# Stability evaluation of a railway timetable at the station level

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# Presentation overview

- Railroad infrastructure operation planning
- RECIFE project
- Stability evaluation model
- Example of stability evaluation
- Conclusion

# Rail transport context

## Rail transport

- ❒ Interest revival as road alternative
- ❒ Competition with other transport modes

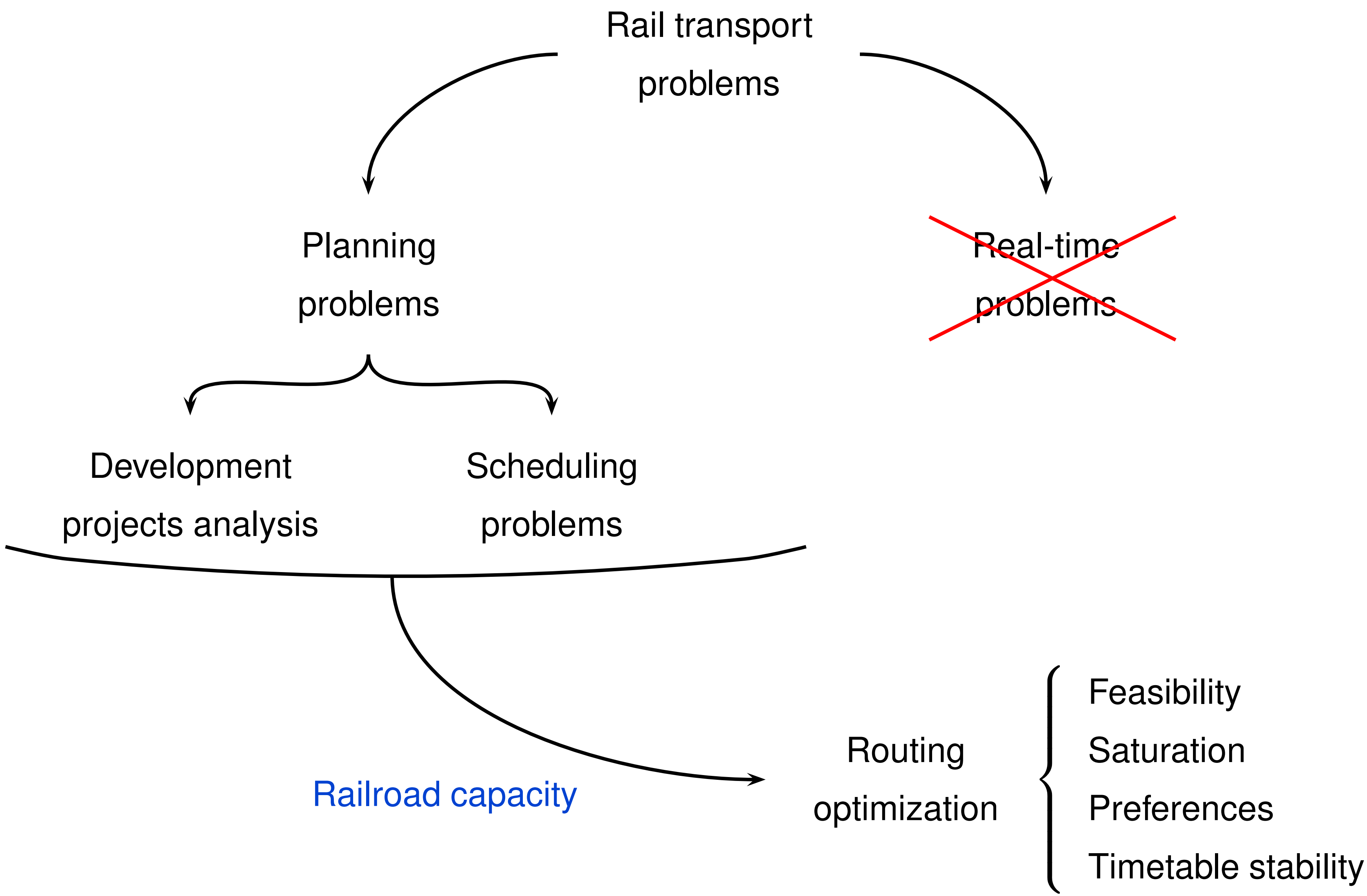
$\Rightarrow$ Traffic increase and evolution

## Tools are needed for

- ❒ evaluating networks limits
- ❒ studying modifications of the network
- ❒ determining a commercial strategy

How to plan railroad infrastructure operation ?

# *Main questions considered*



# Existing softwares

## Homogeneous zones (lines)

- ❒ Analytical methods [UIC, 1978]

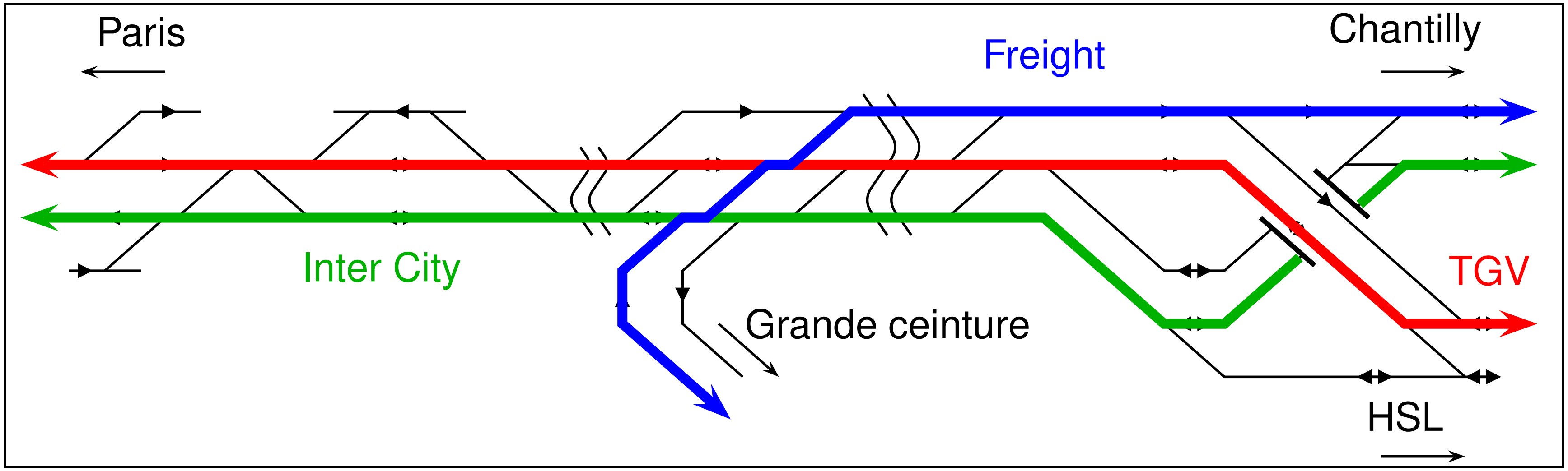
## Heterogeneous zones (junction, station, network)

- ❒ Simulation
- ❒ Constructive methods
  - DONS [van den Berg and Odijk, 1994]
  - CAPRES [Hachemane, 1997]
  - DÉMIURGE [Labouisse and Djellab, 2001]

$\Rightarrow$ mainly on network level

# *Railroad infrastructure capacity*

Given :




+ Safety rules
  Rolling stock technical characteristics
  Service quality

- ❐ How many trains can be routed through the junction within a time interval ?
- ❐ What is the best solution to route these trains ?

