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Improving the safety effect of speed camera programs through innovations: Evidence from the French experience

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ABSTRACT

Problem: This study investigates the effect of the French Automated Speed Enforcement Program (ASEP) on casualties involving different types of road users. *Method*: Interrupted time-series analyses were conducted to estimate the effect of the ASEP. *Results*: Overall, the ASEP was associated with a decrease of 19.7% in traffic fatalities and crashes with injuries. Significant diminutions were observed for passenger vehicles/light SUVs (−25.4%), motorcyclists (−39.0%), and trucks (−15.7%). Adding red light cameras and devices taking pictures of both ends of the vehicle produced, in some cases, additional gains among specific categories of road users. *Conclusion*: Traffic fatalities, crashes with injuries and the severity of crashes significantly declined following the introduction of the ASEP in November 2003. *Practical applications*: ASEPs are an effective strategy to prevent traffic casualties. Innovations such as red light cameras and devices taking pictures of both ends of the vehicle can improve an ASEP.

1. Introduction

In 2001, France had a traffic fatality rate of 13.8 per 100,000 population and was performing poorly in comparison to other OECD countries. According to the *Observatoire National Interministériel de la Sécurité Routière* (ONISR), over 60% of all recorded speeds exceeded the prescribed speed limits: 40% by more than 10 km/h and 5% by more than 30 km/h (ONISR (Observatoire National Interministériel de Sécurité Routière), 2006). Speed limit violations became a major concern for French authorities, as is the case in many other countries (U.S. Department of Transportation, 2004; World Health Organization, 2004).

The lack of effective enforcement was targeted as one of the main problems exacerbating speed limit violations. In fact, a survey published in 2006 revealed that the probability of being intercepted for speeding was relatively low. One could exceed the speed limit by 10 km/h for more than 2000 h before being arrested (ONISR (Observatoire National Interministériel de Sécurité Routière), 2006). Speed limit infringements were largely tolerated by police officers and a significant proportion of fines were unpaid (Carnis, 2011).

In July 2002, President Chirac stated publicly that traffic safety was among the main priorities of his next term. In September 2002, three distinct traffic safety measures were announced: (a) the implementation of an automated speed enforcement program (ASEP), (b) increased penalties for traffic violations, and (c) the creation of new traffic offenses. Prior to the introduction of the ASEP, print and visual media provided wide and positive coverage of the new policy (Carnis, 2011).

The first photo radar devices were installed in November 2003, following a trial period between March and November 2003. About 500 devices have since been installed each year. According to the latest data, approximately 4097 were in operation by the end of 2013. Speed cameras are in operation on the whole road network, which means that drivers are exposed to the program at different stages of their itinerary. Fixed cameras are generally installed on sites experiencing high levels of either crashes or speed limit violations (Carnis, 2011). According to the latest report of the ONISR (2015), 15% of all fixed speed cameras are installed on highways while 15%, 27%, and 4% are respectively installed on national, country, and urban roads. Mobile speed cameras are installed on rural and urban roads and are managed by police officers. Mobile devices are used in different enforcement contexts depending on the police officers' experience and knowledge.

Recently, new types of devices as well as new enforcement strategies were introduced. These new features can be conceptualized as

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innovations aimed at improving the effectiveness of the ASEP. New types of devices were introduced to capture a picture of the rear and front ends of the vehicle (January 2007) and to discriminate trucks from other vehicles (March 2011).[2] These modifications are important features of the ASEP, as motorcycles and scooters do not have a front plate and could avoid detection and punishment. Speed detection was also set at different thresholds, with lower speed limits imposed for trucks. In March of 2013, patrol cars were equipped with mobile devices to improve detection and allow for random supervision while in motion.

The introduction of the ASEP led to a radical increase in the number of citations issued for speed limit violations. Citations per month went from 110,000 before the program to 502,000 after (Carnis, 2008). Assessments also show that the introduction of the ASEP led to significant decreases in average speeds and speed limit violations. The average speed decreased from 89.5 to 79.3 km/h between 2002 and 2012 for passenger vehicles, from 100.8 to 86.1 km/h for motorcycles, and from 78.8 to 71.7 km/h for trucks. The rate of infringements for exceeding the speed limit by more than 10 km/h diminished by 50% while a reduction of about 70% was observed for the overall speed limit infringement rate (ONISR (Observatoire National Interministériel de Sécurité Routière), 2013).

Although their estimates vary, several studies also establish that the ASEP had a preventive effect on traffic injuries (Roux & Zamora, 2013; Carnis & Blais, 2013; ONISR (Observatoire National Interministériel de Sécurité Routière), 2006). For instance, using interrupted time-series analyses, Carnis and Blais (2013) estimated that the introduction of the ASEP was associated with respective decreases of 7.3% and 20.7% in the monthly rate of non-fatal and fatal traffic injuries per 100,000 vehicles. These studies also reveal that effects on traffic injuries were greater on the short term. Firstly, the law of diminishing marginal returns characterizes the effect of the ASEP on traffic fatalities. Between 2003 and 2010, adding radar devices maintained the effect of the ASEP on fatalities but benefits were not proportional to the number of speed cameras in place. Secondly, a decay function was observed for the non-fatal injury series, as the effect of the ASEP on non-fatal traffic injuries dwindled through time (Blais & Carnis, 2013).

By integrating, among other things, driver characteristics, a better understanding of the ASEP in operation can be obtained. Some studies conducted in the United States demonstrate that receptivity to the threat of punishment is inversely related to the ability to avoid punishment (Piquero & Pogarsky, 2002; Piquero & Paternoster, 1998). Short-term effects reported in numerous studies (Carnis & Blais, 2013; Roux & Zamora, 2013; Jones, Sauerzapf, & Haynes, 2008) could be explained by the fact that drivers receptive to the threat of punishment have modified their behaviors and that drivers involved in crashes were not deterred by punishment.

Internationally, a few studies have investigated the effects of ASEPs on collisions involving different categories of road users (Wilson, Willis, Hendrikz, & Bellamy, 2011), but some assessments show variations in collisions and compliance rates. In France, the first speed cameras were only taking pictures of the front end of the vehicle and, as a result, motorcycles and scooters were not identified (Carnis, 2011), a fact that might explain the lower compliance rate among motorcycle drivers (ONISR (Observatoire National Interministériel de Sécurité Routière), 2006). In their assessment of the demonstration program in Scottsdale, Arizona, Retting, Kyrychenko, and McCartt (2008) show that the odds of drivers exceeding the speed limit decreased by 88% since the introduction of speed cameras on Loop 101 of the freeway. Interaction effects between types of road users and the program indicate that cameras were less effective at reducing the proportion of passenger vehicles exceeding 75 mph (equivalent of 135 km/h) than they were for large trucks. An evaluation of the speed camera program introduced in 2002 in Flanders, Belgium, reports that greater decreases in casualties were observed for motorcyclists and pedestrians than for other categories of users (De Pauw, Daniels, Brijs, Hermans, & Wets, 2014). These studies, however, were not specifically designed to identify factors likely to explain variations in the behavior of different categories of road users.

