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Evaluation of Ontario's Street Racers, Stunt and Aggressive Drivers Legislation

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A thesis submitted in partial fulfillment of the requirements for the Master of Science degree in Epidemiology and Biostatistics

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EVALUATION OF ONTARIO'S STREET RACERS, STUNT AND AGGRESSIVE
DRIVERS LEGISLATION

(Thesis format: Integrated Article)

by

Aizhan Meirambayeva

Graduate Program in Epidemiology and Biostatistics

A thesis submitted in partial fulfillment
of the requirements for the degree of
Masters of Science in Epidemiology and Biostatistics

The School of Graduate and Postdoctoral Studies
The Western University
London, Ontario, Canada

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Abstract

The purpose of this thesis was to conduct a process and outcome evaluation of the deterrent effect of Ontario's Street Racers, Stunt and Aggressive Drivers Legislation. The focus of this study was on police enforcement (*implementation*), a change in speeding on the provincial highways (*intermediate outcome*) as well as on a decrease in both extreme speeding convictions and casualties, measured as a sum of injuries and fatalities (*criterion outcomes*). The deterrent effect of the legislation on Ontario drivers was examined, using data obtained from the Ministry of Transportation of Ontario. Employing interrupted time series analyses with ARIMA modelling, we found a significant reduction in both criterion outcome measures for the intervention group(s), comparing the series before and after the intervention. No corresponding changes were found for the comparison group(s). The findings suggest that the examined legal intervention was effective in deterring illegal risky driving behaviours and improving road safety.

Keywords

Deterrence theory, road safety, legal intervention, evaluation, street racing, stunt driving, injuries, fatalities, casualties, suspensions, convictions, interrupted time series, ARIMA modelling.

Co-Authorship Statement

The two manuscripts contained in this thesis are based on the work designed and analyzed by the author, Aizhan Meirambayeva. The thesis supervisor, Dr. Evelyn Vingilis, was the principal investigator of the program of research on street racing and stunt driving. The data for this research was provided by the Ministry of Transportation of Ontario. Each of the co-authors contributed in the form of regular feedback as well as statistical and methodological advice. Aizhan Meirambayeva was the primary author of both manuscripts. Drs. Vingilis, Zou, Elzohairy, McLeod and Jinkun Xiao were co-authors of the manuscripts associated with Chapters 3 and 4 of the thesis.

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Chapter 1

1 Introduction

1.1 The problem of street racing

Risky driving is a key contributor to motor vehicle injuries and deaths. Speeding, and the more extreme street racing and stunt driving, including various activities such as burnouts (rapidly spinning rear tires to produce a trail of smoke), doughnuts (accelerating a vehicle with full steering-wheel lock), wheelies (the forceful acceleration of rear-wheel drive vehicles where the front wheels are lifted above the pavement), ghost riding (putting a vehicle's transmission in gear and then exiting the vehicle while it is still rolling to dance beside it or on the hood or roof), are some examples of risky driving.

Every year in North America thousands of young people lose their lives in motor vehicle crashes.^{1,2} Illegal street racing, and related stunt driving which may be linked to increased risk of motor vehicle collisions and subsequent injuries, deaths and property damage, has become a growing area of research. Until recent years this research area remained largely neglected.³

Despite the fact that very limited research is available on street racing and stunt driving, much research has examined speeding as a contributor to crashes. As the speed of the vehicle increases, so does the risk of a crash and the risk of fatality.^{4,5} That is why speeding, racing and stunt driving are concerning.⁶

An opinion poll conducted among a sample of Canadian drivers reported that the public views street racing as a serious issue of traffic safety, placing it into a category of aggressive driving behaviours.⁷ In a number of countries street racing is seen as a problem of public health and safety.⁸⁻⁹

To combat the issue, different jurisdictions implemented a variety of preventive measures, including legislative changes. However, the published research assessing the effectiveness of implemented countermeasures is sparse.

In September 2007, the Ontario Government implemented Bill 203, “Safer Roads for a Safer Ontario Act”, that included new regulations targeting street racing, extreme speeding and stunt driving. Called “Ontario’s Street Racers, Stunt and Aggressive Drivers Legislation”, the new law increased penalties for and expanded the definition of street racing (speeding 50 km/hour or more over the posted speed limit¹⁰) and introduced new provisions for stunt driving.¹¹

The purpose of this thesis was to conduct a process and outcome evaluation of the deterrent effect of Ontario’s Street Racers, Stunt and Aggressive Drivers Legislation. To the best of our knowledge, no formal evaluation of Ontario street racing and stunt driving laws has ever been done. The results of this thesis have a potential of informing MTO and legislative authorities in other jurisdictions on the achieved effects of the law.

1.2 Objectives

This thesis’s main objective is to provide an evaluation of the Ontario’s Street Racers, Stunt and Aggressive Drivers Legislation, following standard program evaluation methodology with both (implementation) process and outcomes examined. Starting with the roadside suspension data as a surrogate *implementation measure*, I examine the enforcement of this legal intervention by describing the roadside suspensions trend. Additionally, I provide the characteristics of the offenders who had their licence suspended on the spot for street racing/stunt driving and check whether a decline in average highway speed was observed after implementation of the legislation (*intermediate outcome measure*).

I hypothesized, based on deterrence theory, that after the intervention,

1. the number of extreme speeding convictions (first *criterion outcome measure*) would decrease;
2. the number of casualties (second *criterion outcome measure*) would decrease.

1.3 Overview of thesis

Chapter 2 provides a comprehensive literature review on the current state and the extent of the street racing problem, classification of these illegal driving behaviours, characteristics of racers and theories explaining why some people engage in street racing and stunt driving. Additionally, the measures implemented in different jurisdictions to prevent street racing are presented along with the explanation of deterrence theory and a comprehensive causal model of deterrence theory.

Chapter 3 is the first analytic study which tests deterrence theory by conducting a process and outcome evaluation to examine the impact of Ontario's street racing/stunt driving legislation on extreme speeding convictions. Interrupted time series intervention analysis is used. The study provides an overview of the trend in licence suspensions due to racing/stunt driving, estimates the prevalence of these offences, and describes the demographic characteristics of offenders.

The purpose of the second analytic study, presented in Chapter 4, is the conduct of a process and outcome evaluation of the impact of Ontario's street racing/stunt driving legislation on casualties (injuries and fatalities) from speeding-related collisions. The focus of this study is enforcement of the law, reduction in speed, and reduction in casualties. Time series intervention analysis is conducted for testing deterrence theory in terms of collision casualties.

Finally, Chapter 5 presents discussion of the results of the manuscripts, conclusions of the thesis, and recommendations for future research.

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Chapter 2

2 Literature review

This chapter describes the extent and current state of the street racing problem, and provides information on classification of street racing and related activities and characteristics of street racers. Theories explaining racing as well as theories of deterrence are presented, followed by an overview of anti-racing interventions implemented in various jurisdictions and a critical review of the studies which assessed the effectiveness of deterrence measures.

2.1 Classification of street racing and related activities

Street racing is not a new phenomenon, “it is as old as the car itself”.¹ It became popular among young people after the release of movies *Rebel Without a Cause* (1955), *American Graffiti* (1973), *Grease* (1978) and more recently, the popularity was spiked by the movie *The Fast and the Furious* (2001) and its sequel.^{2,3} Despite the disclaimers and service announcements by the movie’s producing studio that encouraged legal driving, police reported an increase in illegal street racing activities inspired by the film.²

Street racing is viewed as a youthful activity and is associated with rebellion against authorities and parents.^{1,4,5} However, not all street racing is illegal. For example, NASCAR, Indy Car and other official races organized on closed circuits on the streets are legal.⁴ So are car rallies like the Paris-Dakar. These are legally approved, controlled and have public safety measures in place. Indeed, the US National Hot Rod Association (NHRA), in 2001, issued a strong statement advocating for street racing at legally sanctioned race tracks and against illegal street racing on public or other non-sanctioned locations.⁶ Thus the view by many is that “illegal street racing is chaotic, dangerous, and criminal”.⁷

Street races can be unorganized and spontaneous, one-time races involving people who do not know each other, and who decide to challenge each other during regular driving.⁴ This type of race can occur when two cars stop beside one another on a double

lane road at a stoplight. One of the drivers signals the other, for example, by roaring his engine to participate in a race. If the challenge is accepted, the impromptu race begins with the green light of the traffic light.^{4,8}

Organized races involve racers and spectators who meet at night at a popular gathering place to decide where the race will take place. Normally, a remote industrial site is chosen, the racing track is marked off 1/4 or 1/8 mile long, the racing cars line up at a start point, and the race starts with the dropping of a flag.^{3,8} Spectators tend to be located close to racing vehicles that are operated by possibly inexperienced drivers.

Additionally, street racing may involve only one vehicle, where the driver is racing against the clock or checking how fast the car can speed.⁴ This type of racing, also known as ‘time or speed trial’⁹, is illegal despite missing the element of competition with other vehicles.

Another kind of street racing is called a “hat race”, also known as a “kamikadze” or “cannonball run”, in which money is put into a hat, after which the hat is taken to an undisclosed location and racers are informed via cell phone about the endpoint location of the race.³ The driver who arrives first at the destination wins the money. This type of race is not confined to one specific road, it may take place over long distances, such as from city to city.⁸ Racers may also get involved in a race in mountain passes or around city traffic, either one car at a time or in a chase-style with a number of vehicles.³

Finally, there are other activities which are related to street racing and stunt driving. These include ‘burn-outs’ (spinning the wheels of the vehicle so that the smoke appears on the road surface), ‘donuts’ (accelerating a vehicle with full steering-wheel lock), ‘rolling road blockages’ (blocking major highways by a slowly moving convoy of vehicles to allow other vehicles to engage in racing in front of the convoy), ‘drifting’ (rapid acceleration of a vehicle around a corner to cause the rear of the vehicle to slide out and the tires to slip on the road).^{4,9-11}

Street racing is reported to be related to a number of other illegal activities such as auto theft, assaults, driving under influence of alcohol or drugs, illegal vehicle modifications,

insurance fraud, curfew violations, gang-related activities, illicit gambling, trespassing, vandalism, littering and other public order offences.^{3, 10}

2.2 The scale and extent of street racing problem

Official statistics on street racing and the casualties associated with it are limited.⁴ In the province of Ontario, Canada, during the first year of the enactment of street racing legislation, 8,459 drivers were charged under the new law.¹² In 2011, in the Waterloo region of Ontario, alone, 69 stunt driving charges were issued, mostly for speeding 50 km/h or more over the speed limit.¹³ Based on the police report, almost one third of the total charges were laid on young drivers less than 20 years of age.¹³ There are no official national statistics in Canada on street racing and stunt driving related deaths. However, the police-run project E.R.A.S.E. (Eliminate Racing Activity on Streets Everywhere) reports that since 1999, 48 fatalities occurred in Ontario, primarily in Greater Toronto Area as a result of illegal street racing.¹⁴

Illegal street racing and stunt driving are a global problem. Oakland, California police reports that it is typical to have 150 street-racing related citations, 80 vehicle impounds and 30 arrests during a weekend evening.¹⁵ Data reported from one individual location suggests that globally, illegal street racing has a high popularity.

The warmest states of the USA, California, Texas and Florida, are reported in mass media as the ones with a high incidence of illegal street racing. According to an article by FoxNews, with the reference to the National Highway Traffic Safety Administration, there were 804 fatalities due to racing-related crashes in the period of 2001- 2006. California had 188 of those deaths, with Texas second at 128.¹⁶

Yet, limited research is available on actual crashes attributed to street racing which resulted in injuries and fatalities. A study conducted in the U SA found that even though a small percentage of road fatalities were due to street racing (0.21%), racing involved risky driving behaviours such as speeding and driving under the influence of alcohol and resulted in serious consequences, including death and high criminal charges, predominantly for teenaged male drivers.¹⁷

A study conducted in Queensland, Australia, identified 169 'hooning' related (Australian term used for street racing and stunt driving) collisions by searching Queensland Transport's WebCrash2 database for the period of 1999-2004, where the search was limited to crashes involving 12-24 year olds.¹⁸ Using the same database for the same time period, 1 fatality and 11 hospitalizations were identified where hooning activities were listed as contributing factors in the crash description.¹¹

Another study conducted in Queensland, which aimed to examine the road safety implications of illegal street racing and associated risky driving behaviours, found that very few of such activities (3.7%) resulted in crashes, and these crashes (none of which were fatal) tended to be single vehicle crashes which were mainly caused by loss of control and collision with the fixed object off-road.¹⁹

A low number of crashes attributed to illegal street racing and associated risky driving is not surprising. The governments' databases of charges and convictions do not have coding specially assigned for street racing, speed trials, stunt driving and related driving behaviours, although the USA recently introduced a code.¹⁷ Moreover, many such activities remain unreported and undetected.^{3, 4, 9}

In the USA in 1998, street racing was added as a driver factor in Fatality Analysis Reporting System (FARS) which contains information on all fatal crashes that occurred in 50 states, the District of Columbia and Puerto Rico.¹⁷ FARS allows coding up to four driver factors contributing to a fatal collision. Using FARS data, the study reported that in the period of 1998-2001, 399 fatalities occurred in the crashes involving racing nationwide.¹⁷ It also found that compared to other fatal crashes, street racing related crashes are more likely to occur on urban roads (OR 4.9; 95% CI 3.8-6.4), to have struck a fixed object (OR 1.8; 95% CI 1.4-2.2) and to have been travelling at speeds exceeding 65 mph (OR 5.6; 95% CI 4.4-7.3).¹⁷

It is often difficult for the police to charge drivers for 'racing' activities as either a police officer or someone else needs to be a witness of this behaviour. Otherwise, due to lack of evidence, no charges can be laid against the violator. It is possible that police charge 'racers' with speeding tickets instead of 'racing' tickets. In the event of a collision,

neither drivers nor passengers are willing to admit to engaging in street racing. This can partially explain the low incidence of casualties due to street racing reported in the literature. For example, the Office of Traffic Safety in California, in one of its recent publications, acknowledged that fatalities and injuries due to illegal street racing are significantly underreported due to the issues with reporting and suggested a need for a reporting system reform.²⁰

Difficulties related to identifying offenders may cause underestimation of the frequency and road safety implications of these risky behaviours. A study which analyzed data from Utah reported that drivers with no citations are about three times more likely to be at zero risk of a crash compared to the drivers cited for street racing.²¹ Based on this finding one would expect to observe a higher number of collisions and casualties attributed to street racing and related activities compared to the numbers reported in the official statistics.

Some data on stunt driving and street racing related activities are captured by various surveys. The results of an Australian survey, involving 717 predominantly young participants recruited via snow balling at the university, suggest that a subset of the sample seems to endorse hooning as their regular activity and that regardless of anti-hooning legislation, street racing remains popular in the studied subset.⁹ Additionally, the same study shows that a large proportion of the sample (almost 40%) reported involvement in past street racing.

Similarly, a survey of 139 high school students in the suburban area of the USA, found that 59% of males and 36% of females reporting racing another vehicle one time or more frequently in the 12 months preceding the study.²² In addition, a Canadian study estimated the prevalence of street racing among high school students in a survey and found that 20.4% of grade 11-12 students holding advanced-level or full licence were reportedly participating in street racing in the 12 months prior to the survey.⁵

Engagement in illegal street racing, especially among young drivers, is a serious public health concern due to risks of serious injuries for racers and innocent bystanders. The results of an annual public opinion poll, conducted by Traffic Injury Research

Foundation, revealed that about 84% of respondents were very concerned or extremely concerned about alcohol or drug impaired driving among young drivers and 75% of the respondents were very concerned or extremely concerned about street racing.²³ It means that Canadians perceive street racing as the second biggest road safety concern after alcohol-impaired driving.

2.3 Characteristics of racers

2.3.1 Heterogeneity of racing groups

It has been documented in previous studies that illegal street racing and stunt driving typically involves primarily young males, of low income, who are blue collar workers or unemployed.^{9, 11, 24} Street racing is perceived by some authors as a transitory activity of the youth.¹ One study states that “young males are going through a period of life in which it is almost expected that they challenge authority, or normative boundaries, including those related to the ‘normal’ functions of public space” (p.183).¹⁰ Some street racers have a history of other delinquent behaviours including heavy drinking, drinking and driving, drug use, risky driving and criminal activities.^{5, 10, 24-26}

Most authors report that the largest group of drivers involved in these illegal driving activities are males aged between 16 and 25.^{1, 3, 17, 18, 24} Some authors predict that young males tend to outgrow such behaviours by their mid-twenties.^{1, 11} However, this is not the case for everyone. A US study reports that the second largest group of street racers includes more mature white male drivers aged 25-40 who race older generations of ‘muscle cars’.³ Other groups described in previous research include wealthy students, young women, car enthusiasts and relatively rich businessmen in middle age.^{10, 11, 18} Therefore, despite the general impression that street racers comprise a homogeneous group, in fact, there is some degree of heterogeneity in the studied population.

According to qualitative research findings, within the young male cohort, classification into subgroups exists. For example, participants of a focus group stated that some subgroups do not engage in drifting and burnouts; they attend car enthusiast gatherings and at times modify vehicles because they share common interest in motor sports.¹⁸ Another subgroup, which is quite small and referred to in Australia as “bogans” and

“louts”, include those who engage in risky illegal hooning behaviours. For these young people, “the adrenaline rush from the knowledge of the illegal and dangerous nature of the sport is the motivation to participate”(p.373).²

Drivers who engage in street racing and stunts claim that they differ on the basis of degrees of risk taking, driving skills and the choice of racing location – remote unpopulated areas or urban streets.^{10, 18}

In Queensland, Australia, a study reported that their sample of male offenders involved in stunts (hooning activities) appeared to be generally risky drivers, who had significantly more traffic violations, crashes and licence sanctions, compared to an age-matched comparison group in the three years prior to the reference date.¹⁹

Since the introduction of Ontario’s street racing and stunt driving law, criticism of the legislation has been voiced, mainly in online forums, by car enthusiasts. Vingilis et al.²⁷ conducted the first Canadian study which examined car club members’ opinions, attitudes and experiences with different aspects of driving, road safety and traffic laws. The researchers investigated a number of questions on Ontario’s street racing and stunt driving legislation. The study results reported that survey participants’ opinions about this particular legislation varied. The respondents agreed the most with some provisions of new law, such as driving out of driver’s seat, having a person in the trunk or driving too closely to other vehicle, an object or pedestrian. However, the majority of the respondents disagreed with roadside licence suspensions and the power of police to impound vehicles.

The quantitative study of 503 members of car and racing clubs in Southern Ontario, found higher self-reported stunt driving for those study participants who had higher scores on the Competitive Attitude Toward Driving Scale, had more positive attitudes toward street racing, and reported playing of “drive’em up” street racing video games.²⁸

2.3.2 Why people engage in street racing and associated illegal driving activities

For some street racers, cars are “tools of self-expression, means to construct a sense of identity and opportunities for people to locate themselves socially.”(p.181)¹⁰

A number of factors have been found to be associated with drivers' attitudes to speeding, risky driving behaviours, traffic violations and involvement in collisions; these include sociodemographic factors, such as age, gender, educational and occupational status, as well as psychological factors.²⁹⁻³¹ One possible factor which is connected to drivers' attitudes to speeding is interest in motor racing sports.³² A New Zealand study, which focused on young male drivers, reported that young males who were more interested in legal motor racing sports events were more likely to engage in risky driving behaviours, including illegal street racing.³³ An Australian study examined the relationship between the level of interest in motor racing sport and attitudes to speeding and driving violations among mature drivers.²⁹ The results showed that in the analyzed group, the level of interest in motor racing sports was significantly related to attitudes toward speeding, controlling for age, educational level and sensation seeking propensity. However, in this study of mature drivers, no significant relationship was found between the level of interest in motor racing and speeding violations.

Research has offered a number of psychological and sociological theories to explain street racing and associated behaviours. Psychological theories suggest that certain personality traits, such as sensation seeking personality, may lead to risky driving because risky driving activities can provide the type of novel and intense stimulation that sensation seekers find pleasurable.^{22,31} In young drivers, sensation seeking and aggressiveness partly explains speeding and street racing.²² A study conducted in Montreal and Ottawa, Canada reported that high sensation seekers were significantly more likely than low sensation seekers to speed, drive faster on highways, drive aggressively and drive after drinking.³¹ Another study found that a high level of sensation seeking was the characteristic of the group of young people who reported involvement in street racing activities.³³ Additionally, an American study reported that higher levels of sensation seeking and aggressiveness were associated with speeding and racing a car.²²

Other psychological theories include social-cognitive theories^{34,35} which posit that cognitive processes of imitation and modelling are important in learning new behaviours. Currently much risk glorifying media exists in movies, television, video games,

YouTube, etc. that experimental and correlational studies have shown to be associated with risky driving.^{36 37, 38 39}

Sociological theories, such as *identity theory* or *subcultural theory* suggest that street racing and related activities may reflect social class⁴⁰, provide meaning to lives and the expression of social identity^{10, 24}. The latter is well described in a study of young street racers in New Zealand:

“...boy racers use their involvement in the subculture to construct a sense of social identity for themselves. Cars can become key tools for doing so, as can dress sense, interaction with peers and the activities that they participate in”.(p.182)¹⁰

Scholars suggest that racing and associated activities are socially constructed and socially reinforced; these are young males with limited social capital, poor academic outcomes, few opportunities and many life struggles. Yet, street racing and associated activities provide a common bond with similarly minded peer groups and even family members, which reinforce a certain lifestyle.¹⁸

A related sociological theory, *problem behaviour theory*⁴¹, proposed by Jessor (1987), suggest that three systems of psychological influence (personality, perceived environment and behaviour) either increase risky or problem behaviours or protect against problem behaviours. The balance between risk factors and protective factors determines young person’s degree of proneness for problem behaviour.

2.4 Street racing countermeasures

2.4.1 Interventions to combat street racing and associated activities

Interventions designed to discourage street racing and associated illegal driving behaviours are generally guided by the 3 E’s strategy (the classic approach to injury prevention), which includes Education, Engineering, and Enforcement.⁴² Education of the public, particularly young drivers on the dangers and the consequences of illegal street racing is used as one of the approaches to combat this dangerous driving behaviour. Road safety education can be included as a requirement to obtain a driver’s licence.⁴³

Additionally, anti-street racing education can be delivered through various channels of

mass media and street racing websites. Reviews of past research have shown that public education and driver training on road safety issues, on their own, generally have limited effect in controlling unsafe driving practices.⁴⁴

The engineering approach may include anti-street racing signs on key traffic corridors and throughout the cities, high-visibility speed limit signs, video-monitoring of intersections, speed bumps and barricades, restriction of traffic flow and its direction.^{3, 43} Smart et al.⁴⁴ proposed a number of anti-street racing engineering solutions, such as installing car governors (speed limiters) or Intelligent Speed Adaptation (ISA) devices on cars, using speed monitoring systems and smart ignition keys, especially for use by parents lending their cars to teenagers. Though these proposed means are not widely accepted by the public so far, the authors describe a good potential for the engineering solutions to tackle the problem of street racing.

Enforcement strategies to combat street racing vary in different jurisdictions and may include police surveillance of popular racing sites, licence suspensions, vehicle impoundment and forfeiture, charging racers and spectators. Police enforcement strategies employed in various jurisdictions depend on the how street racing is defined by the jurisdiction's law and what authorities police are given to deal with the violations.

There is no standard definition of street racing in the legislative literature. In Australia, street racing along with other dangerous driving behaviours is referred to as 'hooning'. Australian legislation declares races between motor vehicles, speed trials and burn-outs as vehicle related offences against their Criminal Code.⁴⁵ In the USA, there is no street racing legislation on the federal level: therefore the state-level laws vary in provisions, definitions, fines and penalties.

In California, a person convicted of a "speed contest", which is defined as "a motor vehicle racing against another motor vehicle, or against the clock, or any other timing device", can be punished by a fine in the amount of \$1000, or imprisoned for not more than 90 days, or both. Police are allowed to impound the vehicle or suspend the driver's licence for the duration of 90 days up to 6 months.⁴⁶ In both California and Texas, spectators of illegal street racing can be cited and fined.³

The Criminal Code of Canada defines street racing as “operating a motor vehicle in a race with at least one other motor vehicle on a street, road, highway or other public place”.⁴⁷ The law sets serious punishment for causing bodily injury or death as a result of illegal street racing, up to life-time imprisonment of the driver.

