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Seatbelt wearing rate in a Chinese city: Results from multi-round cross-sectional studies

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ABSTRACT

Objective: Road traffic crashes impose a heavy burden in China's most populous city, Shanghai. Since early 2016, Shanghai police have started deploying high-resolution cameras and an object-detection algorithm in seatbelt enforcement. Around the same time, an international consortium on road safety launched a series of capacity trainings for law enforcement accompanied by infrastructure renovation and social marketing campaigns in Shanghai. Our objective is to assess the level and trend of seatbelt use in Shanghai over 2015-2017.
Methods: Ongoing observational studies evaluate seatbelt use within the city. Data are collected at eight randomly selected locations throughout the city, stratified by road type and geographic locations. Data collection covers most times of the day on both business days and weekends, providing a full representation of varying traffic models during both rush hours and non-rush hours. At each site, trained field workers observe seatbelt use of occupants in all passing motorized vehicles. A multivariate logistic regression model was developed to analyze the data.
Findings: From October 2015 to December 2017, six rounds of data collection were completed with a total sample size of 77,641 drivers and passengers of motor vehicles. The seatbelt use rate has steadily increased over time, from 60.8% (95% CI: 59.9%–61.7%) in round 1 to 84.9% (84.3%–85.4%) in round 6 (p-value < 0.01). The increase is substantial and statistically significant for both drivers and passengers (p-value < 0.01). Results from the multivariate logistic regression show an annual growth rate of seatbelt use of 8.8% (8.4%–9.1%); the wearing rate was 49.8% (49.0%–50.5%) lower among passengers than drivers; 3.5% (2.9%–4.1%) lower in peri-urban areas than central urban areas; 16.3% (14.3%–18.4%) higher among 18–24-year and 18.9% (17.0%–20.9%) higher among 25–59-year olds than other age groups.
Conclusion and policy implications: Seatbelt use in Shanghai has been boosted during a short period of time through a combined strategy that includes training of police, social marketing campaign, and the deployment of computer vision assisted enforcement. Large cities in China and other countries facing similar challenges with seatbelt wearing may learn from Shanghai's experience.

1. Introduction

Shanghai is the most populous city in China, with 24.4 million residents, 6.5 million of whom are motor vehicle drivers (Anon, 2017). According to the city traffic police, 868 people died due to road traffic crashes in 2016, a number that may be underestimated (Li et al., 2016). Due to the urgent need for effective interventions to improve road safety, Shanghai was included in the Bloomberg Initiative for Global Road Safety (BIGRS), a consortium of international partners funded by Bloomberg Philanthropies (Larson et al., 2016). The BIGRS project aims to adopt internationally recognized best practices to promote road safety in 10 selected cities in low- and middle-income countries.

The World Health Organization (WHO) has identified not using seatbelts as a key road safety risk factor globally (WHO, 2015). Seatbelt use reduces the risk of death in the event of a crash by 50% for front seat occupants and 75% for rear seat occupants (Ichikawa et al., 2002). The National Highway Traffic Safety Administration (NHTSA) of United States advises that seatbelt use is one of safest choices that drivers and passengers can make on the road; and NHTSA estimated that seatbelt use in passenger vehicles saved 13,941 American lives in 2015 (NHTSA, 2018). However, seatbelt use rate remains low in China. Previous studies have shown seatbelt use rates ranging widely from 7% to 65% (Fleiter et al., 2009; Routley et al., 2008; Zhang et al., 2006). An observational study conducted at gas stations in five cities found the

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seatbelt use rate varied between 23% and 47% by city (Huang et al., 2011). Consequently, promoting seatbelt use was identified as one of targets for the BIGRS project in Shanghai.

Various approaches have been explored around the world to improve seatbelt use, including establishing a national safety committee, developing school-based programs, and running social marketing campaigns (Nishtar et al., 2004; Morrow, 1989; Deng et al., 2016). However, one of the most effective strategies to increase seatbelt use and reduce road fatalities is passing and effectively enforcing seatbelt legislation (Shults and Beck, 2012; Pressley et al., 2016). Chinese traffic laws require all occupants to use seatbelts, but there is little compliance due to a variety of reasons, including low awareness and difficulties with enforcement (Routley et al., 2009).