The objectives of this study echo recommendations found in the Cochrane review on speed cameras, namely, to conduct long-term evaluations of ASEP programs and to assess their effects on different categories of road users (Wilson et al., 2011). The French experience permits one to estimate simultaneously the long-term effect of the ASEP (November 2003 to December 2011) and to pinpoint effects specific to categories of road users. As mentioned earlier, innovations were recently added to the ASEP. These included (a) increased identification of two-wheeler vehicles through the imaging of both ends of the vehicle in January 2007, (b) increased safety to vulnerable road users through the installation of red light cameras in July 2009, (c) introduction of discriminatory speed control devices able to identify vehicles categories that are subject to different speed limits (March 2011), and (d) equipment of patrol cars with detection devices for use in motion in March 2013.[3] During this period, speed-lock devices became mandatory for trucks (February 2005). Analyses conducted in the present study investigate the capacity of such innovations to improve the capacity of the ASEP to prevent traffic casualties and to reverse the decay function by punishing violators (e.g., motorcyclists and moped riders) that were previously more likely to avoid punishment.

2. Method

2.1. Data source

Data on traffic crashes were extracted from ONISR annual reports on traffic crashes and injuries. Data found in these reports come from the *Fichier National des Accidents Corporels de la Circulation*, a national database managed by the ONISR. A crash refers to an event in which damages are caused by a moving vehicle. The database contains the essential information gathered at the crash scene by police officers during the 2000–2011 period. Data on the population are collected and published by the INSEE (Institut National de la Statistique et des Études Économiques). The researchers, to identify traffic safety measures introduced for the period under study, used catalogues published by the ONISR. Data were then aggregated on a monthly basis ($n = 144$). Since the ASEP covers the whole French road network, the country (France) was used as the unit for spatial aggregation, rather than the speed camera sites. Such a strategy allows one to estimate the overall effect of the ASEP on the whole road network (Carnis & Blais, 2013).

2.2. Variables under analysis

2.2.1. Dependent variables

In the present study, the effect of the ASEP is estimated on three main dependent variables that are then decomposed into five categories of road users (Table 1). The first dependent variable is the rate of fatal traffic injuries per 100,000 population. Traffic fatalities are defined as deaths occurring within 30 days of a crash. The second dependent variable is the rate of crashes with injuries per 100,000 population. This category includes crashes that took place either on a public or a private road open to circulation, involved at least one motor vehicle, and led to the hospitalization or treatment by a health professional of at least one occupant. The last dependent variable is a severity index: traffic fatalities per 100 crashes with injuries.

Averages and standard deviations for all users and for specific categories are summarized in Table 1. Table 1 also provides counts for traffic fatalities and crashes with injuries. One should note that summing rates

[2] http://www.securite-routiere.gouv.fr/connaitre-les-regles/les-radars (last access June 26th 2014)

[3] This latest measure is not assessed in this article, since data on crashes were not yet available for 2013 when analyses were conducted.

Table 1
Descriptive statistics.

	Fatal injuries (counts)				Fatal injuries per 100,000 population		
	Mean	Std. dev.	Range	Total (2000–2011)	Mean	Std. dev.	Range
All categories of users	465.53	142.22	254–808	67,036	0.75	0.24	0.39–1.33
Specific categories of road users							
Moped riders	28.78	10.52	10–58	4145	0.46	0.17	0.15–0.95
Motorcyclists	72.47	29.37	16–141	10,435	0.12	0.05	0.02–0.23
Vulnerable road users[1]	68.05	20.24	36; 136	9799	0.11	0.03	0.06–0.22
Truck	7.72	3.75	0–19	1111	0.12	0.06	0.00–0.31
Passenger and sport utility vehicle users	282.49	105.52	152–571	40,679	0.45	0.18	0.24–0.94
	Crashes with injuries (counts)				Crashes with injuries per 100,000 population		
	Mean	Std. dev.	Range	Total (2000–2011)	Mean	Std. dev.	Range
All categories of users	7251.86	1629.43	4299–11,093	1,044,268	11.59	2.86	6.62–18.33
Specific categories of road users							
Moped riders	1235.42	284.80	597–1997	177,900	1.97	0.49	0.92–3.30
Motorcyclists	1439.73	335.44	594–2094	207,321	2.29	0.55	0.92–3.43
Vulnerable road users[1]	1596.69	293.72	986–2369	229,924	2.55	0.51	1.50–3.92
Truck	370.22	92.49	222–609	53,312	0.59	0.16	0.35–1.01
Passenger and sport utility vehicle users	6433.93	1542.55	3908–10,168	926,486	10.28	2.70	5.97–16.80
Severity index							
	Mean	Std. dev.	Range	Total (2000–2011)	Mean	Std. dev.	Range
All categories of users	6.35	0.83	4.63–8.80	–	–	–	–
Specific categories of road users							
Moped riders	2.30	0.57	0.92–4.32	–	–	–	–
Motorcyclists	4.88	1.31	1.98–8.24	–	–	–	–
Vulnerable road users[1]	4.26	0.96	2.37–7.46	–	–	–	–
Truck	2.06	0.79	0–4.26	–	–	–	–
Passenger and sport utility vehicle users	4.30	0.76	2.80–6.60	–	–	–	–

[1] This category includes pedestrians and cyclists.

of crashes with injuries for all five categories is greater than for the category including all users. The category including all users is based on the event (with one crash counting as one event). Specific categories count parties that were involved in the crash. A crash involving a passenger vehicle and a motorcycle appears in both the motorcycle and passenger vehicle categories.

2.2.2. Independent variables of interest

Four intervention variables were used to estimate the effect of the ASEP and its innovations on crashes and casualties (Table 2). The effect of each intervention was estimated with two parameters. The first one is a dichotomous variable (0,1) and discerns the before-and-after intervention periods. This parameter is used to assess changes in the level of the series.

The second parameter "Trend*intervention" is an interaction between the intervention and the Trend (see section 2.2.3) variables and counts the time after the intervention. This parameter evaluates the change in the slope of the series. Since speed cameras and innovations were progressively introduced, six different functions were tested for the "Trend*intervention" variable.

1. Linear ($Y = b_0 + b_1 {}^*t$)
2. Logarithmic ($Y = b_0 + b1^*\ln(t)$)
3. Inverse ($Y = b_0 + (b_1/t)$)
4. Quadratic ($Y = b_0 + b_1{}^*t + b_2{}^*t^2$)
5. Power ($Y = b_0 {}^*t^{b1}$)
6. Exponential ($Y = b_0 * e^{b1^*t}$)

Table 2
Description of control and intervention periods for traffic safety measures.

Name of the intervention	Control period (0)	Intervention period (1)
Introduction of the ASEP and innovations introduced to the ASEP		
Introduction of the ASEP	Jan. 2000 to Oct. 2003	Nov. 2003 to Dec. 2011
Devices photograph front and rear ends of the vehicle (ASEP2)	Jan. 2000 to Dec. 2006	Jan. 2007 to Dec. 2011
Red light cameras (REDLIGHT)	Jan. 2000 to June 2009	Jul. 2009 to Dec. 2011
Pictures discriminate trucks from passenger cars (TRUCK1)	Jan. 2000 to Feb. 2011	Mar. 2011 to Dec. 2011
Public communication campaigns		
Chirac's announcement (CHIRAC)	Jan. 2000 to June 2002	Jul. 2002 to Dec. 2011
Other traffic safety measures		
Seatbelt/cellphone/helmet	Jan. 2000 to Feb. 2003	Mar. 2003 to Dec. 2011
Alcohol	Jan. 2000 to June 2003	Jul. 2003 to Dec. 2011
Speed1	Jan 2000 to Nov. 2004	Dec. 2004 to Dec. 2011
Truck2	Jan. 2000 to Jan. 2005	Feb. 2005 to Dec. 2011
Speed2	Jan. 2000 to Dec. 2005	Jan. 2006 to Dec. 2011

Where b_0 is the constant of the equation, b_n represents a regression coefficient, t is the "Trend" variable and "ln" stands for the natural logarithm transformation. Investigating the functional form of the relationship between the ASEP and traffic casualties is useful to give guidance about the optimal allocation of resources to speed enforcement and modifications needed to maintain assets or to achieve further improvements (Tay, 2005; Elvik, 2011).

