Review of Environmental Benefits of Using Roundabouts Instead of Traditional Traffic Signals

Sohana Santra

Abstract

Traffic congestion at intersections remains a significant contributor to environmental degradation in urban areas, with signalized intersections and stop signs generating elevated vehicle emissions, wasted fuel, and excess noise. This study examines whether roundabouts offer a more environmentally sustainable alternative to traditional traffic signals by comparing their impacts across three areas: vehicle emissions and air pollution, fuel consumption and energy efficiency, and noise pollution. The analysis draws on existing research to evaluate how intersection design and traffic control methods influence vehicle behavior, including idling, acceleration, and braking patterns. Findings indicate that roundabouts can reduce CO2 and CO emissions and improve fuel efficiency by minimizing the stop-and-go driving common at signalized intersections, and that well-designed roundabouts can also reduce peak noise levels compared to signals. However, these benefits are not universal. Nitrogen oxide emissions, fuel consumption at high-speed intersections, and noise levels in certain lane configurations were all found in some cases to be worse at roundabouts than at signals, suggesting that environmental performance depends heavily on traffic volume, approach speed, and intersection geometry rather than intersection type alone. This study argues that roundabouts should not be treated as a universally superior design, but rather as one that offers meaningful environmental benefits under specific, identifiable conditions, and that transportation planners should evaluate these conditions on a case-by-case basis rather than assuming roundabouts are always the more sustainable choice.

1. Introduction

Traffic intersections are one of the most persistent sources of environmental strain in urban transportation networks. Every time a vehicle comes to a stop, idles, and then accelerates again, it burns more fuel and releases more pollutants than it would traveling at a steady speed (Mandavilli et al., 2008), while also causing frustration from the stop-and-go pattern. As urban populations continue to grow and traffic volumes rise with them, engineers and city planners have increasingly looked for intersection designs that can move vehicles efficiently while minimizing environmental harm. The modern roundabout has emerged as one of the most widely studied alternatives to the traditional signalized intersection and stop-controlled intersection.

Unlike a traffic signal, which forces vehicles to stop completely at regular intervals regardless of actual traffic conditions, a roundabout requires vehicles only to yield, allowing many drivers to maintain continuous motion through the intersection (Mfinanga, 2013). This difference in design has led researchers to study whether roundabouts offer a meaningful environmental advantage over signals and stop signs, particularly in three areas: vehicle emissions, fuel consumption, and noise pollution. Early studies, such as a Kansas-based analysis of six intersections converted from stop control to roundabouts, found notable reductions in carbon monoxide, carbon dioxide, and other emissions after conversion (Mandavilli et al., 2008). Similar before-and-after field studies using instrumented test vehicles have found that roundabouts can reduce CO_2 and CO emissions compared to signal-controlled

intersections, although the same studies have found that nitrogen oxide (NOx) and CO emissions do not always follow the same pattern, which complicates the overall picture. This results based on driver behavior, as aggressive driving can result in sharp acceleration and deceleration, leading to variability in emissions (Meneguzzer et al., 2008).

Beyond emissions, fuel efficiency is closely tied to how smoothly vehicles move through an intersection. Repeated acceleration and braking, the hallmark of signal-controlled traffic, consume more fuel than steady, continuous movement (Austroads, 2013). Real-world examples support this connection. The city of Carmel, Indiana, which has replaced the majority of its signalized intersections with roundabouts since the 1990s, has been cited by city officials and safety researchers alike as a large-scale case study in both traffic safety and environmental benefit, with estimated fuel savings attributed to the elimination of idling at red lights (Overdorf, 2021). At the same time, not all research agrees that roundabouts universally reduce fuel consumption. Studies of high-speed intersections have found that under certain traffic volumes and geometries, roundabouts can actually increase both fuel use and emissions relative to signals (Ahn et al., 2009).

Noise pollution, though less commonly discussed than emissions or fuel use, is also affected by intersection design. Smoother, more continuous traffic flow is generally associated with lower peak noise levels, since noise from vehicles is closely tied to acceleration and braking events (Gardziejczyk and Motylewicz, 2016; Ahac et al.,2021). However, this relationship is not absolute. Some studies comparing noise levels at roundabouts and signalized intersections directly have found that certain roundabout configurations can produce higher noise levels than nearby signals, depending on lane count and traffic volume (Abdur-Rouf and Shaaban, 2022).

