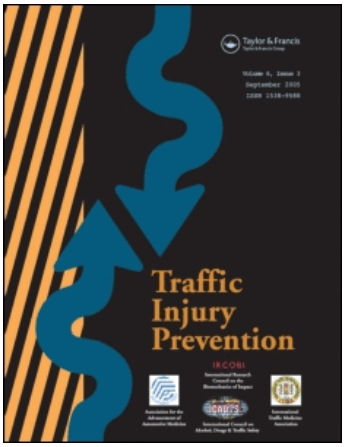

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Safety and Economic Impacts of Photo Radar Program

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Commentary

Safety and Economic Impacts of Photo Radar Program

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Objective. *Unsafe speed is one of the major traffic safety challenges facing motorized nations. In 2003, unsafe speed contributed to 31 percent of all fatal collisions, causing a loss of 13,380 lives in the United States alone. The economic impact of speeding is tremendous. According to NHTSA, the cost of unsafe speed related collisions to the American society exceeds $40 billion per year. In response, automated photo radar speed enforcement programs have been implemented in many countries. This study assesses the economic impacts of a large-scale photo radar program in British Columbia. The knowledge generated from this study could inform policy makers and project managers in making informed decisions with regard to this highly effective and efficient, yet very controversial program.*

Methods. *This study establishes speed and safety effects of photo radar programs by summarizing two physical impact investigations in British Columbia. It then conducts a cost-benefit analysis to assess the program's economic impacts. The cost-benefit analysis takes into account both societal and funding agency's perspectives. It includes a comprehensive account of major impacts. It uses willingness to pay principle to value human lives saved and injuries avoided. It incorporates an extended sensitivity analysis to quantify the robustness of base case conclusions.*

Results. *The study reveals an annual net benefit of approximately C$114 million in year 2001 Canadian dollars to British Columbians. The study also finds a net annual saving of over C$38 million for the Insurance Corporation of British Columbia (ICBC) that funded the program. These results are robust under almost all alternative scenarios tested. The only circumstance under which the net benefit of the program turns negative is when the real safety effects were one standard deviation below the estimated values, which is possible but highly unlikely.*

Conclusion. *Automated photo radar traffic safety enforcement can be an effective and efficient means to manage traffic speed, reduce collisions and injuries, and combat the huge resulting economic burden to society. The cost-effectiveness of the program takes on special meaning and urgency when considering the present and future government funding constraints. The application of the program, however, should be planned and implemented with caution. Every effort should be made to focus on and to promote the program on safety improvement grounds. The program can be easily terminated because of political considerations, if the public perceives it as a cash cow to enhance government revenue.*

Keywords Traffic Safety; Fatal and Injury Collision Reduction; Photo Radar; Economic Evaluation; Cost-Benefit Analysis

Unsafe speed is one of the major traffic safety challenges facing nations around the world. In 2003, unsafe speed contributed to 31 percent of all fatal crashes, causing a loss of 13,380 lives in the United States alone. The economic impact of speeding related collisions is tremendous. According to NHTSA, the cost of such collisions to the American society is over $40 billion per year (Runge, 2005).

This challenge becomes especially prominent as governments at all levels and in many nations experience increasing fiscal constraints. To meet this challenge, automated enforcement devices, including photo radars and red light cameras, have been implemented in many countries (Coleman et al., 1996; ICF, 2003; Retting et al., 2003; Retting & Farmer, 2003). A number of localities in the United States have adopted these techniques (Oesch, 2005; Retting, 2003; Retting & Farmer, 2003; Retting & Kyrychenko, 2002). However, comprehensive studies of the impacts of the program are limited. This is especially true when the economic impact of the program is of concern. To fill this gap, the present study analyzes and reports on a large-scale application of the photo radar program in British Columbia (BC), Canada, a province of 4.2 million people.

The significance of the study lies in its intent to generate knowledge on the effectiveness and efficiency of this automated

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enforcement program, and to inform policy makers and program managers in decision-making relating to speed management and safety improvement. Given the magnitude of the impacts of unsafe speed collisions and the current fiscal conditions of governments, a disciplined examination of the safety and economic impacts of this live-saving, potentially cost-effective program is of great theoretical and practical significance.

The article is organized into seven sections. After the introduction, the study reviews the literature, describes the BC photo radar program, establishes its speed and safety impacts, assesses its economic effects for a base-case, and conducts sensitivity analysis for alternative plausible scenarios. The study concludes by summarizing the findings and highlighting the relevance of program in times of government fiscal constraint.

LITERATURE REVIEW

Various types of photo radar devices and programs have been implemented in many jurisdictions around the world in the past 40 years. Europe pioneered the technology to manage traffic speed and to improve traffic safety. The Netherlands has used photo radar successfully and extensively as an enforcement tool. Germany and Sweden have also used photo radar devices, but with limited success. The difference has been attributed to the presence or absence of enabling legislation in the respective countries (Coleman et al., 1995). Laws in Germany and Sweden required that tickets be issued to the driver, while the more successful jurisdictions allowed the ticket to be charged to the owner of the offending vehicles, regardless of the identity of the driver who committed the offence.

Swali (1993) assessed the speed and safety effect of speed cameras on a major highway in West London. The study found a 97 percent reduction in the proportion of speeding vehicles traveling at 60 mph or faster speed in a 40 mph speed limit zone. The mean speed was reduced by 5 mph and the 85th percentile speed was decreased by 7 mph. Using other trunk roads as controls, the analysis revealed a 19 percent reduction in collisions, a 20 percent reduction in casualties, and a 29 percent reduction in serious and fatal injuries.