A last variable (CHIRAC) captured President Chirac's declaration made in July 2002. Traffic safety became a national priority and the introduction of the ASEP on the French road network was announced. Values prior to July were coded 0 and the following ones were coded 1.

2.2.3. Control variables

Two sets of control variables were operationalized to account for the general trend of the series and monthly variations in traffic crashes. "Trend" is a continuous variable and indicates the time in months at time *t* from the start of the observation period (January 2000 to December 2011). Monthly fluctuations are accounted for by 11 dummy variables (k-1; reference category = December).

In addition to speed cameras, five other groups of measures were introduced between 2000 and 2011: (a) Seatbelt/helmet/cellphone—increased sanctions for not fastening the seat belt, the prohibition of using hand-held cellphone devices while driving and the obligation to wear a helmet for two-wheeler users in March 2003; (b) Alcohol—increased sanctions for driving while impaired by alcohol in July 2003; (c) Speed1—increased sanctions for speed limit violations over 50 km/h (and reduced sanctions for speed limit violations under 20 km/h) in December 2004; (d) Truck2—mandatory speed-lock devices for trucks in February 2005; and (e) Speed2—increased sanctions for speed limit violations over 50 km/h with the possibility of confiscating the vehicle in January 2006. All these measures are expressed by dichotomous variables: units in the pre-intervention period were coded 0 and those in the intervention period were coded 1 (Table 2).

2.2.4. Analytical strategy

In the first place, descriptive analyses were conducted to portrait trends of the series and compare series averages for periods before and after the ASEP. In the second place, interrupted time-series were performed using the autoregressive, integrated, moving average (ARIMA) intervention time-series models (Box, Jenkins, & Reinsel, 2008). Interrupted time-series have been used in several studies to determine whether the introduction of a traffic safety measure leads to changes in the behavior of the series (Beaudoin & Blais, 2010; Nagata, Setoguchi, Hemenway, & Perry, 2008; Keall, Povey, & Frith, 2002).

Since each series has a unique structure, ARIMA models were developed using a three-stage iterative process: (a) identification, (b) estimation, and (c) diagnostic (Box et al., 2008; Yaffee & McGee, 2000). Autocorrelation and partial autocorrelation matrices were inspected during the identification stage to identify both sources of non-stationarity in the series (deterministic or stochastic) and autoregressive and moving average parameters. The predictive validity of these parameters was then assessed in the estimation stage. Since series exhibited seasonality, the identification and estimation stages were realized in two steps. First, seasonal parameters (lag 12) were identified and their errors were re-inspected to detect other lags with significant Q-statistics. Second—in the diagnostic stage—error terms were examined to make sure that they follow a white noise process. With one exception, error terms of all models have a white noise process. Error terms are normally distributed and the homoscedasticity assumption is respected.

Independent variables were then introduced in the models in two distinct steps to estimate the effect of the ASEP and its innovations. In the first step, a series of models were built to estimate the effect of Chirac's announcement, the introduction of the ASEP, and the other control variables. Intervention and control variables were selected using a backward elimination procedure in order to avoid multicolinearity and over-specification problems. For instance, increased sanctions for driving while impaired by alcohol (Alcohol) were highly correlated with the introduction of the ASEP. Both variables could not be integrated in the same model and the variable with the greatest predictive power was kept. In the second step, variables measuring innovations to the ASEP were added to the set of variables selected in the first step. To be included in a model, innovations had to target the category of road users (for instance, devices [Radar2] taking a picture of both ends of the vehicle were only included in models where moped riders and motorcyclists are involved). Since two parameters were used to estimate the effect of the ASEP and its innovations on the dependent variables, at each step, models with the highest stationary r-squared and lowest MAPE (Maximum Absolute Percentage Error) were deemed the most robust (Yaffee & McGee, 2000).

3. Results

As shown in Fig. 1, the fatality series is characterized by a downward trend and a structural break. The dwindling trend and the break occur around Chirac's announcement. Crashes with injuries per 100,000 population are also characterized by a downward trend that seems to start with Chirac's announcement (Fig. 2). The structural break in the series is not as evident and is difficult to discern from monthly fluctuations. The severity index displays a sinusoidal shape: the series peaks in the early 2002 and starts a downward trend up to the mid-2008. Afterwards, a progressive rise characterizes the last segment of the series. Crossing both series of Fig. 2 shows that months with the lowest rate of crashes with injuries are those with the highest values on the severity index.

Table 3 compares averages in traffic casualties for periods before and after the introduction of the ASEP. On average, the fatality rate fell by 41.35% since the introduction of the ASEP, while crashes with injuries and the severity index dropped by 32.82% and 14.29%, respectively. The general picture is, however, influenced by the passenger vehicles and SUV category. Except for trucks, lower decreases are observed for other categories of road users. The lowest reductions in fatalities and crashes with injuries are observed for motorcyclists (−21.43% and −13.10%, respectively). The smallest decline between the two periods in the severity index is observed for moped riders (−6.64%).

Traffic casualties sharply declined over the 2000–2011 period. Yet, descriptive statistics are not immune to biases related to seasonality, maturation, and omitted confounding factors (Shadish, Cook, & Campbell, 2002). ARIMA intervention time-series models overcome these limitations and provide estimations about the effect of the ASEP on all series. Table 4 contains estimations for 18 models. For each road user category, three series of results are provided: (a) one for fatalities per 100,000 population, (b) one for crashes with injuries per 100,000 population, and (c) one for the severity index. Models selected were those with the best goodness-of-fit coefficients. Since different functions were attempted for the Trend*ASEP parameters, Table 4 also specifies the function that was retained for the final model. The absence of coefficient for a traffic safety intervention is represented by "—" and it indicates that the variable was removed from the model as a result of the backward elimination procedure.

When all users are considered, results show that *Chirac's announcement* ($\beta = -.17$; $p < .01$) and the introduction of the *ASEP* ($\beta = -.13$; $p < .01$) are associated with significant declines in traffic fatalities. *Speed2* is also inversely associated with fatalities ($\beta = -.06$; $p < .05$). *Chirac's announcement* ($\beta = -1.66$; $p < .01$) is related to a significant decrease in crashes with injuries. For crashes with injuries, coefficients for the *ASEP* and other traffic safety measures are not significant. The

[4] For crashes with injuries per 100,000 population for all road users (Table 4), we also attempted models where the "*Trend*ASEP*" variable was replaced by a "*Chirac's announcement*TREND*" variable. Results are similar and suggest that the decay started immediately after the public announcement.

