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Maintenance integration in Railway networks

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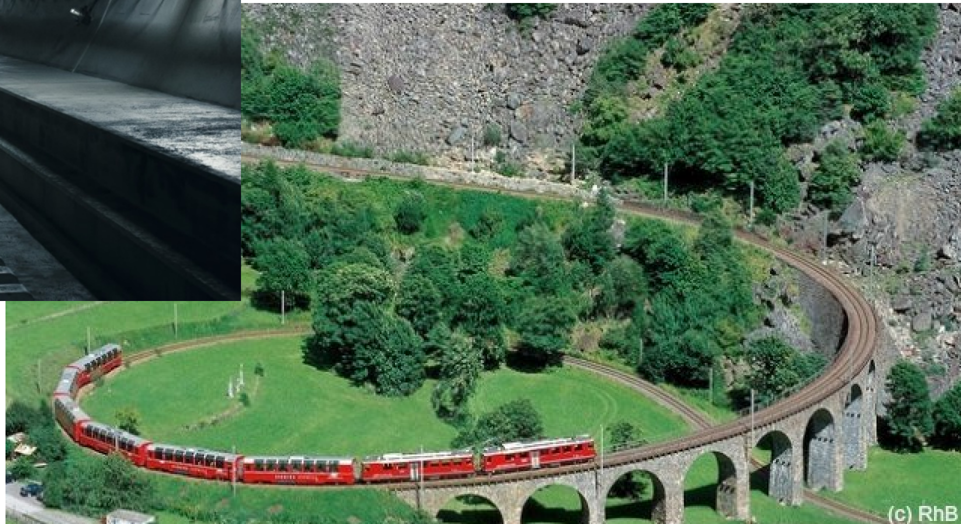
Managing a scarce resource

- Railway safety system
- Expensive infrastructure



Managing a scarce resource

- There is growing competition within/across class across usage
- Capacity allocation via timetable is a lengthy and suboptimal process

Managing a scarce resource

Le véhicule de diagnostic de CFF Infrastructure.

- Competition across usages:
  I need maintenance operation, even though
  they subtract capacity from commercial operations

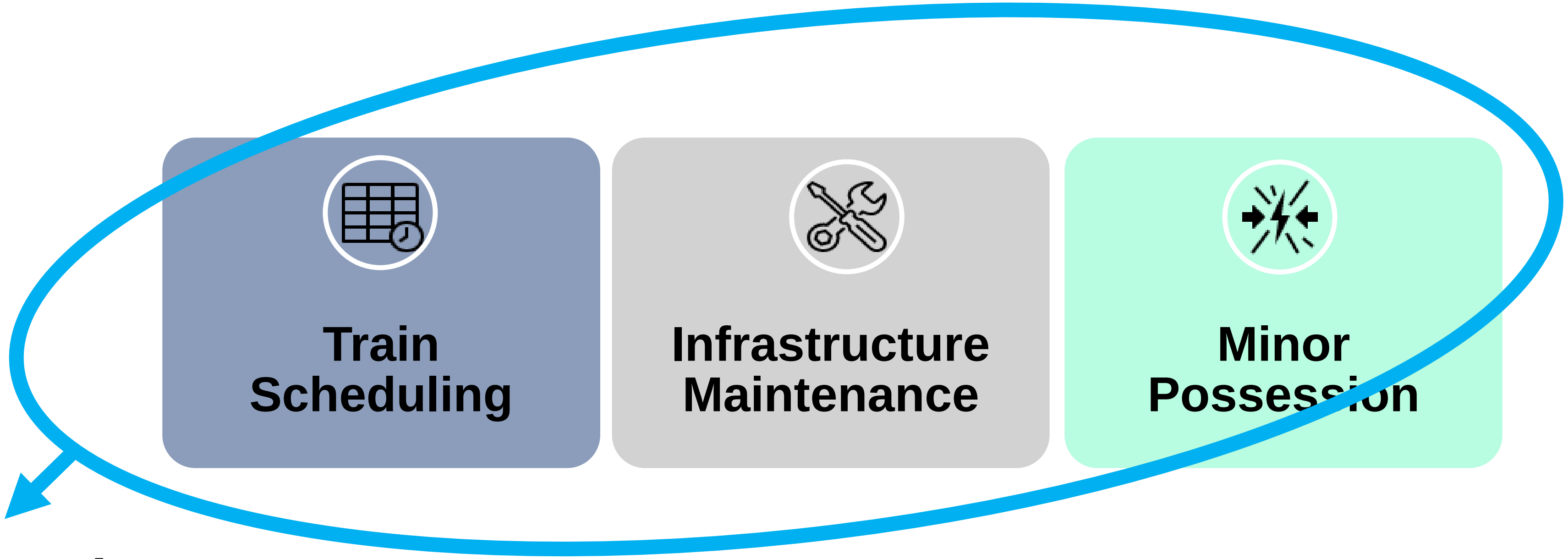
- Maintain a lot,
  with high costs but little disruptions?
- Maintain little,
  with limited costs but necessity to
  take into account large disruptions?

Integrated Planning

Luan, X., Miao, J., Meng, L., Corman, F., Lodewijks, G. (2017) Integrated Optimization on Train Scheduling and Preventive Maintenance Time Slots Planning. Transportation Research Part C 80 pp 329-359

Centulio G, Meng L. D'Ariano A, Corman F (2018) Integrated stochastic optimization approaches for tactical scheduling of trains and railway infrastructure maintenance. Computers & Industrial Engineering

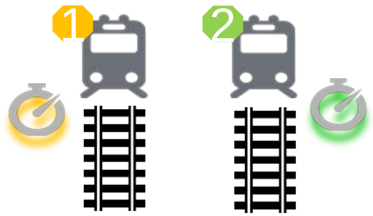
Background – integrated planning approach



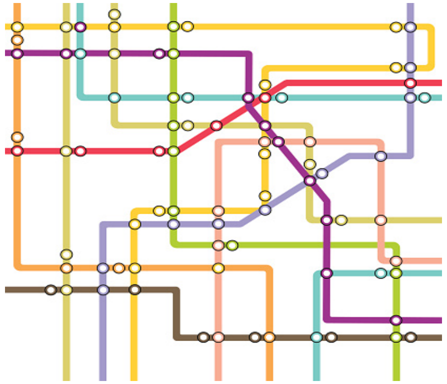
Planning **together**:

- Train scheduling, along routes, arrival/departures times at stations
- Infrastructure maintenance: the rail infrastructure requires periodic maintenance works to be performed by means of limited resources.
- Minor possessions, not allowing any rail traffic during maintenance activities

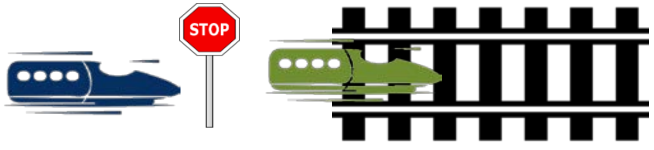
Types of constraints considered



Route←→time

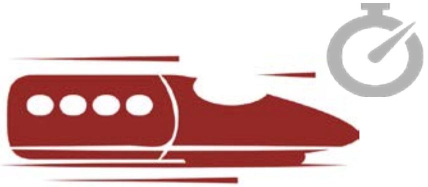


Flow balance



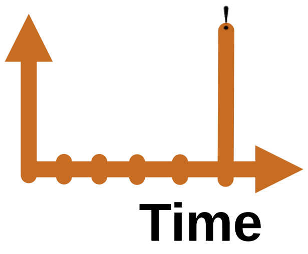
Capacity (trains)

