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A clearer vision for pedestrian guardrails

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Pedestrian guardrails have been used increasingly on Britain's streets since the 1930s, but their value is now being questioned by planners in the light of the new trend of reducing street furniture. This paper disputes claims that guardrail removal enhances safety by presenting evidence of the large reductions in casualties after erection of guardrails, particularly those that do not block visibility. Chronic lack of research is highlighted, with particular reference to visibility and its inadequate treatment in design standards. Deterrence of diagonal crossing is identified as a prime reason why guardrails are so successful in preventing pedestrian accidents, which clarifies how they can be used most effectively. Recent work to improve the design of guardrails is also outlined.

Road accidents make headlines. They are traumatic and costly. A major crash unleashes huge resources of police, medical and technical expertise to repair the human and material damage and to prevent recurrence of the accident.

Non-accidents are very different—accidents which would have occurred but for a safety measure. These accidents leave no record, nor do casualties know that they have been saved, so the benefit of the safety measure is not appreciated.

The syndrome is particularly applicable to pedestrian guardrails because their purpose is not obvious, unlike most safety measures. Warning signs alert drivers to danger, for example, and high-friction surfacing prevents skidding, but do guardrails guide pedestrians, or protect them, or just clutter streets?

The latter view is gaining popularity among planners keen to improve the street environment and to 'empower' pedestrians to walk wherever they want. Removing guardrails might be expected to increase risk, but it is claimed by a leading urban design consultant[1] that if roads are made more dangerous, road users will become more careful and accidents will decrease.

The argument is only valid, however, if road users are aware of a hazard. To demonstrate, just omit de-icing at a bend to make it more dangerous, and watch accidents soar because wet and icy roads look similar. Similarly, removing guardrails increases danger, but for reasons which are more subtle. Elucidation of those reasons is the main purpose of this paper.

Kensington High Street

The most publicised example of guardrail removal is Kensington High Street in London, the radical redesign of which has cost £4·5 million. A total of 715 m of guardrails were removed, a cosmetic treat-

Fig. 1. Children are much safer at guardrails which do not conceal them (right) compared to the traditional concealing design (left)

ment which is being emulated elsewhere because there is widespread ignorance of the benefits of guardrails. Non-accidents are being replaced by accidents, so the need for guardrails will again become evident, as already suggested by a road safety report[2] for Kensington High Street.

The before-and-after accident record from Kensington High Street appeared to vindicate the decision to remove guardrails. Comparing two years before the scheme with two years after, pedestrian casualties fell by 64% compared to 43% for all of the Royal Borough of Kensington and Chelsea, leading to claims such as, 'the results have discredited the belief that railings prevent accidents'.[3]

The road safety report itself was cautious about making such statements because of statistical uncertainties, yet it claimed that 'notwithstanding all of these, the initial results are encouraging and indicate that the innovative approach to design and layout and the type of materials, street furniture and equipment used has not had an adverse effect on safety'.

The conclusion cannot be justified. Individual measures applied to Kensington High Street could have had very diverse results, even if cumulatively they were beneficial. New pedestrian crossings, better street lighting, and anti-skid surfacing, for example, were almost bound to reduce casualties. Others were not. It is nonsense to claim that removing guardrails improves safety, as demonstrated by the report's comment that 'there were injuries to pedestrians who crossed at locations where previously guard-railing was installed'. The guardrails would have been erected to prevent such accidents, so their recurrence is not surprising and raises awkward questions about liability.

Early pedestrian guardrails

Before reviewing the use of guardrails in Britain, a brief historical perspective may be useful. In the 1930s they comprised horizontal tubes between posts, with no infill. Evaluation of 5 km of this guardrail in east London showed that it had not significantly reduced the number of accidents because it could be climbed through easily. Plans to introduce guardrails throughout urban areas were shelved.

To overcome that drawback, the first postwar report on road design[4] advised that guardrails 'should be so designed that pedestrians, particularly children, cannot crawl through them'. The report therefore proposed a new design comprising horizontal top and bottom rails infilled with closely spaced vertical bars, which solved the access problem by making it difficult to climb over or through the guardrail.

