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Demand responsive transport: design of the service and examples

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Asti – February 24th , 2011

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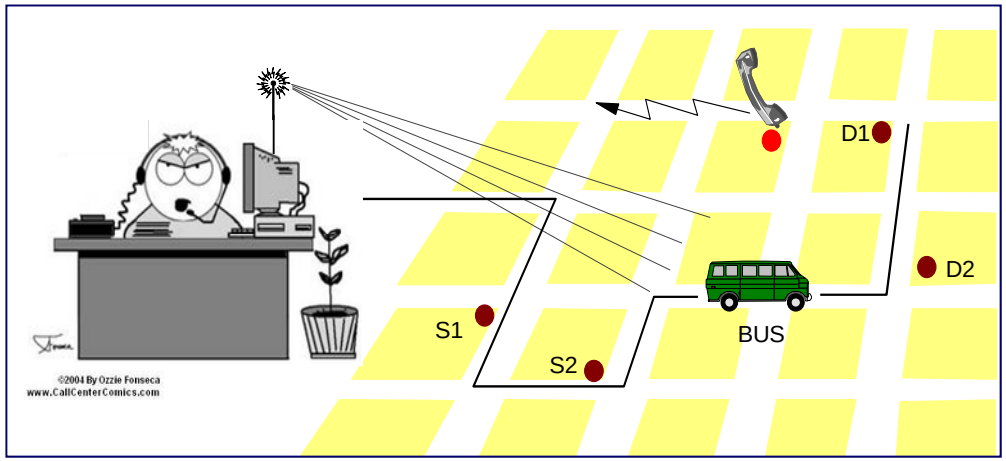
Description of a Demand Responsive Transport (DRT) service

1) The user calls the operation center stating:
   - *number of passengers*
   - *origin and destination*
   - *desired departure and arrival times*



2) The systems allocates two time-ranges, calculated considering
   - *departure and arrival times*
   - *a predefined level of service*

   and ensures departure and arrival times within the calculated time ranges

3) The systems runs algorithms finalized to select
   1. Which **vehicle** of the fleet will pick up the user
   2. Which **route** the vehicle will make
   3. User's **departure and arrival times**

4) The system advice the user whether his request has been *satisfied or refused.*
   If refused, the system negotiates with the user a *modification of departure and arrival times*. The system communicates to the selected vehicle the *variations to routes or scheduled times*

Two different decision problems

- Service planning (design)
  - service area
  - design of the type of service (traditional with deviations, door-to-door, ...)
  - size of the fleet
  - size of the call center
  - communication technologies
  - delays procedures
  - ...
- Service management
  - ACCEPTANCE or refusal of the user
  - choice of the bus to serve each user
  - management of delays and interruptions
  - ...

Outline

- Service planning (design)

  A possible scheme for the design procedure exemplified with a case study: a service in a hilly area in Como during Sundays and holidays

- Service management

  An example of software for the management of the service

A possible scheme for **planning**

Demand analysis
Survey (revealed and stated pref., o/d matrix, ..)

Network
Time-dependent graph

Input

Fleet
n° of buses, vehicles capacity, schedule

Service quality bonds
Max waiting time, Level of Service, ...

Decision variables

Users
booking, online call

Estimated scenarios

Algorithms
routing and scheduling

Simulation

Objectives of the design process
- covering (% served users)
- quality (wait time or travel time)
- costs (n° and schedule of the buses, bus*km)

Solution choice

Steps for the service design (1)

A. Land analysis

Analysis of the territory, the morphological shape and the mobility needs of the area. The road network, on which the demand-responsive system will operate → time-dependent graph of the road network

B. Analysis of the current supply

Assessment on how the current users use the current transportation systems and how the new service would interact with the existing ones

C. Demand analysis

Estimation of the current demand (OD matrices). Construction of the new OD matrix based on the potential demand

D. Generation of different service alternatives

Different alternatives of service with different size of the fleet, operating time, vehicle's dimensions, booking procedures are generated

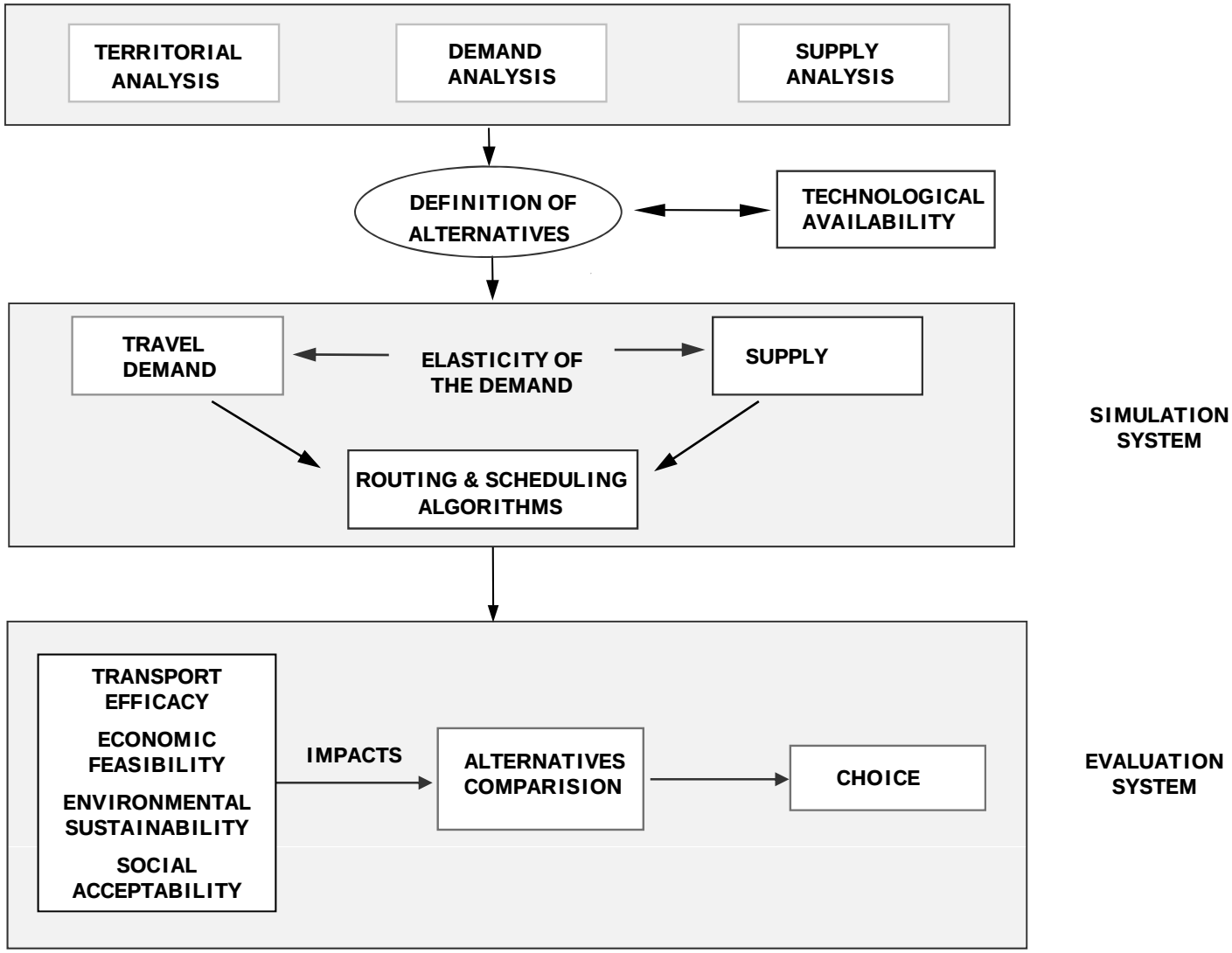
E. Simulation

The service provides in each alternative is simulated with an appropriate software

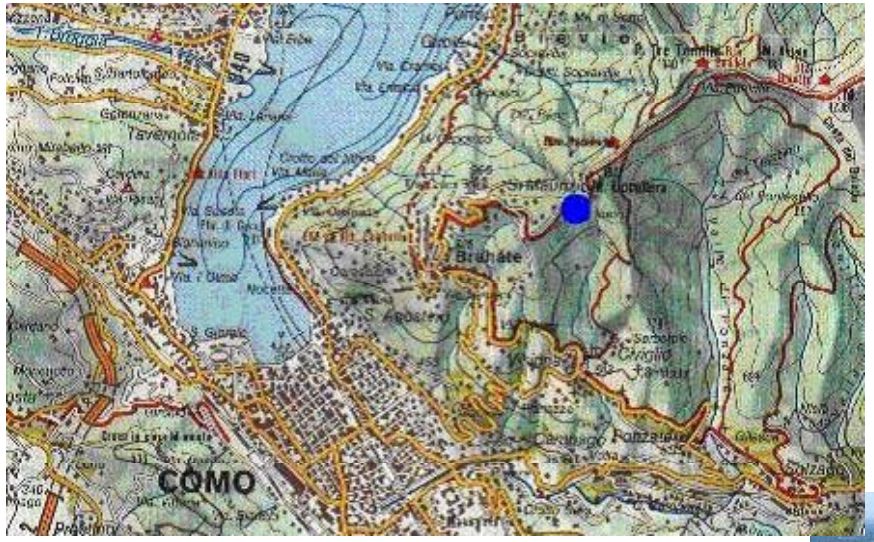
F. Selection of the "best" alternative

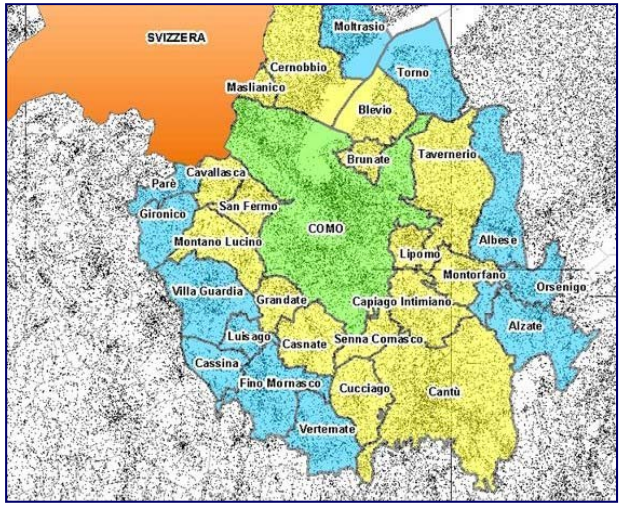
The alternatives are evaluated and compared, possibly using a multi-criteria analysis, with several criteria: e.g. transport efficacy, economic feasibility, environmental sustainability, social acceptability

Steps for the service design (2)



Case of Como

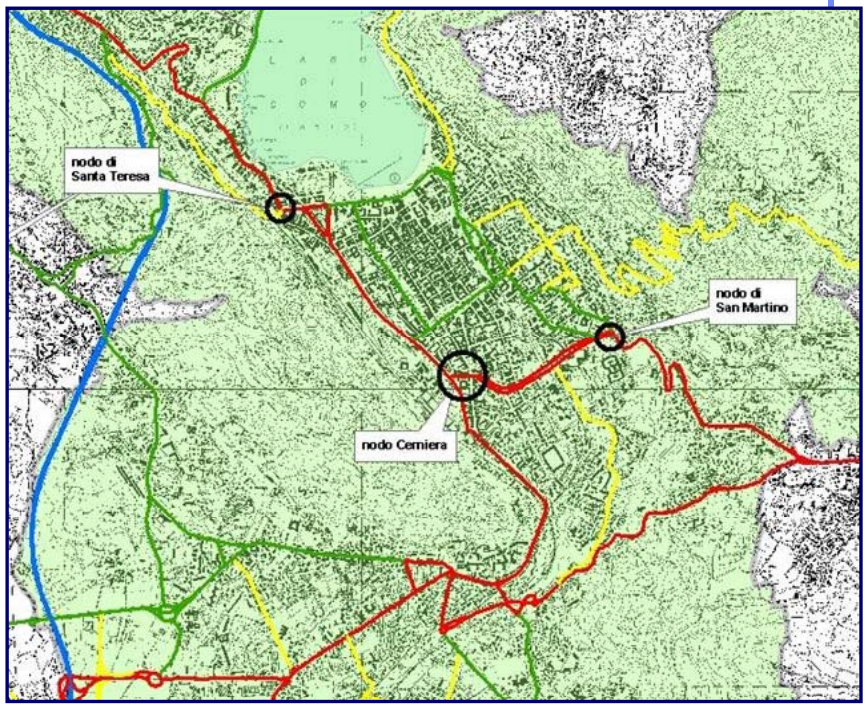

Brunate
COMO


SVIZZERA
Moltrasio
Cernobbio
Torno
Maslianico
Blevio
Brunate
Tavernerio
Cavallasca
Parè
Gironico
San Fermo
COMO
Montano Lucino
Albese
Lipomo
Montorfano
Orsenigo
Villa Guardia
Grandate
Capiago Intimiano
Alzate
Luisago
Casnate
Senna Comasco
Cassina
Fino Mornasco
Cucciago
Cantù
Vertemate