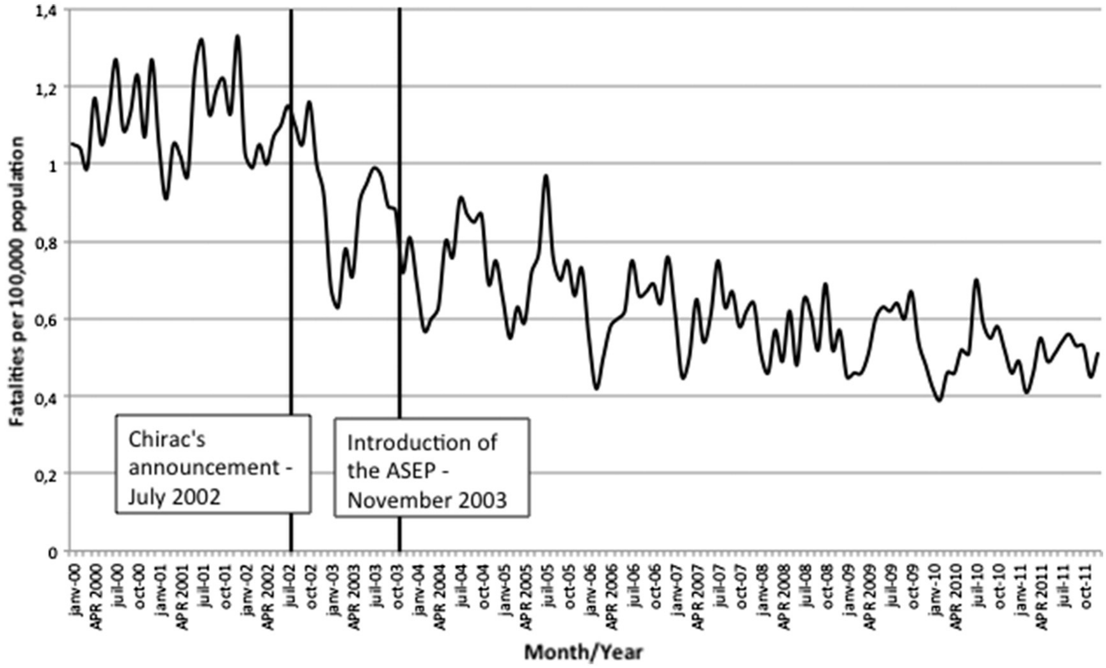

Fig. 1. Trend for traffic fatalities per 100,000 population for the 2000–2011 period.

positive coefficient for the "*Trend*ASEP*" (β = .05; p < .01) variable indicates that the effect of the announcement on crashes with injuries decays with time.[4] Results suggest that the severity of crashes progressively diminishes through time. *Chirac's announcement* (β = −.67; p = .01) and the *ASEP* (β = −.62; p.01) are associated with significant decreases in the level of the severity index and the negative coefficient for the "*Trend*ASEP*" (β = −.02; p < .01) signals an incremental effect throughout the intervention period.

As displayed in Table 4, the passenger vehicles/light SUVs category largely influences estimations observed when all users are considered. With few exceptions, results are the same. One noteworthy result is the preventive effects of other traffic safety measures introduced during the same period. Increased sanctions for speed limit violations over 50 km/h with the possibility of confiscating the vehicle (*Speed2*) and measures targeting seatbelt use, mandatory helmet for two-wheeler users and cellphone use while driving prove to be effective.

Different patterns of results are observed for categories found in Tables 5 and 6. All three series involving motorcyclists display a significant diminution in their level following *Chirac's announcement* (Table 5). The effect of the *ASEP* gradually increases as expressed by significant coefficients for the "*Trend*ASEP*" for fatalities (β = −.009; p < .05) and the severity index (β = −.05; p < .01). In this single model, *Alcohol* (β = −.70; p < .05) and *Speed1* (β = −.60; p < .05) are related to a diminution in the severity index for motorcyclists. Fatalities, crashes with injuries, and the severity index involving moped riders are neither affected by Chirac's announcement nor the ASEP.

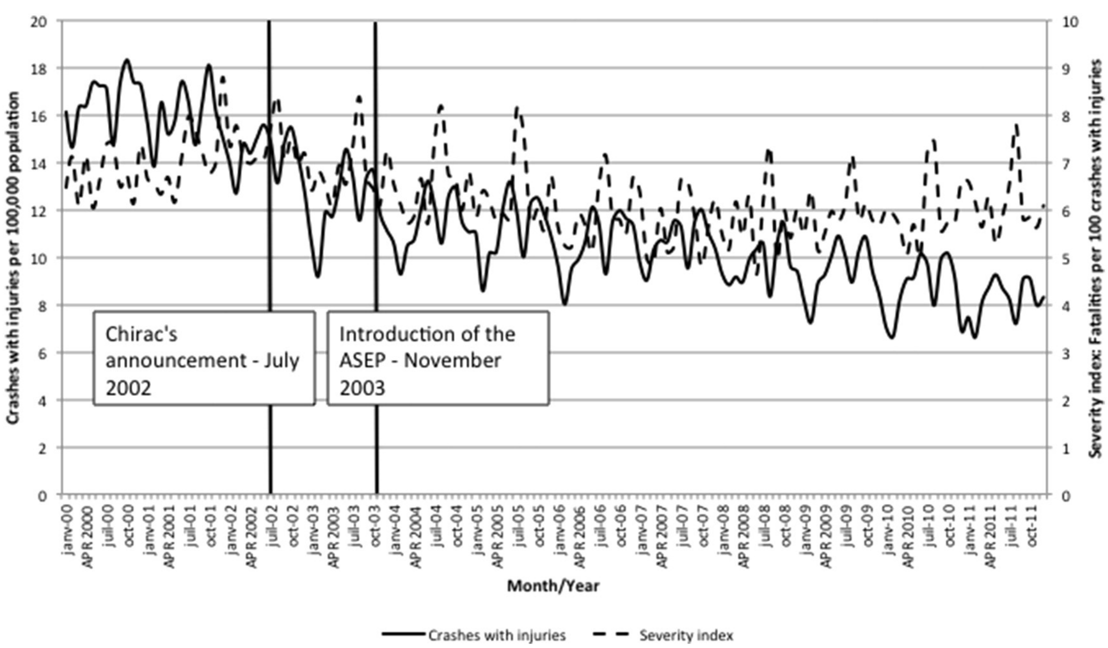

Fig. 2. Trends for crashes with injuries per 100,000 population and the severity index for the 2000–2011 period.

Table 3
Monthly averages in fatalities, crashes with injuries, and the severity index before and after the introduction of the ASEP.

	Period 1: January 2000–October 2003			Period 2: November 2003–December 2011			Percentage change		
	Fatalities	Crashes with injuries	Severity index	Fatalities	Crashes with injuries	Severity index	Fatalities	Crashes with injuries	Severity index
All users	1.04	14.93	7.00	0.61	10.03	6.04	−41.35	−32.82	−14.29
Moped riders	0.06	2.42	2.41	0.04	1.76	2.25	−33.33	−27.27	−6.64
Motorcyclists	0.14	2.52	5.34	0.11	2.19	4.67	−21.43	−13.10	−11.32
Vulnerable road users	0.14	3.04	4.67	0.09	2.31	4.07	−34.71	−24.01	−12.85
Trucks	0.02	0.76	2.37	0.01	0.51	1.91	−50.00	−32.89	−17.39
Passenger vehicles and light SUVs	0.68	13.53	5.02	0.35	8.76	3.96	−48.53	−35.25	−21.12

According to results displayed in Table 6, traffic safety measures did not have any effect on fatalities and crashes with injuries involving vulnerable road users. A decline in the severity index following the introduction of the *ASEP* ($\beta = -.41$; $p < .05$), however, suggests that speed cameras have yielded a beneficial effect on the severity of injuries in the event of a crash. The absence of impact is also observed for moped riders.

