AN ECOLOGICAL ANALYSIS OF CRASH RISK DIFFERENCES BETWEEN ACCESS AND NON-ACCESS CONTROLLED HIGHWAYS IN A LOW-INCOME COUNTRY

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ABSTRACT
Urbanization around highways is frequent in Low- and Middle-Income Countries (LMICs) and can affect traffic safety negatively if it is inadequately-planned. Access control has shown to reduce significantly highway crashes in developed countries, but this intervention has been explored to a lesser extent in LMICs. This case study aimed to compare crash risk differences between an access-controlled highway sections with that of non-access controlled sections in Pakistan.

Using the aggregated data of crashes and vehicle-km travelled, crash fatality and pedestrian crash risks were compared between the 397 km-long sections of access controlled Motorway 1&2 (M1&2) and the 332-km-long non-access controlled road sections of N5 between cities of Attock and Lahore. The crash fatality risk per billion vehicle-km travelled were 47.2 on the access-controlled road sections and 47.4 on the non-access controlled road sections; these rates were over ten times higher than on similar roads in France. Pedestrian crash risks were significantly higher on non-access controlled road sections than access controlled road sections (Risk ratio=3.43, P<0.001, attributable risk proportion=70.1%) indicating that access control could reduce over two-thirds of pedestrian crashes on highways in Pakistan.

Findings from this study should be carefully interpreted because of the ecological study methods. Nevertheless, high crash burden on highways indicated that vigorous efforts are required in enforcing international safety standards in Pakistan. These include, but not limited to, seat-belt or helmet use, vehicle checks, and road safety education of drivers and the population living around highways.
1 INTRODUCTION
Highways are the backbone of the economy by offering timely transport of goods and people. Highway crashes often result in traffic fatalities because of travelling speeds (Kashani, Shariat-Mohaymany, & Ranjbari, 2012; Observatoire National Interministériel de Sécurité Routière [ONISR], 2006). Most of these crashes are preventable by adequate highway design, vehicle checks, and enforcing speed control, seat-belt and helmet use (World Health Organization, 2009), the steps that have made highways one of the safest ways to travel in High-Income Countries (HICs) (ONISR, 2006). Previous highway safety reports from Low- and Middle Income Countries (LMICs) suggested that the crash risks were several times higher than HICs (Sobngwi-Tambekou, Bhatti, Kounga, Salmi, & Lagarde, 2010). This indicated that the LMICs were not able to replicate successfully the required interventions on their highways, possibly because of other safety factors such as the prevalent use of unsafe vehicles and inadequate law enforcement (Ross, Bagunley, Hills, McDonald, & Silcock, 1991; Zhou, Zhao, Jiang, Zhu, & Zhou, 2005).

One such shortcoming is ill-planned urbanization (Ross et al., 1991). Highways in LMICs often develop from low-capacity roads connecting small towns that are upgraded to high-capacity roads once the transport needs start to augment with increasing population (Peden et al., 2004; Ross et al., 1991). Such little is the good quality road network in LMICs that urban sprawl is frequent on highways in LMICs, resulting frequently in traffic congestion and crashes involving pedestrian and motorized two-wheelers (International Road Federation (IRF), 2008; Mohan, 2002). Construction of by-passes around urban areas on highways has been used previously for traffic management but urbanization can engulf these sections because of transportation needs, and this can negatively impact crash risks because of higher speeds (Ross et al., 1991).

Access control i.e., preventing pedestrians, cyclists, and low-power motorized two/three wheelers from entering a highway, has been one of the effective mechanisms to improve travelling and to reduce highway crash fatalities in HICs, even on the sections passing through major cities (Crane, Augustine, & Tait, 2008; Ross et al., 1991). It was suggested that implementing access-control should be a carefully opted in LMICs because few people are motorized in these countries (Mohan, 2002). Further, less is known to what extent access control can contribute towards preventing highway crashes in LMICs compared with HICs (Forjuoh & Li, 1996). This case study aimed to compare crash risk differences between an access-controlled highway sections with that of non-access controlled sections in LMIC settings.

2 ANALYSES
2.1 Setting and design
The study settings were sections of Motorways 1&2 (M1&2) and National highway 5 (N5) in Pakistan connecting Peshawar and Lahore. N5 is in use long before Pakistan’s independence in 1947. The construction of motorway started in 1990, to reduce the traffic burden on N5. M 1&2 are made of 514-km-long road sections. M 1&2 have six lanes. M 1&2 are access controlled, and they are divided by physical barriers. The sections of N5 between Peshawar and Lahore are 395-
km-long, four-lane and are intermittently divided by physical barriers. In this ecological study, aggregated data was used to compare fatality risks by computing risk ratios in which risk was fatalities occurring on two road sections in 2007 and exposure was average vehicle-km travelled on these road sections during the same year. These methods have been previously used to compare different types of road sections (Bhatti, Razzak, Lagarde, & Salmi, 2011a).