Time-space

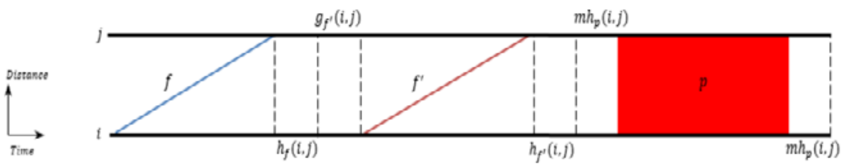


Travel time

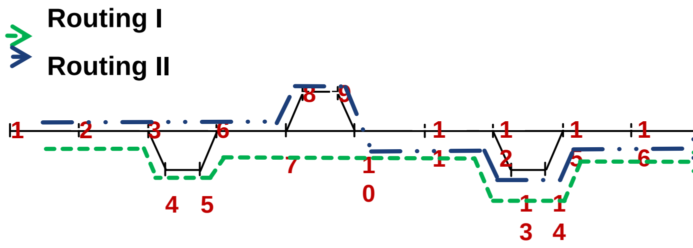
Maintenance tasks



Deadlines



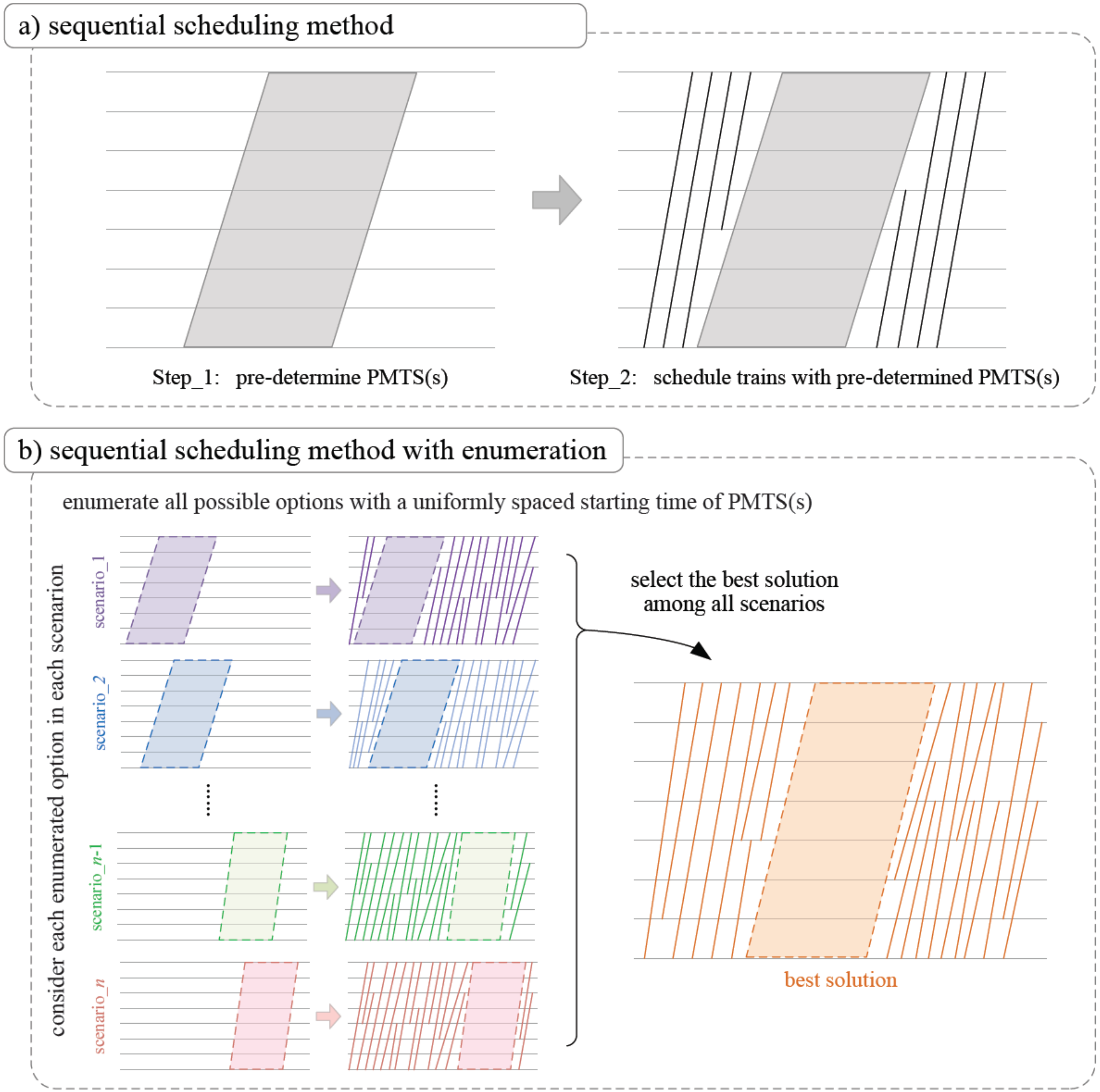
Capacity (maintenance)



