RL-based Rolling Stock Rostering (consider maintenance)

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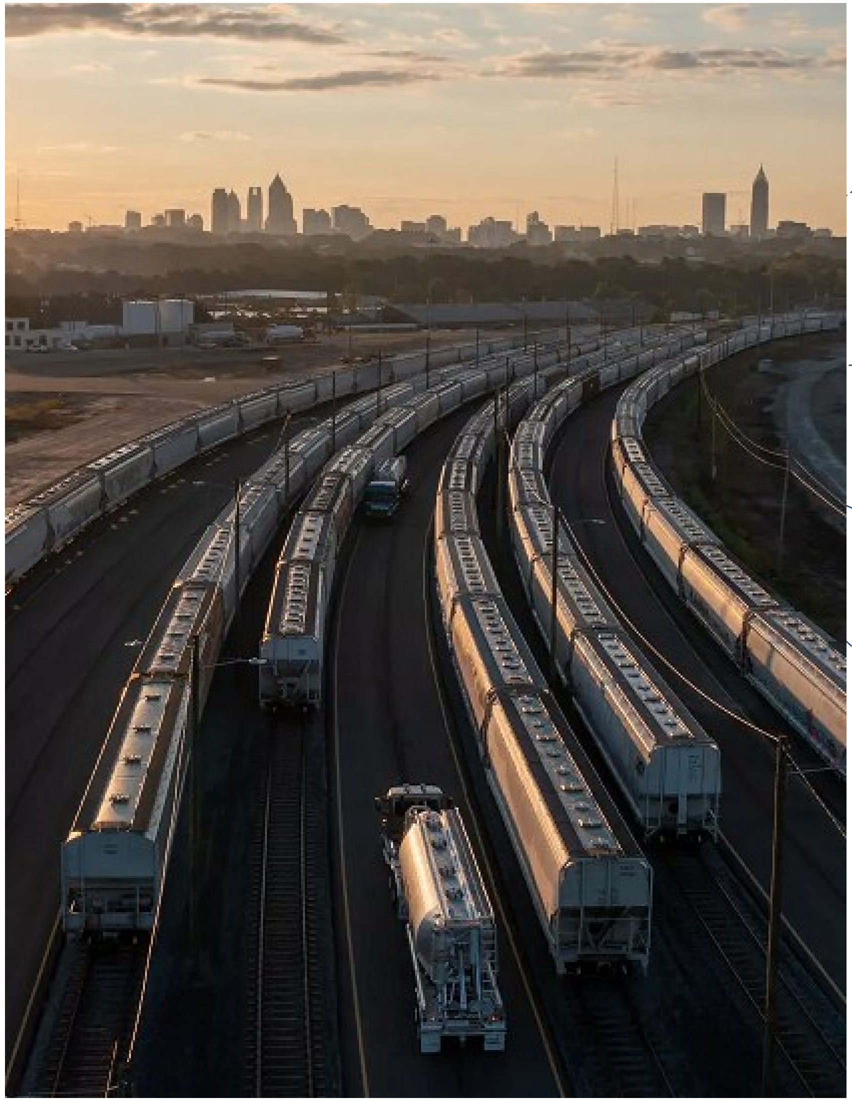
Railway Problem and Motivation



Objective of the PoC
Explore the feasibility of applying RL approaches
Into Rolling Stock maintenance routing problem

Constraints / Requirements
Minimize the overall usage of rolling stock units
Consider the accumulated travelling mileage

Main Issues and Challenges
Data Availability & Acquisition
NP-hard problem if there are too many services to fulfill

Key Performance Indicators
Computation Resources
Usage of minimum rolling stock units

Proof-of-Concept as a Benchmark

AI Application
Adversarial Search

AI Related Disciplines
Reinforcement Learning

AI Techniques
Semi-supervised - Agent Based Modelling
Supervised – Deep Q-Network Learning
Self-Training / Optimization

Inspiring Solutions
Typical maintenance routing (heuristics)
TSP (Travelling Salesman Problem)
CVRP (Capacitated Vehicle Routing Problem)
Intelligent Rolling Stock Rostering

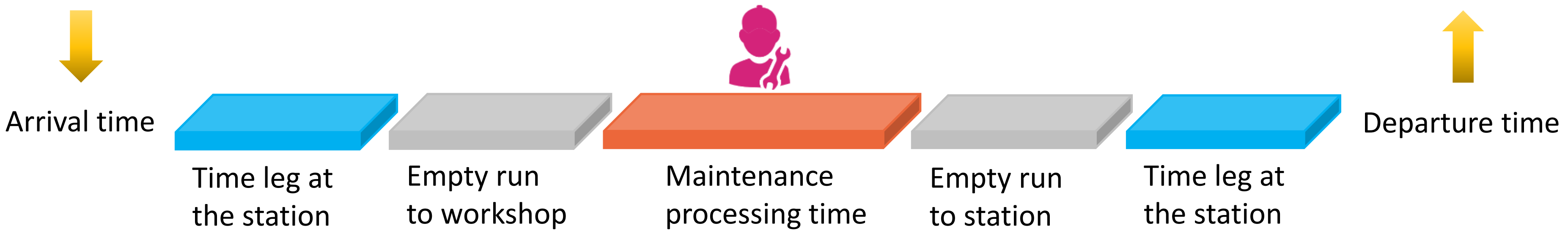
Datasets
TransPennine Express
Real-world timetable data
Synthetic Data