The design was formalised in BS 3049, *Pedestrian Guard Rails (Metal)*,[5] which required guardrails to be infilled. Open guardrails gradually disappeared from Britain's streets. A notable exception, however, is the Kensington High Street experiment, where the 715 m of guardrail have been replaced by just 60 m of open guardrail—an expensive creation of stainless steel tubes without infill. This design may have artistic merit, but is likely to provide as little benefit for safety as its east London predecessor.

Visibility through guardrails

Open guardrails had, however, one major advantage over infilled ones. They provided better visibility, so drivers could see pedestrians through them and vice-versa. With infill bars, visibility is blocked because they overlap to create a solid wall, as seen on the left of Fig.1. A child crossing the street can be completely hidden from the driver, then moments later be in front of the vehicle, making collision unavoidable.

Fig. 2. Guardrail replacement by Visirail restored visibility for right-turning vehicles at this junction, leading to an 80% saving in accidents.

It is nonsense to claim that removing guardrails improves safety

Engineers were aware of the hazard, yet loss of visibility seemed inevitable if infill bars are close enough to prevent access. Evidence that this causes accidents was not readily available, however, because of the strange omission of pedestrian guardrails from police Stats 19 accident returns.[6] The breakthrough came with an important study of guardrails by the Greater London Road Safety Unit (GLRSU) in 1983.[7]

The GLRSU had identified 16 sites where the only change had been the introduction of guardrails, all with infill which blocked visibility. For these sites, a reduction in pedestrian accidents of 27% was found. It was suggested by the author that accidents involving children would show less improvement, being more concealed than adults, so the GLRSU supplied adult and child pedestrian casualty totals, which provided confirmation. Whereas casualties fell by a third for adults they almost doubled for children.

The implications of this discovery for child safety were shocking, and could explain a peculiarity in Britain's casualty statistics. Despite having almost the best record in Europe for driver fatalities, the UK had the worst for child pedestrians—an anomaly which until then had never been explained.

Seeking a solution for this visibility hazard, the author discovered that offsetting rows of infill bars at a shallow angle can provide excellent visibility far ahead of a driver. It was the subject of UK patent 1 585 498[8] and entered licensed production in 1978 with Hugh Logan Engineering under the trademark Visirail.

The new design achieved a transparency of 77%, instead of the total opacity of conventional infill. The dramatic improvement is apparent on the right-hand side of Fig.1. Small children waiting to cross are hidden on the left but fully visible on the right, due to the combination of angled infill and high-visibility posts.

Benefits of visibility

Whereas the transparency of the new design was self-evident, its benefit for safety had to be established. The author therefore carried out an investigation based on the GLRSU research, as reported in a previous paper.[9]

A key finding was that replacing ordinary guardrails with Visirail gave large reductions in casualties, in the order of 50%, with a rate of economic return exceeding 1000% a year when comparing accident costs with total erection costs. Drivers were also found to have about 50% fewer casualties, probably due to fewer shunt accidents when braking to avoid pedestrians and to better visibility at junctions (Fig. 2). Guardrails had dangerously obscured vehicles turning right off this dual carriageway until partial replacement with high-visibility guardrail. The unique repetition of remedial treatment at this site confirmed an 80% saving in accidents,[9] which became significant at the 99·9% level.

The effectiveness of the design was also demonstrated by a mass-action project. Over a period of about 10 years Aberdeen replaced virtually all guardrails with about 8 km of Visirail, the first city to do so. Pedestrian casualties in the city declined by over 50%, as seen in Fig. 3. The chart terminates at 1999 because sales information was not available after expiry of the patent, but high-visibility guardrails continue to be installed and the casualty reduction now exceeds 70%. Although other factors clearly contributed to that figure, the widespread use of high-visibility guardrails is the most plausible reason that Aberdeen's rate of improvement was the greatest in Britain, and helped the city to gain a European Award for Road Safety Strategy.