Taken together, these findings suggest that while roundabouts are frequently framed as an environmentally superior alternative to traditional intersections, the research is more nuanced than that framing implies. The goal is to evaluate not only whether roundabouts offer environmental benefits, but under what conditions those benefits do and do not hold.

2. Vehicle Emissions and Air Pollution at Different Intersection Types

Vehicle emissions are one of the most direct ways that traffic and intersection design affect air quality. As vehicles operate, they release a mix of pollutants including carbon dioxide (CO2), carbon monoxide (CO), nitrogen oxides (NOx), and fine particulate matter (PM2.5), all of which are tied to the vehicle's speed, acceleration, and engine load at any given moment. These emissions are not constant. A vehicle moving at a steady speed produces far less pollution per mile than one that is idling, braking, or accelerating from a stop, since combustion efficiency drops sharply during these transitional states. Because intersections are one of the few places on a road network where vehicles are consistently forced to slow down, stop, or accelerate, they are widely recognized as pollution hotspots within urban transportation systems. This makes intersection design, and specifically the choice between signals, stop signs, and roundabouts, an important factor in determining how much a given stretch of road contributes to local air pollution.

Several studies have examined how intersection type affects vehicle emissions directly, often using real intersections converted from one form of control to another as case studies. An early analysis of six intersections, five in Kansas and one in Nevada, that were converted from stop control to modern roundabouts found that emissions of carbon monoxide, carbon dioxide, and other pollutants decreased significantly after the conversion, with reductions in carbon

dioxide ranging from 16 to 59 percent depending on the time of day (Mandavilli et al., 2003). A related study focused specifically on three Kansas cities, Olathe, Lawrence, and Paola, where a modern roundabout had replaced a stop-controlled intersection, found similar results, concluding that the modern roundabout performed better than the intersections it replaced across nearly every measured pollutant (Mandavilli et al., 2003). More recent field research using a Portable Emission Measurement System installed in an instrumented test vehicle compared a roundabout directly against a signal-controlled intersection and found that CO2 and CO emissions were generally lower at the roundabout, supporting the idea that reduced idling leads to reduced emissions (Meneguzzer et al., 2018). Research conducted in Tanzania on roundabout performance in developing urban areas has also noted that unnecessary stops and delays at signalized intersections, particularly under low traffic conditions, lead directly to increased fuel consumption and emissions from repeated acceleration and deceleration (Mfinanga, 2013).

At the same time, the research on this topic is not entirely one-sided. The same Meneguzzer study that found reduced CO2 and CO at the roundabout also found that nitrogen oxide emissions were higher at the roundabout than at the signalized intersection, a result the researchers attributed to the deceleration driving pattern common at roundabout entries, which can prevent a vehicle's catalytic converter from fully reducing NOx output. A broader review of roundabout emissions research conducted for the California Air Resources Board similarly found that results across multiple peer-reviewed studies were inconsistent. While some studies reported clear decreases in emissions after converting an intersection to a roundabout, at least one study of a high-speed corridor found increases in both emissions and fuel consumption following a similar conversion (Handy, Boarnet, 2014). These conflicting results suggest that the environmental performance of a roundabout compared to a signal is not guaranteed and likely depends on factors such as traffic volume, vehicle speed, and the specific pollutant being measured.

Taken as a whole, this research indicates that roundabouts have real potential to reduce several major categories of vehicle emissions compared to traditional intersections, primarily by reducing the amount of time vehicles spend idling and accelerating from a complete stop. The real-world Kansas conversions in particular provide concrete evidence that this benefit can be realized in practice, not just in theory. However, this benefit is not universal across every pollutant or every traffic condition, and NOx emissions in particular appear to behave differently than CO2 and CO. This distinction matters beyond the emissions data itself, because it suggests that the environmental case for roundabouts cannot rest on a single pollutant or a single study, but instead depends on which outcomes are prioritized and under what traffic conditions a given intersection actually operates. That same conditional logic, as the following sections show, extends beyond emissions into questions of fuel consumption and noise as well.