Routing of trains

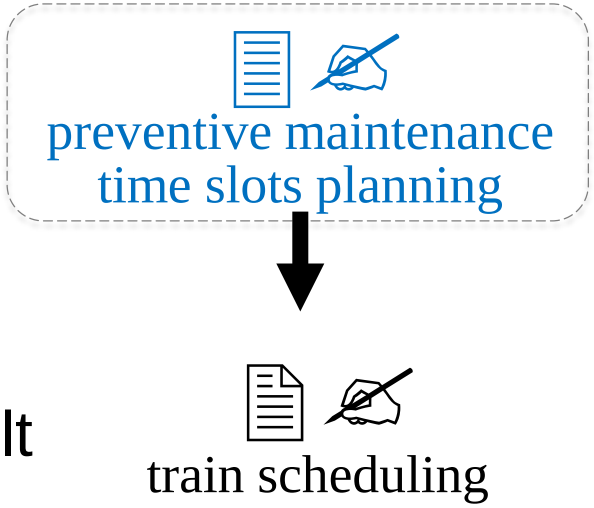
Single possessions

- Integrated is better than *n* sequential solutions

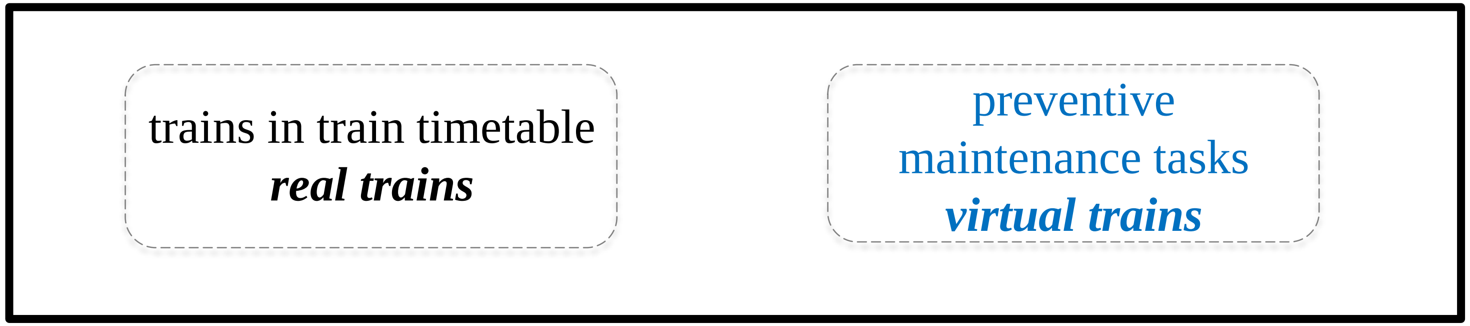


Tradeoff integrated vs sequential planning

- Sequential planning model is easier to solve, suboptimal

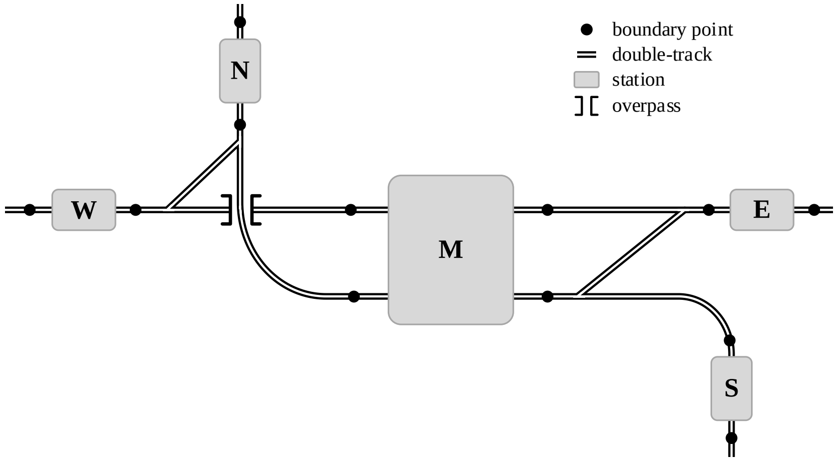


- Integrated planning potentially better, computationally difficult

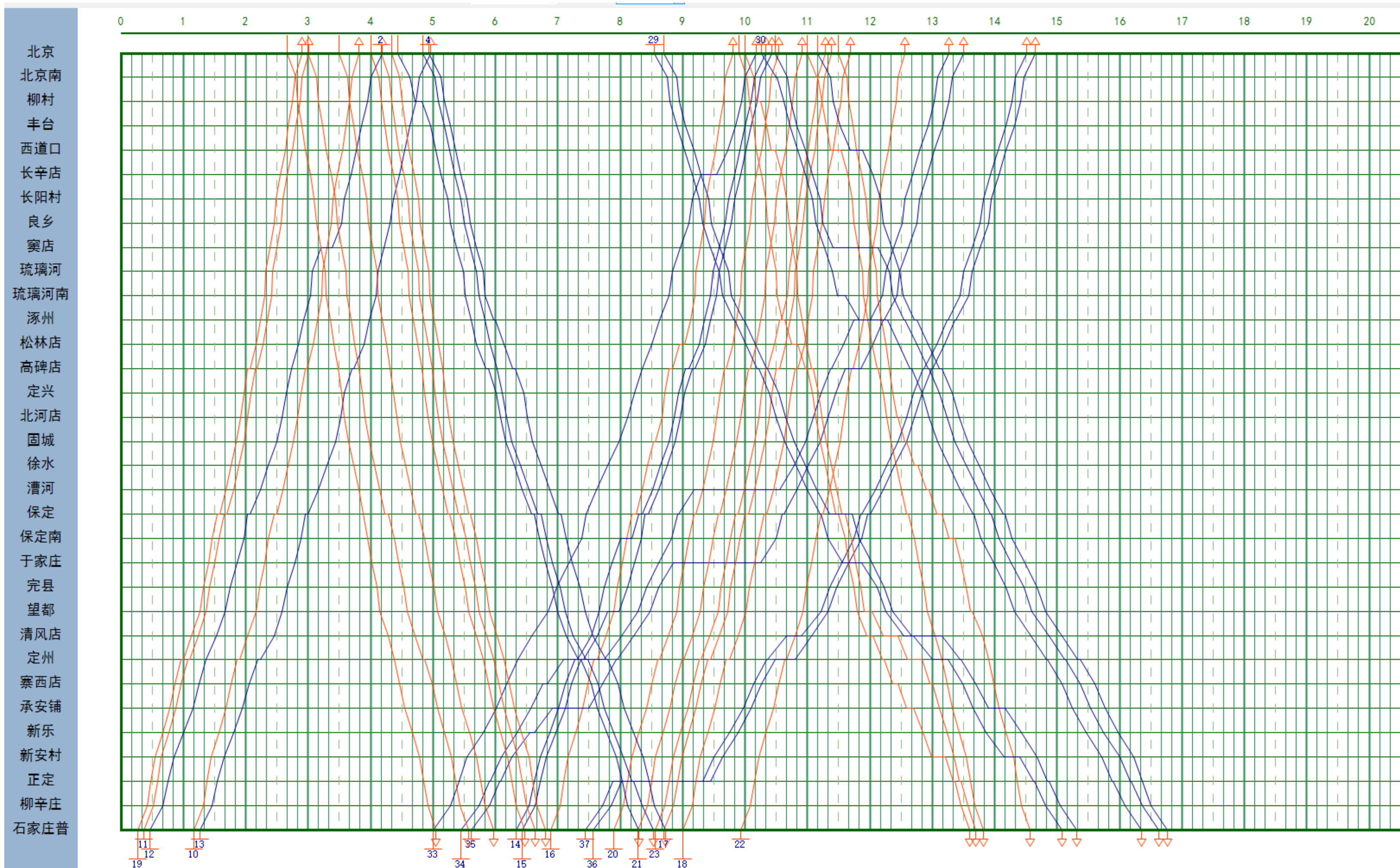


- Lagrangian relaxation scheme to solve the integrated problem

Ideas of the results, real life case



- Chinese High speed network
- Heterogeneous traffic
- Hard to plan maintenance



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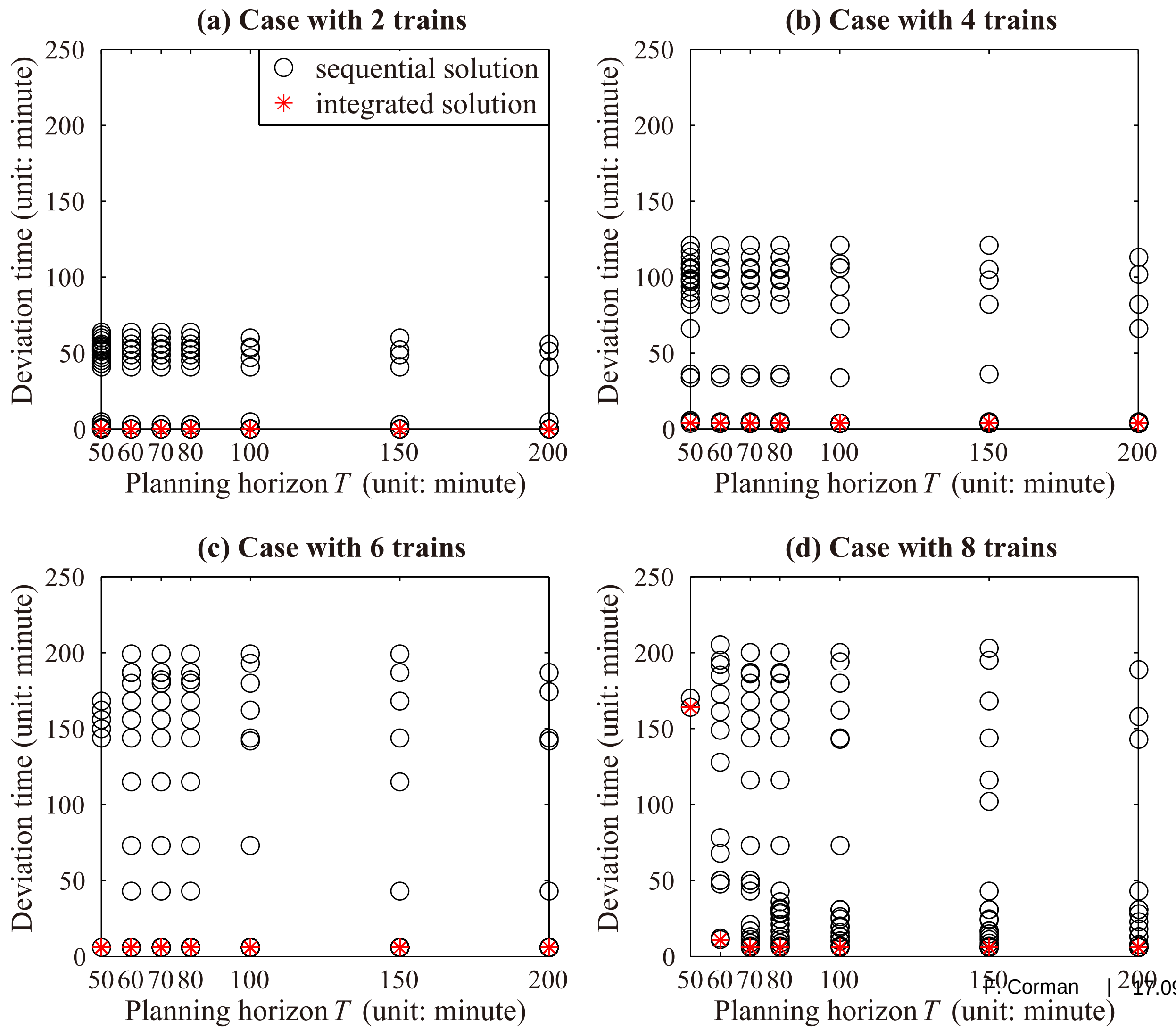
Real life case, results

