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# A two-level fuzzy multi-objective design of ato driving commands for energy-efficient operation of metropolitan railway lines

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**Abstract-**

**Policies for reducing CO2 and other GHG emissions have motivated an increase in electrification in metropolitan areas, mandating reductions in energy consumption. Metro systems are keystone contributors to the sustainability of cities; they can reduce the energy consumption of cities through the use of the economic driving parameters in their onboard automatic train operation systems (ATO) and through the strategic design of efficient timetables. This paper proposes a two-level optimization method to design efficient, comfortable, and robust driving commands to be programmed in all the interstations of a metro line. This method aims to increase the sustainability of metro operations by producing efficient timetables with economic driving for each interstation while considering comfort restrictions and train mass uncertainty. First, in the eco-driving level, an optimal Pareto front between every pair of successive stations is obtained using a multi-objective particle swarm optimization algorithm with fuzzy parameters (F-MOPSO). This front contains optimized speed profiles for different running times considering train mass variations. The global problem is stated as a multi-objective combinatorial problem, and a fuzzy greedy randomized adaptive search procedure (F-GRASP) is used to perform an intelligent search for the optimal timetables. Thus, a global front of interstation driving commands is computed for the whole line, showing the minimum energy consumption for different travel times. This method is analyzed in a case study with real data from a Spanish metro line. The results are compared with the minimum running time timetable and a typical timetable design procedure. The proposed algorithms achieve a 24% reduction in energy consumption in comparison to the fastest driving commands timetable, representing a 4% increase in energy savings over the uniform timetable design.**

**Index Terms- energy saving; sustainability in railway transport; efficient timetable; fuzzy logic; multi-objective combinatorial optimization; train control; train load variation**

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