THE USE OF HARD SHOULDERS AS A TURNING LANE: A SAFETY EVALUATION

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ABSTRACT

This paper investigates the phenomenon of South African drivers using the hard shoulder of the road as an unofficial turning lane. Due to the increasing number of vehicles on our roads, drivers often experience heavy congestion during the peak hours of the day. A growing trend has emerged in the Western Cape of drivers using hard shoulders in advance of a left turn; essentially creating an informal turning lane to reduce travel time by bypassing the traffic queues.

The paper represents an initial safety evaluation of this phenomenon along the R44 between Stellenbosch and Somerset West, and also an attempt to identify geometric and traffic flow conditions common to a number of intersections where this phenomenon is observable. It examines the operating circumstances under which road users appear willing to use the road shoulder, specifically the physical dimensions of road elements and the speed differentials between vehicles travelling in the road shoulder and those of the adjacent lane. It looks further at the interaction between non-motorized transport and motorized transport and measures conflicts between road users that occur as a result of these manoeuvres.

The results failed to find any measurable relationships between road geometry and the emergence of the use of a hard shoulder preceding an intersection, suggesting that the physical design of the intersection is not, in itself, necessarily a contributory factor of this behaviour. However, the conflict analysis showed clearly that conflicts with pedestrians and cyclists are certainly evident when hard shoulders are being used by turning vehicles, and that intersection design currently does not offer sufficient protection for non-motorised traffic at these intersections. A sufficiently high number of conflicts was recorded to suggest that these manoeuvres could result in injury crashes in the future, unless thought is given to either preventing this behaviour, or protecting users more rigorously.

1. INTRODUCTION

Drivers in Stellenbosch and the Cape Metropole area, like others across the country, experience growing congestion levels in traffic each year. For many, the drive to work (and back again) is increasingly fraught with frustration. Ever creative on the road, drivers here are beginning to create new paths for themselves. Any driver who has experienced congestion of the Cape Freeways will have, for example, experienced minibus taxis using the hard shoulders on each side as informal lanes. To a lesser extent this creative approach to defining new lanes is being seen even within the urban road environment. A number of intersections are known through the region to demonstrate the creation of informal turning lanes as frustrated drivers identify the opportunity to move forward, and access traffic signals more quickly, by proceeding on hard shoulders. This phenomenon seems to be growing as the behaviour - and inclination - spreads, and in the absence of any direct countermeasures or negative feedback.

A question arose as to whether any common physical characteristics of the roads could be identified within the intersections where this phenomenon was observed. To this end, a research project was developed which looked specifically at the traffic and road characteristics of six intersections in Stellenbosch and surrounds. In addition to this question, the study sought to identify, at a crude level, whether the behaviour posed any safety risks for road users, and if so, what those may be.

2. LITERATURE REVIEW

The phenomenon of hard shoulder use has received very little research attention internationally as a topic is its own right, but some of the more relevant background literature on this broad topic is summarised below.

2.1 Paved hard shoulders

The paved hard shoulder of the roadway is a reserved area that is usually slightly narrower than the other lanes of the roadway, and whose purpose is to provide a safe place for vehicles to stop in the event of an emergency. The hard shoulder is used for lateral support of the pavement structure, and it also increases the effective width of the lane which increases the lateral clearance between opposing vehicles (Ogden, 1997).

It is common practice in South Africa, a practice in fact permitted by our traffic legislation, for slower moving vehicles to move over to the hard shoulder to let faster moving traffic pass. Chapter 10 of the National Road Traffic Regulations (2000) describes the rules of the road and the usage of hard shoulders, and section 298A lays out the conditions for driving on the hard shoulder of a public road. In brief a vehicle is permitted to drive on the hard shoulder of single carriageway between sunrise and sunset when the vehicle is being overtaken by a faster moving vehicle. Drivers are allowed to drive on the hard shoulder only if the driver does not endanger other traffic and pedestrians. Finally a driver is allowed to drive in the hard shoulder only if the driver can clearly see obstructions in the hard shoulder at a 150 metres distance.

One of the disadvantages of using hard shoulders for overtaking is that vehicles that are stationary in the road shoulder have the risk of being crashed into. In the US, Hauer and Lovell (1984) showed that 10 percent of fatal freeway crashes are related to vehicles who are stationary in the road shoulder (Ben-bassat and Shinar, 2011).