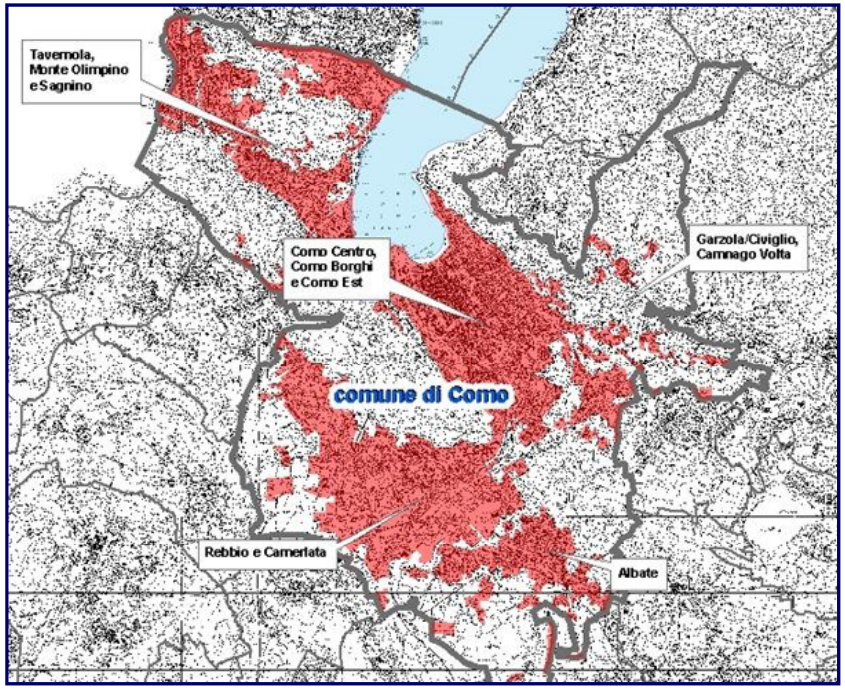
A - territorial analysis

Characteristics of the territory

- Limited space
- Inadequate roads network and high congestion level
- Confused urban development
- Territorial functions concentrated in the Convalle (the center of the city)



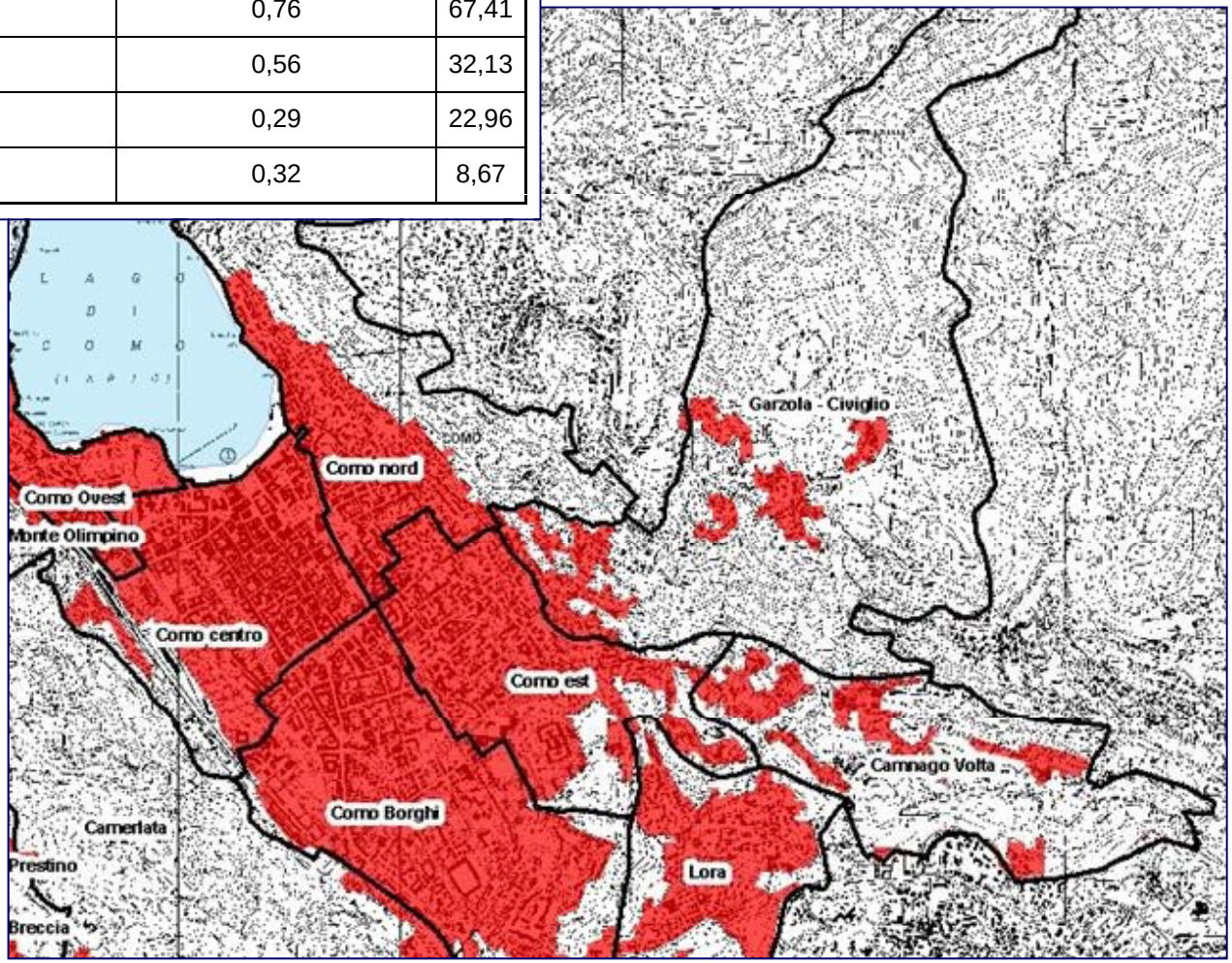
Main roads network and congestion nodes



Urban area

A – Urban area

	Area quartiere [km^2]	Area urbanizzato[km^2]	%
Como Est	1,12	0,76	67,41
Como Nord	1,75	0,56	32,13
Camnago Volta	1,27	0,29	22,96
Garzola/Civiglio	3,65	0,32	8,67



Urban areas distribution

B – current transport supply (1)

- Current operator: SPT Linea and ATM
- 13 urban motorized lines + 1 funicular line
- Radial rides from the center to the suburbs
- Functioning hours: 6.00 – 21.00 (except CC1)
- Frequency between 15’ and 30’ during rush hours, double on holidays (except CC1)

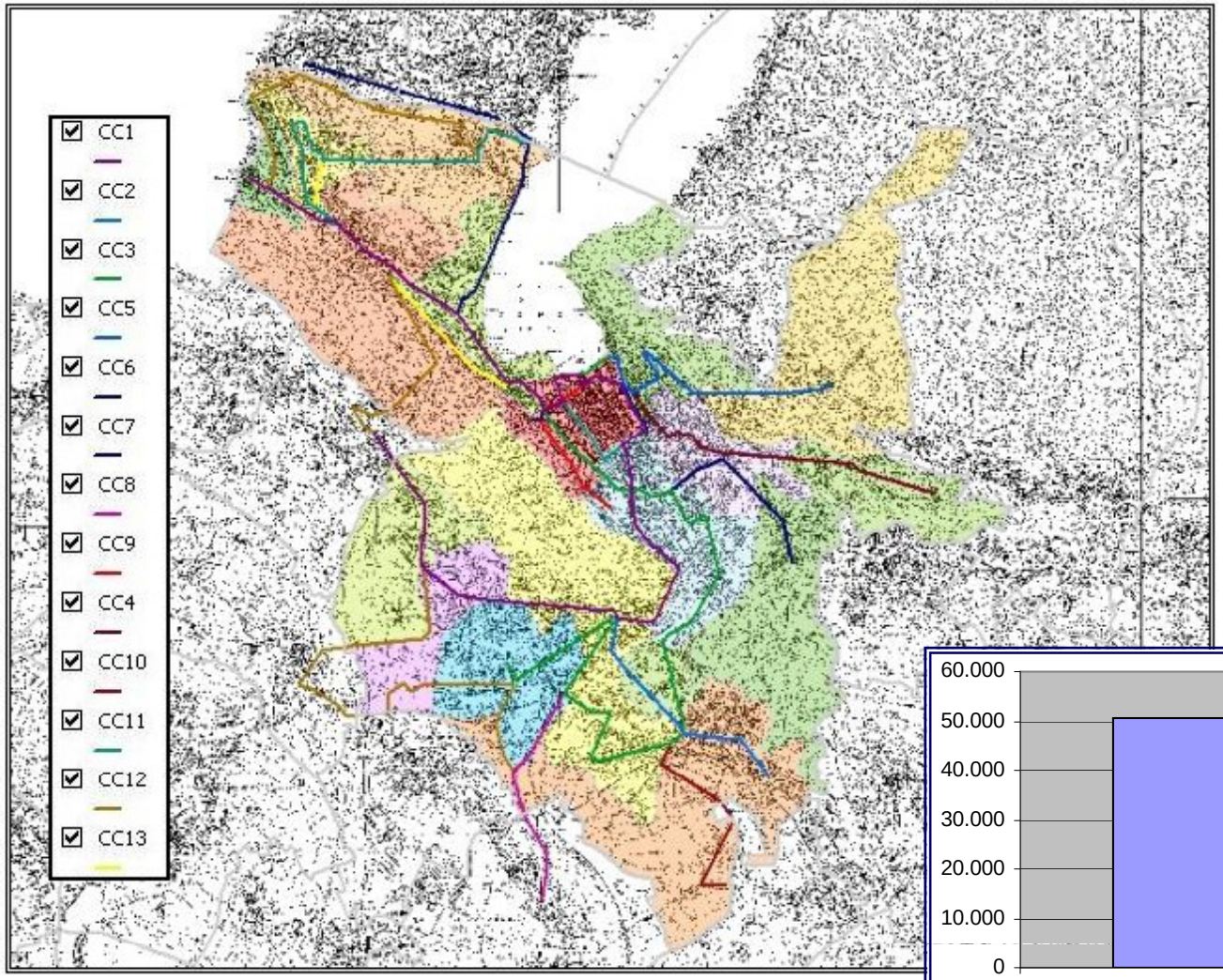
A questionnaire to the bus driver
→ strengths and weaknesses

LINEA: _____ CAPOLINEA: _____
ORA: _____
o Punta
o Morbida

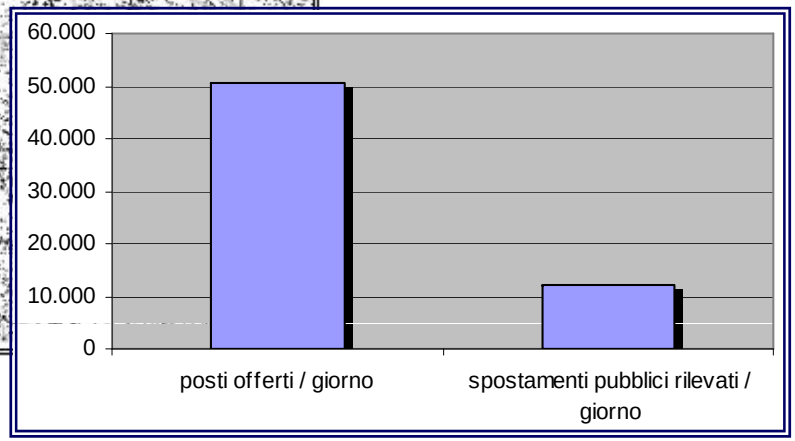
1. Che bus utilizza in genere su questa linea?
_____
2. Quanti posti a sedere ci sono?
_____
3. Quanti posti in piedi ci sono?
_____
4. Quale tratta percorre in genere a pieno carico?
_____

