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An Integrated Methodology to Design Energy-Efficient Timetables

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Outline

- Introduction
- Methodology
- Case study
- Future work

Introduction (1/2)

- Britain's railway industry aims to:
  - deliver a better service
  - reduce costs

- From a timetable perspective, the current method used to construct the British railway timetable shows the following weaknesses[1]:
  - Lack of integrated planning systems
  - Limited consideration given to timetable optimisation

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[1] RSSB, 2013: "FuTRO - GB Timetable optimisation - Baselining the challenge" available from: http://sparkrail.org

Introduction (2/2)

- A novel methodology to produce a timetable is proposed, which is characterised by:
  - a high level of automation
  - integration of an optimisation stage
- The methodology can be applied at a long- or short-term planning stage.

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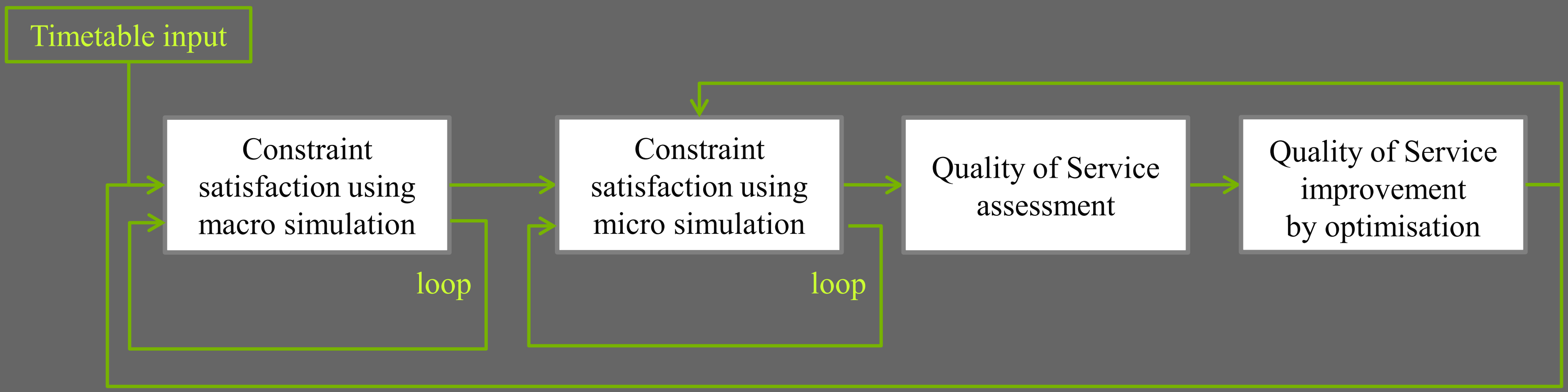
Methodology

- The proposed method combines the following functions in a closed loop:



- A timetable is considered of good quality if it is feasible, i.e. conflict free, and optimised.