Chirac's announcement ($\beta = -.24$; $p < .05$) and the introduction of the *ASEP* ($\beta = -.17$; $p < .05$) both led to decreases in fatalities among truck drivers. The negative coefficient for the "*Trend***ASEP*" term ($\beta = -.008$; $p < .10$) indicates that the effect increases through the intervention period. The public announcement ($\beta = -.10$; $p < .01$) is the sole measure associated with a decline in crashes with injuries involving trucks while the "*Trend***ASEP*" ($\beta = -.02$; $p < .10$) is negatively associated with the severity index, suggesting a gradual effect through time.

Tables 7–9 report results regarding the effects of innovations added to the ASEP on traffic casualties. Since the present analyses seek to assess the added value related to innovations, variables previously identified as being relevant predictors were kept in the models (see Tables 4–6). Variables previously discarded were not reconsidered. Since innovations target very specific categories of road users, they are introduced in the model when relevant. The "*Red light cameras*" variable is present in all models because it targets all road users. Because innovations were gradually implemented on the road network, various functions were tested. When non-significant, the interaction term between the trend and the innovation was withdrawn for the models. For instance, fatal injuries for all road users were first identified as a function of "Chirac's announcement," the "Introduction of the ASEP," and "Speed2" (Table 4). "RED LIGHT" and "RED LIGHT*Trend" were then added to the first set of variables. "RED LIGHT*Trend" was then removed from the final statistical model since it was not significantly associated with fatal injuries (Table 7). The same procedure was used to obtain all estimates presented in Tables 7–9.

Results in Table 7 indicate that innovations did not translate into additional benefits when all types of road users are considered. Red light cameras have initiated a gradual decline on the traffic fatalities series ($\beta = -.09$; $p < .10$) and the severity index ($\beta = -1.04$; $p < .01$) involving vehicles/light SUVs. Innovations have produced mixed results for motorcyclists. Neither the *Red Light* nor *ASEP2* affected fatalities. Crashes with injuries involving motorcyclists are characterized by a significant increase following the introduction of *ASEP2* ($\beta = 2.69$; $p < .05$) and also by a change in the slope of the series ($\beta = -1.27$; $p < .05$), suggesting a preventive effect after the first 2 to 3 months. The logarithmic and negative relationship between "*Trend***REDLIGHT*" and the severity index indicates a gradual and preventive effect on the severity of crashes involving motorcyclists. *ASEP2* did not have any effect on moped riders. On the other hand, a gradual effect is reported for red light cameras on fatalities ($\beta = -.09$; $p < .10$) and crashes with injuries involving moped riders ($\beta = -.06$; $p < .05$).

Table 4
Effects of the ASEP on fatalities, crashes with injuries, and the severity index for all users and passenger vehicles/light SUVs.

	All categories of road users						Passenger vehicles and light SUVs					
	Fatal injuries		Crashes with injuries		Severity index		Fatal injuries		Crashes with injuries		Severity index	
	β	S.E.	β	S.E.	β	S.E.	β	S.E.	β	S.E.	β	S.E.
AR1 parameter	.18*	.09	.46**	.08	−.08	.09	.12	.09	.41**	.08	−.016	.090
Constant	1.23**	.03	18.38**	.54	6.79**	.25	.86**	.02	2.85**	.02	5.17**	.23
Trend	−.002**	.00	−.09**	.02	0.03**	.01	−.002**	.000	−.005	.001	.02**	.01
Chirac's announcement	−.17**	.03	−1.66**	.34	−.67**	.21	−.11**	.02	−.112**	.024	−.45*	.19
Introduction of the ASEP	−.13**	.03	–	–	−.62**	.16	−.08**	.02	−.11**	.04	−.49*	.16
Trend* ASEP	–	–	.05**(3)	.02	−.02**(1)	.008	–	–	.033*(5)	.016	−.02*(1)	.01
Other traffic safety measures												
Speed1	–	–	–	–	−.33*	.16	–	–	–	–	−.30*	.14
Speed2	−.06*	.03	–	–	−.66**	.15	−.05**	.02	–	–	−.54*	.13
Alcohol	–	–	–	–	–	–	–	–	–	–	–	–
Seatbelt/helmet/cellphone	–	–	–	–	–	–	−.05t	−.03	–	–	−.32t	.19
Relationship between ASEP and Trend	None		Inverse		Linear		None		Power		Linear	
Goodness-of-fit												
Stationary R^2	.944		.973		.782		.945		.972		.815	
MAPE	6.41		3.44		4.92		7.536		3.224		6.260	
Test for autocorrelation												
Q (Lag 1)	.029; p = .86		0.00; p = .99		.001; p = .98		.001; p = .98		.058; p = .810		.000; p = .992	
Q (lag 12)	13.57; p = .32		11.39; p = .50		10.63; p = .56		12.77; p = .39		13.50; p = .334		7.28; p = .839	

– Variable removed during the backward elimination process.
1: linear function; 2: logarithmic function; 3: inverse function; 4: quadratic function; 5: power function; 6: exponential function.
t $p < .10$.
* $p < .05$.
** $p < .01$.

Table 5
Effects of the ASEP on fatalities, crashes with injuries the severity index for motorcyclist and moped riders.t

	Motorcyclists						Moped riders					
	Fatal injuries[a]		Crashes with injuries		Severity index		Fatal injuries[a]		Crashes with injuries		Severity index	
	β	S.E.	β	S.E.	β	S.E.	β	S.E.	β	S.E.	β	S.E.
AR1 parameter	.12	.09	.12	.09	.077	.089	.015	.088	.56**	.07	−.07	.09
Constant	.70**	.12	2.20**	.07	2.54**	.45	.556	.035	2.64**	.81	2.17**	.17
Trend	.006**	.004	−.006**	.001	.048**	.014	−.002**	.000	−.012**	.001	−.002*	.001
Chirac announcement	−.40**	.11	−.30**	.06	−.88*	.38	–	–	–	–	–	–
Introduction of the ASEP	–	–	–	–	–	–	–	–	–	–	–	–
Trend* ASEP	−.01$^{*(1)}$	.004	–	–	−.05$^{**(1)}$	.01	–	–	–	–	–	–
Other traffic safety measures												
Speed1	–	–	.35**	.07	−.60*	.25	–	–	–	–	–	–
Speed2	–	–	–	–	–	–	–	–	.31**	.87	–	–
Alcohol	–	–	–	–	−.70*	.30	–	–	–	–	–	–
Seatbelt/helmet/cellphone	–	–	–	–	–	–	–	–	–	–	–	–
Goodness-of-fit												
Stationary R^2	.870		.905		.782		.679		.94		.308	
MAPE	13.514		6.702		10.764		19.83		5.13		17.76	
Test for autocorrelation												
Q (Lag 1)	.013; p = .91		.003; p = .959		.013; p = .91		.000; p = .99		.23; p = .632		.009; p = .93	
Q (lag 12)	7.68; p = .81		10.203; p = .598		4.71; p = .97		9.52; p = .66		10.98; p = .530		16.11; p = .19	

– Variable removed during the backward elimination process.
1: linear function; 2: logarithmic function; 3: inverse function; 4: quadratic function; 5: power function; 6: exponential function.
[t] $p < .10$.
[*] $p < .05$.
[**] $p < .01$.
[a] Expressed per 1,000,000 population to facilitate the presentation of results.

Although red light cameras were installed among other purposes to protect pedestrians at intersections, this innovation is not significantly associated with the decline in traffic casualties involving vulnerable road users. As for trucks, the discriminating pictures and the mandatory speed-lock device did not produce the expected effect. Red light cameras are associated with a decrease in crashes with injuries involving trucks ($\beta = -.05$; $p < .10$) but the positive term for the "*Red Light***Trend*" ($\beta = .05$; $p < .01$) indicates the presence of a decaying effect.

