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Inattentional Blindness and road safety: the potential role of intelligent road studs in reducing accidents.

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Abstract

In-vehicle distraction is often the subject of debate in relation to road safety. Distractions outside of the vehicle, however, are often overlooked. Both situations result in cognitive capture, a form of 'Inattentional Blindness'. This paper investigates the lesser understood external distractions to drivers, and how intelligent transport systems such as illuminated road studs can improve road safety. A case study of a busy roundabout on the Edinburgh City Bypass is described. Using before and after videos surveys, it is demonstrated that the installation of intelligent road studs significantly reduces the number of lane transgressions at the roundabout. Results were found to be valid across all vehicle types, in both daylight hours and at night. The study suggests that the studs have a positive impact on driver behaviour and reduce the incidence of inattentional blindness, thereby improving road safety at such junctions.

Keywords:

Inattentional blindness; road studs; accident prevention

Introduction

Background

'Cognitive Capture' is a form of 'Inattentional Blindness'. It is a phenomenon that affects people when their mind is so focussed on a secondary task that they lose concentration on the primary task in which they were engaged, and something that would otherwise be conspicuous gets missed. It is a phenomenon that will have affected drivers since cars were invented, but is becoming more significant as the number of potential distractions in and around modern vehicles increases.

Distractions that can lead to Cognitive Capture can come from sources inside and outside the vehicle, although it is in-vehicle distractions that has most recently been the focus of public debate. Some in-vehicle sources of distraction are obvious and the use of hand-held mobile telephones, for example, has already been recognised by legislators as a potential safety threat. Road-safety campaigners have long argued that even using a hands-free system is a source of distraction.

Complex instrument panels, sophisticated car entertainment systems and satellite navigation systems are all in-vehicle sources of distraction that have the potential to lead to cognitive capture and which are routinely built into modern vehicles. Furthermore, as car-makers strive to make their vehicles more attractive to buyers there is a temptation to build new functionality into these systems without considering the impact that controlling them will have on a driver's focus.

All drivers, to a greater or lesser extent, will be engaged in unconscious risk compensation, where speed and manoeuvring is matched to the perceived level of risk. The ability to properly assess risk has, therefore, a direct impact on how well the driver carries out this task. Horrey (2009) concluded that drivers underestimate the dangers of multi-tasking while driving precisely because they underestimate the dangers involved. It is reasonable to conclude that many drivers who are trying to multi-task will under-estimate the risk associated with cognitive capture as a result of doing so.

This is a theme recently highlighted by Kinnear and Stephens (2015): "As driving is so complex and requires various cognitive processes, taking on another task when driving can mean a driver is unable to pay sufficient attention to all the activities required for safe driving. This can lead to a processing failure resulting in a loss of control, putting the driver and other road users in physical danger."

Distractions from outside the vehicle

Kinnear and Stephens also highlight figures from the Department of Transport that suggest that, in 2013, 2,995 accidents were the result of distractions in the vehicle, with a further 1,627 from distractions *outside* the vehicle. Recent debate, however, has not highlighted external distractions as a cause of accidents, nor that these distractions might arise as a result of a driver engaging in legitimate driving activity, such as reading road signs and trying to interpret the layout of the road ahead. Some of the distractions from outside the vehicle that can lead to cognitive capture are already implicitly recognised by the Department for Transport in its guidance on road signs. For example, the Traffic Signs Manual encourages the use of simple direction signs and recommends that it is often better to provide information using more than one sign rather than a single over-complex sign.

Whilst it will be for car-makers, car-technology providers, educators, road safety campaigners and legislators to address the risks from all forms of inattentional blindness caused by in-vehicle distractions, distractions from outside the vehicle will need to be addressed by road designers.

It is likely that many more accidents have been caused by inattentional blindness as a result of an external distraction than are included in official figures. A driver focussing on a legitimate task associated with driving, such as trying to interpret direction signs or 'read' the layout of an approaching junction or roundabout that they are not familiar with, but which took away their attention from a more immediate threat, is unlikely to realise that they suffered an episode of inattentional blindness or describe it in a way that would allow police office officers to report it as such.