In the province of Ontario, a “race” and “contest” are defined as

*“any activity where one or more persons engage in any of the following driving behaviours: 1. Driving two or more motor vehicles at a rate of speed that is a marked departure from the lawful rate of speed and in a manner that indicates the drivers of the motor vehicles are engaged in a competition. 2. Driving a motor vehicle in a manner that indicates an intention to chase another motor vehicle. 3. Driving a motor vehicle without due care and attention, without reasonable consideration for other persons using the highway or in a manner that may endanger any person by, i. driving a motor vehicle at a rate of speed that is a marked departure from the lawful rate of speed, ii. outdistancing or attempting to outdistance one or more other motor vehicles while driving at a rate of speed that is a marked departure from the lawful rate of speed, or iii. repeatedly changing lanes in close proximity to other vehicles so as to advance through the ordinary flow of traffic while driving at a rate of speed that is a marked departure from the lawful rate of speed”.*⁴⁸

To reduce injuries and fatalities on the roads, Ontario introduced new road safety measures. On September 30, 2007 a new law (Bill 203)⁴⁹ came into force, which amended previously existing legislation on street racing and increased penalties for aggressive driving and street racing. The same law also added stunt driving to street racing provisions, where the definition of “stunt” includes

“any activity where one or more persons engage in any of the following driving behaviours: 1. Driving a motor vehicle in a manner that indicates an intention to lift some or all of its tires from the surface of the highway, including driving a motorcycle with only one wheel in contact with the ground, but not including the use of lift axles on commercial motor vehicles. 2. Driving a motor vehicle in a manner that indicates an intention to cause some or all of its tires to lose traction with the surface of the highway while turning. 3. Driving a motor vehicle in a manner that indicates an intention to spin it or cause it to circle, without maintaining control over it. 4. Driving two or more motor vehicles side by side or in proximity to each other, where one of the motor vehicles occupies a lane of traffic or other portion of the highway intended for use by oncoming traffic for a period of time that is longer than is reasonably required to pass another motor vehicle. 5. Driving a motor vehicle with a person in the trunk of the motor vehicle. 6. Driving a motor vehicle while the driver is not sitting in the driver’s seat. 7.

Driving a motor vehicle at a rate of speed that is 50 kilometres per hour or more over the speed limit. 8. Driving a motor vehicle without due care and attention, without reasonable consideration for other persons using the highway or in a manner that may endanger any person by, i. driving a motor vehicle in a manner that indicates an intention to prevent another vehicle from passing, ii. stopping or slowing down a motor vehicle in a manner that indicates the driver's sole intention in stopping or slowing down is to interfere with the movement of another vehicle by cutting off its passage on the highway or to cause another vehicle to stop or slow down in circumstances where the other vehicle would not ordinarily do so, iii. driving a motor vehicle in a manner that indicates an intention to drive, without justification, as close as possible to another vehicle, pedestrian or fixed object on or near the highway, or iv. making a left turn where, (A) the driver is stopped at an intersection controlled by a traffic control signal system in response to a circular red indication; (B) at least one vehicle facing the opposite direction is similarly stopped in response to a circular red indication; and (C) the driver executes the left turn immediately before or after the system shows only a circular green indication in both directions and in a manner that indicates an intention to complete or attempt to complete the left turn before the vehicle facing the opposite direction is able to proceed straight through the intersection in response to the circular green indication facing that vehicle.”⁴⁸

It is also not allowed under the new legislation to drive a vehicle on a highway with connected nitrous oxide system, which enhances the acceleration of the vehicle.⁴⁹

Under the new legislation, the maximum fine for conviction for any of these offences was increased from \$1,000 to \$10,000. The minimum fine was increased from \$200 to \$2000. Police have the authority to impound a vehicle for the duration of seven days and immediately suspend driver's licence for seven days for street racing or stunt driving. The court can impose driver's licence suspension for a maximum duration of 2 years for the first offence and for the maximum duration of 10 years for a second conviction, if it occurred within 10 years of the first.

2.4.2 Deterrence theory as the basis of the enforcement measures

Deterrence is one main aim of traffic enforcement and the legal system. If the consequences of violating traffic laws are seen as negative, drivers will adhere to these laws in order to avoid punishment. This refers to the *general deterrence* principle. Additionally, if drivers experienced punishment for violating the traffic laws, they will alter their behaviour on the road in order to avoid being punished again. This refers to the *specific deterrence* principle.

According to classical deterrence theory, individuals will avoid illegal behaviour(s) if they fear the perceived consequences of these action(s).⁵⁰ This theory makes some assumptions related to human behaviour, namely that violation of the law is inversely related to the certainty, severity and swiftness of the punishment.⁵¹ This means that drivers are expected to refrain from violating traffic regulations if they perceive high risk of being apprehended by police, believe there is a high certainty that they would be punished when detected, and that the punishment would be severe and delivered in a timely manner.⁵²

Deterrence theory, in its classical form, has been criticized for perpetuating the notion that the two forms of deterrence – general and specific- occur among distinct populations: members of general public and punished offenders. A reconceptualized deterrence theory by Stafford and Warr⁵³ states that all people are likely to have a mixture of both forms of deterrence and that the avoidance of punishment plays its own role in deterrence. The researchers argue that any person and at any time can experience both general and specific deterrence. Any individual can be viewed “as falling along a continuum characterized by general deterrence at one extreme and specific deterrence at the other.”⁵³(p.129) Stafford and Warr give general and specific deterrence concepts more extended interpretations, compared to the conventional one, by contrasting the kinds of experience with legal punishment:

“general deterrence refers to the deterrent effect of indirect experience with punishment and punishment avoidance and specific deterrence refers to the deterrent effect of direct experience with punishment and punishment avoidance.”⁵³(p.127)

Stafford and Warr’s deterrence theory emphasizes the importance of punishment avoidance and treats it as analytically distinct from suffering a punishment. Experience with punishment avoidance, direct or indirect, affects perceptions of certainty and severity of punishment and subsequent behaviour of the offender.⁵³ In other words, it may encourage crime.

Indirect experience with punishment and punishment avoidance is seen as critical in Stafford and Warr’s model, especially in light of peer involvement. Delinquent

behaviour, they argue, is a group phenomenon and when it comes to judging the certainty and severity of punishment, an offender draws conclusions from the collective experiences of peers more than from personal relatively narrow life experiences. It is also possible, according to the described model, that the presence of companions may alter situational perceptions of certainty and severity:

“...the presence of companions during delinquent episodes may produce a heightened sense of anonymity (one among many) as well as invulnerability among offenders, both of which may translate into perceptions of low certainty and severity.”⁵³ (p.132)

This argument is highly relevant for street racing and associated risky driving, as these behaviours frequently occur in relatively large groups of participants and spectators. The effect of the ‘crowd’ may influence (reduce) the perceptions of certainty and severity of punishment.

Thus, perceptions of certainty, severity and celerity are key to deterrence, which indicates that potential offenders must be aware of the legislation and know that the legislation is being enforced in order for the perception of probability of detection to increase.⁵⁴ Based on the causal models of Vingilis and Salutin⁵⁴ and Vingilis et al.⁵⁵, the application of deterrence theory to Ontario’s Street Racers, Stunt and Aggressive Drivers Legislation would suggest the following model presented in Figure 2.1. A new law should be well publicized and adequately enforced. This should increase the public’s knowledge of the new law and perception of being caught. This, in turn, should deter drivers from street racing and stunt driving, leading to a reduction in offences. Finally, the reduction of street racing and stunt driving should result in improved safety on the roads, measured by collision injuries. An evaluation of the deterrent effect of Ontario’s Street Racers, Stunt and Aggressive Drivers Legislation should include both an evaluation on whether the legislation was enforced as a process (implementation) evaluation and on whether the outcomes were achieved. The second column on Figure 2.1 represents *process* (implementation) measures and the third column represents both intermediate and criterion *outcome* measures.

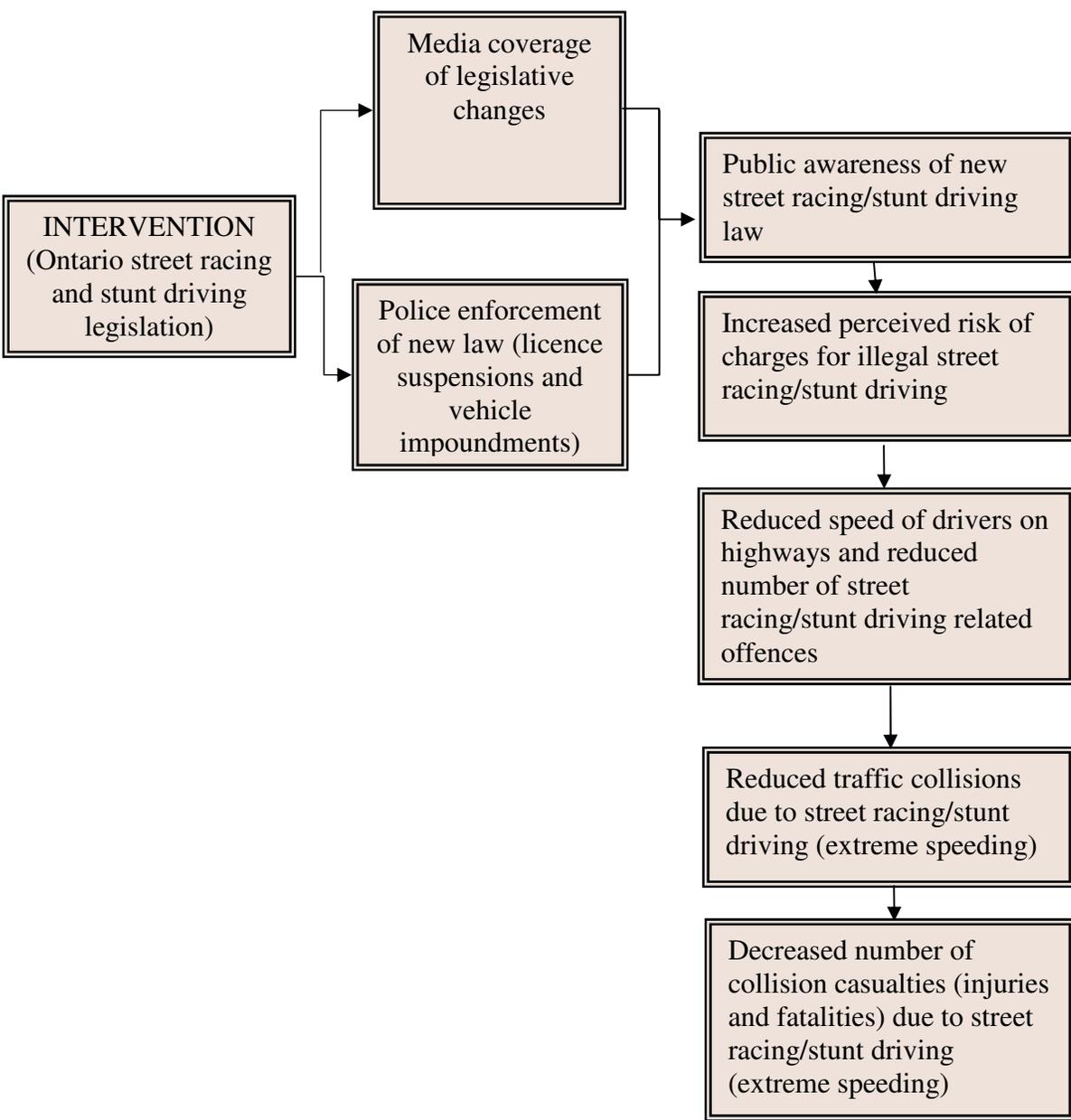


Figure 2.1. Causal model of Ontario’s Street Racers, Stunt and Aggressive Drivers Legislation

2.4.3 Evaluation of the deterrent effect of anti-street racing measures

Various measures have been undertaken in different jurisdictions to reduce street racing and associated risky driving practices. These include educational campaigns, legislative changes, under-cover law enforcement operations, considerable media attention, sanctioned races in the safe and monitored environments of race tracks where participants pay an entrance fee, even informal racing with the police officers.^{3, 4, 56} However, relatively few evaluations have been conducted thus far. Previous studies have mainly evaluated the effectiveness of vehicle impoundment legislations, not directly related to street racing.

Evaluation of the vehicle impoundment law on car crashes by revoked and suspended drivers was conducted in California.⁵⁷ In this study, monthly crash rates of individuals who drove illegally while revoked or suspended were compared to monthly crash rates of non-equivalent no treatment control group, comprised of drivers who were not revoked or suspended in three years prior to and two years after implementation of their vehicle impoundment law. The results showed that there was a significant 13.6% reduction in the crash rates for the revoked and suspended group. However, there was a significant drop (8.3%) in crashes for the control group as well. Joint estimation of both groups did not show statistically significant reduction in the crashes of illegal drivers when the control group was taken in to account in the statistical analyses. In this conceptually and methodologically sound research, potential threats to validity were fairly well accounted for. Some of the limitations, however, may include possible history effects due to the use of non-equivalent comparison groups, as well as missing data for 2 time periods which had to be imputed. The author concluded that the study failed to find general deterrent effect of the vehicle impoundment law and that an external factor, other than the law, was responsible for the drop in crashes.

A second California-based study evaluated the impact of the vehicle impoundment law on the first year of subsequent driving behaviour of revoked, suspended and unlicensed drivers.⁵⁸ The reported results showed that first time offenders and repeat offenders, whose vehicles were impounded, had 23.8% and 34.2%, respectively, fewer subsequent convictions for driving while suspended, revoked or unlicensed, as well as 24.7% and

37.6%, respectively, fewer crashes, compared to a similar control group whose vehicles were not suspended. The author used a matched control group, selecting controls by propensity score matching method, allowing fairly good control of the differences between the treatment and the control groups. Additionally, at the analysis stage, multiple covariates were accounted for. Mentioned methods of bias control contribute to the strength of this study and add confidence to the obtained results.

Voas and DeYoung⁵⁹ reviewed a number of North American studies evaluating various vehicle actions. Even though the quasi-experimental studies varied in quality, the findings were fairly convincing due to explored potential biases and use of statistical or design controls. The general conclusion was reached that the reviewed studies provided evidence of the effectiveness of vehicle-based countermeasures in those jurisdictions where the laws were both well publicized and appropriately enforced.

While American-based evaluation studies provide some support for administrative sanctions such as vehicle impoundment, caution should be taken with generalizing the outcomes of these studies to other jurisdictions because of the difference in target populations.⁶⁰ Vehicle impoundment laws were introduced in 27 States and the District of Columbia in the USA with the purpose of deterring illegal driving behaviours such as drinking and driving and driving while revoked, suspended or unlicensed.⁶¹ Vehicle impoundment is used for other offences in other jurisdictions. For instance, in Australia, vehicle impoundment and forfeiture sanctions were introduced to prevent hooning behaviours. Similarly, in Canada, such sanctions are part of the street racing and stunt driving law.

A study conducted in Victoria, Australia, looked at the effectiveness of vehicle impoundment legislation, as part of the anti-hoon law, in reducing the occurrence and recidivism of hooning.⁶⁰ The study was conducted on a sample of primarily young drivers (n=52), whose vehicles were impounded for hooning, by self-report survey (n= 51) and focus groups (n=21). The results of the study were inconclusive. When asked whether the penalties were harsh enough to deter the participants from hooning, 51% of them replied 'yes' and 49% said 'no'. For repeat offences, 13% of participants reported engaging in no

hooning activities after having their vehicle impounded, while 18% reported hooning three or more times a month since impoundment. With respect to the effectiveness of vehicle impoundment sanctions on recidivist hooning behaviour, the responses varied from effective or periodically effective to ineffective. Inconclusive results may have appeared due to self-report nature of survey, relatively small sample size, caused by low response rate, and possible lack of heterogeneity of the focus group sample. However, the focus group discussion provided a valuable insight into the behavioural and attitudinal factors related to hooning and anti-hoon legislation.

Findings of another Queensland, Australia, qualitative study by Leal, conducted on drivers who were engaged in hooning activities one month prior to the study, suggested that despite anti-hooning laws, the participants did not stop frequent hooning activities and intended to continue doing so.⁶² The study found that punishment avoidance experience of the participants is important for hooning behaviours along with non-legal social factors. Similar to the study conducted in Victoria, the results of this qualitative study was not meant to be generalizable to the population of hooning drivers. Nevertheless, opinions and attitudes of the focus groups' participants did allow the researcher to gather rich information to inform future studies.

A subsequent larger scale study was conducted by Leal⁶³ in Queensland, with the sample of 290 drivers who completed an anonymous online survey. A number of statistical techniques were used in this study including hierarchical linear modelling. Several hooning-related hypotheses were tested. Specifically, with respect to the vehicle impoundment and forfeiture legislation, the results provided some evidence of the effectiveness of the law, as drivers in the sample reduced hooning activities in response to the law. Less frequent hooning was reported as a strategy of punishment avoidance. On the other hand, changing the location of hooning activities was reported more strongly as a punishment avoidance strategy by the participants. The results of the study suggested that even though participants perceived the legal punishment as severe, the non-legal benefits of engaging in hooning activities seemed to outweigh the threats of legal punishment. The study had a few strengths and limitations. While most earlier studies were conducted on limited official statistics of street racers, this study recruited those

who were punished for the offences and those who avoided punishment, leading to greater heterogeneity of the sample of drivers. Another point of strength is the relatively large sample size of drivers who reported engaging in hooning activities 1 month prior to study, allowing sufficient statistical power to detect associations among important variables. Sample selection bias may be an issue in this study as targeting drivers who were recently engaged in street racing and associated hooning behaviours may have overrepresented those drivers who were not successfully deterred. Self-report bias may be another issue in the study along with self-selection bias, as drivers who agreed to complete the survey may not be representative of the general population of hooning drivers. No comparison group, i.e. from the general population, was used in this research. Yet even the potentially biased sample had sufficient heterogeneity to explore relationships among a large number of hooning-related variables.

A further study by Leal⁶³ analyzed the post-impoundment driving behaviour of the hooning offenders as compared to the comparison group with similar age and gender structure. The results of two-way mixed ANOVA suggested that vehicle impoundment reduced hooning infringements in the offender sample and the effect was small, but statistically significant ($\eta^2 = 0.01$, Wilk's lambda = 0.99, $F[1,1218]=7.37$, $p=0.007$). For the comparison group the effect was not significant. Additionally, the results showed significant delay in the number of days between the index day (first traffic infringement) and subsequent traffic infringement of any type in the offender sample in the post-impoundment period compared to a similar measure in the pre-impoundment period. This suggested that the vehicle impoundment law had a positive influence on offenders' driving behaviour in general. The study had a relatively large sample size, controlled for the effects of age and explored the effect of impoundment law beyond hooning offences. However, data and sampling method limitations were present, and a possible effect of the statistical regression to the mean was not controlled.

Another study conducted in San Diego explored the role of various factors which led to reduction of the number of casualties associated with street racing, including vehicle forfeiture law (ordinance).⁵⁶ The list of explanatory variables included among other things, a *spectator ordinance*, the law under which attending illegal street racing events

was an arrestable offence, as well as a *forfeiture ordinance*, which allows forfeiture of vehicles used in street racing. Analyses based on autoregressive Poisson and zero-inflated negative Binomial regression models suggested that the forfeiture ordinance was a significant factor in explaining reduced casualties due to illegal street racing. Data limitations included the lack of a comparison group in this study, but a robustness check was performed with street-racing arrests as an outcome which seemed satisfactory. Consistent results across different methods of analysis added some additional support to the findings. Forfeiture ordinance may be an effective countermeasure to street racing, but the results must be interpreted with caution in light of the study's limitations.

No Canadian study has previously been done evaluating the deterrent effect of Ontario's Street Racers, Stunt and Aggressive Drivers Legislation. The purpose of this study is to fill existing gap in the literature by conducting a process and outcome evaluation of the deterrent effect of Ontario's Street Racers, Stunt and Aggressive Drivers Legislation to explore whether the legal intervention of 2007 had an impact on speeding 50 kph or higher over the speed limit as well as on casualties (injuries and fatalities).

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Chapter 3

3 Evaluation of deterrent impact of Ontario's street racing and stunt driving law on extreme speeding convictions

3.1 Introduction

Risky driving is a key contributor to motor vehicle injuries and deaths.¹ Illegal street racing and associated stunt driving behaviours, such as wheelies (lifting some tires from the surface of the highway) and burnouts (spinning tires), as categories of risky driving, are considered a traffic safety issue of high public concern.^{2,3} Thus Canadians perceive street racing as the second biggest road safety concern after alcohol-impaired driving.

Limited research is available on street racing and stunt driving related collisions and casualties. A study conducted in the USA, using Fatality Analysis Reporting System data for 1998–2001, reported that 399 fatalities were attributed to street racing.⁴ Even though a small percentage of road fatalities were attributed to street racing (0.21%), racing involved risky driving behaviours such as speeding and driving under the influence of alcohol and resulted in serious consequences, including deaths and high criminal charges, predominantly for teenaged male drivers.⁴ Another study conducted in Queensland, Australia, which aimed to examine the road safety implications of hooning behaviours (the Australian term for street racing and associated stunt driving), found that very few of such activities (3.7%) resulted in crashes.⁵ There are no official national statistics in Canada on street racing and stunt driving related collisions or casualties. However, the police-run project E.R.A.S.E. (Eliminate Racing Activity on Streets Everywhere) reports that since 1999, 48 fatalities occurred in Ontario, primarily in Greater Toronto Area as a result of illegal street racing.⁶

However, a low number of crashes attributed to street racing and stunt driving is not surprising. Governments' collision databases do not have coding specially assigned for street racing, speed trials, stunt driving and related activities, although the USA recently introduced a code.⁴ Moreover, many such activities remain unreported and undetected.^{3,7,}

⁸ This is evidenced by surveys that have identified street racing as a common self-

reported activity, particularly among young males⁹⁻¹² For example, Vingilis et al.¹² examined a representative sample of Ontario high school students in grades 11 and 12 with advanced level or full driver's licences; they found that 20.4% of students reported street racing in the past year and the adjusted odds for males racing was 12 times higher than for females. Moreover, a survey of car club members found that those who self-reported street racing and stunt driving were significantly more likely to be younger, to score higher on the Driver Behaviour Questionnaire, the Driver Thrill Seeking Scale, Competitive Attitude Toward Driving Scale, Self-Report Driver Aggression Scale, Risk-Taking Driving Scale and to have been stopped for a traffic offence in the past year.¹³

A variety of countermeasures have been undertaken in different jurisdictions to combat street racing and stunt driving. These include educational and media campaigns, undercover law enforcement operations, sanctioned races in the safe and monitored environments of race tracks where participants pay an entrance fee, even informal racing with police officers, although none of these countermeasures have been formally evaluated.^{3, 8, 14} However, most successful countermeasures for changing driver behaviour have resulted from legal countermeasures, specifically legislation, enforcement and sanctioning.¹⁵ Legal countermeasures are based on classical deterrence theory which posits that individuals will avoid illegal behaviour(s) if they fear the perceived consequences of these action(s).¹⁶ This theory makes some assumptions related to human behaviour, namely that violation of the law is inversely related to the certainty, severity and swiftness of the punishment.¹⁷ This means that drivers are expected to refrain from violating traffic laws if they perceive high risk of being apprehended by police, believe there is a high certainty that they would be punished when detected, and that the punishment would be severe and delivered in a timely manner.¹⁸ Thus legislation that has certain, swiftly administered and severe sanctions should deter street racing and stunt drivers from engaging in these activities.