One of the largest operations of the photo radar program is found in Victoria, Australia. In September 1989, Victoria police introduced its photo radar program with expanded use of 60 speed cameras. As of 1994, the program deployed more than 4,000 hours of the devices per month. The program is associated with an 85 percent reduction in the proportion of speeding vehicles (Hitchens, 1994). The program is also credited with 16 percent reduction in collisions, 21 percent reduction in injuries, and 30 percent reduction in fatalities in the first year of operation (Hitchens, 1994).

Photo radar is gradually taking a foothold in the United States (Oesch, 2005). A number of places, including Mesa, Paradise Valley, Phoenix, Scottsdale, & Tempe, Arizona; San Jose, California; Boulder, Denver, and Ft. Collins, Colorado; Charlotte-Mecklenburg, North Carolina; Toledo, Ohio; Beaverton, Medford, and Portland, Oregon; and Washington, D.C., have witnessed the application and experienced the impact of the program. An earlier adoption of the photo radar program in Paradise Valley deployed Traffic Monitoring Technologies (TMT) photo radar system. Lynn (1992) reported that speeds on most roads in the town were markedly decreased. The program has survived a constitutional challenge and several state law challenges.

More recent application of the photo radar program in Washington, D.C., has reported high level of camera deployment and initial successes in speed and collision reductions. The D.C. police issued more than 400,000 tickets to motorists caught speeding by photo radar cameras last year and collected $24 million in fines. The number of speeding vehicles declined after the implementation of the program. In photo radar enforcement zones, the proportion of speeding vehicles dropped from more than 30 percent to 4 percent. The reduction in aggressive driving was followed by improved traffic safety. In the three years of photo radar operation, traffic fatalities in which speeding was the primary cause have been reduced by 50 percent (Ramsey, 2005).

Very few published studies were found that explicitly assessed the economic impact of photo radar programs. Elvik (1997) conducted a safety and economic evaluation of the photo radar program applied to 64 sections of highways in Norway. He estimated that the program reduced injury collisions by 20 percent at program treatment sites. In his ensuing cost-benefit analysis, he produced estimates of US$49,000 for average start-up costs per road section and US$2.5 million for annual operating costs for the program. He amortized capital cost of the program over a 10-year service life with a 7 percent annual real interest rate. His analysis revealed an annual savings of US$19.5 million in collision reductions and a program benefit-cost ratio of around 8 (19.54/2.45). The study is significant in term of applying sound economic principles to assess the economic impact of the program to society as a whole. A question concerning the comprehensiveness of the study relates to the way that it treated the existence and effect of speed reduction. It seems advisable to consider speed change, as the photo radar program is intended to manage and often reduce speed, at the sites or across the jurisdiction, which has potentially material economic consequences in terms of losses of travel time. No sensitivity analysis was found to test the robustness of the base-case conclusions.

The UK Home Office Police Research Group commissioned a cost-benefit analysis of red light and speed cameras (Hooke et al., 1996). The study focused on 10 police force areas where the program was implemented. The study included costs in purchasing, installing, operating, and maintaining the cameras; court costs; and associated publicity campaign expenditures. The benefits included savings in human lives, injuries and property damages, and revenues from traffic fines.

The UK study revealed a significant net benefit of the speed cameras. It was reported that the £5.3 million investment generated a return of five times this amount after one year, and more than 25 times the amount after five years. All areas achieved a positive return after one year and, in nine out of the ten forces, fine income covered the direct cost of operations. Modeling with

more pessimistic assumptions (e.g., a decline in incident reductions; reductions in fine income) still produced a substantial net benefit for both speed cameras and red light cameras. The study is detailed and very informative. However, it seems to have mixed financial analysis with economic assessment. As the authors correctly pointed out, traffic fines are a transfer from the ticketed to the government. Including revenues from tickets fines as a benefit biases the results in favor of the program when viewed from societal perspective.

A recent three-year study of the Great Britain national photo radar program by PA Consulting Group (Gains et al., 2004) revealed that vehicle speeds at speed camera sites had dropped by about 7 percent following the introduction of cameras. The reduction of speed has been followed by a 33 percent reduction in personal injury collisions at sites where cameras were introduced. At camera sites, there was also a reduction of over 100 fatalities per annum (40 percent fewer). There were 870 fewer people killed or seriously injured and 4,030 fewer personal injury collisions per annum.

Following the UK Department of Transportation valuation method, which assigns £55,000 to each casualty collision, and using the estimated reduction of 4,030 personal injury collisions from their safety effects study, the authors calculated the annual economic benefit of £221 million in 2002 terms. The cost, based on an audited report, is around £54 million per year, resulting in a positive benefit-cost ratio of 4:1. One of the key critics of this study is the non-economic method in the valuation of human lives and injuries. The £55,000 casualty cost valuation is much lower than what would have been derived from sound economic analysis (Miller et al., 1992). For practical consistency, comparability, and theoretical soundness, valuation based on a willingness to pay principle should be used in social cost-benefit analysis to evaluate economic impact of traffic safety programs.

BC PHOTO RADAR PROGRAM

As in the United States and other industrialized countries, unsafe speed is also a key contributing factor to traffic collisions in British Columbia (BC), Canada. More than 8,000 people were injured and 184 people killed in the 10,564 unsafe speeds related collisions in 1995, resulting in severe social and economic cost to British Columbians.

