

# PhD thesis : Multi-modal Urban Transport Modelling and Analysis via Complex Networks, Machine Learning and Big Data Processing

---

- **Level of qualifications required:** graduate degree or engineer diploma in Computer Science or strictly-related field;
- **Starting date:** 2018-10-01;
- **Duration of contract:** 3 years;
- **Deadline to apply:** applications will be reviewed until the position is filled;
- **Main Location:** Lyon, France (LICIT, IFSTTAR/ENTPE): <https://goo.gl/maps/K19HBR4ETZ92>
- **Project Team:**
  - **Advisor:** [Angelo FURNO](#) (CR), LICIT, University of Lyon, ENTPE, IFSTTAR
  - **Co-advisors:**
    - Nour-Eddin EL FAOUZI (DR), University of Lyon, ENTPE, IFSTTAR
    - Eugenio ZIMEO (PR), University of Sannio, Italy
  - **PhD Committee:** Marco FIORE (CNR-Italy), Razvan STANICA (INSA-Lyon), Zbigniew SMOREDA (Orange Sense Labs), Sybil DERRIBLE (University of Illinois, Chicago).

## PhD Thesis subject

---

We are looking for an enthusiastic PhD candidate to carry out research in the context of the ANR-funded JCJC project PROMENADE (*Platform for Resilient Multi-modal Mobility via Multi-layer Networks & Real-time Big-Data Processing*).

The goal of PROMENADE is to devise a novel systemic, real-time data-driven platform for efficient, resilient and smart management of multi-modal urban transport, by integrating innovative and sustainable solutions based on complex networks modelling, machine learning and big data technologies.

The scope of the thesis is proposing and devising an innovative data-driven and dynamic graph-based modelling and analysis framework of multi-modal, large-scale urban transport networks to study their vulnerabilities and resilience.

The subject is at the interface among machine learning, big data processing, networks science and transportation.

## Main activities

---

The PhD thesis will explore complex networks, big data and machine learning methodologies and technologies aimed at grasping the complex inter-relationships existing among multiple transport modes (e.g., private cars, bus lines, subways, trams, railway, etc.) and allowing for a more accurate estimation of their inner properties (vulnerabilities, network clusters, inter-dependencies, traffic dynamics, etc.).

Studying networks individually has been recognized as an extremely crude approximation of the reality, hiding crucial structural and dynamic properties of the modelled system [1, 2]. In [3], authors have showed that real-world interconnected networks are not independent: their coupling can have critical consequences and deeply affects the global behavior of a system. Traditional graph-theory approaches are therefore unable

to identify, anticipate and mitigate network vulnerabilities, and preventing cascading failures due to minor or hardly predictable major events [2]. Additionally, such inter-relationships evolve very rapidly due to frequent changes in users' demand and behaviors, network offer and external factors (e.g., weather and social events).

Very recently, multiplex representations have been successfully considered for studying network failures, traffic congestion and efficiency in multi-modal urban transportation systems.

The thesis will have to respond to the need for overcoming traditional static and mono-modal approaches in modelling and analyzing urban transport networks and their interactions, by targeting a novel framework based on multi-layer networks [1, 2] for capturing the complex and dynamic interactions existing among multiple transport modes, urban infrastructures (e.g., land, telecommunications, water system, power grid, etc.), and urban actors (i.e., network providers, users, planners and operators). Such modelling framework shall have the potential for dealing with the complex organization of real-world, multi-modal systems and the exigence of quantifying the interplays among their different actors and components.

The modelling will be tackled according to a data-oriented, large-scale, and real-time perspective.

Road networks and land maps for the city of Lyon will be retrieved with detailed information (e.g., BD Topo) via the academic partnership existing between IFSTTAR and the National Geographic Institute (IGN). Information on public transport networks and bike sharing systems will be available through an ongoing and consolidated collaboration between IFSTTAR and SYTRAL-Keolis Lyon as well as via open data available on the Data Grand Lyon platform. Traffic data will be available via collaborations with multiple industrial partners (Orange Labs, Mediamobile, SYTRAL-Keolis, etc.). Similarly, for the case of Paris, open-data from RATP will be leveraged to reconstruct the public network topology and its supply information. Crowd-sourced data from OpenStreetMap will also be considered.

The PhD thesis will focus on i) enhancing the multi-layer representation with real-time data and mobility patterns, ii) devise novel metrics that can unfold complex properties of the multi-modal urban network related to transport resilience, iii) providing efficient large-scale implementation of the proposed resilience/vulnerability metrics adapted to multi-layer networks, towards continuous monitoring of network vulnerability.

The PhD position offers the opportunity to work in a multi-disciplinary research environment, to access real-world datasets including large scale multi-modal transport networks, multi-source traffic data (GPS traces, loop data, bluetooth data, etc.), mobile network traffic demands collected in an operational, large-scale French cellular network.

