

Transport in Mountainous Areas: A Digital Twin Methodology for Public and Private Mobility

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Abstract The transition towards sustainable mobility in alpine regions presents unique challenges, requiring advanced tools capable of capturing complex transport dynamics while supporting evidence-based policymaking. This research introduces a proof-of-concept methodology for developing a digital twin framework addressing daily mobility flows in a mountain valley of South Tyrol, with the objective of identifying electrification opportunities for both public and private transport.

The proposed approach combines Activity-Based Modelling (ABM) for behavioural analysis, transport infrastructure analysis, and energy demand profiling through continuous validation processes integrating real-time data from traffic sensors and monitoring stations in the valley. Through SUMO and SAGA frameworks, the methodology uses ABM to simulate mobility chains involving different vehicle types and travel purposes, incorporating both local commuting patterns and seasonal tourist flows while validating against empirical data.

Origin-destination matrices and traffic count data are integrated with ABM outputs to model internal and external connections across the territory, enabling evaluation of multimodal transport dynamics and identification of current service gaps. The continuous validation methodology requires multiple cycles over several years to evolve from this proof-of-concept toward a fully operational digital twin.

Policy integration focuses on testing scenarios through ABM simulations, such as modifications to public transport schedules within the valley's mobility context and evaluating optimised expansion strategies including zero-emission vehicle fleet transitions. Charging infrastructure deployment scenarios are developed based on activity-based behavioural patterns and energy consumption profiles.

Key findings include identification of optimal charging station locations, quantification of potential emission reductions, and mitigation of traffic congestion during high-tourism periods. The methodology employs a formalisation approach for knowledge transfer, enabling replication to other alpine or rural contexts. This transferable framework offers a replicable proof-of-concept model for regions seeking integrated mobility systems aligned with smart region objectives.