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Assessing the impact of closely-spaced intersections on traffic operations and pollutant emissions on a corridor level

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ABSTRACT

Traffic lights or roundabouts along corridors are usually installed to address location-specific operational needs. An understanding of the impacts on traffic regarding to highly-congested closely-spaced intersections has not been fully addressed. Accordingly, consideration should be given to how these specific segments affect corridor performance as a whole.

One mixed roundabout/traffic light/stop-controlled junctions corridor was evaluated with the microscopic traffic model (VISSIM) and emissions methodology (Vehicle Specific Power – VSP). The analysis was focused on two major intersections of the corridor, a roundabout and a traffic light spaced lower than 170 m apart under different traffic demand levels. The traffic data and corridor geometry were coded into VISSIM and compared with an alternative scenario where the traffic light was replaced by a single-lane roundabout. This research also tested a method to improve corridor performance and emissions by examining the integrated effect of the spacing between these intersections on traffic delay and vehicular emissions (carbon dioxide, monoxide carbon, nitrogen oxides, and hydrocarbons). The Fast Non-Dominated Sorting Genetic Algorithm (NSGA-II) was used to find the optimal spacing for these intersections.

The analysis showed that the roundabout could achieve lower queue length (~64%) and emissions (16–27%, depending on the pollutant) than the traffic light. The results also suggested that 200 m of spacing using the best traffic control would provide a moderate advantage in traffic operations and emissions as compared with the existing spacing.

1. Introduction and research objectives

Urban sprawl is known worldwide as the uncontrolled expansion of low-density and single-use suburban development. More than 25% of the European Union's (EU) territory has been directly affected by urban land use (EEA, 2006), and nearly 75% of Europeans live in urbanized areas (UN, 2014). The impact from urban ways of living has increasingly more repercussions well beyond city boundaries. Thus, cities are the defining ecological phenomenon of the 21st century as they have become the major engine of economic development (Newman and Jennings, 2012). Concurrently the phenomenon of urbanization is continuously eroding the countryside and making the boundary between cities and their suburban areas virtually undistinguishable.

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Nomenclature

a	vehicle instantaneous acceleration or deceleration [m s^{-2}]
AADT	Average Annual Daily Traffic
CO	Carbon Monoxide
CO_2	Carbon Dioxide
DPV	Diesel Passenger Vehicles
DTA	Dynamic Traffic Assignment
EU	European Union
FHWA	Federal Highway Administration
GA	Genetic Algorithm
GEH	Geoffrey E. Havers Statistic
GPS	Global Positioning System
GPV	Gasoline Passenger Vehicles
grade	Terrain gradient [decimal fraction]
HC	Hydrocarbons
HCM	Highway Capacity Manual
HDV	Heavy-Duty Vehicles
K-S	Two-sample Kolmogorov-Smirnov test
LDDT	Light Duty Diesel Trucks
LOS	Level of Service
LPV	Light Passenger Vehicles
MAPE	Mean Absolute Percent Error
NCHRP	National Cooperative Highway Research Program
NO_X	Nitrogen Oxides
OBD	On-Board Diagnostic System
O-D	Origin-Destination matrices
POF	Pareto Approximate Front
S	spacing between intersections [m]
US	United States
v	vehicle instantaneous speed [m s^{-1}]
VISSIM	Verkehr In Städten SIMulationsmodell
VSP	Vehicle Specific Power [kW ton^{-1}]
v/c	volume-to-capacity ratio

A representative example of the above issues is found within urban arterials. Series of intersections along corridors are usually implemented according to the available space and do not follow any specific design criteria (Association et al., 2012). Some of these traffic facilities are located in close proximity to each other (due to constraints in terms of land use), and the queue spillback from a downstream intersection can adversely affect the upstream throughput, and, as a result, the overall corridor performance.

Although research of the impacts on traffic performance and emissions of different traffic controls at isolated intersections and an arterial level has been conducted, little attention has been given to the real impacts on traffic regarding the short spacing between adjacent intersections. There is a concern that under specific traffic demands and intersection control (e.g. traffic light or roundabout) the impacts of specific segments of the corridor may be different by varying the spacing between intersections. In addition, the optimization of a particular pollutant (carbon dioxide – CO_2, carbon monoxide – CO, nitrogen oxides – NO_X and hydrocarbons – HC) could dictate different optimal spacing.

The main contributions of this study to the current state-of-art are the following: (1) Understanding the impact of highly-congested closely-spaced intersections within corridors; (2) Implementing a multi-criteria analysis to assess the optimal spacing between intersections to improve corridor-specific operations; and (3) Including specific pollutant criteria (global pollutants which have impacts on global warming; local pollutants which affect human health) to account corridor-specific environmental concerns.

One mixed roundabout/traffic light/stop-controlled junctions corridor is evaluated with the microscopic traffic model (VISSIM) and emissions methodology (Vehicle Specific Power – VSP). After that, a multi-objective genetic algorithm is used to search intersection-optimal spacing and the results are compared with existing conditions. Thus, the objective of this paper is twofold:

1. To compare the impacts of different closely-spaced traffic controls within a corridor on vehicle delay, and global (CO_2) and local (CO, NO_X and HC) pollutant emissions.
2. To find the optimal spacing values for the intersections considering the best traffic control.