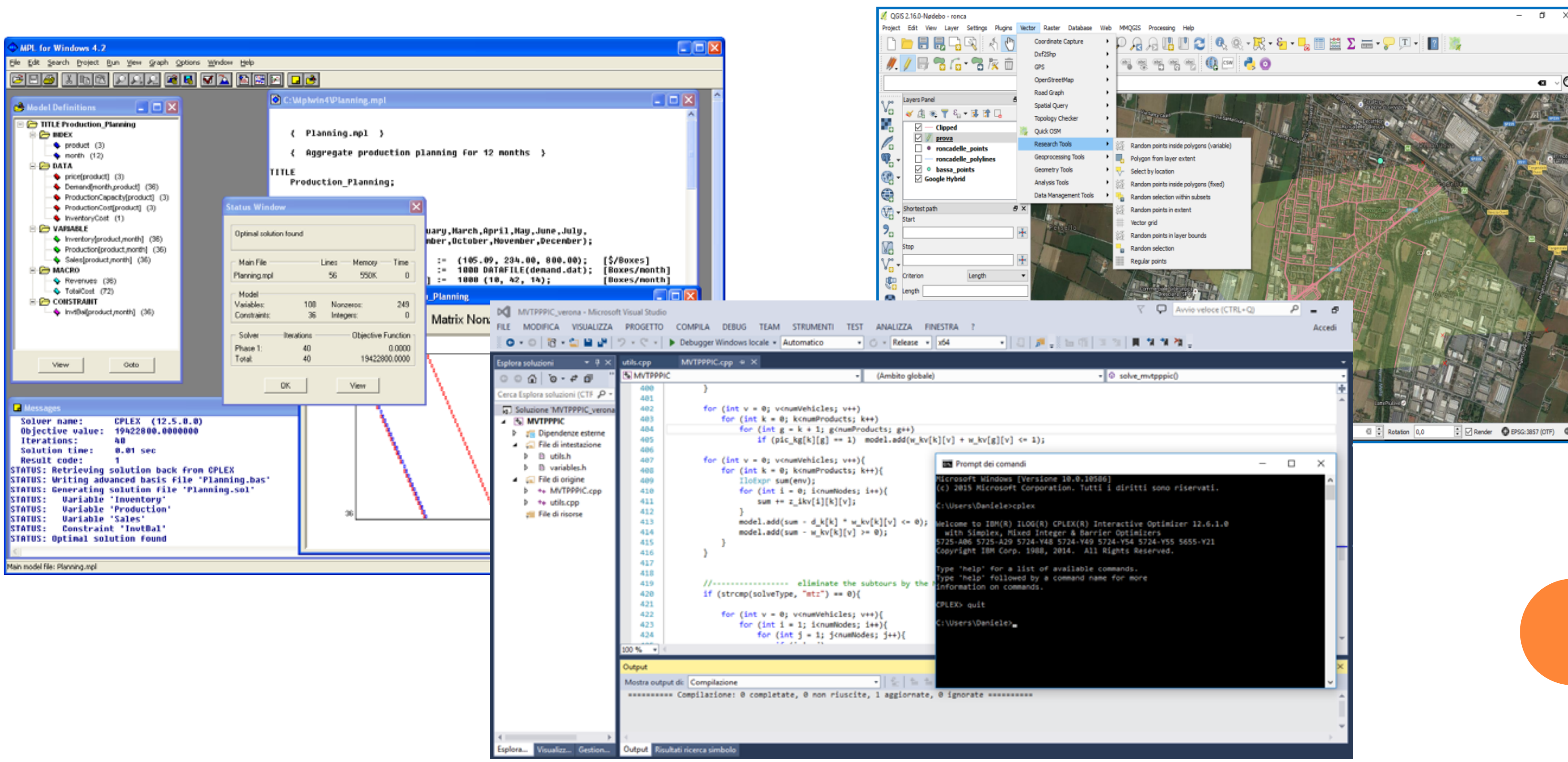
- Optimization techniques and algorithms:
  - Network Algorithms
  - Branch&Bound/Cutting Planes/Branch&Cut





LECTURE TOPIC: LABORATORY

- Solving models with MPL (Mathematical Programming Language)
- Solving models with CPLEX
- Elaborating geo-spatial data with QGIS



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