# RECIFE project

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# The RECIFE project

## Objective of RECIFE

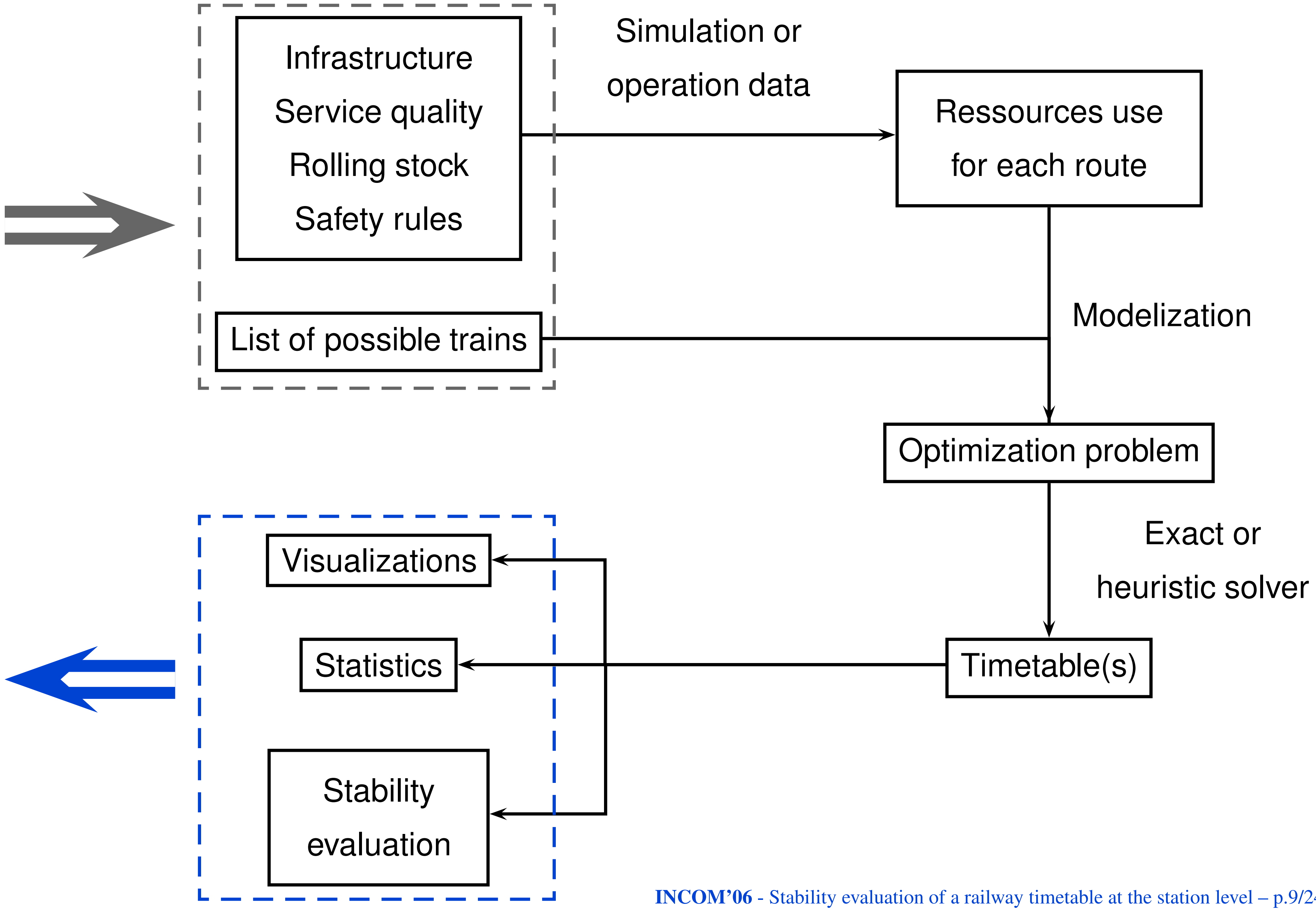
- ❒ Models to evaluate railroad infrastructure capacity of junction or station
- ❒ Solvers based on combinatorial optimization algorithms
- ❒ Application on Pierrefitte-Gonesse node and Lille-Flandres station

$\Rightarrow$ Decision support software

## Partners involved

- ❒ French institute on transport (INRETS)
- ❒ French railway society (SNCF)
- ❒ Ecole des mines de Saint-Etienne
- ❒ Nantes university
- ❒ Valenciennes university

# Global scheme of the RECIFE software



# *Model for capacity evaluation*

## Assumptions

- All possible routes are given
- All possible arrival-date are given

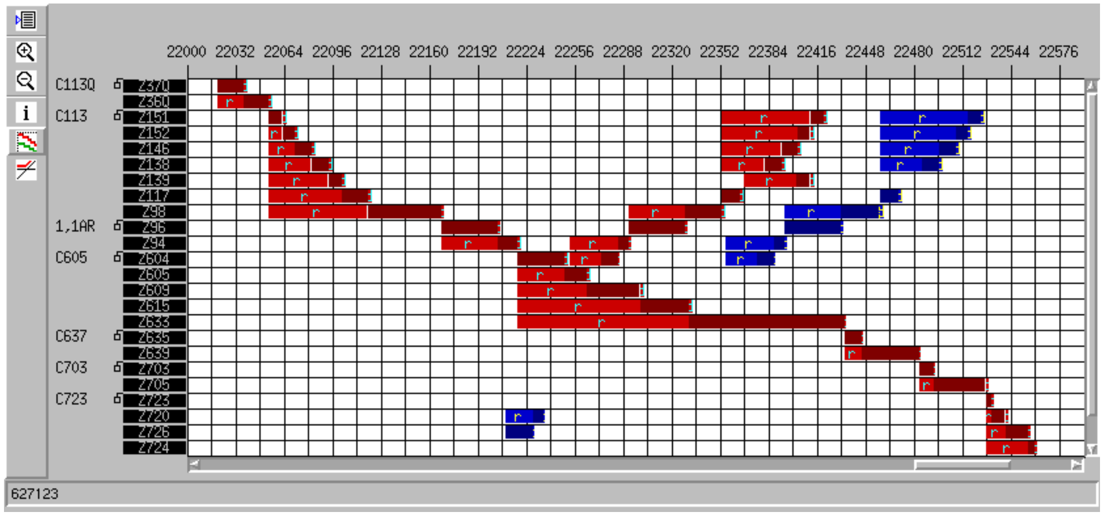
## Combinatorial optimization model [Delorme, 2003]

- multiobjective extension of STATIONS model [Zwaneveld et al, 1996]
- based on binary decision variables

$$x_{t,r,\delta} = \begin{cases} \text{1 if the train } t \text{ is assigned to the route } r \text{ on clear-line} \\ \qquad \text{with a delay } \delta \text{ on its arrival-date} \\ \text{0 otherwise} \end{cases}$$

