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Sustainable transport solution for a medium-sized town in Turkey—A case study

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ABSTRACT

The United Nations projects that 60% of the world's population will be living in urban areas by 2030. Cities account for 2% of the world's area but 75% of the world's energy consumption. For over a century, the automobile has offered affordable freedom of movement within urban areas. However, with the current vehicle population exceeding 850 million, almost all of which are powered by internal combustion engines this situation is becoming unsustainable.

In this article a critical review of the present energy budget of Turkey and its over dependence on imported fuel oil to support the transport sector is carried out. By way of having a closer examination of the energy needs for the private vehicle fleet, experimental work was undertaken for one town in western Turkey—Bolu. The latter town represents a typical municipality in Turkey with the possibility of replication of the present work to other similar conurbations. The work entailed determination of the driving cycle. A software program that has been expressly developed for this type of exercise was then used to ascertain the savings in fossil fuel that may be achieved via use of solar PV-electric vehicles. It has been presently argued that the use of electricity-propelled, two- and four-wheelers offers a sustainable solution.

1. Introduction

Over 6.7 billion people reside on earth, with more than half of the latter population now living in cities and urban areas. With just one out of every eighth human owning a vehicle the current population of automobiles is over 850 million, almost all of which are powered by internal combustion engines. It has been estimated that parked end to end, these vehicles would circle the planet Earth one hundred times (Mitchell, Borroni-Bird, & Burns, 2010).

The year 2007 was the first year in history that more of the world's people lived in urban than in rural areas. The United Nations projects that 60% of the world's population will be living in urban areas by 2030. Furthermore, 80% of the world's wealth will be concentrated in urban areas by that date. The increasing concentration of population and wealth to cities is likely to continue-especially in the developing world. With further global population increase and urbanisation on the horizon congestion will exacerbate the negative impact of the manner in which the automobiles will be driven and on the overall energy consumption. It will not be possible to tackle global automotive energy consumption and green-house gas emissions effectively without a radical change in thinking with respect to urban transport (Mitchell et al., 2010).

For over a century, the automobile has offered affordable freedom of movement within urban areas. Currently, however, a typical automobile is larger and heavier than it needs to be to provide personal urban transport. On an average it weighs 20 times as much as its driver, can travel over 450 km without refuelling, and can attain speeds of over 160 kph. The average vehicle occupies 10 m^2 of road space for parking and is parked about 90% of the time (Mitchell et al., 2010). Furthermore, the typical daily commuting distance in most European cities is less than 40 km.

Worldwide, 18 million barrels of oil is consumed each day by the automobile sector. Annually the vehicles emit 2.7 billion tonnes of CO_2 (International Energy Agency, 2010) and claim 1.2 million lives via accidents (WHO, 2004). Within city centres the average vehicular speeds hardly ever exceed 16 kph (Kenworthy & Laube, 2000).

The first electric car was built in the 1830s by Robert Anderson in Scotland. Breakthrough by Gaston Plante and Camille Faure increased battery energy storage capacity, which led to the commercialization of battery-electric cars in France and Great Britain in the 1880s. Battery-electric vehicles were quiet, clean, and simple to operate, but their batteries took a long time to recharge, were expensive to replace, and had limited range (US Department of Transport, 2010).

Automobiles are quite inefficient with approximately 75% of the energy going into producing heat (MacKay, 2009). In this respect reference is made to Fig. 1 that shows the automobile energy flows

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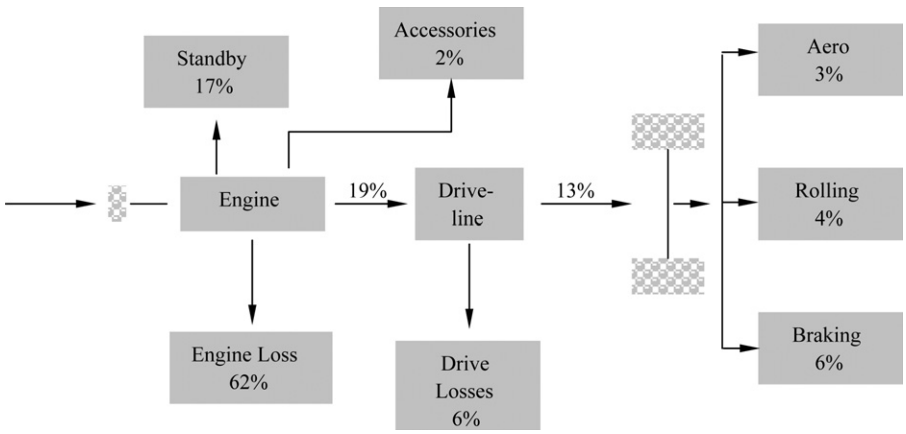

Fig. 1. Energy losses in an automobile.