- Strong lines: CC1 and CC6
- line CC10: load equally distributed
- lines CC4 and CC5: underused in the moderate flow hours and on holidays
- Strong influence of the market

B – current transport supply (2)



Current urban lines routes

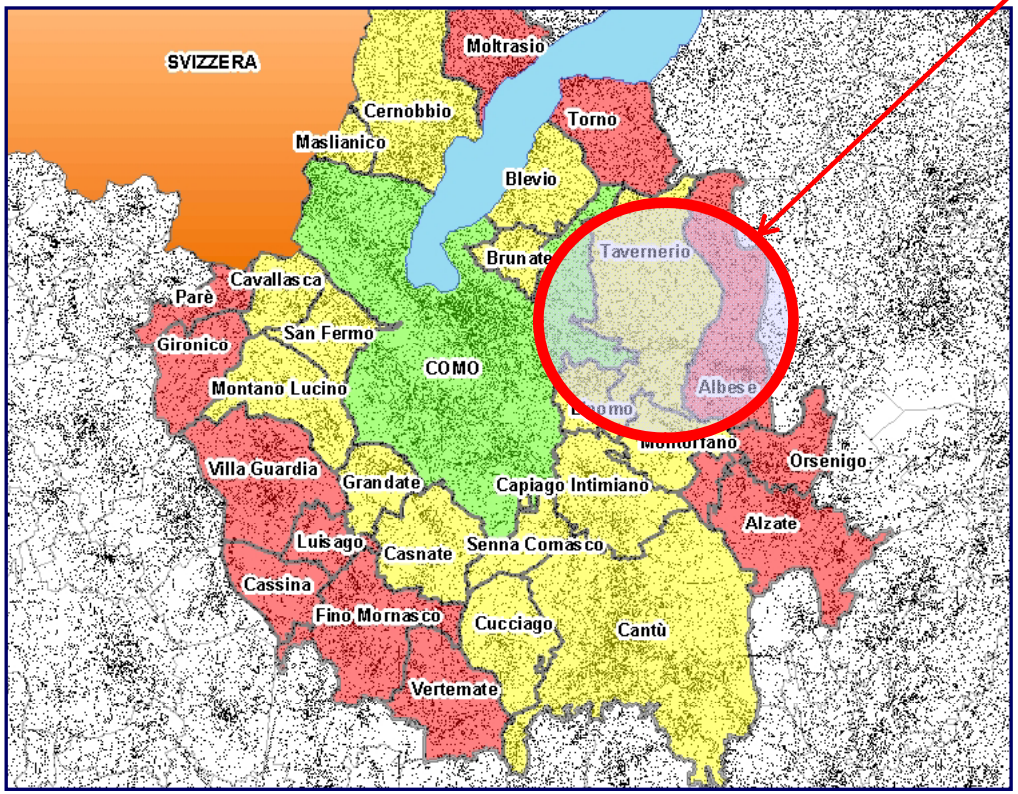


C – current transport demand (Como)

Source

- O/D survey, Regione Lombardia 2002
- Traffic Urban Plan, Municipality of Como
- On bord survey, SPT line

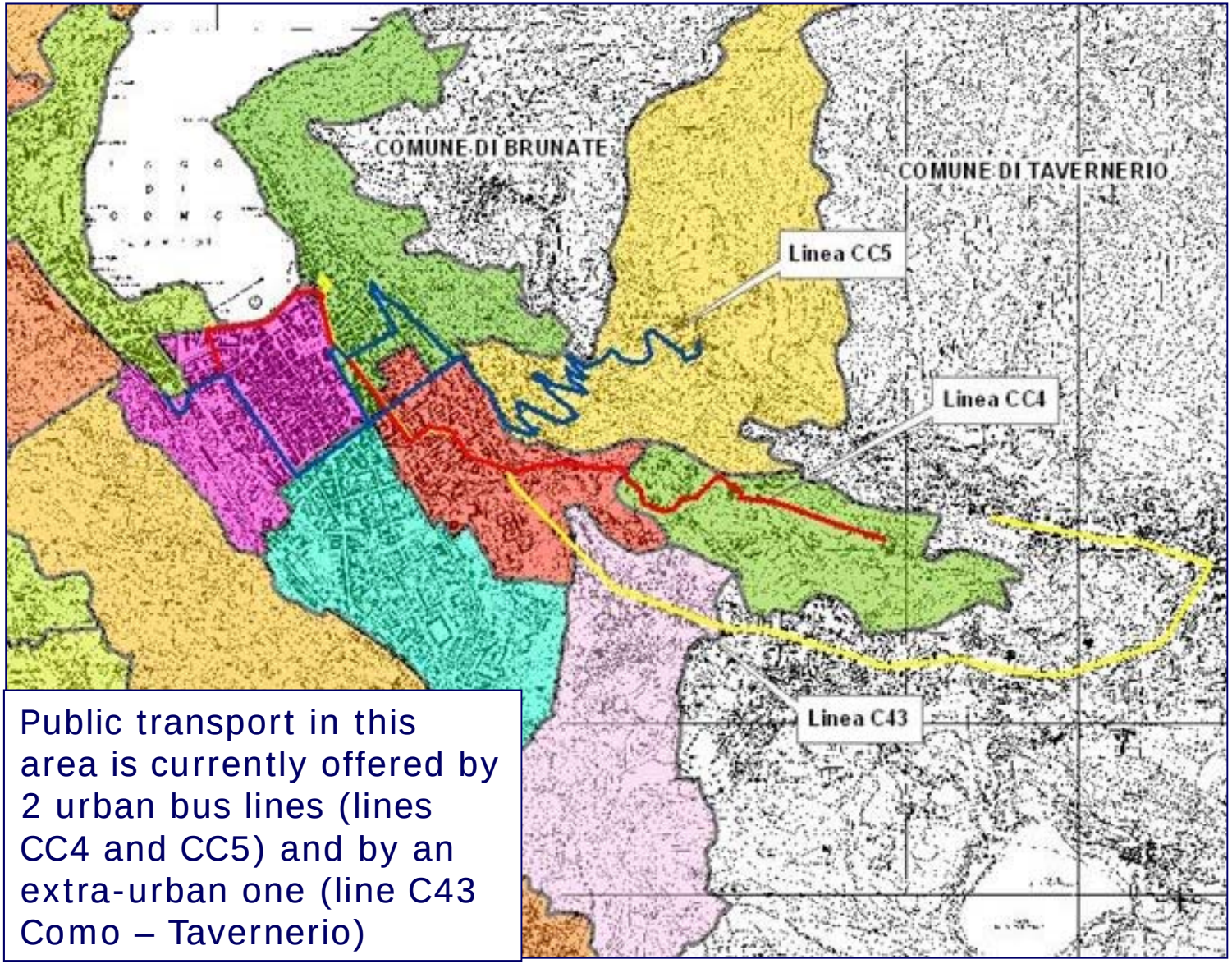
Area of the prospective DRT service



The municipalities around Como

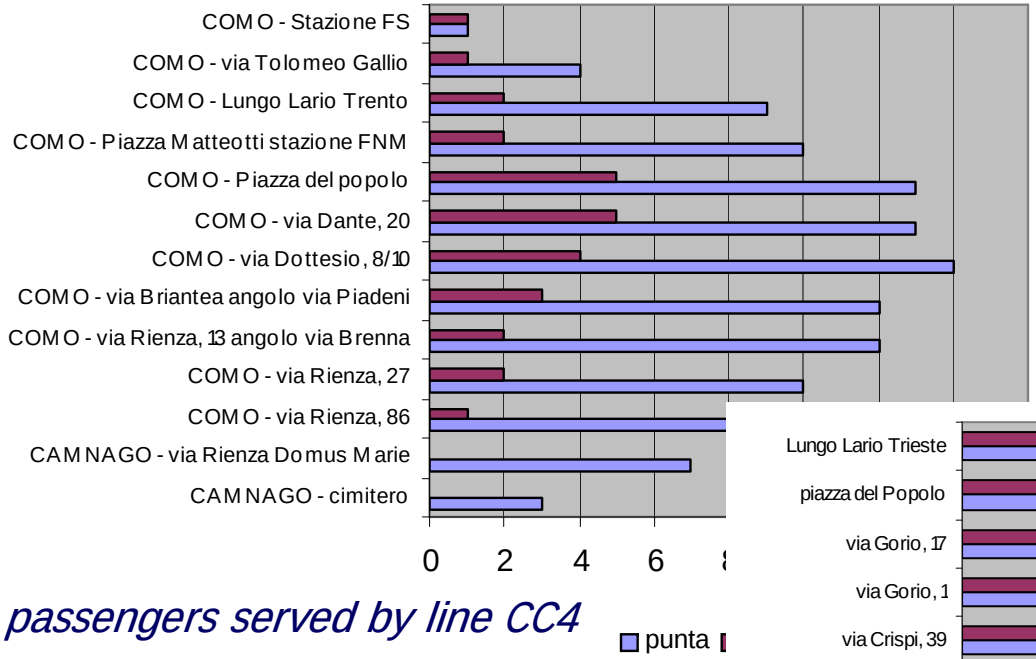
- Como is a strong attractive pole in the morning rush hours
- 80% of the rides is done with private vehicles, also due to the inadequate public transport system

B – current transport supply (3)

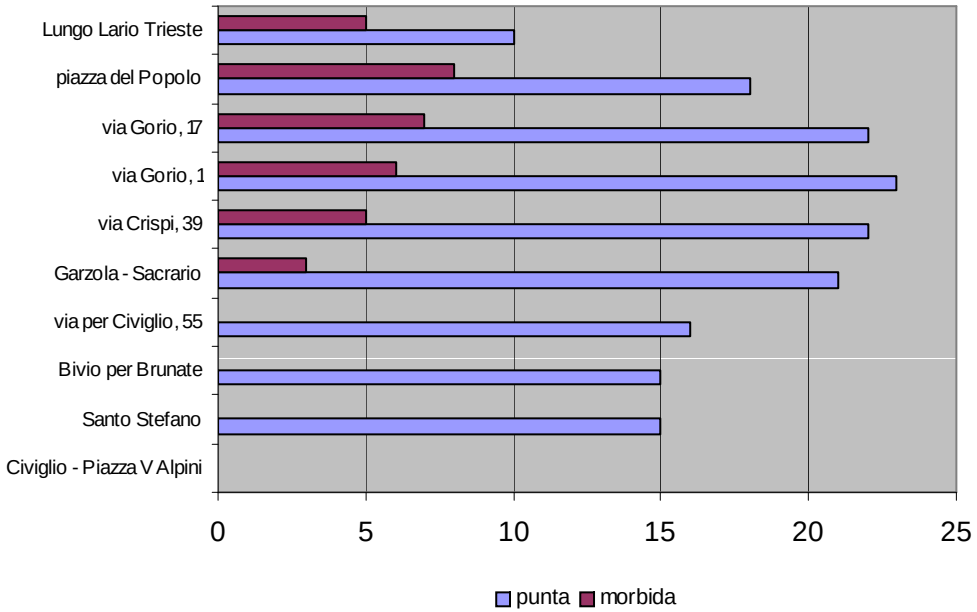


Public transport in this area is currently offered by 2 urban bus lines (lines CC4 and CC5) and by an extra-urban one (line C43 Como – Tavernerio)

B – current transport supply (4)



N° passengers served by line CC4



N° passengers served by line CC5

D – Service configuration (1)