- Integrated always at least as good as sequential
- Computation time proves acceptable

∗ integrated solution

○ sequential solution



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Multiple possessions

- Inherently Multi objective;
  delays of trains and activities pairing
  to decrease possessions

- To minimize possession setup/ release time
- To minimize disturbances to rest of the traffic

- Minimize timetable deviation
- Maximize amount of paired works

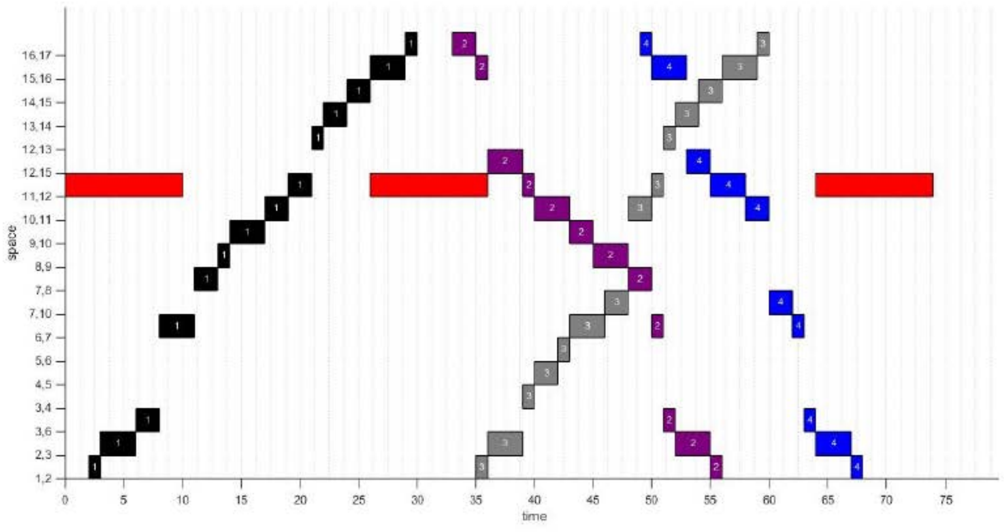


Figure 8: Solution of the first iteration of the ε-constraint method

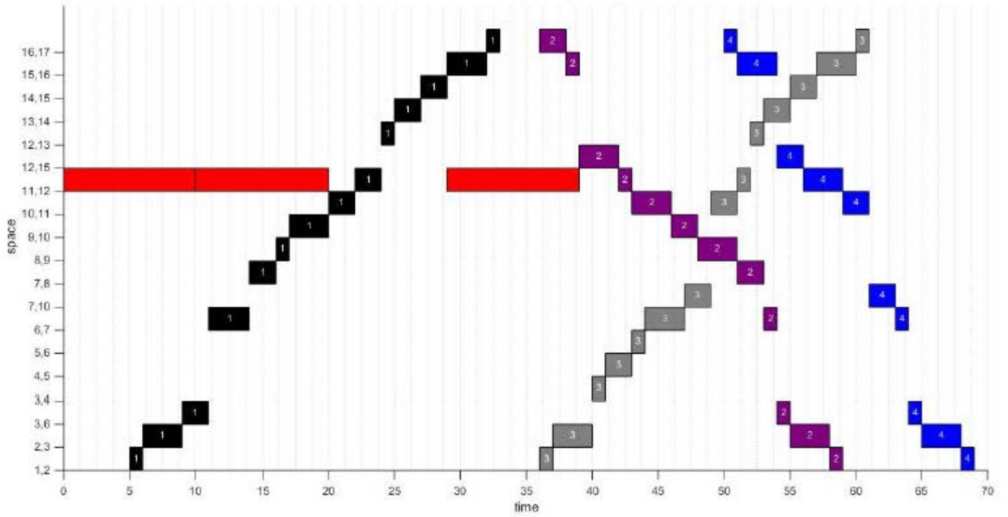
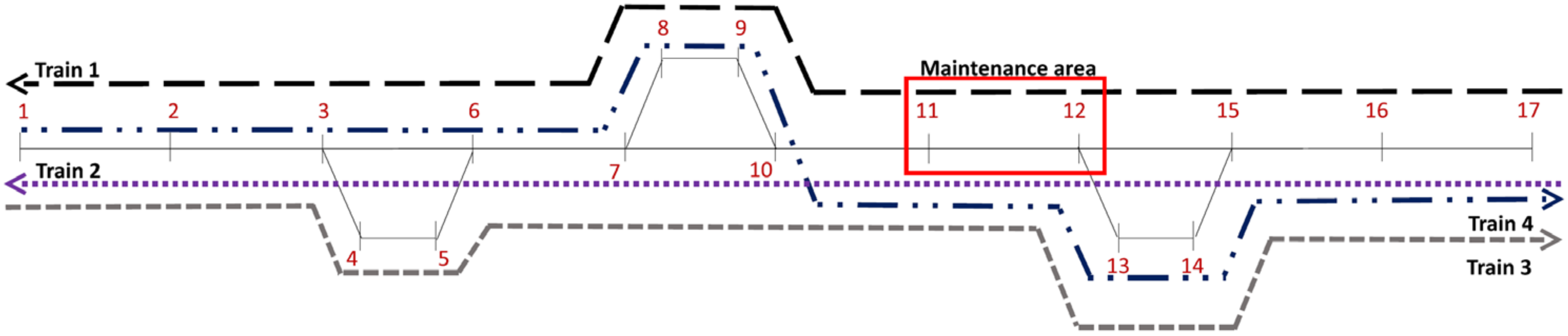
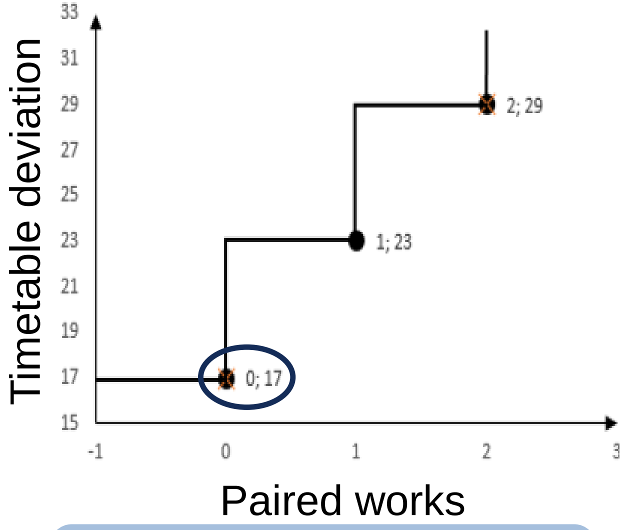


