



Horizon 2020
European Union Funding
for Research & Innovation

AI in railways - analysis phase: main outcomes and their relevance for the next steps

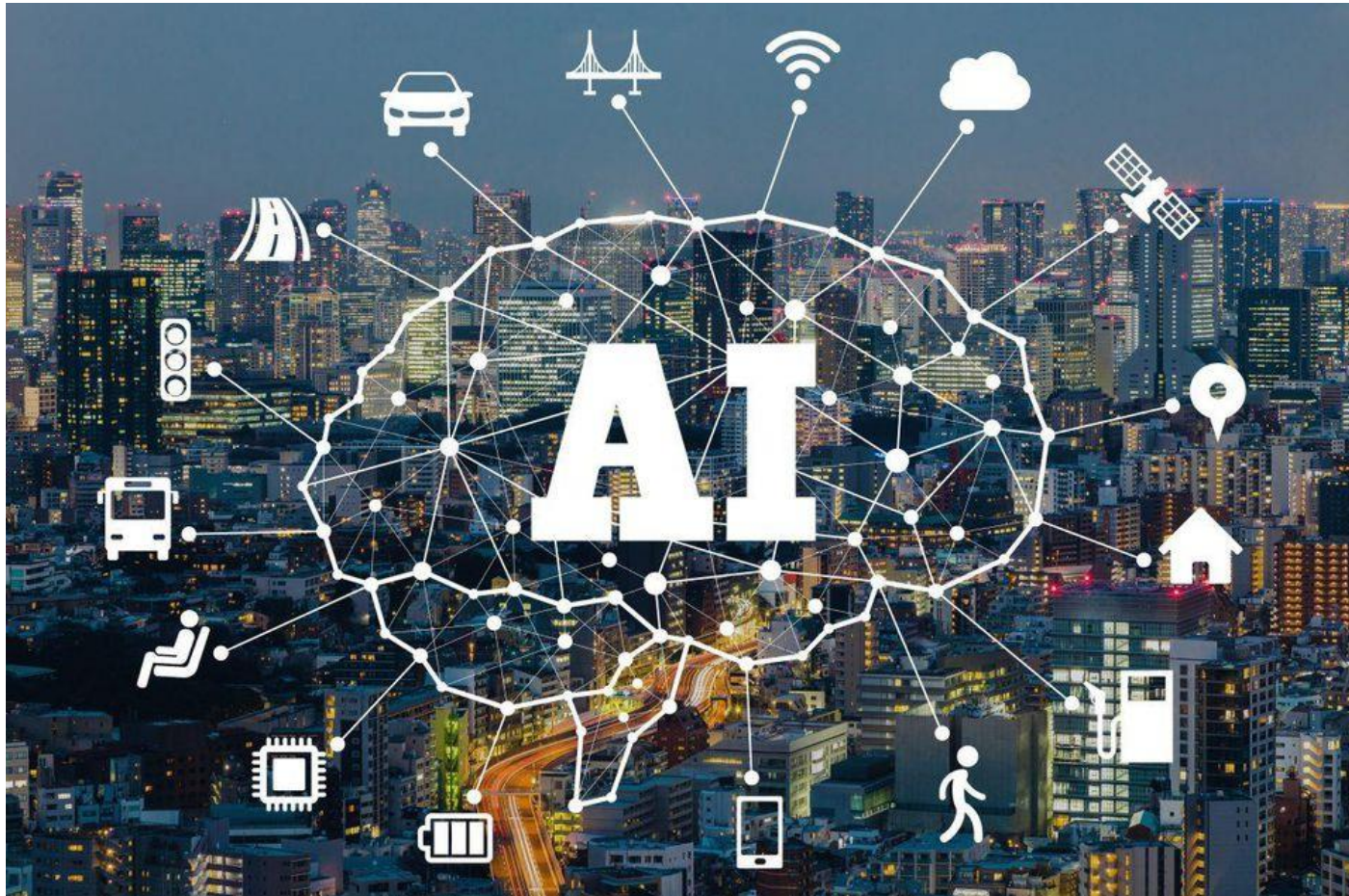
Rob Goverde and Nikola Besinovic
Delft University of Technology

Outline

- Introduction
- What is AI (to railway professionals)?
- AI taxonomy
- Existing applications
- Future research directions