Estimates found in Tables 7–9 were used to compute fatalities as well as crashes with injuries prevented per month and for the whole intervention period (Table 10). Based on estimates obtained from models including all road users, our results suggest that more than 20,000 lives have been saved by Chirac's announcement and the ASEP.

Table 6
Effects of the ASEP on fatalities, crashes with injuries, and the severity index for vulnerable road users and trucks.

	Vulnerable road users						Trucks					
	Fatal injuries[a]		Crashes with injuries		Severity index		Fatal injuries[a]		Crashes with injuries		Severity index	
	β	S.E.	β	S.E.	β	S.E.	β	S.E.	β	S.E.	β	S.E.
AR1 parameter	.10	.09	.055	.088	.02	.09	.058	.089	.24**	.09	.055	.623
Constant	1.96**	0.06	3.91**	.07	5.82**	.24	.86**	.14	.91**	.02	1.58**	.41
Trend	−.003**	.001	−.02**	.001	.002	.003	.005	.004	−.004**	.000	.02*	.01
Chirac announcement	–	–	–	–	–	–	−.244*	.118	−.10**	.02	–	–
Introduction of the ASEP	–	–	–	–	−.41*	.20	−.17*	.08	–	–	–	–
Trend* ASEP	–	–	.02$^{**(1)}$	.002	–	–	−.008$^{t(3)}$	.004	–	–	−.02$^{t(1)}$	.01
Other traffic safety measures												
Speed1	–	–	–	–	–	–	–	–	.06**	.02	–	–
Speed2	–	–	–	–	−.50*	.22	–	–	.07**	.02	−.49^{t}	.28
Alcohol	–	–	–	–	–	–	–	–	–	–	−.91**	.31
Seatbelt/helmet/cellphone	–	–	–	–	–	–	–	–	–	–	–	–
Goodness-of-fit												
Stationary R^2	.805		.921		.618		.498		.922		.241	
MAPE	12.073		4.466		11.176		24.365		6.505		34.276	
Test for autocorrelation												
Q (Lag 1)	.005; p = .945		.000; P = .988		.000; p = .988		.000; p = .990		.000; p = .993		.001; p = .972	
Q (lag 12)	7.79; p = .801		7.71; P = .807		6.35; p = 897		9.564; p = .654		8.896; p = .712		13.40; p = .340	

– Variable removed during the backward elimination process.
1: linear function; 2: logarithmic function; 3: inverse function; 4: quadratic function; 5: power function; 6: exponential function.
[t] $p < .10$.
[*] $p < .05$.
[**] $p < .01$.
[a] Expressed per 1,000,000 population to facilitate the presentation of results.

Table 7
Effects of innovations on fatalities, crashes with injuries, and fatalities per 100 crash with injuries on all categories of road users and on passenger vehicles/light SUVs.

	All categories of road users						Passenger vehicles and light SUVs					
	Fatal injuries[a]		Crashes with injuries		Severity index		Fatal injuries		Crashes with injuries		Severity index	
	β	S.E.	β	S.E.	β	S.E.	β	S.E.	β	S.E	β	S.E.
AR1 parameter	.18*	.08	.44**	.08	−.08	.09	.12	.09	.37**	.09	−.04	.09
Constant	1.25**	.02	17.00**	.24	6.78**	.25	.87**	.02	17.12**	.40	5.15**	.22
Trend	−.002**	.001	−.040**	.004	.03**	.01	−.002**	.000	−.08**	.01	.02**	.01
Chirac announcement	−.17**	.03	−2.81**	.32	−.67**	.21	−.10**	.02	−1.05**	.35	−.46*	.19
Introduction of the ASEP	−.12**	.03	–	–	−.62**	.16	−.07**	.02	−.55^{t}	.28	−.41**	.15
Trend* ASEP	–	–	2.10**(3)	.61	−.02*(1)	.01	–	–	.05**(5)	.01	−.03**(1)	.01
Innovations introduced to the ASEP and other user specific measures												
RED LIGHT	−.002	.028	−.09	.28	.07	.18	.03	.02	−.20	.28	.57	.17
RED LIGHT * Trend	–	–	–	–	–	–	−.09$^{t(3)}$	.05	–	–	−1.04**(2)	.35
Other traffic safety measures												
Speed1	–	–	–	–	−.31^{t}	.16	–	–	–	–	–	–
Speed2	−.06*	.03	–	–	−.63**	.17	−.04^{t}	.02	–	–	−.37*	.15
Alcohol	–	–	–	–	–	–	–	–	–	–	–	–
Seatbelt/cellphone/helmet	–	–	–	–	–	–	−.05^{t}	.03	–	–	−.33^{t}	.18
Goodness-of-fit												
Stationary R^2	.951		.974		.783		.946		.976		.827	
MAPE	6.384		3.464		4.890		7.452		3.351		5.871	
Test for autocorrelation												
Q (Lag 1)	.027; p = .869		.022; p = .883		.001; p = .982		.001; p = .977		.054; p = .816		.000; p = .989	
Q (lag 12)	9.23; p = .683		12.171; p = .432		10.703; p = .555		30.466; p = .002		11.328; p = .501		11.169; p = .514	

– Variable removed during the backward elimination process.
1: linear function; 2: logarithmic function; 3: inverse function; 4: quadratic function; 5: power function; 6: exponential function.
[t] p < .10.
[*] p < .05.
[**] p < .01.
[a] Expressed per 1,000,000 population to facilitate the presentation of results.

Table 8
Effects of innovations on fatalities, crashes with injuries, and fatalities per 100 crashes with injuries involving motorcyclists and moped riders.

	Motorcyclists						Moped riders					
	Fatal injuries[a]		Crashes with injuries		Severity index		Fatal injuries[a]		Crashes with injuries		Severity index	
	β	S.E.	β	S.E.	β	S.E.	β	S.E.	β	S.E.	β	S.E.
AR1 parameter	.11	.09	.18*	.09	.05	.09	−.05	.09	.42**	.08	−.08	.09
Constant	.71**	.12	20.14**	.83	2.54**	.44	−2.95**	.09	3.31**	.04	2.09**	.19
Trend	.006	.004	.01	.02	.05**	.01	−.006**	.001	−.006**	.001	−.001	.002
Chirac announcement	−.40**	.11	−4.50**	.88	−.87*	.37	–	–	–	–	–	–
Introduction of the ASEP	–	–	–	–	–	–	–	–	–	–	–	–
Trend* ASEP	−.009*(1)	.004	–	–	−.04*(1)	.02	–	–	–	–	–	–
Innovations introduced to the ASEP and other user specific measures												
ASEP2	.07	.08	2.69*	1.28	−.20	.30	.11	.07	.14**	.04	−.16	.15
ASEP2*Trend	–	–	−1.27*(2)	.50	–	–	–	–	–	–	–	–
RED LIGHT	−.04	.08	−1.20	.88	−.61^{t}	.32	.14	.14	.07	.06	.01	.13
RED LIGHT*Trend	–	–	–	–	–	–	−.09$^{t(5)}$	.05	−.06*(5)	.02	–	–
Other traffic safety measures												
Speed1	–	–	–	–	−.89**	.28	–	–	–	–	–	–
Speed2	–	–	–	–	–	–	–	–	.10*	.04	–	–
Alcohol	–	–	–	–	−.77**	.29	–	–	–	–	–	–
Seatbelt/cellphone/helmet	–	–	–	–	–	–	–	–	–	–	–	–
Goodness-of-fit												
Stationary R^2	.871		.900		.788		.705		.939		.314	
MAPE	13.241		6.553		10.532		18.569		4.734		17.831	
Test for autocorrelation												
Q (Lag 1)	.016; p = .900		.015; p = .904		.002; p = .968		.006; p = .941		.22; p = .639		.01; p = .906	
Q (lag 12)	6.856; p = .867		6.532; p = .887		8.424; p = .751		19.44; p = .078		11.86; p = 457		18.05; p = .114	

– Variable removed during the backward elimination process.
1: linear function; 2: logarithmic function; 3: inverse function; 4: quadratic function; 5: power function; 6: exponential function.
[t] p < .10.
[*] p < .05.
[**] p < .01.
[a] Expressed per 1,000,000 population to facilitate the presentation of results.

