Decomposition techniques for parking vehicles in depots

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PROBLEM DESCRIPTION

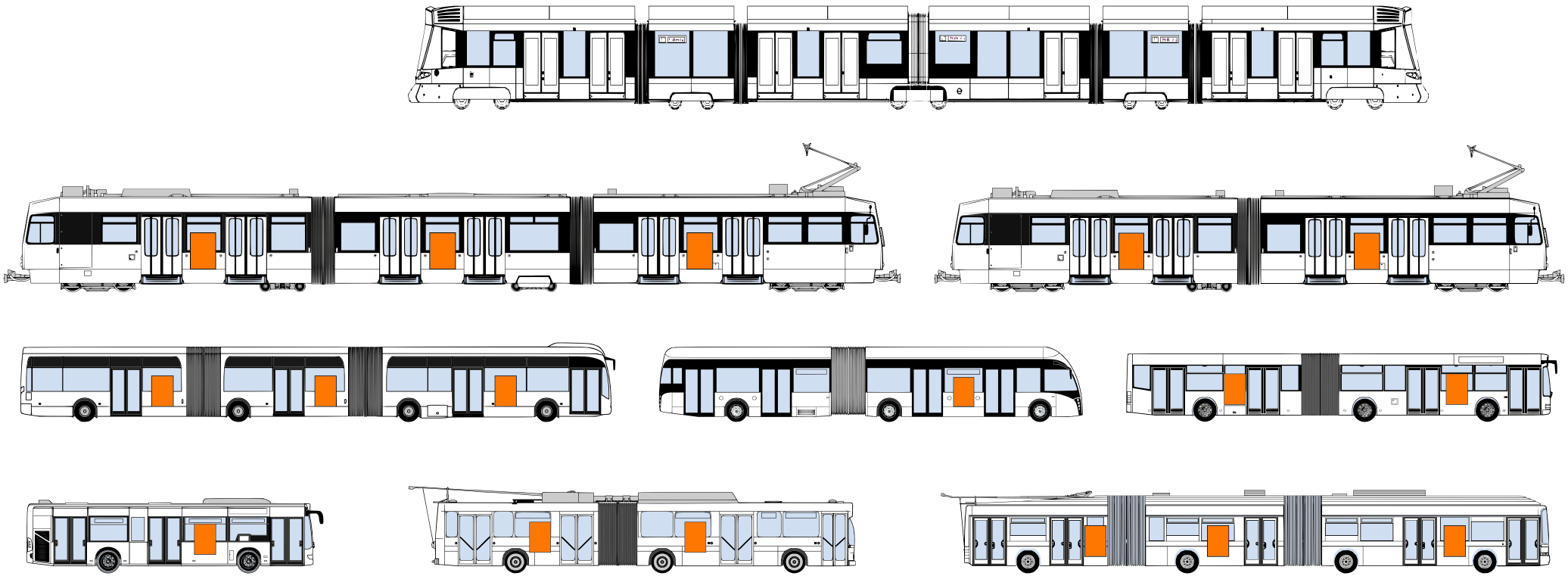
Find a position of each vehicle in the depots of a public transportation company

Vehicles are placed on lanes

Knowing the departure hour of each vehicle, be sure that each vehicle can leave the depot easily