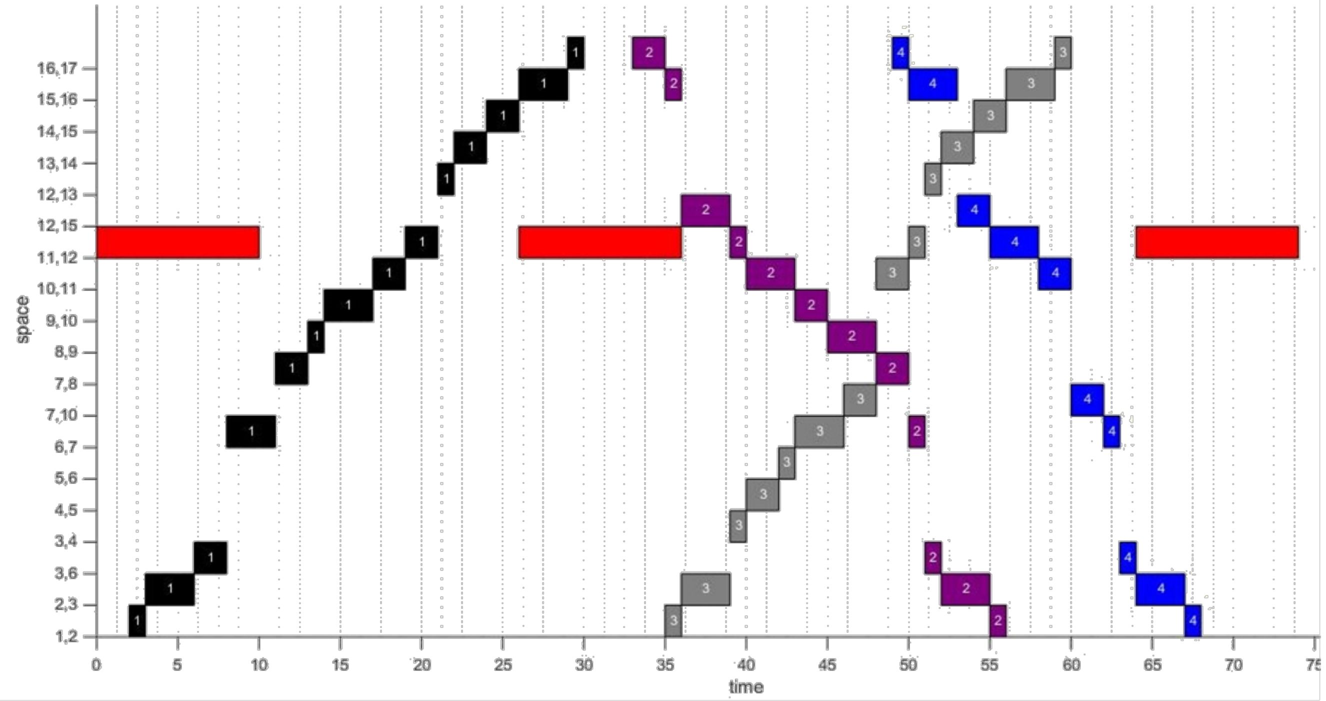
Figure 9: Solution of the second iteration of the ε-constraint method

