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SUSTAINABLE URBAN FREIGHT TRANSPORT: A SIMHEURISTIC APPROACH

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ABSTRACT

In modern society, sustainable transportation practices in smart cities are becoming increasingly important for both companies and citizens. This paper addresses a rich extension of the capacitated vehicle routing problem, which considers sustainability indicators and stochastic traveling times. A simheuristic approach integrating Monte Carlo simulation into a multi-start metaheuristic is proposed to solve it. A computational experiment is carried out to illustrate both the problem and the approach.

1 INTRODUCTION

Nowadays, the growing public concern for the environment preservation and social welfare is leading to more sustainable and smart cities. Some works on routing problems have started to study goals related to fuel consumption. However, there is still a lack of works analyzing sustainability indicators and, to the best of our knowledge, none of them considers stochastic traveling times. Here we present a simheuristic approach (Juan et al. 2015) that integrates the sustainability dimensions (*i.e.*, economic, environmental, and social) and Monte Carlo simulation (MCS) into a multi-start metaheuristic. While the metaheuristic provides promising solutions, the MCS assess them in a stochastic environment by means of simulating scenarios.

In particular, we tackle the capacitated vehicle routing problem with stochastic times (CVRP-ST), which may be defined as a directed graph where each arc is characterized by a traveling distance and a traveling time. The total time of a route is limited by the maximum number of hours that a driver can drive without resting. This constitutes a hard constraint in a deterministic environment. However, this condition cannot be guaranteed in a stochastic environment. For a given solution, each arc has a cost that represents the impacts of traveling through it considering: the *economic dimension*, which depends on the oil price; the *environmental dimension* that considers CO_2 emissions (Zhang, Zhao, Xue, and Li 2015); and the *social dimension*, which monetizes the accident risk (Delucchi and McCubbin 2010).

2 SOLVING APPROACH AND EXPERIMENTS

A simheuristic methodology integrating MCS into a multi-start metaheuristic is presented, which relies on the biased randomization version of the CWS heuristic (Juan et al. 2011) to generate the solutions. The general pseudo-code is shown below.

Algorithm 1 Simheuristic approach

```
1: procedure MAIN PROCEDURE
2:     repeat
3:         sol ← generateSolution
4:         sol ← localSeach(sol)
5:         if {sol is promising} then
6:             expCost(sol) ← MCS(sol)
7:         end if
8:     until stopping criterion is met
9:     return best sol found
10: end procedure
```

The simheuristic has been implemented as a Java application. An experiment has been carried out adapting the following CVRP benchmark instances that may be found in the CVRPLIB library: E-n23-k3, E-n33-k4, E-n51-k5, E-n60-k9 and E-n76-k10. Figures 1 and 2 show the solutions behavior under different road states, and the composition of the solution minimizing the total cost for each instance, respectively.

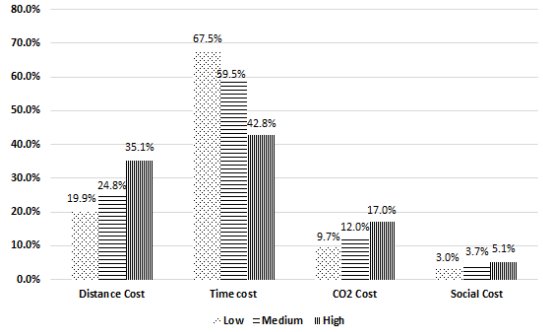

Figure 1: Comparison among different levels of congestion.

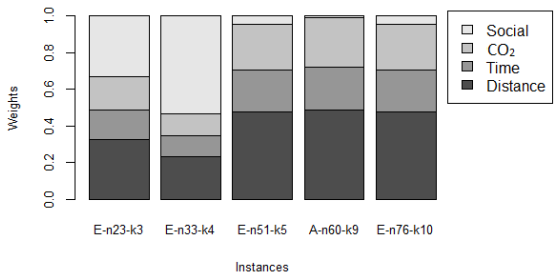

Figure 2: Weight of each component for the best solution.

3 CONCLUSIONS

The growing concern on the negative impacts of transport activities on the environment and population welfare requires the development of optimization methodologies relying on sustainability indicators. To the best of our knowledge, this is the first work addressing a rich vehicle routing problem with sustainability indicators and stochastic traveling times.

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