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Road Safety Effects of Bus Rapid Transit (BRT) Systems: a Call for Evidence

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ABSTRACT *Road injuries are an important cause of global mortality especially in low- and middle-income countries. While these countries undergo major urban transformations, an integral part of their development has often been the implementation of mass transportation systems, including Bus Rapid Transit (BRT) systems. However, the net effect of BRT systems on road safety is still unclear, and while there is reason to believe that BRT systems improve safety, very few available empirical studies have tested this hypothesis using observational data. Furthermore, the existing evidence is mixed and sparse. This paper reviews the available literature on the links of BRT systems and road safety and calls for more research to strengthen the body of evidence on the effect of BRT systems on road safety in the future.*

KEYWORDS *Bus Rapid Transit, Road safety, Evidence-based policy, Knowledge to action gap*

INTRODUCTION

Road traffic injuries (RTI) are the eight leading cause of mortality and the tenth cause of disability in the world, having increased by 46 and 33 %, respectively, since 1990, [1] leading to losses of between 1 and 3 % of the average national gross product. [2] This burden is especially relevant in low- and middle-income countries. Vehicle occupants of public transportation vehicles and mixed traffic as well as pedestrians entering bus roadways are frequent victims of RTI, mainly due to poorly regulated mass transit systems and outdated infrastructure.

Beyond the often cited environmental and transportation benefits, Bus Rapid Transit (BRT) systems have been described as a potential solution to improve road safety by the following: (1) organizing the transportation system, reducing its motorization, and eliminating crowded buses, while renovating the surrounding infrastructure; (2) separating buses from other motor vehicles and pedestrians, which reduces the speed in mixed traffic and prevents contact between buses and other vehicles; and (3) improving fleet quality and training of public transport drivers. [3]

However, the evidence around the potential road safety benefits has not been systematically assessed, and such evidence is needed in order to support the claim that BRT systems actually improve road safety.

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Therefore, the aims of this paper are as follows: (1) to compile the literature on the effect of BRT systems on road safety; (2) to review existing and available scientific literature specifically on the impact of BRT on RTI, assess its quality, and summarize the main findings; and (3) to make recommendations regarding future research needed to inform global road safety efforts.

MATERIALS AND METHODS

We carried out a literature review using search engines including MEDLINE, Google Scholar, EMBASE, and the Transport Research International Documentation database during August of 2014. Following Cochrane recommendations, [4] several combinations of search terms were made. Our final search strategy includes the following search terms: ["Bus Rapid Transit" OR "Bus Priority"] for MEDLINE, ["Bus rapid transit"] was used in EMBASE, ["Bus rapid transit" AND "Safety"] were used in the Transport Research International Documentation database, and ["Bus Rapid Transit" AND "Road safety"] were used in Google Scholar. The search was limited to the following: papers published since 2000 and English language literature. We designed an ex ante search protocol with the following inclusion criteria: papers whose main topic is road safety related to BRT systems and present quantitative empirical data. Our search exclusion criteria included the following research: non-peer reviewed literature, no primary or secondary data quantitative analyses included, prediction modeling studies (with no empirical support), and no description of measurement methods.

For the search review process, we carried out the following steps (Fig. 1). (1) We reviewed in an initial stage all titles, excluding those that were clearly unrelated to the search objective. (2) Of the selected titles, in a second stage, we read all abstracts and based on them, and we selected papers to read in full if they complied with the inclusion and exclusion criteria. (3) Of the selected papers, we reviewed them in full to evaluate if they complied or not with the criteria. If so, their methods and results were collected, and a narrative description was made. The search was documented for future reference.

Finally, we reached out to selected organizations (e.g., Embarq, World Resources Institute, World Health Organization, Global Road Safety Partnership) requesting specific literature that referred to evidence on road safety changes linked to BRT systems, in order to obtain literature that potentially would not be captured during our search.

RESULTS

The initial capture revealed 879 entries across all sources, of which 820 were excluded at the first stage, and 55 more were excluded at the second stage (see Fig. 1). Only four were selected for this literature review given that they complied with the inclusion and exclusion criteria. In total, 875 entries were not selected because the paper was not relevant to the study or there were repeated entries (856), the paper was not in English (9), the paper does not report primary or secondary data analyses or does not present empirical evidence (4), and the paper has not been peer-reviewed (6). One single paper might have more than one exclusion criteria.