Addressing the problem

Designing roads and junctions to avoid external distractions, clear road signing, accurate and easily digested traffic information and clear road and lane delineation, including deploying intelligent road studs, are all likely to reduce the risk of external distractions. Intelligent road studs, however, have only been used in a limited number of sites and where they have they have been shown to reduce accident rates if visibility is an issue. The possibility that they may also be effective in reducing accidents at junctions where drivers might be distracted by the complex layout of the road is less clearly documented.

This paper investigates an innovative method of improving lane adherence at spiral-marked roundabouts through the use of intelligent road studs. It updates previous work (Llewellyn, 2015) through a revised before-and-after case study of a major roundabout on the Edinburgh City Bypass.

Sheriffhall Roundabout

Context

The A720 Edinburgh City Bypass is a major Trunk Road which runs around the south of the capital city of Scotland. It is a strategically important route, and as such many sections of the route are highly congested at several times during the day. All junctions along the route are grade-separated with the exception of one: Sheriffhall Roundabout. Sheriffhall is a six arm roundabout, forming a junction of the City Bypass with an important regional route (A7) and a key local route (A6106).

The roundabout is highly prone to incidents. Accident statistics show over the past ten years, Sheriffhall has the highest number of collisions of any roundabout on the Scottish trunk road network. There is not only a human cost to this issue; collisions at Sheriffhall result in significant delay to traffic with implications on the whole South-East Scotland road network due to its strategic location. As a result, it is frequently the subject of public interest.

Layout and Issues

Sheriffhall Roundabout is traffic signal controlled and features spiral markings to guide drivers through the junction to their destination arm. The layout of the roundabout is shown in Figure 1

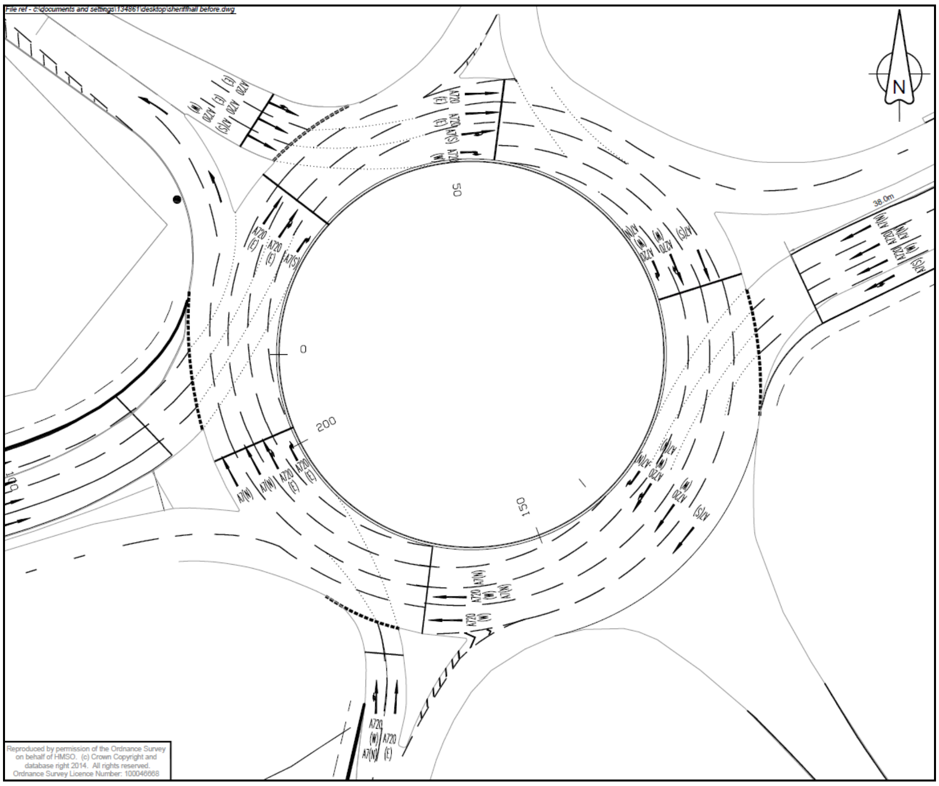

Figure 1 – Sheriffhall Roundabout (Source: Amey)

Advice on the design of spiral marked roundabouts (Department for Transport, 1997) notes that such markings can be effective in reducing side-to-side collisions and forced encroachment of the central island. The objective of the markings is to reduce uncertainty of path and weaving on the circulatory carriageway.