Developments / Implementations
Creating the RS routing/rostering environment
Designing the Q-Learning Algorithm as needed
Writing the training loop

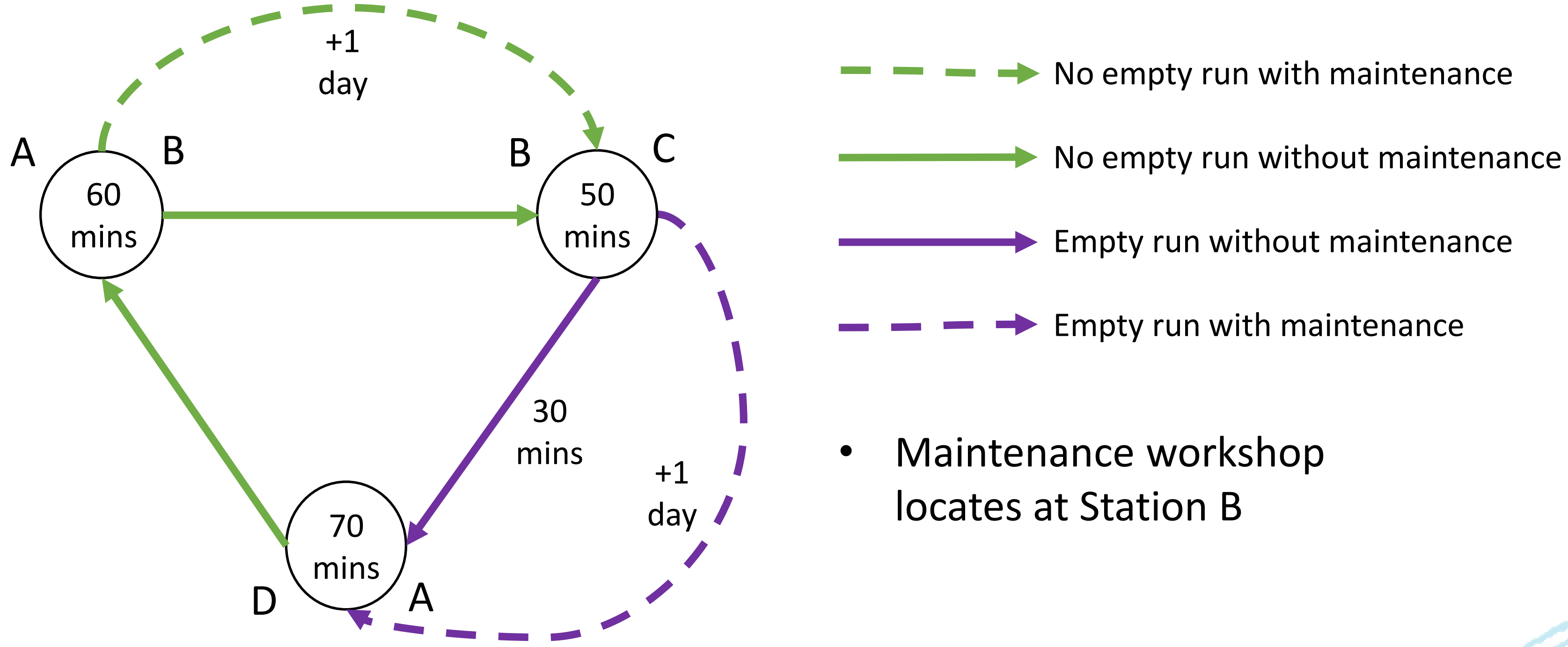
Exploited Software and Framework
Keras-RL: DQNAgent
Scipy, Numpy, Pandas

Hardware Requirements
Google Colaboratory
GPU(s) with CUDA cores and 16GB System RAM