2.2 Hard shoulder running

Hard shoulder running (HSR) is the utilization of the paved shoulder portion of the roadway geometry. HSR has been implemented formally in several countries across the world during peak hours to temporarily increase the capacity of the roadway (Coffey and Park, 2016). The disadvantages with HSR is that it eliminates a recovery area for road users who may temporarily lose control of their vehicle as well as eliminates the use of the shoulder as a refuge area for broken down vehicles (Guerrieri and Mauro, 2016). The advantages of HSR is that it increases the road capacity, shortening travel time and reducing both fuel consumption and pollution emissions (Gitelman *et al.*, 2016).

Research into the effectiveness of hard shoulder running schemes have had mixed results from a safety perspective (though they do, commonly, demonstrate measurable improvements in traffic efficiency). In France, for example, the overall number of crashes increased but serious injury crashes decreased; running off road crashes decreased significantly, but lane-change related crashes increased. In California, crash likelihood was found to be correlated with the number of lanes – the higher the number of lanes, the less the likelihood was that crash rates would increase. In all these cases the roads in question were freeways, devoid of non-motorised traffic such as cyclists and pedestrians.

2.3 Hard shoulders and highway design

The hard shoulder is, of course, only one element of the road way design. Others include lane width, shoulder width, median width, clear zone, vertical and horizontal alignment and roadside landscape which can influence the driver's perception which consequently influences the driver's behaviour (Ben-bassat and Shinar, 2011). Roadway design has been shown conclusively to influence crash rates (Karlaftis and Golias, 2002). Safe and well-designed roads can be defined as roads that minimize the likelihood of losing control of the vehicle as well as prevent conflicts among other road users (Ben-bassat and Shinar, 2011). However, a safe design can lead to situations where road users feel too safe which could lead to increase in speed, reduced attention, boredom and drowsiness (Ben-bassat and Shinar, 2011). Roadways should be designed in such a way that they provide all the safety benefits, but should convey the risk of unsafe behaviour.

2.4 Non-motorised traffic in SA traffic streams.

The presence of pedestrians and cyclists sharing the roadway is a common phenomenon in South Africa (Mokitimi and Vanderschuren, 2017). This is largely due to the lack of infrastructure present for non-motorized transport (Mokitimi and Vanderschuren, 2017). Roadway sharing between non-motorized transport and vehicles is one of the reasons why pedestrian crash rates are so high in South Africa. In Europe it was found that most fatalities resulting from car-cyclist interaction occurred when vehicles were moving in the same direction as the cyclist (Wisch *et al.*, 2017). Vehicles typically find themselves in a situation where they need to overtake cyclists which results in conflict between the two road users (Kovaceva *et al.*, 2017). During these overtaking manoeuvres drivers try to minimize the risk of an accident by maximizing the distance between the vehicle and the cyclist (Kovaceva *et al.*, 2017). This distance is defined as the lateral clearance. Lateral clearance is influenced by the road gradient, posted speed limit, the presence of a road shoulder, the presence of a cycling lane and the presence of a road median (Feng *et al.*, 2018).

As far as pedestrian use of hard shoulders in concerned; many urban roads are built without formal sidewalks and pedestrians are obliged to use hard shoulders as a consequence. Sub- (2) section of the National Road Traffic Regulations (regulation 16) lays out the duties of pedestrians. The law permits pedestrians to walk on the edge of a roadway which does not have any sidewalks or footpaths. It reads: “A pedestrian on a public road which has no sidewalk or footpath abutting on the roadway, shall walk as near as is practicable to the edge of the roadway on his or her right-hand side so as to face oncoming traffic on such roadway, except where the presence of pedestrians on the roadway is prohibited by a prescribed road traffic sign”.

2.5 Effects of Speed and Speed Differentials on crash likelihood

The role of speed in crash risk, and in serious/ or fatal crash risk is well documented. Increasing speed not only enhances the severity of the crash (Aarts, 2006), but it also increases the chances of being involved in a crash (Moore, Dolinis and Woodward 1995).

The UK's Transport Research Laboratory (TRL) published an extensive non-UK based study in 1994. This study found a positive relationship between speed and injury crashes – a 1mph (≈1.61km/h) average speed increase was associated with a 5% change in crash rates (Taylor et al. 2000). More relevant to this study, perhaps, is the fact that speed differences between vehicles has been found to be a precursor for crashes in a number of studies, suggesting that where speed variation on a road is high, there is greater risk for a crash (Lee, Saccomanno and Hellinga, 2002).

