Railway Incident Management using Causal Analysis

Project n° 9

01

Context

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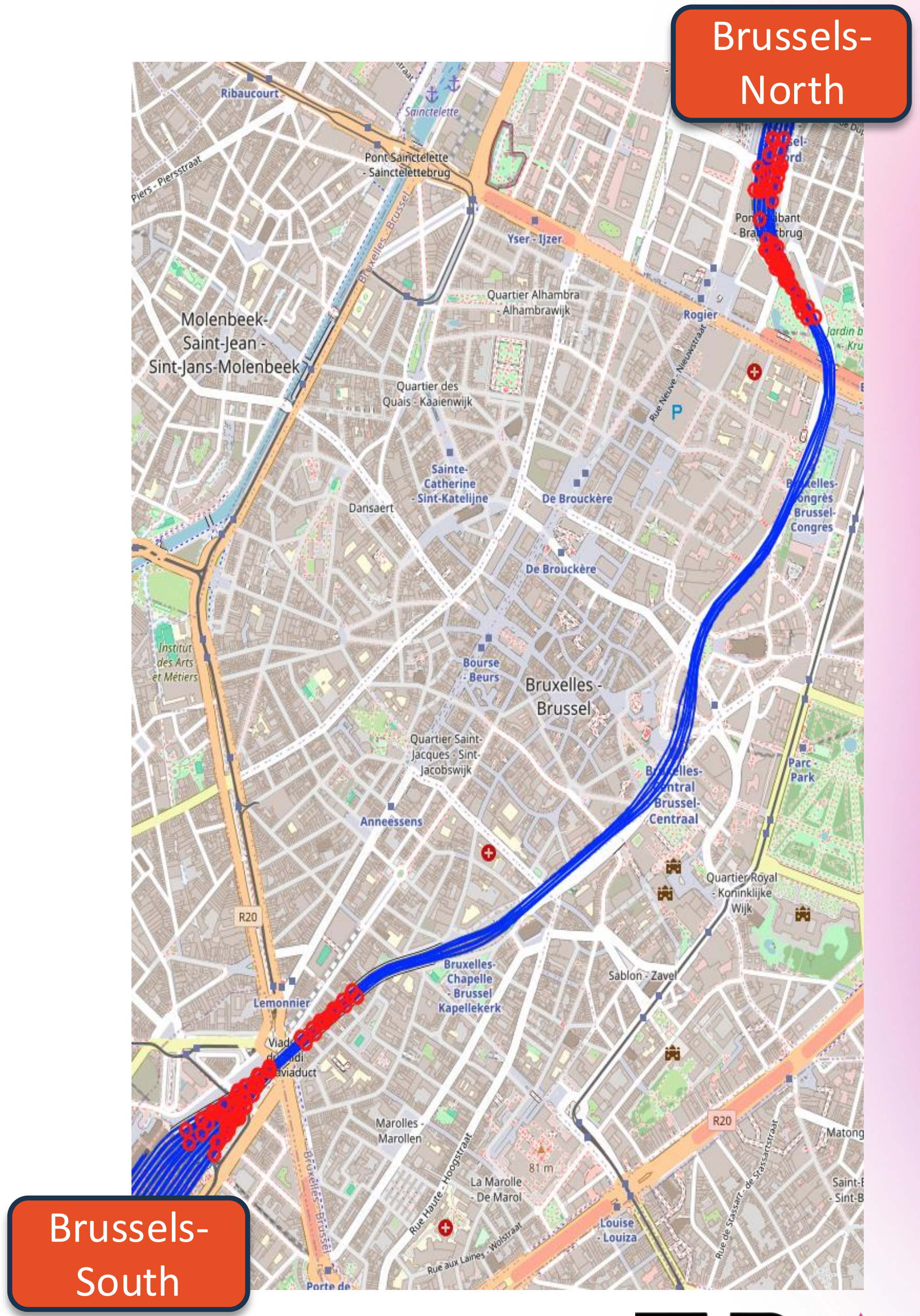
Context : North–South Junction

3,6 km of track

~30% of total fleet (1200 trains/day)

11% of total delay (in 2025)



