



**Politecnico
di Torino**



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Scuola di Dottorato - Doctoral School
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PhD Programme in
Urban and Regional Development

PhD Thesis

**Urban evolution: a dynamic model for
development, sustainability and resilience**

Abstract

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Abstract

Since the middle of the XX century, the world's population has experienced a sharp increase due to a general improvement in living conditions; in the last 35 years the urban population has jumped by 2.3 billion people and analyses show a consolidated trend of this phenomenon, which will result in 68% of people living in cities by 2050. The control of urban processes and which tools to use to achieve this result have, therefore, become a central issue for the management of such complex realities, which are constantly expanding economically, socially etc., not to mention the environmental fall-outs.

Starting from the awareness that contemporary cities are complex systems, like any problem dealing with complexity, it is necessary to use tools and methods suitable for urban governance and future development. This research aims to address the specific topic of urban evolution using Mathematical Dynamic Modelling to predict possible growth scenarios of metropolitan areas and to provide further elements to support decision-makers, in order to guide cities' future development.

The first part of the Thesis focuses on the literature review, selecting those sources that allow the identification of subjects, tools and developments that could form the basis of the experimental core of the research. Thus, starting from the city as a complex system, the path develops starting from the identification of the main characteristics and critical issues.

The analysis of the suitable tools from two perspectives follows: on the one hand, their formal foundations and, on the other, their evolution over time and their use in urban environment or in such a way as to provide a valid reference sample for the experimental part of the research. Complex Networks are mainly studied as a tool to identify and understand the internal structure of an urban system (as key information needed to use as the "initial state" for the mathematical model): big cities have already gone through different stages of organisational evolution (changing over time as a result of social, economic and political events) to the actual state of decentralisation, multipolarity and configuration as *city of cities*. Similarly, dynamic models are extensively examined, in relation to their use over time, up to recent applications for prediction purposes with multiple state variables, that revealed to be particularly interesting: even if related to other areas, they show a surprising adaptability to the metropolitan environment.

Finally, resilience, with the most recent conceptual developments for a city and the primary purpose of testing the possibility of using certain mathematical outcomes as a measure of it. The preliminary analysis is therefore carried out in order to address the relationship between a given mathematical equilibrium and resilience.

The second part of the research focuses on the most innovative and experimental part: the development of dynamic models in urban environment. The 2-variable model is the first to be addressed, considering two state variables (pedestrianisation and people's opinion), deliberately without an indicator of urban growth. An in-depth study of the model is performed through the analysis of the solutions, their behaviour and stability. Then, the third state variable (of an economic nature) is added, arriving to the final 3-variable model (the ultimate objective of the research). The study of the extended model is carried out as an analysis of the consequences that the new variable brings to the dynamics previously defined. For both models, the effects of the Hopf's bifurcation and the behaviour beyond it are presented.

In the end, it is worth highlighting the multidisciplinary analysis carried out: the formation of the equations and the analysis of the equilibria follow a mathematical path, but always identifying the meaning and value of the parameters drawn from eminently urban considerations, just as the equilibria are analysed from both points of view.