3. Fuel Consumption and Energy Efficiency in Intersection Design

Fuel consumption at intersections is closely tied to the same driving behaviors that drive vehicle emissions: acceleration, braking, and idling. When a vehicle comes to a complete stop, it must use additional fuel to overcome inertia and return to its previous speed once it is able to move again. This process is far less efficient than maintaining a steady speed, since a large portion of the energy used during acceleration is required simply to compensate for the kinetic energy lost during braking. At traffic signals in particular, vehicles are often forced to stop and idle for extended periods regardless of whether cross traffic is actually present, which wastes

fuel that would otherwise not be needed if the vehicle could continue moving. Because roundabouts are designed around yielding rather than complete stopping, they have the potential to reduce this kind of wasted fuel consumption by allowing vehicles to maintain more continuous motion through an intersection. Whether this potential is realized in practice, however, depends heavily on traffic volume, intersection geometry, and driver behavior, all of which vary widely across the studies examined in this section.

The relationship between intersection design and fuel efficiency is governed by basic principles of vehicle dynamics. Acceleration from a stop requires an engine to overcome the full inertia of a stationary vehicle, which consumes more fuel per unit of distance traveled than sustaining a constant speed. Braking compounds this inefficiency by dissipating kinetic energy as heat rather than returning it to the drivetrain, meaning that any energy used to reach a given speed is effectively lost the moment a vehicle is forced to stop again. Traffic signals impose this stop and restart cycle on vehicles at regular intervals regardless of whether such a stop is functionally necessary for safety at that moment. Roundabouts, by contrast, are designed around continuous yielding rather than mandatory stopping, and this structural difference is the basis for much of the research examining their potential fuel efficiency advantages.

Empirical support for this advantage can be found in several studies. The same Kansas and Nevada intersections examined for their emissions performance also showed measurable reductions in fuel consumption after converting from stop control to modern roundabouts, a pattern the researchers attributed directly to reduced idling time at the intersection (Mandavilli et al., 2003). Research from Tanzania supports this pattern as well, observing that unnecessary stops and delays at signalized intersections, particularly during periods of lower traffic volume, generate fuel waste through repeated cycles of acceleration and deceleration that would not occur under yield-based control (Mfinanga, 2013). Beyond controlled academic studies, the city of Carmel, Indiana, offers one of the most extensively documented real-world examples of this principle applied at scale. Since the late 1990s, Carmel has replaced the overwhelming majority of its signalized intersections with roundabouts, and city officials have credited the resulting elimination of red-light idling with substantial reductions in municipal fuel consumption and associated carbon emissions, a claim reinforced by independent safety analysis conducted by the Insurance Institute for Highway Safety (Hu, 2026). Carmel's experience is instructive not only because of the scale at which roundabouts were implemented, but because it demonstrates that the fuel savings associated with reduced idling can hold up across an entire municipal road network rather than remaining confined to isolated case studies.

Nevertheless, the broader body of research complicates any claim that this benefit is universal. A study evaluating a high-speed roundabout found that under conditions of elevated approach speed and traffic volume, the roundabout failed to reduce, and in some cases increased, both fuel consumption and vehicle emissions relative to comparable stop-controlled and signalized alternatives (Ahn et al., 2009). Similarly, an on-road evaluation using a Portable Emissions Measurement System across a corridor containing stop-controlled, signalized, and roundabout intersections found that fuel and emissions outcomes at the roundabout varied depending on which type of intersection it was being compared against, undermining any simple claim that roundabouts are inherently more fuel efficient in every context (Hallmark et al., 2011). Taken together, these findings suggest that the fuel efficiency benefits of roundabouts are conditional rather than absolute, and depend on variables such as traffic speed, volume, and the specific geometry of the intersection in question.

This conditionality has a meaningful implication for transportation planning. Rather than treating the roundabout as a universally superior design, the evidence points toward a more careful conclusion: roundabouts appear best suited to intersections with moderate traffic volumes and lower approach speeds, the same conditions under which Carmel's network and the Kansas case studies achieved their strongest results, while their advantages diminish, and may even reverse, at higher-speed, higher-volume locations more typical of major arterial corridors. This reframes the central question of this study away from whether roundabouts are environmentally beneficial in the abstract, and toward the more useful question of under what conditions that benefit can reliably be expected to hold, a question that becomes still more relevant when noise pollution, the subject of the following section, is brought into consideration.