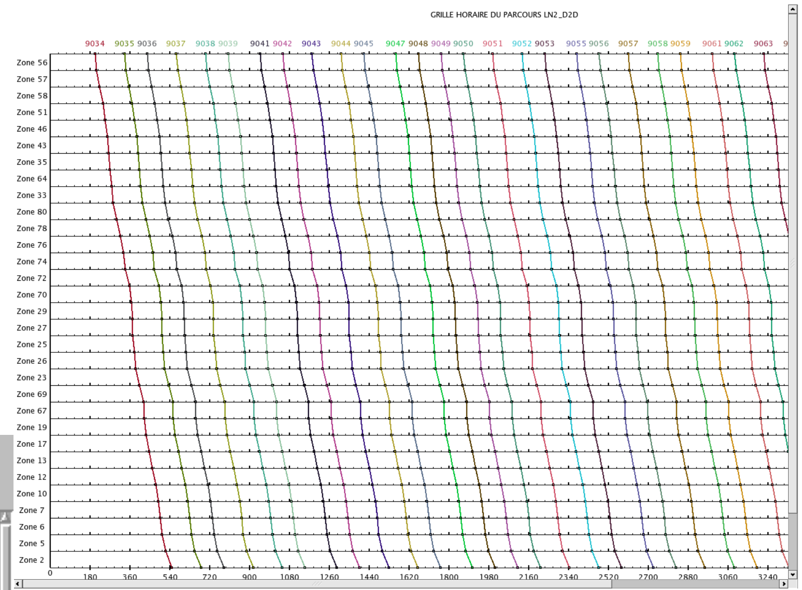
# Visualization of timetables

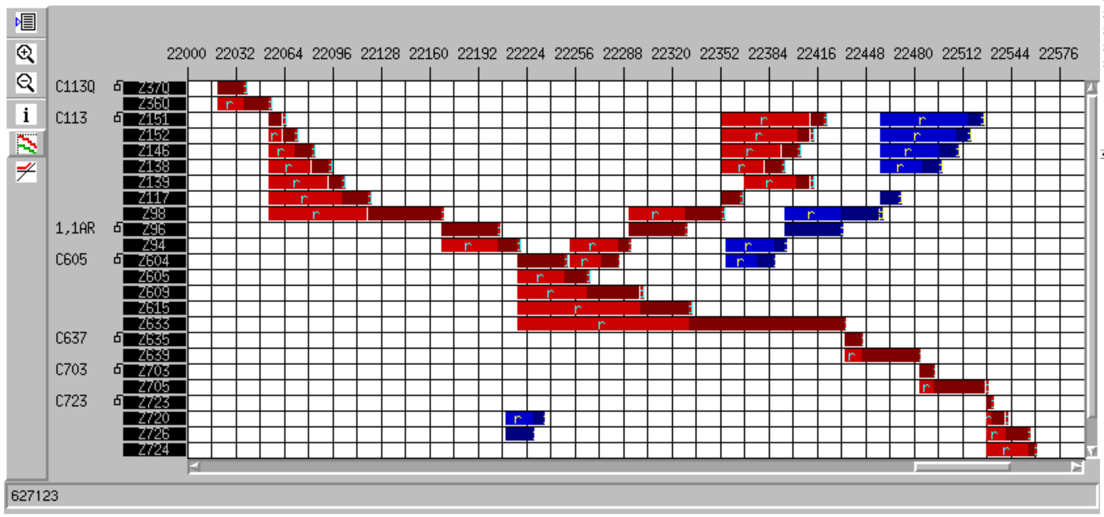
- Gantt chart



# Visualization of timetables

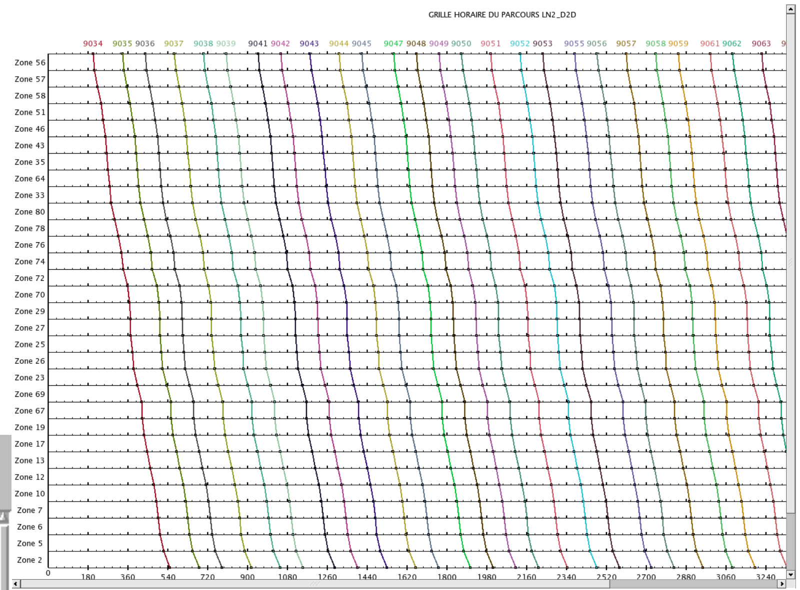
- Gantt chart
- Space-time diagram

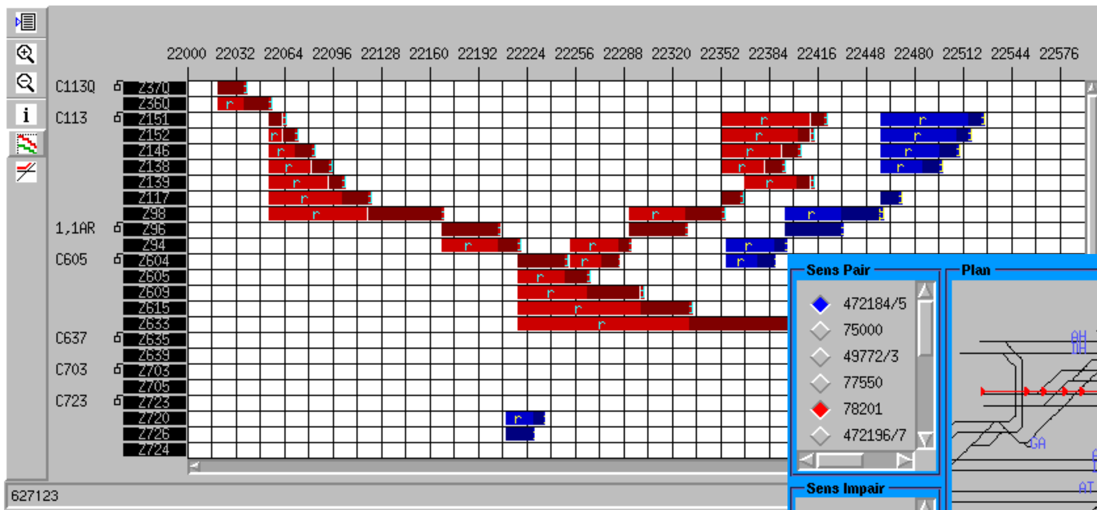


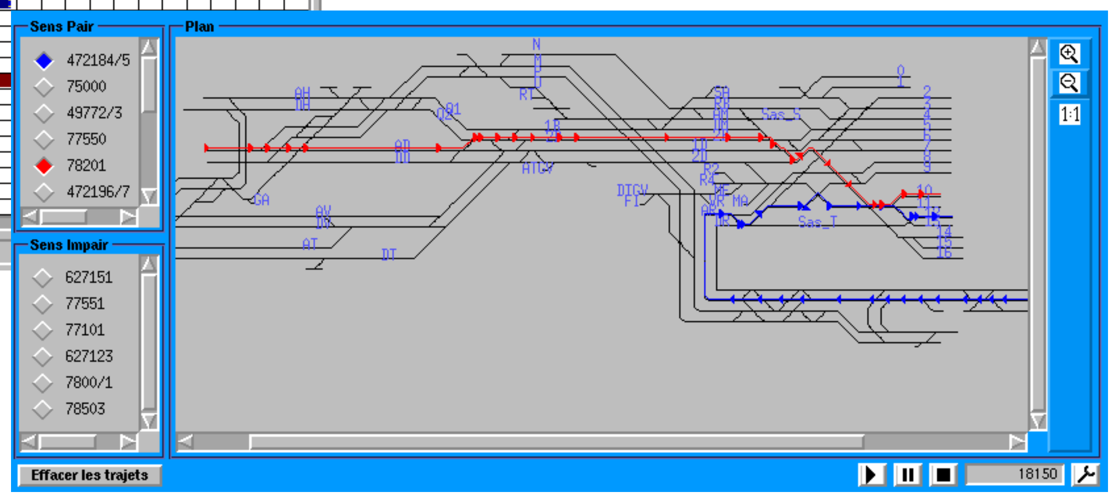



# *Visualization of timetables*

- Gantt chart
- Space-time diagram
- Tracks map
- Simulation



# Stability evaluation model

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# *Previous works on stability*

## Classic methods are based on :

- ❐ either Petri nets
- ❐ or Max-plus algebra

## Type of stability evaluation

- ❐ Recovering time for a cyclic timetable

  $\Rightarrow$ impossible if non-cyclic
- ❐ Time margin of the trains