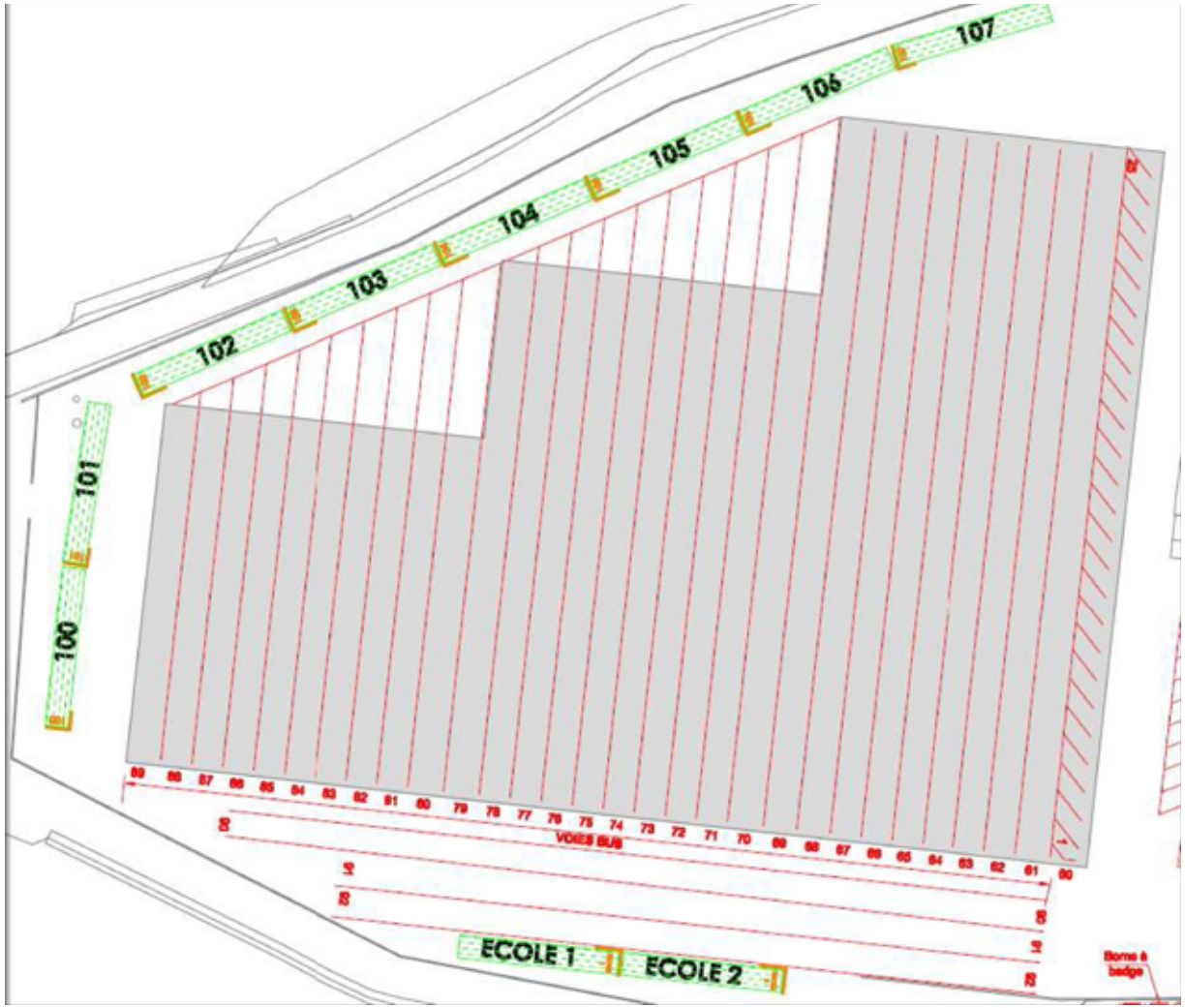
Looks like a bin-packing

The total length of vehicles parked on a lane must not be higher than the length of the lane