In the province of Ontario, Canada, a new law (Bill 203)¹⁹, Ontario's Street Racers, Stunt and Aggressive Drivers Legislation, came into effect on September 30, 2007, which amended previously existing legislation on street racing and increased penalties for street racing and stunt driving. Prior to September 2007 a street racing offence entailed a fine in

the amount of \$200-\$1000. After the introduction of new law, street racing and stunt driving, which includes among other things exceeding the speed limit by 50 kph, results in severe penalties (maximum penalty is highest in Canada):

1. immediate suspension of driver's licence and vehicle impoundment for 7 days, before conviction takes place;
2. upon conviction, a fine in the range of \$2,000-\$10,000, 6 demerit points, possibility of imprisonment for up to 6 months, up to 2 years licence suspension for the first conviction;
3. upon second conviction within 10 years of first conviction, driver's licence suspension up to 10 years.^{19, 20}

During the first year of the enactment of the legislation, 8,459 drivers were charged in Ontario under the new law.²¹ In 2011, in the Waterloo region alone, 69 stunt driving charges were issued, mostly for speeding 50 km/h or more over the speed limit.²² Based on the police report, almost one third of the total charges were laid on young drivers less than 20 years of age.²² The latter statistic is concerning taking into account the limited driving experience of teenage vehicle operators.

In order for the law to be effective in deterring the offenders, it has to be publicized and well enforced.²³ To increase public awareness about the stunt driving law, a number of activities were implemented by MTO, such as educational campaigns targeting secondary and high school students, development and distribution of brochures on speeding and stunt driving, presenting information on the new legislation in the Driver's Handbook, installation of road signs on major Ontario highways with the information on penalties under the new law.²⁴ Mass media in Ontario widely covered the details of the legislation, especially in the first two years of its implementation, mainly due to controversial opinions raised by this law in the public.²⁵ Some suggested the law unconstitutional due to a provision of the possibility of imprisonment for up to 6 months, with no fault of harm or injury.

No formal evaluation has been conducted on the impact of this legislation, although other jurisdictions have evaluated the vehicle impoundment provision of similar legislation.²⁶ A study was conducted on a sample of primarily young drivers (n=52), whose vehicles were impounded for hooning, by a self-report survey (n= 51) and focus groups (n=21). The results of the study were inconclusive. When asked whether the penalties were harsh enough to deter the participants from hooning, 51% of them replied 'yes' and 49% said 'no'. For repeat offences, 13% of participants reported engaging in no hooning activities after having their vehicle impounded, while 18% reported hooning three or more times a month since impoundment. With respect to the effectiveness of vehicle impoundment sanctions on recidivist hooning behaviour, the responses varied from effective or periodically effective to ineffective. Findings of other Australian research involving a focus group (n=22) suggested that despite anti-hooning laws, the participants did not stop hooning activities and intended to continue doing so.²⁷ Another study conducted in Queensland, Australia, examined the effectiveness of anti-hooning legislation, where a sample of 290 drivers completed an anonymous online survey. The results provided some evidence on the effectiveness of the vehicle impoundment and forfeiture law, as drivers in the sample reduced hooning activities in response to the law.²⁸ However, the above studies did not use a quasi-experimental multiple time series design to examine the impact of their legislation.

The purpose of this study was to conduct a process and outcome evaluation of the deterrent effect of Ontario's Street Racers, Stunt and Aggressive Drivers Legislation on extreme speeding convictions. It was hypothesized that male drivers and younger drivers would show a greater incidence of driving suspensions related to the new legislation than female drivers and older drivers, consistent with much other research showing that young drivers and males are most likely to engage in speeding, street racing and stunt driving.^{8, 12, 28, 29}

Additionally, it was hypothesized that because males are much more likely to engage in speeding, street racing and stunt driving, the new law would have more impact in reducing extreme speeding in males when compared to females.

3.2 Methods

3.2.1 Variables

Data on driver licence suspensions and speeding convictions were provided by the Ministry of Transportation of Ontario (MTO). The data sources included the Integrated Court Offences Network (ICON); the Suspension and Impoundment Management System (SIMS) and Drivers Licensing System database. This study received approval from the Office of Research Ethics for Human Subject Use of the University of Western Ontario.

1. Demographic and violation data: De-identified information on the details of suspensions for racing/stunts for the specified period (start date of suspension, end date, driver's characteristics such as sex and date of birth). Each driver was assigned a unique identification number. This allowed us to generate a mini-profile of the suspended violator in terms of age, sex and repeat violations. The records were checked for duplicate records. No duplicates were identified. In the case of repeat violations by the same drivers, which occurred at different dates, we used only the earliest record to create a demographic profile at the time of the first suspension. To estimate the proportion of repeat suspensions in the total number of suspensions, we used all available records.
2. Suspensions data (surrogate process measure): Monthly time series of suspensions of drivers licences for racing/stunts for the period of September 30, 2007 till December 31, 2011. Suspension codes included 85 and 86; both are used for administrative licence suspensions for racing/stunts (Section 172 of Highway Traffic Act). Using these data we produced a plot of violations to Ontario's street racing/stunt driving law from the time the law came into effect until 2011 to identify if police were enforcing the law.
3. Speeding convictions (outcome measure): Time series data on speeding convictions of Ontario drivers for 2003-2011, by speeding category and sex. Speeding convictions were for violation of Sections 128 and 172 of Ontario Highway Traffic Act. From monthly count data on speeding convictions, we selected for analyses the counts for extreme speeding defined by 50 kph and higher over the posted speed limit for all Ontario drivers. The range of extreme speeding of 50 kph and higher over the limit was chosen among

other speed ranges as most of the charges laid under Ontario's new street racing/stunt driving law were for this provision of the law. Convictions for exceeding posted speed limit by 50 kph and higher in post-September 2007 period included convictions based on offences of both the 'old' law (speeding over the limit, Section 128 of HTA) and the 'new' law (racing/stunts, Section 172 of HTA).

These series were used to test whether the number of speeding cases of males (intervention group) exceeding the speed limit by 50 kph and higher would decrease in the post-intervention period versus the pre-intervention period compared to females (comparison group).

3.2.2 Time series intervention analysis

Intervention analysis, first introduced by Box and Tiao (1975), provides a framework for assessing the effect of an intervention on a time series under study. It is assumed that the intervention affects the time series by changing the mean function or a trend of a time series. This approach has become very popular in evaluation of traffic safety interventions or other policies that can affect road safety. A brief summary of this method is described here.

Let y_t denote the time series of interest such as monthly convictions, which may be modeled as

$$y_t = \zeta + \omega S_t^{(T)} + e_t$$

where $t=1, 2, \dots, n$ indicate the observation time points, ζ is a constant term or a pre-intervention mean, ω is the effect of the intervention, $S_t^{(T)}$ is a step function indicating that the intervention occurs at time T , and thus equal to 0 if $t < T$, and 1 if $t \geq T$, and e_t represents the disturbance term or the underlying time series were there no intervention. The null hypothesis to be tested in intervention analysis is that the effect of change introduced at time T is zero, i.e. $H_0 : \omega = 0$. One could consider a two group-comparison. The key issue here is that the pre- and post-intervention data cannot be assumed to be independent and identically distributed. The inherent serial correlation must be accounted for using conventional time series analysis techniques.³⁰ Therefore, the first stage of

intervention analysis is to use pre-intervention data to identify a model of e_t , usually a ARIMA or SARIMA model.³¹

Traffic-related time series data often exhibit seasonal patterns due to weather effects on driving practices. Exploratory analyses included visual inspection of time plots, autocorrelation functions (ACF) and partial autocorrelation functions (PACF) of the series, testing for seasonal and non-seasonal nonstationarity. Following exploratory analyses, ARIMA or SARIMA model parameters were selected by Box-Jenkins³² methodology which allows for the identification of the most suitable model by applying 3 stages: identification, estimation, and diagnostics checking. When the most suitable model was selected, a simple step intervention model³³ was fitted to test statistically for shifts in the level of the series.

Testing for possible outliers was performed to make sure the outliers do not produce spurious relationships between variables or biased estimates of the effect. Procedures for outliers identification and modelling are described elsewhere.³¹ More detailed information on the analytic steps are provided in Appendix A for the intervention group and Appendix B for the comparison group.

Univariate time series models were developed for the purpose of intervention analysis under a number of assumptions:

1. It is a closed system in which the event and the response to the event took place, meaning that apart from the noise of the series, only the intervention had exogenous impact on the series.³⁴ All else remains unchanged or external to the system.
2. The noise structure of the model remains unchanged pre- and post- intervention, implying stability of the model. The only changes are assumed to arise from the impact of the intervention under examination.
3. Stable structure of the driver's population exists in terms of gender distribution during the study period.

The number of the observations before the intervention and after is sufficient to have the power to detect the effect at a chosen level of significance, as justified following the method by McLeod and Vingilis³⁵ which is suitable for time series analyses for traffic safety interventions. In a case of a step intervention and a moderate lag-one autocorrelation ($\phi = 0.5$), with $X=108$ months in total and intervention occurring at time $T=58$, the probability of detecting a change of one standard deviation equals 87%. An online power computation program³⁶ was used to compute the power for a two-sided test at 5% significance level.

ARIMA or SARIMA modelling is usually applied when a dependent variable is continuous. Even though convictions represent a count, not a continuous variable, in the situations where the mean of the series is relatively large, the distribution is usually found to be approximately normal for seasonal or non-seasonal ARIMA model errors; thus the use of Box-Jenkins interrupted time series analysis is justified.³⁷

The time series analyses were performed using R version 3.0.0 (2013-04-03) software.

3.3 Results

3.3.1 Demographic and violation data

During the specified time period 24,401 drivers' licences were suspended for racing/stunts. Four observations had missing values for age and sex, and therefore, excluded from the tables below.

Table 3.1 presents driver suspension data by age and sex, as percent of all drivers and as a percent per licenced driver. Although the 25-64 year old drivers represent the largest number and proportion of licence suspended drivers, it is the 16-24 year old drivers who have the largest percent of suspended drivers per licensed driver. Additionally, males represent the largest proportion of licence suspended drivers (85.5%). Young and mature male drivers are the largest groups in the population of drivers suspended for racing/stunts, 1.21% and 0.37% per licensed drivers, respectively.

Table 3.1. Drivers suspended for racing/stunts by age at first suspension and sex for the period of September 2007 – December 2011

Drivers age	Drivers licenced*		Drivers suspended		% per licenced driver		% of total number of suspended drivers		% of suspended per licenced driver
	Male	Female	Male	Female	Male	Female	Male	Female	Total
<16	0	0	1	0	n/a	0	0	0	n/a
16-24	651,365	592,052	7,852	1,232	1.21	0.21	32.18	5.05	0.73
25-64	3,420,996	3,260,973	12,691	2,257	0.37	0.07	52.02	9.25	0.22
>65	709,263	610,618	309	55	0.04	0.01	1.27	0.23	0.03
Total	4,781,624	4,463,643	20,853	3,544	0.44	0.08	85.47	14.53	0.26

*Data on drivers licensed were obtained from MTO's Ontario Road Safety Annual Report 2010.³⁸

Table 3.2. Duration of licence suspensions for racing/stunts

Duration (days)	Frequency	Percent	Cumulative percent
< 7	61	0.2	0.2
7	22,310	85.9	86.2
8-30	3,216	12.4	98.5
31-365	330	1.3	99.8
>365	47	0.2	100.0
Total	25,964	100.0	100.0

The total number of suspensions (25,964) exceeded the total number of suspended drivers (24,401), due to multiple suspensions per person for a small group of drivers (Table 3.2). The largest number of roadside licence suspensions for racing/stunts (85.9%) were 7 days in duration. The next largest proportion (12.4%) of suspensions was between 8 days up to 30 days in duration, which may possibly be due to a decision of a judge.

Table 3.3. Repeat suspensions by the drivers, for the period of September 2007-December 2011

Repeat times	Frequency	Percent
0	22,974	88.5
1	1,427	5.5
2	1,427	5.5
3	96	0.4
4 or more	40	0.1
Total	25,964	100.0

As shown in Table 3.3, the majority of suspended drivers (88.5%) violated the street racing/stunt driving law once and did not repeat it during the period of time under study while 11% of suspended drivers violated street racing law 1-2 times after the first suspension and 0.5% of suspended drivers were repeat violators with 4 or more suspensions in total.

3.3.2 Roadside drivers' licence suspensions

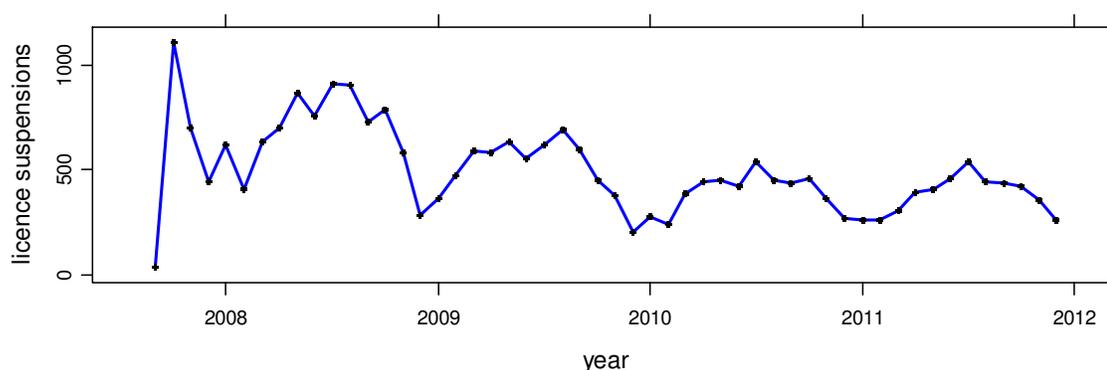


Figure 3.1. Monthly number of roadside suspensions for racing/stunts for the period of September 2007-December 2011

Figure 3.1 presents the time series on monthly number of roadside drivers' licence suspensions as an indicator of police enforcement. The smallest number was observed in September because the law became effective September 30, 2007 and thus these 36 suspensions represent the count for one day only. The largest number, 1110 roadside suspensions took place in October 2007, a month after the enactment of the street racing

law. The large number of post-September suspensions confirms the fact that the law was enforced by Ontario police. Overall, the plot showed a downward trend with clear seasonal patterns: the peaks corresponded to warm months of summer and fall, and the troughs corresponded to winter months.

3.3.3 Extreme speeding convictions

In total, there were 108 observations, 57 observations before the intervention and 51 observations after the intervention. For males the extreme speeding conviction means of the series declined from a pre-intervention mean of 172.23 (s.d. 32.46) to a post-intervention mean of 112.2 (s.d. 46.8) while for females the pre- and post-intervention extreme speeding conviction means were much lower with the pre-intervention mean of 21.67 (s.d. 5.39) and post-intervention mean of 18.98 (s.d. 8.12).

The results of the intervention analysis with step function for male and female drivers are presented in Table 3.4. As described earlier, the intervention variable was modelled as a dichotomous variable, taking on value 0 before the time of intervention and value 1 after the intervention. The maximum likelihood estimates of the intervention variable coefficients as well as seasonal and non-seasonal ARIMA model parameters are shown.

Table 3.4. Parameter estimates of the intervention model fitted to full series

Coefficient	Male drivers group		Female drivers group	
	Estimate	Std.Error	Estimate	Std.Error
Intercept	164.8	11.7**	21.69	1.83**
AR1	-	-	0.470	0.754
AR2	-	-	0.172	0.571
MA1	0.738	0.095**	-0.103	0.758
MA2	0.581	0.100**	0.000	0.313
MA3	0.114	0.083	-	-
SAR1	0.327	0.102**	-	-
Intervention	-45.1	15.5**	-2.89	2.57

Note: * $p < 0.05$ and ** $p < 0.01$. AR stands for autoregressive parameter, SAR – seasonal AR parameter and MA- moving average parameter; the numbers 1, 2, or 3 mean the order of model parameters.

Figure 3.2 presents the monthly extreme speeding convictions for males before and after the introduction of the new law. The red dots on the plot are predicted values based on the model built using pre-intervention data. A significant reduction in monthly convictions for speeding 50 kph or more over the posted speed limit was found for male drivers after the introduction of the street racing/stunt driving law ($P = .004$).

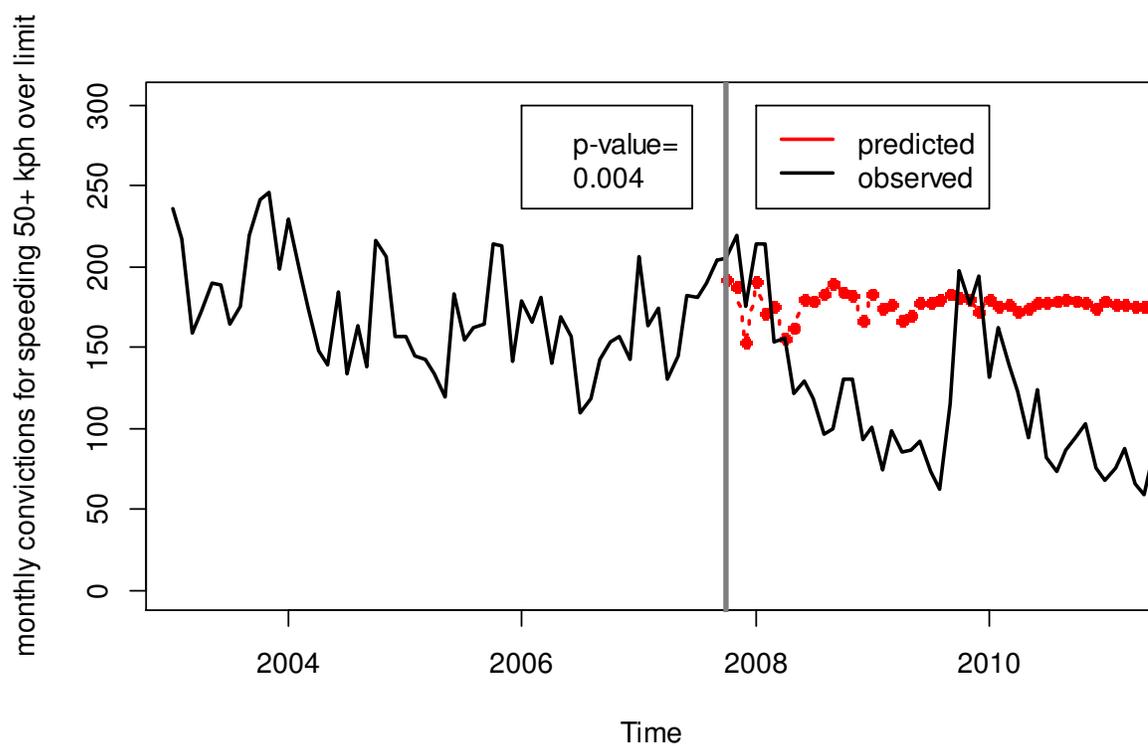


Figure 3.2. Intervention analysis of speeding convictions, intervention group- male Ontario drivers (2003-2011)

Figure 3.3 shows the monthly extreme speeding convictions for females before and after the introduction of the new law. No pre-post change in monthly convictions for speeding 50 kph or more over the posted speed limit was found for female drivers after the introduction of the street racing/stunt driving law ($P=.3$).

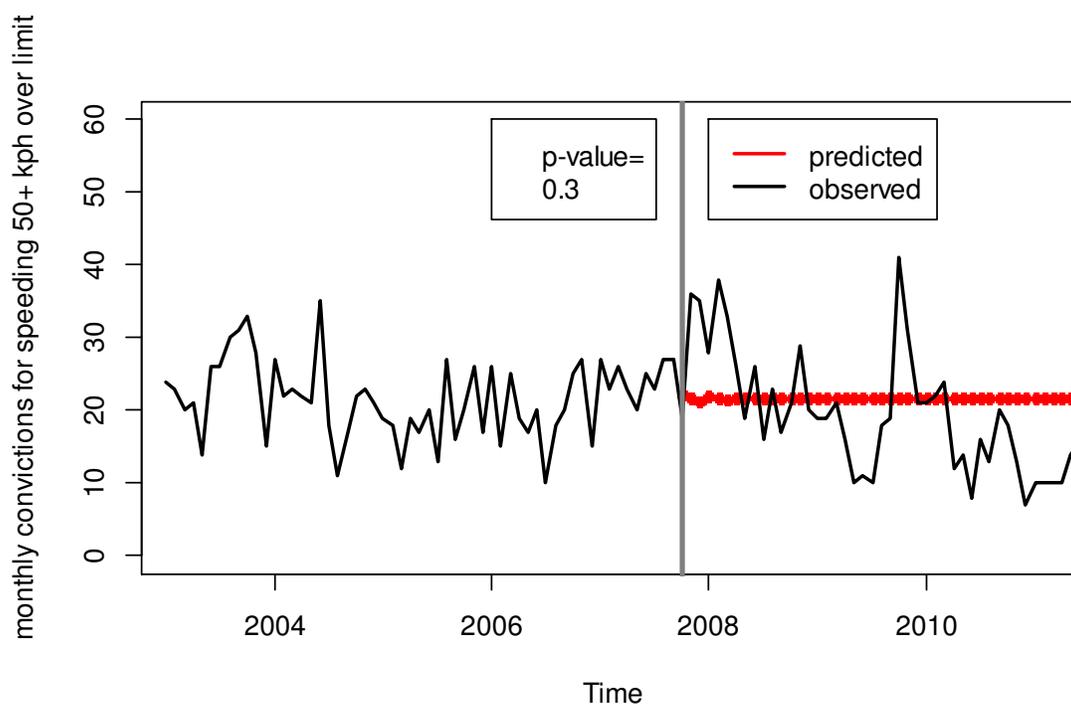


Figure 3.3. Intervention analysis of speeding convictions, comparison group - female Ontario drivers (2003-2011)

3.4 Discussion

This study is the first to examine the impact of Ontario's street racing/stunt driving law on extreme speeding convictions. Consistent with the stated hypothesis, we found a significant reduction in the number of convictions in extreme speeding convictions for speeding 50 kph and over the posted speed limit in the male drivers group, the group most likely to speed, comparing the series before and after the intervention. No significant change was found for the female drivers group. These findings are congruent with deterrence theory that certain, swift and severe sanctions can deter risky driving behaviour and support our hypothesis that legal sanctions would have an impact on the extreme speeding convictions of the male drivers. Vehicle impoundment can be considered as one of the most severe penalties applied to traffic offences, due to temporary removal of the means of transportation.²⁸ Moreover, the offender is responsible for towing and storage fees for the impounded vehicles, in addition to

conviction fines. A roadside licence suspension immediately removes the legal right of operating any vehicles, limiting offender's access to driving for the duration of sanction's application. The minimum fine of \$2000 upon conviction can be a big financial burden, especially for a young driver, not to mention the increase in vehicle insurance premiums. The websites of traffic paralegals warn their potential clients of a large increase in insurance rates for a racing/stunt driving conviction and possible cancellation of the policy, even if there are no other convictions on the record.³⁹ Thus, roadside licence suspension and vehicle impoundment are more immediate, certain and severe than a standard speeding ticket.

The results of an online survey of 370 drivers, who reported engaging in hooning behaviours in Queensland, suggested that drivers perceived the vehicle impoundment and forfeiture as a severe sanction, where severity was measured using severity scale scores. With respect to the perception of certainty and swiftness of punishment, the survey participants perceived that others were significantly more likely than them to have their vehicle impounded; however, their own vehicles would be impounded more swiftly than vehicles of others for hooning offence.²⁸

Road safety literature has mixed evidence on the effectiveness of administrative traffic sanctions in terms of convictions and, in addition, crashes. In the study conducted in California⁴⁰, monthly crash rates of individuals who drove illegally while revoked or suspended were compared to monthly crash rates of a non-equivalent no treatment control group, comprised of drivers who were not revoked or suspended in three years prior to and two years after implementation of the vehicle impoundment law. The results showed that there was a significant 13.6% reduction in the crash rates for the revoked and suspended group. However, there was a significance drop (8.3%) in crashes for the control group as well. Joint estimation of both groups did not show a statistically significant reduction in the crashes of illegal drivers when the control group was taken in to account in the statistical analyses. Similarly a study conducted in Victoria, Australia, as part of the anti-hoon law found inconclusive results.²⁶ In support of deterrence theory, a number of studies found that licence suspensions and vehicle impoundments were effective deterrent measures. For example, a California-based study⁴¹ evaluated the

impact of a vehicle impoundment law on the first year of subsequent driving behaviour of revoked, suspended and unlicensed drivers. The reported results showed that first time offenders and repeat offenders, whose vehicles were impounded, had 23.8% and 34.2%, respectively, fewer subsequent convictions for driving while suspended, revoked or unlicensed, as well as 24.7% and 37.6%, respectively, fewer crashes, compared to a similar control group whose vehicles were not suspended. Similarly, a Manitoba-based study from Canada⁴², evaluated both general and deterrent effects of both administrative licence suspension and vehicle impoundment laws. The effects of two laws could not be separated. The study reported a net 12% decrease in drinking driving fatalities and a net 26% decrease in single vehicle nighttime crashes. Additionally, the laws were found to have deterrent effects on drinking and suspended drivers in terms of repeat offences.