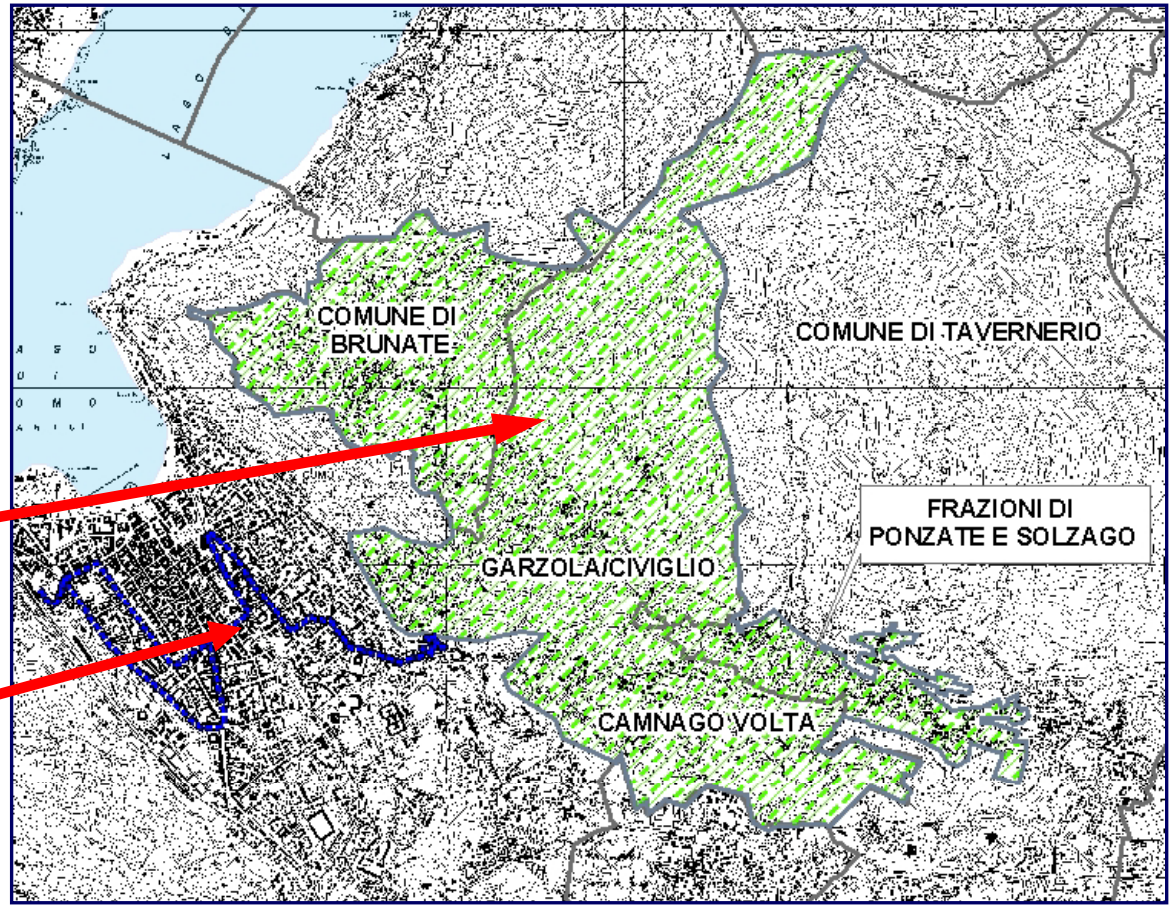
A DRT service in a hilly area during Sundays and holidays

- Needs: current lack of public transport (weak demand areas)
- Functioning days: Sundays and holidays, replacing lines CC4 and CC5
- Functioning hours: 9.00 – 22.00
- Lines length:
  - CC4 6,4 km
  - CC5 7,2 km

Two different kind of service

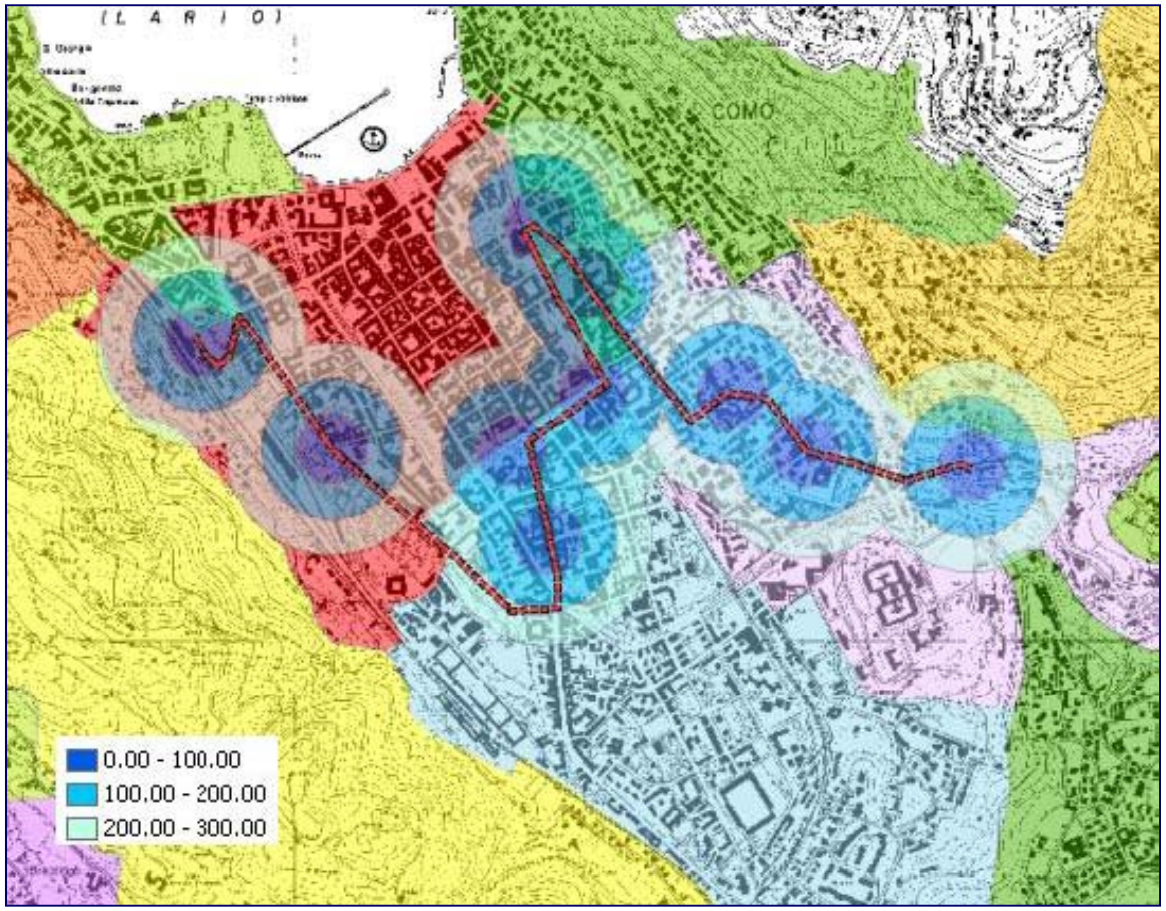
Door to door in a 10 km² area

Traditional with 10 fixed stops in the city center



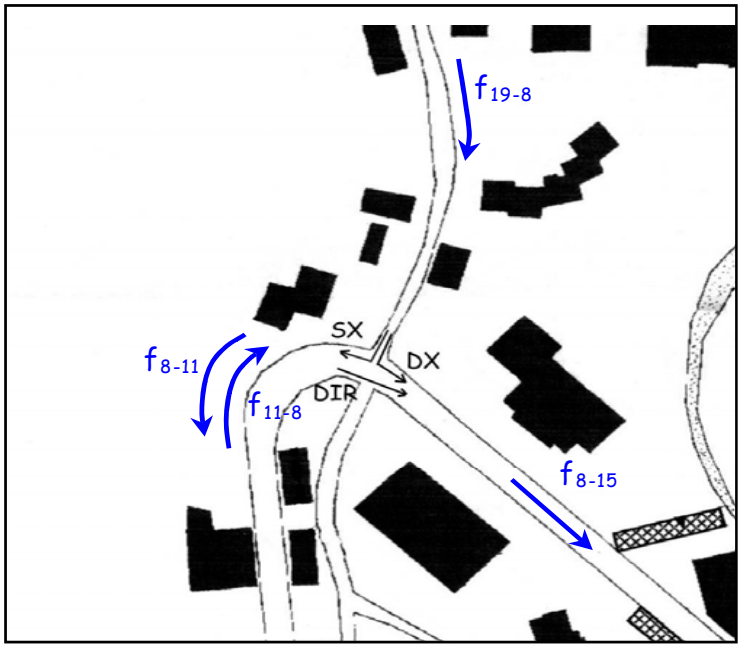
D – Service configuration (2)

The ten stops along the path cover an ample part of the urban area surrounding the historical center

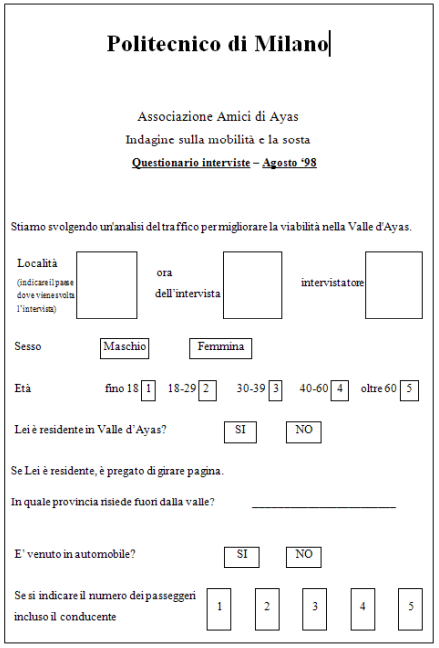


Influence radius of the stops along the fixed path part

C - Estimation of the current travel demand



survey of the traffic flow



Politecnico di Milano

Associazione Amici di Ayas
Indagine sulla mobilità e la sosta
Questionario interviste – Agosto '98

Stiamo svolgendo un'analisi del traffico per migliorare la viabilità nella Valle d'Ayas.

Località (indicare il paese dove viene svolta l'intervista) ☐ ora dell'intervista ☐ intervistatore ☐

Sesso Maschio Femmina

Età fino 18 [1] 18-29 [2] 30-39 [3] 40-60 [4] oltre 60 [5]

Lei è residente in Valle d'Ayas? SI NO

Se Lei è residente, è pregato di girare pagina.

In quale provincia risiede fuori dalla valle? _____

E' venuto in automobile? SI NO

Se si indicare il numero dei passeggeri incluso il conducente 1 2 3 4 5

survey on the current trips characteristics

Origin / Destination (O / D) matrices of the current travel demand

C - Estimation of the current travel demand

Models based on stated preferences

Parte B: DaR

Vi sottoponiamo ora una serie di domande, le risposte che darete dovranno essere riferite ad un ipotetico viaggio tra Antagnod e le funivie di Champoluc.

In ogni domanda vi saranno sottoposte tre possibili scelte:

a) usare l'auto propria pagando il pedaggio

(il tempo di percorrenza è di circa 10 minuti)

b) usare il taxi collettivo - gratuito per i ragazzi al di sotto dei 12 anni

(il tempo di percorrenza è di circa 15 minuti)

e nel caso che non si sia soddisfatti da nessuna delle due alternative precedenti:

c) non venire più in Val d'Ayas

An example of SP survey for a mountain tourist area

Vi chiediamo di riflettere attentamente e di ordinare le tre alternative crocettando «1°» per la scelta più gradita, «2°» per la scelta intermedia e «3°» per la scelta meno gradita.

domanda C1		*Esempi di spesa*			preferenza
		2 giorni	7 giorni	14 giorni	
a) Usare l'auto propria pedaggio al giorno:	10000	20000	70000	140000	1° 2° 3°
b) Servirsi del taxi collettivo (tariffa per viaggio a persona)	2500	10000	35000	70000	1° 2° 3°
c) Non venire più in Val d'Ayas					1° 2° 3°

C – Comments on SP models (1)

- Problems in the calibration
  - Because of the low numbers, the models' coefficients can be not statistically significant
  - Use of revealed preference in similar situations to correct the models

C – Comments on SP models (2)

- What to do with the results of SP demand models?
  - Classical models return the expected value E of passengers that would use the Dial-a-Ride (DaR) service. Then, a program is applied using E to model the DaR system. Problem: the numbers are low and working with the expected value is not correct, because the model of the Dial-a-Ride is not linear.
  - Another approach: simulation.
    N possible instances of the number of passenger are simulated, for instance with a Montecarlo method. The DaR program models the services for each of the N instances, and an expected value is calculated afterwards.