Four main research papers describing road safety changes of BRT were selected (Table 1). Research from Bocarejo et al. [5] shows the challenges on measuring the road safety effects of BRT systems. They performed a before/after analysis using

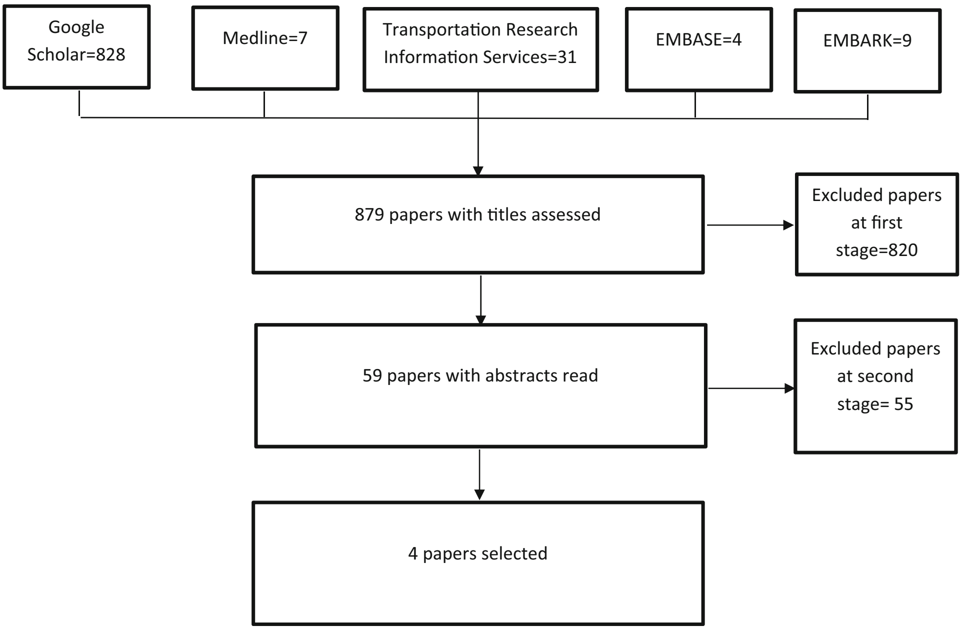

FIG. 1 Results of the literature review for Bus Rapid Transit.

Geographic Information Systems (GIS) analyses of the road safety implications of the implementation of Transmilenio in the Caracas corridor in Bogota, Colombia, between 1998 and 2008. Their conclusions were mixed. Even though they found that the implementation of Transmilenio was related to an overall reduction in serious traffic crashes along the BRT corridors (60 % reduction at Caracas corridor and 48 % reduction for Norte-Quito-Sur (NQS) corridor) compared to the average reduction in Bogota (39 %), there was an increase in the crashes around specific areas of the NQS corridor. There was also the appearance of new spots of high incidence of crashes, apparently related to the higher speed of mixed traffic and the higher flow of pedestrians around the stations. Given that the methodology used on this paper is a before/after study with multiple confounders, in addition to the mixed findings, it cannot be concluded that Transmilenio caused an improvement on road safety during the period.

A second paper by Goh et al. [6] carried out a similar research design, taking advantage of the introduction of a transit signal priority system in the rapid transit routes of Melbourne, Australia, between 2003 and 2007 (see Table 1). They used a mixed-methods approach by carrying out analyses of aggregated data along with the development of a safety audit. They concluded that there was an overall reduction of 14 % with a significance level $p<0.1$ in road crashes in the city. However, during a subsequent audit review, some negative qualitative impacts of the BRT implementation were also found, such as more complex side street exits. Because the analyses were based on aggregated crash data and on before/after analyses, causal inferences cannot be made as to the effect of BRT on road safety.

Duduta et al. [7] performed a mixed-methods study in which they carried out before/after and regression count data analyses with crash data to evaluate the effect of BRT on road safety (Table 1), including road safety inspections and interviews with employees in nine BRT systems. On three of them, the authors conducted difference of means tests to estimate the changes in road crashes before and after the

TABLE 1 Summary of studies on BRT and road safety

Author	Type of study	Setting	Duration	Findings on road safety	Number of crashes by site	p value/ significance level reported
Goh et al. [6]	Before/after analysis	Bogota, Colombia	10 years	Overall reduction in serious accidents by 50–60 %. Increase of crashes around the stations and where mixed traffic lanes were improved.	12,449 serious traffic accidents in two sites	Not provided
Duduta et al. [7]	Before/after analysis	Melbourne, Australia	3 years	14 % overall reduction in all road crashes across 56 sites	160 crashes in the after-period	Significant at 90 %
Duduta et al. [8]	Modeling of changes in infrastructure	Several BRT systems. Different analyses carried out in each of them.	3 to 7 years depending on the city	Findings vary across sites. The authors report mixed results with improvements in road safety by 50 % (Guadalajara), as well as deterioration of road safety by 50 % (Delhi). In the count data model, number of legs and lanes per leg, counterflow, level pedestrian crossing and left turns increase the likelihood of collisions. Center medians reduce collisions.	216 in Mexico City (Mexico); 183 in Porto Alegre (Brazil); 164 in Guadalajara (Mexico); 61 in Bogota (Colombia); 17 in Delhi (India)	$p<0.001$ for the findings described in the count data model
Woodridge [9]	Modeling of changes in infrastructure	Guadalajara, Mexico	5 years	56 % reduction in all road crashes, 69 % reduction in severe crashes.	1010 crashes in the after-period	$p<0.01$

