Impacts of Roundabouts on Passenger Vehicle Use and Greenhouse Gas Emissions

Technical Background Document

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Study Selection

Much of the research on roundabouts focuses on their impacts on safety and traffic flow. Four studies published in peer-reviewed journals that included assessments of the impact of roundabouts on fuel consumption and/or greenhouse gas (GHG) emissions were included in this review (Várhelyi, 2002; Mandavilli et al., 2008; Ahn et al., 2009; Hallmark et al., 2011). Excluded from this review were studies not published in peer-review journals (Zuger et al., 2001; Bergh et al., 2005; Isebrand et al., 2006; Hallmark and Mudgal, 2011) and/or that reported the impacts of roundabouts on emissions of criteria pollutants but not GHG emissions or fuel consumption (Hydén and Várhelyi, 2000; Lima et al., 2013).

Methodological Considerations

The impact of roundabouts on GHG emissions and/or fuel consumption is generally measured in two steps. First, the impact of roundabouts on traffic flow, including the speeds and patterns of acceleration and deceleration of the vehicles traveling through the roundabout, are assessed. Second, traffic flow patterns are translated into emissions and/or fuel consumption. Different techniques can be used for each of these steps, and as summarized in Table 1, the four studies included in this review each used a unique set of techniques.

The impact of roundabouts on traffic flow can be assessed through direct measurement or through simulation. In the car-following technique, used to directly measure effects on traffic flow, an instrumented vehicle driven by a member of the research team follows randomly selected vehicles traveling through the roundabout and mimics their driving patterns (e.g., speed, acceleration, deceleration) as closely as possible. Várhelyi (2002) used this technique, with 600 cars followed during the data collection period before the installation of the roundabout and 800 cars followed during the period after installation. Another approach, used by Mandavilli et al. (2008), is to video-record traffic flow through the roundabout and extract speed, acceleration, deceleration, and other characteristics from the recording. Ahn et al. (2009) used microscopic traffic flow modes (both VISSIM and Integration) and incorporated actual traffic volumes, speeds, and queues observed in the field into the models.

Several different techniques may also be used for the translation of traffic flow patterns into emissions and/or fuel consumption estimates. Várhelyi (2002) used second-by-second emissions and fuel consumption factors based on speed and acceleration. Mandavilli et al. (2008) used the SIDRA software and Ahn et al. (2009) used both the VT-Micro and CHEM microscopic fuel consumption and emissions models to translate traffic flow patterns into emissions and fuel consumption. In contrast, Hallmark et al. (2011) measured emissions directly using a Portable Emissions Monitor (PEMS) attached to a research vehicle driven by two different members of the research team.

The studies also differed with respect to research design and sample size. Várhelyi (2002) and Mandavilli et al. (2008) both used a before-and-after design in which emissions and/or fuel consumption were estimated for the intersection(s) before the installation of the roundabout and again after its installation; the former analyzed 21 intersections, the latter only 6. Hallmark et al. (2011) use a cross-sectional design in which emissions were analyzed for two road corridors that included at least one intersection of each of three types: signalized, stop-controlled (i.e., controlled with stop signs), and roundabout. In this study, emissions for the roundabouts were compared to emissions for the signalized and stop-controlled intersections. Finally, Ahn et al. (2009) performed a simulation of the effects of changing a stop-controlled intersection to a signalized intersection or a roundabout; just one intersection was used in this study.

While the wide variation in the estimated impacts may in part reflect these differences in methodology, several studies point to real sources of variation in emissions. Hallmark et al. (2011) and Hallmark and Mudgal (2011) both found that emissions estimates were highly dependent on driver behavior. In the latter study, emission rates were highest at the signalized intersection for two of the drivers and highest at the roundabout for the other two drivers. Várhelyi (2002), Mandavilli et al. (2008), and Hallmark et al. (2011) show that the impact of the roundabout varies by context; important factors include the design of the intersection prior to the installation of the roundabout, the design of the roundabout, and the relative volumes of traffic on the roads entering into the roundabouts.

The cited studies report different results as to the comparability of the impacts on fuel consumption, GHG emissions, and emissions of criteria pollutants. Várhelyi (2002) found that the impacts on fuel consumption were similar in magnitude and direction to impacts on carbon monoxide (CO) and oxides of nitrogen (NOx) emissions. Mandavilli et al. (2008) found that carbon dioxide (CO_2) emissions reductions were comparable to

CO and NOx emissions reductions. However, Hallmark et al. (2011) found substantial differences in the effect sizes, with the effects on CO_2 emissions generally smaller than the effects on emissions of criteria pollutants. Similarly, Ahn et al. (2009) found that the impacts on CO, NOx and hydrocarbons (HC) were far greater than the impacts on CO_2 and fuel consumption.

Table 1. Study Characteristics

Study	Study location	Study year	Study sites	Study type	Traffic flow analysis	Impacts measured	Emissions or fuel analysis
Várhelyi, 2002	Växjö, Sweden	1991	20 unsignalized junctions, 1 signalized intersection	Before-and-after analysis	Car-following method to collect speed and acceleration data; combined with traffic counts	CO, NOx, and fuel consumption	Second-by-second emissions and fuel consumption factors based on speed and acceleration
Mandavilli et al., 2008	Kansas, Nevada	c.2000	6 stop-controlled intersections	Before-and-after analysis	Traffic data extracted from video-recording	HC, CO, NOx, and CO_2	SIDRA software
Ahn et al., 2009	Loudon County, VA	c.2008	1 stop-controlled intersection	Simulation	Traffic simulation models (VISSIM, Integration) using actual traffic volumes, speeds, and queues	HC, CO, NOx, CO_2, and fuel consumption	Microscopic fuel consumption and emissions models (VT-Micro, CHEM)
Hallmark et al., 2011	Woodbury, MN	c.2010	2 corridors with stop-controlled, signal, and roundabout intersections	Cross-sectional	n/a	HC, CO, NOx, and CO_2	Direct measurement with Portable Emissions Monitor (PEMS); 2 drivers

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