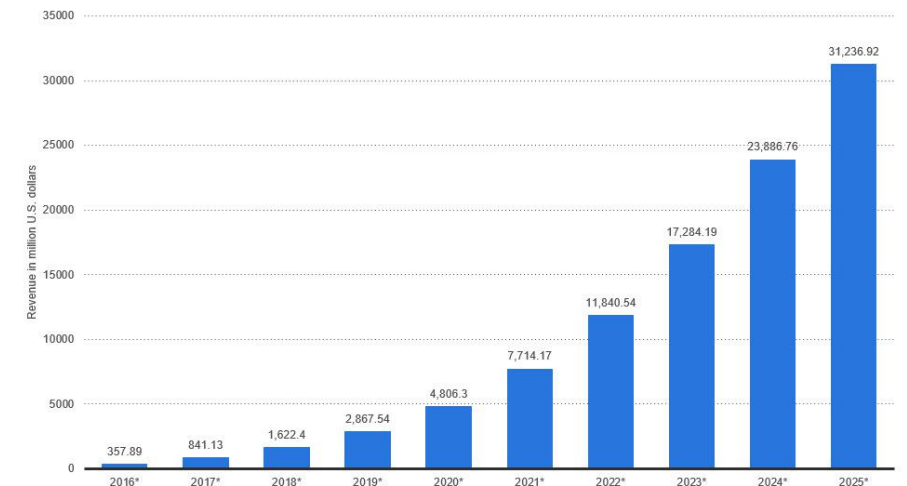


AI is everywhere



Enterprise artificial intelligence market revenue worldwide 2016-2025

Revenues from the artificial intelligence for enterprise applications market worldwide, from 2016 to 2025 (in million U.S. dollars)



statista

AI definition

Various structured and detailed definitions

- capture the broad nature of AI
- abstract and difficult to grasp and thus would not be widely accepted

RAILS definition:

AI is the discipline gathering all the **aspects** that allow an **entity** to determine how to perform a task and/or take a decision based on the **experience** matured by observing samples and/or by interacting with an environment

- **Aspects:** algorithms, theoretical formulations, technologies
- **Entity:** software, hardware, hybrid (train, signal, switch)
- **Experience:** learning, data-driven inference