Anti-street racing laws of other jurisdictions are different from Ontario and cannot be compared directly. However, the results of a study conducted in Queensland, Australia, suggested that their anti-hooning law was effective in deterring the offenders. In this study Leal analyzed the post-impoundment driving behaviour of hooning offenders as compared to the comparison group of similar age and gender structure.²⁸ The results of two-way mixed ANOVA suggested that vehicle impoundment reduced hooning street racing/stunt driving violations in the offender sample and the effect was small, but statistically significant ($\eta^2 = 0.01$, Wilk's lambda = 0.99, $F[1,1218]=7.37$, $p=0.007$). For the comparison group the effect was not significant. Additionally, the results showed significant delay in the number of days between the index day (first traffic infringement) and subsequent traffic infringement of any type in the offender sample in the post-impoundment period compared to a similar measure in the pre-impoundment period. This suggested that the vehicle impoundment law for hooning violations had a positive influence on offenders' driving behaviour in general.

The findings of our study provide additional evidence in support of the deterrent effect of administrative vehicle sanctions for street racing/stunt driving offences. On the other hand, these findings may be due to lower detection of extreme speeding violations. It was not possible to control for this potential bias in this study.

The findings of this study are also consistent with the previous research on demographics of street racers and stunt drivers. Using the data on suspensions for street racing/stunt driving violations, we found that the incidence of these dangerous activities is higher among males, especially young ones. When calculated per licensed driver, 1.21% of young male drivers and 0.37% of mature male drivers, had their licence suspended under the new street racing/stunt driving law between September 2007 and December 2011. Earlier studies reported that risky driving was predominantly a male activity and the prevalence of risky driving among females was relatively low.^{3, 8, 28, 29, 43, 44} The findings of preliminary analyses of another Ontario-based study revealed that the prevalence of self-reported street racing among a representative sample of adults (age 18 and over) in 12 months preceding the survey was low (1%), although younger males reported higher rates of street racing.^{45, 46}

Very small proportions of drivers were found to be suspended for street racing and stunt driving per licenced drivers. This is not surprising as in fact these small proportions may represent the tip of the iceberg. The prevalence of street racing obtained through the self-reported survey of the Ontario sample described above may possibly be underestimated due to social desirability bias. Also, not all committed offences are detected by law enforcement. When an offence is detected, a provincial offence notice (a ticket) is issued. Generally, an offender has three options when a provincial offence notice is served⁴⁷: 1. pay the fine, in which case the conviction is registered; 2. request in person or by mail a meeting with the prosecutor to discuss a possible resolution to a charge; 3. file in person (in court's office) or by mail a request for a trial. Either a prosecutor (pre-trial) or a judge (during trial) considers the circumstances and in some cases the charges laid can be dismissed or reduced; otherwise the offender is convicted and the conviction is registered.

Generally, official statistics reflects registered convictions. Therefore, the real prevalence of street racing remains unknown. Of 2896 charges laid between October 1, 2007 and August 31, 2008, 39% were reduced to other charges, such as speeding, and 20% were withdrawn, stayed, dismissed or acquitted. Former Ontario Provincial Police

Commissioner, J. Fantino, who served in this role in 2006-2010, commented on the low conviction rate as “...small steps in the right direction.”⁴⁸

Additionally, a downward trend on suspensions was observed in Figure 1. It is not possible to draw conclusions on causality and statistical significance, but assuming a constant level of law enforcement over time, this trend can possibly be due to a deterrent effect of the legislation.

Our study has a number of strengths and limitations. Our study was the first in Ontario to evaluate the effectiveness of street racing/stunt driving law. We used quasi-experimental interrupted time series design as it was not possible to randomly assign violators to different sanctions. The findings of quasi-experimental designs are more vulnerable to alternative explanations than experimental designs, but quasi-experimental studies can offer fairly convincing findings if biases are explored and comparison groups are used.⁴⁹

The main threat to internal validity in quasi-experiments is ‘history’, which refers to the possibility that other events external to subjects, occurring during the time period of the study, might have explained the observed outcomes.⁵⁰ Use of a comparison group in the study allows for the control of history effects, although with a comprehensive policy change, such as the street racing/stunt driving law, it is difficult to find an equivalent comparison group, such as males who were not subjected to the new law but resided in the same jurisdiction during the same time period. Thus using females as a comparison group was our best available choice.

Lastly, reliance on official data, which may not represent the complete picture in terms of true prevalence of illegal street racing behaviours, can be considered as a limitation. However, official data are one of the best among available secondary data sources, as administrative databases are well maintained, checked for accuracy and accessible to researchers.

In summary, Ontario’s Street Racers, Stunt and Aggressive Drivers law, which brought high penalties if offenders are convicted, was found to reduce extreme speeding

convictions of male drivers when compared to female drivers, suggesting a possible deterrent effect.

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Chapter 4

4 Road safety impact of Ontario street racing and stunt driving law

4.1 Introduction

Street racing has a long history, starting from the past century when the cars became affordable and widely available to the public.¹ Over time, street racing and associated driving behaviours, which are linked to the increased risk of motor vehicle collisions, injuries, deaths and property damage, have been identified as an international road safety problem.^{2,3} Social surveys conducted in various international jurisdictions have found that the prevalence of self-reported street racing among young male drivers ranged between 18.8 and 69 percent. Vingilis et al.⁴ examined a representative sample of Ontario high school students in grades 11 and 12 with advanced level or full driver's licences; they found that 20.4% of students reported street racing in the past year and the adjusted odds for males racing was 12 times higher than for females.

A study conducted in the USA found that during the period of 1998–2001, 315 (0.021%) of all fatal collisions and 399 fatalities were attributed to street racing.² A study in Queensland, Australia, identified 169 street racing and associated risky driving (so called 'hooning') related collisions, by searching Queensland Transport's WebCrash2 database for the period of 1999-2004, where the search was limited to crashes involving 12-24 year olds.⁵ Another study using the same database for the same time period, identified 1 fatality and 11 hospitalizations where hooning activities were listed as contributing factors in the crash description.⁶ A police-run project, E.R.A.S.E. (Eliminate Racing Activity on Streets Everywhere), reports that since 1999, 48 fatalities occurred in Ontario, primarily in Greater Toronto Area, as a result of illegal street racing.⁷ Even though a small percentage of road fatalities were found to be attributed to street racing in earlier research, street racing involved risky driving behaviours including driving under the influence of alcohol and resulted in serious consequences, such as deaths and high criminal charges.²

Street racing typically involves extreme speeding. Therefore, all the dangers of speeding are highly relevant to street racing. The review of evidence suggests that a 1% increase in speed increases a driver's fatality risk by 4%-12%.⁸ The Traffic Injury Research Foundation reported that over 20% of all collisions in Canada involve excessive speeding or driving too fast for conditions and that in 2006 alone, such collisions resulted in about 800 deaths and about 3000 severe injuries.⁸ After impaired driving, speeding is identified as the second most common contributor to motor vehicle fatalities.⁹ Interestingly however, previous studies suggest that fatal collisions due to street racing and stunt driving, the term used in Ontario to describe street racing-related driving, such as lifting some or all of its tires from the surface of the highway (wheelies) or driving a motor vehicle in a manner that indicates an intention to spin it or cause it to circle (donuts), are not common.^{2,6}

Police collision reports in Canada and most other jurisdictions do not include separate codes for racing, although street racing information can be added to the incident description section of the collision form.⁹ Witnesses are often required to identify a driver's involvement in street racing activities. In the case of a collision, drivers are often not willing to admit to street racing and passengers and spectators of racing vehicles are not eager to be witnesses.^{6,9} Thus, it is reasonable to assume that some of the collisions related to racing are identified as speeding-related in the official reports and statistics "because of the challenge for police to detect and list street racing as a contributor to collisions"(p.150).⁹

Numerous countermeasures against street racing have been employed by different jurisdictions, including drivers' education, sanctioned racing in a safe and monitored environment, installation of speed cameras, under-cover police operations. However, legal countermeasures – legislation, enforcement and sanctioning, were identified in previous research as most successful measures to change driver behaviour.¹⁰ The basis for legal countermeasures is in classical deterrence theory which states that there is an inverse relationship between violation of the law and the certainty, severity and swiftness of the punishment.¹¹ The higher the risk of apprehension by police and the certainty of the punishment upon detection, and the higher the severity of the punishment and its

timely delivery, the higher the chance that drivers will refrain from potential violations of traffic laws.¹² Thus, legislation with certain, severe and swiftly administered sanctions should deter illegal street racing and stunt driving activities.

Street racing is a criminal offence according to the Criminal Code of Canada. A convicted offender may face up to five years in prison, where the punishment may increase up to fourteen years in prison or life-time imprisonment, if a street racing activity caused a bodily injury or death, respectively.¹³ In the province of Ontario, street racing/stunt driving legislation (Bill 203: Street Racers, Stunt and Aggressive Drivers Legislation) was implemented on September 30, 2007. The definition of racing includes driving behaviours of one or more motor vehicles where the elements of competition or chasing are present, while motor vehicles are driven at a speed rate which clearly exceeds the allowed speed limit.¹⁴ The stunts are defined as

“any activity where one or more persons engage in any of the following driving behaviours: 1. Driving a motor vehicle in a manner that indicates an intention to lift some or all of its tires from the surface of the highway, including driving a motorcycle with only one wheel in contact with the ground, but not including the use of lift axles on commercial motor vehicles. 2. Driving a motor vehicle in a manner that indicates an intention to cause some or all of its tires to lose traction with the surface of the highway while turning. 3. Driving a motor vehicle in a manner that indicates an intention to spin it or cause it to circle, without maintaining control over it. 4. Driving two or more motor vehicles side by side or in proximity to each other, where one of the motor vehicles occupies a lane of traffic or other portion of the highway intended for use by oncoming traffic for a period of time that is longer than is reasonably required to pass another motor vehicle. 5. Driving a motor vehicle with a person in the trunk of the motor vehicle. 6. Driving a motor vehicle while the driver is not sitting in the driver’s seat. 7. Driving a motor vehicle at a rate of speed that is 50 kilometres per hour or more over the speed limit. 8. Driving a motor vehicle without due care and attention, without reasonable consideration for other persons using the highway or in a manner that may endanger any person...”¹⁴

Most charges for racing and stunt driving offences are laid for speeding 50 km/hour or higher over the posted speed limit. Street racing and stunt driving offences, if detected, result in following punishment under Bill 203:

1. on the spot suspension of driver’s licence and vehicle impoundment for the duration of 7 days, prior to conviction;

2. upon conviction, a fine ranging \$2,000-\$10,000, 6 demerit points, possible imprisonment for up to 6 months, up to 2 years licence suspension for the first conviction;
3. if second conviction occurs within 10 years of first conviction, up to 10 years licence suspension.^{15, 16}

Enforcement of the law in terms of roadside licence suspensions and subsequent convictions are expected to increase the perception of certainty of punishment. Vehicle impoundment is a quite severe penalty, as not only it entails removal of the vehicle from an offender, but also imposes towing and storage fees on the driver who may possibly face an increase in vehicle insurance for street racing/stunt driving conviction. A fine charged upon conviction, even at a minimum amount of \$2000 is a severe penalty relative to the income level, especially for a young driver. Immediate suspension of a licence is a manifestation of the punishment's swiftness.

Ontario's street racing/stunt driving legislation has not been formally evaluated in terms of its road safety impact. Although other jurisdictions have evaluated the vehicle impoundment provision of similar legislation, the results of which provides mixed evidence about the deterrent effect of vehicle impoundment law.¹⁷⁻¹⁹ These studies, however, did not use a multiple time series design to examine the impact of the legislation.

The purpose of this study was to conduct a process (implementation) and outcome evaluation of the impact of Ontario's street racing/stunt driving legislation on casualties (injuries and fatalities) from speeding-related collisions. The causal model of this legal intervention is presented on Figure 4.1. The focus of this study was enforcement, reduction in speed, and reduction in casualties. According to the causal model, an intervention should be well publicized and adequately enforced to make the public aware of the punishment in relation to the offence. As an intermediate outcome, the drivers may respond by less speeding, which results in improved safety on the roads, measured by collision injuries.

To assess implementation we examined trends for roadside suspensions for racing/stunts for the period of September 2007-December 2011, as a surrogate measure of enforcement. To assess outcomes we examined an intermediate outcome to measure change in speeding and a criterion outcome of casualties by sex and age before and after the new legislation. To check whether there was a change in highway speed, we plotted the average daily highway speed data, obtained from the Ministry of Transportation of Ontario (MTO) for three of the counting stations which collect traffic and speed data on provincial highways. The criterion outcome measure included motor vehicle casualty data analyzed using multiple interrupted time series design. Based on previous studies that young male drivers were the most likely to engage in street racing and associated risky driving behaviours than any other category of drivers, followed by mature male drivers, we hypothesized that these two groups would be the most likely to be deterred and show a significant decrease in motor vehicle casualties subsequent to the introduction of Ontario's street racing/stunt driving legislation.^{4, 19-21} An ideal comparison group to control for possible temporal changes in casualty trends over the pre- and post- new legislation time frame would be males who drove in the same jurisdiction but were not subject to the new legislation. However, as this law was a "full-coverage program", it was not possible to find such a comparison group.²² Females have been shown to be the least likely to engage in street racing and stunt driving. Thus young and mature female drivers were used to serve as comparison groups for possible extraneous temporal changes in casualties; we hypothesized no change in their casualties subsequent to Ontario's street racing/stunt driving legislation.

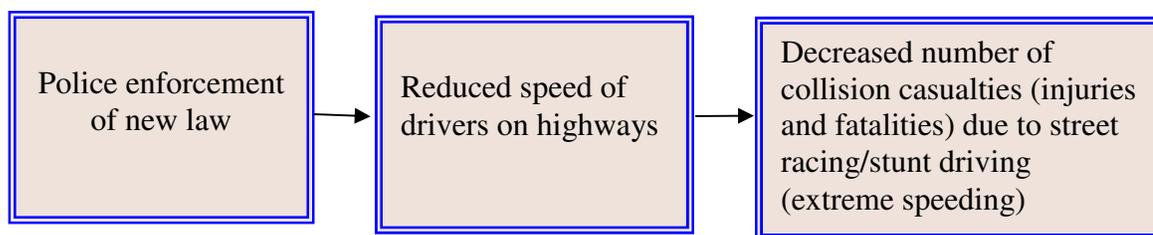


Figure 4.1. The causal model of Ontario street racing/stunt driving legal intervention

4.2 Methods

4.2.1 Variables

The data for the study were provided by the MTO. The goal of the Ministry is to improve Ontario road safety. MTO maintains various administrative databases, including Accident Data System (ADS). The ADS contains data on all reportable motor vehicle collisions in Ontario. In case of the reportable collision, an investigating police officer completes a comprehensive motor vehicle accident report. The report is transferred to the Road Safety Research Office at MTO, which maintains the database. The data were provided by MTO to the research team for the period of 2002-2010. This study received approval from the Office of Research Ethics for Human Subject Use of the University of Western Ontario.

4.2.1.1 Roadside suspension data (process measure)

Monthly time series of the roadside suspensions for street racing/stunt driving (codes 85 and 86) were provided by the MTO for the period of September 2007 till December 2011. Roadside suspensions were used as a surrogate measure of enforcement. We plotted the overall trend of suspensions in the post-intervention period.

4.2.1.2 Highway speed data (intermediate outcome measure)

Major provincial highways have counting stations installed, which collect data on the volume and speed of traffic. The hourly data were provided by MTO for three counting stations: two of them operated on different locations on highway 401 (Putman and Port Hope) and one station collected data on highway 11 (Medonte). The counting stations were periodically out of service due to communication issues (related to modem failure or power outages) or electrical issues (site not receiving minimum required voltage), loop failure, or construction. As a result, a range of missing values spanned between a few hours to a number of months. Missing time series data were imputed using two methods of interpolation, described in Appendix C. Due to a large number of missing values which had to be imputed, we did not proceed with statistical hypothesis testing to compare the average highway speed in pre- and post-intervention periods. Therefore, the

plots along with the mean speed calculated before and after the intervention are presented.

4.2.1.3 Collision casualty data (criterion outcome)

Individual-level collision data were aggregated by month of collision to monthly counts of casualties (injuries and fatalities) of drivers and accompanying passengers in the motor vehicles to produce time series for the period of January 1, 2002- December 31, 2010. This corresponds to 5 years pre-intervention and 3 years post-intervention. Injury was defined as “any bodily harm visible or complained of resulting from the collision”.²³ Fatality was defined as an injury resulting in a death within 30 days from the day of collision.

The Accident Data System specified driver’s action which contributed to a collision. No data element on the collision form was assigned to street racing and stunt driving. Therefore, we used a ‘proxy’ measure to capture motor vehicle casualties relevant to street racing and stunt driving by restricting the driver’s action field to 2 categories: speed exceed limit and speed too fast for condition. This measure is to some extent consistent with stunt driving, which is defined, among other things, as speeding 50 kph and higher over the posted speed limit.

Earlier studies reported that street racing was predominantly a male activity and the prevalence of street racing among females was relatively low.^{9, 19-21, 24, 25} Therefore, the casualties were analyzed separately by sex. Analyses were performed for speeding-related casualties for the following four groups of drivers: young males (aged 16-25), mature males (aged 26-65), young females (aged 16-25) and mature females (aged 26-65). The age division between young and mature drivers was based on the previous studies on characteristics of street racers.^{2, 5, 6, 20, 21}

4.2.1.4 Non-speeding-related casualties (comparison)

To compare whether trends in speeding-related casualties were similar to a general casualties trend, the time series of monthly counts were created and plotted for all non-speeding-related casualties (injuries and fatalities) for the period of January 1, 2002-

December 31, 2010. These series served as a comparison to speeding-related casualties in terms of overall trends.

4.2.2 Statistical analysis

Interrupted time series modelling was used to evaluate the effect of an intervention on a time series and to account for the feature of time series data that the error terms associated with each observation are not independent.²⁶ Traffic-related time series data often exhibits seasonal patterns due to weather effects on driving practices. Exploratory analyses included visual inspection of time plots, autocorrelation functions (ACF) and partial autocorrelation functions (PACF) of the series, testing for seasonal and non-seasonal nonstationarity. Following exploratory analyses, ARIMA or Seasonal ARIMA models were built using Box-Jenkins²⁷ 3 stage methodology: identification, estimation, and diagnostics checking. When the most suitable model was selected, a simple step intervention model²⁸ was fitted to test statistically for the shifts in the level of the series.

In a single intervention case, the general model for time series $\{Y_t\}$ can be written as:

$$Y_t = \text{constant} + I_t + N_t,$$

where

I_t is the change in the mean function due to the intervention and N_t is an error term, modelled as ARIMA or SARIMA procedure. The process $\{N_t\}$ represents the time series for the period with no intervention. Therefore, only pre-intervention data were used to specify the model for the process N_t .²⁹ At the stage of intervention analysis, the same error term model was applied to the complete series Y_t to determine the effect of the intervention.

For the simple step intervention model, the intervention variable can be expressed as:

$$I_t = \omega S_t^{(T)}$$

where ω describes a permanent change in the mean function due to the intervention, and

$$S_t^{(T)} = \begin{cases} 1, & \text{if } t \geq T \\ 0, & \text{otherwise} \end{cases}$$

Testing for possible outliers was performed to make sure the outliers do not produce spurious relationships between variables or biased estimates of the effect. Procedures for outliers identification and modelling are described elsewhere.²⁹ More detailed information on the analytic steps are provided in Appendix D-E for the intervention groups and Appendix F-G for the comparison groups.

Univariate time series models were developed for the purpose of intervention analysis under a number of assumptions:

1. Closed system exists in which the event and the response to the event took place, meaning that apart from the noise of the series, only the intervention had exogenous impact on the series.³⁰ All else remains unchanged or external to the system.
2. The noise structure of the model remains unchanged pre- and post- intervention, implying stability of the model. The only changes are assumed to arise from the impact of the intervention under examination.
3. Stable structure of the driver's population exists in terms of gender distribution during the study period.

The number of observations before and after the intervention is sufficient to have the power to detect the effect at the chosen level of significance, according to the method by McLeod and Vingilis³¹. Assuming a step intervention model and a moderate lag-one autocorrelation ($\phi = 0.5$), with $X=108$ months in total and intervention occurring at time $T=70$, the probability of detecting a change of one standard deviation equals 87%. An online power computation program³² was used to compute the power for a two-sided test at 5% significance level.

Maximum likelihood method was used to estimate the model parameters and the effect of the intervention. The time series analyses were performed using R version 3.0.0 (2013-04-03) software.

4.3 Results

4.3.1 Roadside licence suspensions

A decreasing trend was found for the number of roadside licence suspensions for street racing/stunt driving, starting from September 2007, when the law was implemented, until the end of 2011 (Figure 4.2). However, we were unable to make a statistical inference about the trend and causality, as administrative licence suspensions for racing/stunts were introduced under the new law and were applied starting September 2007. If a constant level of enforcement is assumed over time, the downward trend may represent a deterrent effect of the law.

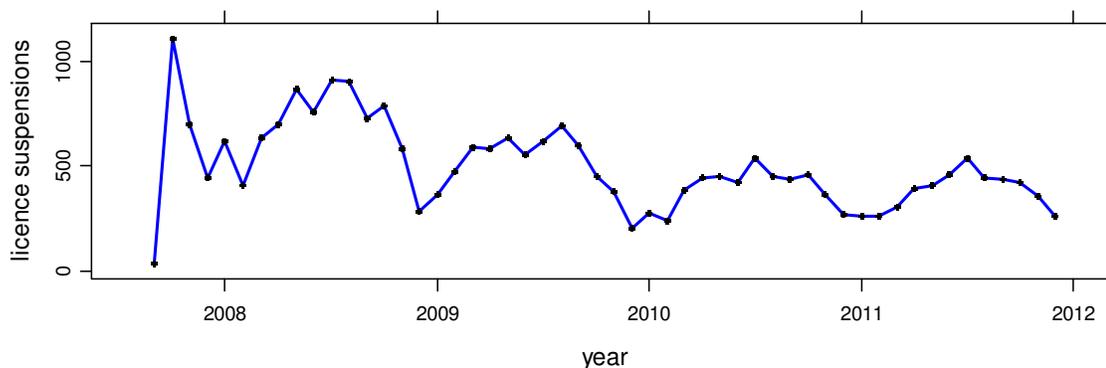


Figure 4.2. Plot of roadside suspensions for racing/stunts for the period of September 2007-December 2011

4.3.2 Highway speed data

Figures 4.3-4.5 show the plots of daily average speed, excluding the peak hours (7-9am and 4-7pm) for three counting stations. Means and standard deviations are reported on the plots for the period before and after the implementation of Ontario street racing and stunt

driving law. In all three plots a slight reduction in the average highway speed was observed, ranging from 1.07 kph (Putnam station) to 3.59 kph (Medonte station). Additionally, in the post-intervention period compared to the pre-intervention period, in all three locations, a relatively large increase in standard deviations was found.