Example

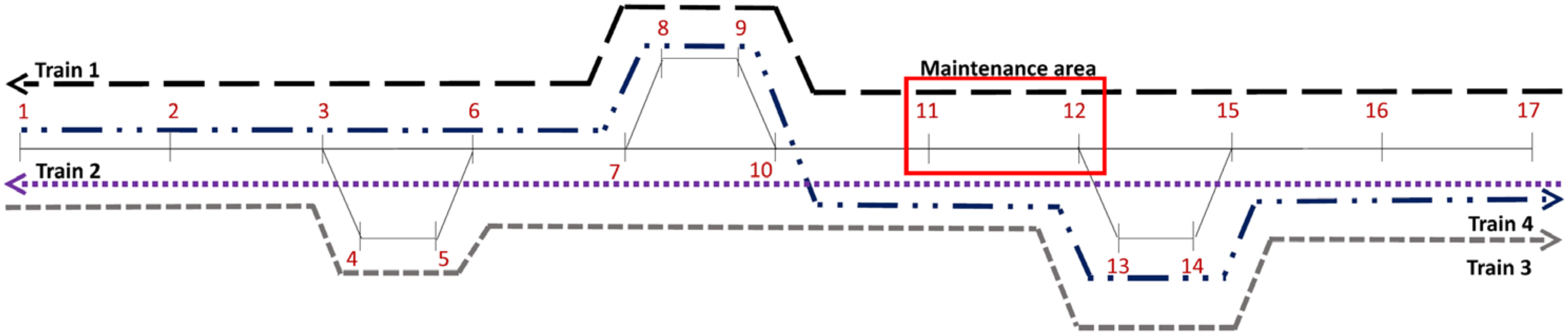


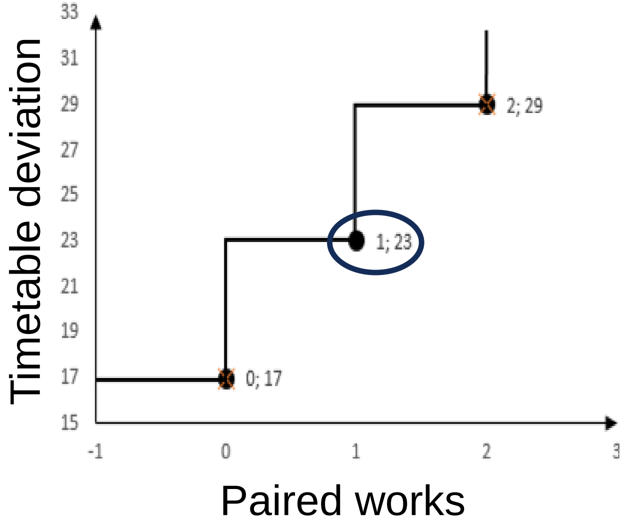


Pareto Front

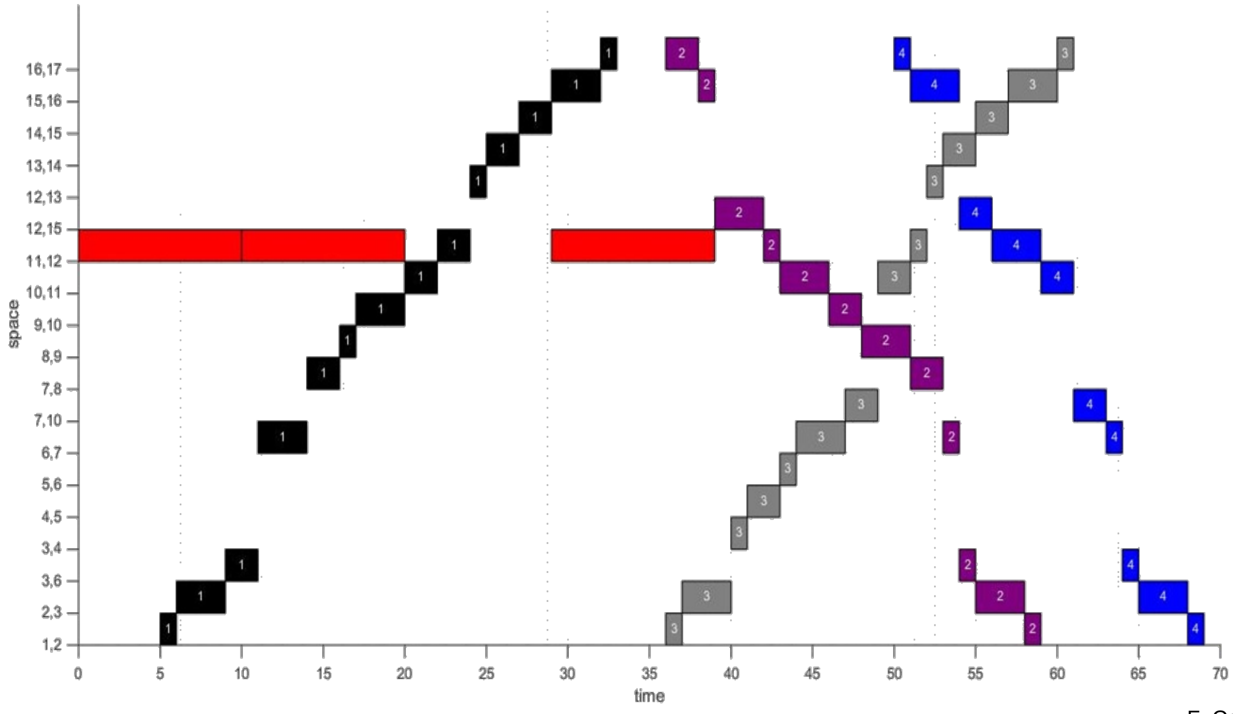


Example

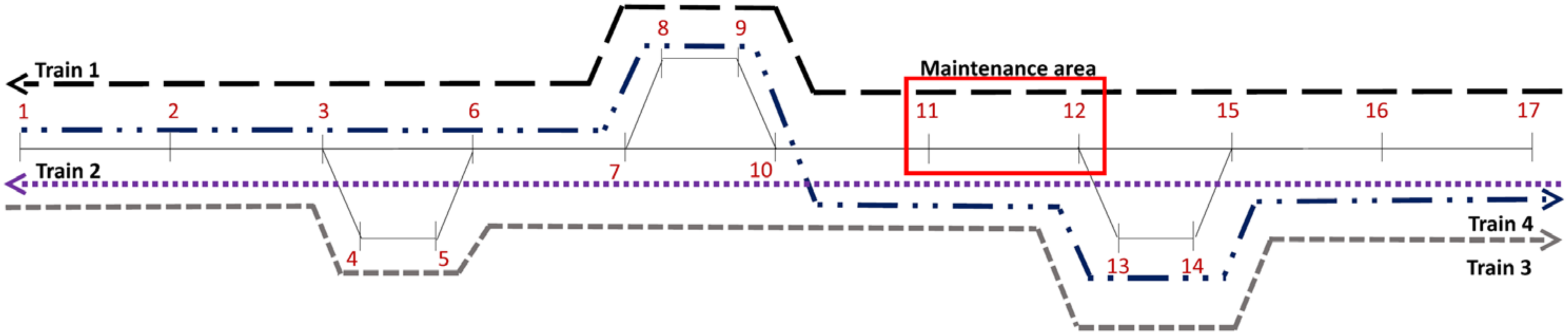


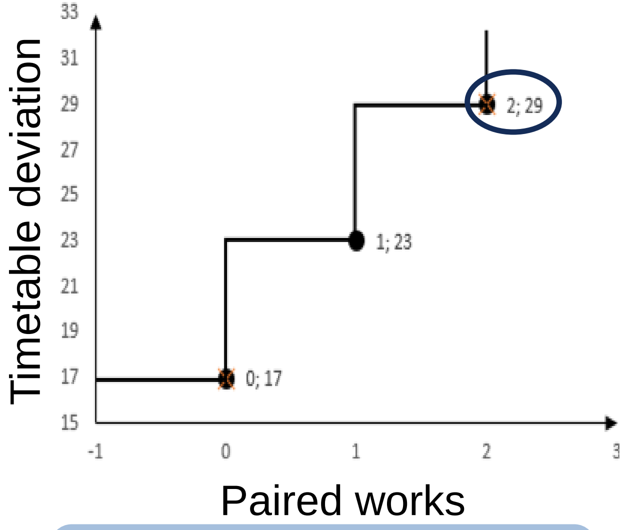


Pareto Front

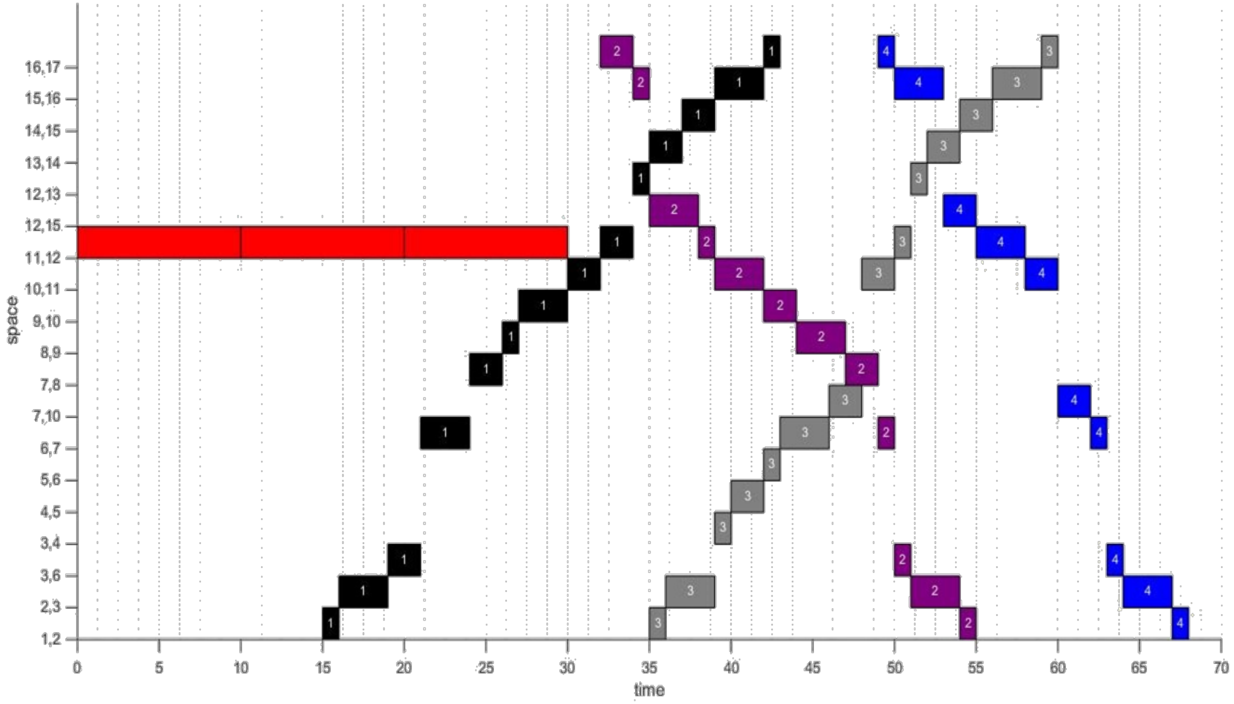


Example





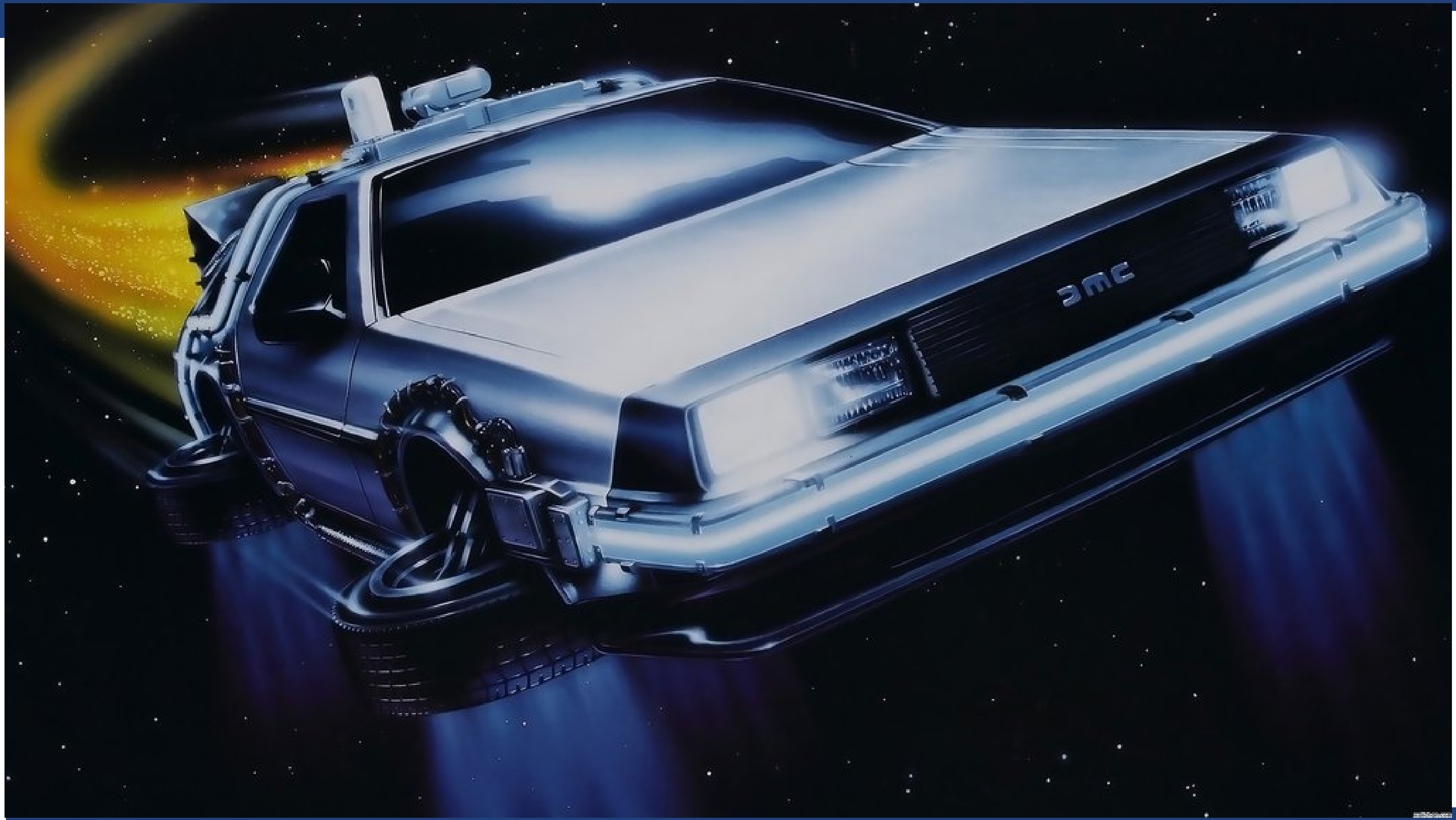
Pareto Front



Results

- Increased effectiveness - more than 25% improvement by integrated planning
- Increase efficiency - good quality can be obtained quickly, less than 60 seconds
