CARBOTRAF – A Decision Support System for Reducing CO_2 and Black Carbon Emissions by Adaptive Traffic Management

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1 ABSTRACT

The CARBOTRAF system combines real-time monitoring of traffic and air pollution with simulation models for the the prediction of CO_2 and black carbon emissions in order to provide on-line recommendations for alternative traffic management options. The system will be implemented within the framework of a FP7 (ICT for Transport) project funded by the European Union and will be tested in the cities Graz and Glasgow (http://carbotraf.eu/).

2 INTRODUCTION

Traffic congestion with frequent "stop & go" situations causes substantial CO_2 and black carbon (BC) emissions. Both CO_2 and BC emissions are known to contribute significantly to global warming [AEGPL2012]. Exposure to BC may furthermore have important health effects [EHP2012]. The traffic control measures available today (e.g. re-routing, traffic light control, dynamic speed limits, variable message signs) when driven by information collected in real-time from the road network, are able to support the reduction of emissions of CO_2, BC, as well as urban air pollutants. However, supporting the decision making in the traffic control centers to derive the necessary control actions from the information collected, in order to minimise emission requires the understanding of complex interactions between traffic, emissions and pollution density. This area is still subject of investigations.

3 OBJECTIVES

CARBOTRAF combines real-time monitoring of traffic and air pollution with simulation models for emission prediction in order to deliver on-line recommendations for alternative adaptive traffic management. The project work will focus on two main investigations.

(1) CARBOTRAF will provide combined real-time CO_2 and BC emission analysis for traffic situations and subsequent simulation of local air quality. The first phase of the project will evaluate the effects of different intelligent traffic management technologies (ITS) measures on total greenhouse relevant emissions as well as on ambient air quality of BC, by modelling and simulation of selected traffic scenarios for the test cities. The results will provide valuable information on efficient ITS strategies and will be used to define the optimal implementation in the test cities.

(2) Test implementation and test operation of real-time traffic management with online decision support will be the second phase of the project. Using AIT's smart eye TDS traffic monitoring [AIT1] and openUWEDAT [AIT2] data collection technologies a collection of emission-relevant traffic parameters will be developed. Such parameters can be (in addition to vehicle volume, fleet composition and speed), for example the portion of accelerating vehicles to improve emission estimation. These data, supported by data from existing roadside sensors such as induction loops, will be the input to the online decision support system. The decision support system will be based on IBM's Travel and Transportation Software Solutions [IBM1] and ILOG Optimization [IBM2] solution. It will provide recommendations to the traffic control centers, computed from the acutal and predicted traffic situations and emission scenarios. Test operations will evaluate the performance of the online decision support system and the actual effect of the ITS-aided traffic management on the emissions. It will provide guidelines and recommendations for adaptive traffic management regarding both, technical and operational issues. The CARBOTRAF project has started in Sep. 2011 an will run for three years.

4 CONCEPTS

4.1 Emission and traffic scenario look-up-table database

After the selection of the test area which is based on the avaiablility and feasibility of implementing ITS measures that are able to reduce overall emissions, microscopic and macroscopic traffic simulations for different scenarios (e.g. weekday morning, weekend, etc.) and selected ITS actions (e.g. incentive for modal change to public transport, traffic light coordination, re-routing, etc.) will be performed. The results will be used to further refine the test area and select the most efficient ITS actions with respect to overall emissions. These traffic scenarios together with the emissions calculated by emission models will be stored in a look-up-table (LUT) database that links the traffic scenarios with the specific overall emission value for that scenario. Together with emission values the impact of the selected ITS measures on air quality, with a special focus on BC concentration, will be also computed and stored in the LUT. These operations are performed prior to the pilot installations and are sketched on the left side of Figure 1.