4. Noise Pollution and Environmental Quality Around Roundabouts

Noise pollution from road traffic is generated primarily by engine activity, tire friction, and aerodynamic effects, all of which vary significantly with a vehicle's speed and rate of acceleration. Unlike a vehicle moving at a constant, moderate speed, a vehicle that is braking hard, idling, or accelerating sharply produces louder and more variable noise output, since these actions place greater demand on the engine and generate more abrupt changes in sound pressure level. Intersections are therefore a natural focal point for traffic noise, since they are one of the few locations on a road network where vehicles are routinely forced into these noisier driving states. Because roundabouts are designed to minimize complete stops in favor of continuous yielding, they are often assumed to produce lower peak noise levels than signalized intersections, where vehicles must fully stop and then accelerate again once the signal changes. This assumption forms the basis for much of the research examined in this section, although, as with emissions and fuel consumption, the evidence is not entirely consistent across studies, intersection geometries, and traffic conditions.

Traffic noise is closely linked to the same driving behaviors examined in the previous two sections. Engine noise, tire friction, and aerodynamic sound all increase during hard acceleration and braking, which means that intersections requiring frequent stops are likely to generate more variable and more intense noise than intersections that allow vehicles to maintain a steadier pace. Because roundabouts are designed to minimize complete stops, researchers have hypothesized that they should also reduce peak noise levels compared to signalized intersections, where vehicles routinely come to a full stop and then accelerate again once the signal changes.

Several studies support this expectation. Research examining the influence of roundabout geometry on noise output found that the deflection built into a roundabout's design, which controls how sharply vehicles must slow down as they enter, plays a significant role in determining how effective the roundabout is as a noise abatement measure, with better optimized geometries producing more stable vehicle speeds and correspondingly lower noise levels (Ahac et al., 2009). This finding aligns with broader research on traffic noise near signalized roundabouts, which has similarly emphasized that the pattern of traffic flow interruption created by an intersection's control method has a direct effect on the noise generated in its vicinity (Gardziejczyk and Motylewicz, 2016). Taken together, this research suggests that noise reduction at roundabouts is not automatic, but instead depends heavily on how well the intersection is designed, particularly the geometry that governs vehicle speed as drivers enter and circulate through the intersection.

This dependence on design and context becomes especially clear when roundabouts are

compared directly against signalized intersections under real traffic conditions. A field study conducted in Doha, Qatar measured noise levels at both signalized intersections and roundabouts across a range of lane configurations and found that the relationship between intersection type and noise was far from straightforward. In some comparisons, two-lane roundabouts produced higher noise levels than two-lane signals, despite the theoretical advantage roundabouts are assumed to hold, while in other configurations the expected pattern held and roundabouts were quieter (Abdur-Rouf and Shaaban, 2022). This result complicates the assumption, common in earlier and more theoretical research, that roundabouts are inherently quieter simply by virtue of reducing complete stops. Instead, it suggests that factors such as lane count, traffic volume, and local driving behavior can outweigh the theoretical noise benefits of yield-based intersection control.

These findings, when placed alongside those on emissions and fuel consumption, reinforce a pattern that runs throughout this study. Roundabouts are frequently designed and marketed around the assumption that reduced stopping automatically translates into environmental benefit, and in many documented cases, including well-optimized roundabout geometries and lower volume intersections, this assumption holds. However, noise, like emissions and fuel consumption before it, does not respond uniformly to intersection type alone. Geometry, traffic volume, and lane configuration all mediate whether a roundabout actually delivers a quieter environment or, in some cases, a louder one. This consistent pattern across three distinct environmental measures suggests that the central finding of this study is not simply that roundabouts are better or worse than signals, but that their environmental performance is conditional on design and context in ways that deserve closer attention from planners before roundabouts are treated as a default solution.