  $\Rightarrow$ nearly null for saturated timetable

| New model based on delay propagation |
|---|

# Delay propagation

## 2 types of delay

- primary delay caused by a disruption
- secondary delay due to interactions between trains

## Impact of a primary delay

- secondary delays generated directly or indirectly

## How to prevent conflicts

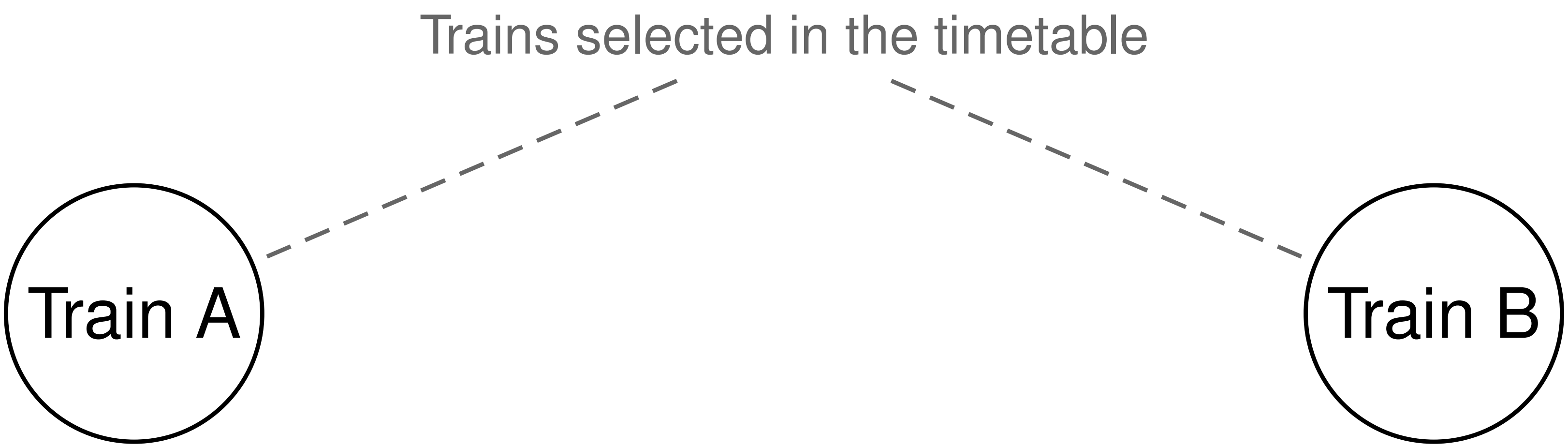
- delay of arrival-date of other trains
- Same routes and scheduling (no on-line Re-optimizing)

$\Rightarrow$ only short primary delay

# Graph of potential direct conflicts

Use of potential direct conflict

## Represented with a graph $G(V, E, w)$



# Graph of potential direct conflicts

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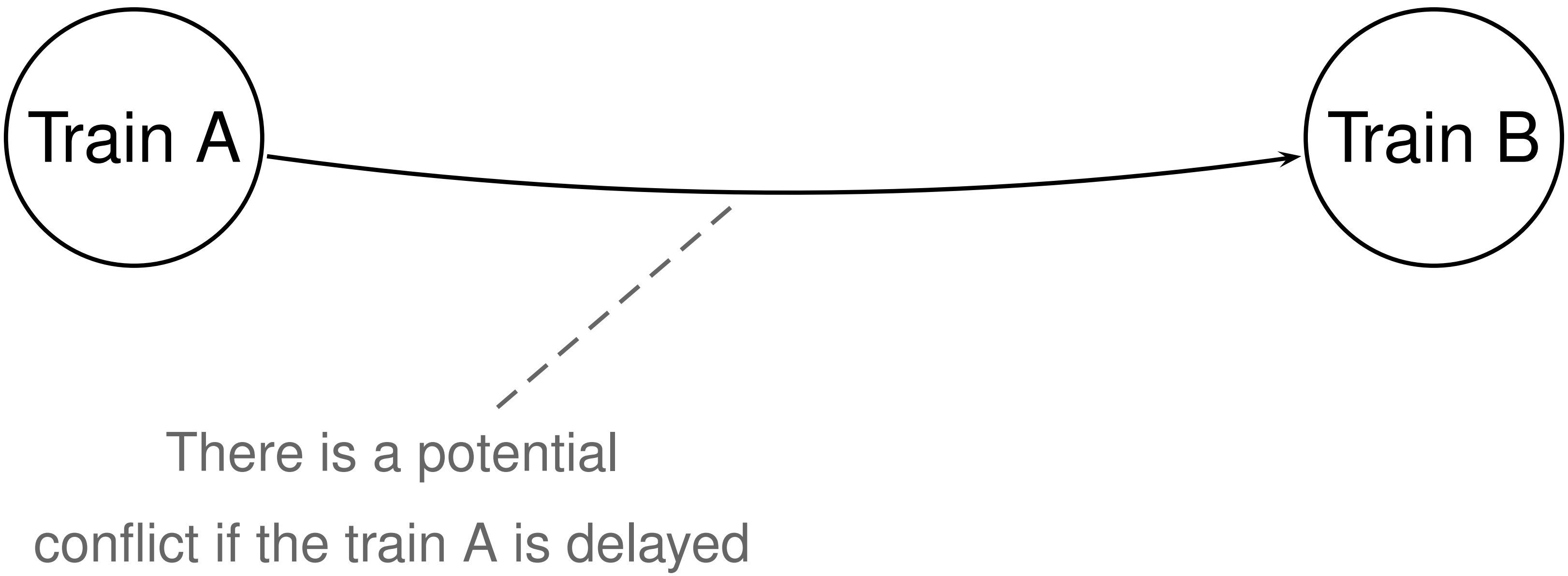