2.2 Travelling exposure data
In 2007, the operational length of M1&2 was 397 km i.e., from district Attock to Lahore. Therefore, we selected sections of N5 from Attock to Lahore to make realistic comparisons accounting for 332 km long sections. To compute average vehicle-km travel, information was extracted from the National Highway Authority traffic count surveys conducted in Dec 2007 at different locations. They were conducted separately for the North and South directions: ten locations for M1-2 and nine locations for N5 (National Highway Authority, 2008).

2.3 Crash fatality data
The National Highway and Motorway Police (NHMP) is responsible to enforce traffic rules on both road sections (Khoso, 2007). The enforcement is divided into approximately 40-km-long sections. For each crash, patrol officers file a report including details about crash location, users involved including pedestrian and crash outcome (fatal/severe injury i.e., requiring transport to hospital) (Khoso, 2007; Nishtar et al., 2004). These data from these reports is computerized at a central location, and yearly reports are published. For this study, we extracted data from the 2007 annual reports of the selected highway sections.

2.4 Risk comparisons
Vehicle-km travelled per year was computed by multiplying traffic counts with 365 and the length of the road section in which the traffic count survey was conducted. Fatality rates were compared using fatality per 100 crashes, per 100 km section, and per $10^9$ vehicle-km travelled (fatality risk). Fatality risk difference was computed by subtracting fatality risk on N5 by that on M1&2. Attributable risk proportion was assessed by $(\text{Risk N5-Risk M1&2})/\text{Risk N5}$. Similarly rates were computed for crashes involving pedestrians (Rockhill, Newman, & Weinberg, 1998).

3 RESULTS
3.1 Crash fatality risk differences
On average, a total of 2.24 billion ($10^9$) vehicle-km were travelled on M1&2, whereas, 3.03 billion vehicle-km were travelled on selected sections of N5. A total of 162 crashes on M1&2 resulted in 106 fatalities on M1&2, whereas, 201 crashes resulted in 144 deaths on N5 (Table 1). Fatality per 100 crashes and per 100 km of road section were higher on N5 than those on M1&2. About 47 persons died per billion vehicle-travelled on both road sections. The fatality risk difference was 0.2 per $10^9$ vehicle-km with fatality risk ratio of 1.01 ($P=0.98$). The attributable fatality risk proportion was 0.3% for non-access controlled highway sections.
3.2 Pedestrian crash fatality risk differences

A total of 14 pedestrian crashes occurred on M1&2, of which 10 were fatal, and four resulted in severe injuries (Table 2). On N5, 65 pedestrian crashes occurred, of which 25 were fatal, and 40 other resulted in severe injuries. Pedestrian crashes, fatal and severe injury risks were higher on non-access controlled road sections than those on access control road sections. The attributable risk proportion of non-access control was 70.8% for pedestrian crashes, 45.8% for fatal and 86.5% for severe injury pedestrian crashes.

Table 1. Crash Fatality risks on two different highways between Peshawar and Lahore, Pakistan (2007)

<table>
<thead>
<tr>
<th></th>
<th>Access controlled (Motorway 1&amp;2)</th>
<th>Non Access controlled (National highway 5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Km</td>
<td>397</td>
<td>332</td>
</tr>
<tr>
<td>Km travelled (x10^9)</td>
<td>2.24</td>
<td>3.03</td>
</tr>
<tr>
<td>Crashes</td>
<td>162</td>
<td>201</td>
</tr>
<tr>
<td>Fatalities</td>
<td>106</td>
<td>144</td>
</tr>
<tr>
<td>Fatality per 100 crashes</td>
<td>65.4</td>
<td>71.6</td>
</tr>
<tr>
<td>Fatalities per 100 km section</td>
<td>26.7</td>
<td>43.4</td>
</tr>
<tr>
<td>Fatalities risk per 10^9 km travelled</td>
<td>47.2</td>
<td>47.4</td>
</tr>
<tr>
<td>Fatality risk difference/10^9 km travelled</td>
<td>0.2</td>
<td></td>
</tr>
<tr>
<td>Fatality risk ratio*</td>
<td>1</td>
<td>1.01</td>
</tr>
<tr>
<td>Attributable fatality risk proportion (%)</td>
<td>0.3</td>
<td></td>
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</tbody>
</table>

* P=0.98

Table 2. Pedestrian crash risks on two different highways between Peshawar and Lahore, Pakistan (2007)

<table>
<thead>
<tr>
<th></th>
<th>Access controlled (Motorway 1&amp;2)</th>
<th>Non Access controlled (National highway 5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pedestrian crashes</td>
<td>14</td>
<td>65</td>
</tr>
<tr>
<td>Pedestrian crash risk per 10^9 km travelled</td>
<td>6.2</td>
<td>21.4</td>
</tr>
<tr>
<td>Pedestrian crash risk ratio*</td>
<td>3.43</td>
<td></td>
</tr>
<tr>
<td>95% Confidence interval</td>
<td>1.93-6.11</td>
<td></td>
</tr>
<tr>
<td>Attributable pedestrian crash risk proportion (%)</td>
<td>70.8</td>
<td></td>
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</tbody>
</table>

