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 (<u>Várhelyi</u>, 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 (<u>Hydén</u> and <u>Várhelyi</u>, 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

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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 (CO₂) 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	Study	Study sites	Study type	Traffic flow	Impacts	Emissions or fuel
	location	year			analysis	measured	analysis
<u>Várhelyi</u> ,	Växjö,	1991	20 unsignalized	Before-and-	Car-following	CO, NOx,	Second-by-
2002	Sweden		junctions,	after	method to collect	and fuel	second
			1 signalized	analysis	speed and	consumption	emissions and
			intersection		acceleration data;		fuel consumption
					combined with		factors based on
					traffic counts		speed and
							acceleration
Mandavilli	Kansas,	c.2000	6 stop-controlled	Before-and-	Traffic data	HC, CO,	SIDRA software
et al.,	Nevada		intersections	after	extracted from	NOx, and	
2008				analysis	video-recording	CO_2	
Ahn et	Loudon	c.2008	1 stop-controlled	Simulation	Traffic simulation	HC, CO,	Microscopic fuel
al., 2009	County, VA		intersection		models (VISSIM,	NOx, CO ₂ ,	consumption and
					Integration) using	and fuel	emissions
					actual traffic	consumption	models (VT-
					volumes, speeds,		Micro, CHEM)
					and queues		
		_					
Hallmark	Woodbury,	c.2010	2 corridors with	Cross-	n/a	HC, CO,	Direct
et al.,	MN		stop-controlled,	sectional		NOx, and	measurement
2011			signal, and			CO_2	with Portable
			roundabout				Emissions
			intersections				Monitor (PEMS);
							2 drivers

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