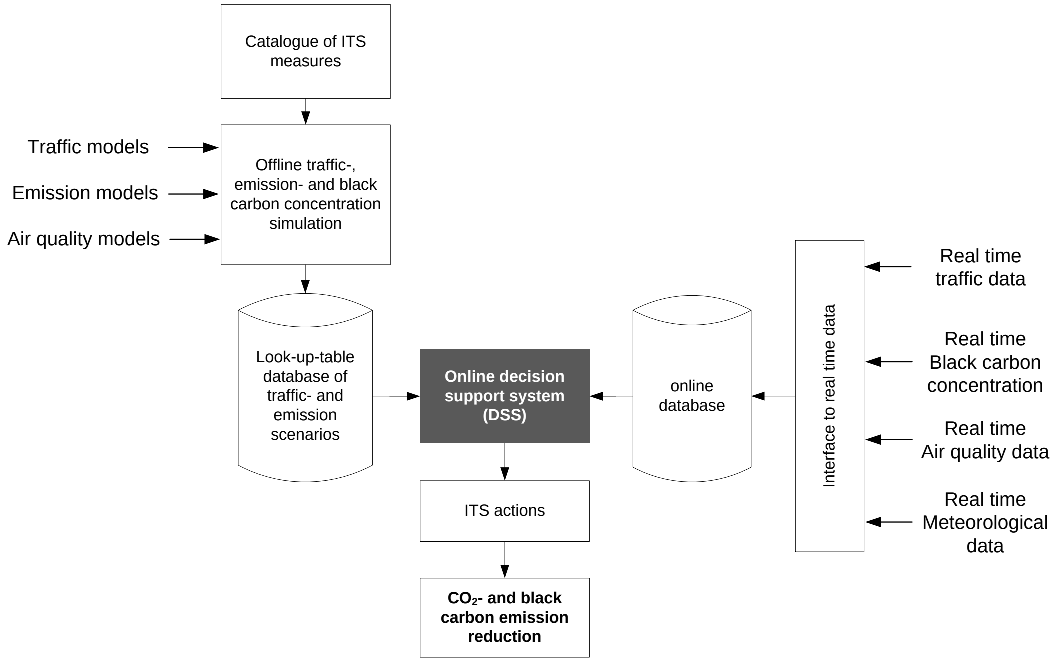

Fig. 1: General architecture of the CARBOTRAF system.

4.2 "Emission-specific" traffic monitoring

Traffic congestion with frequent "stop & go" situations causes substantial increase in emissions (CO_2, black carbon as well as air pollutants) in contrast to free flowing traffic. To derive the necessary control actions from the information collected requires modelling and computing the traffic state depended emission of vehicles. The output of vehicle emission models strongly depend on the acceleration state of the vehicles. Today's traffic monitoring devices typically collect information on traffic volume, fleet composition and average speed. However, there is currently no commercially available traffic monitoring device that is able to collect information in real-time on the composition of the traffic in terms of vehicle acceleration states (accelerating/constant speed/decelerating).

The smart eye TDS traffic data sensor is a fully embedded traffic monitor based on dynamic vision sensor (DVS) technology. The DVS is a CMOS imager chip with very high temporal resolution (better than 1 millisecond) as well as on-chip motion detection and background suppression [LICHT2008]. The pixels of the imager encode motion as time stamped x,y-coordinates in an asynchronous data stream. Thus the DVS efficiently encode the trajectories of the vehicles motion. The current smart eye TDS system monitors traffic on up to four lanes simultaneously and records speed and class individually for each detected vehicle [BAUER2007, GRITSCH2008].

Figure 2 shows data recorded for the concept evaluation of cars entering a roundabout. The still image of the roundabout and the two detection zones defined are depicted on the left of fig.2. Each detection zone extends about 10 m (equivalent to approximately 40 pixels of the sensor) in the direction of vehicle movement. Example trajectory data are plotted in imager coordinates (x) as a function of time (t). Figure 1 (right) shows examples of about 15 seconds of data of four vehicles trajectories in space-time x,t representation. The high time resolution of the sensor allows extracting the vehicles trajectories with high precision. The trajectories for zone 1 show two vehicles with constant speed (marked "C"), and one vehicle decelerating ("D") and stopping at the entry.

Exploiting this information the individual vehicle data sets provided by the traffic data sensor in real-time are additionally tagged with acceleration information (accelerating/constant speed/decelerating states) to allow inferring the quantity of accelerating vehicles in the vehicle collective. This information will be used in the CARBOTRAF project to support the online calculation of traffic emissions for a test area.