Chinese traffic laws specify two enforcement approaches for traffic police: onsite and offsite enforcement. In the onsite approach, traffic police pull over a vehicle in which occupants are suspected of a traffic violation, check the driver and vehicle information, inform the driver of the suspected violation, confirm the violation, and potentially issue a ticket. The driver is entitled to dispute the cited violation with the police. Chinese traffic laws forbid police from issuing a ticket to the driver at a later date or time for a violation that they have personally observed. This traditional onsite enforcement approach is widely used in road safety management for many risk factors, such as drink driving, making an illegal left turn, or crossing the road median. A limitation with this approach is that frequently pulling over vehicles may aggravate traffic congestion, a widespread problem that is currently the priority for traffic police in many Chinese cities, including Shanghai. In these highly congested cities, police usually do not pull over vehicles for non-emergency or "minor" violations, such as not wearing a seatbelt, to avoid aggravating traffic congestion. The procedures around onsite enforcement and resulting difficulty in enforcing seatbelt law partially contributed to the low seatbelt compliance rate in China (Huang et al., 2011). As a result, seatbelt requirement is commonly enforced when a driver is stopped for other reasons, such as speeding, illegal lane change, or involvement in a crash.

Offsite enforcement mainly refers to electronic enforcement, which has become increasingly popular in traffic law enforcement with the widespread availability of high-tech devices, particularly in speed and red light enforcement (Brian Bochner and PTOE, 2010; Luoma et al., 2012; Retting et al., 2008; Thomas et al., 2008; He et al., 2013). In the electronic enforcement approach, electronic devices document the violations, usually in the form of pictures and videos. When a traffic ticket is issued to a driver, it is substantiated by proof, giving the driver an opportunity to dispute the violation. For example, several photos of the vehicle before and after the intersection are needed to substantiate a ticket for a red light violation. With recent development of computer vision techniques and increasing availability of high-resolution traffic cameras, some cities have started using the electronic approach in seatbelt enforcement, and achieved substantial increase in seatbelt use rate (Zhou, 2013). Compared with onsite enforcement, the electronic approach increases productivity, accuracy, efficiency and safety during traffic law enforcement (Decina et al., 2007).

In early 2016, Shanghai police started using computer vision algorithms to detect violations in seatbelt enforcement, following the "*Technical specifications for image forensics of road traffic offences (GA/T 832–2014)*" issued by the Ministry of Public Security of China. All images are automatically captured through high-resolution traffic cameras and analyzed using computer algorithms, with suspected violations manually confirmed by police officers before issuing tickets.

The BIGRS project launched a series of interventions almost simultaneously with the introduction of electronic enforcement of seatbelt use laws in Shanghai. Seatbelt-related intervention activities include convening stakeholder meetings, improving law enforcement capacity, educating general public through social marketing campaigns, and building the capacity on road safety among local professionals. In particular, given the limited experience in seatbelt enforcement among traffic police, BIGRS partners organized a series of training workshops where the experience with seatbelt enforcement was shared by police officers from other countries, such as Australia and Poland.

As a result of the combination of information and enforcement, the goal of this paper is to assess the level and trend in compliance with seatbelt laws in Shanghai. The specific objectives: 1) estimate the prevalence of seatbelt use from a city-level representative sample; 2) obtain the prevalence of seatbelt use disaggregated by sex, type of occupant, and type of vehicle; and 3) assess the temporal trend of seatbelt use through multi-round cross-sectional observations.

2. Data and methods

Ongoing observations assess seatbelt use in Shanghai. Our observational studies are conducted at eight locations selected using a stratified sampling approach. Two ring expressways divide Shanghai into central urban area (within inner ring expressway), urban area (between inner and outer ring expressways), and peri-urban areas (outside outer ring expressway). Given the difference in traffic density and mode in those areas, our site selection was stratified by several road classifications (elevated road and ground road; varying speed limits) and geographic locations (Fig. 1). All eligible sites meet the following three criteria: location must be safe for observers; observers may be located at an elevation that is higher or equal height to passing vehicles; and locations where local population rather than tourists are more likely to be observed.