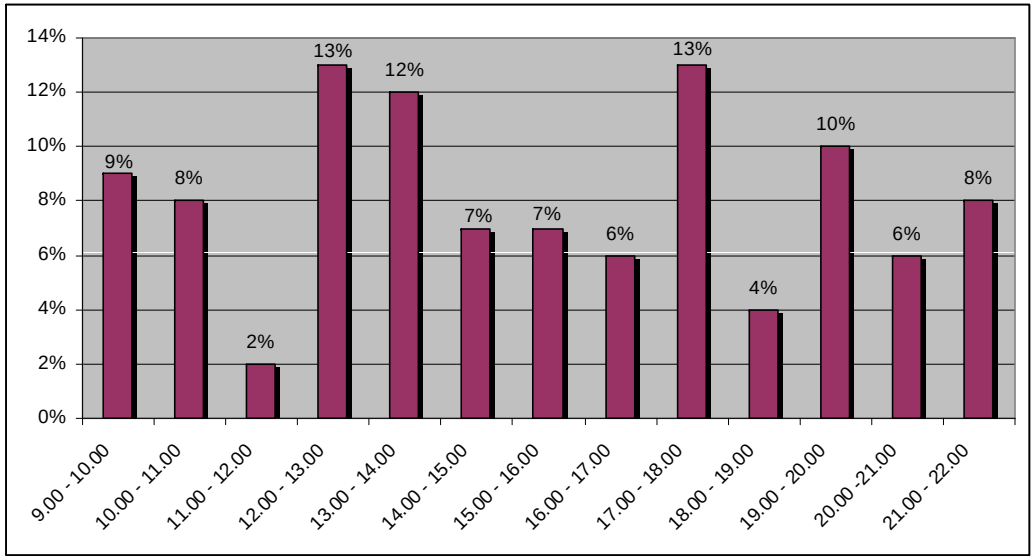
C – Potential demand estimation

Volume of moving

From the SPT survey on board → find out the load of transported passengers and the main motivations of the trip

⇩

200 daily trip requests



Addresses of origin / destination

area involved in the door to door service

⇩

Random extraction from the data base

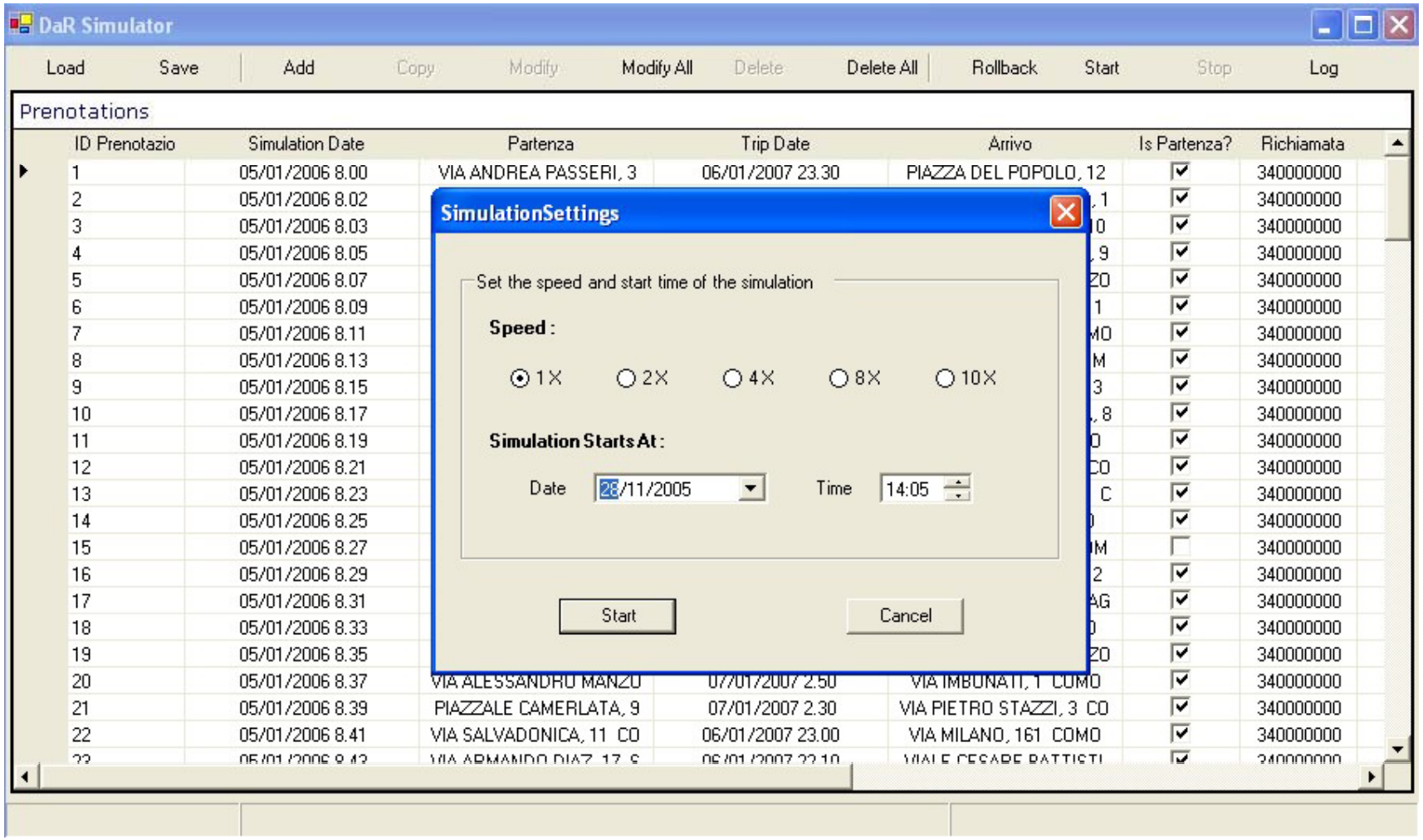
(Montecarlo method)

Fixed city center path

⇩

Fixed stopsCC4/CC5

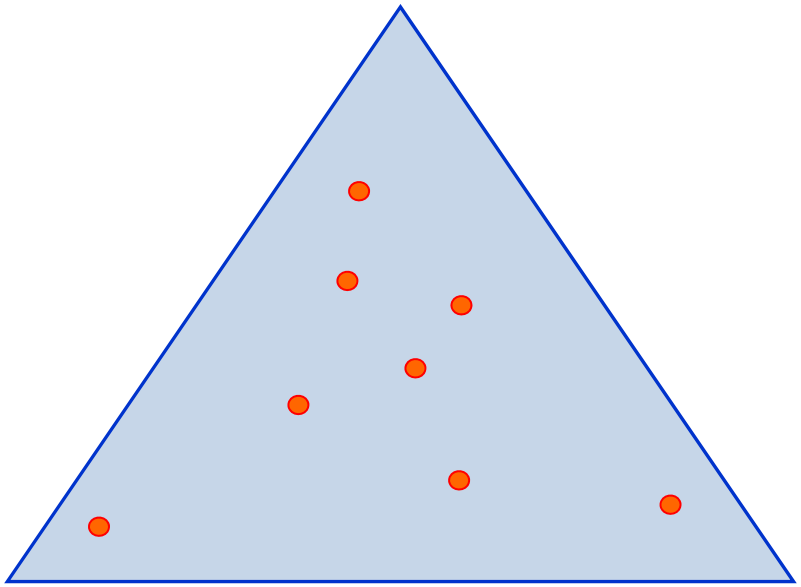
D – a DRT simulation software



D – Simulation

Trade-off among different objectives

COVERING
- % served users
- served area



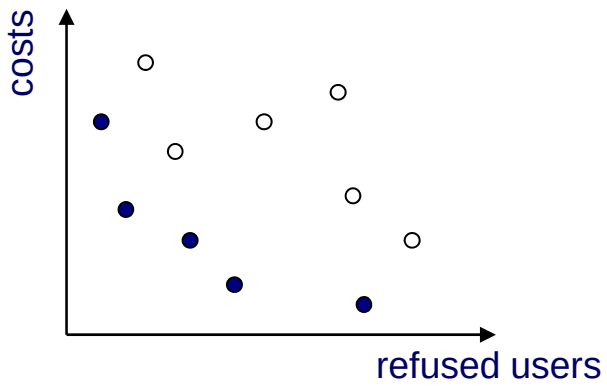
COSTS
- n° buses
- schedule of the buses
- bus*km

SERVICE QUALITY
- travel time
- waiting time

We need a decision support system to choose among service alternatives, which have conflicting effects on different evaluation criteria

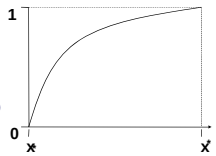
E – A decision support system

Effects of the alternatives



● Efficient alternatives ○ Dominated alternatives

Utility functions



Importance of the points of view

	W
cr.1	w_1
cr.2	w_2
⋮	⋮
cr.i	w_i
⋮	⋮

Scores of the alternatives (ranking)

$$V(k) = \sum_i w_i \cdot v_i\left(g_i(k)\right)$$

1, ...,k, ...,n alternatives
1, ..., i, ...,m criteria

E - Actors of DRT services

The organization involves ***actors*** with their own ***objectives***:

- USERS → **quality** of service (e.g. Level of service, LoS)
- MANAGERS → fleet **rationalization** (plant and operating costs)
- URB. PLANNERS → territorial **coverage** and scheduling

E - Simulation of the service

Level of service	n° buses	accepted requests		refused requests	
		n°	%	n°	%
SPT (current) quality	3	192	96%	8	4%
Better quality	4	194	97%	6	3%

Current SPT service

2 buses with 64 seats on CC4
2 buses with 40 seats on CC5

~~4 buses~~

3 buses with 15 seats

Outline

- Service planning (design)

  A possible scheme for the design procedure exemplified with a case study: a service in a hilly area in Como during Sundays and holidays

- Service management

  An example of software for the management of the service

A possible scheme for **planning**

Demand analysis
Survey (revealed and stated pref., o/d matrix, ..)

Network
Time-dependent graph

Input

Fleet
n° of buses, vehicles capacity, schedule

Service quality bonds
Max waiting time, Level of Service, ...

Decision variables

Users
booking, online call

Estimated scenarios

Algorithms
routing and scheduling

Simulation

Objectives of the design process
- covering (% served users)
- quality (wait time or travel time)
- costs (n° and schedule of the buses, bus*km)

Solution choice

A possible scheme for **management**

Network
Time-dependent graph

Service quality bonds
Max waiting time, Level of Service, ...

Fleet
n° of buses, vehicles capacity, schedule

Input

Users
Bookings trough the website or the call center

Real requests

Fleet
bus to serve each user, schedule of the pick-ups and deliveries, routes

Decision variables

Algorithms
routing and scheduling

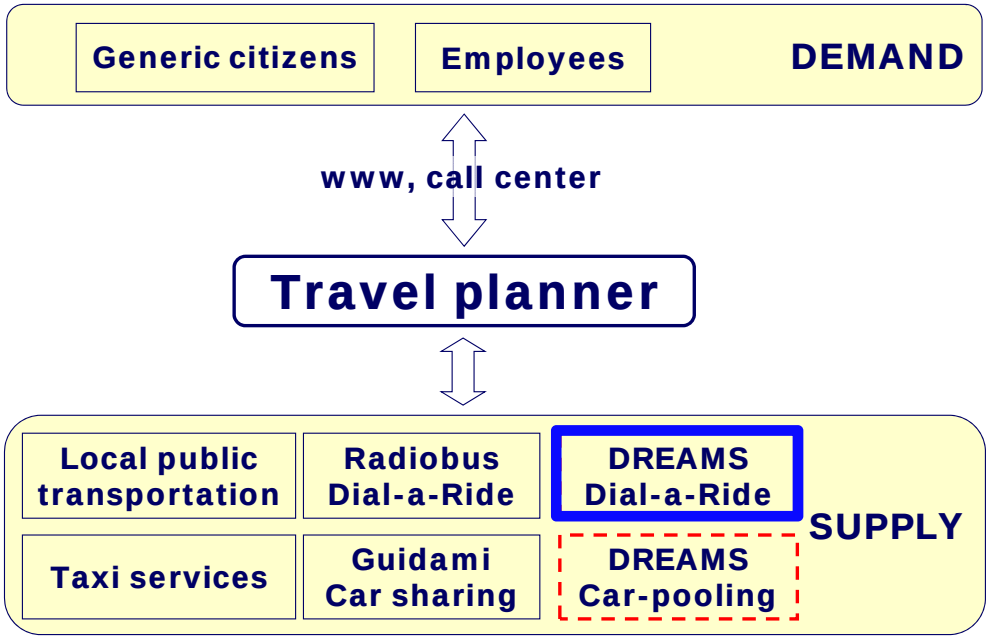
Compute the solution

Evaluation elements:
- covering (% served users)
- quality (wait time or travel time)
- costs (n° and schedule of the buses, bus*km)

Monitoring parameters

A sw example: the DREAMS project

An integrated information and management system for traditional and demand-responsive mobility services in the city of Milan



Financed by the Italian Ministry of the Environment and by the Municipality of Milan.