Mitchell et al. (2010).

for the tank-wheel chain. Research and development is being carried out into manufacturing affordable electric automobiles that offer an improved overall thermodynamic efficiency and in this respect the car manufacturer Nissan has announced plans to produce 50,000 Nissan "Leaf" electric cars in the UK starting in 2013 with a global production of 200,000 units per year. At the same time Chinese manufactured electric scooters are also increasingly making their entry in European cities with a typical scooter costing around 1200 Euro. Such scooters emit around 33 g CO_2/km if charged with fossil fuel electricity. The latter figure however drops to a significantly lower value of 1.3 g CO_2/km if solar energy is deployed to charge the scooter's lead acid batteries (Muneer, Clarke, & Cullinane, 2009a). Within the UK market the 'Charge' scooter company has made available an 'S1' electric scooter that uses lithium-ion batteries and costs 2800 Euro. The 48-V, 40 Ah battery requires 4 h to add an 80% charge and can deliver a 55 km trip. 'Charge' is also exploring the possibility of providing solar PV panels for an upcoming 400-home eco community in Newcastle, England with the view to charge their electric scooters. The PV panels will be sourced from 'China Solar' against a module cost of 1100 Euro/kW peak capacity.

There is also innovative work being carried out by manufacturers such as General Motors to drastically reduce the size of the present automobile by introduction of ultra-small vehicles (Mitchell et al., 2010). The latter will be more expensive than electric bikes, but they should be less expensive than conventional cars. Powered by a 4 kWh lithium-ion battery pack and propelled with two 5 kW wheel motors they will weigh around 450 kg.

Electric motors are typically three to four times more efficient than their petrol-fired counterparts. They also have far fewer moving parts, i.e. there are only five main moving parts in an electric vehicle as opposed to hundreds in an internal combustion engine. It may easily be shown that the overall efficiency of all-electric vehicle (power plant-to-wheel energy chain) is around twice that of its petrol-engine counterpart, taking the tank-wheel chain for the latter vehicle. Trials conducted by the Finnish Think City car company has shown that the lithium-ion batteries can hold a charge that is worth 160 km of travel distance with the batteries themselves lasting more than 10 years. Furthermore, lithium is being sourced from dried salt lakes in South America and China. There are also plans for lithium to be extracted from salt water from sea. Work is also under progress for development of battery technology based on other light metals such as zinc or nickel.

The main goal of this work is to review the energetic and environmental impact of the transportation sector in Turkey, assess the propulsion energy requirement of automobiles for a small town's fleet and then determine the benefits of replacing a proportion of the conventional fleet with electric two- and four-wheelers. With the view to conserve maximum possible propulsion energy, the use of kinetic energy recovery system shall also be investigated. As opposed to the presently available hybrid cars, all-electric propulsion lends itself more naturally for energy conservation via regenerative braking for maximising the battery charge.

2. Turkey and its economy

Turkey is made up of a European part, Eastern Thrace, and an Asiatic part, the Peninsula of Anatolia, separated by the Dardanelles, the Sea of Marmara and the Bosphorous. Eastern Thrace located in the southeast of the Balkan Peninsula, makes up less than one-thirtieth of the country's total land area. Anatolia is a mountainous area with many lakes and wetlands. The Ponticas range in the north and the Taurus range in the south form the natural boundaries for the Anatolian Plateau, which extends eastward to form the Armenian plateaus (The World Guidebook, 2004). Turkey is one of the largest economies within the Balkan region achieving an average annual growth rate of 5.6% over the past 25 years and a GDP/capita of 9980 Euro (in 2009). Strong population growth of 1.45% per annum and rapid urbanization has played an important role for development of Turkey. Table 1 presents information on the make-up of Turkish population centres.

Turkey is a free market economy that is oriented towards Western markets. It also has strong ambitions to join the European Union and this factor has been beneficial but also taxing with respect to its changing economic situation. Turkey imports nearly 70% of its energy requirements. The country spends 40–50% of its total export income to import fuel, mainly crude oil and natural gas. Table 2 shows that the transport sector is an increasing and considerably high cost centre for Turks.

2.1. The energy budget

The following energy and econometric data for the year 2009 will enable an assessment that pertains to the present study:

Table 1
Breakdown of Turkish cities according to their population.

	Number of cities
Over 5 million	1
Between 1 and 5 million	4
Between 500,000 and 1 million	5
Between 100,000 and 500,000	36
Between 50,000 and 100,000	25