In response to the problem, the BC government introduced the BC photo radar program in 1996. The BC photo radar program was funded by the Insurance Corporation of British Columbia (ICBC), a government-owned provincial crown corporation (similar to public authorities in the United States), established to provide universal auto insurance to BC motorists. ICBC is also responsible for driver licensing, vehicle registration and licensing, and commercial vehicle compliance. The rationale for ICBC's involvement and investment is predicated on the expected claim savings which would accrue to the insurance corporation.

Theoretically, the BC photo radar program was conceived following the general deterrence model of law enforcement (Ross, 1982). It was hypothesized that increased certainty and swiftness of punishment for violating traffic laws would induce a change in reckless driving behavior, which would in turn lead to improved traffic safety. To generate this general deterrence effect, the BC photo radar units were designed to be mobile, deployed widely across the whole province. The overarching idea was to create a perception that you would be caught and punished wherever and whenever you speed in the province. It was postulated the general deterrence effect of the BC photo radar program would lead to a reduction in traffic speeds and speed variances, which would in turn cut unsafe speed related collisions and injuries (Maycock, 1993).

The BC photo radar program deployed 30 mobile photo radar units across the province. The photo radar unit used the AutoPatrol PR-100, made by American Traffic Systems, as its detecting and photographing device. Each unit of the device includes a cross-the-road Doppler radar, a camera with a flash, and a laptop computer, all mounted in an unmarked mini van. When triggered by a vehicle exceeding the posted speed limit by a specified margin, the camera and computer system capture and record the license plate and speed of the offending vehicle. The photo radar device has a margin of error of 1 km per hour. The equipment was operated mostly in day times by police officers; there were no un-manned or civilian-operated units as seen in some other jurisdictions (Hooke et al., 1996).

Consistent with the program's stated goal of improving traffic safety, the BC photo radar program was initially operated primarily at sites of community complaint about speeding problems and high frequency of collisions, following stringent guidelines (ITCU, 1996). The trigger speeds for the camera were set to be the 85th percentile speed (only 15 percent of vehicles traveling faster) or 11 km over the posted limit, at the discretion of the police officers. The restriction on deployment locations was relaxed to some extent in the second year of program operation.

The program started operation with a five-month warning phase, during which the owner of the offending vehicles received warning letters rather than violation tickets. Fines ranging from C$115 to C$173 were imposed on August 2, 1996, with the highest fines in school and construction zones. From November 1997 fines were raised to C$115 to C$460 per incident. Although the photo radar tickets were issued to the vehicle's registered owner, those owners who were not driving the vehicle at the time of the alleged infraction could nominate the actual driver to pay the fine.

When enacted, the program had wide public support, with close to two-thirds of British Columbians supporting the photo radars (ICBC, 1997). However, grassroots and political oppositions started to organize soon after its commencement. The program was portrayed as a cash cow for the government as opposed to a public safety initiative. The program subsequently became an election issue, with the opposition party promising to cancel it if elected. They opposition party won the subsequent election. The BC Photo Radar Program was officially terminated at midnight June 27, 2001.

SPEED AND SAFETY IMPACTS

Two studies were conducted to assess the speed and safety effects of the photo radar program. These include a province-wide impact assessment and a site-specific study to corroborate the results. These studies were reported earlier in two separate publications (Chen et al., 2000, 2002). The province-wide impact study used time series analysis method to assess the macro level effect of the program across the whole jurisdiction. The study controlled for trend, seasonality, and key traffic safety related variables, including amount of driving, alcohol consumption, economic condition, and other concurrent traffic safety programs. The site-specific study verified the causal links between the photo radar program and the observed reductions in collisions and injuries. It focused on a selected highway section for in depth study of program implementation and outcomes. This study employed comparison group design to control for trend, and potential traffic and collision migration to non-photo radar enforcement sections of highways. Empirical Bayesian method was used to improve data use efficiency and estimation precision.

The studies show that both traffic speed and traffic collisions declined following the introduction of the program. The province-wide study reported that the proportion of speeding vehicles at photo radar deployment sites decreased from more than 60 percent in the warning letter phase to 37 percent in the first year and to 30 percent in the second year of program operation. The proportion of speeding vehicles remained at below 30 percent level afterward. The proportion of excessive speeding vehicles, defined as exceeding speed limited by 16 km/hr or more, decreased from more than 10 percent in the warning letter phase to 3 percent in the first year and to 2 percent in the second year.

Traffic speed at non-photo radar enforced locations also declined, consistent with the predictions of the general deterrence theory. Based on speed monitoring devices across the province, the average proportions of speeding vehicles declined from 78 percent in the pre-PRP period, to 73 percent in the first year of program. It then stabilized at that level (74 percent) thereafter. The proportion of speeding vehicles exceeding speed limits by 16 or more km/h across the monitoring sites declined from 27 percent in the pre-PRP period to 22 percent in the first year, and then rose slightly to 23 percent and stabilized afterwards. The reduction in speed led to the stabilization of violating vehicles detected and violation tickets issued to registered owners of offending vehicles. The monthly number of tickets issued by the photo radar program is shown in Figure 1.

The reduction in speed is followed by a reduction in traffic collisions and collision casualties. Using data from both the police and ambulance services branch of the BC government, the time series, province-wide study showed that on a annual basis, the program was associated with approximately 2,220 (14%) less traffic collision injuries and up to 79 (26%) less collision fatalities, including pedestrians. These numbers correspond to 1,542 and 70 reductions, respectively, in injury and fatal collisions, using the victim/collision ratio of 1.13 and 1.44 for injury and fatal collisions, respectively, based on BC traffic collision and injury statistics.