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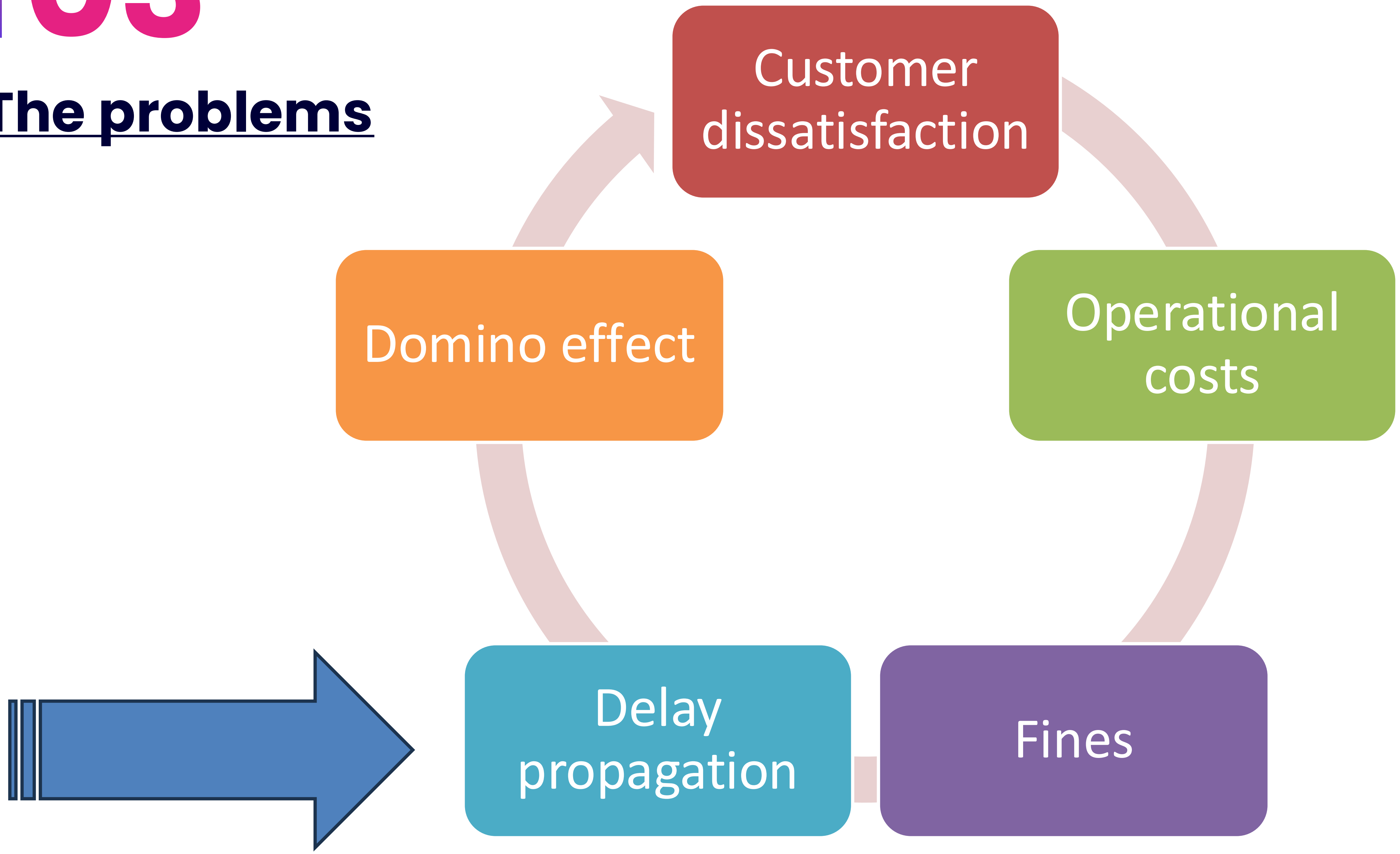
The problems



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Problem : Understand instead of predict

Delay prediction	Forecast future delays	✓
Delay monitoring	Measure and track delays	✓
Traffic regulation	React and manage operations	✓
Root cause understanding	Identify what triggers propagation	✗
Counterfactual reasoning	What if we had acted differently?	✗

We know WHAT happened.
We don't know:

