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Introducing specific power to bicycles and motorcycles: Application to electric mobility

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ABSTRACT

Electric bicycles and motorcycles have emerged as a possible way of improving the transportation system sustainability. This work's aim was to quantify the energy consumption, the trip travel and the driving dynamics on specific routes in Lisbon, Portugal. Six electric and conventional bicycles and motorcycles were monitored, and a methodology to quantify the power required in each driving second was developed: Motorcycle and Bicycle Specific Power (MSP and BSP respectively). MSP and BSP allows characterizing energy consumption rates based on on-road data and to define real-world operation patterns (driving power distribution), as well as to benchmark the different propulsion technologies under the same baseline of specific power. For negative MSP and BSP modes, the conventional and the electric motorcycles and bicycles demonstrated a similar pattern. However, their behavior was different for positive modes, since electric technologies allow reaching higher power conditions. The methodology developed estimates accurately the energy consumption (average deviation of $-0.19 \pm 6.76\%$ for motorcycles and of $1.41 \pm 8.91\%$ for bicycles). The MSP and BSP methodologies were tested in 2 Lisbon routes. For the electric motorcycle an increase in trip time (+36%) was observed when compared to the conventional one, while for the electric bicycle a 9.5% decrease was verified when compared to the conventional one. The Tank-to-Wheel (TTW) energy consumption for motorcycles was reduced by 61% when shifting to electric mobility, while a 30% Well-to-Wheel (WTW) reduction is obtained. For the electric bicycles, an additional energy use is quantified due to the battery electricity consumption.

1. Introduction

The transportation sector is deeply connected to the way society lives, being responsible for the mobility of people and of goods. In 2011, it was responsible for 33% of the European final energy consumption, with the road transportation sector presenting a 82% share of that energy consumption (EUROSTAT, 2013). Furthermore, the transportation sector is also a source of local pollution which results in health problems (European Environment Agency, 2010). This can be demonstrated by statistical gathered data between 1997 and 2008, by the member countries of the European Environment Agency, showing that more than 20% of the population who lived in metropolitan areas was exposed to higher PM_{10} and NO_2 concentrations than the local limit values allowed (European Environment Agency, 2010). Consequently, one alternative to reduce the impact of the transportation sector, especially in urban environments, is to promote less energy demanding transportation

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Acronyms

BSP	Bicycle Specific Power
CB	Conventional Bicycle
CM	Conventional Motorcycle
CO_2	Carbon Dioxide
EB1	Electric Bicycle 1
EB2	Electric Bicycle 2
EM1	Electric Motorcycle 1
EM2	Electric Motorcycle 2
GPS	Global positioning System
MSP	Motorcycle Specific Power
SO_2	Sulfur oxide
TTW	Tank-to-Wheel
VSP	Vehicle Specific Power
WTT	Well-to-Tank
WTW	Well-to-Wheel

modes that can also provide a cheaper, less noisy and a more sustainable alternative than a day-to-day car commute. Bicycles or motorcycles can be seen as an alternative way to gasoline or diesel vehicles for individual urban mobility use, since they enable people to travel longer, faster, with less effort than walking, and with low environmental impact, which makes them efficient transportations modes.

Motorcycles are commonly used in Asia as an affordable fuel-powered vehicle that can enhance mobility in urban centers. However, in Portugal, in 2010, the share of motorcycles in the vehicle stock was of around 3% (Autoinforma, 2014). Although still in residual figures compared to other countries, motorcycles are traditionally less energy demanding than conventional light-duty vehicles in an analysis based on energy per passenger kilometer. Furthermore, the use of bicycles is even more gainful as it allows its users to move at significant speeds, for short distances, with no emissions which brings health benefits (Wang, 2011; Lindsay et al., 2011).

The use of motorcycles does not require a specific infrastructure deployment since they share the road with light-duty vehicles. Nevertheless, recently, some European and American cities have started to deploy dedicated infrastructures to promote bicycle using, including bike-lanes and bike-sharing systems (Baptista, 2013).

However, according to bicycle users, daily commuting still face some drawbacks namely when using conventional bicycles, such as difficulty to travel for very long distances and over hills, as well as the possibility of arriving at their destination (e.g. workplace), sweaty or tired (Dill and Rose, 2012). The introduction of electric bicycles and motorcycles can address some of these issues. On one hand, in electric bicycles, the electric motor will significantly reduce human effort. On the other hand, energy consumption is typically lower in electric motorcycles when compared to the conventional motorcycle (Bishop et al., 2011), bringing the advantage of zero local emissions and of a potential noise reduction. Regarding electric bicycles, although presenting an additional energy use (due to the electric powertrain), it is expected that the overall energy use (human and electricity) is lower than the conventional bicycle energy use (Mendes et al., 2014).

Nevertheless, there are still few studies that quantify the real-world operation impacts of using electric bicycles and motorcycles. Some cities in China observe these technologies as viable and cost-effective when compared to other means of mobility (Cherry and Cervero, 2007). However, other cities are more skeptical toward these electric technologies due to the potential environmental impacts, interference with traffic and safety issues (Cherry and Cervero, 2007). A study in the United States (Dill and Rose, 2012) indicates that most people who own an electric bicycle use it to replace a conventional one or even the car, but not to replace motorcycles or scooters. However, other studies indicate that an electric motorcycle is a good substitute for conventional motorcycles or private cars.

In Oxford, United Kingdom, a study designed to capture the real world driving patterns (using a GPS) and charging behavior (using an energy data-logger) indicates an average energy consumption of 0.10 kWh/km and Well-to-Wheel benefits of 6.1 times less energy, 3.8 times less greenhouse gases and 5.9 times less operation costs compared with the best-selling car (Bishop et al., 2011). Regarding the best-selling conventional motorcycle (petrol), the benefits of using an electric bicycle were 2.9 times less energy, 1.8 times less greenhouse gases and 2.7 times less operation costs (Bishop et al., 2011). This study indicates that the efficiency improvement is around 65% on an electric powertrain compared with conventional.

The environmental aspects of electric solutions are very important since they do not present local pollutant emission (in the Tank-to-Wheel stage), but they are very dependent on the electric energy production system (Well-to-Tank stage). For instance, in China, the comparison between electric bicycles with other transport modes (bus) (Cherry et al., 2009) concludes that electric bicycles have higher emissions of SO_2 (due to burning coal for electricity production) compared to a bus. Nevertheless, the emissions of other pollutants are lower as far as electric bicycles are concerned.

However, the real operational impacts of using bicycles and motorcycles highly depend on operational factors and a systematic approach for dealing with these technologies is still lacking.