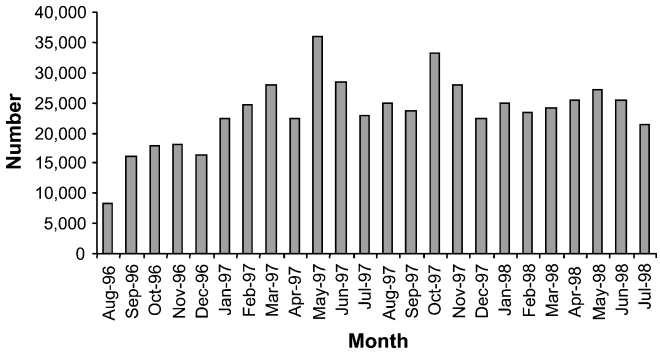

Figure 1 Number of photo radar violation tickets by month.

The site-specific study provided corroboration of the causal links between the photo radar program and the reduction in speed and collisions. By using better controlled design (before-after, comparison group method) and highly efficient (Empirical Bayesian method) statistical techniques, the site-specific study again found that the BC photo radar program reduced speed and improved safety at the photo radar deployment locations over and above the program's general effect at non-photo radar locations. The mean speed has been reduced from above 90 km/hr to under 80 km/hr, the posted speed limits.

The reduction in speed and speed variance at non-photo radar monitoring sites is more fundamental, as it measures the free will of drivers in the absence of the photo radar enforcement and it has greater implications for safety improvement across the province. The site-specific study shows that the mean speed at the non-photo radar monitoring site decreased by approximately 2.4 km/h, which represents a 3% reduction in speed. The standard deviation of speed declined by 0.5 km/h, amounting to a 6% reduction in speed variance (Chen et al., 2002).

The site-specific study estimates that the program reduced collisions from 16% to 7%. This result supports the safety impact assessment of the province-wide study in qualitative terms. Both studies suggest that the photo radar program reduces traffic speed and improves traffic safety. These estimated physical impacts lend legitimacy and provide input in the following cost benefit analysis on the economic impacts of the program.

ECONOMIC IMPACT

Method

Cost-benefit analysis was conducted to assess the economic impacts of the photo radar program. The analysis was pursued from two perspectives, societal and an insurer's. From the societal perspective, all residents of the British Columbia were given standing. From the public insurer perspective, only the economic consequence of ICBC that provided the funding for the program was of concern. The analysis compared the program with a noprogram, status quo alternative. A 6% discount rate was used in the base case scenario, following the

guideline of the British Columbian government (BC Ministry of Transportation, 1996). The costs and benefits were annualized for the calculation of net benefit per year. All calculations and their results are expressed in 2001 Canadian dollars. The study took a conservative stance when assumptions were made in the base case analysis. The potential bias was partially addressed in the ensuing sensitivity analysis, wherein ranges of plausible scenarios and assumptions were tested for robustness of the base-case conclusions (Broadman et al., 2001).

Impact Itemization and Valuation

The economic evaluation attempted to include all major impacts of the photo radar program on society as a whole and on ICBC in particular. It grouped the impacts into costs and effects, recognizing the potential of negative effects of the program, expected or unintended. The costs of the program were broadly classified into two categories, start-up (capital) and operating. The operating costs were further broken down into police costs, photo/tickets processing and processing serving costs, maintenance costs, and court costs. The main effects included reductions in fatal and injury collisions, time loss due to slower traffic speeds, and time loss of private citizens who opted to dispute photo radar tickets. The costs and effects of the program were monetized based on competitive market price, government guidelines, or shadow prices, subject to availability and appropriateness. A summary of the key costs and effects included in the study is presented in Table I. Brief descriptions of each impact and its corresponding valuation method are provided in the following sections.

Capital Expenditure (Start-Up Costs). The capital expenditure, or start up costs, of the program include planning, photo radar equipment purchasing, software development, signing, and program education/publicity campaign. The cost data were obtained from ICBC and BC government offices. The total capital expenditure for the program is approximately C$33 million based on official accounting records. This capital costs were amortized over a 10-year period, corresponding to the estimated economic life of the equipment (Elvik, 2001). The annualized program capital expenditure was about C$4.7 million.

Table I Cost and effect categories

Category	Description	Data source
Cost	Capital (start-up) costs	ICBC
	ICBC operating costs	ICBC
	Police costs	AG
	Court costs	AG
Effect	Fatal and injury collision reduction	Police, Ambulance Services
	Time lost—travel	MoTH, NRC
	Time lost—disputing tickets	BC Stats

Note: AG is the BC Ministry of Attorney General; MoTH is the BC Ministry of Transportation and Highways; NRC is Natural Resources Canada; BC Stats is the BC government's statistical Service.

Police Costs. A stand-alone police force was created for the deployment and administration of the photo radar units. The police force was composed of 102 full time equivalent (FTE) uniformed police officers of Royal Canadian Mounted Police (RCMP) and local police that operated the photo radar devices, 13.5 FTE charging officers who reviewed the photographs of violating vehicles, and four office administrative staff who provided the command and support services. The standard costing rate for each of the groups is C$85,000 for RCMP and $73,690 for local police, C$43,101 for charging officers, and C$71,681 for administrative staff. The police costs were calculated by summing up the number of officers in each category multiplied by their respective standard costing rate. The typical yearly police cost for the photo radar program thus calculate, plus a 20% of overhead, was around C$11.746 million annually. This is in close proximity to the BC Ministry of Attorney General's police cost accounts for the program (ICBC, 1999).

