Effective Measures to Improve Road Safety at Toll Plazas in Ireland

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ABSTRACT: Currently, there are eleven traditional toll plazas in Ireland with eight of them located on the high-speed road network. On the approach to these facilities, drivers are required to make many rapid decisions which could result in speed variation, driver's confusion, and sudden lane change manoeuvres. Therefore, toll plazas are one of the most dangerous segments on high-speed roads [1]. Collision data obtained from Irish toll plazas and adjoining roads showed that due to relatively higher concentrations of collisions in the vicinity to toll plazas, these locations are often identified as collision clusters during regular road safety audits. With varying extent of road safety features at each toll plaza, it is crucial to establish the most efficient actions which could be followed universally by all these facilities, thus resulting in decreasing occurrence and severity of collisions. This paper combines analysis of worldwide literature, road safety audit reports, interviews with road safety auditors and online survey amongst relevant professionals. The research was to establish the best low-budget solutions to the road safety problem at toll plazas in Ireland. It was found that different improvements concerning road markings, signage and geometrical layouts may positively impact on road safety in toll plaza locations. Results from analysis of primary and secondary data showed that installation of lane guidance and warning bars on the approaches, installation of Variable Message Signs, lane guidance layout signs, interactive speed limit signs and other measures allowing free-flow of vehicles through toll plaza were found to be the most effective.
In summary, measures which contributed to decreasing the approach speed of vehicles and provides clear information to drivers about oncoming road layout were found to be the most likely applications to reducing occurrence and severity of collisions on toll plazas.

KEY WORDS: CERI 2020; TOLL PLAZA; ROAD SAFETY; SAFETY MEASURES; IMPROVEMENTS; ROAD SAFETY AUDIT; ROAD TRAFFIC COLLISSION.

1 INTRODUCTION

Currently, road safety in Ireland is at a very high level. In the latest international road safety statistics, Ireland placed 4th best with approximately 3 fatalities per 100,000 inhabitants per annum [2]. This result was only slightly higher than in the United Kingdom, Switzerland, and Norway. As shown in Figure 1, the fatalities decreased significantly after 2007 when Irish motorway network started developing rapidly. As construction of these quality roads were mostly funded by Public Private Partnerships (PPP), toll plazas were installed on them to regain the investments over the contract period. Unfortunately, most toll plazas in Ireland became accident black spots with much higher concentration of collisions than any other part of the same road.

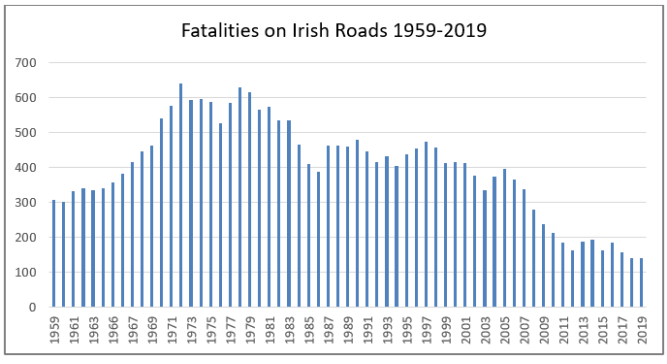


Figure 1. Fatalities on Irish roads 1959-2019 [3].

There is a lack of Irish standards specific to geometrical design of toll plaza facilities. Current plazas' designs were based on British Standards which are not strictly enforcing unified layouts of different plazas, giving leeway to designs suiting the operator rather than making it familiar to all road users. As most collisions occurring on toll plazas are material damage and minor injuries only, the problem of collisions in these locations is not prioritised by RSA, TII or Local Government road Authorities. Therefore, decisions about any improvement actions recommended during regular periodic road safety audits are left to private companies owning the road. Since majority of improvements incur a cost, these companies are understandably reluctant to any changes. Therefore, any valid measures proposed in this research should be actively endorsed by the road Authorities.
Education of drivers in proper use of toll plazas is one of the important steps which could improve road safety as most accidents on toll plazas occur due to driver's error. Varying toll plaza signage and layout designs which are not strictly unified across Irish road network are likely to be a contributory factor to these errors.
Drivers unfamiliar with layout ahead may become confused and perform sudden braking or lane changes. It was therefore the aim of this research to seek measures which could be implemented across all Irish road networks thus making all toll plazas more consistent in signage and traffic management.

2 METHODOLOGY

In search of the most effective measures which could improve road safety on Irish toll plazas, information was obtained from the existing toll facilities. Other sources of data involved interviews and online surveys amongst relevant professionals who are actively involved with road safety on toll plazas in

Ireland. A methodology involving all these sources of data is described in section 2.1 to 2.4 of this paper.