Speed differentials between vehicles on adjacent lanes has been less well investigated, especially on urban roads. Most work has been carried out on freeways where speed adjustment/taper lanes are introduced; as well as in situations where climbing lanes are warranted. At posted speeds of 80 km/h, a safe speed differential is considered by SANRAL to be in the region of 15 km/h (SANRAL, 2011 Geometric Design Guide). No equivalent 'safe' speed differentials for adjacent lanes have been found for urban road with 60 km/h limit.

2.6 Driving behaviour and eroding standards or driver behaviour

Driver behaviour is, at a high level, influenced by the driver's personality, experience, attitude and roadway environment (Ben-bassat and Shinar, 2011). Much research has been carried out into the role of risk taking, aggression and law-breaking among road users worldwide, with most research confirming such trends among young male drivers in particular (Massie, Campbell and Williams, 1995; Carter *et al.*, 2014). However, on a day to day to day level, driving standards are arguably being eroded across the wider spectrum of motorists in South Africa. The pressure for time; the examples of poor driving exhibited increasingly by other road users, and the lack of negative feedback are arguably factors that contribute to a gradually reduced standard of driver behaviour.

It is useful to consider driver choices from the perspective of theoretical models. Most theories postulate that decisions about driving 'style' are the result of a) social norms (or what other people – particularly people held in some esteem - see as acceptable); the advantages that their decisions may give them, and the perceived level of behavioural control they have (Azjen, 1991). When previously 'deviant' behaviour becomes acceptable, it is largely because all three of these factors are present: social norms have changed to be more accepting of certain behaviours; there is a calculated advantage (time or cost) to be gained by the behaviour, and a motorist can see few obstacles preventing the desired behaviour (this normally means no chance of penalty). Where the three factors co-exist, a singularly rich environment for creative (and often dangerous) driving emerges.

3. METHODOLOGY

3.1 Site selection and details

Five sites were selected for the observations. These are numbered and listed as follows:

Site 1: The intersection of Strand Road (R44) and Van Rheede Road in Stellenbosch.

Site 2: The intersection of Broadway Boulevard (R44) and Main Road (M9) in Somerset West.
Site 3: The intersection of Strand Road (R44) and Safraan Road in Stellenbosch.
Site 4: The intersection of Strand Road (R44) and Tegno Road in Stellenbosch.
Site 5: The intersection of Strand Road (R44) and Webersvallei Road in Stellenbosch.

A typical configuration is shown in Figure 1, which is a Google Earth satellite image for the intersection of the R44 Broadway Boulevard and Main Rd in Somerset West.

Figure 1: Typical road layout showing hard shoulder and turning lane (this example taken from Site 2), Google Earth 2019.

Road characteristics for each of the sites were collected and are as follows:

Table 1: Site characteristics

Site No.	Peak Flow (veh/h)	Speed limit (km/h)	Gradient	Length of turning lane (m)	Shoulder width (m)	Formal sidewalk present
1	2100	60	-5%	80	2.7	No
2	2350	60	-5.6%	100	3.0	No
3	2000	60	0.7%	85	2.2	No
4	2800	80	3.5%	200	2.2	No
5	2650	80	6%	110	2.6	No

All intersections in the sample include two through lanes and two turning lanes, one for left and right turning traffic. In all of these cases the hard shoulder was used as an extension to the formal turning lane – in other words, drivers would move into the hard shoulder to get faster access to the turning lane which began officially closer to the signals.

All of the study intersections are signal controlled, and all signal phases included a dedicated right turn phase. Specific signal timings and intersection capacity determinations were not included as part of the study, but LOS was estimated to be comparable across all sites.

3.2 Study methodology

The study was based exclusively on traffic observations. No surveys of driver motivation were carried out, and so the results cannot explain the phenomenon of drivers using hard shoulder in terms of motorists' justification, but simply attempt address the goal of identifying the physical circumstances which may lend themselves to this behaviour emerging. The second main goal of the research was to assess whether there were any specific risks for road users as a result of this behaviour.

Site observations were conducted at the five different sites over a period of three weeks, concentrating on the highest peak hour that was relevant for each intersection. Some intersections experienced peak traffic demand in the mornings (for example Sites 1, 4 and 5); two were under pressure during afternoon/evening peak times (Sites 2 and 3). During site visits, traffic counts were conducted, recording data such as the total number of road users using the road shoulder to access the turning lane as well as the total number of road users turning left. The different types of conflict were observed and their frequency was recorded. Pedestrian and cyclist activity was recorded.

In addition to observations of the traffic flow, traffic speeds were recorded with the use of a radar speed gun – this recorded the speed of the vehicles travelling in the hard shoulder as well as road users travelling in the adjacent lane.