Photo/Tickets Processing, Process Serving, and Maintenance Costs. The photograph and violation tickets processing costs include photograph processing, data management and analysis, and tickets generating and mailing expenses. The process serving costs cover the personal delivery of the tickets to the owner of the offending vehicle after failing to reach him or her by registered mail. The equipment maintenance costs pay for the regular checks and repairs of the photo radar unit and related equipment. Summary costs for photo/tickets processing, process serving, and maintenance were obtained from ICBC accounting records. The annual costs for the three categories were C$7.1 million, C$1.6 million, and C$1.5 million, respectively.

Court Costs. The photo radar program caused incremental workload to the provincial court systems. This included additional services from a prosecutor, support staff, justice of the peace, sheriffs, and court/registry clerks. The standard costing rates for each of the groups were C$106,844, C$52,919, C$90,252, C$47,920, and C$46,796, respectively. The annual time spent on processing photo radar tickets for each group was calculated by multiplying the number of tickets disputed times unit time spent for each group in case handling. The marginal costs resulting from the BC photo radar program for each group were then computed by multiplying the annual time spent on dealing with photo radar related cases times the unit cost of the respective group. The annual total incremental costs for the court system were then obtained by summing up the costs across the groups. The resultant incremental cost, including a 20% overhead, for the photo radar program was approximately C$1.9 million.

Effect from Reduction in Fatal and Injury Collisions. Previous assessments showed that the BC Photo Radar Program was effective in reducing traffic collisions (Chen, 2002; Chen et al., 2000, 2002). It was estimated that the program prevented 1,542 injury and 70 fatal collisions annually. The estimated reduction in property damage only (PDO) collisions was statistically insignificant. This is not unexpected for a photo radar program,

which is aimed at reducing high-speed, severe casualty collisions. Given that the effect on PDO is unreliable in magnitude and low in unit value relative to injury collisions, taking a conservative stance, the benefit of this benefit category was excluded from this analysis.

Distinct valuation methods were used to arrive at the annual savings from the societal perspective and the ICBC perspective. From the societal perspective, fatal collisions and injury collisions are valued at C$4.6 million and C$120,000 per collision, respectively, following the advice from Ted Miller (1992). The annual total safety benefit for the photo radar program is calculated by summarizing the products of the number of fatal and injury collisions reduced by the photo radar program, multiplied by the corresponding value for the collision type. The calculation revealed that from a societal perspective, the annual safety benefit of the photo radar program approximated C$513.9 million. From the ICBC perspective, however, the benefit of the program was much smaller. The ICBC average claim cost is C$50,000 for a fatal collision and C$40,000 for an injury collision. Using this set of values, and replicating the same computation as from the societal perspective produced an estimate of C$65.5 million of annual savings for ICBC.

Time Loss Due to Speed Reduction. The objective of the BC Photo Radar Program was to manage traffic speed across the province, thereby reducing traffic collisions both at the photo radar deployment locations and across the province as a whole. However, the reduction in traffic speeds also led to increased travel time. To value this effect, data from various sources were obtained. These include yearly total vehicle-distance of travel in BC (41.7 billion vehicle-kilometer of travel for passenger cars and 4.3 billion vehicle-kilometers of travel for trucks for 1998) from Natural Resources Canada; estimated mean traffic speed reduction of 2.4 km/hour derived from aforementioned physical impact studies (Chen et al., 2002); occupancy rate of 1.4 for passenger vehicles from BC Ministry of Transportation and Highways; and unit value of travel time of C$10 for passenger cars and C$28 for trucks based on guidelines from BC Ministry of Transportation and Highways (1997).

The loss in travel time due to speed reduction was estimated by computing the difference in total travel times required to complete the yearly vehicle-kilometers of travel at the speeds before and after the introduction of the program. The value of the travel time loss is estimated by multiplying the total time loss, times occupancy rate and times the unit value of travel time. The annual value of the time loss due to speed reduction was thus calculated to be C$371.6 million. This was a substantial societal cost that would have been undetected if this impact of speed management program were omitted from consideration.

Time Loss in Disputing Tickets. Registered owners of ticketed vehicles have the right to dispute speed violation tickets in court. Because the time consumed in disputing tickets is a loss for productive activities, it should be counted as a cost in the base case cost-benefit analysis, especially when the study proclaimed to take a conservative approach. Time lost in disputing photo radar tickets was estimated by multiplying the actual number of disputes (fewer than 10% of tickets) by the estimated average time spent to attend a court hearing, and times the average hourly wage of BC workers. The time lost in disputing tickets was estimated to be 3 hrs based on court records, and the average salary was C$17 from labor statistics (BC Statistics, 1999). The computation produced C$1 million of annual costs for the alleged offenders who decided to dispute the speeding tickets generated by the photo radar program.

Not all potential impacts are included in the present cost-benefit analysis. This is due to theoretical and practical reasons. For example, revenues generated from photo radar fines were not reflected in the benefit calculation when analyzing from the societal perspective. This is because traffic violation fines are simply a transfer from ticketed alleged offenders to the government. Photo radar fines were excluded from ICBC benefit. This is because the revenues were collected by, and accrued to, the provincial government, not the insurance corporation. The potential environmental impact was deemed small, given the estimated 2.4 km/hr reduction in speed, and the theoretical/practical complications in measuring and assigning a widely accepted value for the impact. Following the convention in transportation CBA analysis (Transport Canada, 1994) and the examples in previous studies reviewed in this paper. The environmental effects were excluded from the cost-benefit analysis. The omissions are considered not large enough to materially alter the overall results of the study.

