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Ex-post environmental and traffic assessment of a speed reduction strategy in Madrid's inner ring-road

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ABSTRACT

Since urban traffic is a major source of CO_2 and NO_x emissions, cities play a key role averting climate change and combating air pollution. Most researchers agree on the need of designing comprehensive mitigation strategies instead of applying isolated measures. Nevertheless, it is important to understand the specific impact and scope of each measure to look for the most effective synergies among them. In 2004, the Madrid City Council launched a plan to re-design its inner ring-road to move traffic out of the city centre. For safety reasons the planned speed limit for the full-renovated South-West section was finally reduced from 90 km/h to 70 km/h. Besides contributing to traffic safety, this strategy could also be seen as positive to the environment due to the associated reduced fuel consumption and lower emissions. However, lower speed limits have lower rates of community acceptance due to its impact on average travel times at the individual level. This paper conducts an ex-post evaluation of this speed reduction strategy to explore its environmental and traffic performance impacts. The results support the thesis that, in this velocity range, lower speed limits present important opportunities for reducing GHG and air pollution in the section affected by the measure, without substantially altering traffic performance. The implementation of the new speed limit policy produces a 14.4% and 16.4% reduction in CO_2 and NO_x emissions respectively, while global travel time remains virtually constant and the saturation rate decreases slightly. Besides, this cost-effective measure reveals great potential to reduce air pollution in highly populated urban areas located next to urban highways. This work provides local policy makers and city managers with useful insights regarding potential co-benefits of traffic optimization and speed reduction management to reduce mobile source emissions in urban environments.

1. Introduction

In the EU-27, transportation is responsible for 20.3% of total greenhouse gas emissions, and about 88.2% of all GHG emissions are related to CO_2 (EEA, 2012a). The transport sector is also a key source of air pollutant emissions, and accounts for 58% of emissions of NO_x, 18% of NMVOC, 30% of CO, 21% of SO_x, 27% of $PM_{2.5}$ and 22% of PM_{10} (EEA, 2012b). At an urban level, it is estimated that cities account for two-thirds of the world's overall energy consumption and contribute an estimated 70% of the world's GHG (IEA, 2014). Particularly, urban transport contribution to CO_2 emissions is estimated at around 25%. Moreover, road transport is the largest contributor to NO_x emissions in urban environments (EEA, 2006). The average contribution of urban and local traffic to NO_2, which is one of the components of NO_x, concentration, is estimated at 64% (Sundvor et al., 2012). Furthermore, an increase in transport activity, and hence a rise in transport emissions, is expected in the near future due to: (i) the predicted growth in urban population (over half the world population now lives in cities, and estimations indicate that over 70% will do so by 2050), (ii) the predicted growth in passenger vehicles (there are about 1.2 billion passenger vehicles today, a figure that is expected to reach 2.6 billion by 2050 (UN-HABITAT, 2011), and (iii) the current trend of urban decentralization in virtually all metropolitan areas (Giuliano and Small, 1999).

A number of authors are examining the role of transportation in climate change mitigation, both in general (e.g. Schipper and Fulton, 2003; Wright and Fulton, 2005; Åkerman and Höjer, 2006; Chapman, 2007; Bristow et al., 2008; Yang et al., 2009) and at an urban level (e.g. McAndrews et al., 2010; Banister, 2011a; Hickman et al., 2013). All of them suggest that there is not a single measure to effectively reduce GHGs; therefore, mitigation strategies should be designed with a comprehensive approach. Successful solutions to achieve low-carbon transport systems should include, but are not limited to, land-use interventions, promotion of public transport systems and non-motorized transport modes, improvement of vehicle fuel efficiency and implementation of transport demand management strategies and traffic management solutions.

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Although most researchers agree on the need to design holistic transport emissions reduction policies instead of individual measures, it is critical to understand the explicit impact and scope of each isolated measure in order to (i) better understand potential co-benefits, (ii) look for the most effective synergies, and (iii) select the most appropriate geographic area to apply them. This paper shows how implementing a cost-efficient measure in one artery of the city it to achieve environmental and operation benefits for the whole city is possible. To do so, it conducts an ex-post evaluation of a speed reduction strategy in Madrid's inner ring-road (M30) using a model for the joint assessment of the impact of reduced speed limits on traffic operation and emissions in the city of Madrid (Spain). In particular, this paper will analyse the effects of reducing the speed limit from 90 to 70 km/h on an 8.8 km section of the M30.

This work provides local policy makers and city managers with useful insights regarding potential co-benefits of traffic optimization and speed reduction management in order to reduce mobile-source emissions in urban environments. In contrast to previous studies, this paper takes both the environmental and traffic performance impacts of the measure into account, as well as the different spatial effects of GHGs and air pollutants.

The following section explains the importance of traffic and speed management strategies in fighting both climate change and air pollution. It compiles different examples of CO_2 and NO_x reduction strategies, highlighting the fact that usually scant attention has been paid to the joint impact on emissions and traffic performance. Section 3 provides background information on the city of Madrid, and specifically on the M30 ring-road where the speed limit reduction was applied. Section 4 explains the assessment model, scenarios and indicators used for the joint analysis of traffic performance and emissions. Section 5 reports the results of the assessment model in terms of the variation in the selected traffic performance and emissions indicators for an average working day. Finally, the assessment conclusions and policy recommendations are set forth in Section 6.

