Conference Paper

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Examining the Influence of Road Slope on Carbon Dioxide Emission using Extended Floating Car Data

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Abstract. Traffic contributes to a high amount of total greenhouse gas emission. This paper examines the issue whether road slope has a significant influence on carbon dioxide emission when driving a car. CO2 measurements are temporally and spatially restricted when using conservative methods, so this work makes use of extended floating car data (xFCD). An experiment is being set up for collecting data, which has been acquired for four months using an xFCD-equipped vehicle. In this time period, about 100 recordings have been acquired. Findings include a moderate positive correlation between road slope and CO2 pollution. This fact has been substantiated by a Pearson Correlation analysis. Consequently, an influence of slope on greenhouse gas emissions appears to be present for a certain local area.

Keywords. Floating car data (FCD), xFCD, CO2, Emission

1. Introduction

Carbon dioxide (CO2) is considered as one of the main causes of global warming. Because of the increasing use of cars, CO2 values in the atmosphere rise, even though the combustion technologies get more efficient. In 2013, about 20 percent of global greenhouse gases in the European Union have been emitted due to the infrastructural sector. In the United States, the transportation sector even comprises an amount of about 33 percent on greenhouse gases (Gately et al. 2013). Consequently, improving vehicle techniques is a very important research area (Stocker 2014).

Introducing the extended Floating Car Data technology (xFCD), Pucher (2015) and Krampe et al. (2013) have been establishing a capable technique for traffic analysis. Enriching the common FCD technique with data acquired from vehicle diagnostic systems, it is possible to analyze CO2 emission with respect to spatio-temporal phenomena.

The aim of this paper is to show that the composition of the roads, in particular the slope, has a direct influence on carbon dioxide emissions. Therefore, extended Floating Car Data is being analyzed.

2. Using Extended Floating Car Data for Traffic Analysis

Floating Car Data has evolved to a reliable and cost-effective way to gather accurate traffic data. Whilst many conservative methods for collecting vehicle data like inductive loops or video cameras are inflexible, FCD technology is capable of providing real-time traffic data without high maintenance or installation costs (Fabritiis et al. 2008).

Apart from coordinates, Floating Car Data includes a timestamp. Hence, spatio-temporal processes can be analyzed and depicted. Since FCD is very suitable for traffic pattern analysis, highly frequented means of transportation like taxis or busses preferably get equipped with this technology (Körner 2011).

For tooling up a vehicle with FCD qualified gear, the SAE J1962 standard of interest can be utilized. Since 1993, every European vehicle owns an electronic system in order to control driving-specific functions like fuel injection, temperatures or appearing trouble codes. In 2001, this procedure has been standardized in the course of the Euro III agreement. For extracting this kind of data, an OBD connector can be used. When enriching this output with corresponding spatial data using an external device, Floating Car Data is being produced (Ortenzi et al. 2010).

Since other vehicle parameters like fuel consumption can also be extracted easily using vehicle diagnostics, there is a development of the common FCD technique. Extended Floating Car Data (xFCD) is a combination of spatio-temporal data and further vehicle parameters. These days, xFCD is a popular technology utilized for analyzing CO2 emission (Pucher 2015).

3. Examining the Influence of Road Slope on CO2-Emission using xFCD

For reviewing the influence of road slope on carbon dioxide emission values of a car using xFCD, an experiment has been set up. Within a period of time lasting from October the first of 2015 until February the first of 2016, an xFCD equipped vehicle has been used in order to acquire traffic data. For a route located within the Bundesstraße 17 in Augsburg, Germany, about 100 records have been acquired. In order to enhance the relevance of the results of the experiment, a dataset has been created for both the outbound trip and the way back.

As a platform for xFCD measurements, a 2014 petrol-fueled Seat Leon with the specification of 110 HP has been used (Seat 2016). Furthermore, an OBD2 Bluetooth adapter has been utilized. For collecting data from the interface and enriching it with spatial information, the application 'Torque Pro' running on a Samsung Galaxy tablet has been applied.

The selected route line acquired from OpenStreetMap (OSM) has been split into segments. *Figure 1* illustrates averaged instantaneous CO2 emission values for the outbound trip. As seen, pollution varies by more than 100 g/km across the route.

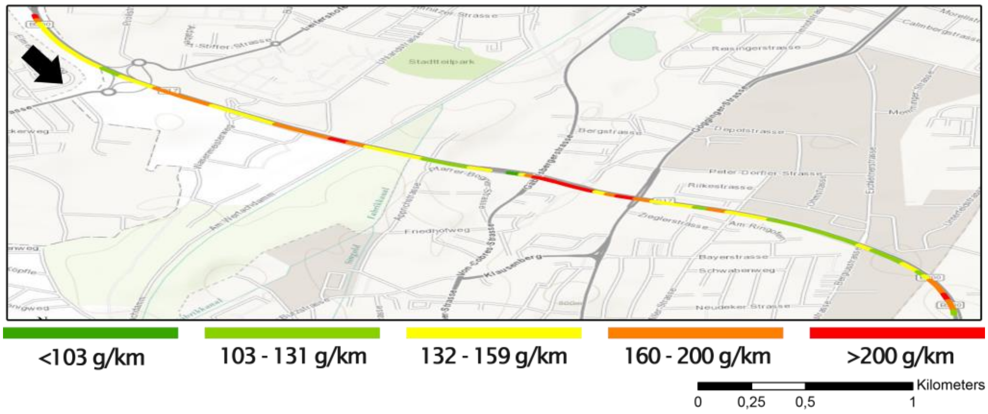

Figure 1. Averaged instantaneous CO2 emission values (outbound trip).

