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Improving Lane Adherence at Signalised Roundabouts with Intelligent Road Studs – A Case Study

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Abstract

Spiral markings at signalised roundabouts improve traffic flow but can reduce safety due to poor lane discipline. This paper describes an innovative method of improving lane adherence at signalised spiral-marked roundabouts through the use of intelligent road studs.

To achieve this, a before-and-after case study of a major spiral-marked, traffic signal controlled roundabout on the Edinburgh City Bypass was undertaken. The research revealed a substantial reduction in lane transgression at the roundabout and a corresponding reduction in collision rate.

Since its installation, the success of the scheme has been recognised with six national transport awards.

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1. Background

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

Figure 1: Sheriffhall Roundabout

Sheriffhall roundabout has historically been highly prone to incidents. Statistics show that over the past ten years, Sheriffhall had the highest number of collisions of any roundabout on the Scottish trunk road network. Although grade-separation is proposed in the long term, a more immediate, cost-effective alternative solution was urgently required.

The roundabout was last modified through a capacity improvement scheme undertaken in 2008. This comprised the widening of the circulatory carriageway from three lanes to four and the widening of three congested approaches. Despite these improvements, a Stage 4 Road Safety Audit carried out three years later showed 22 further reported injury collisions, representing a continuation of the pre-existing accident rate.

The audit report cited poor lane discipline as the prime cause of collision at the roundabout. It was suggested that this was due to the level of difficulty that certain drivers may be having in understanding and reacting to the complexity of the junction. The auditors suggested that further investigation of measures to reinforce lane discipline were required.

2. Scheme Design

The challenge facing the design team was that all traditional forms of lane discipline reinforcement had been exhausted. The roundabout approaches featured multiple sets of lane designation signs and markings; in addition, a comprehensive lighting scheme had been installed to ensure clarity in all conditions.

A new, more radical approach was required. In response to the challenge, it was proposed to introduce LED-powered, intelligent road studs (Figure 2) to guide the A720 mainline traffic through the roundabout. The intention being that the studs would encourage drivers to stay within their lane by drawing drivers' attention to the delineation of the existing lane markings and guide them through the roundabout.

Figure 2: Intelligent Road Stud

Whilst it was anticipated that the studs would benefit the through movements on the roundabout, a potential issue became apparent that drivers on the circulatory carriageway from the minor arms would be confused by the studs. As this would be counterproductive, a more innovative solution was sought.

The solution came in the form of a scheme using actively controlled road studs, where the studs are switched on and off in coordination with the traffic signals on the roundabout. This scheme is the first of its type in the UK and its operation is illustrated in Figure 3.

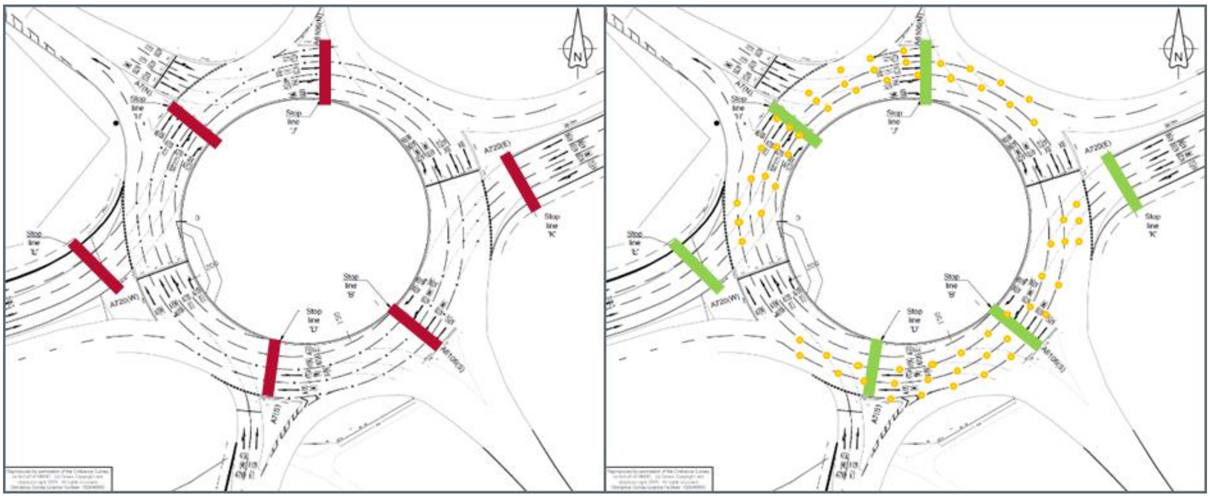

Figure 3: Operation of Road Studs (Signal Phasing Simplified for Clarity)

3. Research Methodology

Video surveys were used to assess the effectiveness of the studs. Prior to their installation, four video cameras were installed covering the four quadrants of the roundabout.