But…

LENGTH OF PARKING LANES NOT IDENTICAL

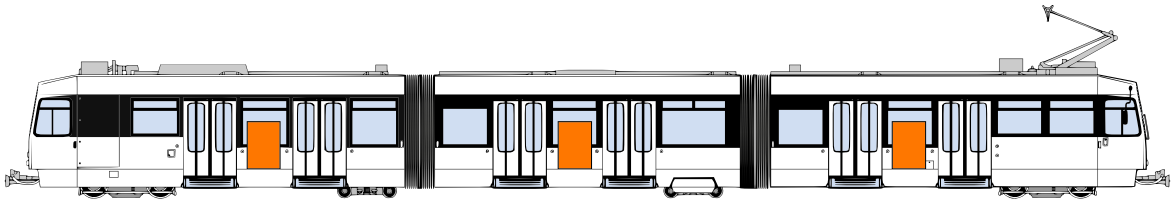


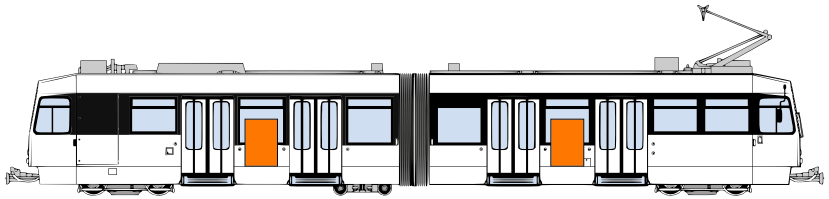
And few lanes may block all the depot

And…

SPECIALIZED EQUIPMENT FOR LANES

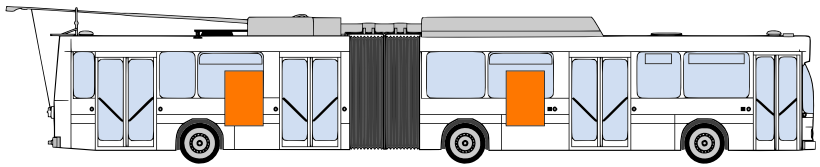
Tramway

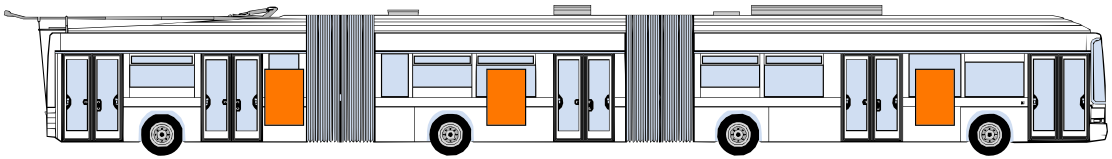




Tram-car can be placed only on rail

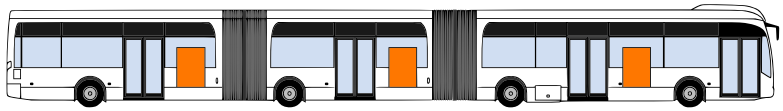
Trolley buses

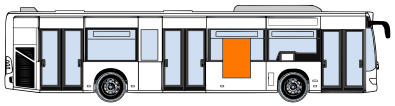


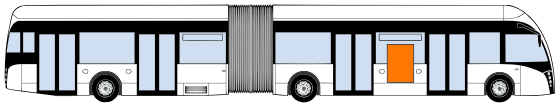


Must have electrical wire overhead

Buses







Can be parked everywhere

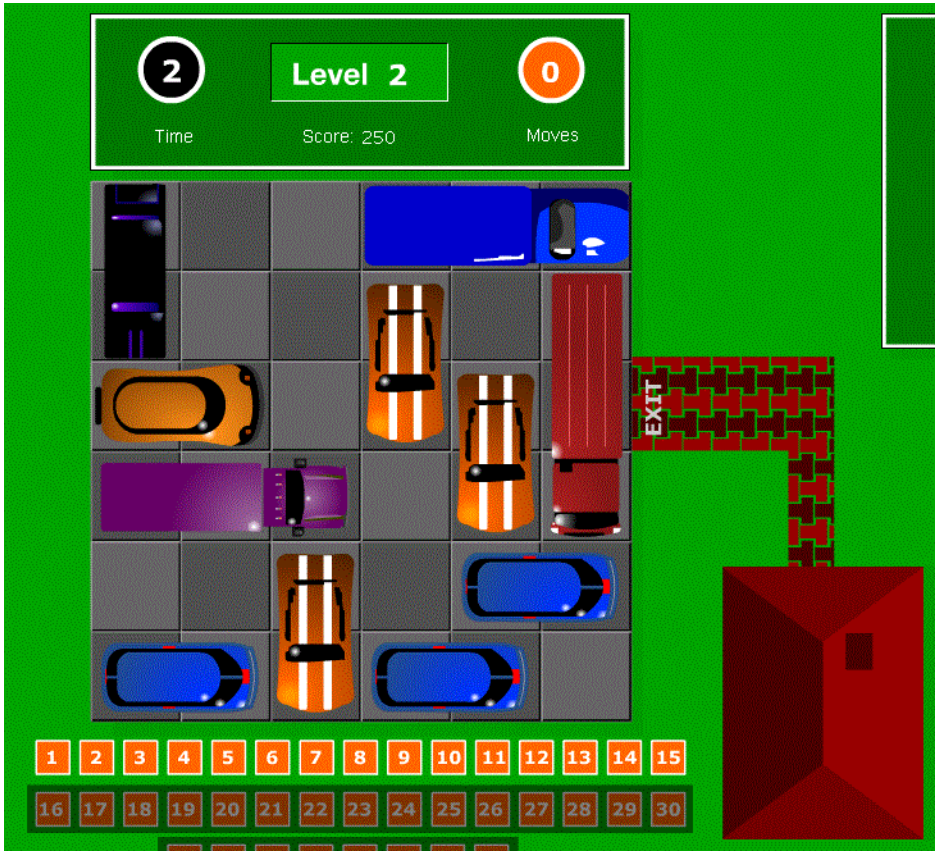
And…

FAVOUR NATURAL MOVES IN THE DEPOT

The departure hour of each vehicle is precisely known and must be respected

The return hour may fluctuate due to traffic conditions

Moving a vehicle not placed at the right place in the depot may be very complicated



There are vehicles that must stay in the depot for maintenance

PARKING THE VEHICLE AT THE RIGHT PLACE WHEN RETURNING TO THE DEPOT

Add a set of constraints :

Each lane must contains only a single type of vehicle

Not so easy to respect :

Exception for lanes blocking the depot

Sum of lanes length almost equal to the total vehicle lengths : about 8km

When arriving in the morning, the 400 drivers must find a vehicle of right type

Difficult if vehicle of a given type are spread over the depot

Add another set of constraints :