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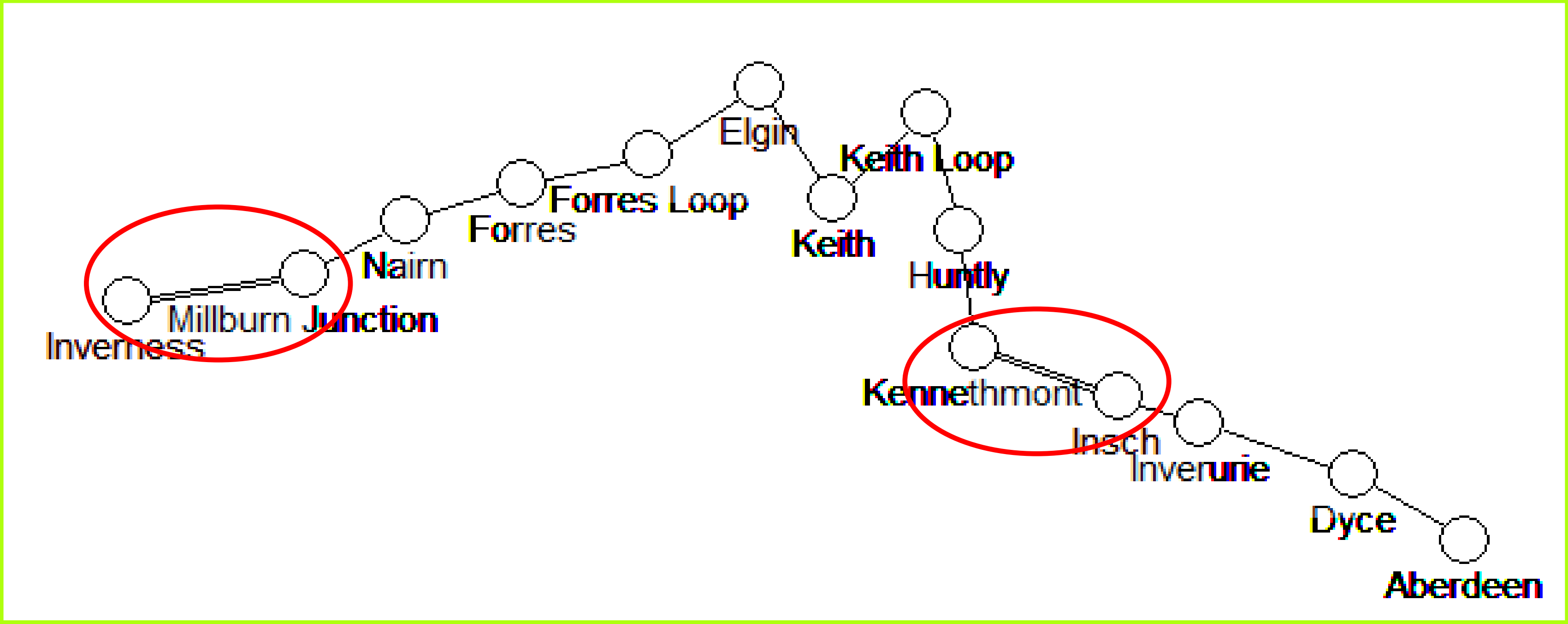
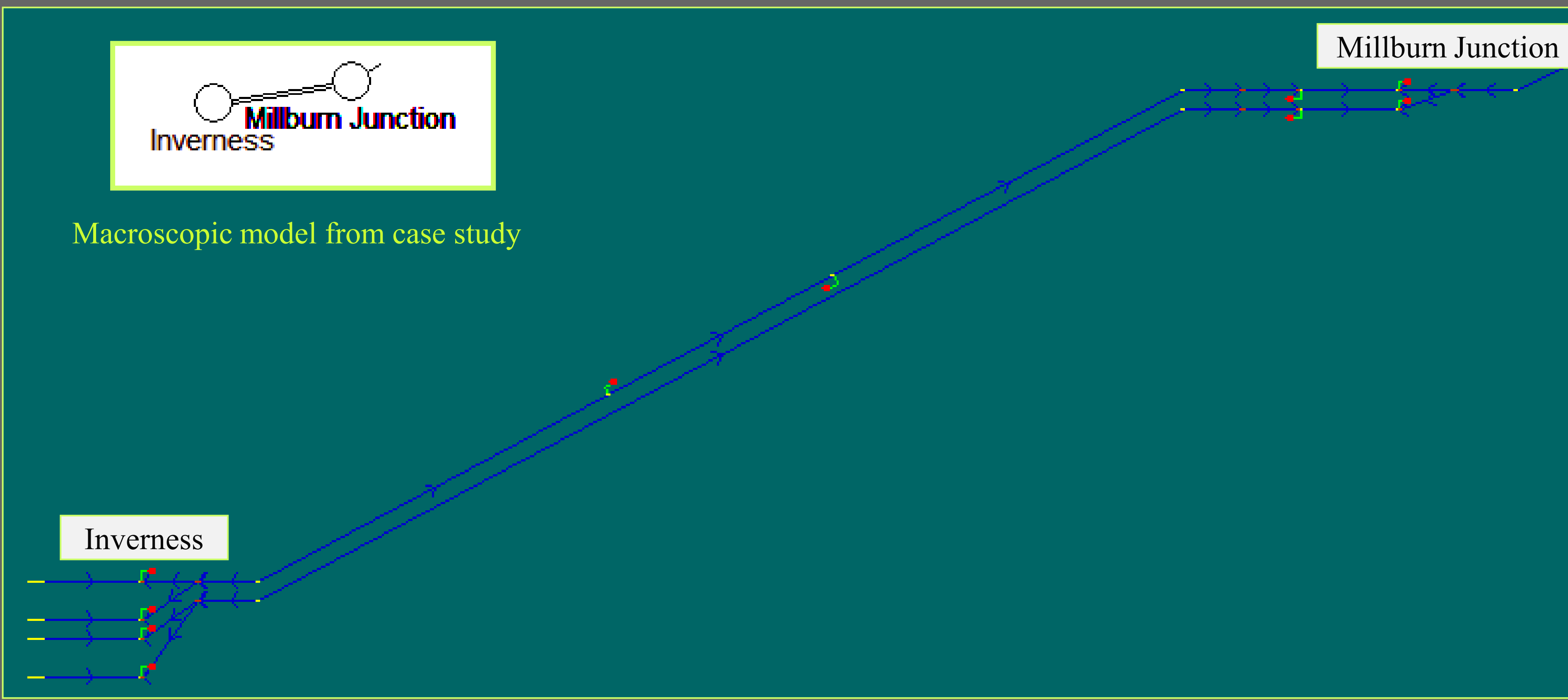
Feasibility analysis at macroscopic level