Table 9
Effects of innovations on fatalities, crashes with injuries, and fatalities per 100 crashes with injuries on vulnerable road users and trucks.

	Vulnerable road users						Trucks					
	Fatal injuries[a]		Crashes with injuries		Severity index		Fatal injuries[a]		Crashes with injuries		Severity index	
	β	S.E.	β	S.E.	β	S.E.	β	S.E.	β	S.E.	β	S.E.
AR1 parameter	.28**	.09	.04	.09	.019	.090	.06	.09	.11	.09	.055	.623
Constant	2.01**	.07	3.92**	.07	5.82**	.27	.14**	.14	.95**	.02	1.58**	.41
Trend	−.007**	.001	−.022	.001	.002	.005	.001	.001	−.005**	.000	.02*	.01
Chirac announcement	–	–	–	–	–	–	−.05*	.12	−.07**	.02	–	–
Introduction of the ASEP	–	–	–	–	−.42^{t}	.23	−.04*	.09	–	–	–	–
Trend*ASEP	–	–	.018**(1)	.002	–	–	−.002$^{t(3)}$	.005	–	–	−.02$^{t(1)}$	.01
Innovations introduced to the ASEP and other user specific measures												
TRUCK1 (discriminate)	–	–	–	–	–	–	–	–	–	–	–	–
TRUCK2 (speed lock)	–	–	–	–	–	–	–	–	–	–	–	–
RED LIGHT	.16*	.07	–	–	−.01	.23	.002	.02	−.05^{t}	.03	–	–
RED LIGHT*Trend	–	–	–	–	–	–	–	–	.05**(2)	.01	–	–
Other traffic safety measures												
Speed1	–	–	–	–	–	–	–	–	.09**	.02	–	–
Speed2	–	–	–	–	−.50*	.23	–	–	.10**	.02	−.49^{t}	.28
Alcohol	–	–	–	–	–	–	–	–	–	–	−.91**	.31
Seatbelt/cellphone/helmet	–	–	–	–	–	–	–	–	–	–	–	–
Goodness-of-fit												
Stationary R^2	.871		.900		.788		.502		.931		.241	
MAPE	13.241		6.553		10.532		24.285		5.814		34.276	
Test for autocorrelation												
Q (Lag 1)	.016; p = .900		.015; p = .904		.002; p = .968		.000; p = .991		.028; p = .867		.001; p = .972	
Q (lag 12)	6.856; p = .867		6.532; p = .887		8.424; p = .751		11.521; p = .34		8.903; p = .711		13.40; p = .340	

– Variable removed during the backward elimination process.
1: linear function; 2: logarithmic function; 3: inverse function; 4: quadratic function; 5: power function; 6: exponential function.
[t] $p < .10$.
[*] $p < .05$.
[**] $p < .01$.
[a] Expressed per 1,000,000 population to facilitate the presentation of results.

Estimates are lower when users are broken down by categories. This situation could be explained by the fact that a single model could not be developed for fatalities involving public transport because few cases were available. Similarly, the lives of some moped riders and vulnerable road users were probably saved by the *ASEP* when all users are considered in a single model (even if coefficients are not significant in models specific for moped riders and vulnerable road users). Innovations added to the ASEP as well as other preventive measures permitted the saving of 2800 more lives. Passenger vehicles/light SUV users are those who benefited the most from the ASEP and other traffic safety measures with more than 16,000 lives saved.

Estimating the number of crashes with injuries prevented by Chirac's announcement and the ASEP for specific categories of users is more tedious, as parties involved in a crash are counted instead of the event. When all users are considered, Chirac's announcement is associated with a 19.71% decline in the rate of crashes with injuries. The positive coefficient for the “Trend*Intervention” indicates that the changes in the level of the series were more limited at the outset of the intervention. The fulfillment of the initially advertised traffic safety measures and enforcement activities probably gave greater impact to Chirac's announcement (Carnis, 2013).

Chirac's announcement and the ASEP also include the “trend*ASEP” term when statistically significant in the model. “Other measures” refer to measures that are included in models presented in Tables 7–9 (innovations as well as other traffic safety measures). Changes in relative percentage were computed by using the average of all differences in Y_t with and without the intervention.

4. Discussion

The objectives of this article were twofold: First, interrupted time series analyses were conducted to estimate the effect of the French ASEP on various categories of road users; second, additional analyses were performed to determine whether adding features targeting specific categories of road users—specifically users that were likely to avoid punishment—improve the effect of the ASEP.

Supporting results from reviews on speed camera programs (Blais & Dupont, 2005; Pilkington & Kinra, 2005; Thomas, Srinivasan, Decina, & Staplin, 2008; Wilson et al., 2011), the present analyses show that the introduction of the ASEP—alongside Chirac's announcement—was associated with significant decreases in fatalities and collisions with injuries. While the effect of the ASEP is stable through the whole intervention period for the fatality rate, a decaying effect is observed for crashes with injuries. The multiplication of speed cameras over the road network helped in maintaining a significant effect on fatalities, but the preventive effect nonetheless wears off for crashes with injuries. Our results concur with estimations and conclusions found in Carnis and Blais (2013). Results also indicate that since Chirac's announcement and the introduction of the speed camera program, crashes are less likely to result in fatal injuries. Overall, the present results provide further evidence that ASEPs are an effective strategy to prevent traffic casualties.

When rates were broken down according to road user categories, the ASEP and Chirac's announcement produced differential effects. The most noteworthy decreases in relative percentage are observed for fatalities involving passenger vehicles/light SUVs (36.60%), motorcycles (37.78%), and trucks (15.69%). In terms of lives saved, passenger vehicles/light SUVs is the category of drivers who benefited most from the ASEP. In contrast to what is observed for the passenger vehicles/light SUVs, the introduction of the ASEP did not amplify the preventive effect initiated by the public announcement on crashes with injuries for motorcyclists and trucks. Since the introduction of the ASEP, declines in the severity index are observed for trucks, motorcycles, and passenger vehicles/light SUVs. Fatalities and crashes involving moped riders and vulnerable road users were not affected by the ASEP and its

Table 10
Lives saved by Chirac's announcement, the introduction of the ASEP, and other measures/innovations.