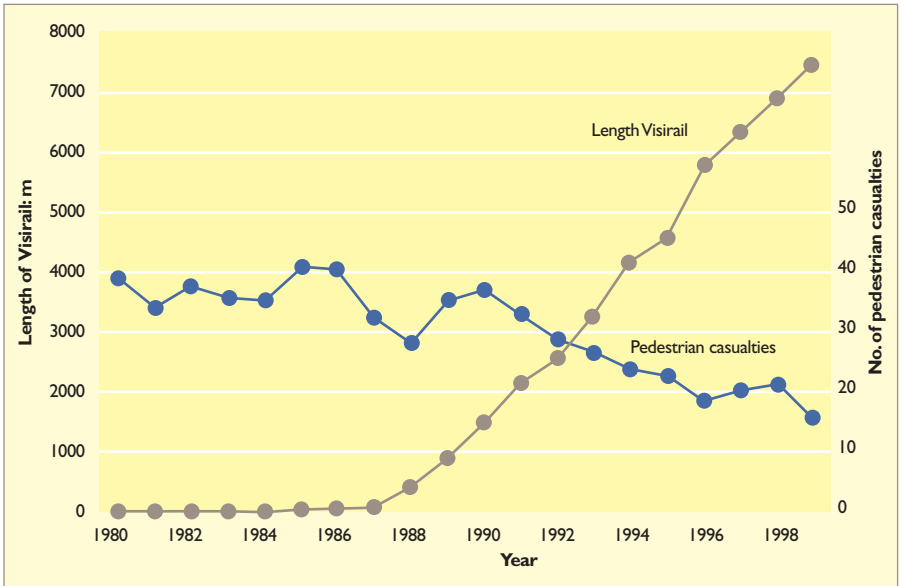

Fig. 3. Pedestrian casualties in Aberdeen reduced in direct proportion to the length of Visirail installed (no sales data were available after expiry of the patent in 1999)

Dramatic improvements such as these suggest that the 1000 km installed throughout Britain may be the main reason that the pedestrian casualty rate has been transformed from almost the worst in Europe, with about 200 casualties per day, to near average. From study sites and a case history from Aberdeen, a UK saving in the order of 10 000 pedestrian casualties per year may be attributable to Visirail.

In 1988, media coverage of the author's research forced government action. A nationwide investigation led to a draft report, but the Scottish Accident Prevention Council then announced in 1990 that the report and all documentation 'had gone astray', with the recommendation that 'the report be buried due to the time factor involved' (personal communication from SAPC, 2 November 1990). It has never been resurrected, and no information from the investigation was ever disclosed.

The author was invited in 1989 to join the British Standard committee revising BS 3049 *Pedestrian Guard Rails (Metal)*[5] to create the new BS 7818 *Pedestrian Restraint Systems in Metal*.[10] Commercial and political influences, unfortunately, prevented effective specification of guardrail transparency and permitted designs which had been proscribed by BS 3049, such as the open guardrail used at Kensington High Street. The efficacy and safety of current guardrails is therefore highly variable.

In 2003, however, a report on guardrails was published by the University of Southampton for Transport for London.[11] Reflecting the change in emphasis from safety to aesthetics, a stated aim of the report was 'eliminating street clutter and improving the street scene', so it advised 'that the erection of new guardrails should not be considered if alternative safety measures can be used'.

The advice is difficult to reconcile with the report's finding that 'the pedestrian accident rate at sites without railing was 2·5 times that at sites with railing, and the difference is statistically significant'. This large differential indicates that much of the railing was of a high-visibility design, but types of guardrail had not been recorded nor was visibility taken into account, so the research had limited value.

Another investigation cited in that report was more informative. Before-and-after accident rates from a six-year study of four Visirail sites in Wolverhampton showed a 79% reduction in casualties, about three times greater than the concealing guardrails in the GLRSU study. While such results left no doubt about the safety benefits of high-visibility guardrails, why they were so significant was a mystery. That was the author's next line of investigation.

Perceptual error in road accidents

The conventional wisdom about the purpose of guardrails, as presented in the University of Southampton report,[11] is that they 'protect pedestrians by preventing them from … crossing at unsafe places' and 'may be of benefit by helping to guide pedestrians to the designated crossing place'.

Whereas the effects are self-evident, it was not credible that they could produce such large casualty savings. An unknown, beneficial visual factor was suspected because previous research by the author had shown that subtle perceptual errors could have massive effects on road safety.

