Traffic Signal Safety

Analysis of Red-Light Running in Maine

FINAL REPORT

TECHNICAL REPORT

May 24, 2004

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ABSTRACT

The aim of this report is to suggest how to make signalized intersections safer, in particular in respect to crashes caused by red-light violations. The report includes a review of literature, analysis of crashes, and interviews with Maine drivers. One conclusion is that the drivers are completely unaware that there was a red light in about a quarter of the crashes caused by red-light running violations. One way of improving the safety of the location may be to replace it with a modern roundabout. Another conclusion is that signalized intersections should be vehicle actuated if possible or else coordinated with nearby signals. More enforcement by police or automatic surveillance is by the public considered the most effective ways to reduce red-light running. Finally, the most important factor in reducing red-light running frequency, as well as the number of serious crashes caused by red-light running, is never having a posted speed limit greater than 35 mph through a signalized intersection.

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EXECUTIVE SUMMARY

Traffic Signal Safety—Analysis of Red-Light Running in Maine

Introduction

This three-page Executive Summary highlights some of the findings of this study. A 12-page more detailed summary starts on page 9. The main text of the report giving additional information to the interested reader starts on page 21.

The primary objective of this project is to inform Maine Department of Transportation and the public of how red-light running contributes to crashes at signalized intersections in Maine. Studies by the Insurance Institute for Highway Safety (IIHS) indicate that the safety of signalized intersections has deteriorated because of an increasing number of drivers running red lights. IIHS did not include Maine in their studies.

The first part of the project was to conduct a literature review which included over 80 documents. Among the findings of this review is that red light running crashes in the U.S. cause the death of about 1,000 people and close to 100,000 injuries each year. The literature review discusses the effect of traditional enforcement as well as of automatic surveillance. It also covers the effect of Intelligent Transportation System technologies, conventional technologies, strobe lights, light emitting diodes, advance warning signs, exclusive left-turn phasing, longer evacuation times, vehicle actuation, and signal coordination.

Crash-Data Analysis

Official statistics provided by Maine Department of Transportation (MDOT) show that there were 10,169 reported crashes at signalized locations in Maine in the three-year period from 1999 to 2001. Of these, 4203 (41.3%) were classified as intersection-movement crashes, whereas 5325 (52.4%) were classified as rear-end. Of the intersection-movement ones, 2611 were identified as left-turn crashes. The crashes caused six fatalities, 277 incapacitating injuries, 1461 evident injuries, and 3115 possible injuries. Three out of the six people who were killed were unprotected road users; one was a pedestrian, one a bicyclist and one a motorcyclist. The pedestrian and bicyclist disregarded the traffic-control device. The motorcyclist collided with a vehicle making a left turn. One more person was killed in a left-turn collision where both parties entered on green 'balls.' Finally, two people were killed at high-speed locations where the parties had perpendicular through courses and one of them ran a red light. There were no fatal rear-end crashes.

Fatal and Incapacitating Red-Light Running Crashes

There were 76 fatal and incapacitating injury crashes that involved red-light running vehicles. The actual police reports were analyzed for these. Two thirds of the drivers disregarding the signal were men. This roughly reflects the mileage driven by men and women respectively. An analysis by age shows that people below age 25 and above age 70 are overinvolved in red-light running crashes.

Bicyclists and pedestrians frequently are at fault in crashes at signalized intersections. On the other hand, motorcyclists seem to be following traffic-control devices in exemplary ways, even if that does not prevent them from being injured in these crashes. A surprising finding is that drivers of pickup trucks are much more likely to run red lights than drivers of passenger cars.

A crash-time analysis shows it was daylight in 82% of the crashes and dark with streetlights lit in 15%. The roadway was dry in 85% of these serious crashes, wet in 14% and covered by snow or ice in 1%. About 10% of the crashes occurred at locations with a speed limit of 45 mph or higher, 42% of them on 25 mph streets and the remaining 48% on 30 to 40 mph-streets.