- ❑ **WHY it propagated**
- ❑ **WHAT IF it happened differently ?**

Causal Discovery for Root Cause Analysis

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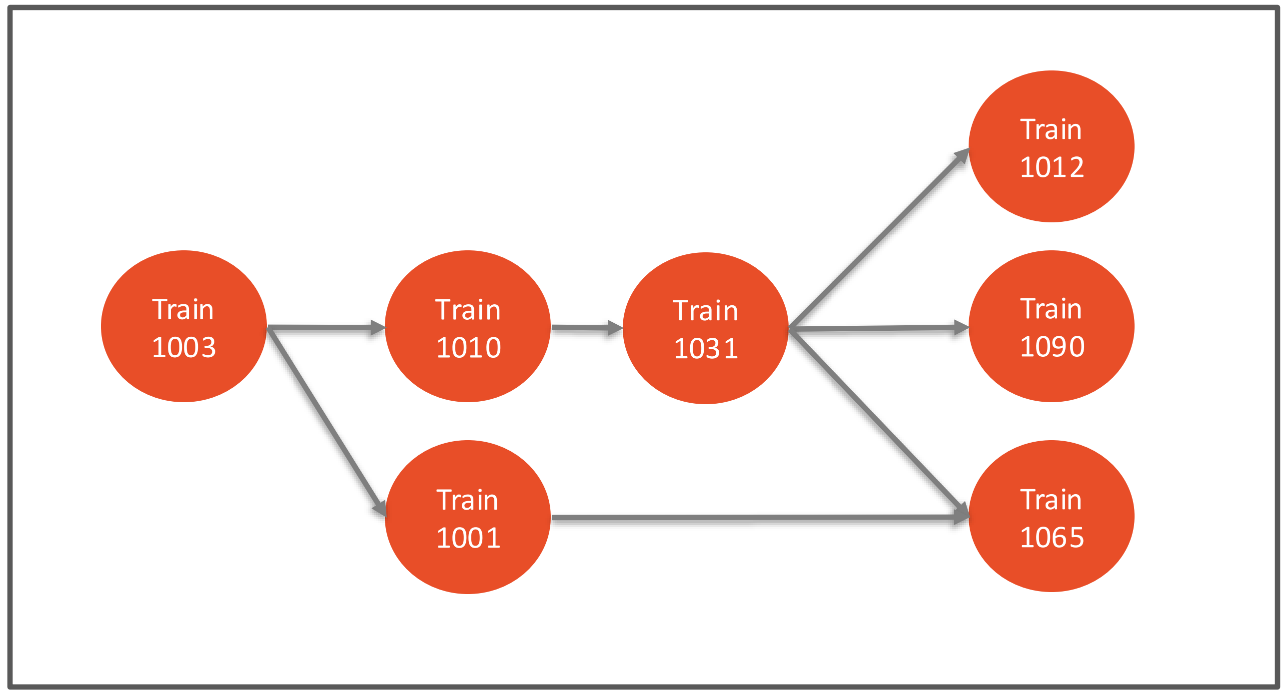
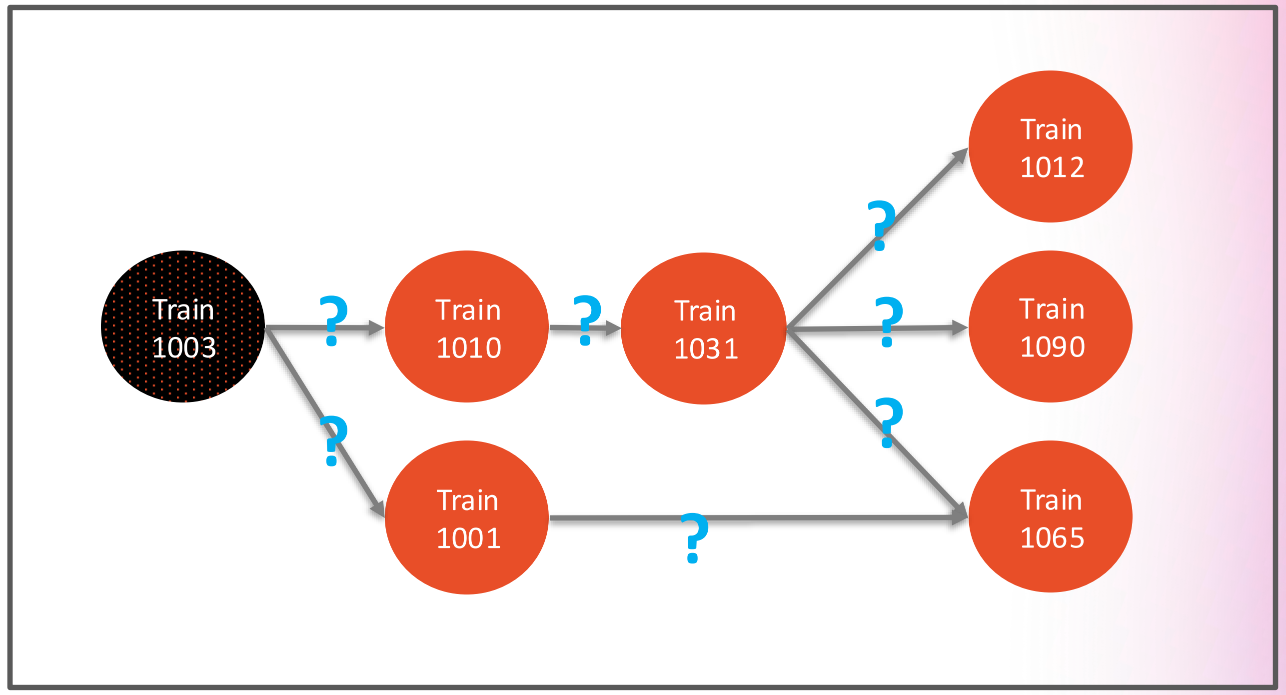
Our solution