Then from the list of eligible sites, two were selected from the central urban area, two from the urban area, and four from the peri-urban area. Data collection covers both business days and weekends; it also covers the whole period from 07:00 to 20:00 h, providing a full representation of varying traffic models during both rush and non-rush hours.

At each site, trained field workers from the Shanghai Municipal Center for Disease Control and Prevention (CDC) observe seatbelt use of occupants in all passing motor vehicles. Field workers also collect information on the age and sex of all drivers and passengers, and type of vehicle. Site description including weather, traffic volume, road surface conditions, number of lanes, and law enforcement activities was collected before each observation session.

The observational method has been extensively used in road safety studies (G-l et al., 2008; Akaateba et al., 2014; Wu et al., 2012). This method provides access to road safety behaviors of interest in real life situations, has stronger validity than interviews that are vulnerable to misreporting, and is able to reach a wide range of people at a reasonable cost (Boyko, 2013). We provided comprehensive trainings to all field workers before the first round data collection, and repeated refresher trainings before each subsequent round. Through the trainings, the field workers practiced the observational methods on the roads; and their observational results were compared with records from video footages taken at the scene.

Both descriptive statistical method and multivariate logistic model were used to analyze the data. For bivariate analysis, a proportion test based on a binomial distribution was used to test the statistical significance of difference between groups or change over time (Acock, 2008). For multivariate analysis, the following logistic model was used

$$logit(y_i) = X_i\beta$$

where i indexes occupant; $y_i = 0/1$ is an indicator of occupant i not wearing (0) or wearing (1) seatbelt; X_i is the vector of covariates for occupant i including an intercept; β is the vector of regression coefficients. The covariates included in the model are observation date (measured in years), sex of occupant, type of vehicle, day of week (weekend; weekday), type of occupant (driver; passenger), city development area (central urban; urban; peri-urban), and age group (< 18 or > 59 years; 18–24 years; 25–59 years). The model coefficients measure the impact of a one-unit change in a model covariate on the