2.1 Online Survey

Part of the primary data obtained for the research originated from an online survey responded by fifteen relevant professionals. These were predominantly engineering and management staff of PPP companies operating roads with toll plazas.

The online questionnaire sought answers about previous effective improvements and preferred future enhancements to toll plazas which were likely to decrease collision rates in these locations. A few proposed measures including introduction of speed cameras and altering geometrical layouts to hybrid type toll plazas were also tested amongst participants.

Some questions explored experiences concerning funding currently available for toll plaza improvements including opinions on the idea of government incentives towards future road safety measures. Other topics concerned education of drivers, their common mistakes when using toll plazas and usefulness of road safety audits in the process of improving toll plazas road safety. The survey was confidential to ensure the opinions were not restricted.

2.2 Interviews with Road Safety Auditors

Five road safety auditors were interviewed as part of this research. All of these professionals interviewed have previous experience as a team leader in assessing road safety on toll plazas in Ireland.

The interview framework consisted of structured and semi structured questions. The content of all questions and topics was linked to the online questionnaire. This approach allowed to compare opinions of road safety auditors and other professionals on the same aspects of road safety on toll plazas.

2.3 Road Safety Audit Reports

Currently, all PPP roads containing toll plazas are contractually required to undergo a collision monitoring audits every 3 years. These audit reports prepared by independent consultants are known as a collision monitoring report and they include information about collisions occurred on the project road within the study period. Auditors analyse the collisions and provide recommended actions which should be followed to minimise their occurrence in the future. The audit reports used for the research were obtained from 6 different toll plazas in Ireland and contained a total of 25 years study period.

In most of these audit reports, toll plazas featured as collision clusters and were analysed separately. Collating this data specific to toll plazas allowed to compile these road safety measures which were favoured and prioritised by road safety auditors.

2.4 Other sources of data

In conjunction with a detailed literature review of relevant technical literature which informed the research, unstructured consultations with other professionals from Ireland and Poland were conducted. Some information was obtained to supplement the data obtained from survey, interviews, and road safety audit reports.

3 RESULTS AND DISCUSSION

After collating and interpreting all obtained data, the results were grouped into several categories which concerned various aspects related to the research. As shown in Table 1 these categories included road signage, road markings, geometrical layouts, and speed control measures. A discussion detailing these results are presented in sections 3.1 to 3.4 respectively.

Table 1. Summary of findings from data analysis.

Category of measure	Proposed Measures	Benefits	Limitations
Signage	Lane guidance signs VMS signage	Good advance information for drivers, less lane-changing manoeuvres, visibility of VMS signs is better in all weather conditions	High Initial cost of installation, power supply needed for VMS signs
Road Markings	Yellow bar approach markings, Lane guidance markings Speed limit roundels	Better guidance while approaching toll lanes, less lane changing, better warning about reduced speed limit ahead	Road markings require investment for initial installation and periodic maintenance, repainting which incurs costs
Geometrical layouts	Barrier-free express lanes	Better capacity of express lanes, no collisions with barriers	Higher speed of vehicles in unrestricted lanes and a potential increase in toll violations
Speed control Measures	Interactive speed limit signs Speed cameras	Visual feedback for drivers about their current speed, efficient enforcement for speed compliance	The installation cost for signs. Cameras would have to be managed by An Garda Siochana

3.1 Road Signage

Road signage is the first piece of toll plaza inventory every driver encounters while approaching these locations. Different categories of signs have specific roles in warning, informing and guiding drivers and they need to be used appropriately to present these messages in clear and efficient way. The signs on

approaches should give clear and adequate warning to drivers of which lane they should use at toll plazas [4]. During the online survey and interviews with road safety auditors, topic of signage was explored to establish what could be improved with signage at these toll plazas. It was evident from data collected from the research interviews, road safety auditors highlighted the need for improved lane guidance signage before toll plaza as presented in Figure 2. Signage concerns was also identified during multiple road safety audits which were analysed during the research. Some locations in Ireland already benefit from installing these signs which unfortunately aren't mandatory to use on all plazas [5]. Signage of this type informs drivers of the toll plaza layout ahead and if effective, it minimises occurrence of sudden lane changes on the approaches.