There is, however, evidence to suggest simply implementing spiral-markings on a roundabout may not lead to the desired changes in driver behaviour. Much of the available literature (Wong et al. (2012), McCann (1996)) concedes that a road-based marking approach at roundabouts to regulate circulatory may not lead to universal compliance with the layout.

By their nature, the markings and signage associated with such roundabouts are numerous and complex. This presents drivers with a significant amount of information to process, potentially leading to issues of inattentional blindness as previously discussed.

Adopted solution

Following the success of Intelligent Road Studs in influencing driver behaviour in other applications (Muspratt, 2012), it was proposed that they could be applied to Sheriffhall Roundabout to reduce cognitive capture and provide a clear route. The final design produced featured studs associated with the A720 through movements at the roundabout, as shown in Figure 2

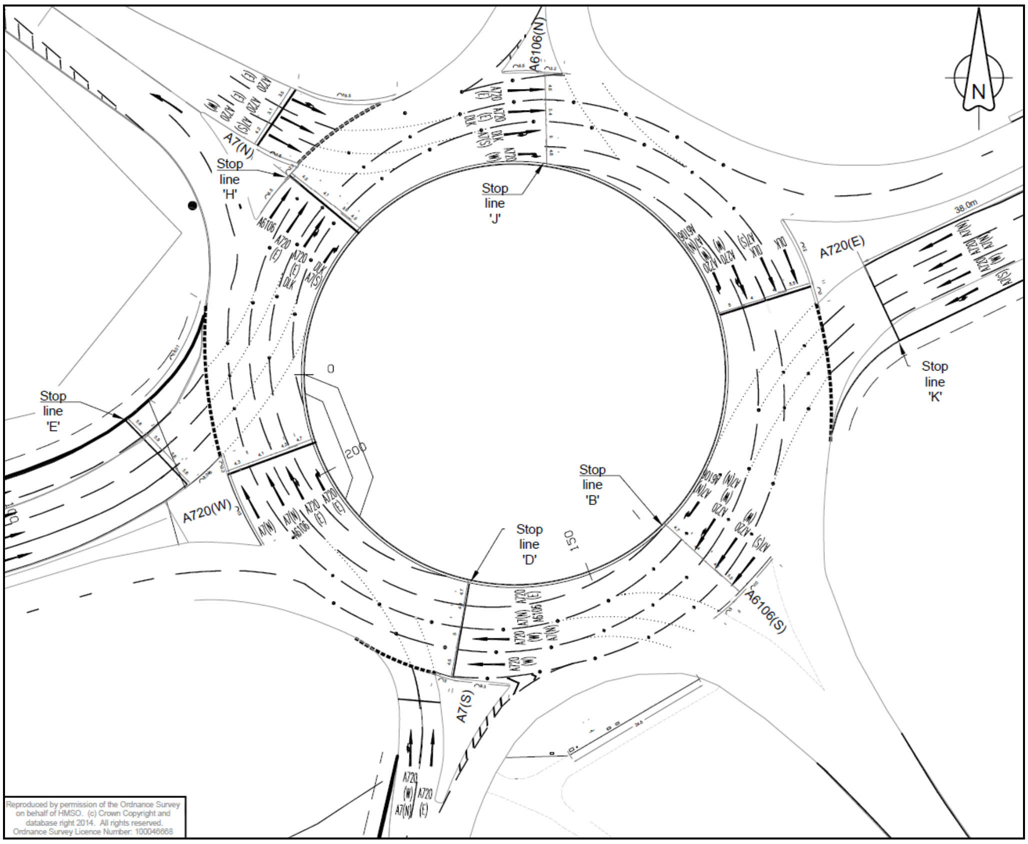

Figure 2: Layout of Intelligent Road Studs (Source: Amey)

The design of the installation is such that illumination of the studs is co-ordinated with the traffic signal phasing. Essentially, when the A720 City Bypass movement is signalled red, the studs are extinguished and traffic from other arms may enter the roundabout. When the A720 City Bypass through movements are signalled green, the studs are activated. This results in drivers being presented with a clear, illuminated path through the roundabout as shown in Figure 3.