Investigation into the causation of accidents at bends led to the conclusion that spiral transition curves increase the risk of accident by making a bend appear shallower than actuality. Minor realignment to remove the illusion by making bends wholly circular was found to eliminate most accidents, even on acute bends, without the need for any other safety measure.[12] The State of California did a corroborative study which confirmed that circular curves were safer,[13] and discontinued the use of transition curves, but they persist in Britain as an irrational and dangerous appendage in UK Department for Transport design codes.

Another form of illusion identified by the author specifically endangers children. Our innate perceptual process for estimating time-to-collision from optic flow was shown to be inadequate for driving. Instead, drivers judge distance from size, but tend to mispercieve children as taller and more distant than they actually are, which delays braking. The hypothesis was tested by computer simulation at Aberdeen University and shown to be a factor in most child pedestrian accidents.[14,15] Rectifying it would therefore be hugely beneficial for the 700 child pedestrians who are killed on roads daily[16] but there appears to have been no subsequent research by the UK Department for Transport or elsewhere.

Children continue to be blamed for their accidents, and road safety education, is expected to safeguard them, despite evidence of its limited value,[17] yet the most dangerous errors seem to be made not by child pedestrians but by drivers.

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Risk due to diagonal crossing

The perception studies revealed that the influence of subtle visual errors in road accidents is significant but largely unsuspected and unexplored. In seeking to explain why high-visibility guardrails were so effective in curbing accidents, therefore, it seemed possible that perceptual factors in addition to transparency were responsible.

One possibility was that the standard 1 m height of guardrails would help drivers judge the height and therefore distance of pedestrians, but this effect would be very localised.

A more credible perceptual factor is prevention of diagonal crossing. A person crossing the road diagonally is effectively blind to one side because, although peripheral vision is very sensitive to movement, it extends little beyond 180°. A location where diagonal crossing is common might thus be expected to have a high casualty rate. This is supported in BS 7818 by the statement: 'crossing approaches … are the most dangerous sections of the road for pedestrians'.[10] It follows that if unilateral blindness to traffic is a prime cause of pedestrian accidents, then prevention of diagonal crossing by erecting guardrails could account for their effectiveness in preventing them.

The proposition was first examined by returning to the GLRSU study.[7] It had reported that extending guardrails is more than twice as effective as new guardrails in reducing accidents. Commenting on this odd statistic, the University of Southampton report[11] concluded that it 'seems counter intuitive and there appears to be no logical reason for it'. Nor did the GLRSU study itself offer clarification. With the diagonal crossing hypothesis, however, an explanation emerged. A short guardrail may do little to discourage diagonal crossing and could even increase it, so extending the guardrail could be more effective than the original one in preventing accidents.

The GLRSU study allowed further verification. If diagonal crossing is hazardous, then guardrails on both sides of a street would be expected to prevent more accidents than guardrails on only one side. This was confirmed. Two-sided sites were almost twice as effective as single-sided sites, both for new guardrails and for extended guardrails.

Fig. 4. Optimal use of the new Visiflex guardrail to discourage diagonal crossing and maximise casualty reduction—according to BS 7818,[10] guardrails should extend at least 20 m either side of a crossing

The author's earlier paper[9] also provided evidence. It collated several researchers' findings, showing that increase in pedestrian flow on a crossing is correlated with decrease in accident rate. Because pedestrian flow increases as guardrails are extended, a mathematical model was created to relate length of guardrail to accident frequency. The paper acknowledged, however, that, 'why pedestrian concentration should greatly reduce risk is not clear', a mystery that remained unsolved for almost 20 years.

Diagonal crossing at last provides an answer—false correlation. As guardrails are extended and decrease diagonal flow, direct flow over the crossing must increase. Hence the causal correlation for risk is with diagonal flow, not direct flow.

The mathematical model had predicted that relatively short lengths of high-visibility guardrail, in the order of 25 m, would reduce pedestrian casualties by about 70%, which is supported by subsequent evidence, such as the Wolverhampton study. That result can be interpreted as confirming that modest lengths of guardrail are sufficient to prevent diagonal crossing, so the recommendation of BS 7818 that 'a restraint system … should be installed on both sides of the road and should extend a minimum distance of 20 m in either direction from the crossing' is a rational and important one.

