HOW THE OPTIMAL ADJUSTMENT OF TRAFFIC LIGHTS CAN CHANGE TRAFFIC INDUCED CO_2 EMISSIONS

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ABSTRACT

Within the European Union (EU), total Greenhouse Gas (GHG) emissions were significantly reduced between 1990 and 2012. Despite this reduction, the transport sector remains quite problematic in terms of CO_2 emissions reduction (EU, 2014). Road transport is the leading sector among those whose emissions have increased since 1990, heavily contributing in the change of climate and the overall environmental pollution. Therefore, the adoption of effective and targeted traffic management strategies and measures is recently characterized as an alternative solution to the constantly growing problems of the urban environment and climate change mitigation. Traffic signals are an important factor of energy consumption and emissions increase. They additionally cause delays at intersections affecting the performance of traffic and their phase coordination at urban arterials is attributed with significant benefits regarding fuel consumption and emissions decrease, by improving traffic flow, through its homogenization. The present paper examines how the main parameters that are related to the functionality of traffic lights' timing can affect the performance of traffic flow in terms of CO_2 emissions reduction and the provision of the thresholds of traffic signal cycle times that minimize pollutants' emissions. In this direction, a sensitivity analysis, at Thessaloniki's road network main arterial (section of Tsimiski street), is conducted in order to identify how the phase duration and split of traffic states can be optimized in terms of CO_2 emissions reduction. The analysis is implemented through the integration of the traffic microscopic model VISSIM with the instantaneous speed-based emission model Enviver. Results reveal significant reduction of emissions as traffic lights' cycle time increase as well as when good coordination is applied, yet only at specific intersections, dependent on the geography of the network.

Keywords: greenhouse gas emissions, traffic lights, transport emissions model

1. Introduction

Growing urban settlements purportedly experience growing environmental challenges, among which the mitigation of climate change holds a prominent role. Unraveling the main causes behind the ever-present changing climate, the transportation sector is to be found as a main contributor of CO_2 emissions (EEA, 2014). Despite of CO_2 reduction being at the crux of policies agendas at European Union (EU) and global level in the last decades, and although the total emitted amount since the early '90s in EU has been significantly decreased (15% lower than the 1990-level for the EU-15), road transport induced CO_2 emissions have failed to follow the trend (EEA, 2014). On this context, the impact of urban traffic is crucial, since it is believed to be at fault of approx. 40% of total road CO_2 emissions in 2013 in EU (EEA, 2013). In an effort to address the latter, various strategies have been proposed and applied at cities worldwide, in the form of measures, investments or concrete actions; efforts towards loosening vehicles' circulation dependence on fossil fuel, shift to alternative modes of transport and use of intelligent traffic management to name but a few (Giannopoulos *et al*., 2012). Additionally, traffic signals, constituting an integral part of transportation infrastructure irrespective of the geographical context, can also add to this cause through its traffic regulating role (Koonce *et al*., 2008). Traffic signals are an important factor of energy consumption and emissions increase at urban networks. They often cause delays at intersections and at road links, affecting the performance of traffic flow. The optimum signal timing (techniques that are used so as to specify and to regulate the priority at intersections), as well as the integration of traffic signals in urban strategies are actions that can multi-dimensionally improve the efficiency of road network (increased capacity, reduced fuel consumption and emissions, enhanced road safety). The main advantage of traffic signal strategies, regarding the fuel consumption and emissions reduction, is that they act on traffic flow as a whole, contributing to its homogenization and therefore lead to a smoother traffic flow with less dynamics. Several research efforts have been conducted in an effort to quantify the impact of well-planned traffic signals (in terms of green time per movement, coordination) on traffic-induced CO_2 emissions. Table 1 summarizes the main related findings.

Table 1: Literature review summary

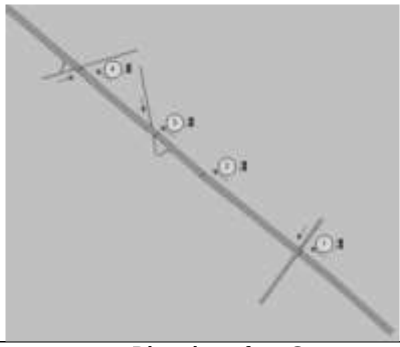
Researcher	Case Study	Network Extent	Approach	Traffic model used	Emission model used	CO_2 emissions reduction	Fuel Consumption reduction
Rahka *et al*. (2000)	Test Network	Single arterial	Modelling	Integration	VT-micro	-	Approx. 50%
Li *et al*. (2004	Nanjing, CN	Single intersection	Field traffic data collection	-	Modal emission approach	-	Fuel cons. minimization at higher cycle lengths
Stevanovic *et al*. (2009)	Utah, US	Urban network	Modelling	Vissim	CMEM	-	In fuel cons. optimization, 1,5 % lower consumption compared to a delay optimization
Madireddy *et al*. (2011)	Antwerp, BE	Suburban arterial	Modelling	Paramics	Versit+	10%	-
Coensel *et al*. (2012)	Test Network	Single arterial	Modelling	Paramics	Versit+	10-40%	-

According to the literature, it is evident that optimally planned and coordinated traffic signals are able to reduce fuel consumption and traffic-induced CO_2 emissions. Yet, the majority of the reviewed research efforts concentrate fragmentarily on the cycle length (CL) or the coordination of signals respectively. Moreover, the results show a dispersion concerning the nature and the characteristics of the road network (urban, suburban etc.). The present work examines in parallel the CL with the coordination of traffic signals at a real urban arterial that faces high traffic demands during a typical weekday. Given their importance in the success of urban transport strategies, in this paper we quantify the impact of traffic signals-related parameters on traffic induced CO_2 emissions by analyzing the CL, movement green time, coordination and offset of signals located at a major 4-lane arterial in the city center of Thessaloniki, Greece. For the evaluation and assessment of the analyses we deploy an integrated modelling process combining a microscopic traffic simulator and a vehicle-trajectory based emission model.