All vehicles of the same type must be placed on contiguous lanes

Not always possible

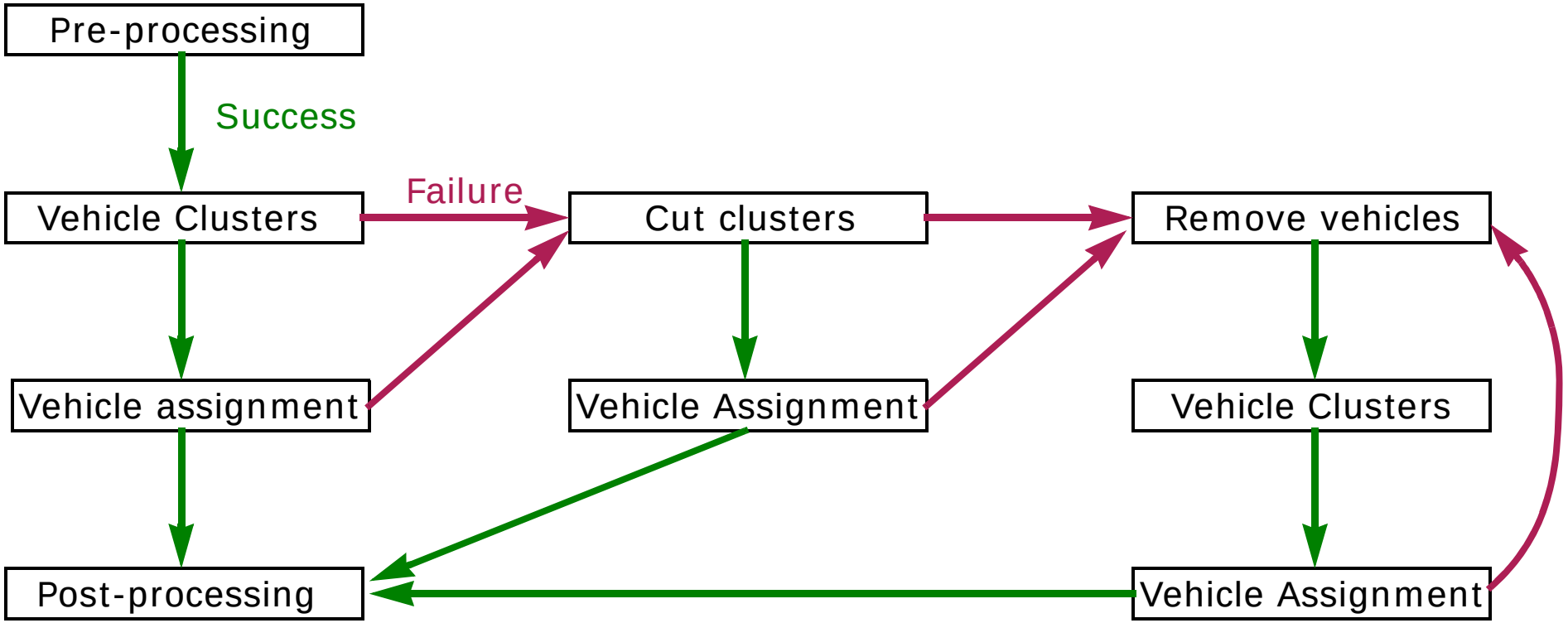
Objective functions

Maximize the number of free lanes

Minimize the distance of blocks of vehicles of a given type that are not contiguous

Minimize the sum of unused space in occupied lanes

GENERAL SOLVING METHOD



Pre-processing

Fill the lanes blocking the depot with the vehicles having earliest service time

A solution is always produced

Partially, in the worst case

First decomposition level

Make blocks of vehicles of a given type

Do not consider the departure hour of each vehicle (assigned in a second phase)

Consider the higher number of vehicles that must go outside the depots during a week

e.g. Monday morning

The other parking plans can be based on the blocks found for the busiest one

Vehicles not in service can be placed on « free » lanes

Solution method

Exact backtracking method

Variables: all possible positions for each block

Depth first search by fixing variables with fewer possible values first

Keep 10 solutions that maximize the number of free lanes (1. objective) and

minimize sum of unused space on lanes

If no feasible solution found: Create additional blocks by splitting largest blocks of vehicles