It is expected that the successful candidate will contribute to top-tier computer networks, self-adaptive distributed systems, big data and transportation-related conferences and journals (IEEE INFOCOM, IEEE ICDM, ACM SIGKDD, IEEE Big Data, IEEE Transactions on Autonomous and Adaptive Systems, Transportation Research Board, IEEE Intelligent Transportation Systems, Transportation Research, etc.).

## **Skills**

---

We look for strongly motivated candidates with a strong background in computer science, mathematics and probability/statistics. Candidates with proven skills in the fields of big data, network mining and distributed

programming will be preferred. Knowledge of complex networks and machine learning theory will be strongly appreciated. Programming skills with Scala, Java, Python or R are desired.

Proven written and verbal communication skills with fluency in written and spoken English.

## Benefits package

---

- Abroad visiting periods in Italy or US;
- Subsidised catering service
- Partially-reimbursed public transport
- Social security
- Paid leave
- Flexible working hours
- Sports facilities

## Salary

---

- 2,500-2700 euros (gross monthly salary),
- 1,400-1,500 euros (net salary)

## Recruiters' Contacts

---

- Angelo FURNO / [angelo.Furno@ifsttar.fr](mailto:angelo.Furno@ifsttar.fr)
- Prof. Nour-Eddin EL FAOUZI / [nour-eddin.elfaouzi@ifsttar.fr](mailto:nour-eddin.elfaouzi@ifsttar.fr)
- Prof. Eugenio ZIMEO / [zimeo@unisannio.it](mailto:zimeo@unisannio.it)

## Required documents

---

- A curriculum vitae;
- The complete record of master grades (relevé de notes M1 and M2 for French candidates)
- A one-page motivation letter discussing how the candidate's background and research interests relate to the proposed subject and bibliographic references [1-6].

## About the Transport and Traffic Engineering Lab, IFSTTAR - ENTPE

---

The Transport and Traffic Engineering Laboratory (LICIT) is a Joint Research Unit under the dual administrative supervision of the [French Institute of Science and Technology for Transport, Development and Networks](#) (IFSTTAR) and the [National Post-Graduate School of Public Civil Engineering](#) (ENTPE). It is recognized for its work in traffic modelling and engineering. The laboratory has already developed many successful applications for both traffic information and simulation tools

The IFSTTAR is a state-financed scientific and technological institute under the supervision of the Ministry of Research and the Ministry of Transport. The Institute's activities involve diverse fields as acoustics, mechanics, mathematics, computer science, electronics and electro-technical sciences. The diversity of the approach used to carry out the different research programmes gives a multidisciplinary characteristic to the IFSTTAR research teams.

The IFSTTAR research programme covers many aspects of work involved within this project including driving aids, information, assistance and automation; transport networks and services; sustainability, environment and road safety. IFSTTAR has been and still is heavily involved in various projects, especially European Commission-supported research like the INTRO project. IFSTTAR's experience will be used to assist in achieving the aims of this project.

The ENTPE, one of the largest French engineer school, is under the supervision of ministry of transport, trains practitioners and specialist engineers in the various fields of land use, planning, buildings, transport, environment, city policy, etc. Besides this education activities, ENTPE undertakes a strong research activity. Research is carried out in five laboratories covering the expertise of the school: Geo-material, Housing Sciences, Civil Engineering and Building, Environment Sciences Laboratory, Transport Economics, and Traffic Engineering.

## Relevant References

---

- [1] A. Aleta, S. Meloni and Y. Moreno, "A Multilayer perspective for the analysis of urban transportation systems," *Scientific reports*, vol. 7, p. 44359, 2017.
- [2] M. Kivelä, A. Arenas, M. Barthelemy, J. P. Gleeson, Y. Moreno and M. A. Porter, "Multilayer networks," *Journal of complex networks*, vol. 2, pp. 203-271, 2014.
- [3] S. V. Buldyrev, R. Parshani, G. Paul, H. E. Stanley and S. Havlin, "Catastrophic cascade of failures in interdependent networks," *Nature*, vol. 464, p. 1025, 2010.
- [4] **A. Furno**, E. Faouzi, R. Sharma, E. Zimeo, "Fast Computation of Betweenness Centrality to Locate Vulnerabilities in Very Large Road Networks," 97th Transportation Research Board Annual Meeting (TRB), 2018.
- [5] **A. Furno**, M. Fiore and R. Stanica, "Joint spatial and temporal classification of mobile traffic demands," in *INFOCOM 2017-IEEE Conference on Computer Communications*, IEEE, 2017.
- [6] **A. Furno**, M. Fiore, R. Stanica, C. Ziemlicki and Z. Smoreda, "A tale of ten cities: Characterizing signatures of mobile traffic in urban areas," *IEEE Transactions on Mobile Computing*, vol. 16, pp. 2682-2696, 2017.