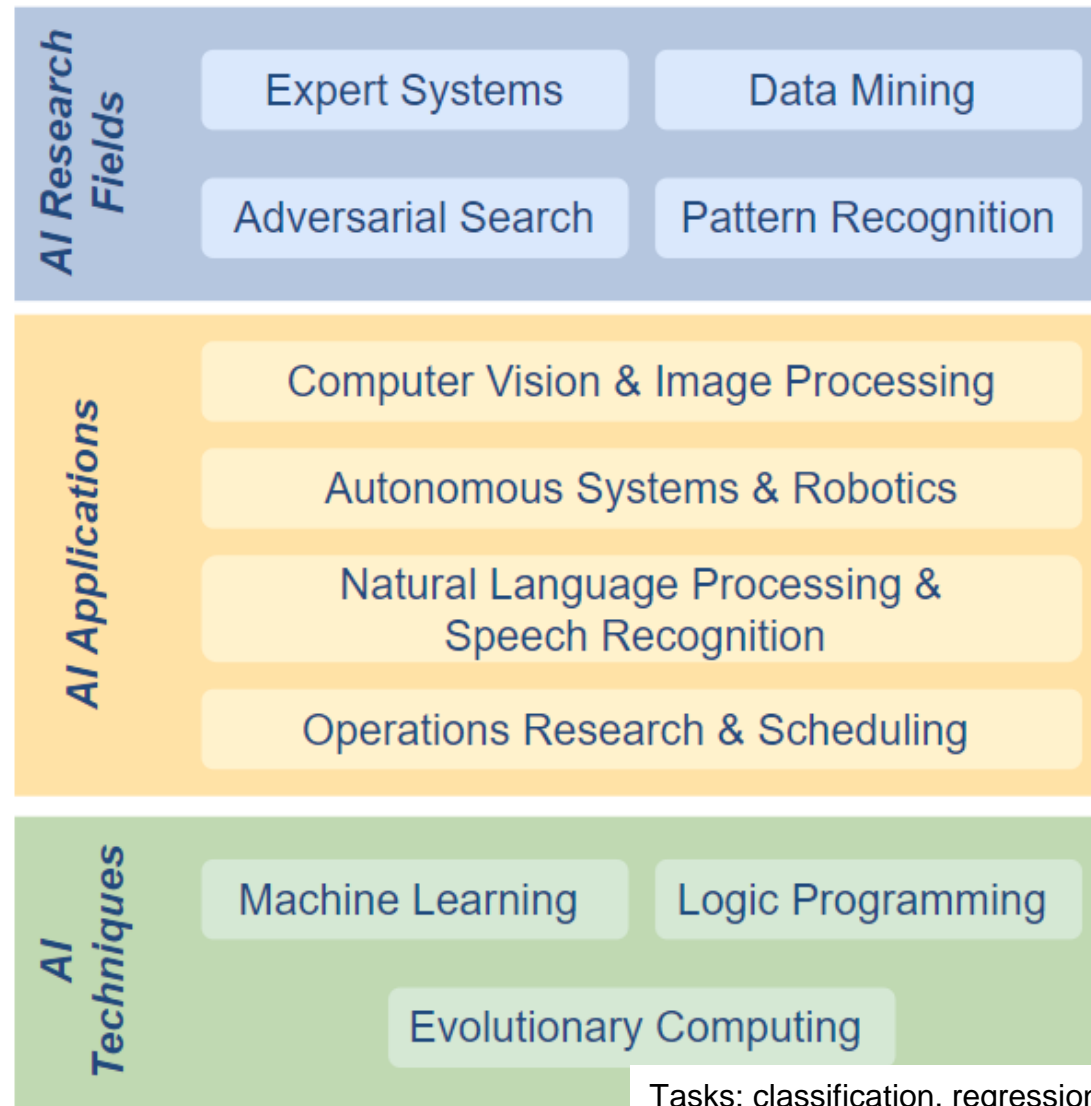
AI taxonomy

- **Class diagram** to establish formal connections

Three main classes:

- AI Research Field
- AI Application
- AI Technique

Data: numbers, pictures, shapes



Tasks: classification, regression, clustering

Algorithms: SVM, tree-based, Bayesian, NN

Learning paradigm: supervised, unsupervised, reinforcement

Training modality: from scratch, transfer

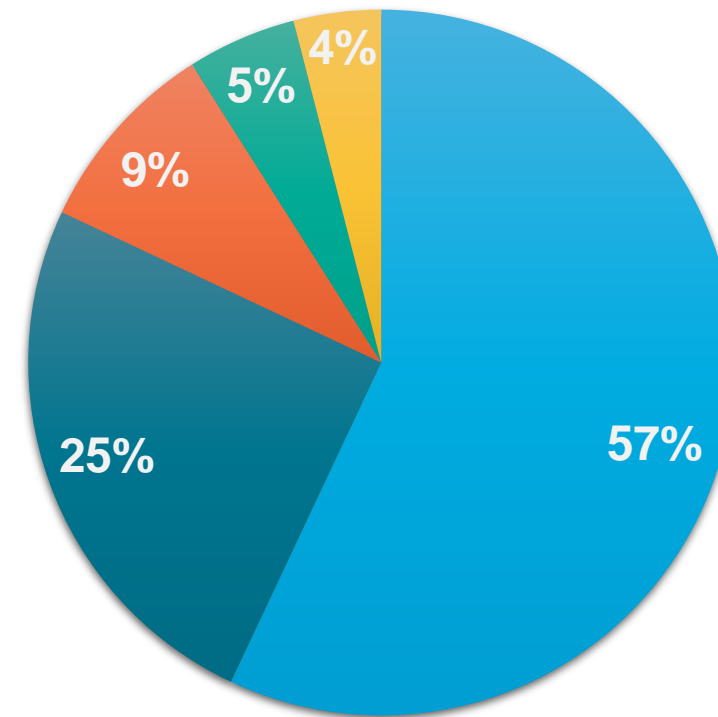
Existing applications

- Seven subdomains



Existing applications

- Majority in Maintenance and Inspection
- No papers in Revenue management and Transport policy



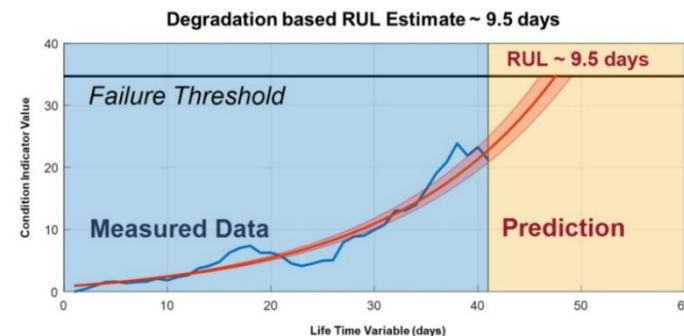
- Maintenance & Inspection
- Traffic Planning & Management
- Safety & Security
- Autonomous Driving & Control
- Passenger Mobility