Category of users	Values predicted based on variables included in the models			
	Average fatalities per 100,000 population avoided per month by Chirac's announcement and the ASEP (change in relative percentage)	Average fatalities per 100,000 population avoided per month by Chirac announcement, the ASEP and other measures (change in relative percentage)	Lives saved on average per month by Chirac's announcement and the ASEP (total lives saved: July 2002–December 2011)	Lives saved per month by Chirac's announcement, the ASEP and other measures (total lives saved: July 2002–December 2011)
All users	0.28 (27.27%)	0.31 (31.07%)	175.79 (20,040)	200.54 (22,862)
Passenger vehicles/light SUVs	0.16 (25.37%)	0.23 (36.60%)	100.49 (11,456)	145.18 (16,550)
Motorcycles	0.08 (39.02%)	0.08 (37.78%)	52.73 (6011)	52.73 (6011)
Moped riders	0 (0%)	0.0024 (5.26%)	0	1.56 (47)
Vulnerable road users	0 (0%)	+0.016 (+15.32%)	0	+10.41 (+124)
Trucks	0.02 (15.69%)	0.02 (15.69%)	12.62 (1438)	12.62 (1438)

Formula used to compute the number of saved lives.

$Yt_{(withintervention)} = \omega + \beta^{*}Trend_t + \theta^{*}Dummy\_month_t + \gamma^{*}Chirac_t + \alpha^{*}ASEP_t + \delta^{*}Others\_innovations_{it}$

$Y_{t(without\ the\ intervention)} = \omega + \beta^{*}Trend_t + \theta^{*}Dummy\_month_t$

$\Delta Y_t = Y_{t(withouth\ the\ intervention)} - Y_{t(with\ the\ intervention)}$

$\Delta Y_{t\ (in\ relative\ percentage)} = (\Delta Y_t / Y_{t(without\ the\ intervention)})^{*}100$

announcement. A slight decrease in the severity index is observed among moped riders following the introduction of the ASEP. Lastly, our results show that the functional form of the relationship between the "ASEP*Trend" term and traffic casualties is contingent upon categories of road users. For instance, the ASEP did not affect the slope of the fatality series involving passenger vehicles/light SUVs. A downward and linear trend was, however, initiated by the ASEP on fatalities involving motorcyclists. Combined together, these results call for developing accident modification function for each category of road user (Elvik, 2011).

Several innovations were progressively introduced and modified the original ASEP. As previously mentioned, these additional features can be conceptualized as measures designed to reduce punishment avoidance among particular categories of road users. Results are mixed on the impact of such innovations. These innovations provided relatively minor gains in comparison to the ASEP, although they permitted the targeting of specific road users. While slight preventive effects are observed for trucks with the introduction of red light cameras, moped riders, passenger vehicles/light SUVs, and casualties involving vulnerable road users were not influenced by this measure. Globally, red light cameras are not associated with large reductions in traffic injuries and fatalities. Truck casualties did not decrease following the introduction of mandatory peed-lock devices and radars discriminating trucks from other road users. While the gradual implementation of speed cameras taking pictures of both ends of the vehicle was associated with a significant decrease in crashes with injuries involving motorcycles, no effect was recorded for fatalities.

Controlling for other traffic safety measures addressed criticisms against existing assessments of speed camera programs. Some claim that studies overestimate the effect of the ASEP, as potential confounding factors and/or other traffic safety measures are not accounted for (Roux & Zamora, 2013; Wilson et al., 2011). Our results show that decreases in traffic casualties in France are a function of Chirac's announcement, the introduction of the ASEP (and probably the strong and positive media coverage), other traffic safety measures included in our models and additional factors (such as safer vehicles, demographic and economic changes) that could have initiated the downward trend (the trend variable displays a negative coefficient in several models).

Trends in infringements suggest that the effectiveness of recent legislative reforms highly depends upon their strict enforcement. Infringements for speed limit violations have been multiplied by more than eight times between 1999 and 2011 (from 1.2 to 10.7 millions). Infringements for crossing priorities and running the red light have been multiplied by a factor of nine (0.12 million to 1.1 million) and since 2003 about 500,000 infringements have been reported for cellphone use while driving (Carnis, 2013). In sum, messages transmitted through Chirac's announcement and new provisions in the Road Code were supported by in intensive enforcement activities.

Our results differ from most studies that have investigated the effect of ASEPs on different categories of road users. Retting et al. (2008) found that speed cameras were more effective for large trucks than for passenger vehicles. In our studies, the greatest preventive effects are observed for motorcyclists and passenger vehicles/light SUVs with respective decreases of about 39% and 25% in fatalities per 100,000 population. These two categories of users account for about 87% of all saved lives with the ASEP and almost all lives saved by other traffic safety measures. The assessment of the Belgium ASEP observes the highest decreases in severe injuries and fatalities for pedestrians and motorcyclists (about 37%; De Pauw et al., 2014). Such differences remain difficult to appraise and future studies should provide a detailed description of the program under study and major traffic safety problems (Thomas et al., 2008). Additional insights could also be acquired by elaborating user-specific Nilsson's power models. A recent study shows that Nilsson's formula was not directly applicable to traffic speed change on urban arterial roads (Cameron & Elvik, 2010). Equivalent changes in average speeds could produce differential effects depending on the road user vulnerability.

Variations in effects produced by features added to the ASEP also call for future studies. More investigations are needed to pinpoint factors that could explain the lack of effect of red light cameras on vulnerable road users. Additional studies are also needed to investigate contexts in which vulnerable users and other road users converge in contentious situations. Studying contexts in which crashes occur could also provide useful information to understand different effects produced on moped riders and motorcyclists. Lastly, the mandatory speed-lock device for trucks suggests that other strategies than automated enforcement programs are available for competent authorities. Prevention strategies targeting vehicles, such as speed-lock devices and alcohol ignition interlock, remove the opportunity for at-risk behaviors and could thus produce significant benefits if installed in all vehicles (Sergerie, 2005; Blais, Sergerie, & Maurice, 2013).

Despite the optimistic results produced by the ASEP on traffic fatalities and injuries, this study highlights some limitations. First, it was not possible to estimate the effect of the ASEP on casualties for all categories of road users. Crashes involving public transportation were too uncommon to be included in the analyses. As well, pedestrians and cyclist had to be merged in a single category, as were passenger vehicles and light SUVs. Second, one must note that several measures were introduced during a short lapse of time. Some measures—especially the introduction of increased sanctions for impaired driving in July 2003 and the ASEP in November 2003—were highly correlated. Although the ASEP variable was kept in practically all models for its superior predictive power, one must keep in mind that a fraction of the preventive effect of the ASEP is accountable to increased sanctions for drunk driving. Lastly, our models did not account for potential interactions between increased sanctions for speed limit violations and the introduction of the ASEP. Such analyses could shed light on the potential effect of increasing the severity of sanctions when the ASEP already guarantees a swift and certain punishment.

5. Conclusion

Results from this study show that Chirac's public announcement and the introduction of the ASEP were associated with a decrease of about 27% in fatalities per 100,000 population or a total of 20,040 lives saved for the 2002–2010 period. This figure is consistent with estimates proposed in a previous study (Carnis & Blais, 2013). Preventive effects were mainly observed for passenger vehicles/light SUVs, motorcyclists, and truck drivers. Except for vulnerable road users, red light cameras improved the effectiveness of the ASEP—as shown by significant decreases in at least one series for each category of road users. The introduction of devices taking pictures of both ends of the vehicle proved to be effective in decreasing crashes with injuries among motorcyclists. Overall, adding punishment avoidance features marginally improved the initial ASEP. Finally, results prove that ASEPs are effective for enforcing traffic safety regulations, but further refinements and strategies are needed to prevent casualties among all categories of road users.

Conflict of interest

None.

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