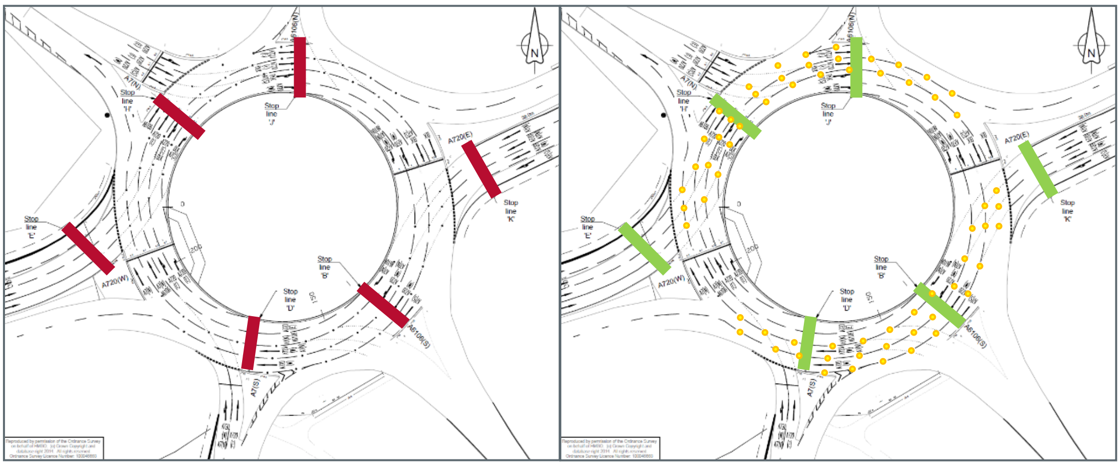

Figure 3: Co-ordination of studs with traffic signals

Research Methodology

Observational Survey Method

The method of assessment chosen to measure the impact of the studs on the operation of the roundabout was an observational video survey. To assess the change in driver behaviour as a result of the studs, a 'without studs' and 'with studs' before and after survey was undertaken. In both surveys, four cameras were mounted around the roundabout covering all parts of the circulatory carriageway.

The 'before' surveys were undertaken between 31 January and 8 February 2015. Cameras were configured to record from 0400-2200 daily; overnight hours were excluded as it was considered that the limited video storage capacity would be better used for a greater number of days to maximise exposure to varying conditions.

An initial set of 'after' surveys were carried out 20 May to 26 May 2015. The results of these surveys are reported elsewhere (Llewellyn, 2015). As this initial survey was undertaken in summer, significantly different sunset/sunrise times applied. This paper reports the result from a new survey undertaken between 13 and 21 February 2016, with similar lighting conditions to the original 'before' survey.

Research Questions

The theory of spiral roundabout markings is drivers stay in lane throughout their path through a roundabout. In assessing the effect of the intelligent road studs on the appropriateness of this theory, the following research questions were developed to be answered before and after installation of the studs:

- How frequently do lane transgressions occur?
- By what degree do vehicles transgress lanes?
- Do different vehicle types have different propensities to transgress lanes?
- Are lighting conditions a factor?
- Is density of traffic a factor?

To answer these questions, definitions of terms were firstly established.

Lane Transgression

An initial observational study of the video collected from the roundabout confirmed that various different degrees of lane transgression occur. Some vehicles were observed to encroach only by a small margin, for example by overrunning the white line markings with their wheels. Larger transgressions, where vehicles straddled lane markings were also observed. The final type of transgression involved vehicles manoeuvring to take up virtually all of the adjacent lane, or make a complete lane change which may or may not involve them returning to their original lane.