2. Literature review

From a macroscopic point of view, transport emissions are a function of driving conditions (average speed is the input for macroscopic emission models, although traffic dynamics are also important), total travel activity (km travelled), and vehicle technology and fuel efficiency. Traffic management strategies can affect the first two factors, which are indeed closely related. Among all traffic management strategies, one of the most cost-effective ways of reducing road transport emissions is lowering speed limits (TRB, 2012). A recent study on Spanish motorways (Monzon et al., 2012) concludes that, out of those analysed, the most effective traffic management strategy to reduce emissions is the reduction of motorway speeds for cars, a finding also borne out by the sensitivity analysis.

Higher speed transportation fosters economic development by enhancing mobility, decreasing travel times and facilitating access to goods, services and facilities. Higher speeds still enjoy significant rates of support from society and industry, although they imply major adverse impacts on safety, environment and the liveability of urban areas (ECMT, 2004). Speed limits have traditionally had a twofold function (Archer et al., 2008). On the one hand, they limit maximum speed to improve safety, and on the other, they reduce dispersion in driving speeds, which not only increases safety but also improves traffic flow efficiency. Like Sweden Vision Zero (Tingvall and Haworth, 1999), numerous other studies support the idea that lower speed limits lead to a significant reduction in traffic accidents (Woolley, 2005; Aarts and Van Schagen, 2006; De Pauw et al., 2013).

New trends arising from global concern about climate change also ascribe an energy conservation function to speed limits. It is well known that during the 1970s oil crises, the US government applied a nationwide speed limit reduction of 90 km/h to conserve fuel, which remained in effect for almost 25 years. In several countries in Europe, as well in Spain, this measure was replicated by setting a range of speed limits. In 2011, for energy conservation reasons, the Spanish government lowered the motorway speed limit again, in this case from 120 km/h to 110 km/h. Asensio et al. (2014) evaluated this policy and found evidence of a 2% to 3% fuel consumption reduction. Although lower and more strictly-enforced speed limits have proved to be a straightforward and efficient policy for reducing road transport externalities (accidents, emissions, noise and so on), community acceptance is still low due to its impact on average travel times at the individual level. However, the effects of speed on reducing travel times tend to be overestimated, especially in urban areas where time savings are often small or negligible due to short trip length and frequent stop-and-go cycles, usually caused by numerous intersections, traffic lights or heavy congestion rates (Archer et al., 2008). Moreover, current trends in transport sustainability research, suggest that both distances travelled and speed should be reduced to look for positive co-benefits for the environment, energy, social inclusion, wellbeing and the economy (Banister, 2011b). This proposition is also supported by May et al. (2011), who argue for the integration of sustainable transport and road safety policies to facilitate better environmental and road safety outcomes. According to the results of a European public poll (FER, 2011) about two thirds of EU citizens were willing to modify a car's speed in order to reduce emissions. However, around 40–50% of drivers (up to 80% depending on the country and type of road) drive above the legal speed limit.

A number of studies have examined the relationship between speed limits and reduced emissions or fuel consumption. In Germany, a 4.8% reduction in fuel consumption was achieved after lowering the speed limit to 100 km/h on motorways and 80 km/h on roads outside urban areas (GIER, 1996). A recent study on Spanish motorways (Monzon et al., 2012) concludes that the reduction of motorway speeds for cars, could led to a 5.5% reduction in CO_2 emissions. Most studies also show that a reduction in speed limits leads to lower air pollutant emissions. In Austria, lowering speed limits on motorways from 130 km/h to 100 km/h led to a 17% reduction in NO_x and 25% in CO_2 emissions (ECMT, 1996). Keuken et al., 2010 conducted a study in Rotterdam showing a 5–30% decrease in NO_x emissions after reducing the speed limit from 100 km/h to 80 km/h on its urban ring-road. Orbital motorways bring about major environmental problems: barrier effects, noise, air pollution and GHG emissions due to their high annual average daily traffic (AADT), high average speeds during off-peak hours, and high congestion rates during peak hours. There are a number of studies assessing their impact on transport, accessibility and land use (e.g. Gutiérrez and Gómez, 1999); however, there are scant examples analysing their environmental impacts (Monzon et al., 2005) and even fewer of how implementing lower speed limits in orbital motorways can reduce traffic emissions (Keuken et al., 2010). Environmental issues are crucial in cities where urban ring-roads run through dense built-up areas, which is the case of M30 (Monzon and Villanueva, 1996).

Some of the studies mentioned before introduce some examples of how lower speed limits can reduce traffic emissions. However, there is a lack of studies and tools combining the two points of view: traffic analysis and exhaust emissions. Besides, the impact lowering speed limits has on travel times remains questionable (Shefe and Rietvel, 1997) and, according to the European Environmental Agency (EEA, 2011), it could be more acceptable through scientific evidence and knowledge-sharing. The joint assessment proposed in this paper will provide insights on the environmental benefits of speed reduction policies, as well as on their potential trade-offs regarding urban mobility.

3. Case study background and relevant targets

Madrid is a city of 3.5 million inhabitants, and 6 million in its metropolitan area. It is undergoing a rapid suburbanisation process, in which population and jobs are moving out of the city centre. This process is