Existing applications: Maintenance & Inspection

- Problems: detection, diagnosis, prediction, autonomous activities
- Assets: Rail, joint, switch, catenary, wheel
- Data: tabular (e.g. current signals, vibration signals or audio signals), images, videos
- Most applied techniques: Decision trees, ensembles, deep learning (i.e. supervised and unsupervised)

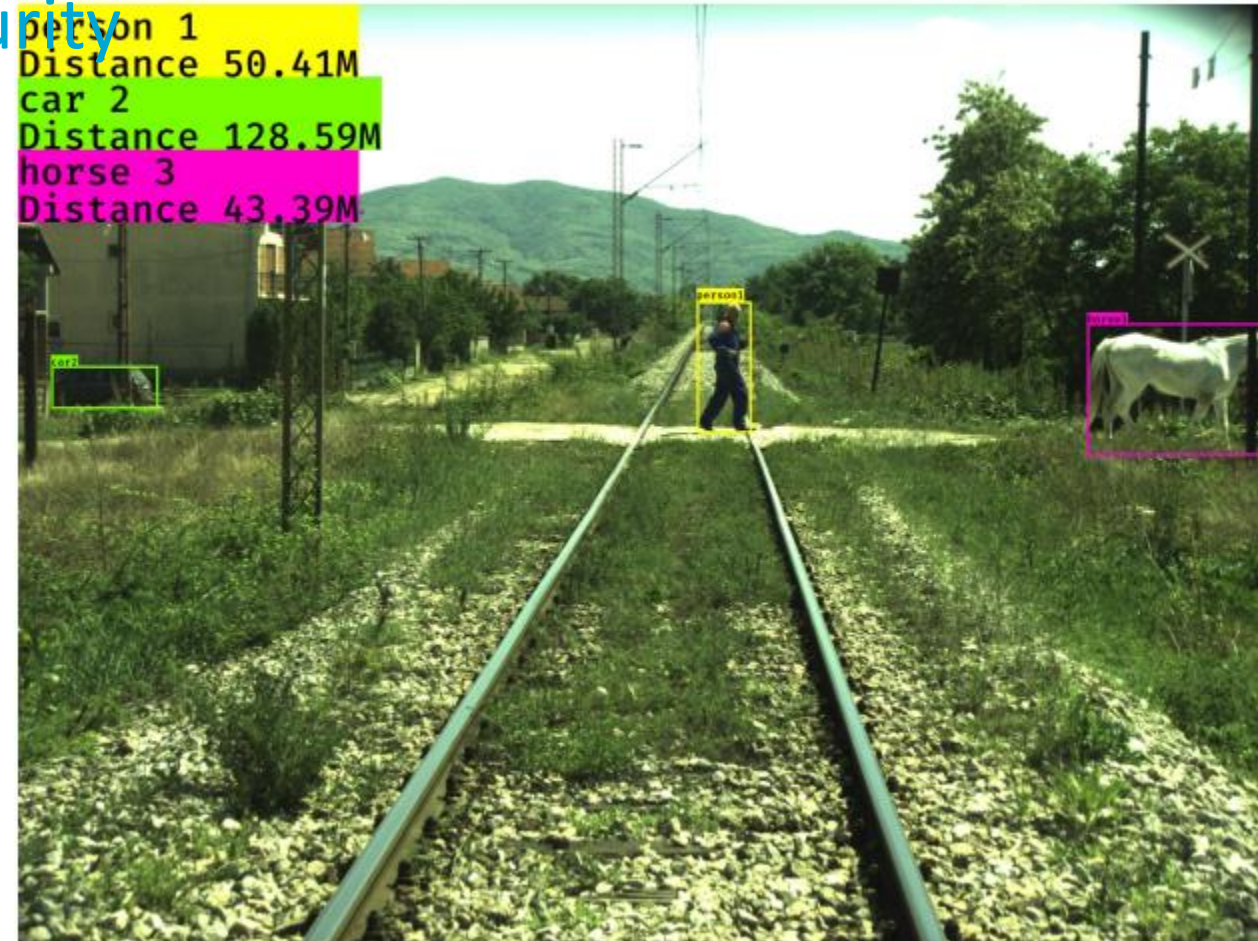
Limited work:

- Combination of autonomous system and AI to perform intelligent autonomous maintenance
- Difficult to identify best approach for a given task, highly depends on dataset and its processing



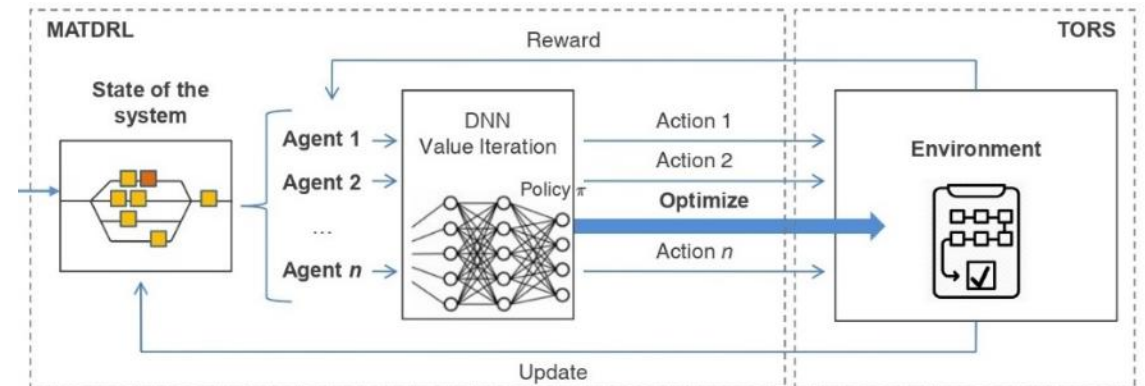
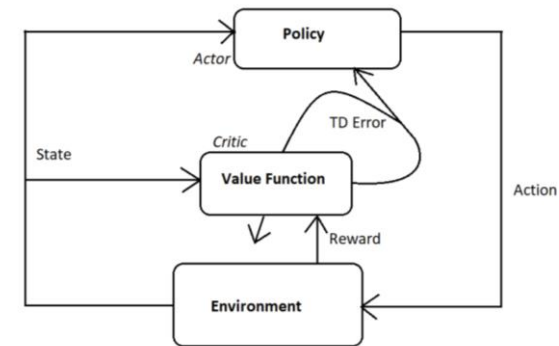
Existing applications: Safety & Security

- Problems: object detection, station security and incident analysis
- Most novel applications are developed based on Expert systems and Bio-inspired methods.
- Computer vision & image processing techniques have been used in anomaly/object detection
- Natural language processing (NLP) of railway accident reports



Existing applications: Traffic Planning & Management

- Problems: traffic predictions, timetabling, rescheduling, shunting
- Predictions address railway lines, providing some initial promising results (trees, forests, NN, RNN)
- ML-based “optimization” approaches for
 - Dispatching (RL, Deep RL)
 - Shunting (multi-agent Deep RL)
- Mostly toy/simplified problems investigated so far
- ML/RL require significant development



Existing applications: Autonomous Driving & Control

- Problems: energy-efficient driving, DAS, ATO
- Genetic algorithms and RL to improve the safeguard level on autonomous driving
- Mainly theoretical simulations, lack of real data
- Limited research on non-vital control systems – expert system can grant valuable knowledge