The travel planner request

origin

day and time

destination

The travel planner output

Available services

Cost

Travel time

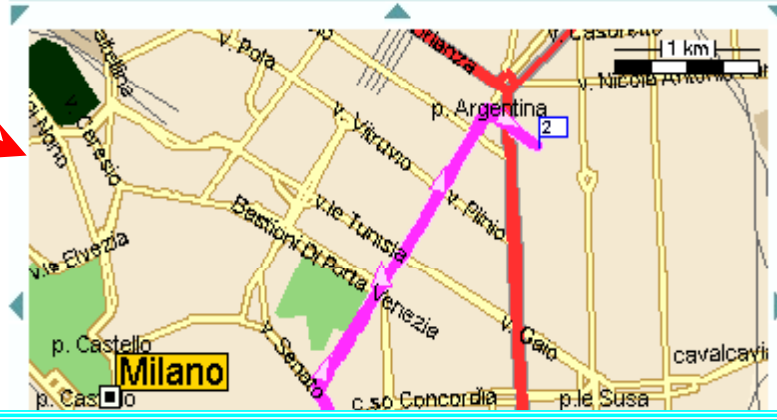
Route with the private car

Servizio	Tempo	Costi	
Auto Privata	17-20'	3-4 €	Vai
Taxi	16-17'	6-7 €	
Trasporto pubblico urbano	17-22'	1 €	Vai
Servizio a chiamata DREAMS	17-40'	3 €	Prenota

Servizi svolti in orari o data diversi da quelli richiesti:

Servizio	Tempo	Costi	
RADIOBUS	16-25'	2,5 €	Vai

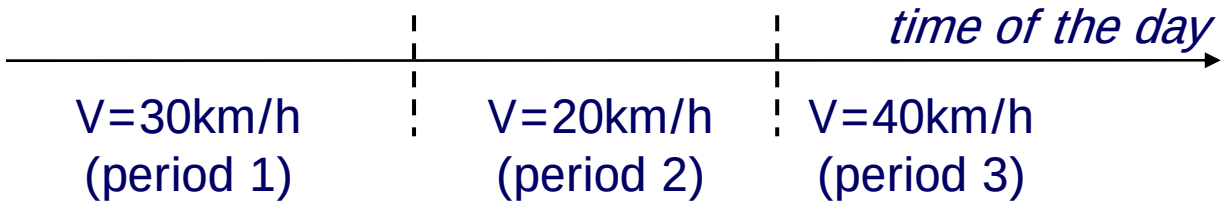
Dove sei:



Time-dependent network model

Different levels of congestion during the day

Modeling time-dependent speed on a link

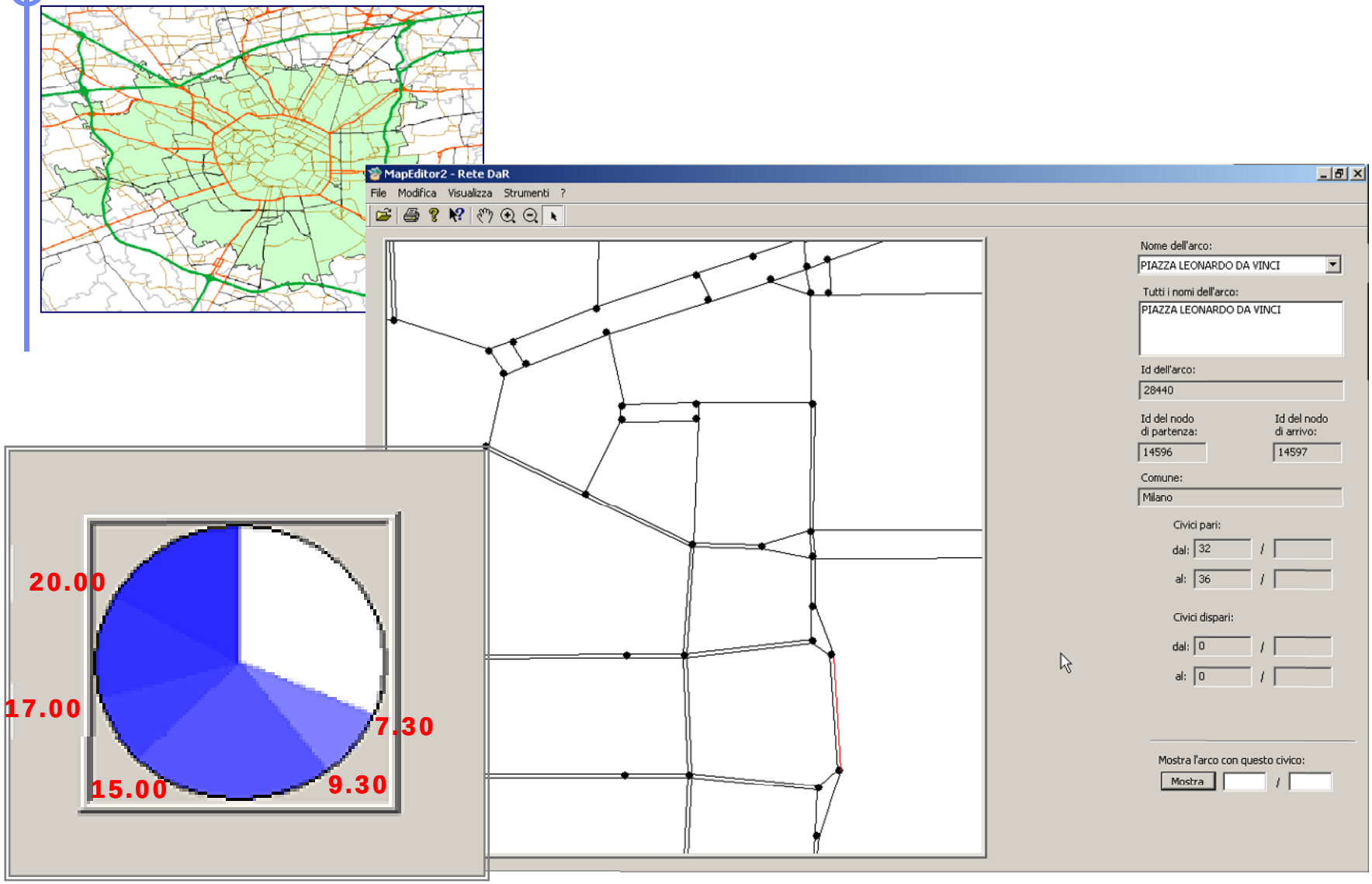


In the software, time-dependency can be assigned as follows

- Free assignment
  - The speed of each link is modified directly for each period (small network), or
  - A database already calibrated, for instance, by the mobility agency of the city is imported.

- Proportional assignment
  1. A parameter is associated to each period
  2. The speed of each link is multiplied for that parameter and a factor that depends on the class of the link (small road, highway, ...)