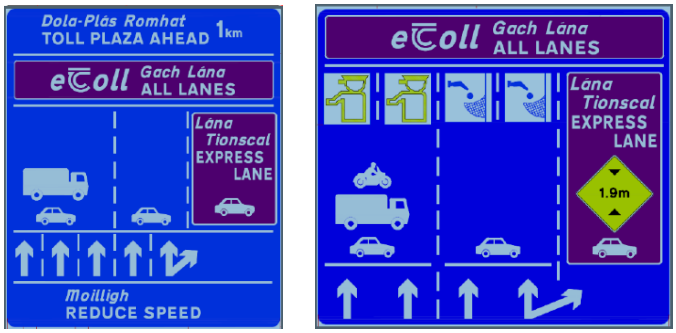
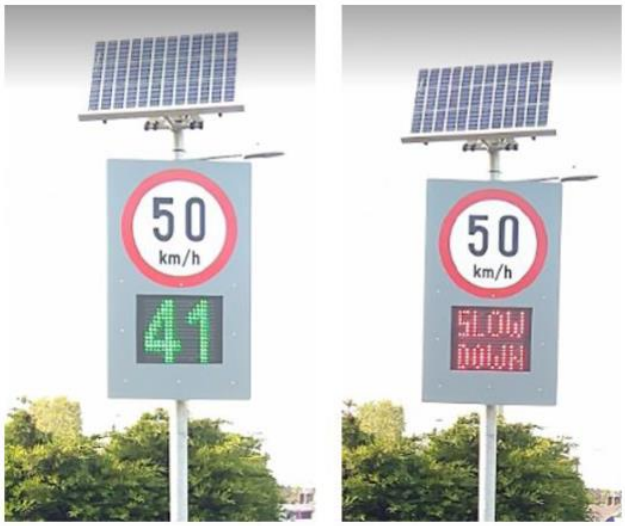


Figure 2. Toll plaza advance lane guidance signage [5].

Another important finding from the research concerned excessive speed of the vehicles approaching toll plazas. Adequate speed limit signage was therefore found to be an important measure at toll plazas. As confirmed by the majority of road safety audit reports and inveterate in the survey and interviews, interactive speed limit signs were found to be very effective in decreasing speed of vehicles. As shown in Figure 3, signs of this type display the current speed of the approaching vehicle and according to the measured values may change font colour, flash or display pre-programmed messages. Drivers are more likely to obey these interactive signs more than static ones which may result in lesser collisions on the approaches to toll plazas and also resulting in a decrease in severity of any collisions occurring.

Another finding from the research in relation to signage concerned Variable Message Signage (VMS). Over half of the participants of the online survey and majority of road safety auditors indicated that increased presence of VMS was likely to improve road safety at toll plazas by showing messages to drivers more effectively. As most suggestions concerned VMS speed limit signage, some auditors suggested these signs to be used as gantries on approaches to the toll plaza showing in real time closed and opened toll lanes ahead.

With all signage enhancements it should be noted that only sufficient signage should be included on toll plazas so there is no sensory overload occurring to drivers [6].



a) b)

Figure 3. Example of interactive speed limit sign messages – a) when the speed limit is adhered to, b) when speeding is detected (source: author)

3.2 Road Markings

Road markings were researched on the approach and exit from toll plazas. The approach markings are predominantly used for guiding the vehicles towards toll lanes.

It was stated by four of the five road safety auditors that the priority should be given to installation of lane guidance road markings before entering into toll plaza lanes. This recommendation was included in a number of road safety audit reports where markings of this type were not present. Twenty percent of online survey participants were in favour of this measure. However, forty six percent of the online survey participants prioritised transverse yellow bars on the approaches to toll plazas. These are designed to warn drivers about the dangerous area ahead. The markings give a visual and tactile feedback for the driver and their spacings decrease closer to the plaza, convincing most drivers to reduce speed on the approach. These road markings however were not recommended in road safety audit reports, possibly due to the cost of their maintenance requiring periodic repainting.

Speed limit roundels presented in Figure 4 were also suggested by three auditors during the interviews and listed in road safety audit reports as recommended measures. These markings supplement vertical speed limit signage which can be missed by drivers especially in the areas before toll plaza where the road width is increased. During a study carried out in Hong Kong, it was confirmed that following introduction of some additional lane guidance at toll plaza express lane, average lane changing rate decreased by 23%, conflict count by 44% and crash count by 38% [7]. Therefore, adequate road markings can be highly effective in reducing occurrence of collisions on toll plazas.