On the basis of the above, three different classifications of lane transgression were defined: '25% transgression', '50% transgression' and 'lane change' as shown in Figure 4 below.

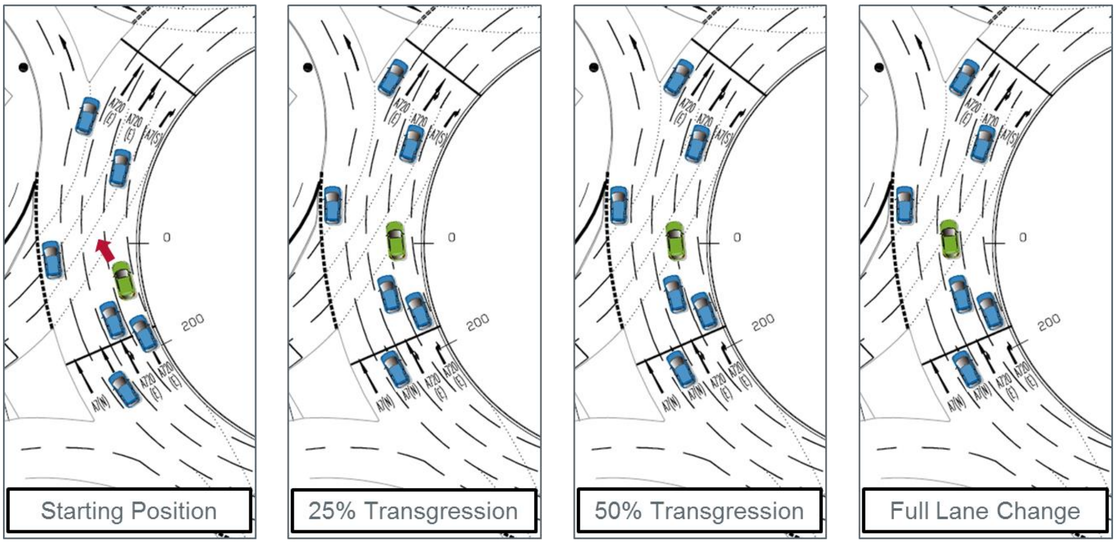

Figure 4: Lane Transgression Definitions

All of these transgressions have the potential of resulting in collisions between vehicles on the roundabout; however, vehicle type may also be a potential factor.

Vehicle Types

Categorisation of vehicle types was undertaken based on the standard definitions used for UK traffic counts (DfT, 2015). The definitions were refined into three categories: small, medium and large. This was done to reflect the amount of road space, both in terms of width and length that each vehicle type occupied. The classifications under each vehicle type were as shown in Table 1.

Small Vehicles	**Medium Vehicles**	**Large**
Motorcycles	Light Goods Vehicles (<3.5t)	All DfT Commercial Vehicle classes (inc. buses)
Cars	Cars with caravans/trailers	

Table 1 – Vehicle Classes

Data Analysis

All analysis was undertaken by manual observation of the video. The procedure adopted was for the observers to watch selected periods of video, recording for any given time segment:

- the total number of vehicles, disaggregated by the vehicle type; and
- any instances of lane transgressions, disaggregated into vehicle type and transgression type.

In order to assess driver behaviour under typical conditions, two neutral weekdays (Tuesday and Thursday) and one weekend day (Saturday) were chosen for assessment. Samples of data were gathered for various traffic and lighting conditions. The times and conditions analysed were:

08:00 – 09:00, morning peak, daylight	17:00 – 18:00, evening peak, darkness
12:00 – 13:00, lunchtime peak, daylight	21:00 – 22:00, off-peak, darkness

14:00 – 15:00, off-peak, daylight	

Results

Transgressions by Vehicle Type

For each period sampled, the total hourly flow and the number of vehicles by type making the three categories of transgression were recorded. The number of transgressions were then divided by the hourly flow to give a transgression rate, expressed as a percentage. The transgression rates for small, medium and large vehicle across the three transgression categories are shown in Table 2

