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SUSTAINABLE URBAN FREIGHT LOGISTICS: A COST, GLOBAL EMISSIONS AND POWER CONSUMPTION DATA-DRIVEN MODELLING APPROACH

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Summary: Quantifying urban freight distribution global greenhouse gas (GHG) emissions, power consumption (PC) and operational delivery costs is increasingly scrutinized due to its significant environmental impact and businesses accountability. Key factors such as vehicle type, technology choices, infrastructure characteristics, and Urban Consolidation Centre (UCC) positions substantially influence operational efficiency, which can be addressed by freight demand models integrated with mobile emission and costs modelling methodologies. This study proposes an empirical agent-based operational spatial modelling approach that includes producing firms, consuming firms, and carriers to estimate freight demand based on shipments, integrated with COPERT V and VECTO methodologies to estimate GHG emissions, PC and distribution costs. Our methodology accounts for the effects of updated internal combustion engine (ICE's) and electric trucks penetration on the operational fleet, road network slopes, route assignments, peak/off-peak recharging times and logistics HUBs (UCC) impacts on environmental and economic indicators in Mall of Scandinavia logistics network. Slope estimations were derived from a GIS-based road network integrated with a Digital Elevation Model (DEM), while routes were assigned using Dijkstra algorithm for the shortest path with slope restrictions. Outputs includes number of trips, vehicle kilometres travelled (VKT) based on origin-destination, available fleet capacities, and sustainable key performance indicators (KPIs) related to distances travelled, fleet speed, capacities and technologies. VKT estimations showed a range of 60693.92 to 45854.26 in baseline operations and HUBs insertion. Environmental KPI estimations showed a range of total CO2 emissions from 37939.50 kg to 22989.13 kg, PC from 141901.07 kWh to 89368.16 kWh and distribution costs from 257493.74 SEK to 175790.18 SEK in observed current baseline operation and proposed HUBs with updated vehicle technologies, respectively. The insertion of HUBs with updates ICE's and electric vehicles showed significant reductions to total CO2 emissions, PC and distribution costs. In addition, proposed methodology was implemented to assess off-peak vehicle recharging times with 100% electric current fleet. Green electricity production showed a cost range of 62399.51 SEK to 14602.62 SEK without HUBs and 56418.76 SEK to 13203.02 SEK with proposed HUBs, varying recharging between peak and off-peak times, respectively. The analysis highlights the potential for environmentally efficient freight distribution strategies to simultaneously reduce operational costs in urban settings. Simulations indicated that replacing outdated, lower-capacity internal combustion engine vehicles with efficient, higher-capacity vehicles could reduce the total number of trips and emissions, supporting policy-making, urban planning and sustainability initiatives. Key factors such as cost of sourcing, filling rates, operational speeds, vehicle capacity, fleet fuel and propulsion technology, route choices and HUB positions significantly affect urban freight distribution indicators related to global emissions, power consumption and costs, underlining the importance of an integrated approach to sustainable logistics planning.