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Methods for solving road network problems with disruptions

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Abstract

In this study, we provide two approximate methods for solving both Unidirectional and Multidirectional Road Network problems with Disruptions and connecting requirements. These problems aim at defining alternative paths to deviate traffic flows, allowing the arc orientation to be reversed, such that the network remains strongly connected. The objectives are set to minimize the total travel cost and the number of reversed arcs. Two methods, a Biased Random Key Genetic Algorithm and an Iterated Local Search, are proposed. Numerical experiments with single objective and bi-objective versions are performed and results are hence compared to the exact method studied in previous works.

Keywords: Road network, Heuristics, Biased Random Key Genetic Algorithm, Iterated Local Search.

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1 Introduction

In a real urban network, maintaining a fluid traffic is a key point due to the density of population in urban areas, and the population needs concerning the multiple daily travels. This issue will become relevant and difficult to manage since the concentration of population living in urban areas by 2030 will be about 5 billions of people over 8,3 billions, according to the United Nation Organization. Moreover, the urban sprawl and its road networks cannot be extended indefinitely. In this context, we investigate methods to address disruptions on urban networks by defining alternative paths to deviate the traffic flow.

Disruption of routes can break the network strong connectivity, i.e. existence of a path between every pair of nodes. Thus, alternative paths may require the direction of vehicles' flow to be reversed for some routes, named arc reversals. Another practical solution consists in alternating the traffic. We investigate the Road Network Problem with Disruptions (RND) that is a generic term used to address the Unidirectional Road Network Problem with Disruptions and connecting requirements (URND) and the Multidirectional Road Network Problem with Disruptions and connecting requirements (MRND). A unidirectional road network relies on a simple, directed and connected graph, while a multidirectional road network is modeled by means of a directed, connected, and loopless multigraph. In both problems URND and MRND, two goals are considered: (i) minimizing the number of arc reversals and (ii) minimizing the total travel distance, such that arc reversals are allowed and the road network remains strongly connected. This situation can disturb the users' habits, which justifies the minimization of arc reversals. The major difference between URND and MRND is that the input graph for URND is a representation of one-way road networks, a situation usually found in downtown; while for MRND, the graph is a multigraph, that can model lanes in any urban network. If the objectives (i) and (ii) are optimized simultaneously, the URND and MRND are referred as bi-URND and bi-MRND.

The URND complexity, a mathematical model and Pareto fronts using the ϵ-constraint method were studied in [9]. In [10], the authors show that any instance of the MRND can be represented by a 2-directed multigraph, and present an extended mathematical model. Here, the contributions are the following. We propose heuristic methods able to handle both bi-URND and bi-MRND. For this purpose, a Biased Random Key Genetic Algorithm (BRKGA) [7] and an Iterated Local Search (ILS) [11] were developed. In order to allow the ILS to manage a bi-objective function, the objectives are