		25% Transgression	50% Transgression	Full Lane Change
Small Vehicles	Before	2.78%	0.55%	1.84%
	After	1.84%	0.27%	1.17%
	% Change	**-33.92%**	**-50.50%**	**-36.17%**
Medium Vehicles	Before	5.64%	1.19%	2.31%
	After	2.29%	0.57%	1.24%
	% Change	**-59.47%**	**-52.32%**	**-46.25%**
Large Vehicles	Before	6.04%	0.60%	1.19%
	After	3.67%	0.33%	1.89%
	%Change	**-39.19%**	**-45.96%**	**59.10%**

Table 2 – Change in Transgression Rate by Vehicle Class

Across all but one of the vehicle and transgression categories, a decrease in the rate of vehicles straying from their lane was observed. In many cases this was a significant reduction; for example, medium vehicles, where a two-thirds reduction in 25% transgressions could be observed. The category where an increase was observed was on a very small number of vehicles, and is therefore not considered significant.

Transgressions by Lighting Conditions

Table 3 shows the impact of lighting conditions on transgression rates.

		25% Transgression	50% Transgression	Full Lane Change
Daylight	Before	8.00%	1.59%	3.16%
	After	5.62%	0.52%	1.71%
	% Change	**-29.78%**	**-67.20%**	**-45.96%**
Darkness	Before	9.67%	4.06%	5.19%
	After	7.86%	1.65%	7.55%
	% Change	**-18.69%**	**-59.38%**	**45.55%**

Table 3 – Change in Transgression Rate by Vehicle Class

It is interesting to note that the stud is effective in hours of daylight as well as during hours of darkness. The results demonstrate that the high-intensity output of the stud - which can be clearly seen during most daylight conditions - has an influence on driver behaviour throughout the day.

Transgressions by Flow Rate

The final research question regarded the variation of lane transgression with traffic flow. To analyse this relationship, the transgression rate for each hour sampled was plotted against the associated flow rate. Regression analysis found that a logarithmic curve formed an appropriate trendline for the gathered data. The variation of transgression rate with traffic flow before and after implementation of the studs is shown in Figures 5 and 6 below.