‘Before’ data was gathered 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, with further surveys being undertaken from 13 to 21 February 2016, with similar lighting conditions to the original ‘before’ survey.

Analysis of the video was performed manually and the following periods were selected for assessment:

08:00 – 09:00, morning peak, daylight
12:00 – 13:00, lunchtime peak, daylight
14:00 – 15:00, off-peak, daylight
17:00 – 18:00, evening peak, darkness
21:00 – 22:00, off-peak, darkness

From the video, instances of vehicles crossing the lane markings – or ‘transgressions’ - on the roundabout were recorded. The survey results were reported in the form of a transgression rate. A transgression rate was chosen as this allows comparison of the success of the measure across all traffic flows. Given that collision statistics do not allow an accurate measure of success for a substantial period after completion, the transgression rate provides a useful proxy for collision potential.

Three lane transgression types (25%, 50%, Full Lane Change) were defined against three vehicle classes, as shown in Figure 4 and Table 1 below.

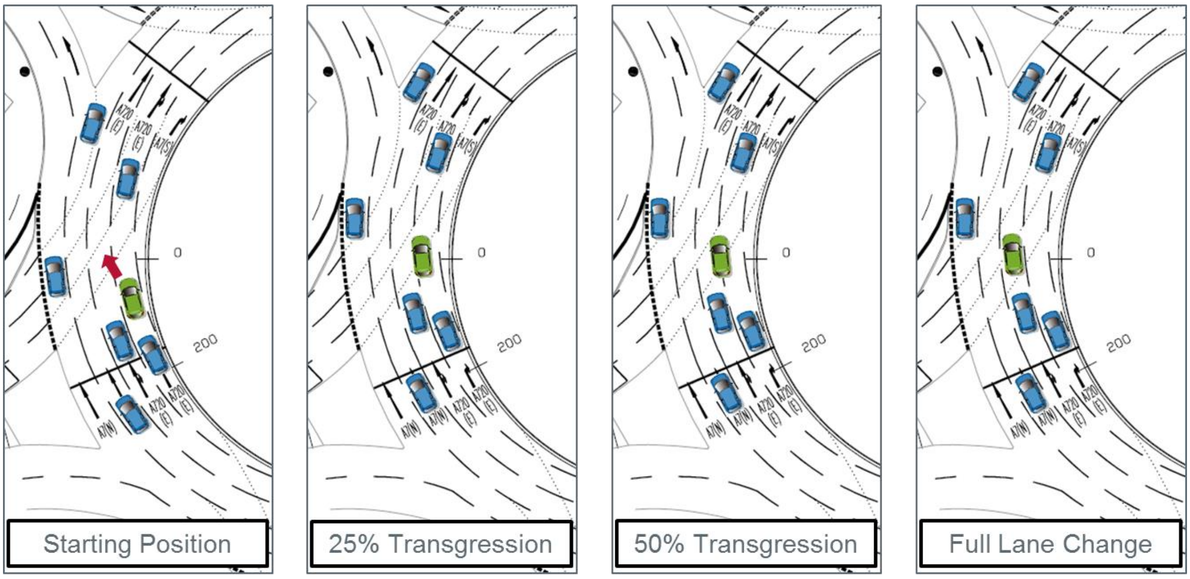

Figure 4: Transgression Types

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

4. Results

The transgression rates for small, medium and large vehicle across the three transgression categories, before and after the implementation of the studs 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.

Table 3 shows the impact of lighting conditions on transgression rates, before and after implementation of the studs.

		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.

A final analysis was undertaken to determine whether transgression rate changed with flow. 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.

