Chapter 10
Optimization of Traffic Network Design Using Nature-Inspired Algorithm:
An Optimization via Simulation Approach

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ABSTRACT

In this chapter the application of a nature-inspired technique in conjunction with simulation models to optimize the siting of concentration nodes in a traffic network of urban area is presented. The solutions of this optimization problem involve the redesign of the network by adding nodes and arcs to the current traffic network. The problem is a sub-problem of the most general "Traffic Network Design Problem". For this resolution a Genetic Algorithm approach was design and development. The popular Simulator of Urban Mobility (SUMO) is use as traffic simulator in order to evaluate the solutions obtained. This chapter contains the conceptual models and the results of the Optimization via Simulation technique proposed.

INTRODUCTION

These days, urban expansion has become a special issue due to the impact in ecosystem, biodiversity and human activities (Bhatta, Saraswati & Bandyopadhyay, 2010; He, Tian, Shi, & Hu, 2011; Haregeweyn, Fikadu, Tsunekawa, Tsubo, & Meshesha, 2012; Poelmans & Rompaey, 2010). However, the absence of urbanization planning policies around the world has turned this expansion process chaotic and disorganized A very common phenomenon is the urban sprawl, which means that a city has spread into several suburbs connected with the commercial and economic center of the town through highways, resulting thus in vehicle dependency (He, Okada, Zhang, Shi, & Li, 2010).

DOI: 10.4018/978-1-4666-9644-0.ch010

When planning to expand a city, it is necessary to achieve a sustainable use of the land, to exploit the roads and highways with low traffic, and to reorganize the urbanization process in order to guarantee a minimization of the environmental impact and a reduction of traffic problems (He, Tian, Shi, & Hu, 2011).

In this context, in recent years a lot of work has focused on redefining expansion areas in urban settlements (Ferreira & Condessa, 2012), and on employing Geographical Information Systems with sensors to test the impact of urban planning policies (Stanilov & Batty, 2011; Xiao et al., 2006). If investing in new infrastructure (sensors, data recover stations, etc.) is not possible, then the simulation and optimization heuristics become the alternatives to analyze the impact of urban expansion models on the landscape (Poelmans & Rompaey, 2010). In this chapter it is proposed to use a framework based on Optimization via Simulation (OvS) which combines Genetic Algorithms (GA) and Traffic Simulation in order to evaluate the organization urban planning in the cities, taking into account its impact on the traffic network.

The objectives of this chapter are:

- Introduce the traffic optimization problem.
- Introduce the "Origin-Destiny Traffic Assignment Problem".
- Explain how to model the "Origin-Destiny Traffic Assignment Problem".
- Show the main aspects of Genetic Algorithms and Optimization via Simulation.
- Introduce the traffic simulation.
- Explain how to solve the "Origin-Destiny Traffic Assignment Problem" with Genetic Algorithms and Optimization via Simulation.
- Test the effects of parameters selection over the solutions found by OvS.

BACKGROUND

City growth reflects a progressive dynamic that is hardly ever planned, resulting in a decrease of the general performance of its sub-systems (Xiao et al., 2006). In the case of the traffic sub-system, a population growth means more vehicles in the system, higher probability of traffic jams, longer travel times etc. (He et al., 2010). Even though this is not easy to control, it is possible to establish policies related to urbanization permits, to create industrial centers and to encourage activities in strategic zones, which will allow us to control the way the city grows and its associated traffic sub-system (Xiao et al, 2006). In this line, the traffic simulation (Li & Sun, 2012; Nagel, & Schreckenberg, 1992) revels itself as a useful tool to quantify the impact of a certain traffic network topology and the corresponding population assignment (Garcia-Nieto, Olivera & Alba, 2013).

In this chapter, the authors present the problem of deciding where to foment the installation of urban, industrial and/or commercial complexes so that it has a minimum effect over the total traffic system: considering the network already has a certain structure and a dynamic flow restricting possible configurations. The authors define this proposed decision problem like "Restatement of The Traffic Network" and the underlying optimization problem "Origin-Destiny Traffic Assignment Problem" (ODTAP). The ODTAP is an underlying problem of the "Network Traffic Design Problem" (NTDP). The NTDP is the NP-Hard problem of building a traffic network in such a way to minimize the performing function of the system, i.e., the mean travel time in general. In this context, several literature works exist in relation to NTDP, some of them related to the ODTAP issue and urban planning (Friesz, 1981; Current & Min, 1986; Yang & Bell, 1997; Yang & Bell, 1998; Current & Marsh, 1993; Baquela & Olivera, 2014).