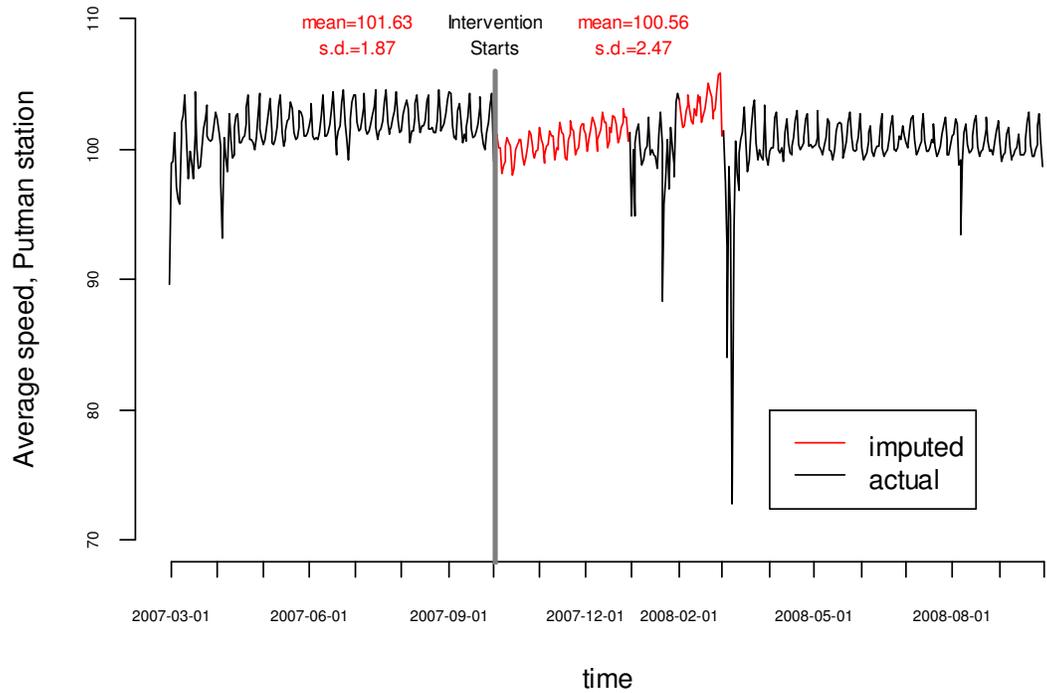


Figure 4.3. Plot of the average highway speed, Putnam counting station (highway 401), for the period of March 2007-September 2008.

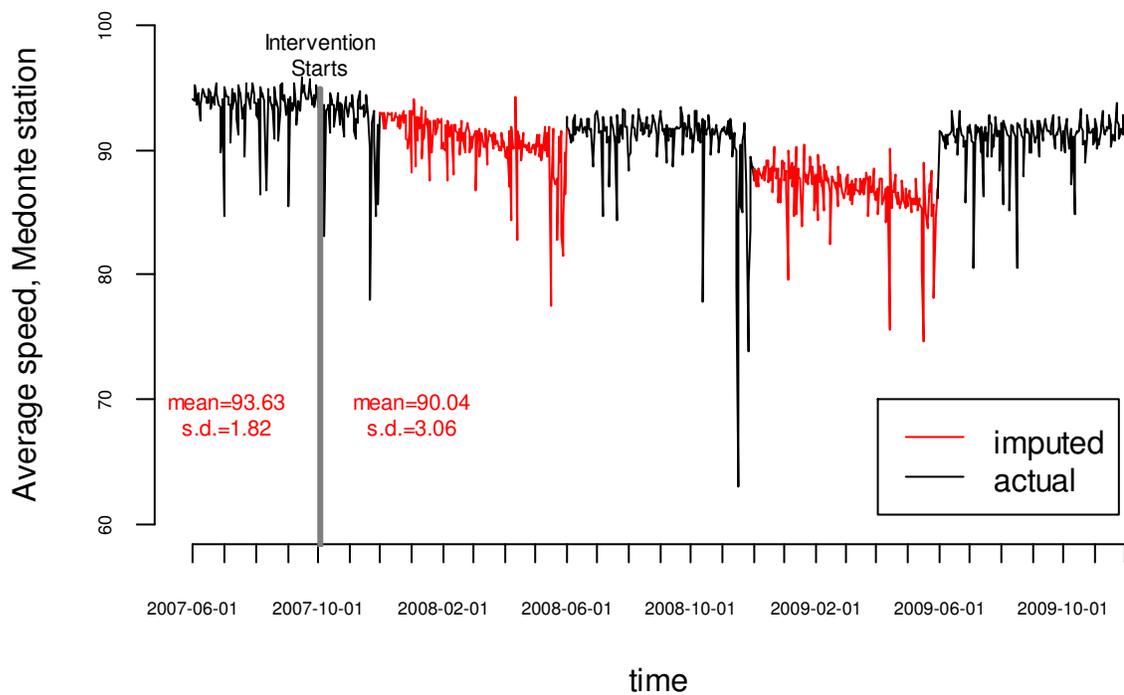


Figure 4.4. Plot of the average highway speed, Medonte counting station (highway 11), for the period of June 2007-November 2009.

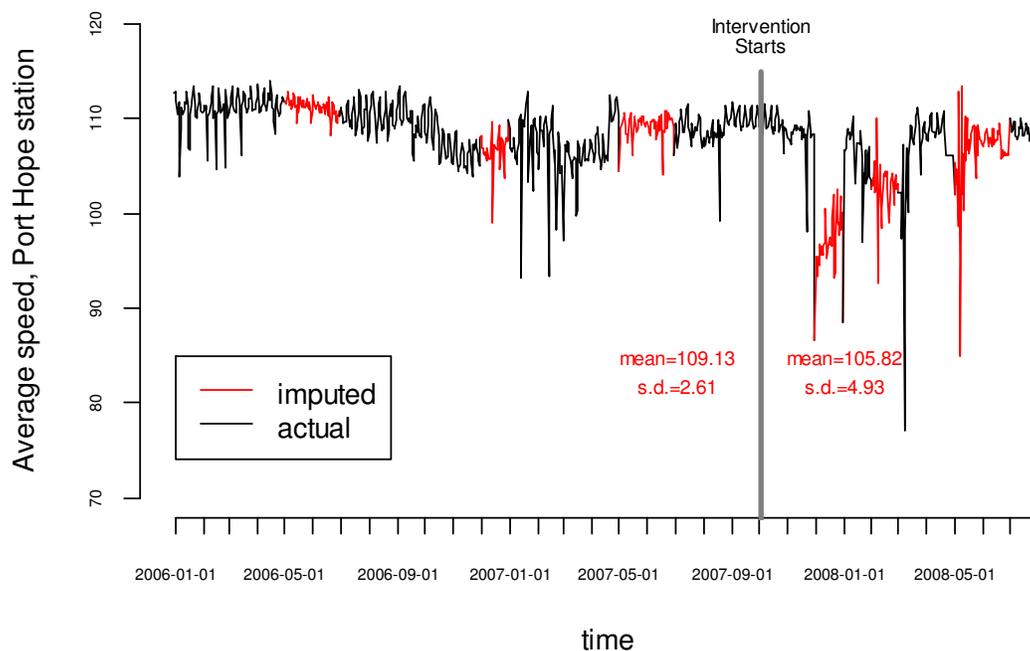


Figure 4.5. Plot of the average highway speed, Port Hope counting station (highway 401), for the period of January 2006-July 2008

4.3.3 Analyses of casualties

a) Casualties resulting from collisions involving vehicles operated by young male drivers.

Casualty time series demonstrated a decrease in the mean of the series from 136.72 (s.d. 29.08) before the intervention to 96.82 (s.d. 21.49) after the law came into effect. The series were tested for stationarity and subjected to interrupted time series analysis. The results of intervention analysis using seasonal ARIMA modelling are shown in Table 4.1.

Table 4.1. Parameter estimates of the intervention model fitted to full casualty series, young male drivers group

Coefficient	Estimate	Std Error
Intercept	136.93	5.23**
AR1	0.244	0.098**
SAR1	0.364	0.101**
Intervention	-37.80	7.64**

Note: * $p < 0.05$ and ** $p < 0.01$. AR1 stands for the first order autoregressive parameter, SAR1 – seasonal first order autoregressive parameter

The effect of the intervention on time series of casualties was found to be negative indicating a statistically significant reduction ($p < 0.001$) in the number of casualties in the post-intervention period compared to the pre-intervention period (Figure 4.6). The red dots on this plot and all subsequent plots represent predicted values based on the model built using pre-intervention data.

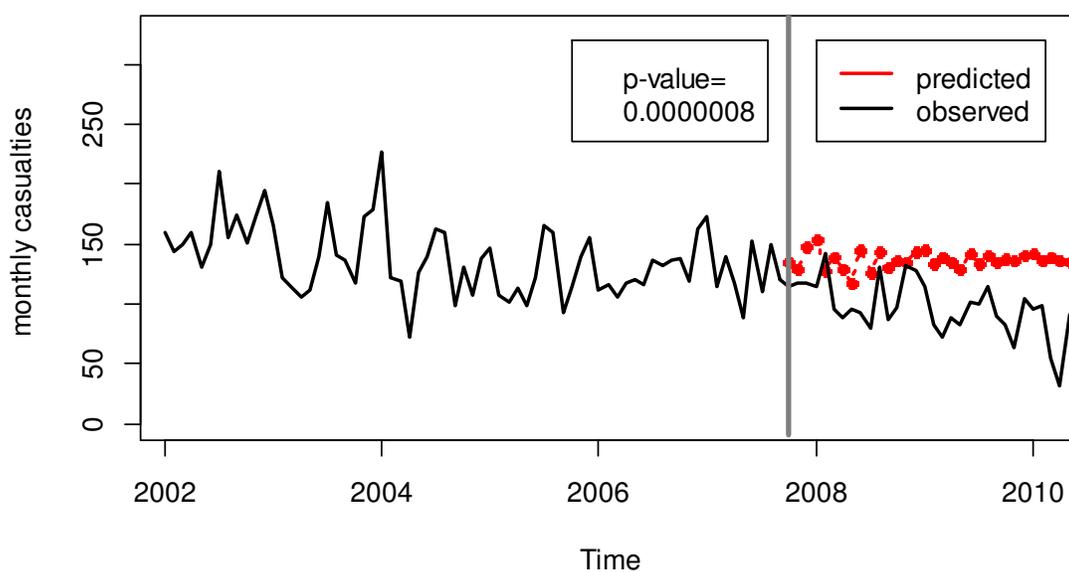


Figure 4.6. Intervention analysis plot of casualties in collisions for vehicles operated by young male drivers, Ontario, 2002-2010

- b) Casualties resulting from collisions involving vehicles operated by mature male drivers

Intervention analysis was performed on log-transformed time series data due to the issue of heteroskedasticity. In the pre-intervention period, mature males casualty series had the

mean 164 (s.d. 74.8), while in the post-intervention period, the mean of the series was 123.85 (s.d. 58.41). Parameter estimates from the intervention model are shown in Table 4.2.

Table 4.2. Parameter estimates of the intervention model fitted to full log-transformed casualty series, mature male drivers group

Coefficient	Estimate	Std Error
Intercept	4.966	0.082**
SAR1	0.694	0.067**
Intervention	-0.199	0.085*

Note: * $p < 0.05$ and ** $p < 0.01$. SAR1 stands for first order seasonal autoregressive parameter.

The negative coefficient of the intervention variable means there was a reduction ($p = .02$) in casualties in the post-intervention period, compared to the pre-intervention period (Figure 4.7).

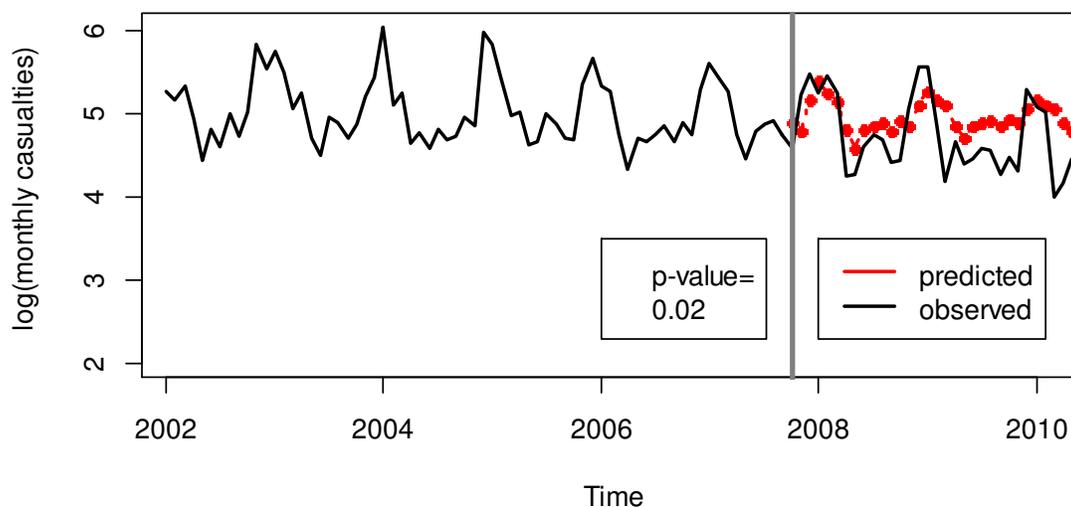


Figure 4.7. Intervention analysis plot of casualties in collisions for vehicles operated by mature male drivers, Ontario, 2002-2010

- c) Casualties resulting from collisions involving vehicles operated by young female drivers (1st comparison group)

In the pre-intervention period, the mean of the series was 60.15 (s.d. 26.13), which decreased in the post-intervention period to 48.36 (s.d. 25.38). The estimated parameters of the model are shown in Table 4.3. No statistically significant effect ($p=0.20$) was found for the intervention variable (Figure 4.8).

Table 4.3. Parameter estimates of the intervention model fitted to full casualty series, young female drivers group

Coefficient	Estimate	Std Error
Intercept	57.97	5.13**
SAR1	0.755	0.058**
Outlier(25 th observation)	48.3	12.6**
Intervention	-5.64	4.65

Note: * $p<0.05$ and ** $p<0.01$. SAR1 stands for first order seasonal autoregressive parameter

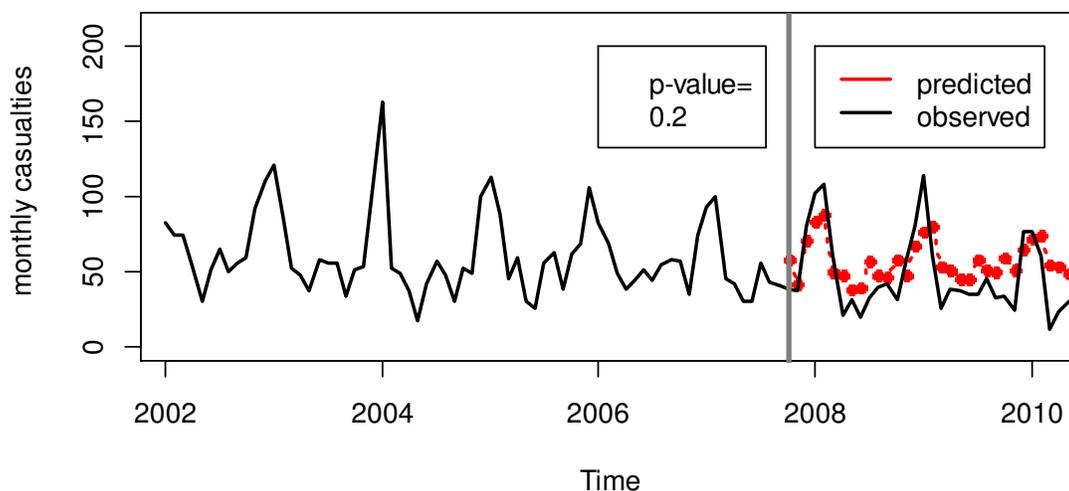


Figure 4.8. Intervention analysis plot of casualties in collisions for vehicles operated by young female drivers, Ontario, 2002-2010

- d) Casualties resulting from collisions involving vehicles operated by mature female drivers (2nd comparison group)

A decrease in the mean of the series was observed from 95.57 (s.d. 65.83) before the intervention to 84.44 (s.d. 60.76) after the intervention. Due to non-constant variance over time, log-transformation of the series was performed. Parameter estimates are shown in Table 4.4. No significant intervention effect was found ($p=0.6$) in the collisions of mature female drivers (Figure 4.9).

Table 4.4. Parameter estimates of the intervention model fitted to full log-transformed casualty series, mature female drivers group

Coefficient	Estimate	Std Error
Intercept	4.310	0.172**
AR1	0.221	0.104*
SAR1	0.440	0.092**
SAR2	0.405	0.096**
Intervention	-0.062	0.113

Note: * $p<0.05$ and ** $p<0.01$. AR1 – first order autoregressive parameter, SAR1 – first order seasonal autoregressive parameter; SAR2 – second order seasonal autoregressive parameter.

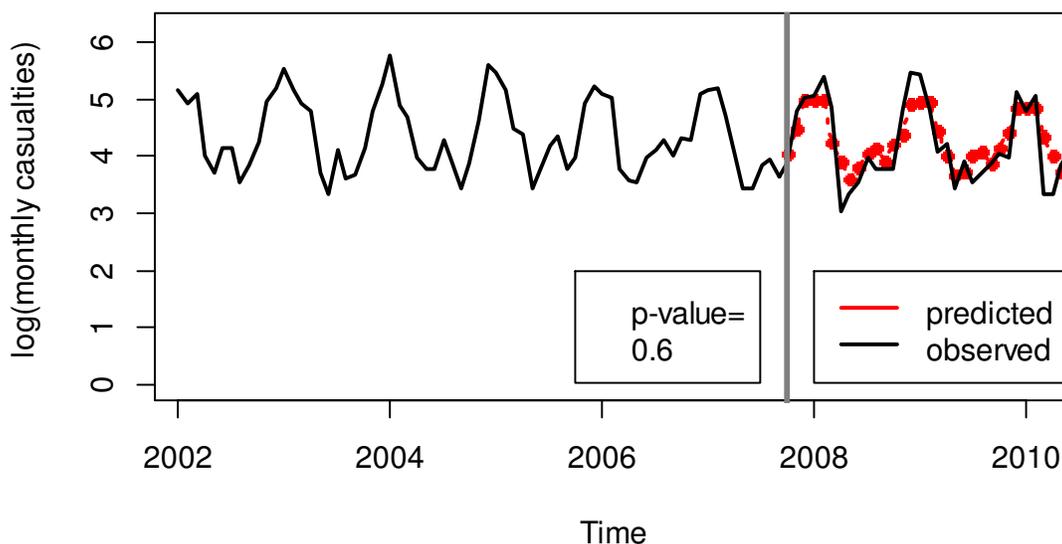


Figure 4.9. Intervention analysis plot of casualties in collisions for vehicles operated by mature female drivers, Ontario, 2002-2010

4.3.4 Total non-speeding-related casualties

The time series plot of total non-speeding-related casualties, as an additional comparator, is shown in Figure 4.10. In the period following 2008, a slight increase in non-speeding-related casualties was observed.

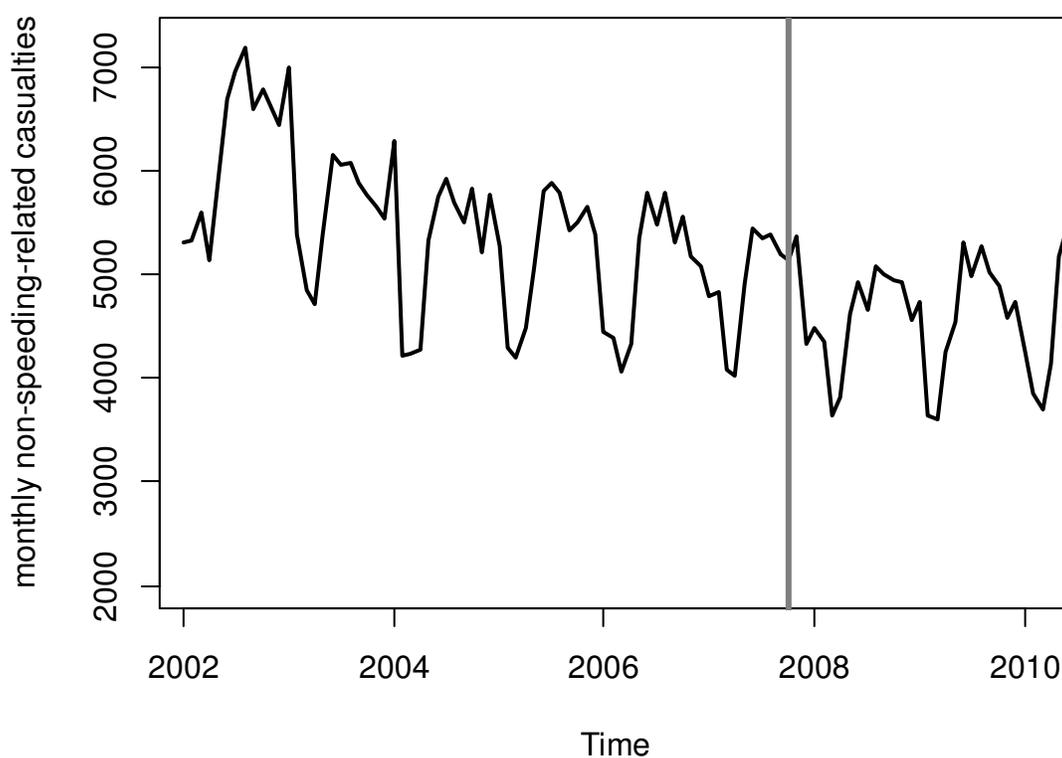


Figure 4.10. Time series plot of non-speeding-related casualties, Ontario, 2002-2010

4.4 Discussion

This study presents a formal evaluation of the impact of Ontario's Street Racers, Stunt and Aggressive Drivers Legislation. The findings support the three hypothesized steps of the causal model of the intervention, namely, evidence of enforcement, a decrease in speed and speed-related vehicle casualty reduction. As hypothesized, we found that the casualties from speeding-related collisions involving young male drivers, the primary intervention group, decreased in the post-intervention period compared to pre-intervention period, and the effect was highly statistically significant ($p < 0.001$). For the

secondary intervention group, mature male drivers, the intervention effect was found to be negative and significant at 5% level ($p=.02$). No effect was found for both comparison groups, young female drivers ($p=0.2$) and mature female drivers ($p=0.6$). The results suggest that the intervention was effective in reducing injuries and fatalities from speeding-related collisions in the intervention groups.

With respect to the implementation of the legal intervention, we found some evidence of the law enforcement, using the monthly counts of administrative licence suspensions as the measure of implementation. A month after the law came into effect, more than 1,000 suspensions occurred under Bill 203. The monthly suspensions were exhibiting gradual decrease over time, with the elements of seasonal patterns – higher number during warm seasons. Even though no conclusion could be made in terms of causality of statistical significance of pre- and post- intervention changes, the plotted data do show that the law was enforced: a licence suspended means a charge was laid. Assuming a constant level of law enforcement over months, it was possible that the decrease in suspensions resulted from the deterrent effect of the legal intervention.

Additionally, our findings show some evidence of potential speed reductions on three provincial highways. Comparing the means of the average daily highway traffic speed in Figures 4.3-4.5, in all three plots the post-intervention average highway traffic speed (excluding peak hours) was slightly lower than the pre-intervention average traffic speed. Simple comparison of the speed means in the pre- and post- intervention periods may not be a strong indicator of deterrence; however, it still provides some insight into possible safer driving practices, which could potentially result in lower number of traffic collisions.

The findings above are supporting deterrence theory that certain, swift and severe sanctions can deter risky driving behaviour, as predicted by the causal model in Figure 1.1, hypothesizing that enforcement of the law through severe punishment would reduce speeding, which would be manifested in a lower average highway traffic speed in the post-intervention period; additionally, speeding-related casualties decreased in both

intervention groups comparing pre- and post- intervention periods, implying improved traffic safety on Ontario roads.

This was the first study to evaluate Ontario's Street Racers, Stunt and Aggressive Drivers Legislation using casualty data and interrupted time series analysis. A few previous studies have evaluated the administrative licence suspension and vehicle impoundment provisions for other offences, such as driving while under influence of alcohol, or driving while suspended. A study by Mann et al.³³ evaluated the early effects of Ontario Administrative Driver's Licence Suspension (ADLS) law of 1996 using interrupted time series analysis with ARIMA modelling. The law required that drivers with high blood alcohol concentration (BAC>80 mg%) or refusing to provide breath sample, would immediately have their licence suspended for 90 days. The outcome measure was the monthly proportion of drivers killed in Ontario with BAC exceeding 80 mg% for the period of 10 years. The intervention was found to be associated with a significant 17.3% reduction in fatalities, suggesting the presence of deterrent effect of the ADLS.

A subsequent study by Asbridge et al.³⁴ evaluated the general deterrent effect of Ontario's ADLS law on total driver fatalities over a 25 months period after the introduction of the law, and used two provinces – Manitoba and New Brunswick as control. Similar to our study, interrupted time series analysis with ARIMA modelling was used. Ontario's ADLS law was associated with the significant reduction in total driver fatalities, while no effect was found in control provinces.