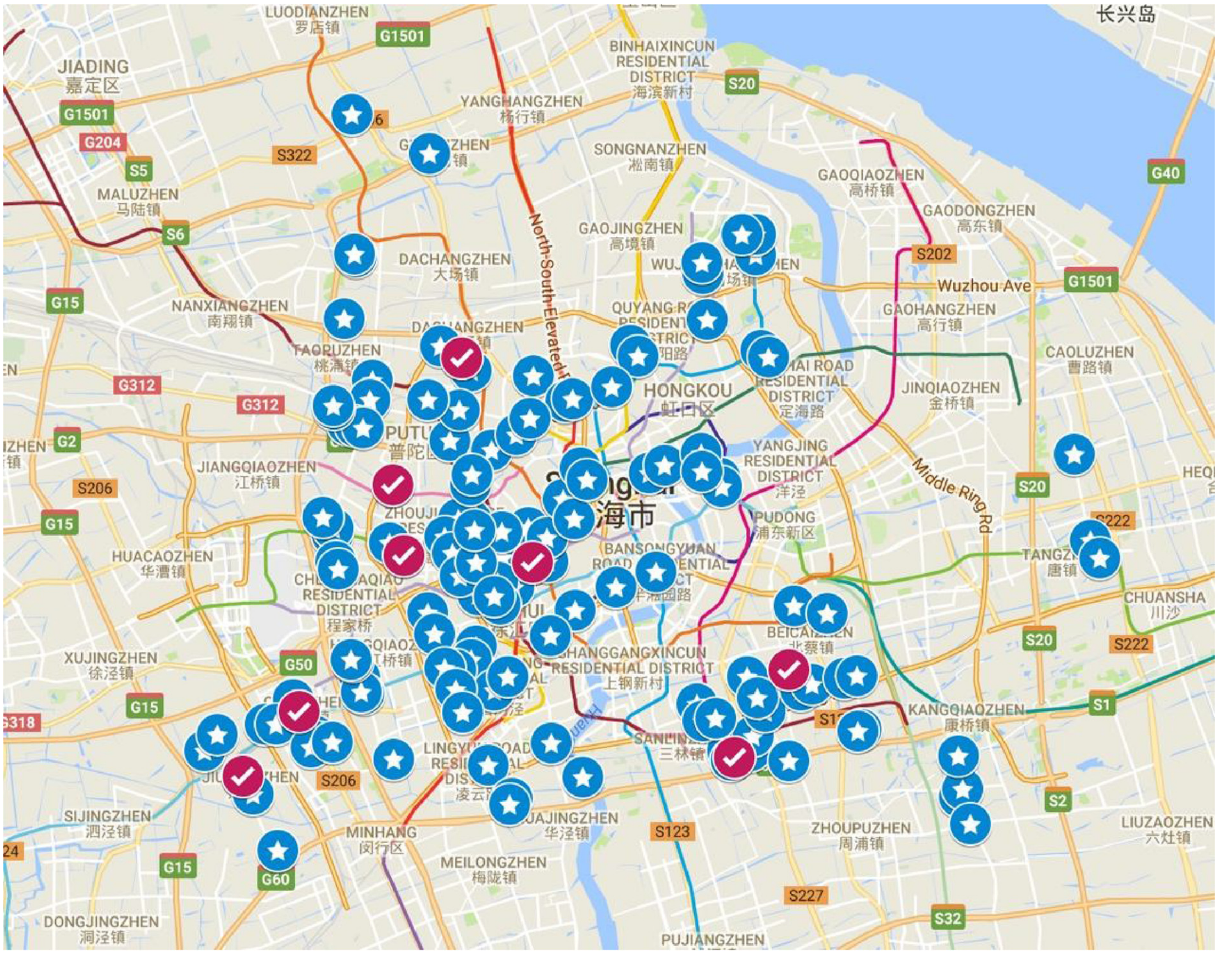

Fig. 1. Observation sites for seatbelt use studies in Shanghai.
Note: blue stars denote eligible locations; red checks denote selected observation sties.

outcome. Due to the nonlinear nature of the model, that impact varies with the value of covariates. The target audience of our studies and the BIGRS project includes not only researchers, but, more importantly, policy makers, who may not find odds ratios sensible. To facilitate an interpretation of the coefficients, average marginal effects (AME) were calculated and presented. AME denotes the average change in the probability of an outcome when a covariate increases by one unit (Williams, 2012).

All data analyses were conducted in Stata 15 SE (StataCorp., 2017). Ethical and institutional approval was obtained from Johns Hopkins Bloomberg School of Public Health, USA.

3. Results

Between October 2015 and December 2017, six rounds of data collection have been completed with a total sample size of 77,641 drivers and passengers (Table 1). About half of the observations were conducted in the morning (07:00–11:59) and the other half in the afternoon or early evening (12:00 – 20:00). The number of male occupants is more than three times that of female occupants, with the sex ratio of male over female among drivers even more imbalanced, rising to about eight. Approximately four-fifths (81%) of the observed occupants were 25–59 years old, with about 16% in the 18–24 age range. The most common type of vehicles were sedans or saloons (47%), followed by SUVs/four-wheel drive vehicles (4WD) (17%).

The seatbelt use rate has steadily increased over time, from 60.8% (95% CI: 59.9–61.7) in round 1 to 84.9% (84.3–85.4) in round 6 (p-value < 0.01) (Table 2). Throughout the article, confidence intervals were calculated using a binomial distribution, which is the default approach for count data (Greene, 2011). The intervals reflect the uncertainty when a sample is used to make an inference about a parameter in the population. Disaggregating by type of occupants, the increase is statistically significant for both drivers (77.1% in round 1 to 96.1% in round 6; p-value < 0.01) and passengers (16.2% in round 1 to 47.9% in round 6; p-value < 0.01) (Fig. 2). Despite the overall increase, considerable difference in seatbelt use rate between drivers and passengers was observed in all six rounds. In round 1, the ratio of seatbelt use rate for drivers over passengers was 4.8 in round 1; and it gradually decreased to 2.0 in round 6, implying a higher growth rate in seatbelt use among passengers than drivers.