Annual Net Benefit

The costs and benefits were compiled and compared and the results are shown in Tables II and III from the societal and the ICBC perspectives, respectively. As shown in Table II, on an annual basis the program generated approximately C$114 million of net social benefit. The single largest benefit was accounted for by reductions in fatal and injury collisions (C$513.9 million per year), while the single largest cost was due to the loss in travel time (C$371.6 million per year). On balance, the BC photo radar program generated substantial societal net benefit for the British Columbians.

Table II Societal perspective, costs and effects of BC photo radar program

Description	Annualized cost/benefit, C$000
Capital	4,745
Ticket/photo processing	7,141
Equipment maintenance	147
Process serving	1,557
Police	11,746
Court	1,954
Total cost	27,290
Safety improvement	513,930
Time lost—travel	−371,643
Time lost—dispute tickets	−1,041
Total effects	141,245
Net benefit	113,955

Table III ICBC perspective, costs and savings of BC photo radar program

Description	Annualized cost/benefit, C$000
Capital	4,745
Ticket/photo processing	7,141
Equipment maintenance	147
Process serving	1,557
Police	11,746
Court	1,954
Total cost	27,290
Safety improvement	65,554
Total savings	65,554
Net savings	38,264

From the ICBC perspective, Table III indicates that the program produced C$38 million net savings annually. Claim savings generated by photo radar were estimated at C$65.6 million per year, more than double the estimated program costs of C$27.3 million. The public insurer, ICBC, and its policyholders gained substantially from the photo radar program. This net benefit could be distributed to increase reserves to strengthen the financial position of the public owned corporation, or to be used to reduce policyholders' premiums in current and future years.

Although positive results were found for both perspectives, a substantial difference exists in the estimated net benefits. The difference can be largely explained by the divergent valuation methods of human lives from the societal and the ICBC perspectives. While the society assigned more than C$4.5 million in 2001 dollars to a fatal collision, ICBC paid out approximately C$50,000 on average to its policyholders for such a collision. The order-of-magnitude valuation disparity therefore rendered a much higher net benefit to the photo radar program from the societal perspective, although this difference was to some extent offset by the inclusion of various negative impacts in the societal perspective analysis. The significant costs due to the reduction in average traffic speed affected the social and economic well being of the driving population and the general public, but it did not impact the financial bottom line of ICBC. The difference in net benefits between the two perspectives would have been much greater, had the societal cost of speed reduction not been taken into account.

SENSITIVITY ANALYSIS

Many assumptions and estimations were made and used in the above base-case analysis. These assumptions and estimations introduced potential error and uncertainty to its conclusions. For example, the 6% nominal discount rate was based on recommendation of the Ministry of Transportation. Although this discount rate is considered modest and reasonable, it is a contentious issue and open to discussion. Second, fatal and injury collisions were valued at C$4.6 million and C$.12 million, respectively. These were based on statistical valuation method following willingness to pay principles, adjusted for BC settings. Although this method is considered most valid and consistent in economic principles, it is not yet accepted by the judicial system nor has it been widely adopted in previous cost benefit analyses in the field of traffic safety and transportation. Third, the base case study did not consider the excess burden of taxation. Given that the program was funded by taxes, the deadweight loss could have exerted an impact on the net benefit of the program. Finally, there are always estimation errors in the studies of the physical impacts of speed and collision reductions. These errors could also have materially affected the conclusion of the study. To address these issues, a sensitivity analysis was conducted to test the robustness of the base-case conclusions.

The sensitivity analysis investigated plausible scenarios by altering assumptions and estimations for significant variables. Table IV shows the alternate values considered and provides brief descriptions of the rationales. For example, the selection of 3% discount rate as an alternative value was based on the recommendation of the Panel on Cost-Effectiveness in Health and Medicine. The selection of the 10% was based on the required rate from the U.S. Office of Management and Budget. Parameter values for other significant variables were selected from probable ranges, or on one-standard deviation from the expected values basis, when estimates from physical impact studies were of concern.

Table V shows the results of the sensitivity analysis from the societal perspective. For comparison and illustration purposes, base case results are also presented in the table as the first column. Table V suggests that the base case study results are robust for all plausible alternate assumptions except for significant estimation errors on collision reductions. The net benefit becomes negative (−C$15 million per year) if the real reductions in fatal and injury collisions are both one standard below the estimated values. This is possible, but not likely, as the chance for each scenario to occur is smaller than 16%.

Table VI shows the results of sensitivity analysis from ICBC's perspective. It indicates that photo radar created net savings under all plausible assumptions tested in this sensitivity analysis. ICBC, as the funding agency and public auto insurer, is a winner, a beneficiary of the photo radar program. This is informative

Table IV Sensitivity analysis alternate values

Variable	Base case	Parameter selection	Alternate values	Rationale
Discount rate	6%	BC. MoTH guideline	3–10%	Other guidelines
Reduction in speed	2.4 km/hr	Estimates	2.0–2.8 km/hr	±1 SD
Reduction in injury & fatal collisions	Injury = 1542 Fatal = 70	Estimates	1,154–1,929 54–87	±1 SD
Injury/fatal collision valuation	Injury = C$0.12 M Fatal = C$4.58 M	Estimates	10%	Similar jurisdictions
Marginal excess burden of taxation (MEB)	0%	Omit	125%	Deadweight loss range

Table V Sensitivity analysis—societal perspective, thousands of 2001 Canadian Dollars