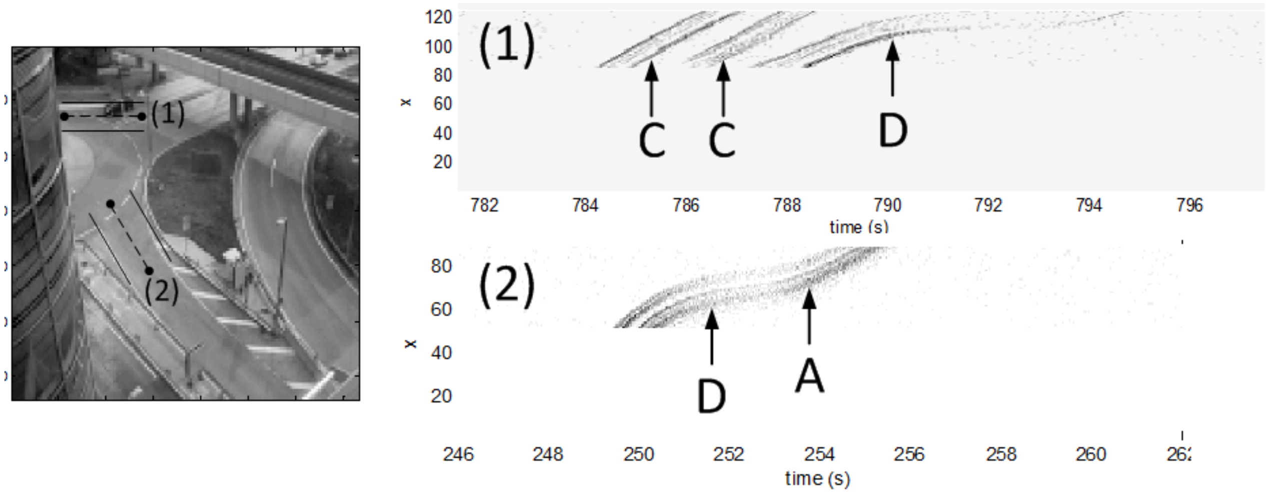

Fig. 2: Acceleration detection by vehicel trajectory analysis with a smart eye TDS traffic sensor. Test data recorded with the sensor at the two entries of a roundabout are shown. Uppercase letters indicate the vehicle acceleration state: "C" constant speed, "D" deleration, "A" acceleration.

4.3 Real time decision support

The decision support system (DSS) based on IBM's Travel and Transportation Software Solutions and ILOG Optimization solution is the heart of the CARBOTRAF system. It will receive real-time data from the sensors deployed in the test area and derives scenario-correlated emission values from the LUT (see fig.1, right). The major steps in the operation of the system are:

Step 1: Real time monitoring of the traffic situation

Traffic monitors (existing devices and additional smart eye TDS with acceleration detection capability installed by the project) measure speed, volume and composition of vehicles and detect emission relevant traffic states (e.g. number of accelerating vehicles). Air quality is also monitored.

Step 2: The traffic situation is predicted by the macroscopic traffic models of the DSS 30-60 minutes into the future.

Step 3: For the current and prediction traffic situations the CO2 and BC emissions are derived from searching the LUT for the scenarios.

Step 4: An improved traffic scenario is selected that is able to satisfy the traffic demand at a reduced total CO_2 & BC emission. Further defined key performance indicators will also be taken into account.

Step 5: ITS action options are displayed to the traffic centre operator who finally deceides on their implemetation („human in the loop").

5 SUMMARY AND OUTLOOK

CARBOTRAF targets to reduce CO_2 and back carbon (BC) emissions by smart traffic management. Pilot operations of the system are planned in Graz and Glasgow. The systems innovative approache links CO_2 /BC- aspects and ITS measures with a focus on a "emission-reduced" traffic rather than a "pure" travel-time optimization.

The first result that will be available in the project is the handbook of ITS actions for each of the test cities, resulting from traffic models and simulation of emissions for different scenarios for the selected test area. The handbook will be valuable information on optimal ITS strategies. The test operation of the CARBOTRAF system will evaluate the performance of the online Decision Support System and the actual effect of the ITS recommendations on the total CO_2 and BC emissions. The result will be compiled in a handbook for cities regarding diminution of CO_2 and BC. It will provide guidelines, recommendations and "best practice" solutions for emission reduction by adaptive traffic management regarding both, technical and operational issues.

The goals of CARBOTRAF will be reached by a complementary and coherent consortium of 8 European partners including research institutes and universities (AIT, VITO, IMPERIAL COLLEGE LONDON, Österreichisches Forschungs- und Prüfzentrum Arsenal) and companies (IBM, Air Monitors, European Tech. Serv., EBE Solutions) from 4 European Members States. The expertise of these organisations is sorted from the intersecting areas of smart sensors, traffic telematics, air quality, numerical analysis and computational intelligence.

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