Females were more likely to use seatbelts than males, whether they are drivers or passengers. This gender gap has been closing over time; by round 6, the use rate is almost identical for males and females (Fig. 3).

Results from the multivariate logistic regression are mostly consistent with those from the univariate and bivariate analyses (Table 3). After adjusting for other covariates, seatbelt wearing use has increased at annual rate of 8.8% (8.4%–9.1%). Compared with Sedan/Saloon, SUV/4WD has a higher seatbelt wearing rate while all other types of vehicles have a lower rate. The seatbelt wearing rate is 49.8% (49.0%–50.5%) lower among passengers than drivers. Peri-urban areas have a lower (3.5%; 95% CI: 2.9%–4.1%) wearing rate than central urban areas. The wearing rate is 16.3% (14.3%–18.4%) higher among 18–24-year old and 19.9% (17.0%-20.9%) higher among 25–59-year olds than other ages (i.e. < 18 or > 59 years). The difference between male and female is not statistical significant, nor is the difference

Table 1
Description of the sample in 6 rounds of observational study.

Characteristics	Round						Total
	1	2	3	4	5	6	
Total	11,892	9,393	12,028	13,638	14,501	16,197	77,649
Observation time							
Morning	6,671	4,649	5,172	6,584	7,391	9,112	39,579
Afternoon	5,221	4,744	6,856	7,054	7,110	7,085	38,070
Male	9,888	7,163	9,602	10,564	11,615	12,729	61,561
Driver	7,933	5,668	7,674	8,417	9,681	10,888	50,261
Passengers	1,955	1,495	1,928	2,147	1,934	1,841	11,300
Female	2,004	2,230	2,426	3,074	2,886	3,468	16,088
Driver	779	916	1,071	1,005	1,051	1,540	6,362
Passengers	1,225	1,314	1,355	2,069	1,835	1,928	9,726
Age							
< 18	166	135	144	302	253	235	1,235
18-24	10,131	457	104	942	902	164	12,700
35-59	1,593	8,762	11,733	12,141	13,262	15,688	63,179
> 59	2	39	47	253	84	110	535
Type of vehicle							
Sedan/Saloon	5,460	4,156	5,517	6,560	6,270	7,278	35,241
Pickup/Light truck	988	511	568	473	655	492	3,687
Truck/Large truck	195	179	391	443	379	464	2,051
Bus	347	367	488	422	610	454	2,688
Minibus/Minivan	1,724	1,229	1,474	1,439	1,587	1,626	9,079
SUV/4WD	1,359	1,400	1,850	2,492	2,282	3,217	12,600
Taxi	1,792	1,538	1,688	1,734	2,679	2,504	11,935
Others	27	13	52	75	39	162	368

Table 2
Seatbelt use rate by characteristics of occupants and vehicles.

Characteristics	Round						Total
	1	2	3	4	5	6	
All	60.8	64.1	72.4	74.4	81.4	84.9	74.3
Sex							
Female	45.4	58.7	62.4	61.8	63.8	69.3	61.4
Male	63.9	65.8	75.0	78.0	85.8	89.1	77.6
Type of vehicle							
Sedan/Saloon	68.6	72.2	82.3	81.1	87.4	87.8	80.8
Pickup/Light	47.7	40.1	46.1	55.8	66.1	77.4	54.7
Truck/Large	52.8	42.5	57.5	62.5	73.1	74.8	63.6
Bus	15.9	42.2	27.3	13.5	48.9	57.3	35.6
Minibus/Minivan	58.0	60.1	68.9	65.7	79.0	88.7	70.4
SUV/4WD	73.5	78.5	85.0	84.3	89.4	90.0	85.0
Taxi	47.1	48.5	55.9	66.6	74.9	76.2	63.7
Others	48.1	7.7	42.3	30.7	59.0	76.5	56.0
Day of week							
Weekend	58.6	63.2	73.8	71.2	80.8	81.1	73.0
Weekday	61.9	64.6	71.6	75.9	81.7	87.4	74.9
Type of occupant							
Driver	77.1	79.1	85.8	90.7	94.5	96.1	88.4
Front passenger	17.4	38.0	47.9	54.5	66.5	68.1	48.1
Back passenger	2.1	2.4	3.1	6.0	6.3	5.4	4.9
Area							
Central urban	63.5	71.1	74.2	74.5	75.7	83.0	74.4
Urban	68.4	78.4	75.2	76.6	82.3	84.1	78.9
Peri-urban	58.7	57.0	71.3	73.8	83.0	85.8	73.0
Age group							
< 18 or > 59 years	10.1	11.5	22.5	29.7	15.7	23.8	21.5
18-24 years	61.7	51.9	65.4	35.7	71.7	48.2	60.0
25-59 years	60.1	65.8	73.3	79.4	83.8	86.6	78.6