Description	Base case	Discount rate		Speed reduction (km/hr)		Death/injury reduction		Death/injury valuation		MEB (125%)
		3%	10%	2.0	2.8	−1 SD	+1 SD	+10%	−10%	
Cost										
Capital	4,745	4,094	5,684	4,745	4,745	4,745	4,745	4,745	4,745	5,931
Process derving	1,557	1,557	1,557	1,557	1,557	1,557	1,557	1,557	1,557	1,946
Equipment maintenance	147	147	147	147	147	147	147	147	147	184
Ticket/photo processing	7,141	7,141	7,141	7,141	7,141	7,141	7,141	7,141	7,141	8,926
Police	11,746	11,746	11,746	11,746	11,746	11,746	11,746	11,746	11,746	14,683
Court	1,954	1,954	1,954	1,954	1,954	1,954	1,954	1,954	1,954	2,442
Total costs	27,290	26,639	28,229	27,290	27,290	27,290	27,290	27,290	27,290	34,113
Effect										
Safety improvement	513,930	513,930	513,930	428,275	599,585	628,946	384,584	565,323	462,537	513,930
Time loss—travel	−371,643	−371,643	−371,643	−307,881	−436,165	−371,643	−371,643	−371,643	−371,643	−371,643
Time loss—dispute tickets	−1,041	−1,041	−1,041	−1,041	−1,041	−1,041	−1,041	−1,041	−1,041	−1,041
Total effects	141,245	141,245	141,245	119,353	162,379	256,262	11,900	192,638	89,852	141,245
Net benefit	113,955	114,606	113,016	92,062	135,088	228,972	−15,390	165,348	62,562	107,132

in cost sharing consideration among various public and private organizations that are contemplating the application of the program.

CONCLUSIONS

The present economic evaluation shows that the BC Photo Radar Program has has net benefits for BC society as a whole and for the public owned Insurance Corporation of British Columbia in particular. The program was successful in reducing fatal and injury collisions, with an estimated net economic benefit of approximately C$114 million per year. These results are robust to all plausible scenarios tested except for major errors in overestimating collision reductions. From the sponsoring insurance corporation's perspective, photo radar created base-case net savings of approximately C$38 million per year. The program produced a net savings of at least C$21.8 million per year, even under the least favorable assumptions. Photo radar speed enforcement is an effective and efficient traffic safety initiative that could make a substantial contribution to reducing deaths and injuries from traffic collisions attributable to excessive speed and generate substantial savings for society and the insurance industry. The cost-effectiveness of this automated speed enforcement program is especially relevant at the present time when governments are cutting back traffic safety funding. The trend in government fiscal austerity can only be expected to get worse in the foreseeable future, when all governments, struggle to balance their budgets, confronted by looming escalating medical and social security expenses, due partly to baby boomer retirement.

Automated enforcement programs, including photo radar programs, are not without controversies and difficulties. On the contrary, given its far-reaching impact on the majority of the driving population, they have aroused substantial, and often heated, debates of people from all walks of lives. Besides the point that most people dislike traffic fines, two deeper and legitimate concerns relate to privacy and government motives. Opposition from a privacy viewpoint, by and of itself, has not gained ground recently. The majority of the public seems to be willing to tolerant automated camera enforcement for traffic

Table VI Sensitivity analysis—ICBC Perspective, in thousands of 2001 Canadian Dollars

Description	Base case	Discount rate %		Speed reduction (km/hr)		Death/injury reduction		Death/injury valuation		MEB (125%)
		3%	10%	2.0	2.8	−1 SD	+1 SD	+10%	−10%	
Cost										
Capital	4,745	4,094	5,684	4,745	4,745	4,745	4,745	4,745	4,745	5,931
Process serving	1,557	1,557	1,557	1,557	1,557	1,557	1,557	1,557	1,557	1,946
Equipment maintenance	147	147	147	147	147	147	147	147	147	184
Ticket/photo processing	7,141	7,141	7,141	7,141	7,141	7,141	7,141	7,141	7,141	8,926
Police	11,746	11,746	11,746	11,746	11,746	11,746	11,746	11,746	11,746	14,683
Court	1,954	1,954	1,954	1,954	1,954	1,954	1,954	1,954	1,954	2,442
Total Cost	27,290	26,639	28,229	27,290	27,290	27,290	27,290	27,290	27,290	34,113
Savings										
Insurance savings	65,554	65,554	65,554	65,554	65,554	81,880	49,073	72,110	58,999	65,554
Total savings	65,554	65,554	65,554	65,554	65,554	81,880	49,073	72,110	58,999	65,554
Net savings	38,264	38,915	37,325	38,264	38,264	54,589	21,783	44,819	31,708	31,441

and public safety gains. This has been shown empirically by the initial public support of the photo radar program in the BC photo radar study and the literature reviewed from other jurisdictions.

The opposition on government motive ground seems to be more widespread and potentially potent presently. Phrasing government motives in terms of hidden taxation through traffic fines has a value and emotional overtone. This issue could be mitigated by government agencies and program management carefully designing and implementing future programs. Speed surveys and engineering studies to ensure the appropriateness and fairness of existing posted speed limits, extensive education campaigns to inform the public of the consequences of unsafe speed and the effectiveness and efficiency of photo radars, and careful selection of high speed collision prone sites to focus the program on safety improvement goals are just a few ideas to obtain and sustain public support. Given that public policies are decided at the political level, public sentiment and political considerations often determine decision outcomes. This is probably the main reason for what has occurred in British Columbia, regardless of the program's significant safety and economic net benefit.

