PHD proposal: Simulation/optimization for cross-border logistic flows based on a territorial digital twin and a real-time decision-support visualization platform

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Introduction and Context

The EcoLogiX project responds to the program's priority of improving multimodal and sustainable cross-border mobility. It is part of specific objective 3.2, which focuses on developing regional and local mobility that is resilient to climate change, smart, and intermodal.

The cross-border partnership is tackling a shared challenge: the predominance of road transport in freight flows, despite the availability of efficient but underused river and rail infrastructure.

The overall objective of the project is to promote an effective modal shift towards more sustainable modes of transport (rail and waterways) by providing public and private actors with concrete decision-making tools.

EcoLogiX aims to improve the planning and management of logistics flows between Wallonia and Hauts-de-France, building on the complementarity of existing and future infrastructure.

One of the main obstacles to a large-scale modal shift lies in the lack of shared, dynamic and decision-oriented tools allowing stakeholders to:

- visualize infrastructures and flows at the territorial scale,
- understand how the logistics system actually operates,
- assess and compare alternative transport scenarios, in particular those based on rail and inland waterways, in terms of cost, environmental impact, congestion and robustness.

The EcoLogiX project is part of this context and aims at contributing to the development of a more sustainable, resilient and efficient organization of cross-border freight transport. Its ambition is to support the transition towards more intermodal logistics systems by providing public authorities and economic stakeholders with concrete, operational and shared decision-support tools. The overall objective of EcoLogiX is to promote an effective modal shift towards more sustainable transport modes by providing public and private actors with concrete decision-support tools. More specifically, EcoLogiX aims to improve the planning and management of logistics flows between Wallonia and Hauts-de-France by building on the complementarity of existing and future infrastructures. A central outcome of the project

is the development of a digital platform enabling the visualization of multimodal transport infrastructures and freight flows, the construction of scenarios, and the evaluation of their economic and environmental impacts. This platform is intended to act as a territorial digital twin of the freight transport system, fed by heterogeneous data sources and offering an up-to-date and dynamic representation of the system.

In this framework, the present PhD thesis plays a central role. It aims at providing the modeling, simulation and optimization foundations of this digital platform, and at designing methods allowing the analysis, comparison and recommendation of multimodal transport scenarios, with a particular focus on demonstrating the feasibility and relevance of rail and inland waterways solutions.

Research Hypothesis and Objectives

This thesis will be conducted within the framework of the **Interreg France-Wallonie EcoLogiX** and hosted at the LAMIH laboratory.

As member of the “EcoLogiX” project, UPHF plays a central role as leader of the “Decision Support Tool” module. We participate in the design and development of the digital tool for visualizing existing and future infrastructure, as well as cross-border goods flows. This tool will integrate data from various sources (GPS, sensors, traffic data) to provide an up-to-date and dynamic view of transport networks and to support the interactive exploration and comparison of multimodal transport scenarios.

The main activities, in collaboration with other partners, include:

- Development of the Decision Support Tool: Creation of an interactive software platform accessible to transport stakeholders, facilitating strategic planning and optimization of logistics flows and enabling the real-time or quasi-real-time visualization of multimodal freight flows at the territorial scale.

- Needs and Scenario Analysis: Assessment of end-user needs (public authorities, businesses) and simulation of transport evolution scenarios based on demographic, economic, and environmental changes, with a particular focus on scenarios of modal shift from road to rail and inland waterways.

- Integration of New Technologies: Leveraging innovations such as artificial intelligence, Big Data, and digital twins to enhance the resilience and efficiency of cross-border logistics chains, and to build a territorial digital twin dedicated to freight transport.

The research work will follow the plan outlined below:

- State of the art of existing solutions and tools: This first period will be dedicated to the study of the literature where both the scientific contributions and the technical tools will be analyzed;

- Study of simulation and digital twin issues and challenges: simulation including data processing pipeline from logistics network data mapping to visualization;

- Optimization for border logistics flow management: data processing pipeline from collection and data schema definition to valuation and exploitation via optimization and AI;

● Integration, evaluation, and validation of the proposed solutions: this will involve developing use cases for the integration of the proposed solution.

● Dissemination, writing, and defense: the last six months will be dedicated to finalizing the latest scientific and technical contributions and to writing the thesis manuscript which will give a complete view of the scientific questions addressed, the up-to-date state-of-the-art, the proposed solutions, and their evaluation.

Prerequisites

- Master's degree or equivalent in Logistics, Computer Science, Industrial engineering or operational research
- Good background in optimization, computer science and web development tools (Cplex, Python, …).
- Experience in Mathematical programming, simulation and AI frameworks

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