Existing or new timetable → Analysis of infrastructure and headway time constraint satisfaction at macro-level → Resolution of possible violations by the timetable planner → *Feasible timetable at macro-level*



Feasibility analysis at microscopic level

Timetable from the previous stage → Analysis of constraint satisfaction at micro-level → Resolution of possible violations by the timetable planner → *Feasible timetable at micro-level*



Macroscopic model from case study

Quality of Service (QoS) assessment

Log file with:
- *arrival/departure times*
- *train energy consumption*

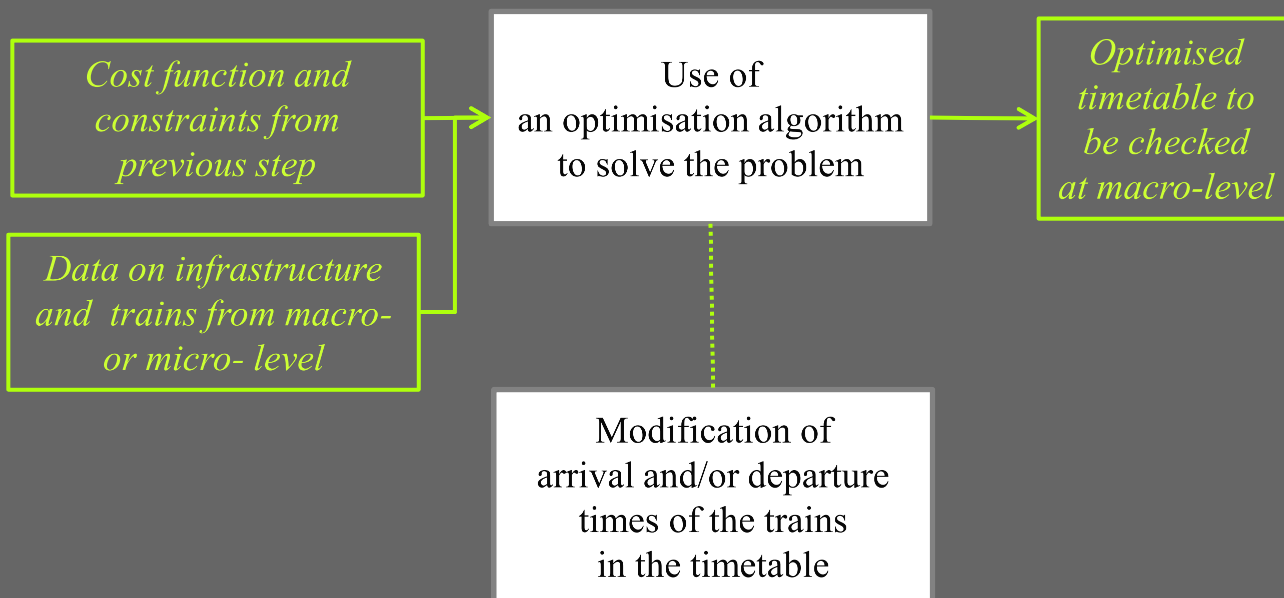
→ Analysis of the timetable using a set of key performance indicators