3.3 Data collected

The following information was collected during the site observations of the six selected sites, namely:

- The average number of vehicles turning left in a typical peak hour
- The average number of vehicles using the road shoulder prior to turning left
- The average number of vehicles using the hard shoulder to access the turning lane
- The number of pedestrians in total, and the number using the hard shoulder
- The number of cyclists in total, and the number using the hard shoulder
- The type of conflicts observed and their corresponding frequency
- The interaction between motorised and non-motorised forms of transport
- The speed differentials between the vehicles on the road shoulder and those on the adjacent lane.

4. RESULTS

4.1 Vehicle counts

The observations conducted at the five sites during the peak hours of the day were recorded using a GoPro camera. Table 2 provides a summary of the observed left turning movement at each site.

The table below presents the number of vehicles using the hard shoulder to join the turning lanes as a percentage of all left turns, and also as a percentage of the through traffic flow. In addition, the relative numbers of hard shoulder users when the queue length was longer than the provided turning lane (i.e. where the turning lane had reached capacity), and shorter than the provided turn lane (where the turning lane still had space), were counted.

Table 2: Summary of left-turning movement for each site

Site	Total number of vehicles turning left (Average per observed hour)	Average number of vehicles using the hard shoulder as an extension to the turning lane when the queue length in the adjacent lane is…		Average number of vehicles using the hard shoulder as an extension to the turning lane	Average % of turning vehicles using hard shoulder	Average % of all traffic using hard shoulder as an extension to turning lane
		…LONGER than the length of the turning lane	…SHORTER than the length of the turning lane			
1	120	35	28	63	52.5	3.0
2	343	328	0	328	95.6	13.9
3	83	46	13	59	71.1	2.9
4	768	42	386	428	55.7	15.3
5	344	108	31	139	40.4	5.2

In considering the five sites as a whole, no clear pattern can be seen. At only one site (site 2) hard shoulder users were present only when the turning lane was already full. In the other four sites hard shoulder users were present both when the turning lane was full and when it still had capacity. In fact observations at Site 4 showed that the vast majority of vehicles used the hard shoulder when the turning lane still had capacity. This suggests that intersection capacity itself may be less a factor in the emergence of this behaviour than perceived waiting time.

4.2 Turning and geometric design elements of the road

In the search for patterns between the incidence of hard shoulder users and geometric design elements of the road, once again, as with traffic volumes, no clear relationships were discernible. The width of the hard shoulder, the gradient, and the length of the turning lane were examined as possible contributors to the tendency to use the hard shoulder, with no reliable conclusions (refer to Table 3). Significance testing was carried out for all single elements as well as for combinations of elements (e.g. gradient *and* length of turning lane) but in all cases no p value was less than 0.05.

Table 3: Geometric design features and hard shoulder running

Site No.	Peak flow (veh/h)	Gradient	Length of turning lane (m)	Shoulder width (m)	% of turning vehicles using hard shoulder	% of all traffic using hard shoulder as turning lane
1	2100	-5%	80	2.7	52.5	3.0
2	2350	-5.6%	100	3.0	95.6	13.9
3	2000	0.7%	85	2.2	71.1	2.9
4	2800	3.5%	200	2.2	55.7	15.3
5	2650	6%	110	2.6	40.4	5.2

In every case, then, the geometric design elements appeared to have no measurable bearing on the propensity for a site to develop a problem of this sort. The factors seem to be largely random. With a larger sample of sites this may change, but from the sample in this study there were no clear correlations between road geometry and hard shoulder use prior to a left turn.

If physical circumstances are not themselves encouraging the emergence of these behaviours, what could potentially be the factors that might make one site more likely than another to develop this trend? The answer to this would require further research, in particular detailed motivational research among motorists. Factors such as the perceived waiting time due to the length of the queue, the prevailing speed of the traffic, the predicted manoeuvre of the preceding vehicle and queue lengths could potentially be factors in the decision making process for using the hard shoulder as a turning lane. On the other hand, it could be simply expedience: one driver follows the example of another, and very soon more drivers follow suit with the result that traffic flows become permanently altered over time.

4.3 Safety issues

Safety concerns were identified largely in the light of vulnerable road users, but conflicts between motorists were also counted.

Table 4 shows the average speed of vehicles measured during the observation periods (always during peak traffic flows). The table presents the speed of traffic travelling in the road shoulder), the speed of vehicles travelling in the adjacent lane as well as the speed difference between these two data sets.