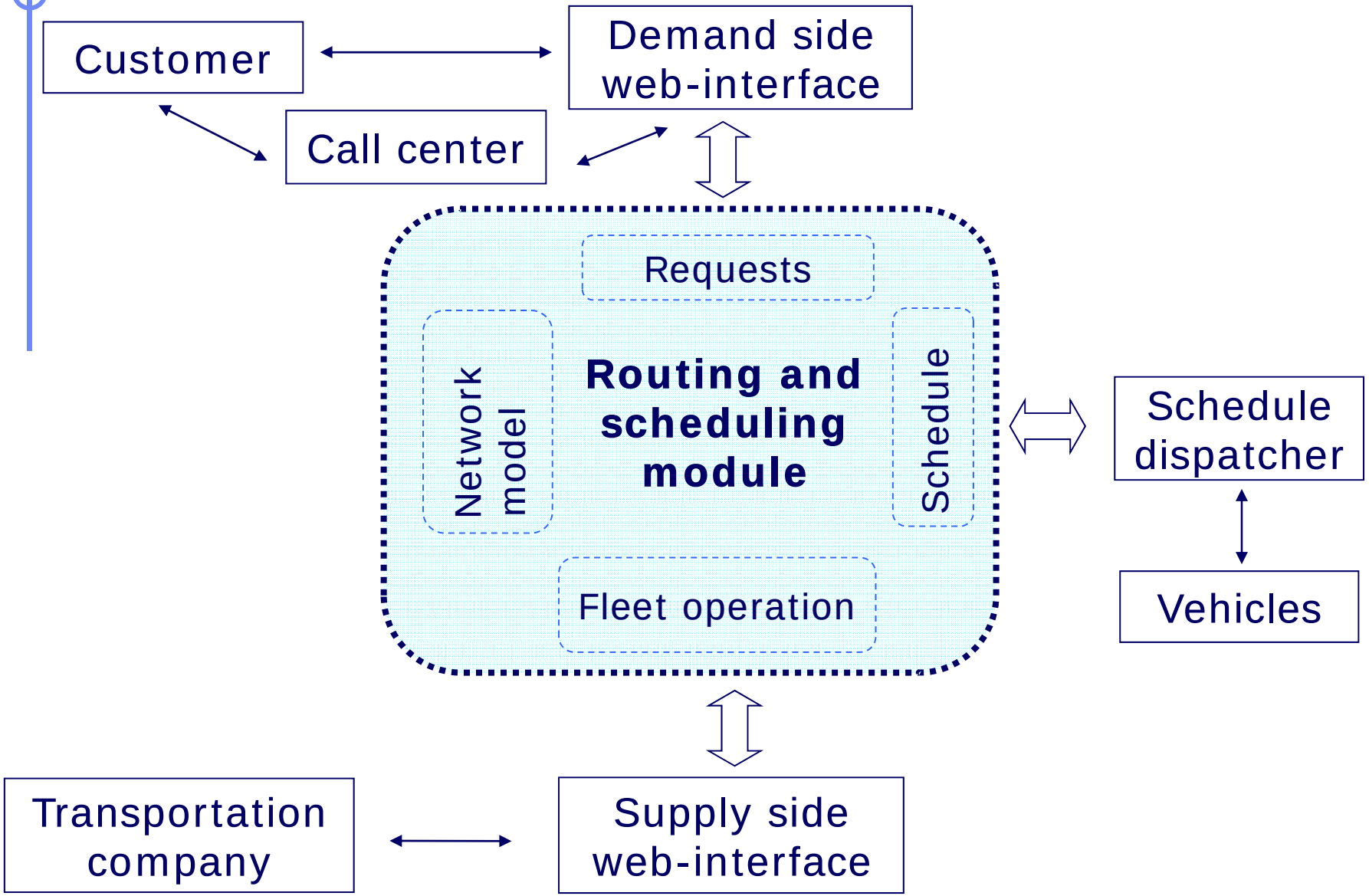
The network editor



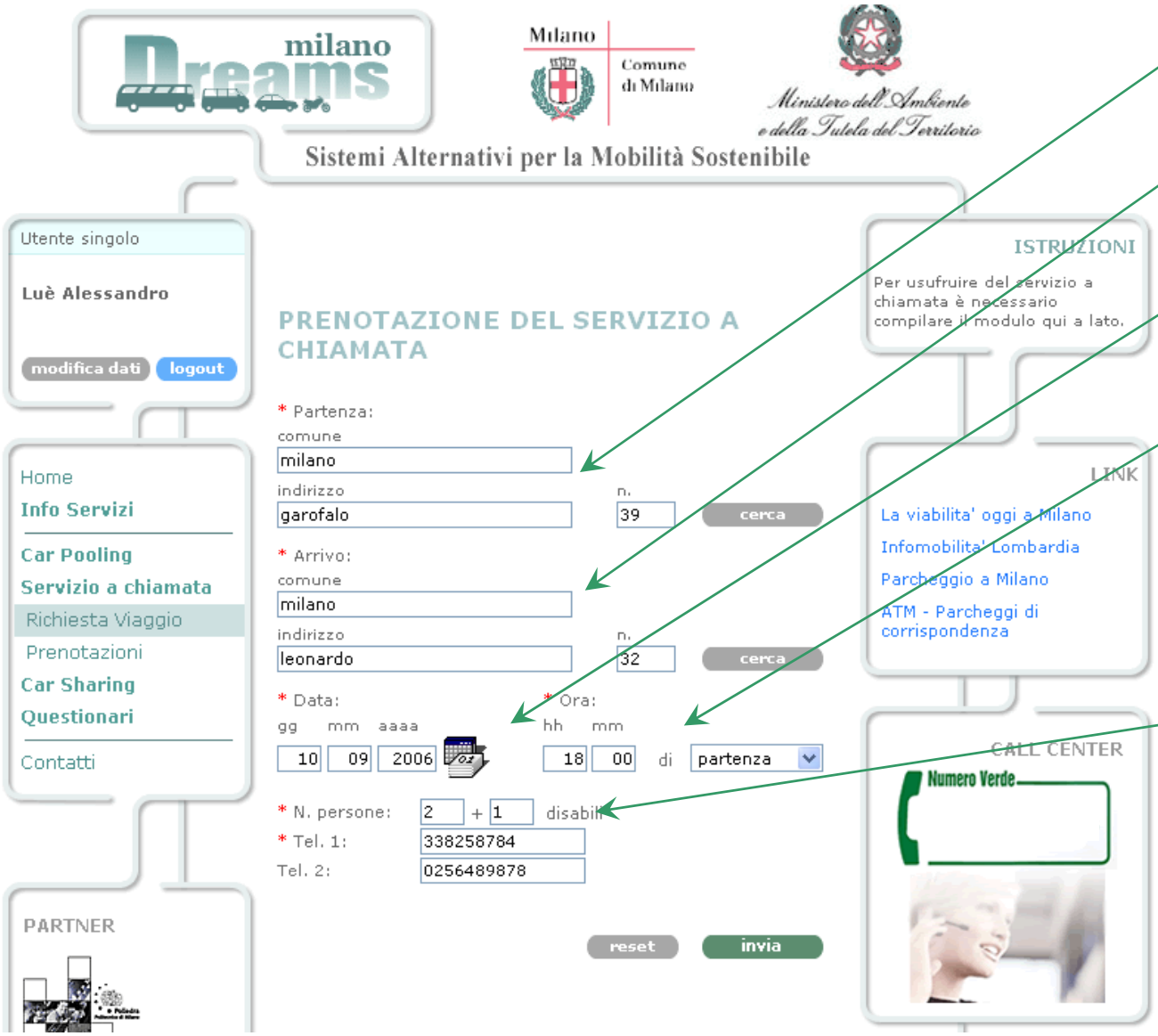
The DREAMS Dial-a-Ride

- A web-based software that manages:
  - off-line as well as on-line passenger requests;
  - several transportation companies;
  - several territorial areas;
  - different categories of users (students, disabled, elderly, ...).
- Users
  - the customers → *trip requests*
  - the companies → *fleet operations*
  - the mobility agency → *planning and monitoring*

DaR - The architecture



DaR - The reservation



origin

destination

day

earliest departure time OR latest arrival time

number of people

Characteristics of service requests

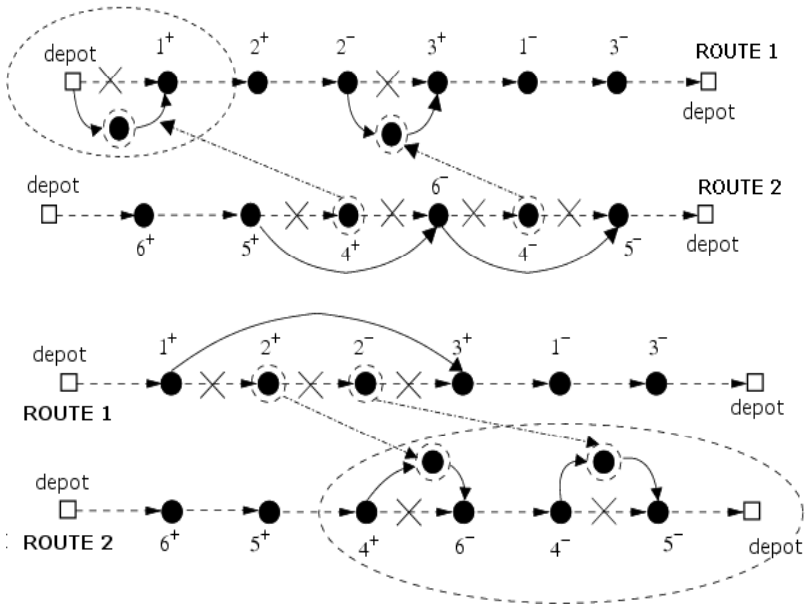
- The service requests can be performed:
  - before the start of the service (**offline problem**)
  - during the service (**online problem**)
- The requests performed by phone or on the website need an answer (acceptation or negotiation) during the same call:

  we need an **insertion algorithm** very fast (< 1 minute)

Algorithms review

Vehicle routing and scheduling problems are *NP-hard* (=no one knows a good way to solve them optimally):

- Exact algorithms cannot deal with large problems
- Heuristic methods required
  - Simple heuristics: constructive or improvement methods
  - Metaheuristics: genetic algorithms, ant systems, neural networks, simulated & deterministic annealing, tabu search



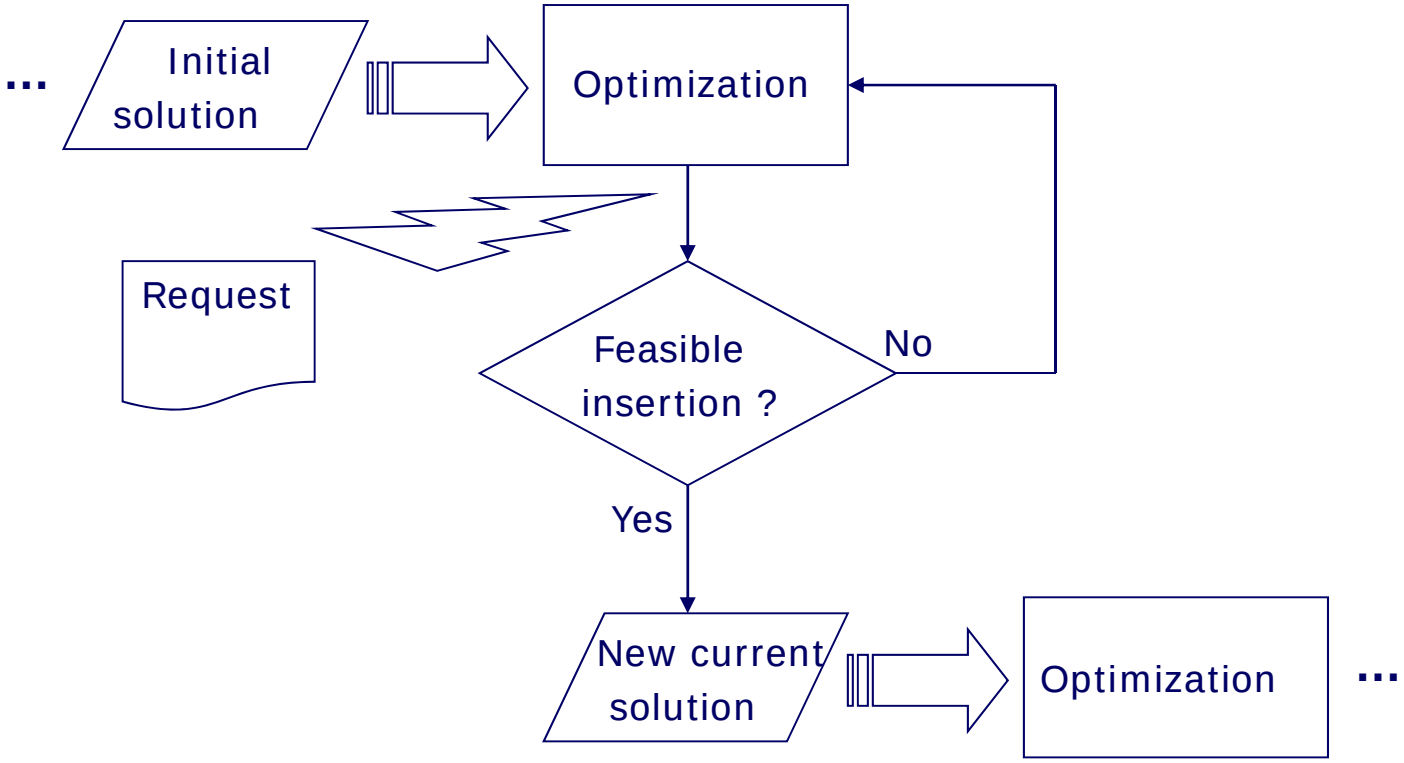
The tail node request 4 of arc (4,2) is moved to the route of the head node request 2

The head node request 2 of arc (4,2) is moved to the route of the tail node request 4

Realized algorithm structure

Off-line algorithm

On-line algorithm



The algorithm

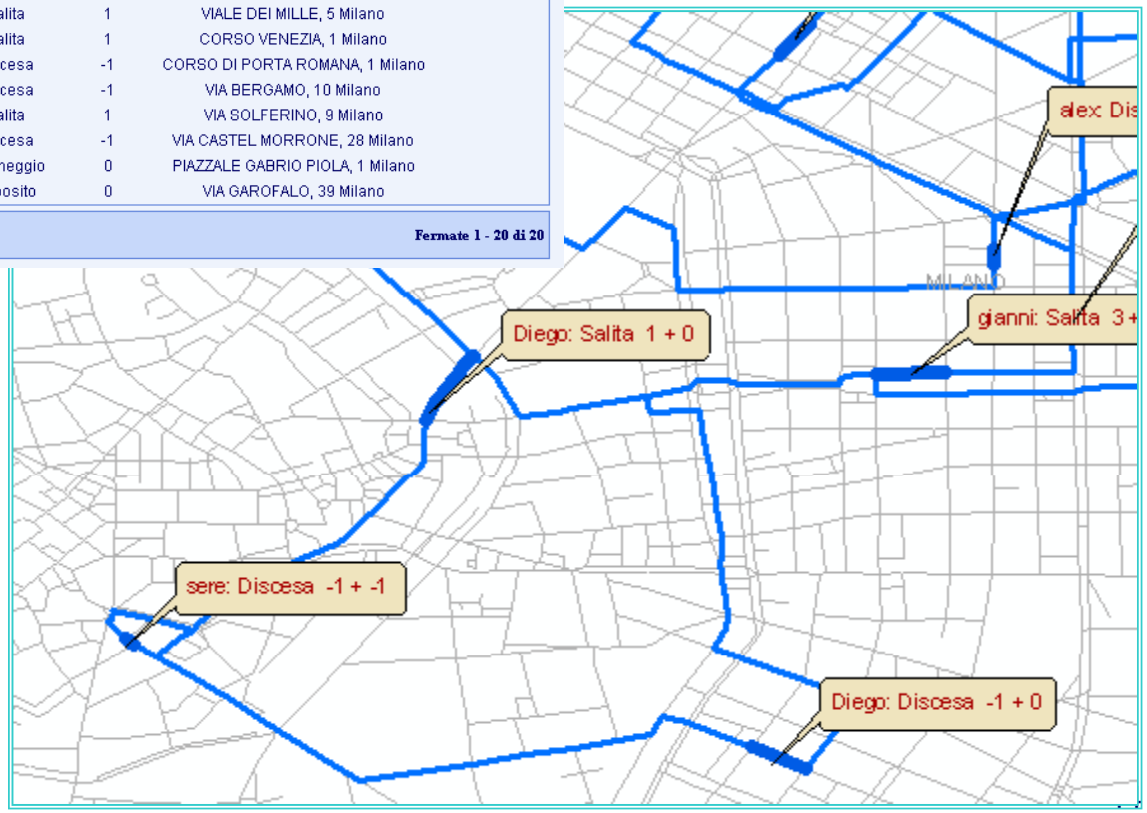
- Insertion (first solution)
  - Insertion of the new customer's request in the first feasible position, between the already booked requests
  - Answer to the customer in a few seconds
- Optimization of the insertion
  - Improvement of the solution, without modifying the positions of the booked requests
  - Objective function: max the level of service and min the number of vehicles
  - If a new request is made, the optimization stops and lets the new request to be inserted before continuing
- Post-optimization
  - In the idle time, the system optimizes the schedule of all the inserted requests, using a meta-heuristic