Problem scenarios

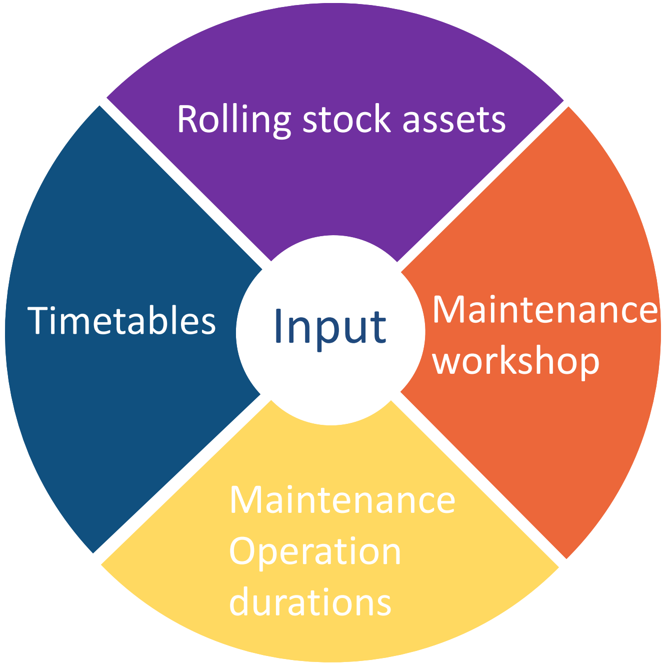


Illustrative Example



- Maintenance workshop locates at Station B

Approach: A Modular Architecture



Objective: Rostering with the minimum costs of RS units (consider maintenance activities)

Rostering

Each train service represents as a node

Arcs denotes the train movements between two consecutive services

Maintenance

Categories of Arcs :
Empty run with/without maintenance
No empty run with/without maintenance

Reinforcement Learning module

Agent
Environment
States
Actions
Reward

Approach: reinforcement learning components

The settings of reinforcement learning module

Fundamental settings

- Set the **Agents** as the RS units, keep the number of agent as less as possible

- Maintain several **Q-matrixes** for each arc category - there are multiple arcs between each station pair

- **Objective** constraints: Minimum overall costs of RS units & number of empty runs

States maintained

- Accumulated kilometres (AK) as the **AK-state** (For each RS units)

- **Maintenance-state**: When the AK over a threshold, i.e., maximum kms for maintenance, set the next **action** with a penalty value: Fail

Other settings

- **Reward**: the necessary costs (measured with time) between two consecutive services, including empty run time + station waiting time + maintenance time (if any)

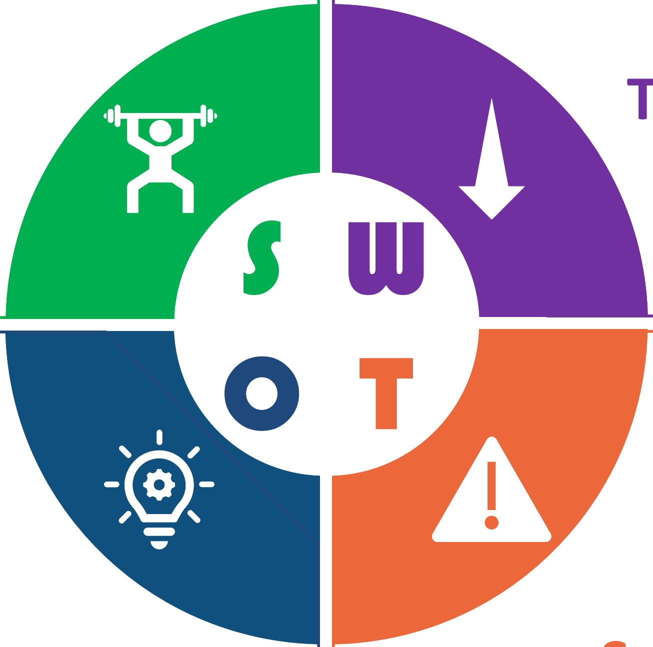
- **Environment**: the different train services to deliver with different origins & destinations, and the next station where to navigate

- **Actions**: at each location, the decisions to make are "which service do I chose to deliver next"

SWOT Analysis of the Investigated Approach

Adaptability
Optimization
Learning from experience
Flexibility and Scalability
Handling uncertainty
Trade-off exploration

Data requirements
Training time and complexity
Lack of interpretability



Enhanced efficiency
Cost reduction
Friendly to dynamic environment

Safety concerns
Sensitivity to unseen senarios
Integration challenges

Recommendations

Multi-objective optimization

Additional objective functions such as energy consumption, Operational resilience

Integration with predictive maintenance

Condition monitoring
Failure prediction

Transfer learning and generalization

Reduce the training time & resource requirements

Thank you for your attention!

RAILS
Roadmaps for AI Integration in raiL Sector

- ✓ *Deliverable D3.1: WP3 Report on case studies and analysis of transferability from other sectors (safety and automation)*
- *Deliverable D3.2: WP3 Report on AI approaches and models*
- ✓ *Deliverable D3.3: WP3 Report on experimentation, analysis, and discussion of results*
- *Deliverable D3.4: WP3 Report on identification of future innovation needs and recommendations for improvements*

Available at: https://rails-project.eu/downloads/deliverables/