The findings of other studies also support deterrence theory and show that licence suspensions and vehicle impoundments were effective measures against the law violations. For example, a Manitoba-based study from Canada³⁵, evaluated general and deterrent effects of both administrative licence suspension law and vehicle impoundment law, which effects could not be separated. It found a net 12% decrease in drinking driving fatalities and a net 26% decrease in single vehicle night time crashes. Similarly, a number US-based studies reported reduction in alcohol-involved fatalities associated with implementation of immediate administrative licence suspension laws applied to alcohol-impaired driving.³⁶⁻⁴⁰ However, the findings of some other studies did not provide

evidence supporting the effectiveness of immediate licence suspensions laws in improving road safety and reducing overall fatality and injury rates.^{41, 42} To the best of our knowledge, none of the previous studies evaluated the effectiveness of anti-street racing laws in Ontario or other jurisdictions in terms of reduction in fatalities and injuries.

Our study has a number of strengths and limitations. This study was the first to examine formally the effectiveness of Ontario's street racing/stunt driving law on reducing casualties from speeding-related collisions. A very comprehensive and complete data source of collisions originating from the MTO was used. We employed quasi-experimental interrupted time series design as it was not possible to randomly assign violators to different sanctions. The findings of quasi-experimental designs are more vulnerable to alternative explanations than experimental designs, but they can offer fairly strong findings if control groups are used and biases are explored.⁴³

Use of comparison groups in the study allows for the control of the history effects. 'History' refers to the possibility that other external events, occurring during the time period of the intervention, might have explained the observed outcomes.⁴⁴ Although we used a non-equivalent comparison groups due to a comprehensive policy change, such as Ontario's Street Racers, Stunt and Aggressive Drivers Legislation, using young and mature females as comparison groups was our best available choice.

We are aware of another legislative change which could have affected speeding casualties – mandatory truck speed limiter regulation, which was introduced starting January 1, 2009 and fully enforced 6 months after its implementation. However, this intervention could not produce the results similar to the observed street racing/stunt driving intervention effect for the following reasons:

- truck speed limiter regulation was applied only to trucks, not to all vehicles on the roads and highways;
- the population of truck drivers consists mainly of mature male drivers, as the average age of a truck driver was estimated as ranging between 44 and 51^{45, 46} due to fewer young

people entering the industry; thus the reduction in casualties in our primary intervention group (young male drivers) relative to the comparison group (young female drivers) could not be due to truck speed limiters regulation. However, the effect of truck speed limiters on the casualties of mature male drivers could not be completely ruled out.

To check whether the reduction in speeding-related casualties over time was caused by the general downward trend of casualties, we also plotted and analyzed monthly non-speeding casualties from Accident Data System for the same time frame. In the post-law period in Figure 4.10, the increase in non-speeding casualties was observed, which is an opposite trend to the one observed on speeding-related casualties in the post-intervention period (Figures 4.6-4.9).

The use of a proxy variable for identifying street racing/stunt driving casualties was an additional point of limitation. The collision database did not have a special code assigned for racing/stunt driving, and speeding-related codes was the best possible option. Additionally, the relatively short available post-intervention period of time did not allow for the use of more advanced transfer functions than a simple step intervention.

Keeping in mind all the limitations, this study has some important implications. First, our findings provide additional evidence in support of the general deterrent effect of administrative vehicle sanction. Second, this study points to the possibility of behavioural change in response to a legislative intervention. As predicted by our causal model, the implementation of Ontario's Street Racers, Stunt and Aggressive Drivers Legislation may have led to safer driving practices of Ontario drivers, resulting in fewer casualties, measured as a sum of injuries and fatalities of drivers and accompanying passengers.

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Chapter 5

5 General discussion and conclusions

5.1 Studies' findings in the context of classical deterrence theory

The purpose of this study was a process and outcome evaluation of the deterrent effect of Ontario's Street Racers, Stunt and Aggressive Drivers Legislation which came into effect in September 2007. The evaluation was performed following the steps of the causal model in Figure 5.1. Due to limited resources and data availability, all components of causal model could not be examined. The focus of this thesis was on three components, which included police enforcement (*implementation*), measured as administrative roadside licence suspensions, a change in speeding on the provincial highways (*intermediate outcome*) as well as decrease in both extreme speeding convictions and casualties (*criterion outcomes*). When examining the changes in both criterion outcomes, we tested deterrence theory, which was described in detail in Chapters 2-4.

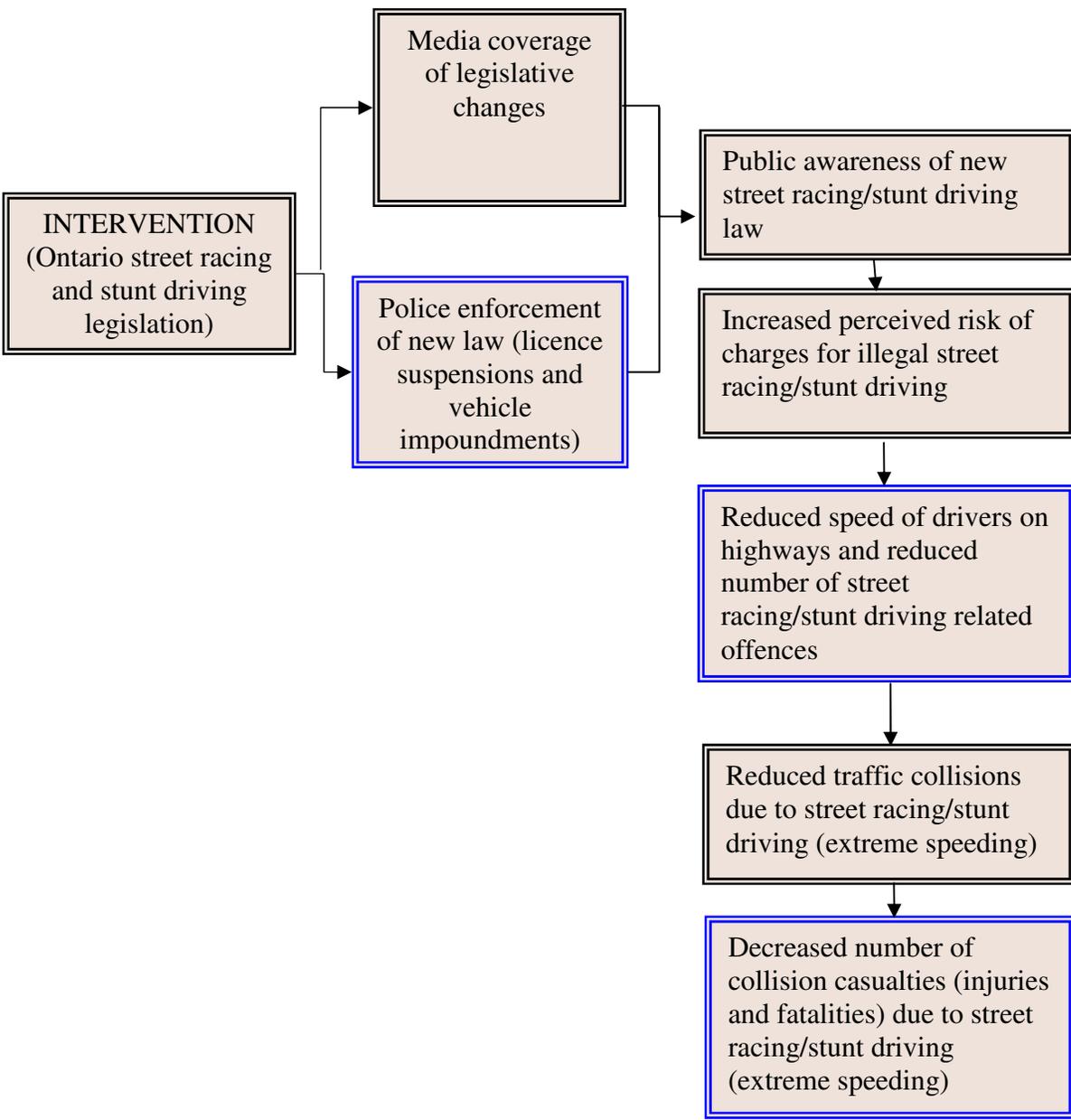


Figure 5.1. Examined elements of causal model of Ontario’s Street Racers, Stunt and Aggressive Drivers Legislation

Deterrence theory posits that sanctions will be effective in changing behaviour “to the extent that they are perceived as being certain, swiftly applied, and severe” (p.93).¹ Here certainty refers to the probability of punishment, severity reflects the size of punishment, and swiftness refers to how quickly punishment is administered. When these three primary characteristics of sanctions are appropriately perceived, they have the potential of reducing illegal driving activities.¹ Two types of deterrence (general and specific) is presented in earlier research. Within traffic safety literature, general deterrence refers to the deterrent effect of legal sanctions on those drivers who were not sanctioned, but who were presumably aware of the punishment for a particular driving behaviour. Specific deterrence refers to the deterrent effect of punishment on sanctioned drivers whose prior experience with punishment and fear of new punishment are expected to reduce their future traffic law violations.¹

In Chapter 3, we found a significant reduction ($p=.004$) in the number of extreme speeding convictions for speeding 50 kph and over the posted speed limit in the intervention group (male drivers), comparing the series before and after the intervention. No significant change was found for the comparison group (female drivers). Similarly, in Chapter 4, we found that the casualties from speeding-related collisions involving young male drivers and mature male drivers, primary and secondary intervention groups, decreased in the post-intervention period compared to pre-intervention period, and the effect was statistically significant at 5% level, ($p<0.001$ and $p=.02$, respectively). No effect was found for the comparison groups, young female drivers ($p=0.2$) and mature female drivers ($p=0.6$). The findings of both studies suggest that the examined legal intervention was effective in deterring speeding convictions and speeding-related casualties among males. Thus, the significant reduction in extreme speeding convictions and in collision casualties in the intervention groups provide some evidence supporting the general deterrence theory applied to traffic safety research. Ontario’s Street Racers, Stunt and Aggressive Drivers Legislation has not been previously evaluated; however a number of earlier studies tested deterrence theory evaluating the effectiveness of other

legal interventions, such as vehicle actions for drinking-driving offences, implemented in various jurisdictions.

A number of previous studies used econometric techniques of time series for testing the hypothesis of classical deterrence theory with the purpose of evaluating the effectiveness of legal interventions, using fatalities or casualties data as outcome variables. Ross^{2, 3} reviewed the studies on the effectiveness of drunk driving legislation in several developed countries including Scandinavia, Europe and North America, and conducted interrupted time series analyses on the indicators of drunk driving. He concluded that the evidence of deterrence was present, which manifested in the reduction of alcohol-related fatalities after the implementation of the legislation, but the deterrent effect was found to be temporary. He described that the size of the deterrent effect was larger in those jurisdictions, where the law was “more controversial, more publicized, and more newsworthy” (p.69).² He speculated in this review that the initial deterrent effect and its later decay could be explained by initial overestimation of the probability of punishment by the drivers caused by high publicity. As drivers learned through their experiences that the risk of punishment is low, the deterrent results subsided. In a later review on a similar topic Nichols and Ross¹ found that licence actions, including suspension and revocation, were more effective in deterring drinking drivers, compared to other sanctions (i.e. fines).

Contrary to findings of Ross, Votey^{4, 5}, who performed both time series analyses and cross sectional simultaneous equation estimation using collision data from Scandinavian countries, reported that the deterrent effect of the legal intervention resulted in the reduction of alcohol-related fatalities, after controlling for distance driven, alcohol consumption and other control variables. He also found that the deterrent effect was persistent rather than transitory. Similar findings were reported in the re-examination of the British Road Safety Act of 1967 by Phillips, Ray and Votey⁶, for which Ross² earlier found short-term deterrent effects. Using the Box-Jenkins interrupted time series approach, the study results showed that there was a significant reduction in monthly road casualties as a result of the law and that the intervention effect was small in size, but persistent.

The results of more recent studies, using a similar methodological approach to this thesis for evaluating the impact of drinking driving legislation, were in line with the earlier research. For example, studies by Mann et al.⁷ and Asbridge et al.⁸ evaluated the early effects of Ontario's Administrative Driver's Licence Suspension (ADLS) law of 1996 using interrupted time series analysis with ARIMA modelling. The law required that drivers with high blood alcohol concentration (BAC>80 mg%) or refusing to provide breath sample, would immediately have their licence suspended for 90 days. Ontario's ADLS law was associated with the significant reduction in alcohol-related fatalities and total driver fatalities, respectively, suggesting the presence of a deterrent effect of this legal intervention. Similarly, a number US-based studies reported a reduction in alcohol-involved fatalities associated with implementation of immediate administrative licence suspension laws applied to alcohol-impaired driving.⁹⁻¹³

However, not all evaluation studies provide uniformly deterrence results. Some studies on drunk driving legislation,^{14, 15} using various statistical methodologies, did not provide evidence supporting the effectiveness of immediate licence suspensions sanctions in improving road safety and reducing overall fatality and injury rates.

The main findings of this thesis provide evidence supporting *general* deterrence within the framework of classical deterrence theory. Additionally, a few other thesis findings provide indirect support for the validity of the main conclusions. First, a decreasing trend was found for the number of roadside licence suspensions for street racing/stunt driving, starting from September 2007, when the law was implemented, until the end of 2011. It was not possible to make a statistical inference about the trend and causality, since suspensions for racing/stunt driving were implemented as a part of a new legislative initiative. However, assuming a constant level of law enforcement over time, this trend could possibly be due to deterrent effect of the legislation.

Second, comparing the means of the average daily highway traffic speed, measured on the three locations, a slight decrease was found in the post-intervention period relative to the pre-intervention period. This small decrease was observed on all three descriptive time series plots. Although due to data limitations, analytical statistical methods were not

employed in performing the comparisons of the means, the findings may still suggest the possibility of reduced speeding after the implementation of the law, representing safer driving practices and, possibly, general deterrence.

Lastly, I found that in the population of drivers, who had their licences suspended on the spot for street racing/stunt driving, young and mature male drivers were the largest groups, representing 1.21% and 0.37% per licensed drivers, respectively. These findings were consistent with the previous research on demographics of street racers and stunt drivers, which also found that the incidence of these dangerous activities was higher among males, especially young ones.¹⁶⁻¹⁹ In terms of recidivism of offenders, it was found that the majority of suspended drivers (88.5%) violated the street racing/stunt driving law once and did not repeat it during the period of time under study, while 11% of suspended drivers violated street racing law 1-2 times after the first suspension and 0.5% of suspended drivers were repeat violators with 4 or more suspensions in total. The fact that the large proportion of suspended drivers (88.5%) did not repeat street racing/stunt driving violation within the period of the study, suggests that licence-related legal sanctions may have caused a *specific* deterrent effect, as defined above.

5.2 Study limitations

The first limitation of this research is that it did not measure all components of the causal model using analytic statistical techniques, due to data and resource limitations. The studies integrated within this thesis focused mainly on impact evaluation with a small process evaluation component. Ideally, these studies should have been preceded by measuring the level of public awareness of the law. It was assumed here that individuals were knowledgeable of the new law and legal sanctions for the street racing and stunt driving offences. However, it may be possible that some violators, i.e. first time offenders, were not knowledgeable prior to their conviction. MTO implemented a number of activities in publicizing Ontario's street racing law, such as educational campaigns targeting secondary and high school students, development and distribution of brochures on speeding and stunt driving, partnership with multiple community stakeholders to raise awareness of stunt driving and street racing, presenting information

on the new legislation in the Driver's Handbook, electronic publications and news releases in MTO's website. Additional publicizing efforts included a video produced by Canadian Autosport Clubs of Ontario which promoted safe racing on race tracks as well as the installation of road signs in 'hotspots' on roads and highways throughout the province which inform drivers about legal sanctions for speeding 50 kph over the speed limit.²⁰

Second, the assumption was made that other than the legal intervention, all external factors remained relatively stable or constant. We acknowledge the possibility of the change in the age and gender mix within the population of drivers over time. Young male street racers were found in earlier studies to be 'maturing out' from these risky driving activities when reaching mid-20s.^{17, 21-23} It could be possible that over time heavy offenders matured out of racing, while new young drivers entering the drivers' population had less interest in racing or extreme speeding. Looking at the age and gender characteristics of drivers involved in speeding-related collisions from the Accident Data System dataset, which was used for the second study, on average, in the pre-intervention period, 12.9% of drivers were young males, and the number declined slightly to 11.8% in the post-intervention period. It is possible that this change in the collisions of young male drivers is due to less driving by young people. A study by University of Michigan Transportation Research Institute reported that in several countries, including the USA (time frame of 1983-2008) and Canada (time frame of 1999-2009), there was a decrease in young drivers and an increase in older drivers.²⁴ Moreover, during economic recessions people, especially young ones tend to drive less, since fewer people are employed.²⁵ One of the threats to validity, selection bias, may occur, when the makeup of the intervention group changes at the time of intervention. The numbers reported above (1% decrease in young male speeding-related collisions) suggests that age-gender mix in the primary intervention group did remain relatively stable comparing pre- and post-intervention periods. Thus, selection bias may not an issue in this study. An additional assumption I made was that a constant level of law enforcement of the new law had occurred, although it is quite possible that enforcement over time decreased as policing priorities may have changed.

Third, no multigroup analyses were performed with the simultaneous estimation of the intervention effect in the intervention and in the comparison groups. Within-group and between-groups comparisons were made using interrupted time series analyses in two preceding chapters. The possibility of Type II error could not be completely ruled out.

Additional limitations included use of a proxy variable to identify street racing-related collisions and use of a comparison group which was exposed to the same legislative intervention as an intervention group. As described in two preceding chapters, these were the best possible available options for evaluating the impact of anti-street racing legal intervention in Ontario. Moreover, the collision data represented only casualty collisions reported to the police and trends may have been different for collisions that were not reported to police.

Despite these listed research limitations, the studies have some important implications. These studies were the first to provide a formal evaluation of Ontario's street racing and stunt driving legislation in terms of a process and outcome evaluation. We used a quasi-experimental interrupted time series design in both studies. Intervention analysis using time series data with ARIMA modelling is considered a fairly strong statistical method with high degree of internal validity.^{26, 27} This approach has been widely employed in previous studies examining policy initiatives, including road safety research. The findings of our studies provide additional evidence in support of the general deterrent effect of administrative vehicle sanctions. Examination of the overall trend of non-speeding related casualties, which exhibited a different pattern compared to speeding-related casualties, provided greater support to the validity of the findings. Also, the findings suggest the possibility of a behavioural change in response to a legislative intervention. Reduced speed on the highways and decreasing trend of roadside licence suspensions may have been male drivers' responses to the legal intervention.

5.3 Future research

The studies presented in this thesis can be considered as 'preliminary' evaluation studies, utilizing the simplest forms of the transfer functions in the intervention analyses due to limited post-intervention data availability. From the aggregate or macro perspective, in

the future, when a larger number of post-intervention years of data becomes available, confirmatory studies can potentially be conducted using longer time series and more complex transfer functions.

From the micro perspective, future studies should examine the components of the causal model which were not investigated as a part of the scope of work of this research. Using individual-level data, the level of public awareness of Ontario's street racing law can be estimated. Additionally, future studies can compare the time to next street racing/stunt driving or extreme speeding conviction before and after the intervention, using analytic techniques of survival analysis. Moreover, studies involving convicted violators of this law can investigate their personal experiences of specific deterrence, the factors associated with street racing/stunt driving in the Canadian perspective, perceived risk of sanctions, perceived severity of legal punishment and the degree of law compliance in post-conviction period.

5.4 Summary and conclusions

In summary, Ontario's Street Racers, Stunt and Aggressive Drivers Legislation, implemented in 2007, seemed to be effective in deterring the illegal risky driving behaviours under examination of male drivers. This conclusion was reached due to an estimated reduction in the post-intervention period of both *criterion outcome* measures, which included extreme speeding convictions and speeding-related collision casualties. A general deterrent effect of the law resulted in improved road safety in the province. The results of this study have a potential of informing MTO and legislative authorities in other jurisdictions on the achieved effects of the law.

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Appendices

Appendix A: Time series of male drivers' convictions for speeding 50 kph and higher over the speed limit

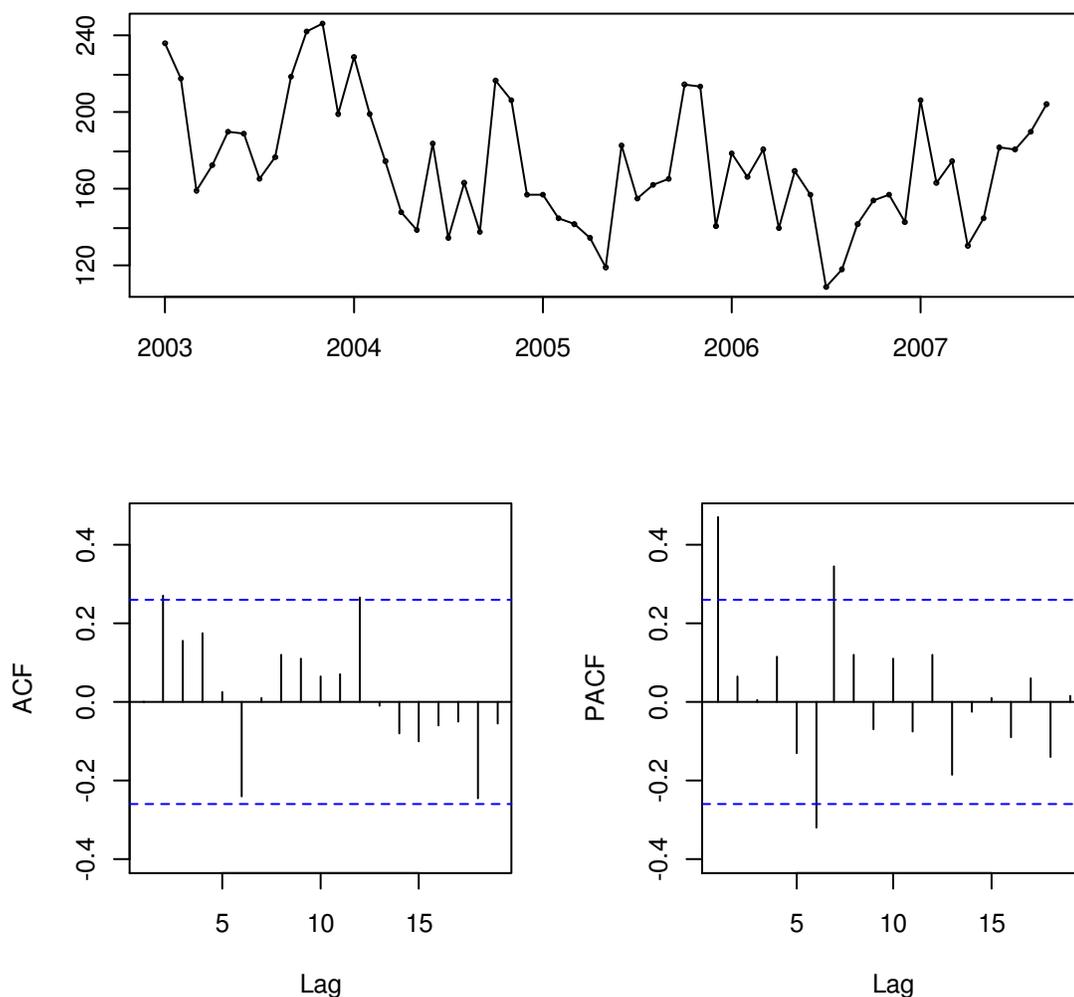


Figure A.1. Time series plot, ACF and PACF of pre-intervention series for male drivers convictions for exceeding the speed limit for 50+kph over the posted speed limit

The series were found to be stationary, based on autocorrelation functions plots and the results of augmented Dickey-Fuller test of stationarity (not shown). No differencing was required. ACF and PACF of pre-intervention series from Figure A.1 were used as a starting point to determine the parameters of the model. The best model was chosen

based on lowest Aikake information criterion (with correction) and model adequacy, meaning that the model passed all diagnostic tests for residual analyses. Residuals were expected not to be autocorrelated, be random and follow normal distribution. The most suitable and parsimonious model, which passed the diagnostics tests for the series under investigation, was found to be SARIMA(0,0,3)(1,0,0)₁₂. The results of the model diagnostics are shown in Figure A.2.