implementation of the study. Regarding the difference of means tests, the first exercise was performed in Bogota (Colombia), where the authors estimated the reduction in fatalities by 60 % in association with implementing the BRT. The authors acknowledged, nonetheless, that there was a concurrent downward trend in road injuries in Bogota, which might confound their results. The second exercise was in Guadalajara (Mexico), where they found that after the implementation of BRT, monthly crashes in the corridor reduced by almost 50 % ($p<0.01$). However, in Delhi (India), they found that road traffic deaths more than doubled after the BRT implementation. The authors concluded that pedestrian exposure to buses is associated to RTI and that it explains the variability across sites. The authors conclude that specific engineering considerations such as emphasis on protecting pedestrians must be made when designing BRT systems.

Second, by using data from Mexico City and Guadalajara (Mexico) and Porto Alegre (Brazil), the authors conducted count data regression analyses to evaluate the engineering characteristics that affect the likelihood of having crashes in a given corridor. Number of legs and lanes per leg, counterflow, level pedestrian crossing, and left turns were found to increase the likelihood of collisions whereas center medians reduce them. Similarly to prior papers, differences of means tests based on before/after studies cannot support the inference of a causal effect of BRT on road safety. Importantly, the variability around the findings in the three cities where the differences of means tests were performed demonstrates that there is no a one-fits-all formula for BRT systems.

In their 2013 paper, Duduta et al. [8] developed a Bayesian model to create safety performance functions in order to retrospectively estimate the crashes and injuries taking place in areas where BRT systems have been implemented. One of the assumptions of the model is that the changes in road safety are a direct function of the changes in road infrastructure and, therefore, a product of the BRT system. The main issue with this assumption is that there was no attempt to prove empirically that those changes would not have happened without the BRT system and that concurrent unobservable factors, such as changes in police activity along the corridors, renovation of surrounding infrastructure, or changes in local policy, would not take place in a counterfactual scenario (without the BRT). The authors found in their models that the deployment of *Macrobus* BRT in Guadalajara (Mexico) reduced road crashes by 56 % over a period of 3 years along the BRT corridor. Again, by assuming that the BRT is the only factor determining the changes in infrastructure and that there are no time-varying unobservable factors that might endogenously affect the estimation, the effect size of BRT system on road crashes might be overestimated.

DISCUSSION

This paper found a very limited body of literature describing the road safety improvements related to BRT systems. Most of the literature available does not address directly the effect of BRT on road safety or does not provide data to empirically support such effect.

Few research studies are available in the peer-reviewed literature (especially for middle-income countries). In these few studies, the results on the effect of BRT systems on road safety are mixed and suggest that a one-fits-all formula does not apply to the improvement of road safety by BRT systems.

In evaluating the limited literature on road safety and BRT systems, several key issues stand out. First, little attention is paid to the heterogeneity of the urban environment around the BRT lanes. Comparing across countries or even within the same country is challenging due to structural differences of each BRT system. [7] Urban environment considerations are important because they might greatly affect the variability of the effects of BRT systems in reducing road injuries, even though they are not directly related to the BRT system itself. Second, most cities implementing BRT systems are also making investments in other road safety infrastructure, which is leading to a profound urban and policy transformation, concurrently with structural changes in national policy and the economy (BRT systems require large investments, and usually loans). This implies that in such analyses, concurrent unobserved events are likely to affect the reduction in deaths leading to potentially biased results. [9] Third, most studies lack tools to make inferences on causality using observational and non-experimental data, as they usually make before/after studies with no real counterfactuals. [9] Fourth, some of the support for BRT is based on modeling infrastructure changes related to BRT systems, rather than on empirical data, implying that there is an urgent need for real-world evaluations.

BRT systems are supposed to reduce road traffic crashes and injuries by reducing the speed in their corridors, by reducing the circulation of mixed traffic, and by modifying the surrounding infrastructure. However, this paper calls for more empirical studies on the effectiveness of BRT on road safety using observational data, so policy makers can take the best evidence-based decisions based on the strongest possible empirical literature.

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