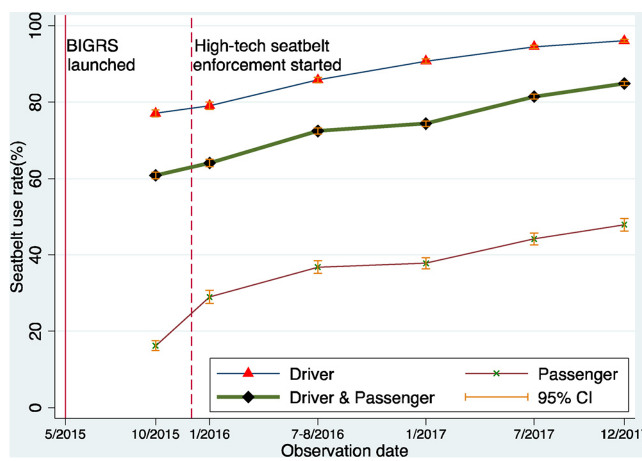

Fig. 2. Trend of Seatbelt wearing rate for drivers and passengers in Shanghai.

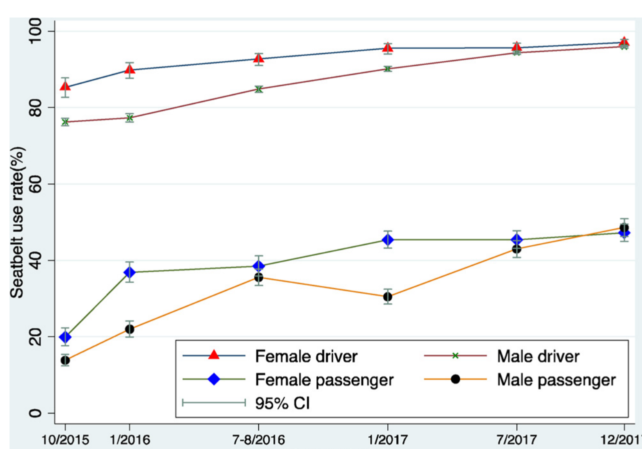

Fig. 3. Trend of seatbelt use rate by sex and type of road user.

Table 3
Average marginal effects (AME) from the multivariate logistic model of seatbelt use in Shanghai.

Covariate	AME	95% Conf. Interval	
Year	0.09***	0.08	0.09
Sex (ref: female)			
Male	0.00	−0.01	0.00
Type of vehicle (ref: Sedan/Saloon)			
Pickup/Light	−0.17***	−0.18	−0.15
Truck/Large	−0.16***	−0.17	−0.14
Bus	−0.51***	−0.52	−0.50
Minibus/Minivan	−0.08***	−0.08	−0.07
SUV/4WD	0.04***	0.03	0.04
Taxi	−0.12***	−0.12	−0.11
Others	−0.25***	−0.29	−0.20
Day of week (ref: weekend)			
Weekday	0.00	−0.01	0.00
Type of occupant (ref: driver)			
Passenger	−0.50***	−0.51	−0.49
Area (ref: central urban)			
Urban	0.00	−0.01	0.01
Peri-urban	−0.03***	−0.04	−0.03
Age group (ref: < 18 or > 59 years)			
18-24 years	0.16***	0.14	0.18
25-59 years	0.19***	0.17	0.21

Notes: **p < 0.05; **p < 0.01; ***p < 0.001; reference group in parenthesis.*

between weekday and weekend.