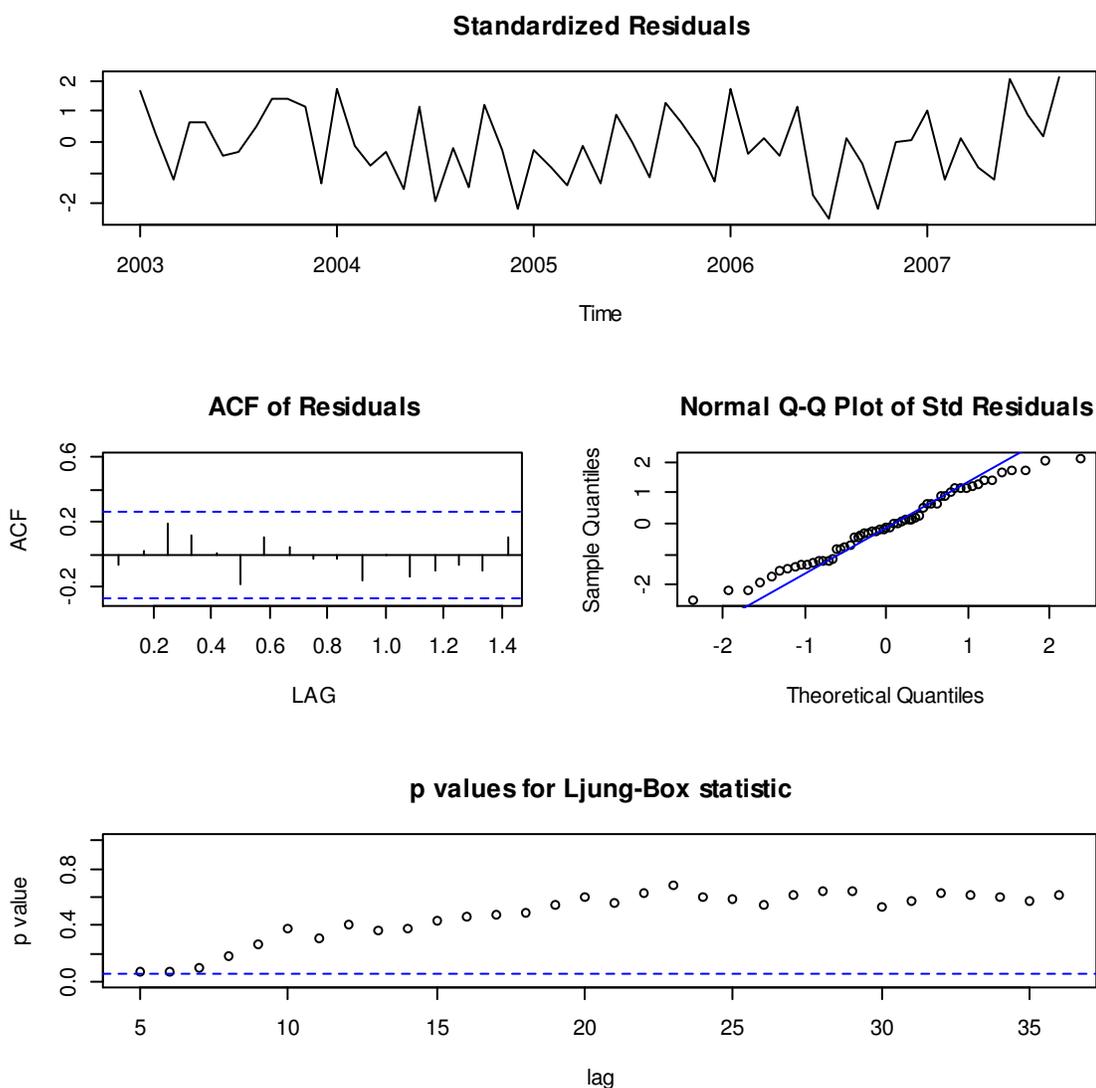


Figure A.2. Model diagnostics for SARIMA(0,0,3)(1,0,0)₁₂

ACF residual plots of the fitted model did not show any significant spikes. For the first 8 lags the results of Ljung-Box test did not reject the hypothesis of error term randomness

(p-value = 0.175). Shapiro-Wilk test results (p-value= 0.233) and residual Q-Q normality plot suggested that residuals were normally distributed. Diagnostics results suggested that the residuals followed white-noise process.

Appendix B: Time series of female drivers' convictions for speeding 50 kph and higher over the speed limit

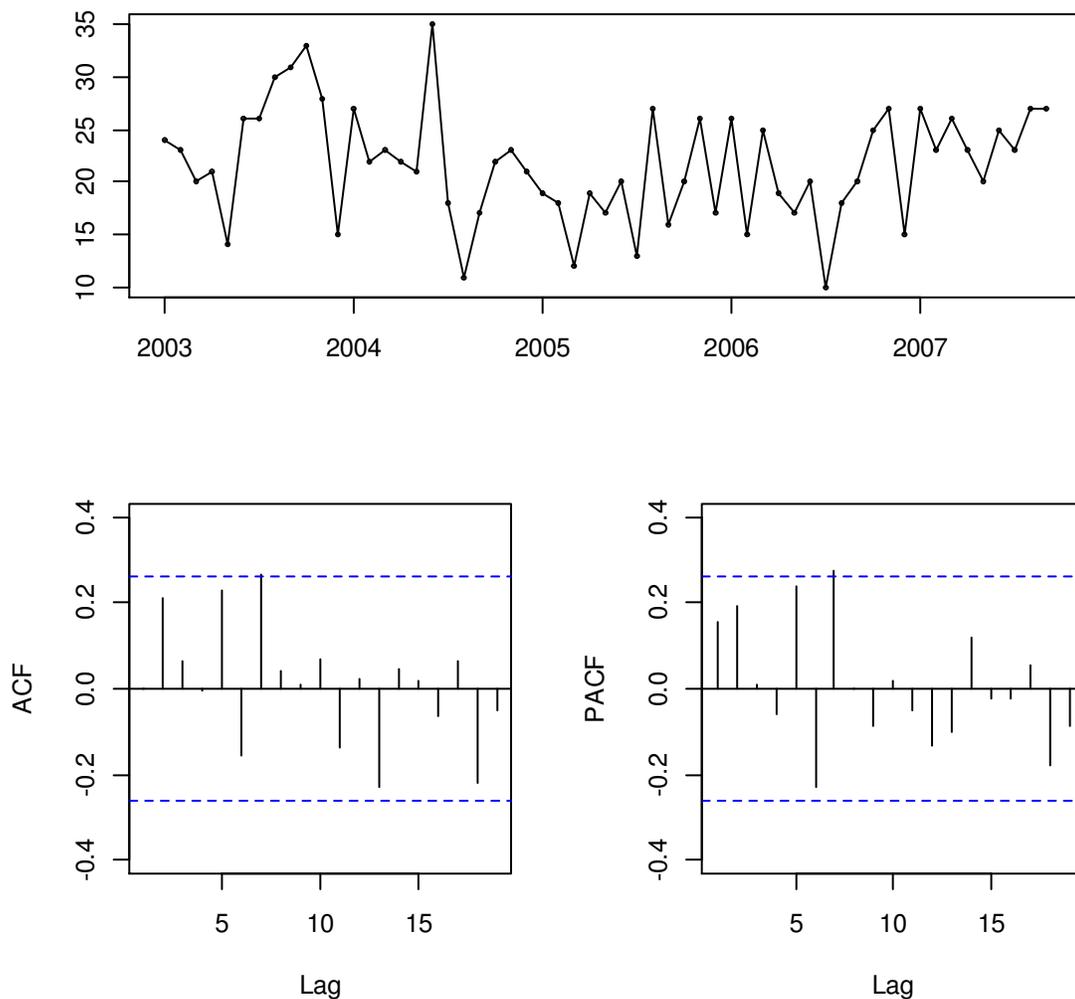


Figure B.1. Time series plot, ACF and PACF of pre-intervention series for female drivers convictions for exceeding the speed limit for 50+kph over the posted speed limit

The results of stationarity tests (not shown) and exploratory analyses of ACF and PACF showed that series were trend stationary. No seasonal pattern was observed in the plot.

Among multiple fitted models, only one model – ARIMA(2,0,2) was found to fit the data relatively well. Diagnostic tests are shown on Figure B.2.

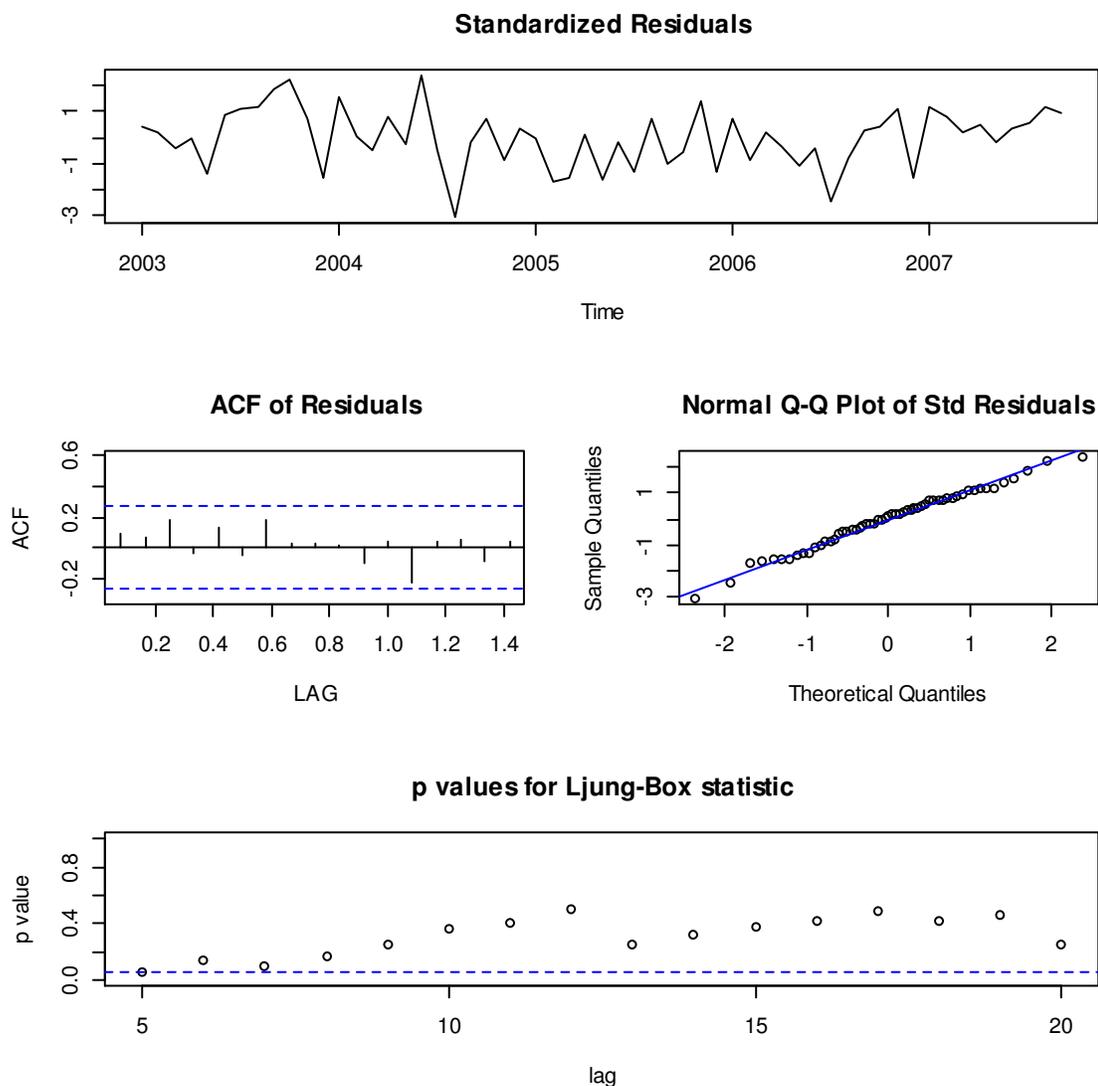


Figure B.2. Model diagnostics for ARIMA(2,0,2)

Residual analyses of fitted pre-intervention ARIMA (2,0,2) model suggested that residuals followed white noise process. Using Ljung-Box test the hypothesis was tested whether the first 8 autocorrelations were significantly different from than what would be expected from a white noise process. The result (p-value = 0.168) for the Ljung-Box group test of autocorrelations suggested that the residuals were not different from a white noise series.

Note, that the plot of predicted and observed series in post-intervention period depicted in Figure 3.3 suggests no systematic difference. The series of predicted values follow a line due to absence of seasonal component in ARMA model. The forecasted series show the tendency to the mean of the series if there is no differencing and the mean is non-zero, which is the case with the analyzed series.¹

Reference:

1. Hyndman RJ, Athanasopoulos G. Forecasting: principles and practice 2013 [11.05.2013]; Available from: <http://otexts.com/fpp/>.

Appendix C: Imputation of missing values using ‘optimal’ method

We imputed missing time series with a two-step process. First, for the hourly average speed missing data, we used PROC EXPAND procedure in SAS, which interpolates missing time series based on the preceding nonmissing data. By default, PROC EXPAND procedure fits cubic spline curves to the nonmissing values of variables to form continuous-time approximations of the input series. Output series are then generated from the spline approximations. After imputations, hourly data was aggregated to a daily average speed data excluding the peak hours (7-9am and 4-7pm).

Second, large chunks of missing data were imputed using the method developed by Dr. Weerasinghe, described in detail elsewhere.¹ The main idea behind this applied method is forecasting time series using the available piece of data before the missing values, then backcasting the time series using the next available piece of data, and finding the average between forecasted and backcasted values. The averaged forecast errors are accounted for as well, as these are added to the average values obtained. The forecast errors were computed from fitting the models to the series before and after the missing data.

Reference:

1. Weerasinghe S. A missing values imputation method for time series data: an efficient method to investigate the health effects of sulphur dioxide levels. *Envirometrics* 2010; 21:162-72.

Appendix D: Autocorrelation functions and model diagnostics for time series of young male casualties

Based on ACF and PACF of the pre-intervention series (Figure D.1) as well a stationarity test (not shown), the series were found to be stationary. Among a few possible models, the chosen model was SARIMA(1,0,0)(1,0,0)₁₂, based on the principles of parsimony and the best diagnostics (Figure D.2)

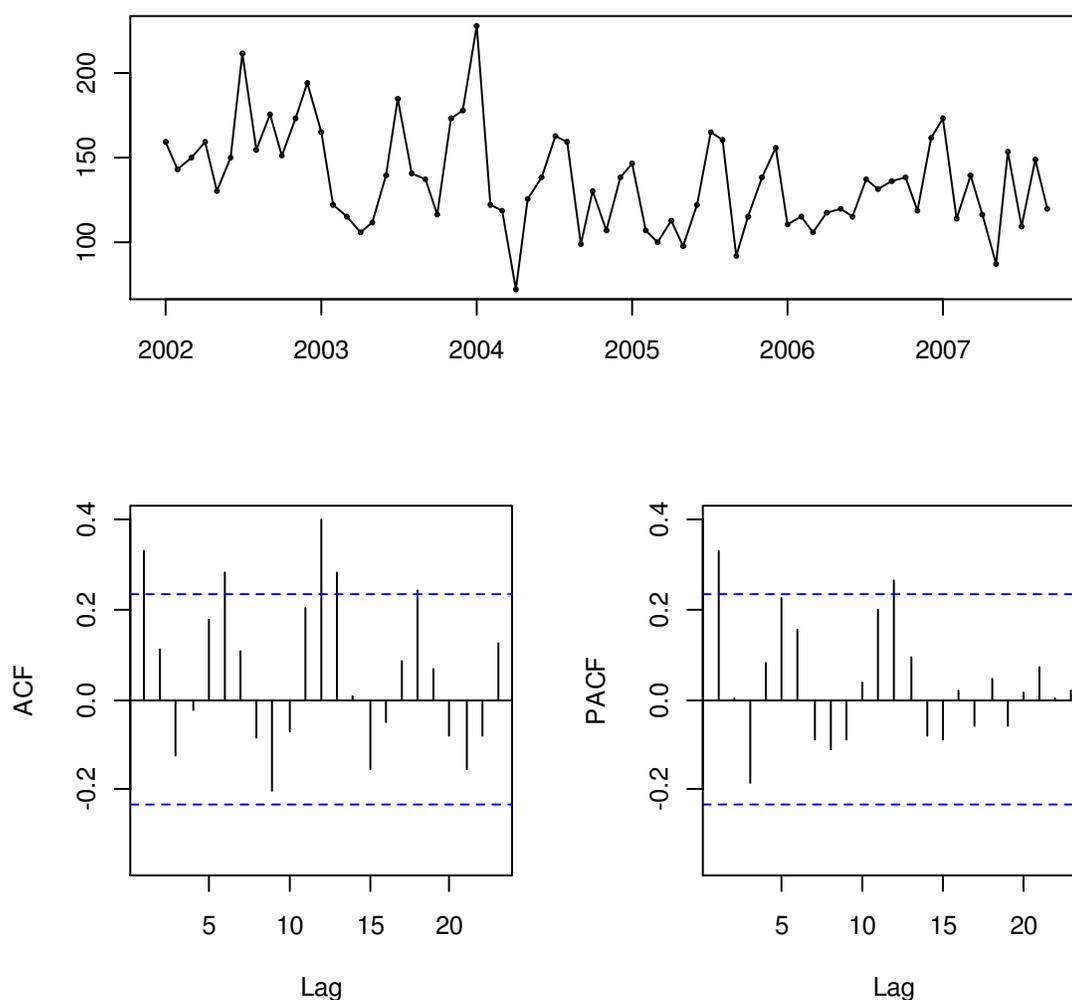


Figure D.1. Time series plot, ACF and PACF of pre-intervention series of casualties, young male drivers

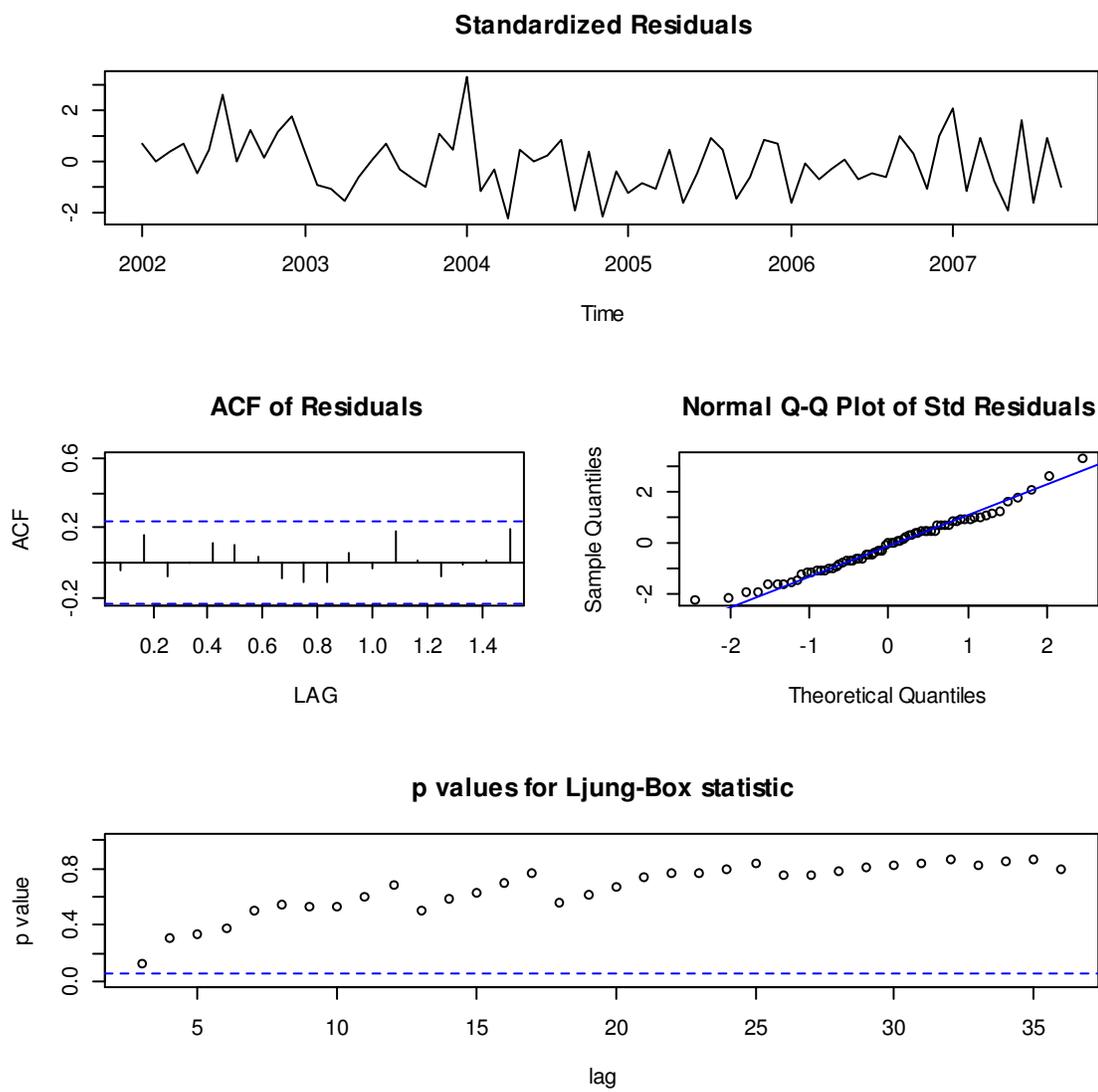


Figure D.2. Model diagnostics from fitting SARIMA (1,0,0)(1,0,0)₁₂ model to the series of casualties, young male drivers group. Residuals from fitted model are normally distributed, no significant spikes are observed on ACF of Residuals, Ljung-Box test p-values are above the critical value. Errors are not different from white noise.

Appendix E: Autocorrelation functions and model diagnostics for time series of mature male casualties

Figure E.1 shows the time series plot of mature male drivers casualties due to exceeding the speed limit and speeding too much for conditions.

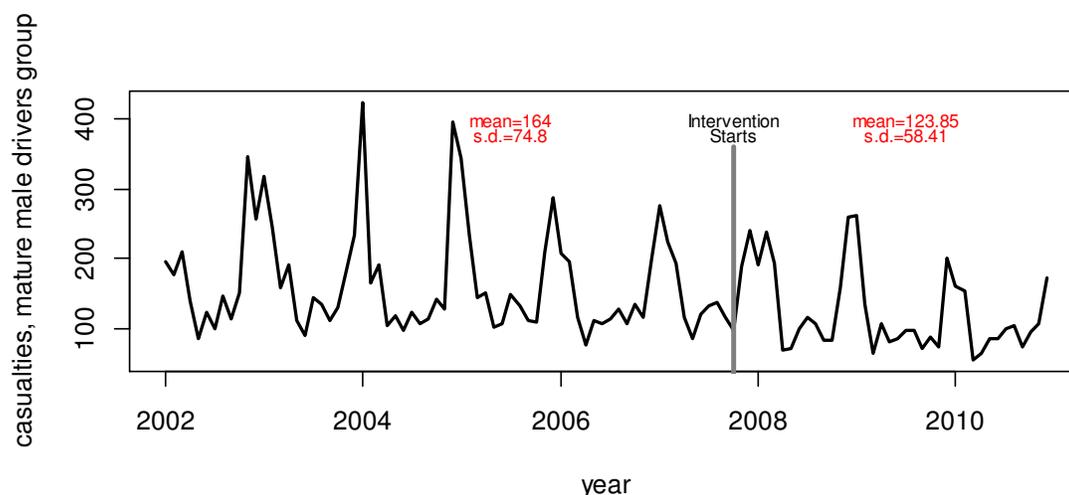


Figure E.1. Time series plot of the casualties from the accidents involving the vehicles of mature male drivers who were speeding over the limit or speeding too fast for conditions, Ontario, 2002-2010

The variance is decreasing over time. Original time series required log-transformation for smoothing the variance. Based on ACF, PACF and stationarity test (not shown), the log-transformed series were found to be stationary. The best model that was chosen for analysis was SARIMA (0,0,0)(1,0,0)₁₂. The model passed all diagnostic tests. Shapiro-Wilk test results (p-value = 0.640) showed that the residuals from the fitted model were normally distributed.