Table 4: Speed Differentials

Site number	Average speed in the shoulder (km/h)	Average speed in the adjacent lane (km/h)	Speed difference (km/h)
1	43	52	9
2	42	37	5
3	51	46	5
4	63	73	10
5	42	51	9

As mentioned earlier, the literature on safe speeds suggests that the speed differential for adjacent lanes should not be greater than 15km/h. In all cases in this study, the speed differentials recorded for the six sites were less than 15km/h. Safety issues between vehicles in adjacent lanes (whilst moving) appeared to be extremely low, and no merge conflicts were identified over the course of the observations, in spite of the fact that drivers on hard shoulders were potentially disadvantaging drivers who had obediently stayed and queued in the formal turning lane. Surprisingly enough even the minibus taxi drivers appear to be accommodated without hostility by the conventional motorists. At this stage, among all sites in this study, there seems to be an acceptance of the hard shoulder turners.

Motorized and non-motorized road users share the road space at all the observed sites. None of the sites in the study provided sidewalks for non-motorized road users; this is not uncommon in South African towns and cities.

The relationship between vehicle speed at impact and the probability of a fatality of a pedestrian is well documented in the literature. Tefft (2013) and many others have shown that there is a 90% chance that a pedestrian would die in an impact of 87 km/h. This value decreases to 25% if the speed of the vehicle is 52 km/h, and to 10% at 38 km/h. Only one of the five sites displayed a hard shoulder running speed of less than 38 km/h hour, suggesting that a significant injury problem could emerge should pedestrians be injured at these locations.

Table 5 shows the number of conflicts recorded at each site in relation to the total volume of vehicles, pedestrians and cyclists using the road shoulder.

Table 5: Summary of conflicts at each site

Site	Total number of pedestrians using the road shoulder	Total number of cyclists using the road shoulder	Total number of conflicts at each site
1	9	51	9
2	1	10	15
3	35	3	33
4	0	2	0
5	14	10	1

It can be seen that site number 3 had significantly more pedestrian conflicts than the other sites. Here, many conflicts were due to minibus taxis using the road shoulder for loading and offloading passengers, meaning that there were more pedestrians present at this location and the potential for conflict was increased by the behaviour of the taxi drivers. Across all sites, however, conventional passenger vehicles were observed in conflict situations with pedestrians, so it was not only the minibus taxi drivers at fault.

From the observations carried out it seems that the use of hard shoulders has a potentially high risk where cyclists and pedestrians are present.

5. CONCLUSIONS

The research covered in this report was an initial investigation into the relationship between the physical design and general traffic flow features of intersections, and the likelihood of an informal left turning lane being created on the hard shoulder. The observations failed to show any clear relationship between specific or combined design features, or indeed any traffic conditions, and this phenomenon. Although the size of the sample was small, the key sites in and around Stellenbosch where this phenomenon was seen were included in the study. If physical features and traffic flow characteristics are not, in that case, direct contributing elements to this occurrence, it is likely that these behaviours emerge as a consequence of simple human habit. If there is randomness to the geometry, it is almost inevitable that we will see this behaviour proliferating, irrespective of the physical elements in the intersection. This does not, however, mean that the design of an intersection does not matter in this regard.

The primary concern arising from the study is the high number of conflicts counted between vehicles in turning lanes and VRUs. The bulk of these conflicts involved minibus taxis and buses, but normal passenger vehicles were involved as well. In all cases the conflicts would have been avoided had pedestrians been protected on sidewalks, and had cyclists been separated from the traffic in a more formal manner.

So what does matter, looking ahead to intersection design in the future, is what role the physical elements can play in making the emerging behaviour as safe as possible. The presence of a protected sideways space - and separated space for cyclists - is possibly the most important element in this case. Most of the conflicts of concern in this study related to vehicle conflicts with these road users and thus the protection of non-motorised users becomes even more critical than before. Lateral clearance between cyclists and other vehicles means that the widths of hard shoulders, too, should be considered.

Given that the behaviour investigated here is most likely the tip of a growing iceberg, it seems prudent for traffic engineers to seriously consider the implications of hard shoulder running in advance of traffic signals, with an eye to protecting the safety of all road users. At the moment this behaviour is still fairly new, and it would appear that (the measured conflicts notwithstanding) many motorists proceed along the hard shoulder with a fair amount of caution. That could well change as hard shoulder running at intersections becomes viewed as 'normal' driving behaviour, and the drivers develop an enhanced sense of entitlement to proceed at all costs.

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