Figure 4. Example of speed limit roundels and warning yellow bars on the approach to toll plaza (source: Google Maps)

3.3 Geometrical Layouts

During the post-construction operational stage of toll plazas, limitations for revising geometrical layouts are significant. These limitations may concern lack of available space for accommodating revised layouts and the cost of construction or realignment of toll lanes. As detailed in the literature review, online survey, and interviews with road safety auditors, the most preferred geometrical layout measure on toll plaza concerned transition into a free-flow system. This system is the most effective way of improving road safety on toll plazas as vehicles can travel through the toll point at normal motorway speed without the need for braking or changing lanes. Research of some traditional and hybrid toll plazas in the USA confirmed the overall 76% reduction in accidents collision rates following their conversion into all electronic free-flow system [8].
As this is an extreme step which requires investment into new tolling equipment, demolition of the existing toll booths and incurs further operational costs it could not be a feasible improvement for private companies managing toll plazas in Ireland.
The interim geometrical improvement which could be applied to Irish toll plazas is removal of barriers from express lanes, adapting hybrid-like toll plaza layouts. This solution would increase throughput of all toll plazas and collisions with toll barriers in express lanes would be eradicated. However, it would need some planning for non-compliance with payments and for coping with speed of the vehicles in unobstructed lanes.

3.4 Speed control measures

Most vehicles travel towards toll plazas within the applicable speed limits. As the vehicles approach the toll plazas, the vehicles not using express lanes are forced to come to a complete stop at the toll booths. The problem with speeding on toll plazas is therefore in between these areas and is related to the occurrence of speed differential between vehicles approaching at different speeds [1]. The differential has a negative impact on road safety when vehicles travelling faster approach slower vehicles. Rear end and side swipe collisions identified during road safety audits are largely attributed to noncompliance with speed limits. Road safety auditors listed speeding as one of the major errors of drivers using toll plazas. Therefore, essential to regulate and unify the approach speed of all vehicles, minimizing the occurrence of speed differential.
Along with interactive signs and speed limit road markings described earlier, speed on toll plazas can be effectively managed by installation of speed cameras. This measure met with overall approval amongst road safety auditors and survey participants. It was also listed as a secondary recommendation for a speeding problem in one of the road safety audit reports. This measure was used on one of the Polish toll plazas on A4 between Krakow and Katowice and initially provided the expected results. In Ireland, these speed cameras would have to be managed by An Garda Siochana and preferred option would be to have them activated at random times to keep drivers alert of the speed enforcement measures.

Data from road safety audit reports, provided evidence that some Irish toll plazas also introduced speed enforcing measures in barrier operated express lanes. These barriers do not lift for vehicles which approach at speed above set threshold – usually small percentage above speed limit. It was also established in one of these reports that drivers familiar with this system tend to enter express lane at slower speeds, thus creating speed differential with vehicles using other toll plaza lanes located approximately 200 meters after entrance to express lane.
This issue highlights the need for unified speed of vehicles well in advance of toll plazas. This would also allow the drivers to have more time to make decisions and minimize negative effects of any collisions occurring.

4 CONCLUSIONS AND RECOMMENDATIONS

The main aim of this research was to establish low budget road safety measures which are likely to improve road safety at Irish toll plazas. The research data sources included literature review, online survey, interviews with road safety auditors and road safety audit reports from multiple toll plazas in Ireland. The results obtained from all these sources were analysed and grouped into several topics. It was found that different improvements concerning road markings, vertical signage and geometrical layouts can positively impact on road safety on toll plazas. Results from analysis of primary and secondary data showed that installation of lane guidance and warning bars on the approaches to toll plazas were found to be the most preferred improvements of road markings. It was established that Variable Message Signs, lane guidance layout signs and interactive speed limit signs could effectively reduce speed on the approaches to toll plazas and minimise lane-changing manoeuvres. Geometrical measures which allowed a free flow of vehicles through toll plazas were found to be the most effective.
In summary, measures which contributed to decrease the approach speed of vehicles and provide clear information to drivers about oncoming road layout were found to be the most crucial to reducing occurrence and severity of collisions on toll plazas.
To add meaning to this research some actions should be considered by Authorities responsible for road safety in Ireland.

Some survey and interview questions tested opinions about additional funding for toll plaza operators exclusively for road safety improvements at these facilities. The vast majority of professionals agreed that some additional funding could accelerate introduction of road safety measures. Road Safety Authority and Transport Infrastructure Ireland would be the most adequate to develop and manage such incentives.
Unification of signage and road markings on toll plaza should also be more enforced by legislation to make all these facilities more familiar for all drivers.
Finally, relevant road operators should share their experiences related to any implemented measures and strive to come up with new solutions for reducing collision numbers and their severity at toll plazas in Ireland.

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