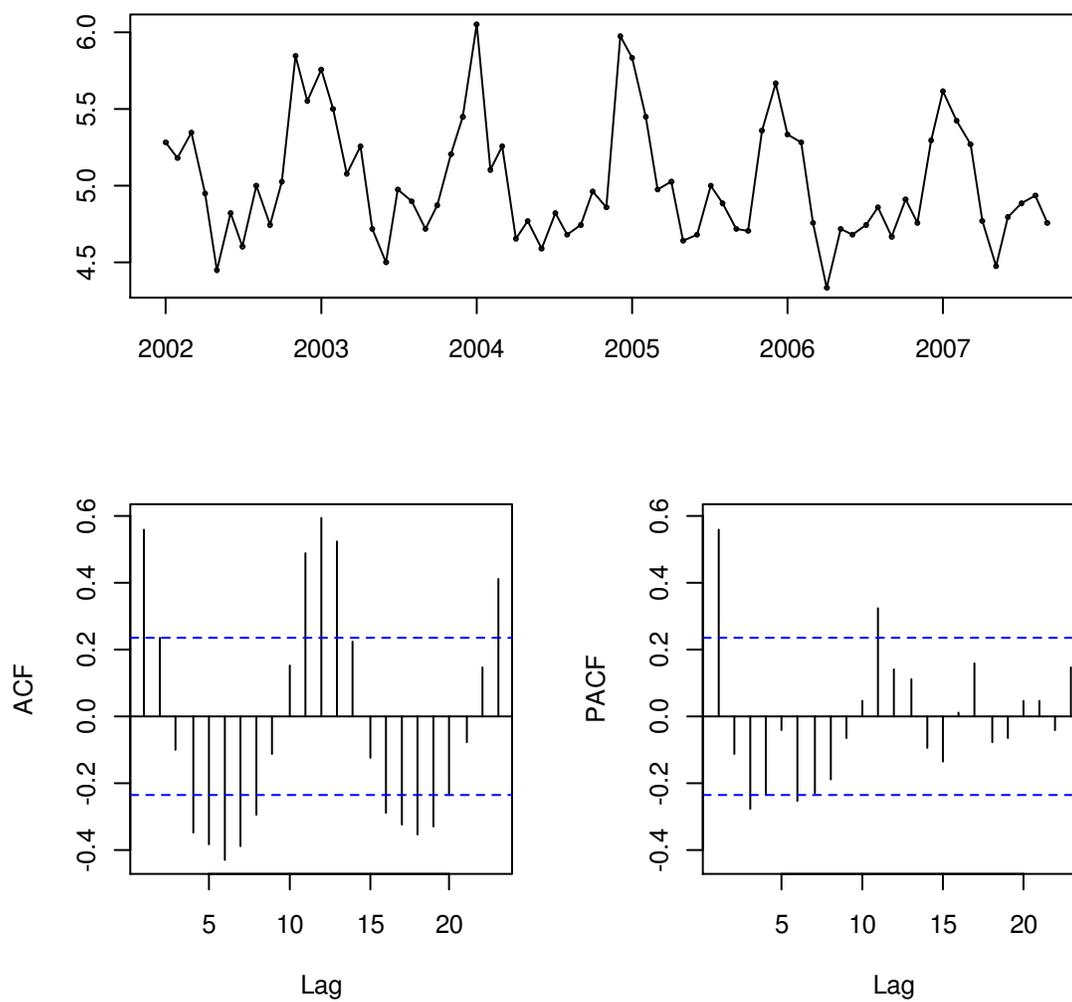


Figure E.2. Time series plot, ACF and PACF of log-transformed pre-intervention series of casualties, mature male drivers

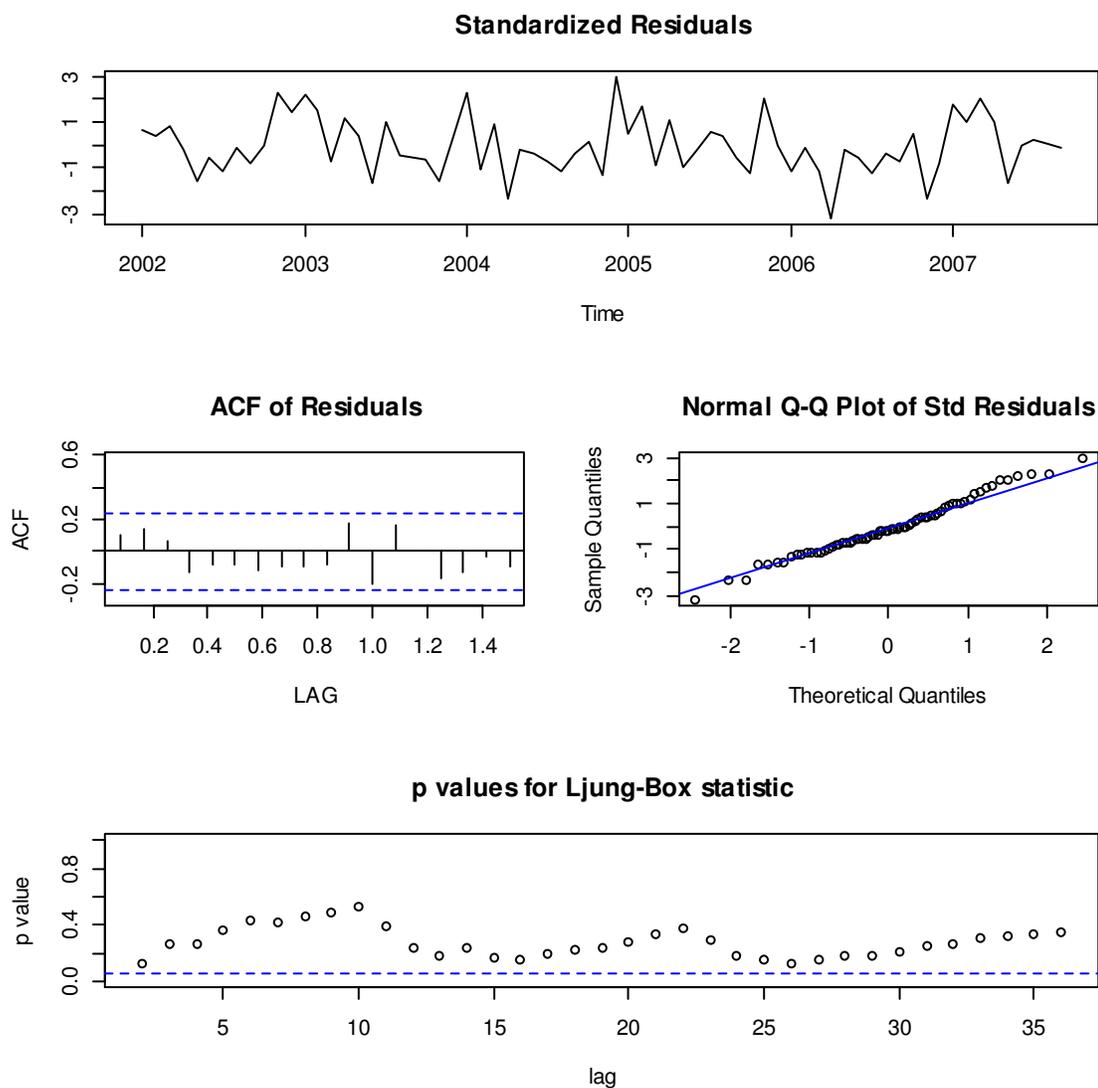


Figure E.3. Model diagnostics from fitting SARIMA (0,0,0)(1,0,0)₁₂ model to the series of log(casualties), mature male drivers group. Residuals from fitted model are normally distributed, no significant spikes are observed on ACF of Residuals, Ljung-Box test p-values are above the critical value. Errors are not different from white noise.

Appendix F: Autocorrelation functions and model diagnostics for time series of young female casualties

The series were found to be stationary based on autocorrelation functions and Augmented Dickey-Fuller test. The selected model was SARIMA(0,0,0)(1,0,0)₁₂. Fitted model passed the diagnostic tests. One outlier was identified and accounted for in the model. After incorporating the outlier into the model, the residuals from the fitted model were found to be normally distributed (Shapiro-Wilk test p-value =0.231)

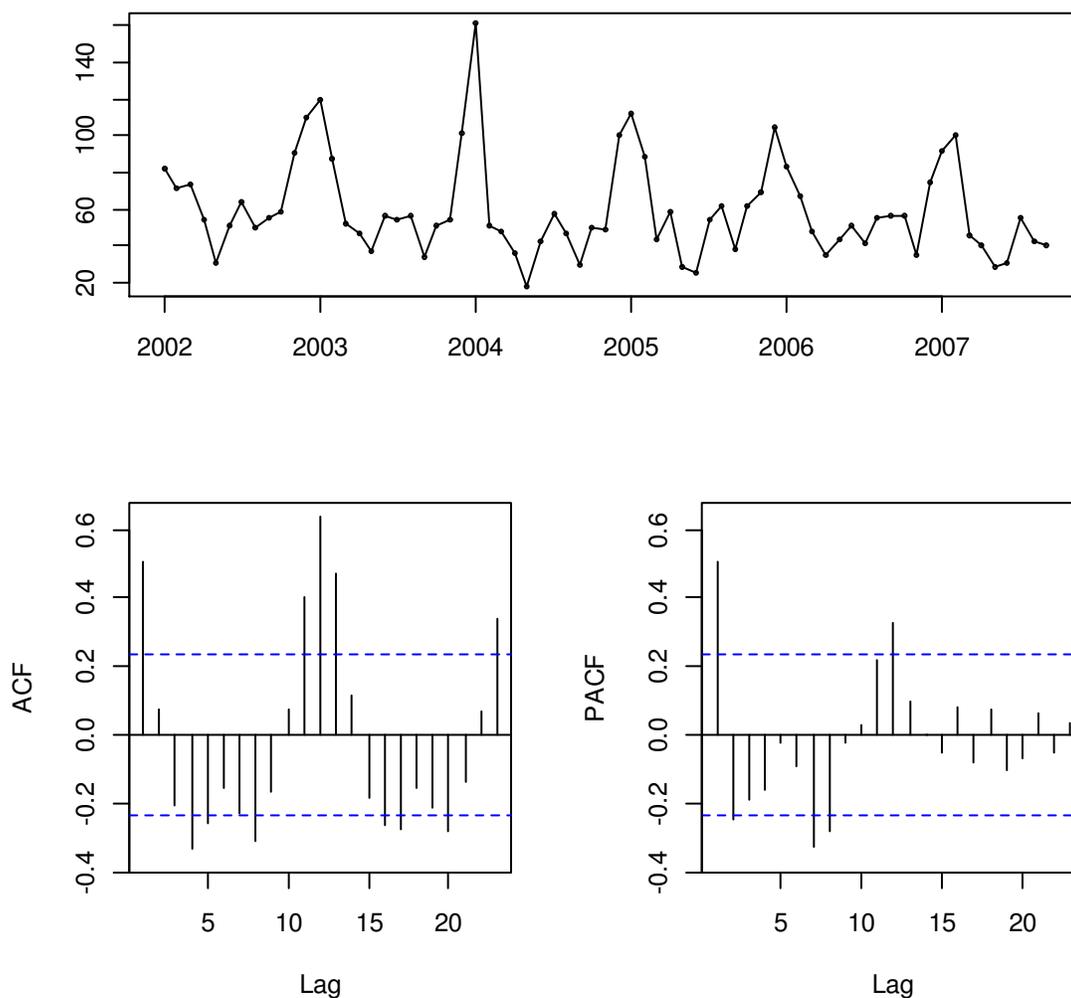


Figure F.1. Time series plot, ACF and PACF of pre-intervention series of casualties, young female drivers

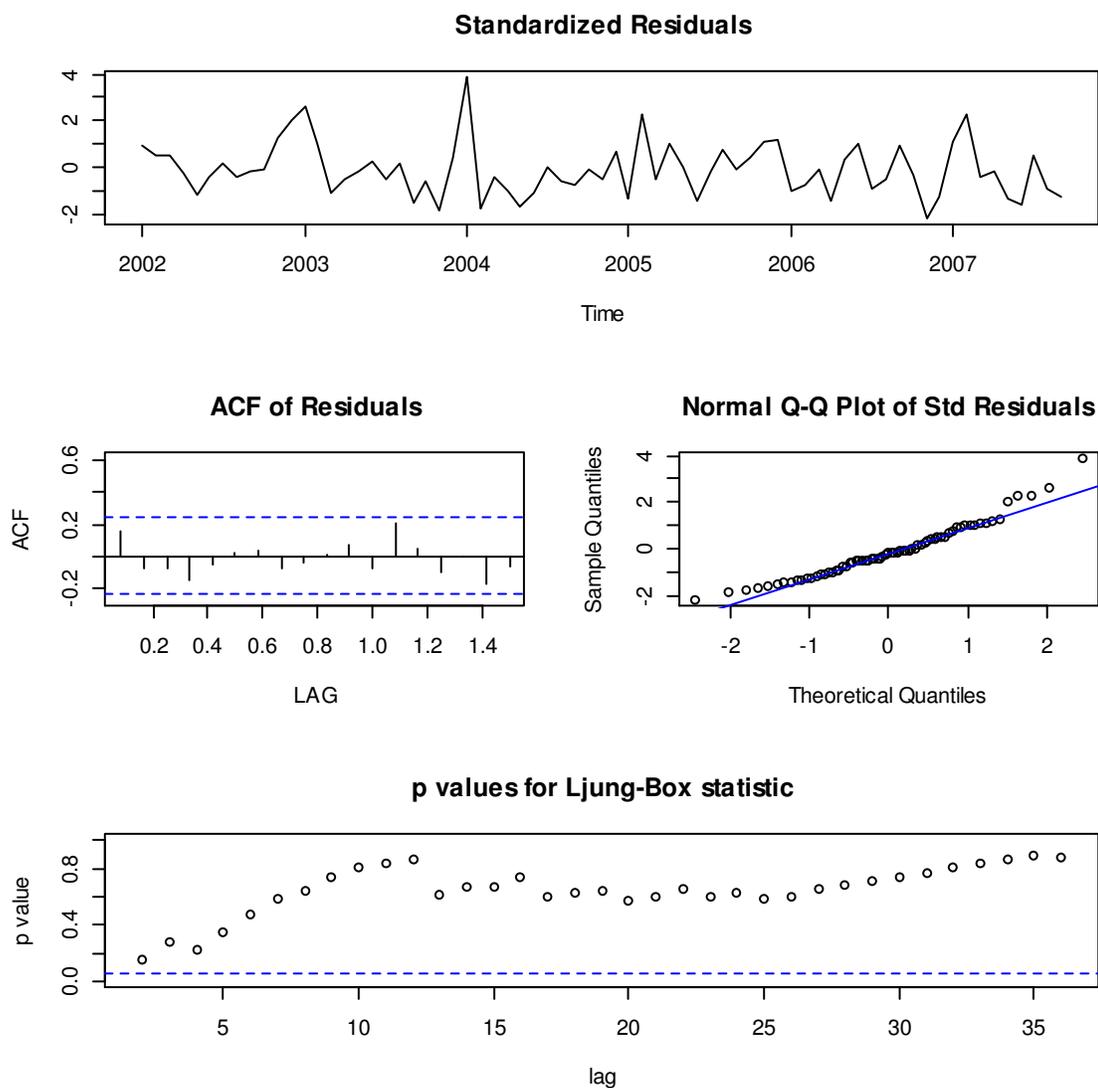


Figure F.2. Model diagnostics from fitting SARIMA (0,0,0)(1,0,0)₁₂ model to the series of casualties, young female drivers group. An outlier was identified and modelled as a pulse-function. After accounting for the outlier, the residuals from the fitted model were found normally distributed, no significant spikes observed on ACF of Residuals, Ljung-Box test p-values are above the critical value. Errors are not different from white noise.

Appendix G: Autocorrelation functions and model diagnostics for time series of mature female casualties

Log-transformation of the series was required due to decreasing variance over time (heteroskedasticity). After transformation the series were found to be stationary based on autocorrelation functions and Augmented Dickey-Fuller test. The selected model was SARIMA(1,0,0)(2,0,0)₁₂. Fitted model passed the diagnostic tests. No outliers were identified. Residuals from the fitted model were found to be normally distributed (Shapiro-Wilk test p-value =0.827)

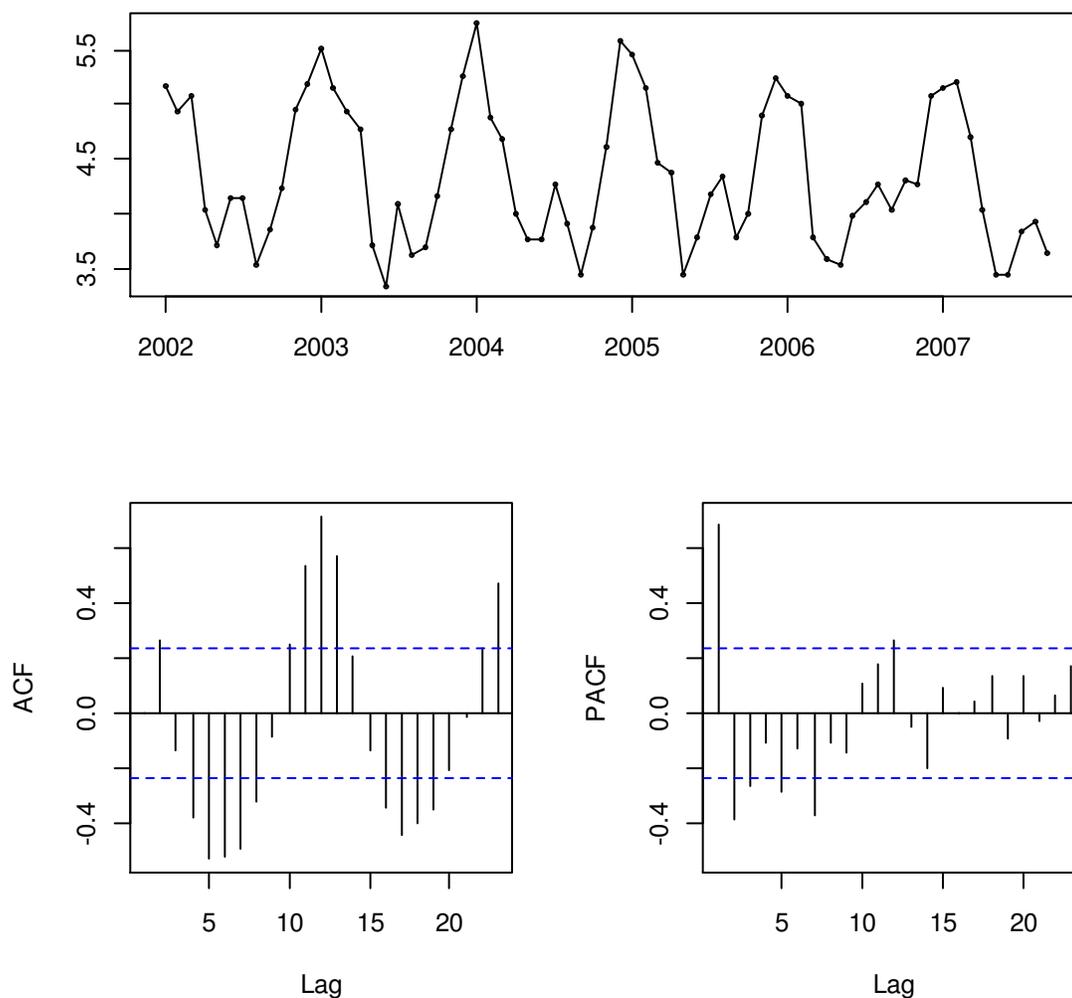


Figure G.1. Time series plot, ACF and PACF of pre-intervention series of casualties, mature female drivers

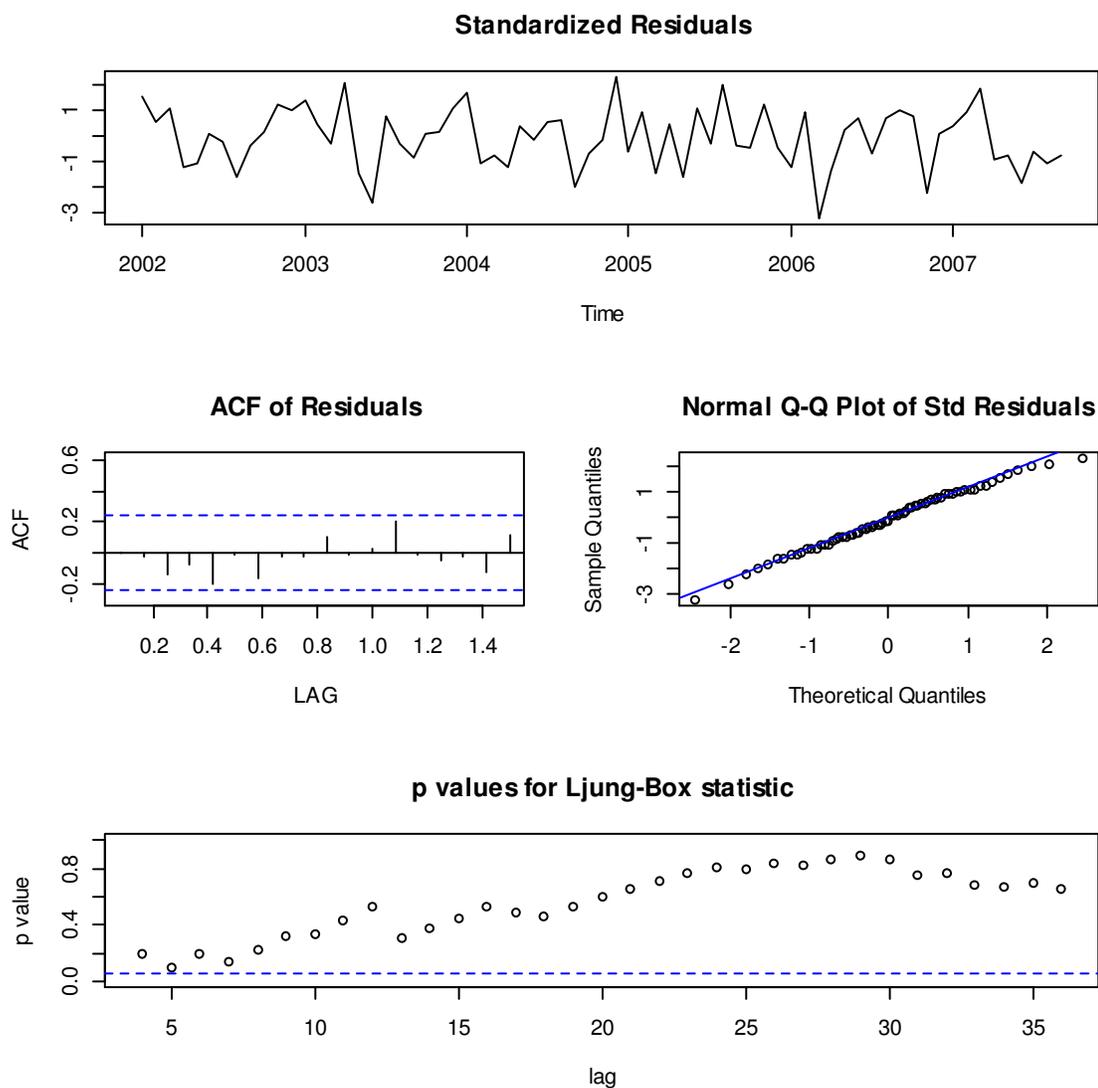


Figure G.2. Model diagnostics from fitting SARIMA (1,0,0)(2,0,0)₁₂ model to the series of casualties, mature female drivers group. The residuals from the fitted model were found normally distributed, no significant spikes observed on ACF of residuals, Ljung-Box test p-values are above the critical value. Errors are not different from white noise.

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