2. Materials and methods

2.1. Study Area

The study area is located in Thessaloniki in Northern Greece. The arterial examined in this paper consists of three intersections and represents Tsimiski Street in Thessaloniki, Greece, a major one-way 4-lane arterial located in the city centre with a total length of 3,9 km. It serves a total of 54.000 vehicles (approx. 3.200 during peak hour) in a typical weekday, while critical vehicle flows are also observed during weekends (Stamos *et al*., 2012 & 2013; Mitsakis *et al*., 2013). For this arterial, signalizing timing plans with emphasis on the adjustment of the CL and the coordination (implementation of different offsets) are examined.



Signal Group	Direction of Traffic	Green Time	Cycle Time
1	↖	0-65	90
	↙	67-88	90
2	↖	0-65	90
3	↖	0-66	90
	↓	68-87	90
4	↖	0-66	90
	↗	70-89	90

Figure 1: Study area (left) and traffic lights location and timing in Tsimiski street (right)

2.2. Methodological approach

For the evaluation purposes of the present work, an integrated modelling approach has been followed, in which the traffic microscopic simulator VISSIM (Fellendorf & Vortisch, 2010) has been combined with the instantaneous emission model Enviver (Ligterink & Lange, 2009). The approach is able to capture and quantify the effect of traffic signals timing settings on traffic-induced CO_2 emissions (Figure 2).

Figure 2: Schematic representation of modelling process that has been adopted

Table 2: Description of coordination scenarios

Scenario	ID	Cycle length	Coordination	Offset
1	a	60	N	-
	b	90		-
	c	120		-
2	a	60	Y	PS = 30 km/h
	b	90		
	c	120		
3	a	60		PS = 40km/h
	b	90		
	c	120		
4	a	60		PS = 50km/h
	b	90		
	c	120		
5	a	60		Same offset (10s)
	b	90		
	c	120		

A scenario-based approach has been followed in order to assess differing parameters of the examined arterial's traffic signals. The first part of the analysis examines the sensitivity of traffic-induced CO_2 emissions according to the CL. Several CLs (50s to 120s) are analyzed, while no coordination is applied (for all signals of the main stream the green time starts simultaneously). The second part of the analysis examines the coordination of traffic signals at three pre-defined CLs (60s, 90s, 120s) with and without coordination with differing progression speeds. Offsets are determined by the distance between two intersections and a selected coordination (progression) speed (PS) (30-50 km/h). Current conditions are reflected in the Base Case (BC) Scenario, contained under Scenario 1 (Table 2).

3. Results and analysis

The sensitivity-analysis on optimal CL shows that when the latter increases, CO_2 emissions are decreased. This is depicted in Figure 3, with emission factors (EF) in g/km representing an average value of the traffic flow's CO_2 emissions. This depends on the CL and the coordination quality determined by the PS selection, which is able to ensure the uninterrupted flow for the main traffic stream. Figure 3 also depicts the % difference in CO_2 of all the scenarios and cases compared to the overall BC. The traffic signals coordination analysis shows that the latter can provide significant benefits (up to 10%) compared to the BC, for most cases Further examination within the same cycle cases, shows that for the CL of 90s, the coordination can bring benefits up to 3%, compared to the same CL non-coordination scenario, 4% for the CL of 60s compared to the non-coordination scenario of the 60s cycle, while a 4% reduction is observed for coordination at a CL of 120s compared to the uncoordinated signals of the same cycle.

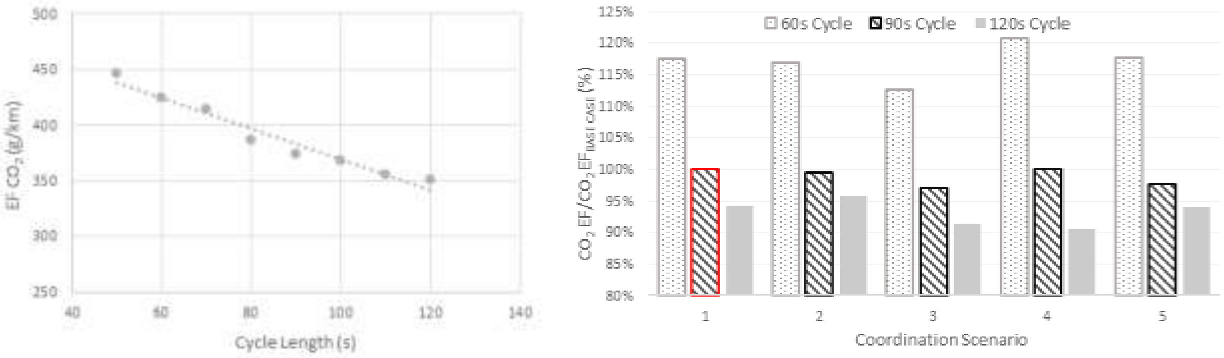


Figure 3: CL and EF CO_2 correlation (left) and % CO_2 difference to BC (red) (right)

4. Conclusions

The present work reveals the importance of the integrated modelling approach in the quantification and explanation of benefits that arise from the implementation of measures that target on the reduction of traffic-induced CO_2 emissions. Concerning traffic signals' adjustment, an increase of the CL is able to reduce CO_2 emissions though with considerations on increased delays of traffic and pedestrians. Signal coordination is able to provide significant benefits, even at an urban environment, in the range of 4% depending on its quality. The application of coordination in parallel with a CL change can bring positive emission reductions results in the range of 10%.

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