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Decarbonising the transport sector: a very efficient human-powered vehicle designed through a customer requirement-driven approach

Integration of modal shift analysis and comparative life cycle assessment to the mechanical design

By

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Declaration

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The problems of climate change have become undeniable, and we are now approaching, or possibly have just passed, the point of no return. At present, about one third of global greenhouse gas (GHG) emissions come from the transport sector, and these emissions are rising worldwide even after the push for vehicle electrification. Much of the problem is related to vehicles becoming heavier and to more people opting to move around by car. The most practical and powerful means to decrease emissions in this sector is to redesign cities around more human-centric models, abandoning the car-centric approach. However, this process can be slow, as many municipalities are not even considering such an approach yet. Moreover, people do not move around only within cities. If we want to assess the overall issue, we need an integrated approach, that can also be implemented where road infrastructures are slower to change. For this reason, this thesis proposes an integrated approach of the vehicle design, where the mechanical design is intertwined with a comparative life cycle assessment (c-LCA) and a survey analysis.

The case studio is that of velomobiles, which are a class of human-powered vehicles (HPVs) fully enclosed in aerodynamic and structural shells that offer protection from the weather and from injury in case of an accident. Their possible massive introduction to the market is evaluated through a survey to detect customer requirements that would make velomobiles a practical alternative to cars. Subsequently, a c-LCA is performed to address the possible reduction in emissions related to routine trips of the people surveyed. The analysis is comprehensive, also including the impact of diets, which are generally disregarded when speaking of mobility, but are intrinsically interconnected to the impact of the transport sector when HPVs are involved. Results show that velomobiles have the practical potential to reduce GHG emissions of the transport sector thanks to a positive modal shift from more polluting modes of transport. The analyses are performed with dedicated software and simulators purposely designed for this thesis to address the problem thoroughly.

After the c-LCA, some technical details concerning the design of the velomobile are presented. Particular focus is given to the minimisation of the aerodynamic

resistance and to the design of the transmission system. A few insights on safety are also provided, although the topic is only briefly addressed. This work does not provide a complete design of a velomobile, but rather an assessment framework and the preliminary design of selected subsystems.