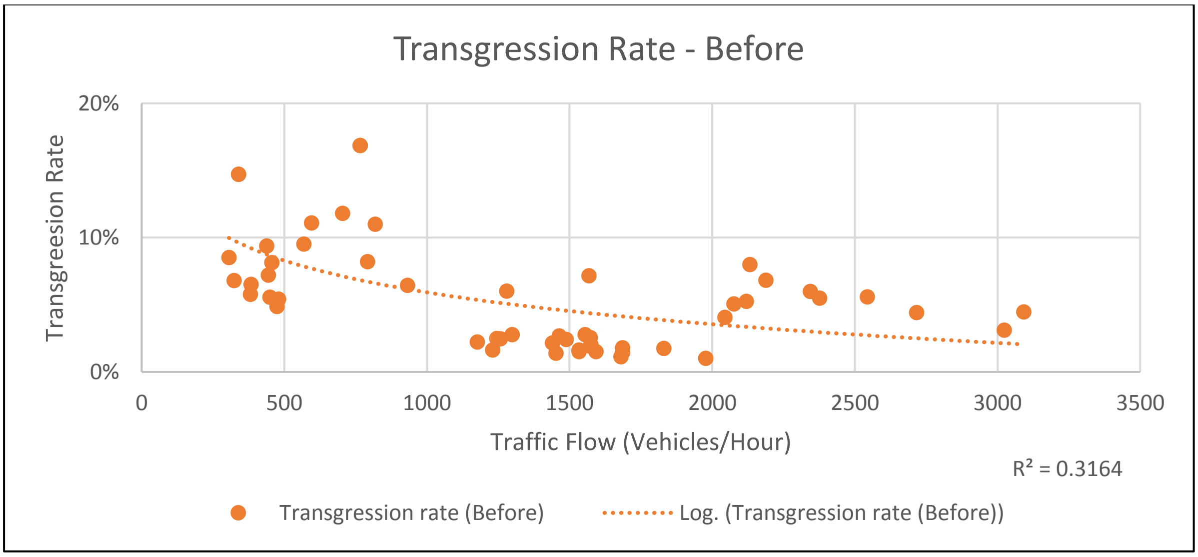

Figure 5: Transgression Rate by Traffic Flow Before Stud Implementation

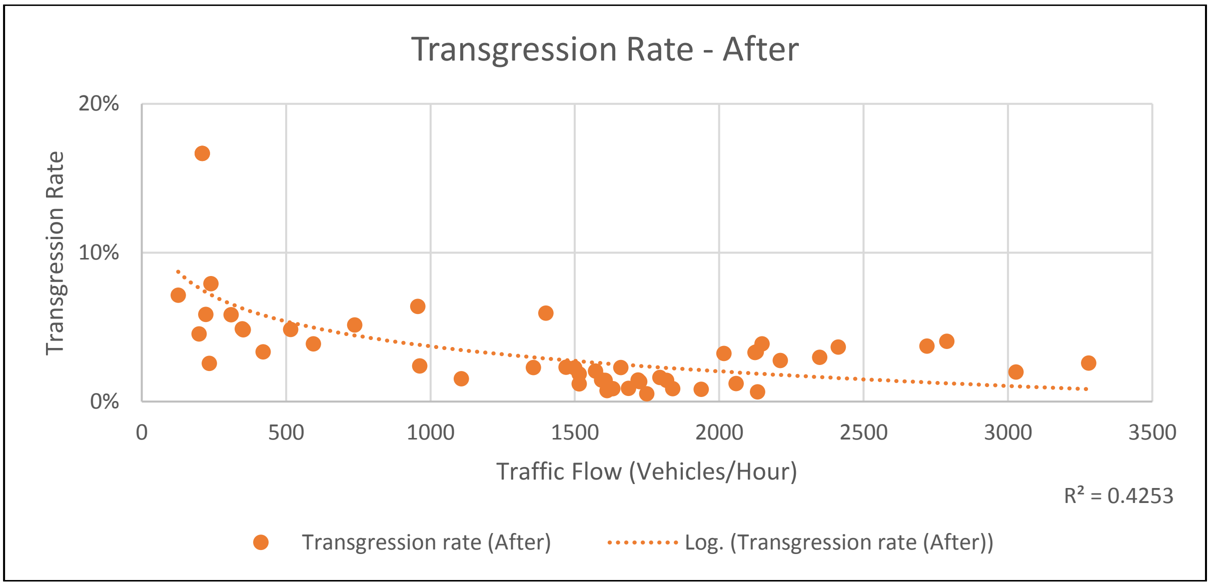

Figure 6: Transgression Rate by Traffic Flow after Stud Implementation

The graphs illustrate 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%.

Across all flows, the transgression rates were lower with the studs in place than with the no studs scenario.

5. Conclusion

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 was 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 lane discipline 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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