Evidence that relatively short lengths of guardrail give large casualty reductions also answers the planners' complaint that guardrails 'create an unpleasant constrained environment for pedestrians, stopping them from crossing where they want to'.[11] The inconvenience of minor diversions round short lengths of guardrails is trivial compared to the enhanced safety which they produce.

Development of guardrails

There can no longer be any doubt that visibility through guardrails makes them safer, but other aspects of guardrail design have tended to be ignored. It is therefore appropriate to consider not only if guardrail transparency can be further enhanced, but also whether other features such as durability and economics can be improved.

The author sought to achieve these aims with a new design, trade marked Visiflex, which replaces the original Visirail design (Fig. 4). It entered licensed production with Bridge Parapets Ltd in 2006, based on UK patents. Transparency is significantly improved, such that only one type of panel is needed—removing the difficulty of having to select from alternative configurations of infill bars.

Another benefit is resilience, due to cantilever panels which act as portal frame/torsion box structures. Minor vehicle impacts which tended to buckle rails and posts no

longer do so, and collisions sufficiently severe to destroy panels are unlikely to damage the heavy-duty stub posts. Panels can therefore be rapidly replaced with no need for excavation. The net result of the innovations is that not only are transparency and safety improved, but so also are planning, installation, crash integrity, durability, maintenance, appearance and full-life cost. The prototype in Fig. 4 demonstrates 'ideal' use at a pedestrian crossing—sufficient guardrail to prevent diagonal crossing and ensure maximum safety, without inconveniencing pedestrians.

The production version in Fig. 5 is erected where concealing guardrails are most dangerous: at a school entrance. It reveals what an adult seldom appreciates: the need for a small child to see as well as be seen through guardrails.

Conclusions and recommendations

Two important criteria for minimising pedestrian casualties by installing guardrails have been identified: that guardrails should not block visibility and should be sufficiently long to deter diagonal crossing. If these criteria are met, evidence suggests that casualty savings of 80% can be anticipated. This also suggests that rather than removing old guardrails to enhance streetscapes, it is preferable to replace them with high-visibility guardrails.

With fresh understanding of how guardrails affect safety, the limitations of the experiments in east London and Kensington High Street are clear. Neither had used guardrails effectively. Another major experiment should therefore be conducted to evaluate the effects of high-visibility guardrails on safety and thus to facilitate drafting of better standards and guidelines.

A possible experiment would be to identify a long street with a poor accident record for pedestrians, then install high-visibility guardrails extensively on one half of the street, to facilitate analysis of its accident record by comparison with the untreated half. Another is mass-action installation of high-visibility guardrails at schools, to reduce Britain's toll of 30 child pedestrian casualties a day.[18] Successful conclusions to such experiments could justify the widespread use of guardrails anticipated by the east London study 70 years ago.

The paper has also shown the potential for identifying other perceptual problems on roads, and rectifying them. There has been little bureaucratic will to do so, unfortunately, particularly when flawed design methods are part of the problem. Perhaps this lack of vision is most in need of resolution.

Acknowledgements

The author gratefully acknowledges the facilities and assistance of the University of Aberdeen. The support of Hugh Logan and Danny Mackay in developing Visirail and Visiflex has been invaluable.

Fig. 5. High-visibility guardrails both allow drivers to see children and vice versa

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Discussion

P14989 A clearer vision for pedestrian guardrails

by Douglas Stewart (August 2007)

Contribution by Daniel Moylan

Douglas Stewart makes three points: that guardrail through which motorists can see is safer than 'solid' guardrail; that guardrail at pedestrian crossings prevents diagonal crossing; and that Kensington High Street is a disaster. The first is plausible, the second debatable and the third merely ill-informed.

Most guardrail removed from Kensington High Street was installed to prevent loading in the days before decriminalised parking enforcement. It is no longer needed. The small amount retained is mostly there to prevent people tripping over Trief kerbs that form part of the Underground tunnel just beneath the surface. The author says the design of this is unsafe because people can climb through it, as children did in the 1930s, the most recent evidence he refers to to support his argument. In fact it is astonishing that, given the opportunity, this potentially enjoyable risk sport (climbing through guardrail) has not yet taken off in Kensington High Street: perhaps modern kids are less adventurous— or more sophisticated—than their 1930s counterparts.