DaR - The vehicle schedule

ID Prenotazione	Username	T. Minimo	T. Effettivo	T. Massimo	Operazione	Passeggeri Caricati	Indirizzo
		08:00	**10:02**	**08:00**	**Deposito**	**0**	**VIA GAROFALO, 39 Milano**
		10:02	10:14	10:49	Parcheggio	0	VIA GAROFALO, 39 Milano
3287	alex	10:55	10:54	10:55	Salita	2	VIA GAETANO STRAMBIO, 5 Milano
3231	andreaD	11:00	11:06	11:00	Salita	1	VIA GAROFALO, 39 Milano
3231	andreaD	11:04	11:11	11:04	Discesa	-1	CORSO BUENOS AIRES, 28 Milano
3287	alex	11:05	11:28	11:05	Discesa	-2	PIAZZA LIMA, 1 Milano
3228	ale	11:09	11:29	11:09	Salita	1	VIALE GRAN SASSO, 1 Milano
3247	AlbertoC	11:11	11:31	11:11	Salita	1	PIAZZALE GABRIO PIOLA, 1 Milano
3230	gianni	11:17	11:37	11:17	Salita	3	CORSO INDIPENDENZA, 5 Milano
3247	AlbertoC	11:22	11:41	11:22	Discesa	-1	PIAZZALE PAOLO GORINI, 5 Milano
3228	ale	11:24	11:44	11:24	Discesa	-1	VIA GAETANO STRAMBIO, 5 Milano
3230	gianni	11:29	11:47	11:30	Discesa	-3	VIA VITRUVIO, 20 Milano
3242	sere	11:34	11:51	11:34	Salita	1	VIALE DEI MILLE, 5 Milano
3244	Diego	11:38	11:54	11:40	Salita	1	CORSO VENEZIA, 1 Milano
3242	sere	11:41	11:57	11:43	Discesa	-1	CORSO DI PORTA ROMANA, 1 Milano
3244	Diego	11:47	12:00	11:49	Discesa	-1	VIA BERGAMO, 10 Milano
3251	alex	11:57	12:02	11:58	Salita	1	VIA SOLFERINO, 9 Milano
3251	alex	12:05	12:10	12:15	Discesa	-1	VIA CASTEL MORRONE, 28 Milano
		12:14	12:15	22:58	Parcheggio	0	PIAZZALE GABRIO PIOLA, 1 Milano
		23:00	14:52	23:00	Deposito	0	VIA GAROFALO, 39 Milano

Refresh

Fermate 1 - 20 di 20

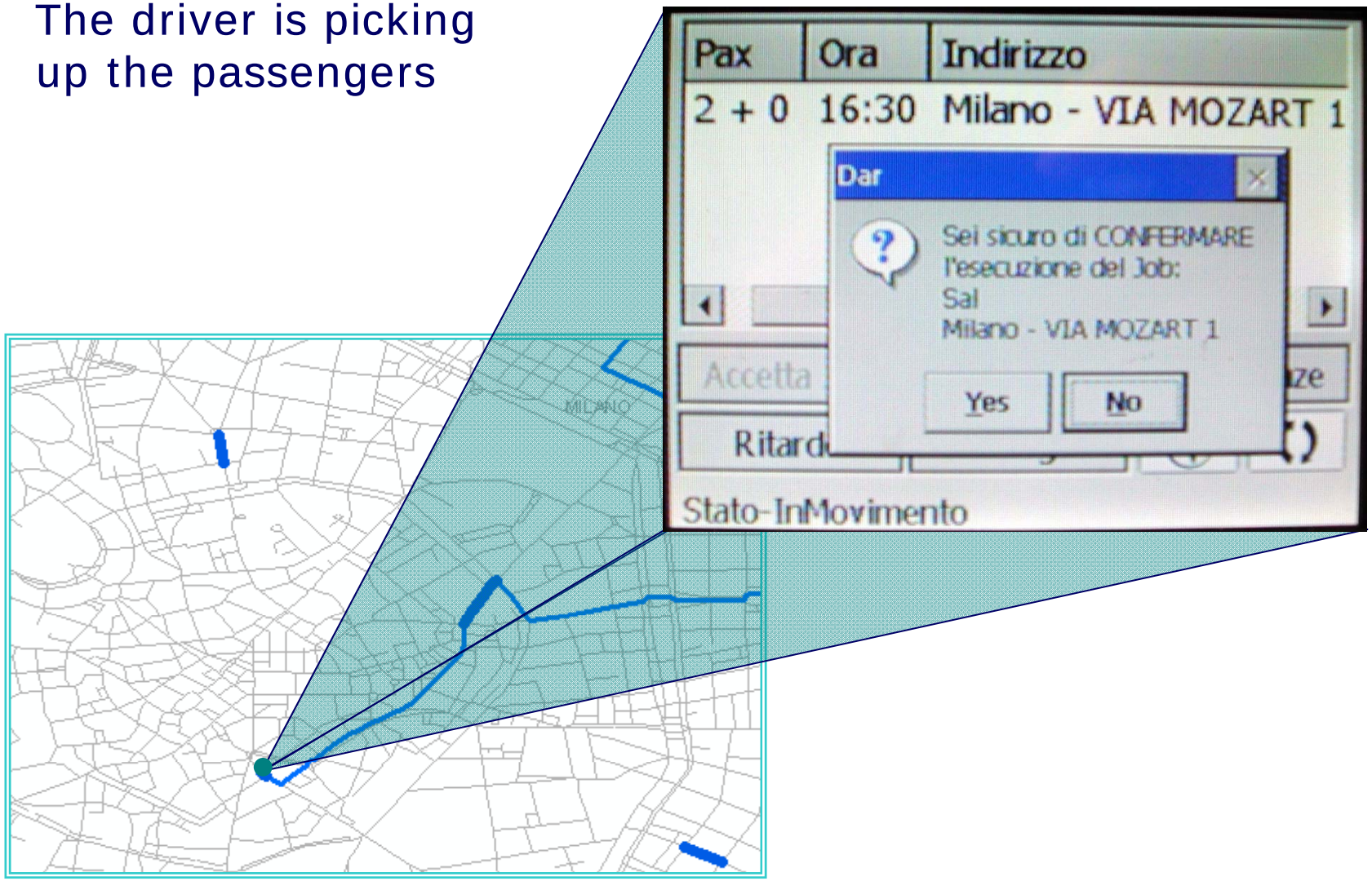


DaR - The communication (1)

The driver receives a pick-up job

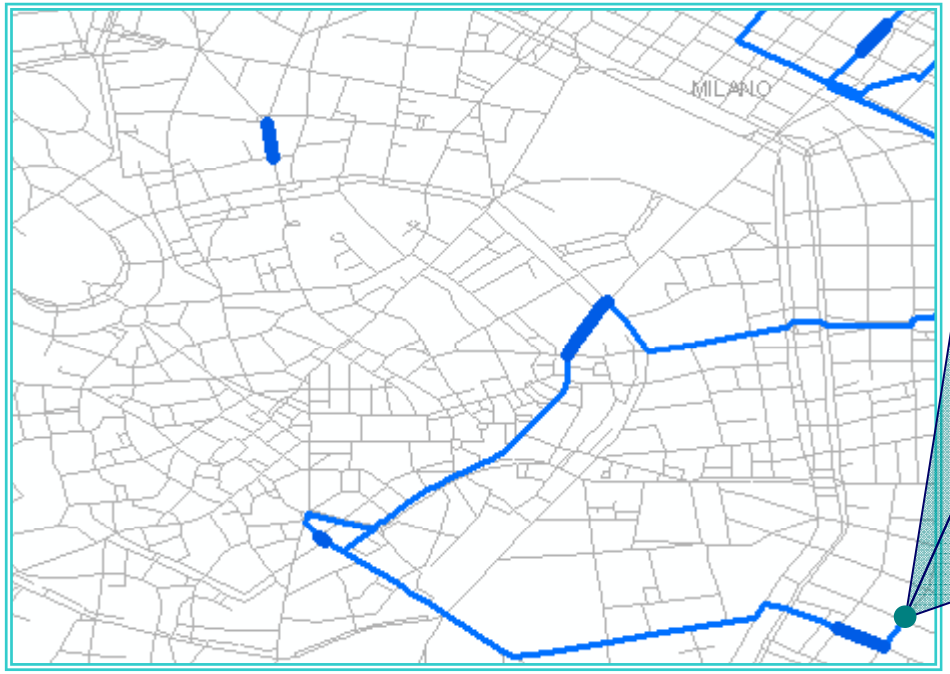
DaR - The communication (2)

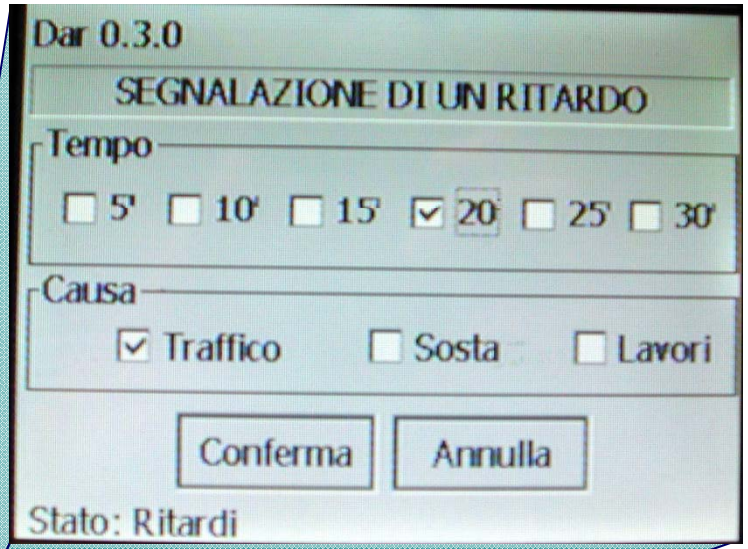
The driver is picking up the passengers



DaR - The communication (3)

The driver communicates that he is 20 minutes late, due to traffic congestion





DaR - Statistics

Statistiche delle Flotte

Interrogazione Temporale

	GG	MM	AAAA				
dal	6	4	2006	dalle	0	:	0
al	6	4	2006	alle	23	:	59

☑ Tutto il Giorno

Calcola

Tipo Giorno

☑ Lunedì ☑ Sabato e Prefestivi
☑ Martedì ☑ Domenica
☑ Mercoledì ☑ Altri Festivi
☑ Giovedì
☑ Venerdì ☑ TUTTI

Bus	Fermate	Distanze	Pass. x Km	Utenti Serviti
bucaneve	**5**	**1,7179 Km**	**0,00 Km**	**0 + 0**
ciclamino	5	0 Km	0,00 Km	0 + 0
girasole	5	1,8019 Km	0,00 Km	0 + 0
iris	5	0 Km	0,00 Km	0 + 0
margherita	5	2,4616 Km	0,00 Km	0 + 0
orchidea	63	14,6902 Km	29,25 Km	26 + 3
primula	5	0,3924 Km	0,00 Km	0 + 0
rosa	57	21,6175 Km	40,85 Km	22 + 4
tulipano	63	15,7027 Km	45,60 Km	27 + 2
viola	5	0 Km	0,00 Km	0 + 0

Bus 1 - 10 di 10