In any case: stop after a given CPU time

Second phase: vehicle assignment

First phase

Create blocks of lanes with same vehicle type

Second phase

Assign departure hour to each vehicle

Additional constraints

Minimal time interval for 2 vehicles leaving on the same lane

Avoid delay if a vehicle have a problem

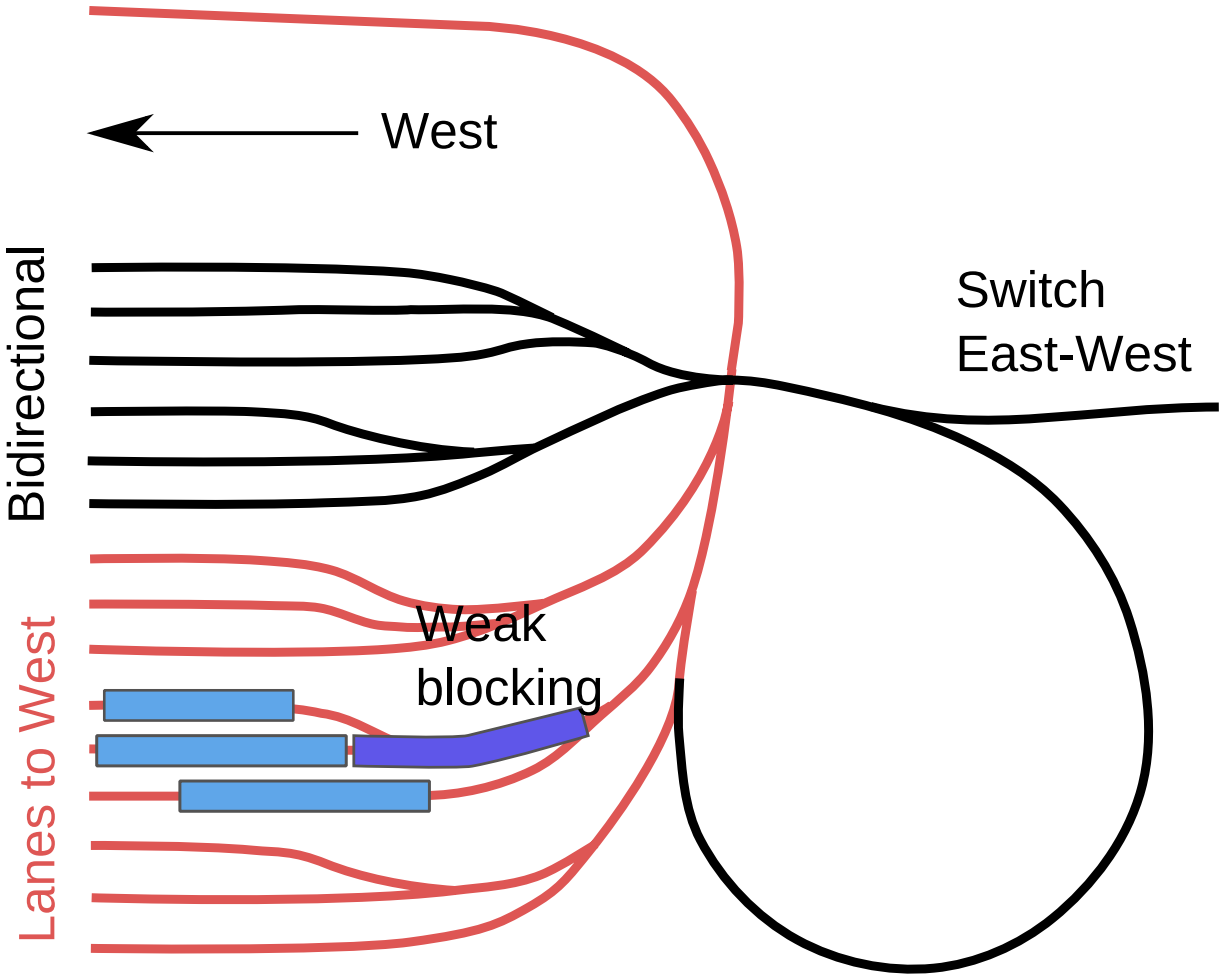
Maximal time interval for 2 vehicles leaving the same lane

Avoid to have lanes not empty while additional vehicles for rush hours return to the depot

And…

TOPOLOGICAL CONSTRAINTS

Tramway lanes are uni- or bi-directional



The trolley bus in the middle and in front of a group of 3 lanes must leave first

Mega-buses cannot be placed on every lanes

And…

ADDITIONAL CHARACTERISTICS

Different equipment for the same vehicle type

Video camera (required if the vehicle is in service after 22h)

Ticket distributor (required for few lines)

Different schedule (timetable) types

Additional service for rush hour

Return before 20h for cleaning

Objective function

First hierarchical objective :