Horses for courses and learning by doing are the paths that Kensington and Chelsea has followed—and would recommend to others—not rigid adherence to the use of a patented product in every case.

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Author's response

I suggest readers judge the validity of the contributor's comments on the three points for themselves, by referring to the paper.

The main reason that he is unaware of 'modern kids' climbing through open guardrail as they did in the 1930s is not that they have become less adventurous or more sophisticated. It is that most children are now kept indoors because streets are so dangerous, a consequence of our failure to apply science to understand accidents and engineering to prevent them.

One exception is high-visibility guardrail, but 'rigid adherence to the use of a patented product' is unnecessary. Although the original Visirail is no longer produced, several copies are available due to expiry of its patent several years ago. Its successor, Visiflex, has patents which help to ensure its improved performance and quality.

Contribution by Graeme Swinburne

I must refute the author's statement in his paper that, 'Non-accidents are being replaced by accidents, so the need for guardrail will again become evident, as already suggested by a road safety report for Kensington High Street.' The report to which the author refers does not draw this conclusion, in fact quite the opposite.

The original aim of the project was to ensure accident levels did not increase and at least followed the borough trends. Also, much of the guardrail in Kensington High Street was never introduced as a road-safety measure, but to stop parking and the resulting congestion. With the introduction of decriminalised parking, there are now other ways local authorities can keep traffic moving.

Work carried out for the Central London Partnership and Transport for London by Jan Gehl showed the considerable amount of 'non compliance' with guardrail by pedestrians, and questioned its genuine effectiveness in some locations.

I note the author invented Visirail and its successor Visiflex, for which he must take much credit. In the past I have specified Visirail when it was considered the right solution but I would like to point out that it isn't only planners who are questioning the appropriateness of some established solutions.

Kensington High Street and the other similar projects which are being implemented across the country involve a great deal of design and very close scrutiny, post implementation. The Royal Borough of Kensington and Chelsea was not cavalier when it took the decision to remove guardrail, it followed a metre-by-metre analysis of the problems. Then, when the changes were made, there followed a period of meticulous monitoring. This was very labour-intensive, but if you are going to break away from the model I and many others have followed over the last 30 years, you will have to commit the time and resources.

Whilst I am sure the examples given by the author are the most appropriate solution for those specific locations, you could conclude from the text that there is only one solution. This is obviously not the case and I am sure that is not the message the author wanted to send. However, let us ensure the new generation of engineers and highway designers are well trained and use the best of good design, which may not always involve the use of guardrail.

Unlike 70 years ago, modern children do not appear to be climbing through the new open guardrail in Kensington High Street

The Royal Borough of Kensington and Chelsea was not cavalier when it took the decision to remove guardrail, it followed a metre-by-metre analysis of the problems.

Author's response

Just because guardrailing is introduced to stop parking does not preclude it from preventing accidents. This is demonstrated by the pedestrian accidents that occurred[2] where guardrails had previously been installed in Kensington High Street.

Jan Gehl's attitude to guardrails may be influenced by their rarity in his own country, Denmark. Unlike Britain, pedestrians in Denmark are required to use pedestrian crossings, which are liberally provided. So although Danes are spared the 'herding' by guardrails which Gehl dislikes, they are in effect herded by legislation instead. Research comparing these alternative methods to prevent diagonal crossing and safeguard pedestrians could be invaluable.

'Non-compliance' by pedestrians can be a problem with excessive lengths of guardrail, which pedestrians may jump over; and with very short lengths, which can promote diagonal crossing and its perceptual hazard. The remedies are self-evident.

Professor Gehl's report *Towards a Fine City for People*[19] has the laudable aim of making London a 'walking-friendly' city. The most unfriendly experience that a pedestrian can suffer is collision with a vehicle so, if the effectiveness of guardrails is being questioned, why were no accident data presented? Had their safety record been investigated it would have been discovered that even if guardrails may not improve the streetscape, at least they are friendly and very cost-effective.

