SUBJECT FOR THE INSA-UT PHD PROGRAM OF THE CHINA SCHOLARSHIP COUNCIL

Thesis Title:

"**Design of Intelligent Cycling Ecosystems: Optimization of Infrastructure, Adaptive Navigation, and Immersive Simulation for Sustainable and Safe Urban Mobility**"

Context and Issues:

Cycling mobility is a cornerstone of sustainable transport policies in modern cities. However, cyclists face several major challenges:

- Inadequate infrastructure: Cycling lanes and bike parking facilities are often insufficient, poorly located, or poorly designed, limiting their use and effectiveness.
- Inefficient navigation: Existing navigation tools do not sufficiently account for cyclists' individual preferences (safety, comfort, travel time) or urban constraints (traffic, topography, etc.).
- Complex interactions: Conflicts between cyclists, pedestrians, and vehicles, particularly at intersections, are frequent and hinder the adoption of cycling as a daily mode of transport.

The objective of this thesis is to propose an integrated approach to improve urban cycling mobility by combining:

1. The optimization of cycling infrastructure.
2. The development of personalized navigation systems for cyclists.
3. Virtual reality simulation to study and optimize interactions between cyclists and other road users.

Context and Challenges:

The development of soft mobility, particularly cycling, is a priority for cities seeking to reduce their carbon footprint and improve urban quality of life. However, several challenges persist:

- Insufficient infrastructure: Lack of safe cycling lanes and facilities adapted to cyclists' needs.
- Poorly adapted navigation: Absence of decision-support systems that consider cyclists' specific needs (safety, comfort, interactions with other users).
- Risky interactions: Cyclists are often exposed to dangerous situations, particularly at intersections and in high-traffic areas.

This thesis proposes an innovative approach to address these challenges by combining optimization methods, cutting-edge technologies (virtual reality, artificial intelligence), and urban simulation tools.

Objectives of the Thesis:

1. *Optimization of Cycling Infrastructure*:
    - Problem: How to optimally locate and design cycling infrastructure (cycling lanes, bike parking) to meet demand while maximizing safety and minimizing costs?
    - Criteria considered:
        - Cycling demand: Cyclist flows, points of interest (schools, businesses, etc.).
        - Safety: Reduction of conflicts with other users (pedestrians, vehicles).
        - Costs: Construction and maintenance costs.
        - Interactions: Harmonious integration with other transport modes (public transport, cars, etc.).

2. *Optimization of Navigation Systems for Cyclists:*
    - Problem: How to provide cyclists with real-time optimal routes tailored to their preferences and urban constraints?
    - Criteria considered:
        - Safety: Avoidance of high-risk areas (dangerous intersections, busy roads).
        - Travel time: Minimization of journey time.
        - Comfort: Consideration of slope, cycling lane quality, etc.
        - Interactions: Management of interactions with other users (pedestrians, vehicles).
3. *Virtual Reality Simulation and Interaction Optimization:*
    - Problem: How to study and optimize interactions between cyclists, pedestrians, and vehicles in a complex urban environment?
    - Use of virtual reality (VR) to simulate immersive urban scenarios. Participants will wear VR headsets and pedal on a stationary bike, enabling the study of their behaviors and reactions in critical situations (intersections, conflicts with pedestrians or vehicles).
    - Tools: Integration of SUMO to model real-time traffic and inject virtual vehicles and pedestrians into the VR environment.
    - Objective: Propose optimization algorithms to improve interactions between cyclists and other users, reducing conflicts and enhancing traffic flow.

Expected Results:

- Optimization models for the location and design of cycling infrastructure.
- A personalized navigation system for cyclists, accessible via a mobile application.
- A virtual reality platform to simulate and study interactions between cyclists and other users.
- Optimization algorithms to improve interactions and reduce conflicts.
- Measurable improvement in the safety, comfort, and efficiency of urban cycling mobility.

Keywords:

- Combinatorial optimization
- Operational research
- Cycling infrastructure
- Navigation systems
- Virtual reality (VR)
- Urban simulation (SUMO)
- Cyclist-pedestrian-vehicle interactions
- Sustainable mobility
- Road safety

Candidate Profile:

- The candidate should have a strong background in computer science (Master level).
- A mastery of tools related to Virtual Reality (Unity, immersive headsets) would be an undeniable plus.
- An advanced level in English (writing and speaking) is required.

Supervisor:

Supervisor: Pr. Mahjoub DRIDI