1. Temporal Causal Discovery for Diagnostic

Output : cause-effect diagram



2. SUMO to simulate what-if scenarios

Output: decision-making aid

*We know **why delays are propagating** and what is the **best action to take** to avoid them*

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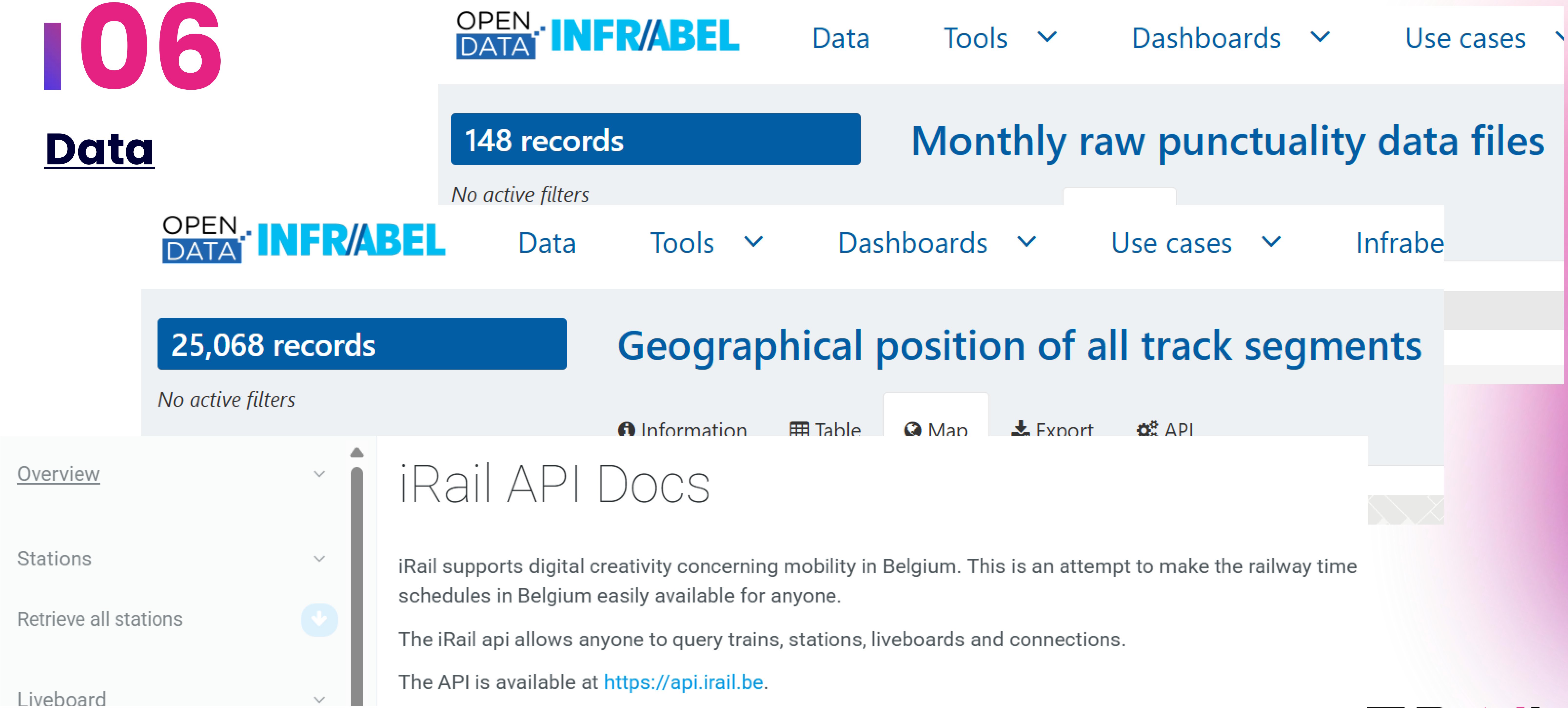
Data