After the £5 million enhancement of Kensington High Street, 17 fewer pedestrian casualties per year were recorded.[2] Similar expenditure to install high-visibility guardrails at pedestrian crossings throughout Britain would prevent more than 2000 pedestrian casualties per year, based on before-and-after studies. If we are serious about preventing death and injury to pedestrians, especially children, priorities for action and funding should be urgently reviewed.

I agree that 'questioning the appropriateness of some established solutions' by engineers is necessary. Getting rid of pedestrian guardrails is just one example of a solution that is flawed and dangerous. There are several others. The UK Department for Transport requires political encouragement to identify these mistakes and rectify them. Otherwise, major errors such as removing guardrails will be perpetuated, and road users will continue to suffer avoidable accidents.

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Discussion

My paper does, I admit, focus on one particular solution. However I know of no other remedy for pedestrian accidents whose benefit is so large, so cost-effective and so widely applicable as high-visibility guardrail, so I make no apology for my emphasis. I trust the contributor's analyses and monitoring will lead him to the same conclusion.

Contribution by Steve Reeves

The removal of guardrail should only be considered when part of a wider design for the whole streetscape and not in isolation. The removal of guardrail should only be deemed appropriate where the wider design incorporates features that ensure vehicle speeds are reduced to less than 30 km/h (20 mph) and thereby reduce the risk of accidents and collisions.

No one I have met in the profession would suggest removing guardrail from crossing points of distributor roads and so on but, within the urban environment where vehicle traffic should be secondary to pedestrian movements (as recommended in the Manual for Streets20), removal of unsightly barriers should be welcomed and embraced.

On a wider point, the author's attitude means that planners and so on take engineers less seriously and give less weight to our opinion as a result. After all, the evidence suggests that the socio-economic problems of some suburban estates have been contributed to by the prescriptive highway design requirements insisted upon by my older colleagues in the industry.

Removing guardrail is a great benefit to the urban environment and we engineers should use our vast experience to ensure that streetscape design maximises the levels of safety afforded to road users whilst ensuring they have a welcoming environment in which to live and work.

Author's response

I agree that if traffic speeds are very low, risk could be so reduced that guardrail is not justified. There is, however, little official guidance on which to base such decisions.

If movement of pedestrians is a priority, their safety should be also. Removing guardrail may improve amenity but will normally increase casualties. This may be predicted from before-and-after accident statistics for guardrail, if the date of installation is known. Without such evidence that it is not preventing accidents, which is unlikely, it might be wise to obtain indemnity insurance, as did councillors before deciding to de-clutter Kensington High Street.

Engineers in progressive fields such as electronics, aerospace or structures are taken very seriously. They create products which are tangible and profitable, unlike accident and investigation prevention engineers who have to 'sell' non-accidents, which are neither. That is why road accident investigation and prevention is an engineering backwater, in chronic need of innovation and development.

Contribution by Norman Gill

I notice that Douglas Stewart did not include the statistics when, following a guardrail being bent by a car, a high-visibility guardrail at a road junction was mistakenly replaced with an infilled one, then later replaced again by a high-visibility one. The accident rate increased and then decreased again, though I do not have the figures.

Author's response

The contributor is referring to the junction seen in Fig. 2 of the paper. A length of 22 m of masking guardrail had been replaced by high-visibility guardrail to rectify poor visibility for right-turn vehicles and pedestrians. Based on a study boundary 20 m from the high-visibility guardrail, total accidents fell from about five to one a year.

Three years later, the high-visibility guardrail was temporarily removed, then the original guardrail was replaced in error, again blocking visibility. By the time this was corrected, less than one year later, five injury accidents had occurred.

High visibility guardrail was accidentally replaced with infilled guardrail at this road junction, resulting in a five-fold increase in accidents

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High-visibility guardrail was then re-erected, and the accident rate returned to about one a year. This evidence of improvement is so obvious that its significance level of more than 99·9% is rather academic. Considering right-turn accidents only, 12 were recorded with the masking guardrail, but none with the high-visibility guardrail.

There was no other significant change at the junction during the study period, so it was clear that over 40 people had been saved from death or injury solely by improving visibility.

The author (d.l.stewart@btopenworld.com) would welcome details of any other before-and-after statistics which may have been collected for high-visibility guardrails.

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