Group vehicles by additional characteristics inside a block of the same type

Second objective :

Deviation from ideal departure time interval

SOLUTION METHODS FOR ASSIGNMENT

Enumeration with backtracking

Takes topological constraints into account

Depth first search always find a solution, if any

Stopped if computational time too high

Tabu search

Only invoked in case of backtrack abortion

In practice, for improving over second hierarchical objective

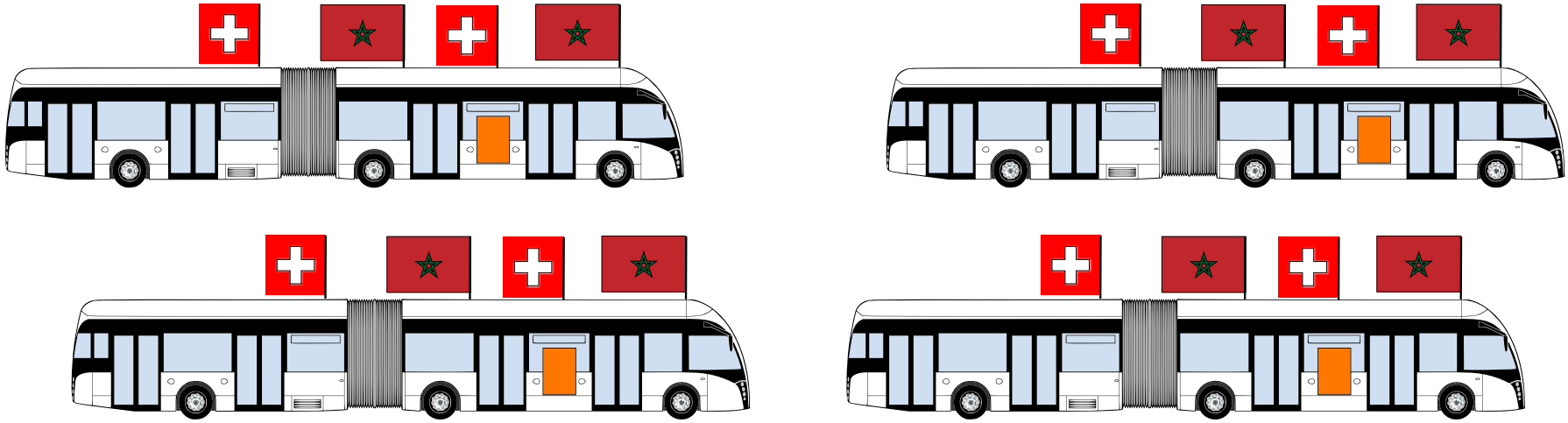
Neighbourhood :

- Exchange 2 schedules
- Only feasible solutions considered

Tabu list

- Prevent to exchange the same schedules for a fixed number of iterations
  - Guarantee that 2 executions lead to the same solution

Cluster in the depot vehicles servicing the international district



NUMERICAL RESULTS

None ! But…

Problem size

5 depots

155 lanes from 18m to 134m

6 different types of trolley buses (12m, 18m, 25m)

5 different types of buses (12m, 18m, 25m)

4 different types of tram-car (up to 53m)

11 parking plans for a week :

- Monday, Tuesday, Thursday (morning, noon, evening)
- Wednesday noon
- Friday evening

1750 schedules to handle for a week

450 schedules on morning for the working days

COMPANY USAGE

Building parking plans from scratch

Few times a year, build ideal parking plans :

- Each time the national railway timetables changes
- At the beginning of vacation periods (reduced service)

Everyday use

Modify ideal parking plans :

- Timetable modifications due to works on streets
- Additional services (sportive manifestations, school, ...)

Start as far as possible in the building process

Company satisfaction

Add additional constraints

Groups of 3 adjacent lanes must be freed before 8 in the morning

Create angle parking for the private vehicles of the employees