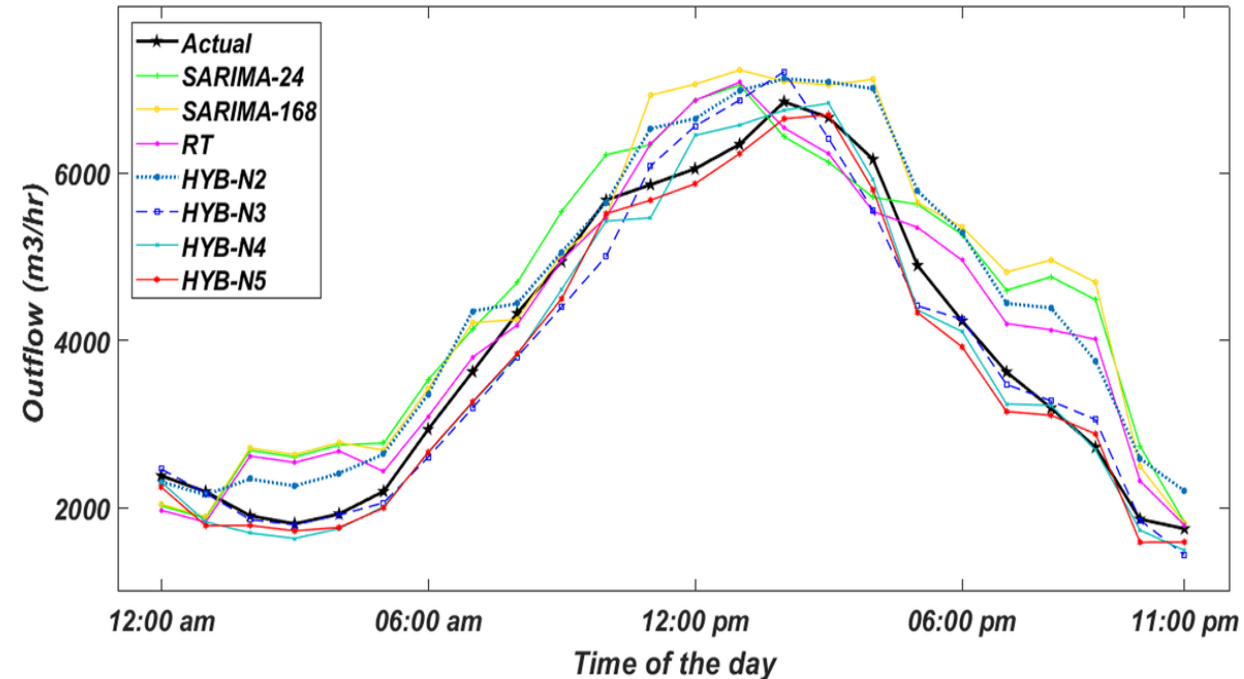
Recently:

- Learning engine characteristics from realized data



Existing applications: Passenger Mobility

- Problems: short-term predictions, passenger experience
- Still limited pool of research papers
- Neural Networks, NLP
- Results across the studies are difficult to be compared
- NLP to evaluate passenger satisfaction with the operations by analysing the information extracted social media.





Future research directions

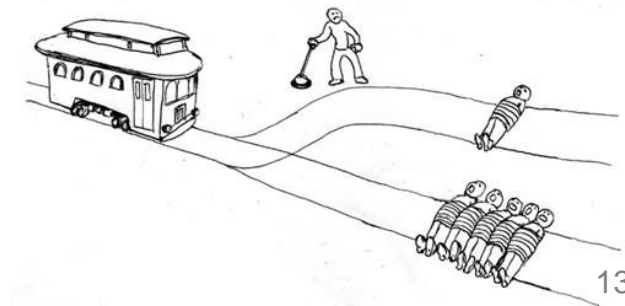
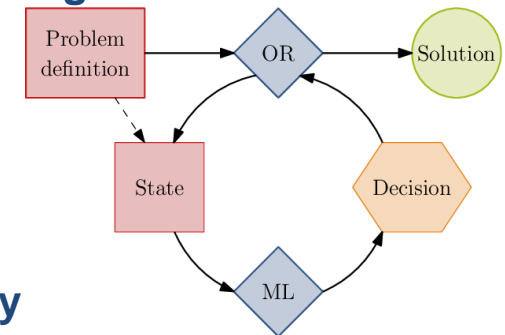


Promising directions

- **Autonomous systems for maintenance**
- Real-time data mining for maintenance and autonomous driving
- Machine learning for autonomous driving
- **Operations research for traffic planning and management**
- AI for revenue management

Challenging directions

- **Trustworthy AI for automated driving and safety**
- Computer vision for traffic planning and management
- Operations research for safety and policy
- Human-in-the-loop, e.g. Active Learning



Conclusions

Five main takeaways:

- Railway AI is still at its **early stages of development** (except M&I)
- **Great potential** of AI applications for future railway systems
- **Data quality and availability** shall be ensured, to support the further uptake
 - ✓ Pappaterra et al. (2021). A Systematic Review of AI Public Datasets for Railway Applications, *Infrastructures*.
- Need for **regulations** for AI (e.g. UAVs, ATO)
- Focus on **simpler** but understandable models
- Stay tuned for new developments at www.rails-project.eu