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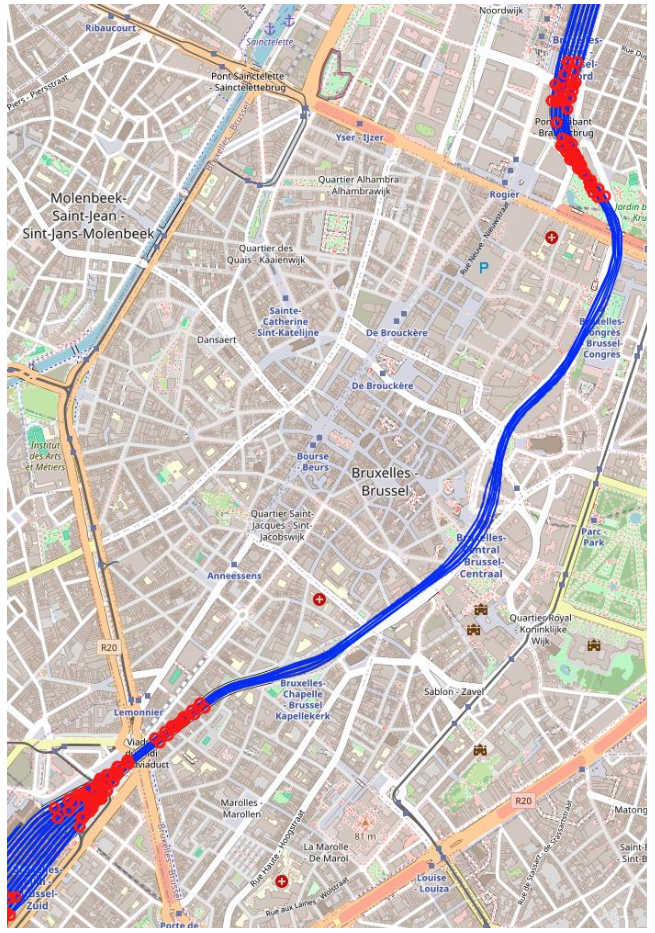
Data

Micro Network Topology



Rail Switch

Traffic data

TRAIN NO	STOPPING PLACE	PLANNED TIME ARRIVAL	REAL TIME ARRIVAL
1003	BRUSSELS-NORTH	10:15:03	**10:25:45 (+10m)**
1065	BRUSSELS-CHAPELLE	10:31:20	10:34:10 (+3m)
1042	BRUSSELS-MIDI	10:47:55	10:46:30 (-1m)

iRail API

Extended Info such as platforms, etc.

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Work Plan

Data Team

- Synthetic data generation
- Preprocessing

What you will learn

Realistic Railway data generation from openly available data sources

Simulation Team

- SUMO setup
- Counterfactual simulation

What you will learn

One of the most used traffic simulation tools in academia and industry

Causality Team

- Explore SOTA Methods
- Build Causal Graph

What you will learn

Granger Causality, PCMCI, Varlingam, Causal Assumptions

Deployment Team

- Make it accessible
- Brick on Factory

What you will learn

Put everything together, bring it to life, make it useful!

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Work Plan

Gian Marco Paldino – Postdoctoral Researcher at ***MLG-ULB (Team Leader)***
- Multivariate Time Series analysis
- Forecasting
- Causal inference

Data Team	Synthetic data generation Preprocessing
mulation Team	SUMO setup Counterfactual simulation
Causality Team	Explore SOTA Methods Build Causal Graph
Deployment Team	Make it accessible Brick on Factory

Melih Taki – Jr. Data Scientist at ***DTSC-BRAIN (Team Leader)***
- Railway systems
- Digital twins
- Causal inference

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Expertise Sought

Are you a network topology expert?