→ Definition of the optimisation problem

→ *Optimisation cost function and constraints*

Example of a graph representing the journey time indicator

QoS improvement by optimisation



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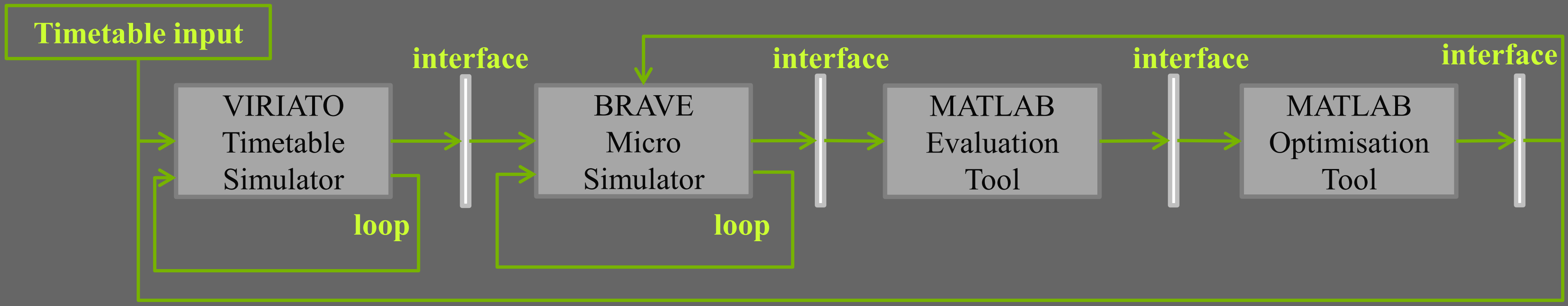
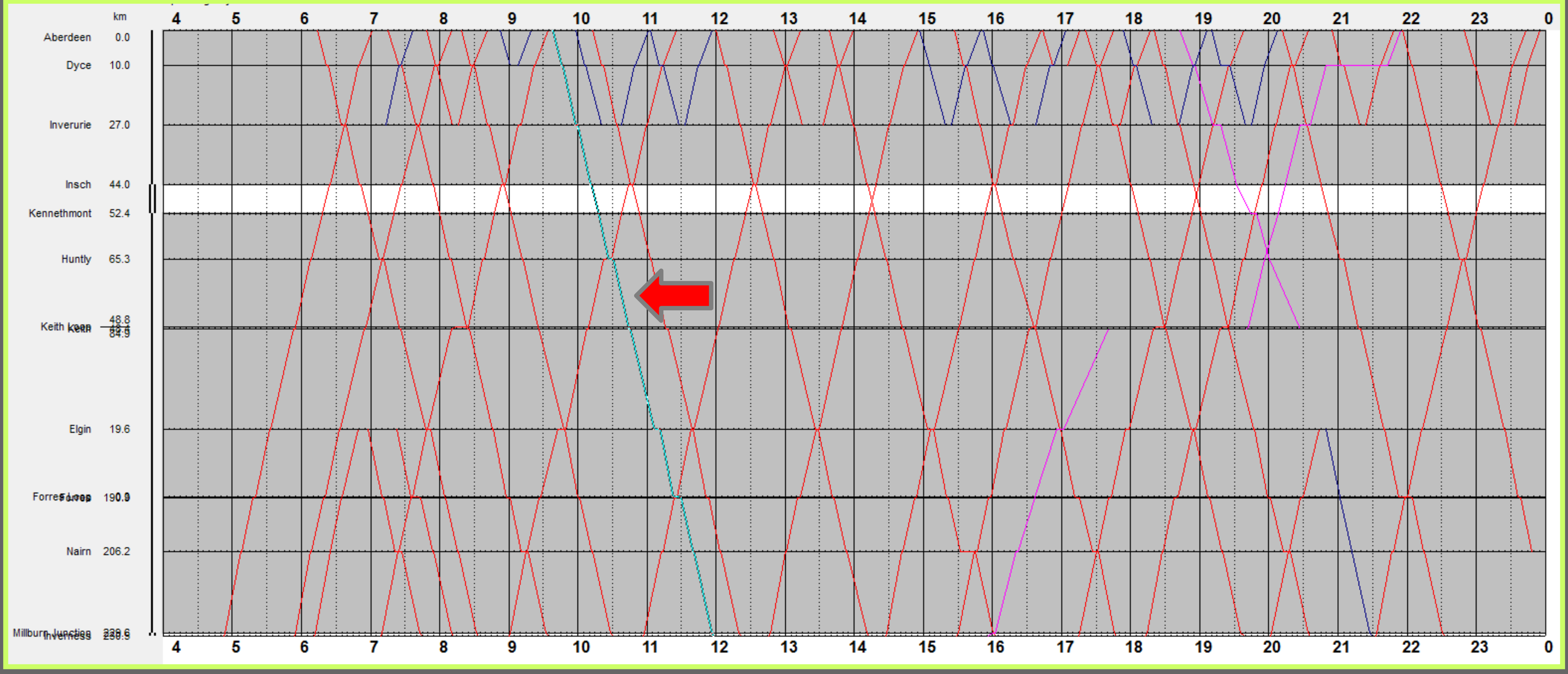
Implementation