# Graph of potential direct conflicts

Use of potential direct conflict

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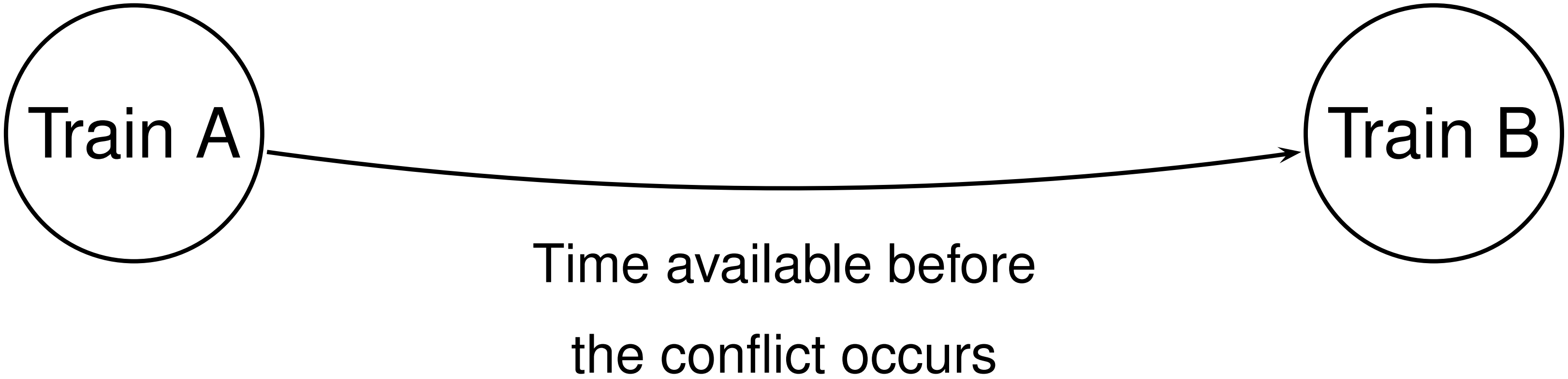


# Computation of stability evaluation

## Computation of the secondary delays generated

- Time margin between Train A and B = shortest path in $G(V, E, w)$
- Secondary delay generated by a primary delay of Train A on Train B =

$$\max(0,\ \text{Primary delay}(A) - \text{Shortest path}(A, B))$$

## Stability evaluation of a timetable

- Sum of all the secondary delays generated by each train
- Inspired by the know-how
- Importance of the primary delay

$\Rightarrow$ several values considered

# *Example of stability evaluation*

- ❒ Railroad infrastructure operation planning
- ❒ RECIFE project
- ❒ Stability evaluation model
- ❒ Example of stability evaluation
- ❒ Conclusion

# Description of the example

## Didactic instance on Pierrefitte-Gonesse node

- 6 possible trains considered
- 450s between the first and last arrival dates

## Optimization problem

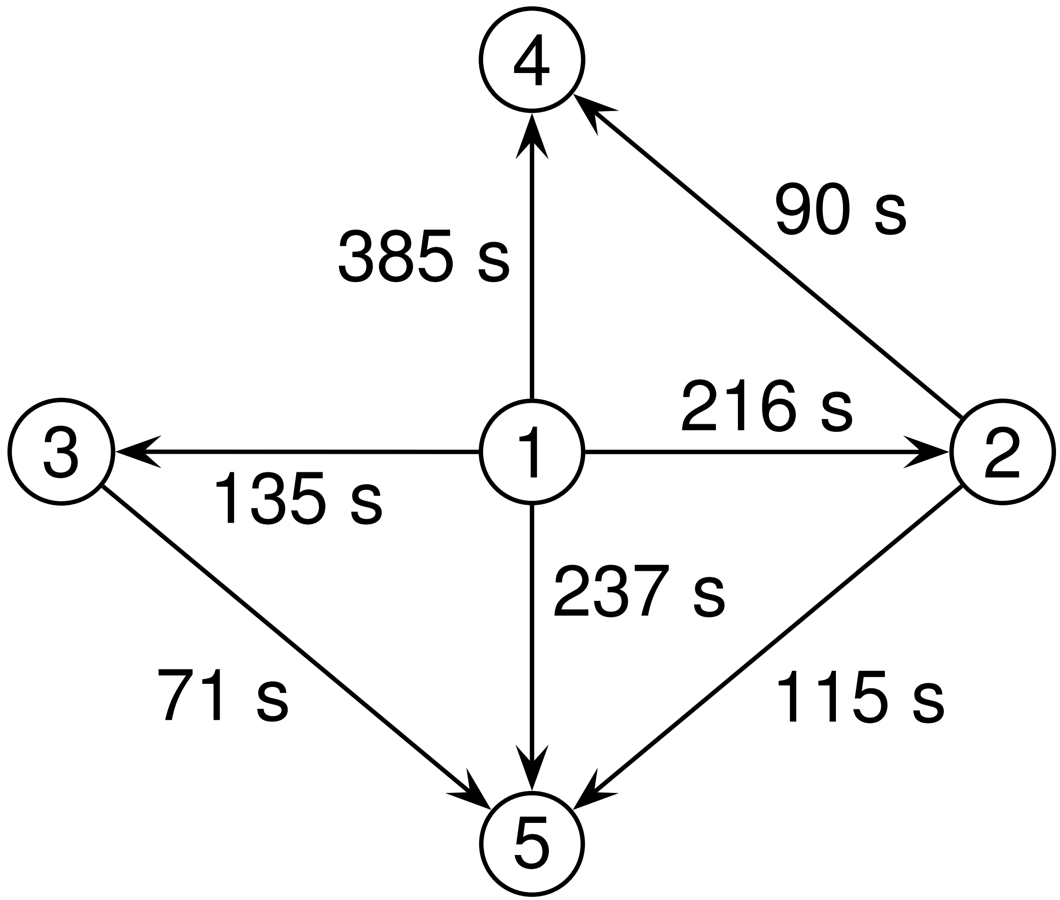
- Conflicts determined with SYSIFE simulator [Fontaine and Gauyacq, 2001]
- Heuristic solver GRASP [Delorme et al, 2004]

$$\Rightarrow \begin{cases} 5 \text{ trains routed (optimal solution)} \\ 15 \text{ different timetables generated} \end{cases}$$