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REFERENCES

BC Ministry of Transportation and Highways. (1997) *MicroBencost Guidebook: Defaults and Standardized Economic Analysis for Highway Improvement Projects in British Columbia*. Victoria, BC, BC Ministry of Transportation and Highways.

BC Stats. (1999) *Customized Report of Average Salaries for BC Labor Force*. BC Ministry of Management Services, Victoria, BC, Canada.

Broadman AE, Greenberg DH, Vining AR, Weimer DL. (2001) *Cost-Benefit Analysis: Concepts and Practice*, 2nd Edition. Prentice Hall, Upper Saddle River, NJ.

Chen G. (2002) *Using Empirical-Bayesian Method to Assess Traffic Safety Programs*. Paper presented at the Canadian Multi-Disciplinary Traffic Safety Conference XII, London Ontario.

Chen G, Wilson RJ, Meckle W, Cooper P. (2000) Evaluation of BC photo radar program in British Columbia. *Acc. Anal. Prev*., Vol. 32, No. 4, pp. 517–526.

Chen G, Meckle W, Wilson RJ. (2002) Speed and safety effect of photo radar enforcement on a highway corridor in British Columbia. *Acc. Anal. Prev*. Vol. 34, No. 2, pp. 129–138.

Coleman JA, Paniati JF, Cotton RD, Parker Jr. MR, Covey R, Pena Jr., HE, Graham D, Robinson ML, MaClauley J, Taylor WC, Morford G. (1996) FHWA Study Tour for Speed Management and Enforcement Technology. U.S. Department of Transportation, Washington, DC.

Elvik R. (1997) Effects on Accidents of Automatic Speed Enforcement in Norway, Transportation Research Record, Vol. 1595, pp. 14–19.

Elvik R. (2001) Cost-benefit analysis of road safety measures: Applicability and controversies. *Acc. Anal. Prev.*, Vol. 33, pp. 9–17.

Gains A, Heydecker B, Shrewsbury J, Robertson S. (2004) *The National Safety Camera Programme: Three-Year Evaluation Report*. PA Consulting Group, London, UK.

Hitchens D. (1994) The Traffic Camera Initiatives. In Traffic Technology International '94, UK: International Press, Dorking, UK.

Hooke A., Knox J, Portas D. (1996) Cost-benefit analysis of traffic light and speed cameras. *Police Research Series*, paper 20. Police Research Group, London, UK.

ICBC. (1997) *Tracking Survey*. Insurance Corporation of British Columbia, Research Services, Vancouver, BC.

ICBC. (1999) *Photo Radar Summary—ICBC Cost, as of December 31st*. Insurance Corporation of British Columbia, Vancouver, BC.

ICF Consulting and Imperial College Centre for Transport Studies. (2003) *Costs-Benefit Analysis of Road Safety Improvements—Final report*. ICF, London.

ITCU. (1996) *Guidelines for Photo Radar Deployment*. British Columbia Integrated Traffic Camera Unit, Vancouver, BC.

Lynn CW, Garber NJ, Ferguson TK, Lau R, Alcee JV, Black JC, Wndzel PM. (1992) *Automated Speed Enforcement Pilot Project for the Capital Beltway: Feasibility of Photo Radar—Final Report*. Virginia Transportation Research Council, Charlottesville, VA.

Maycock G. (1993) *The Use of Cameras for the Enforcement of Speed Limits: Enhancing Their Effectiveness*, TRL Report produced for the County Surveyors' Society, Berkshire, UK.

Miller TR. (1992) Crash costs for British Columbia, Contract 034535, BC Ministry of Transportation and Highways, Victoria, BC, Canada.

Miller TR, Viner J, Rossman S, Pindus N, Gellert W, Douglass J, Dillinghan A, Blomquist G. (1991) *The Cost of Highway Crashes*. (FHWA-RD-91-055)) US Department of Transportation, Federal Highway Administration, Washington, DC.

Oesch SL. (2005) *HB 443 Automated Speed Enforcement. Statement Before the Maryland House Environmental Matters Committee*, The Insurance Institute for Highway Safety, Washington, DC.

Ramsey CH. (2005) Chief Ramsey on Traffic Cameras. *Washington Times*, Jan 28.

Retting RA, Kyrychenko SY. (2002) Reductions in injury crashes associated with red light camera enforcement in Oxnard, California. *Am. J. Pub. Heal.* Vol. 92, No. 11, pp. 1822–1825.

Retting RA, Ferguson SA, Hakkert AS. (2003) Effects of red light cameras on violations and crashes: A review of the international literature, *Traf. Inj. Prev*., Vol. 4, No. 1, pp. 17–23.

Retting RA. (2003) *Speed cameras—public perceptions in the US. Traf. Eng. Con.* Vol. 44, pp. 100–101.

Retting RA, Farmer CM. (2003) Evaluation of Speed Camera Enforcement in the District of Columbia, *Transportation Research Record*, Vol. 1830, pp. 34–37. Transportation Research Board, Washington, DC.

Ross HL. (1982) *Deterring the Drinking Driver*. Heath & Co, Lexington, MA.

Runge JW. (2005) Remarked prepared for MD, Runge Administrator of HSTSA, on Lifesaver 23, HSTSA Reward Luncheon, Washington, DC.

Swali LN. (1993) The Effect of Speed Cameras in West London, PTRC 21st Annual Meeting 1993, Seminar C. London, England.

Transport Canada. (1994) *Guide to Benefit-Cost Analysis in Transport Canada*, http://www.tc.gc.ca/bca/Guide_e.htm. Accessed July 2002.