Important information for the experiment is the development of slope values throughout the given route. Therefore, the following formula has been used (Taborton 2011):

$$Slope = \frac{\Delta y}{\Delta x} = \frac{Rise}{Run} \qquad (1)$$

Once the CO2 emission of the car and the slope values of the road segments are acquired, a first comparison can be done. *Figure 2* shows the development of the computed values for both the outbound trip and the way back.

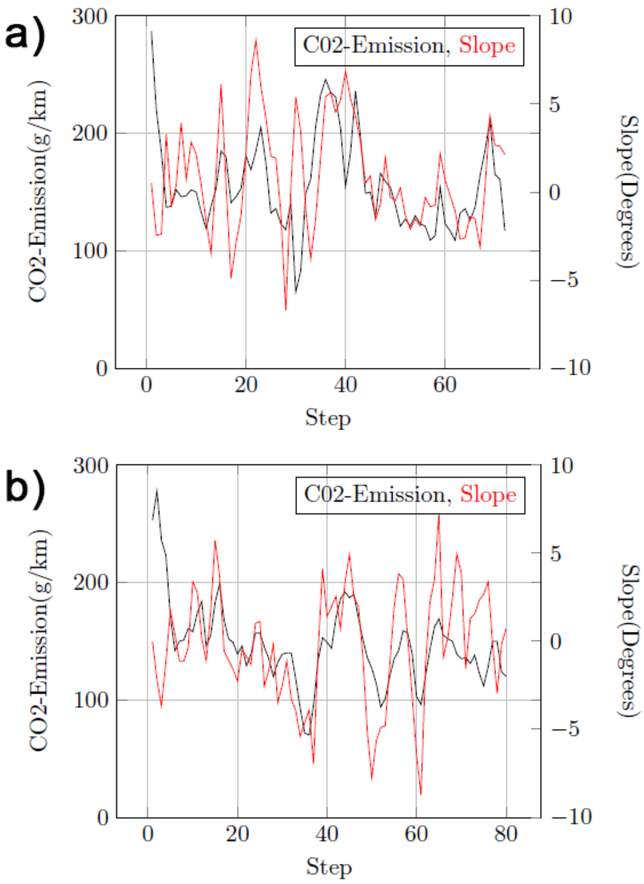

Figure 2. Comparison of CO2 emission and slope for the outbound trip (a) and the way back (b).

The values of CO2 emission and slope are illustrated with a line plot. A correlation can be approximated when comparing the development of both graphs. A Pearson Correlation analysis has been conducted using the following formula (Rubin 2012):

$$r = \frac{n(\sum xy) - (\sum x)(\sum y)}{\sqrt{[n\sum x^2 - (\sum x)^2][n\sum y^2 - (\sum y)^2]}} \qquad (2)$$

Results computed with *Equation 2* are being listed in *Table 1*. Both datasets show a moderate positive correlation of about *0.4*. Thus, there is a certain correlation between slope and CO2 emission, at least for a local area.

Pearson Analysis	Outbound trip		Way back	
	Slope	CO2-Emission	Slope	CO2-Emission
Slope	1		1	
CO2-Emission	0.370952331	1	0.407700613	1

Table 1. Pearson Analysis for the outbound trip and the way back.

4. Conclusions and Discussion

The issue of the present work is to show that road slope influences carbon dioxide emission. Therefore, extended floating car data (xFCD) is used. The paper describes an experiment in order to examine the influence of slope on CO2 emission. An amount of about 100 recordings has been acquired for a car driving on a part of a motorway back and forth for four months. Findings include a moderate positive correlation of about *0.4* for the outbound trip as well as the way back. An influence of road slope on CO2 emission is shown for a local area.

A positive correlation of about *0.4* is a good result for a real-world environment. Challenges occur in the data collection process. Within three months of acquiring data, there is always the possibility of appearing sources of error like traffic jams, car accidents or building sites. Still both outbound trip and way back results show analogical correlations, which is an indicator of accuracy.

Nevertheless, there are some factors to improve for further analysis. Regarding the process of preparing the CO2 emission values for computing the influence, averaging has been performed. The use of other statistical methods like standard deviations need to be utilized in order to evaluate the results.

Further experimental setups should consider more complex road systems than just a part of a motorway. Additionally, there are multiple types of cars with different fuel types and consumption specifications. Furthermore, a higher sample size increases the significance of the results.

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