Fatal pedestrian crashes

<table>
<thead>
<tr>
<th></th>
<th>Access controlled (Motorway 1&amp;2)</th>
<th>Non Access controlled (National highway 5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatal pedestrian crashes</td>
<td>10</td>
<td>25</td>
</tr>
<tr>
<td>Fatal pedestrian crash risk per 10^9 km travelled</td>
<td>4.5</td>
<td>8.2</td>
</tr>
<tr>
<td>Fatal pedestrian crash risk ratio*</td>
<td>1.85</td>
<td></td>
</tr>
<tr>
<td>95% Confidence interval</td>
<td>0.89-3.84</td>
<td></td>
</tr>
<tr>
<td>Attributable fatal pedestrian crash risk proportion (%)</td>
<td>45.8</td>
<td></td>
</tr>
</tbody>
</table>
Severe injury pedestrian crashes | 4 | 40
Severe injury pedestrian crash risk per $10^9$ km travelled | 1.8 | 13.2
Severe injury pedestrian crash risk ratio* | 7.39 
95% Confidence interval | 2.64 | 20.64
Attributable severe pedestrian injury risk proportion (%) | 86.5

4 DISCUSSION
This case study showed that fewer fatalities were reported on the access-controlled highway sections than on non-access controlled. However, there were no significant differences in crash fatality risks between the two types of road sections. Exposure to non-access controlled road sections could have contributed to only 0.3% excess risk of traffic fatalities with similar enforcement-, road user-, and vehicle-related crash risk factors. The significant differences in crash fatality risks were observed only for pedestrian crashes, fatalities and severe injuries. The results suggested that over two-third of pedestrian crashes on urbanized sections could be avoidable by access control.

4.1 Limitations
Findings from this study are needed to be interpreted carefully because of the ecological design. Furthermore, findings might be limited because like many other LMICs police crash fatalities are hugely underreported in Pakistan (Nishtar et al., 2004). A previous survey on southern sections of N5 showed that police reported only one of five traffic fatalities, and pedestrian fatalities were less likely to be reported than other road user fatalities (Bhatti, Razzak, Lagarde, & Salmi, 2011b). The posited reasons of underreporting were avoiding lengthy and expensive litigation process from users’ perspective and performance evaluation from the police perspective. It is likely that fatality underreporting was higher for N5 than M1&2 because of its proximity to major towns and its non-access control function. This suggested that fatality risk and attributable risk proportion might be underestimated for non-access controlled N5. Nonetheless, crash fatality risks on both highways were over ten times higher than that reported for access controlled road sections in France (ONISR, 2006).

Insignificant difference for fatality risks between non-access and access-controlled was not surprising. Risky road user behaviours and poorly maintained vehicles are the frequent causes of RTCs in LMICs. Our previous study showed that helmet and seat-belt use on the highway was inadequate (Bhatti, Ejaz et al., 2011). Further, the current legislation only obligates the driver and front-seat occupant to wear seat-belt, whereas, other passengers may or may not choose to wear. More often than not, seat-belts are unavailable in old vehicles particularly in buses and trucks thereby increasing crash vulnerability on both types of highways (Bhatti, Ejaz et al., 2011; National Highway and Motorway Police, 2007). Furthermore, poor vehicle conditions and use of old tyres at higher speeds have claimed many lives, calling for more strict enforcement measures on both highways (National Highway and Motorway Police, 2007; Sobngwi-Tambekou et al., 2010).
Our results showed that despite access control pedestrian crashes still occurred on selected highway sections. Understandably, people from nearby populations resorted to connect on foot with each other crossing this high speed road. Highway safety culture has not been adopted yet in Pakistan, and urbanization around highways is not uncommon (National Transport Research Centre, 1985; Nishtar et al., 2004). Nonetheless, findings indicated that access control could potentially reduce a significant number of highway crashes involving pedestrians. Findings pointed out that accounting local transportation needs in urbanization and access-control design might reduce pedestrian crashes that are likely to result in fatalities and severe injuries (Ross et al., 1991). Road and local municipal authorities can identify these problems and timely prevent them (Bhatti, Ejaz et al., 2011; Silveira, 2003). Moreover, low community awareness about highway risks can be improved from targeted road safety education (Nishtar et al., 2004).

4.2 Conclusions

In conclusion, this case study, with its limitations, showed that crash fatality risks on access controlled road sections and non-access controlled road sections were similar in Pakistan. The only significant impact of access control was on reducing crashes involving pedestrians. Transportation needs often dictate the construction of access control highway, however, previous and current findings suggested that future prevention on both types of highways should focus on raising enforcement levels. In particularly, more efforts are required to implement traffic safety standards, including but not limited to, seat-belt or helmet use, vehicle checks, and educating drivers and population living near highways about crash hazards. Lastly, establishing consultation groups between municipal and road authorities may help in understanding local crash factors, reinforcing political and community support, and developing interventions to reduce crashes.

FUNDING

None.

CONFLICT OF INTERESTS

None.

REFERENCES