- Each stage of the process is:
  - implemented using an appropriate software tool
  - interfaced to the other steps



Case study (1/3)

- The methodology has been used to add one service to the Winter timetable 2013 on the single-track line between Aberdeen and Inverness in Scotland.



Initial timetable with one additional train

Case study (2/3)

- The performance indicators selected in the QoS assessment (third stage) are energy consumption and journey time.

- The optimisation problem solved in the fourth stage consists of minimising the energy consumption of the additional train, while its total journey time is as close to the scheduled one as possible.

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Case study (3/3)

- The optimisation algorithm used in this case study is a genetic algorithm.

- The population in the genetic algorithm is made of possible target speeds for the train on each section of the route.

Parameter	Value	Parameter	Value	Parameter	Value
Number of variables	10	Upper Bound (UB)	line speed limit	Stop Criterion (max number of generations)	30
Population Size	50	Lower Bound (LB)	40 km/h lower than line speed limit	Stop Criterion (number of stall generations)	5
Number of elites	2	Crossover rate	0.8	Tolerance value	0.0001

Genetic algorithm parameters

Case study – results (1/2)

- The final solution allows the added train to reduce the energy consumption by 22.8% while it keeps the same total journey time in comparison with its initial path.

Run	Energy reduction	Difference from scheduled journey time (sec)	Constraints violated?
1	-20.4 %	-0.559	Yes
2	-21.0 %	-0.294	Yes
3	-21.3 %	-0.125	No
4	-20.7 %	0.077	No
5	-22.0 %	0.067	No
6	-22.8 %	0.054	Yes
7	-19.5 %	-0.131	Yes
8	**-22.8 %**	**-0.042**	**No**
9	-20.7 %	0.128	Yes
10	-22.2 %	0.032	Yes

Optimisation results over 10 runs

Case study – results (2/2)

- The initial and the final speed profile of the added train are shown in the figure below.

Comparison between the initial (top) and the final (bottom) speed profile

Future work

- The method will be consolidated and its scalability will be validated:
  - it will be applied to a group of trains
  - the analysis of its impact on the system will be carried out

- Different optimisation problems will be considered that take into account the trade-offs between:
  - capacity and robustness
  - capacity and passenger convenience

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Thank you for your attention

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