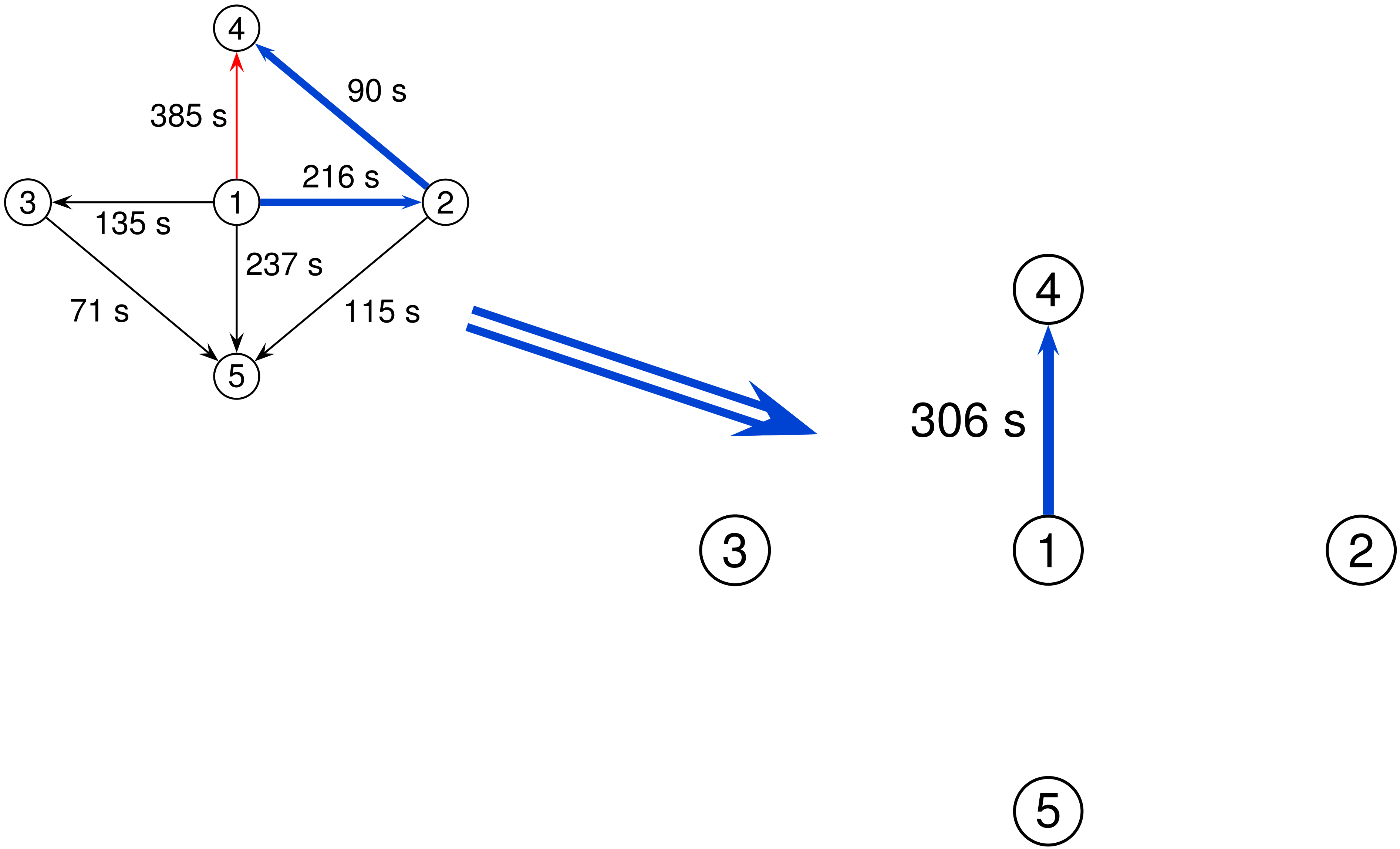
# Stability evaluation of one timetable

## One graph generated for each timetable

- Graph of potential direct conflicts :