- The experiments demonstrate that the integrated scheduling method is at least as good as the sequential one, and the proposed algorithm is able to exploit the large solution space effectively.
- Identify Pareto-optimal solutions within multi objective problems

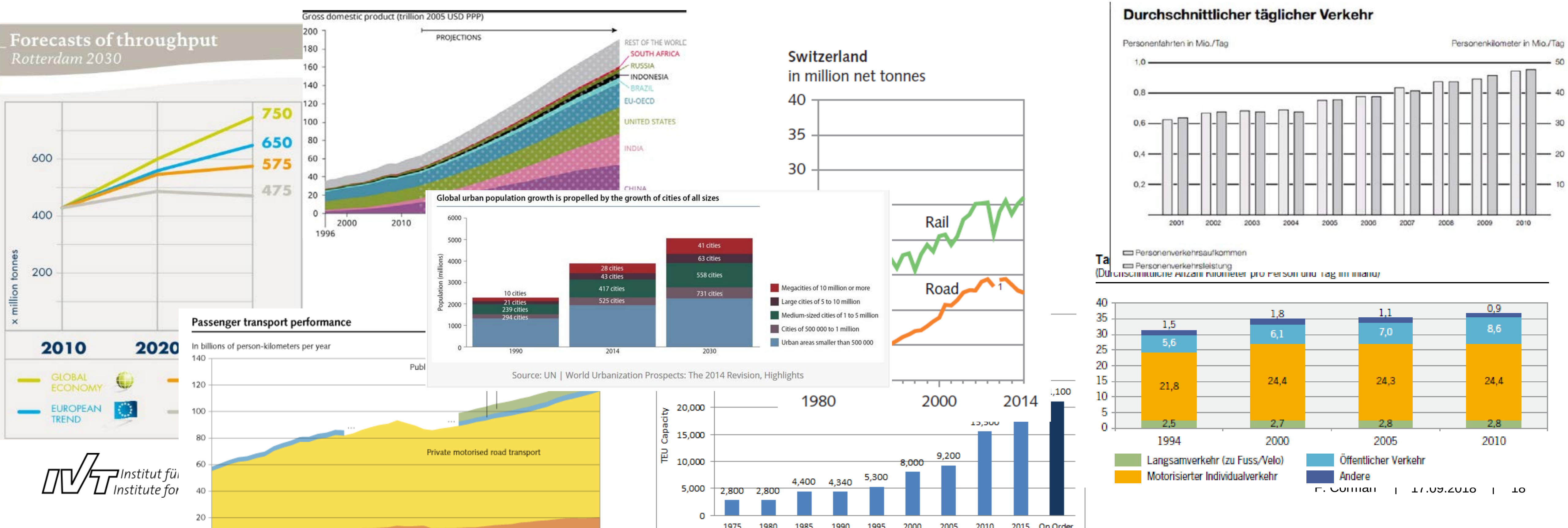
- Possibility to plan for uncertain duration, uncertain maintenance requirements



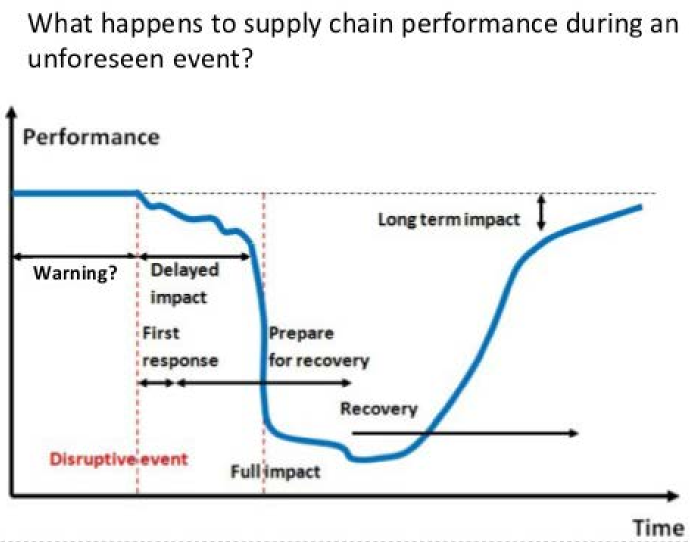
Future

Increasing mobility needs

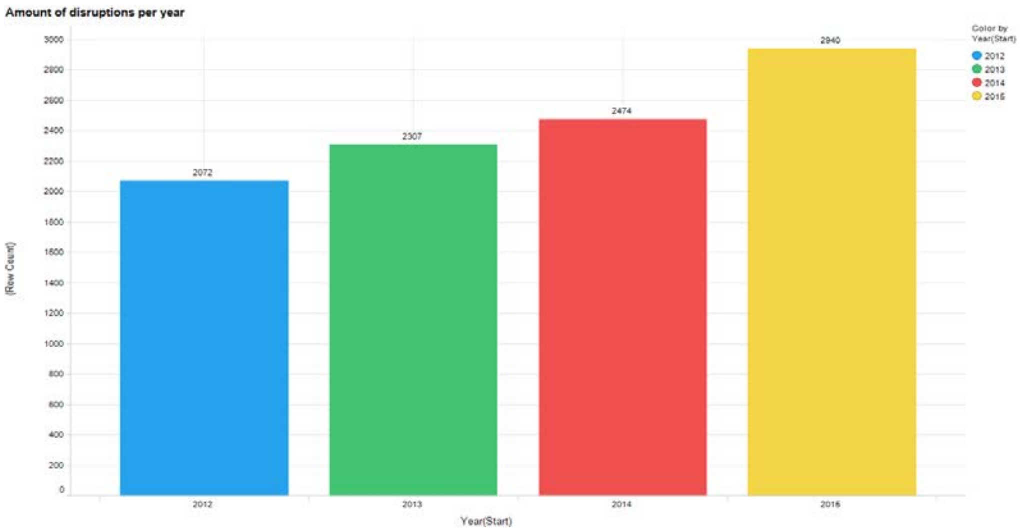
- Increasing mobility needs; Mobility as a service; urban & interurban level
  Higher reliability, performance, availability