Do you particularly like trains?

Do you know Causality inside out?

Do you have optimization expertise?

Your hobby is to run SUMO simulations?

Have you ever worked with railway data?

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Real life problem

A lot to learn

Impactful solution

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Expertise Sought

Axis 1

- Railway Data & Domain Knowledge

Axis 2

- Simulation and Optimization

Axis 3

- Decision making

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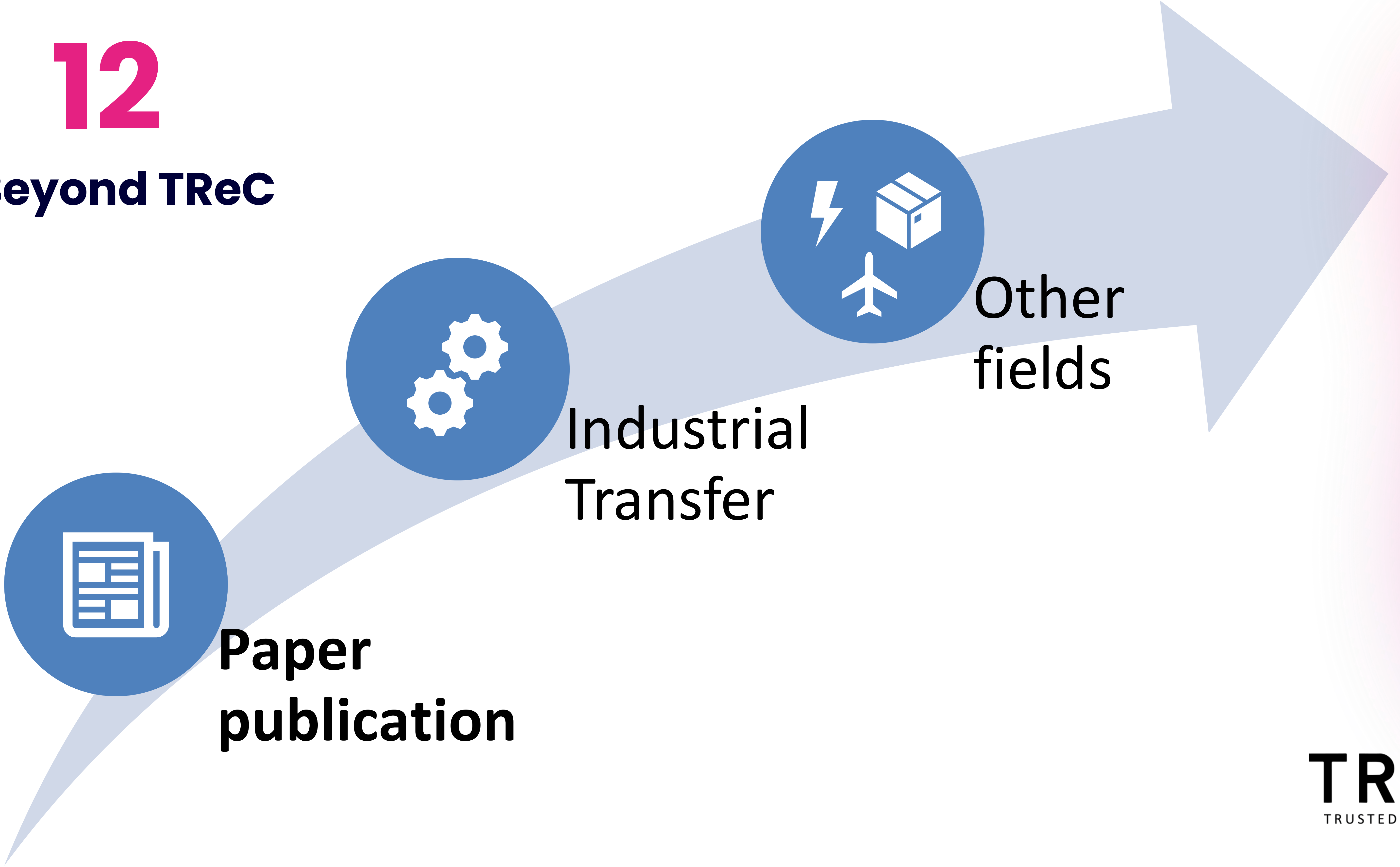
Beyond TReC



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THANK YOU FOR YOUR ATTENTION !

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