# Shortest path computation



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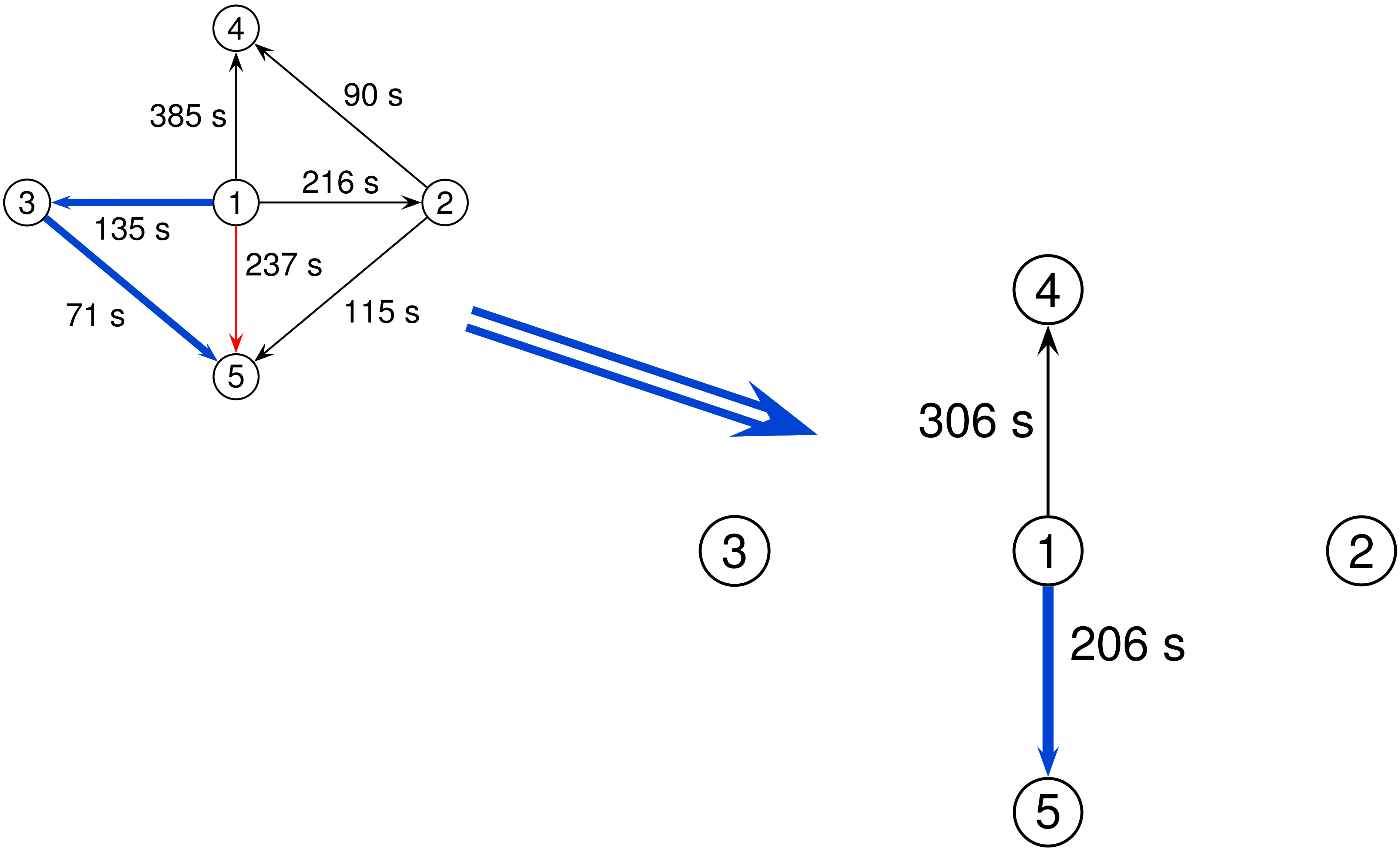
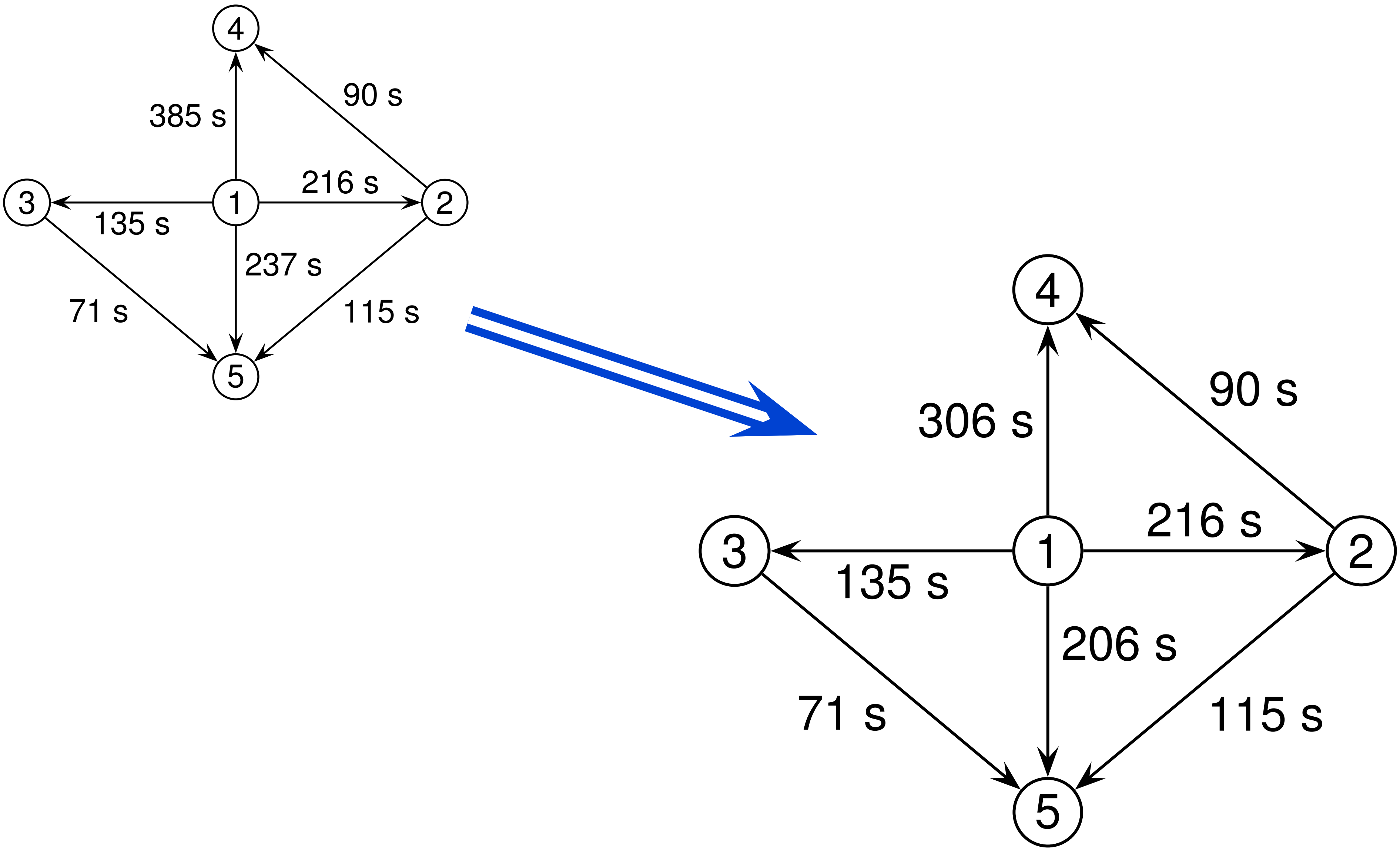