More sensitivity to disruptions



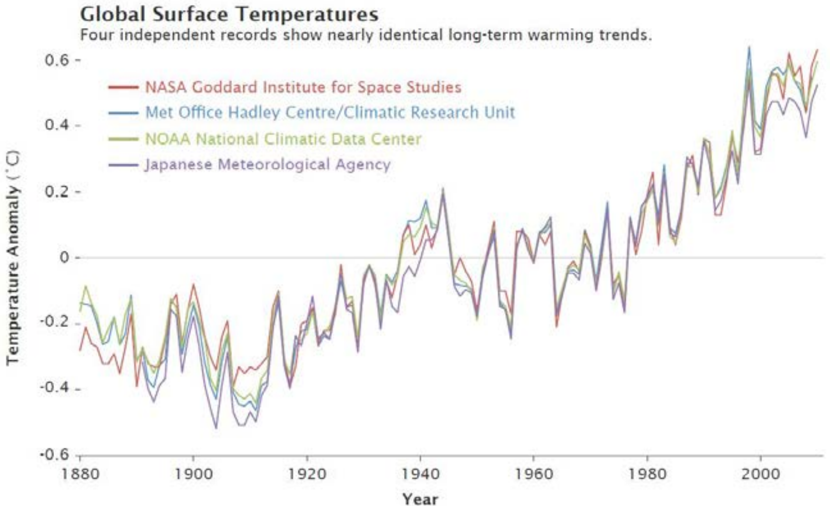
Sheffi, Y. (2005) *The Resilient Enterprise - Overcoming Vulnerability for Competitive Advantage*, MIT Press



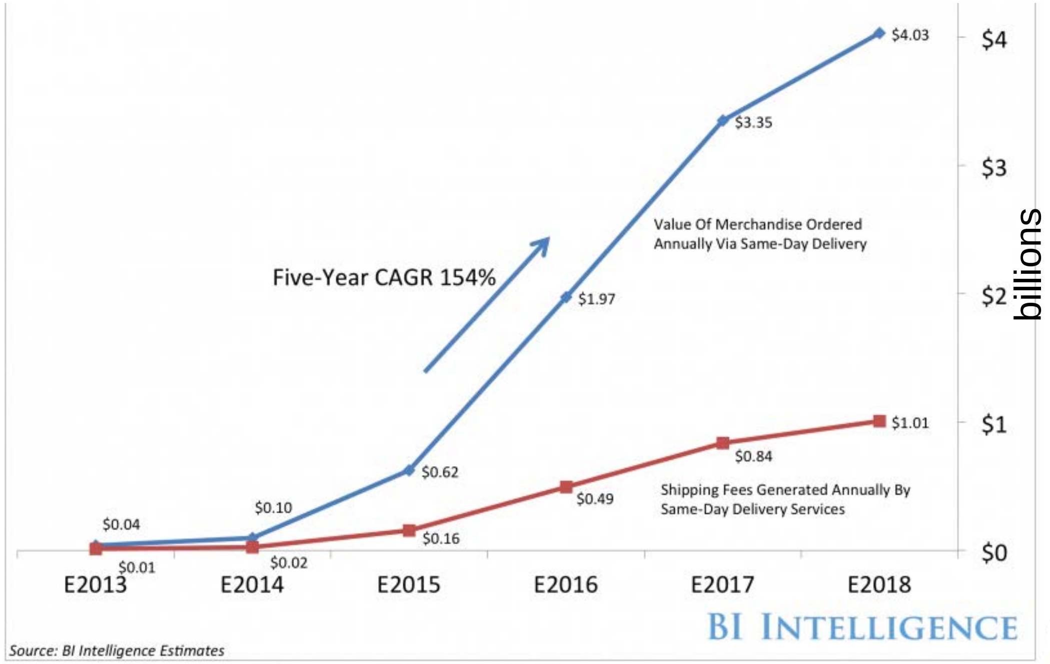
2012 2013 2014 2015

Amount of events classified as disruption, Dutch Network [Corman]

Rastatt Tunnel disruption, august- October 2017-DB AG

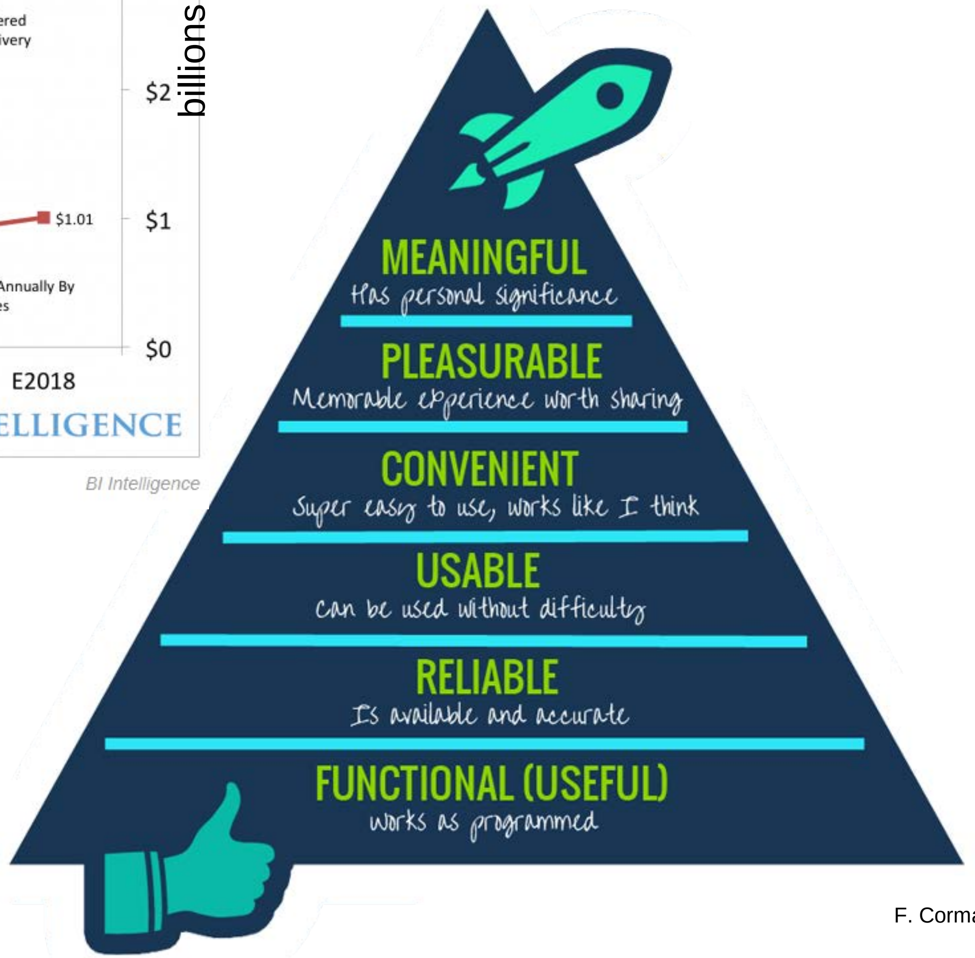


More demanding people; less budget available for operations



Same-day delivery will grow in the triple-digits

BI Intelligence



Future works

- Understand better the link data-information-value
- Stronger mathematical formulations, able to handle complex infrastructure and vehicle processes
- Improve the optimization planning for practical instances with more trains and more complex railway infrastructures.
- Deeper integration of stochastic condition monitoring and optimization
- Integration of the proposed methodology within the railway process, train planning and management tools

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