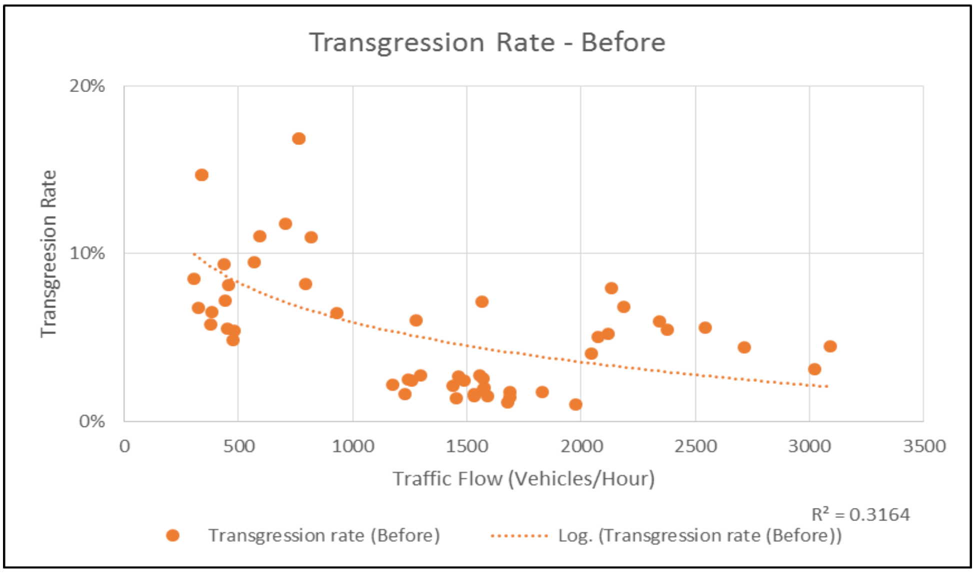

Figure 5: Transgression Rate by Traffic Flow Before Stud Implementation

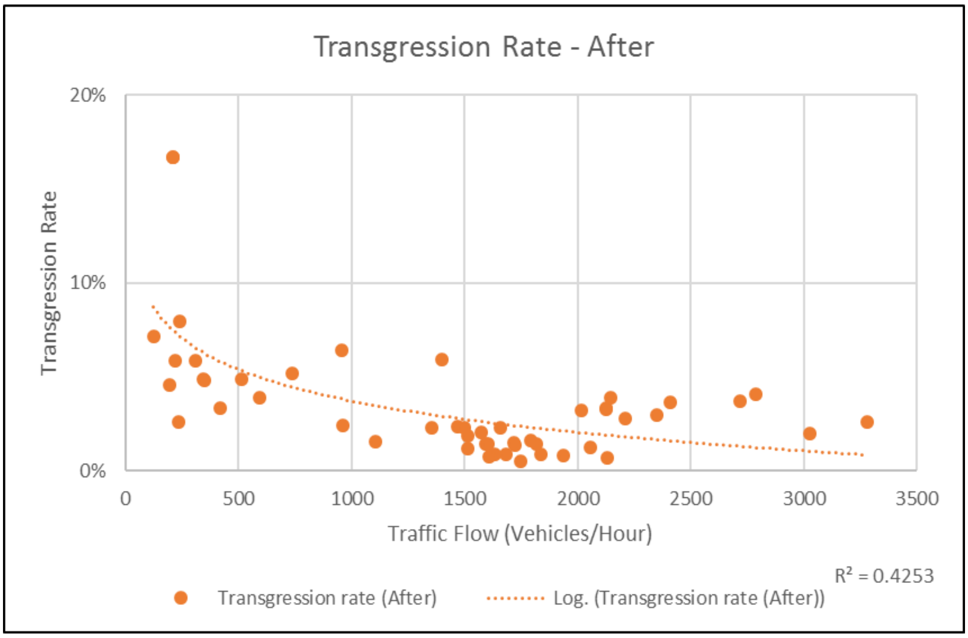

Figure 6: Transgression Rate by Traffic Flow after Stud Implementation

The graphs illustrates that as traffic flow increases, the rate of lane transgressions can be expected to decrease. This is an intuitive relationship; as traffic flow increases, drivers are more likely to be aware that they are surrounded by vehicles, thus are less likely to change lanes.

Conversely at lower flow levels drivers may take more chances, such as in conditions that may be experienced late at night when there is very little traffic. In such time periods, transgression rates can be as high as 18%.

After the studs were implemented, a similar relationship exists with the transgression rate decreasing as the traffic flow increases. However, the trendline indicates that overall, the rate of transgression is much lower than previously observed without the studs in place, particularly in the low to mid flow range.

In addition to the overall rate being lower, the spread of transgression rate values is much narrower. This would suggest that driver behaviour is more predictable and uniform following the installation of the studs, suggesting that inattentional blindness is less of an issue.

Conclusion

The theory of spiral marked roundabouts is that vehicles stay in a clearly defined lane throughout their passage across the junction. Transgressions into other lanes or full changes of lane by vehicles may not be anticipated by other drivers; as a consequence, a risk of collision is inherent. It is suggested that inattentional blindness may be a contributory factor to this type of driver behaviour due to the amount of information that is presented to drivers in such layouts.

The work undertaken here found that the implementation of the intelligent road stud resulted in a reduction in lane transgression activity across nearly all vehicle types and manoeuvres studied. This reduction in transgressions reduced the number of vehicles exposed to a risk of collision from between 33 and 60%. Driver behaviour was found to be more predictable and consistent following implementation of the studs. Lane discipline was improved and as a result, the probability of vehicle conflicts is reduced. There may also be benefits to traffic flow due to improved predictability of paths through the roundabout.

Based on the findings of this study, the intelligent road stud is recommended for consideration as a low-cost road safety measure at sites where inattentional blindness is believed to be an issue. Whilst it is not a panacea for all lane transgression issues, the evidence presented here suggests that it can result in a significant reduction in the risk of collisions.

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