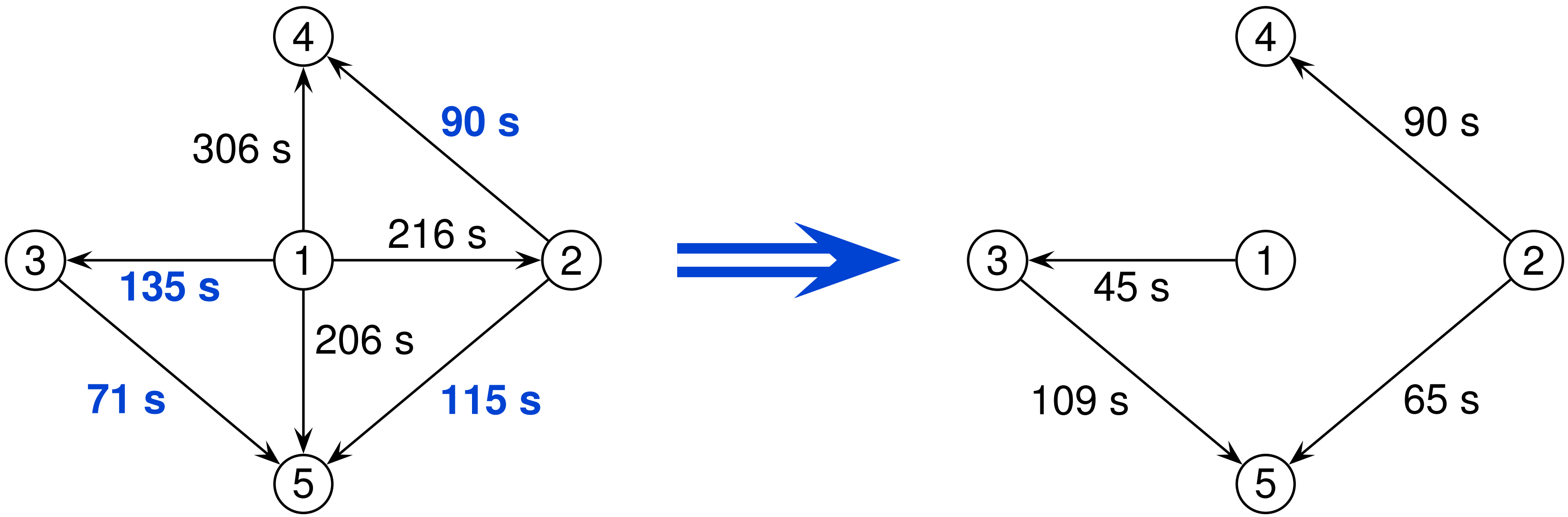
# Shortest path computation



# Resulting stability evaluation

## Secondary delays computation

- for a primary delay of 180 s




Total delay generated by train 1 : 45 s

Total delay generated by train 2 : 155 s

Total delay generated by train 3 : 109 s

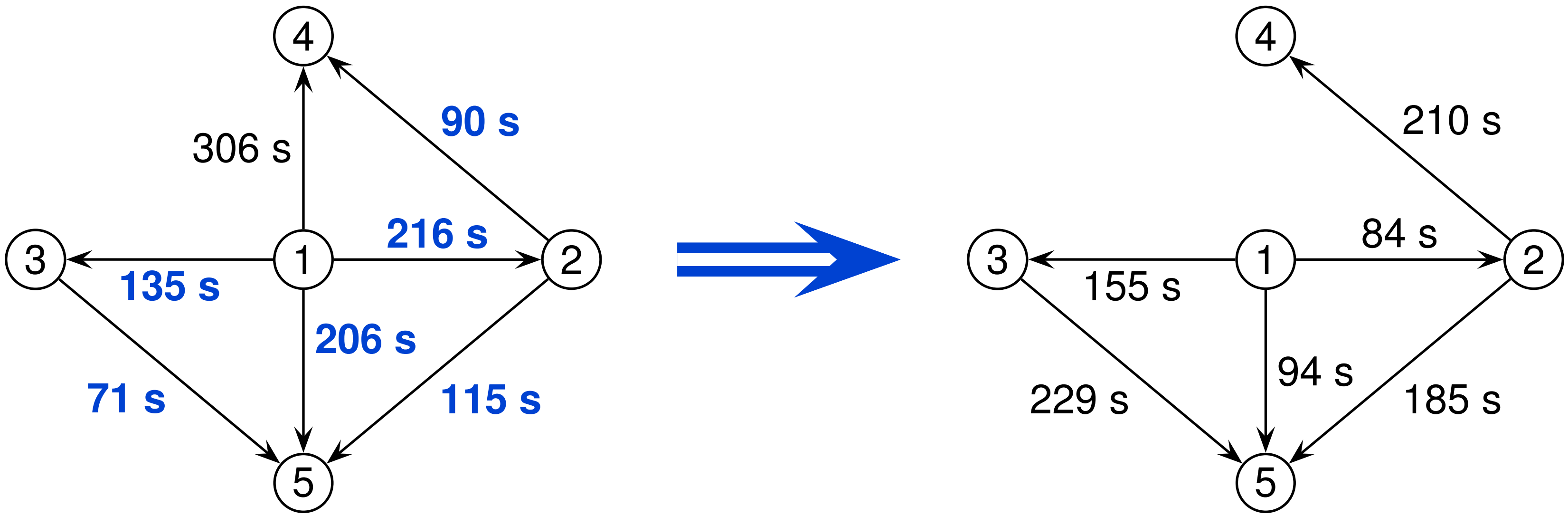
Total delay generated by train 4 and 5 : 0 s

**Stability evaluation = 309 s**

# Resulting stability evaluation

## Secondary delays computation

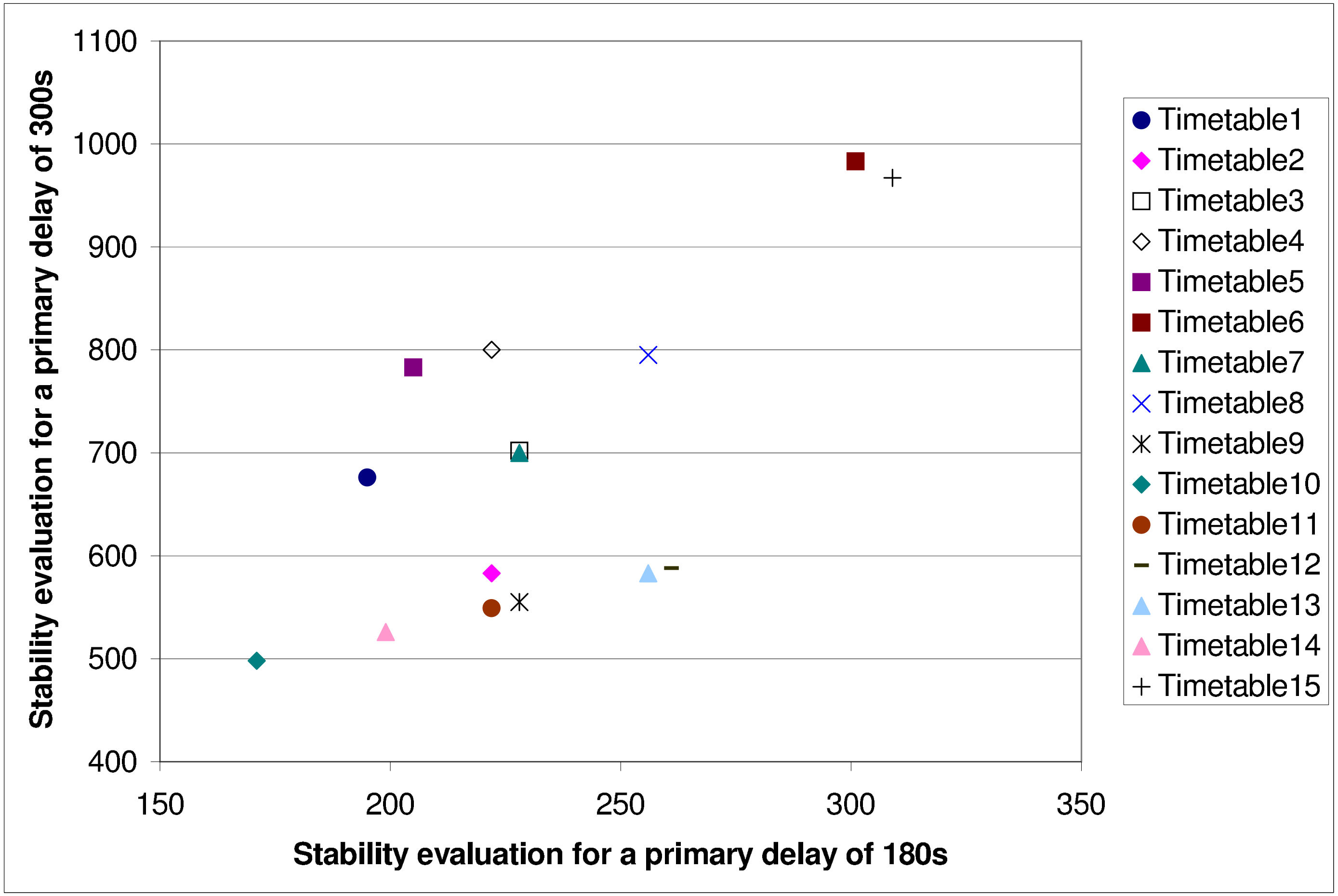
- for a primary delay of 180 s : 309 s
- for a primary delay of 300 s




| | | |
|---|---|---|
| Total delay generated by train 1 | : | 333 s |
| Total delay generated by train 2 | : | 395 s |
| Total delay generated by train 3 | : | 229 s |
| Total delay generated by train 4 and 5 | : | 0 s |
| | **Stability evaluation =** | **957 s** |

# Comparison of the timetables

## 2 stability evaluation for each timetable



# Conclusion

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# Conclusion

## A new model for stability evaluation

- railroad timetable of junction or station
- delay propagation method
- using shortest path computation

$\Rightarrow$ integrated in a decision support system for railroad capacity evaluation

## Future research works

- integratation of multi-criteria analysis
- stability optimization