**VEHICLE ROUTING IN HILLY TOPOGRAPHY CITIES. ECONOMIC AND ENVIRONMENTAL EFFECT OF THE SLOPE ON ROUTE SELECTION**

**Victor Fabio Suarez Chilma1, William Sarache2, Yasel Costa3**

*1Universidad Nacional de Colombia. Cra 27 # 64-60, Manizales, Colombia.*

*Email: [vfsuarezc@unal.edu.co](mailto:vfsuarezc@unal.edu.co)*

*2Universidad Nacional de Colombia. Cra 27 # 64-60, Manizales, Colombia.*

*Email: [wasarachec@unal.edu.co](mailto:wasarachec@unal.edu.co)*

*3MIT-Zaragoza Logistics Center. Edificio Náyade 5, C/Bari 55 – PLAZA, 50197 Zaragoza, Spain. Email:* [*ycosta@zlc.edu.es*](mailto:ycosta@zlc.edu.es)

**Abstract**

In the vehicle routing problem, the shortest route minimizes costs (fuel consumption) and time. However, some contributions have demonstrated the effect of road gradient on both fuel consumption (cost) and emissions. In hilly topography cities, the heights variations generate multiple slope changes between two nodes (positive and negative). In this way, even if a route is the best in terms of distance (shortest route), it is not necessarily the best in terms of fuel consumption. Consequently, when assuming a flat terrain, the majority of existing vehicle routing models are unrealistic in the context of hilly cities.

Since existing vehicle routing models applicable to the topographic realities of hilly cities are scarce, this paper proposes a mathematical model to evaluate transportation routes considering the economic and environmental performance. The model was validated in the city of Manizales which is located in the Andean mountains of Colombia at 2,200 meters above sea level. According the obtained results, when considering variable slopes, the best route is not necessarily the shortest one, due to the need to reduce the CO2 emissions. In fact, the fuel consumption and CO2 emissions, were inferior to a 7.6% in comparison to the shortest route.

**Keywords:** Vehicle routing; hilly cities; fuel consumption; optimization.

**Acknowledgments**

The authors would like to thank Colciencias (Fondo Nacional de Financiamiento para la Ciencia, la Tecnología y la Innovación "Francisco José de Caldas") for its financial support (Project 111971551628).