4. Discussion

To our knowledge, our studies are one of the few multi-round cross-sectional studies on seatbelt use conducted in a Chinese city. Compared with previous single-round observations, our multi-round observations allow for more reliable and accurate estimation of trends; and our large sample size allows for disaggregation by occupant role and demographics, road features, and geographic location. Our multivariate logistic model identified vehicle and demographic measures that are associated with seatbelt use. The information is valuable for monitoring road safety performance and evaluating programs.

The seatbelt use rate in Shanghai has been boosted from 60.8% to 84.9% within a period of two years. While this safety behavior in Shanghai is now substantially higher than in the past and other Chinese cities, there is still room for improvement compared to the best performers in the world. Many other high-income countries have higher prevalence of seatbelt use (WHO, 2015; Abbas et al., 2011). For example, the population-based National Occupant Protection Use Survey in the United States found a seatbelt use rate of 89.7% among drivers and passengers in that country in 2017 (Li and Pickrell, 2017).

Despite these achievements, the seatbelt wearing rate among rear passengers remained very low in Shanghai, around 5% in the most recent round. Wearing a seatbelt among rear passengers improves not only their own safety, but also that of front occupants, as the forward movement of unbelted rear passengers can endanger front occupants in the event of frontal collisions (Shimamura et al., 2005). One study found that the risk of death for belted front passengers was raised by nearly five-fold due to the presence of unbelted rear passengers; about 80% of fatalities among belted front passengers could be avoided if all rear passengers are belted (Ichikawa et al., 2002). Unfortunately, the computer vision technique is unlikely to function for this rear passengers because of visibility issues. Strengthening seatbelt laws has been shown effective in promoting seatbelt use among rear passengers (Bhat et al., 2015). Targeted social marketing campaigns are another option (Smith, 2006). This adverse impacts of one person's action on the well-being of another person, called negative externalities in economics, result in outcomes that are not socially optimal (Dybvig and Spatt, 1983). Given the negative externalities on the safety of drivers and front passengers due to rear passengers' nonuse of seatbelts, it is in the interest of drivers and front passenger to insist that rear passengers wear seatbelts.

Consequently, disseminating this knowledge may make it more likely for front occupants, who already have a high wearing rate, to remind rear occupants to buckle up.

As observational studies conducted in a complex setting, this report has several limitations. First, despite our effort to cover all major types of locations and different days and times, our sample may still have missed certain types of location and time. For example, due to safety concerns, our observations did not cover late night or very early morning or places unsafe for observers. Second, many other activities and changes were occurring and influencing seatbelt use in Shanghai while high-tech enforcement was being implemented and expanded. Shanghai police launched an one-year long major traffic renovation on March 26, 2016, though seatbelt use was not a focus. Other governmental agencies, academic institutes, and non-governmental organizations have also been working on promoting seatbelt use. As a result, it is difficult to attribute the change in seatbelt use to any one institution or activity. There was no observation before the launch of BIGRS and only one round before the deployment of high-tech seatbelt enforcement, making it statistically infeasible to accurately estimate the contribution of those two interventions to the change in seatbelt wearing rate. Third, all indicators were based on observations, which might be affected by an observer bias. Some demographic indicators, such as sex and age group, may not be observed accurately, though there is no reason to believe that bias is substantial or systematic.

Despite the limitations, the observed consistent increase in seatbelt use during such a short period of time demonstrates the potential of combined enforcement strategies, including technical innovation, capacity building, and social marketing campaign (Chisholm et al., 2012). Shanghai has addressed the difficulty in seatbelt enforcement and successfully increased seatbelt use in the city. The experience shows that a robust monitoring and evaluation program can be developed and used to assess the change in road safety risk factors over time. The observed increase indicates the effectiveness of high-tech enforcement in combination with intensive capacity building and social marketing activities when traditional enforcement approaches are ineffective. Cities in China and other countries facing similar challenges with seatbelt wearing may learn from Shanghai's experience.

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