5. Discussion

The findings presented across the three preceding sections point toward a conclusion that is more nuanced than the common framing of roundabouts as an unambiguous environmental improvement over traditional intersections. Taken individually, each topic offers real support for the idea that roundabouts can reduce environmental harm relative to signals and stop signs. The Kansas and Nevada case studies demonstrated measurable reductions in vehicle emissions after converting from stop control to roundabouts (Mandavilli et al., 2003); Carmel, Indiana's large-scale roundabout network has been credited with substantial reductions in municipal fuel consumption (Overdorf, 2021), and well-optimized roundabout geometries have been shown to reduce peak noise levels compared to signalized alternatives (Ahac et al., 2021). If these results were the only evidence available, the case for roundabouts as an environmentally superior intersection design would be straightforward.

However, each of these three areas also produced findings that complicate this conclusion in a strikingly similar way. Nitrogen oxide emissions were found to be higher at a roundabout than at a comparable signalized intersection, even as carbon dioxide and carbon monoxide emissions decreased at the same site (Meneguzzer et al., 2018). Fuel consumption and emissions increased rather than decreased at a high-speed roundabout, reversing the pattern seen in lower-speed, lower-volume Kansas intersections (Ahn et al., 2009), and this inconsistency was echoed by a broader review of the literature that found no single, reliable direction of effect across multiple peer-reviewed emissions studies (Handy, Boarnet, 2014). Noise levels at certain two-lane roundabouts in Doha, Qatar were found to exceed those at comparable signalized intersections, directly contradicting the assumption that reduced stopping

automatically produces a quieter intersection (Abdur-Rouf and Shaaban, 2022).

The recurrence of this same pattern across three otherwise distinct environmental measures is itself a meaningful finding. It suggests that the variable actually driving environmental outcomes is not intersection type in isolation, but rather the interaction between intersection type and a set of contextual factors, including traffic volume, approach speed, lane configuration, and geometric design. Roundabouts appear to perform most reliably under conditions of moderate traffic volume and lower approach speed, precisely the conditions present in the Kansas conversions and in much of Carmel's residential and mixed-use street network. Their advantages become less consistent, and in some documented cases reverse entirely, at higher speed or higher volume locations more typical of major arterial corridors, as demonstrated by both the high-speed roundabout study on fuel consumption and the mixed noise results from Doha (Ahn et al., 2009; Abdur-Rouf and Shaaban, 2022).

This conditionality carries a direct implication for how transportation planners and policymakers should approach the decision to convert a given intersection to a roundabout. Rather than adopting roundabouts as a default or universally preferred design on the assumption that they are inherently more sustainable, planners would be better served by evaluating each candidate intersection on its own traffic characteristics, including expected volume, approach speeds, and surrounding land use. A roundabout well suited to a quiet residential intersection may perform quite differently if placed at a high-speed arterial crossing, and the research reviewed in this study suggests that this distinction matters more than the binary choice between roundabout and signal itself.

It is also worth acknowledging the limitations of the evidence base underlying these conclusions. Several of the studies discussed rely on a small number of case study intersections, which limits how confidently their findings can be generalized to intersections with different traffic patterns, climates, or vehicle fleet compositions. Additionally, most of the research reviewed here measures short-term, localized outcomes at the intersection itself, rather than accounting for potential downstream effects, such as changes in overall route choice or vehicle miles traveled, that a roundabout conversion might produce across a broader road network. Future research that accounts for these broader, network-level effects would help clarify whether the environmental benefits observed at individual intersections persist, diminish, or compound when considered at a citywide scale, as in the case of Carmel, Indiana.

6. Summary

This study set out to examine whether roundabouts offer meaningful environmental benefits over traditional signalized intersections across three key areas: vehicle emissions and air pollution, fuel consumption and energy efficiency, and noise pollution. The evidence gathered suggests that the answer depends heavily on context rather than being a simple yes or no. In many documented cases, roundabouts have demonstrated real reductions in emissions, fuel use, and noise compared to signals, particularly at intersections with moderate traffic volumes and lower approach speeds, while certain pollutants, high-speed or high-volume locations, and lane configurations have produced results that run counter to this pattern. Rather than treating roundabouts as a one-size-fits-all solution, transportation planners should weigh the specific traffic characteristics of each intersection under consideration, since environmental performance appears to be shaped as much by where and how a roundabout is built as by the fact that it is a roundabout at all. This more careful, context-driven approach offers a more honest and ultimately more useful framework for future infrastructure decisions than a blanket preference for

one intersection design over another.

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