An analysis by town shows that the communities with the highest per capita frequency of serious injury crashes caused by red-light running are Auburn (6.9 per 10,000 people), Lewiston (3.6), Winslow (2.6), Bangor (2.5), Saco (2.4) and Presque Isle (2.1).

Observations of Red-Light Running

The overall frequency of red-light running is, in the literature, reported to vary with location from a low of around 0.05% to a high around 3.9%. Observations from 15 intersections around Maine are all within this range—varying between 0.1% and 1.3% if dividing the number of through vehicles entering on red by the total number of entering through vehicles. The percentages would be much higher if right-turning vehicles were included. The highest observation was found on a 4-lane, high-speed road in a rural setting (Route 202 through Manchester) whereas the lower percentages typically were found in lower-speed, urban environments.

Calculating the red-light running frequency as a percentage of those arriving during red, gives observations from 0.2% to 5.1%. The percentage running the light of those arriving as first vehicle after the signal turned red varied between 0.3% and 18%. If observing only those drivers that arrive within the first two seconds of red, an even higher percentage ran the light, between 3 and 97%.

Interviews with Maine Drivers

During 2002 and 2003, 334 completed surveys of people in Maine were collected by students.

People were asked what they typically do when approaching a signal that is changing so that it would become red just when they got to the stop line, if they proceeded with unchanged speed. A majority of drivers said they would slow down and stop but a majority of younger drivers would speed up in this situation. Only a very small minority of drivers admit to running a light which is clearly red before they get there.

People were asked if they could recall having run any red lights in the last 12 months. Over 75% of drivers below age 25 admit to this whereas only 38% of drivers 50 or older admit to it. In reality, people may have run lights more than they remember/admit to.

About 31% of people admit to knowingly[1] having run the 'latest' signal they entered on red while 43% claim they did it by mistake[2] and 11% say they became aware of the red signal so late that they did not have the option to stop. Finally, 7% say they were completely unaware that they had run the red light until they afterwards were told by a passenger (or police officer) that they had done so. This last category would be underreported since many people would have no passenger telling them about it.

People were asked if they have been stopped by police for running a red light and 34 of the 334 people participating in the survey admit to this.

People were asked what they think could be done to have *other* people run red lights less frequently. Five fixed alternatives were offered besides a fill-in line. Among the fixed alternatives, *photo enforcement* was the most favored with 44% supporting it followed by *longer yellow times* with 36%, *more police enforcement* with 35%, *shorter red times* with 20%, and *television information about risk of running red lights* with 15%.

The next question addressed what we can do to have the interviewee himself/herself

[1] They knew the light probably would change to red before they entered.

[2] The light changed to red quicker than expected.

run red lights less frequently. It was an open question with no given alternative answers. Again, most people suggested that enforcement, either through photo enforcement or more police on the streets, would be the most effective way of having them run fewer lights.

A total of 41 interviewees had been involved in crashes at signalized intersections as a driver (29 people) or passenger (12). Sixteen of the 41 people involved in crashes were occupants (typically the driver) of the vehicle running a red light. In three of these cases (19%), the driver misjudged the timing and thought it would not change to red so quickly. In two cases (13%) the driver was unaware that the signal had changed to red. In one case (6%), the driver was completely unaware that there was a signalized intersection, and in another case (6%) the driver did not see the signal since it was blocked by a truck.

Conclusions and Discussion

If we want to reduce the number and severity of crashes involving drivers running red lights, we need to do one or more of the following:

- reduce drivers' need to stop
- increase the likelihood drivers will stop
- reduce the likelihood of a (serious) crash if a driver runs a red light.

One way to achieve the goal of reducing drivers need to stop is to reduce the number of signalized intersections. Spontaneously, ten people suggested that we should have fewer signalized intersections and another three people suggested that signals go to flashing operation at night. Also in the survey, three people suggested that signals be better coordinated. Coordination of signals can significantly reduce the number of drivers facing a red light if it is done well. As indicated in the literature review, vehicle actuation is an alternative way to reduce the percentage of people facing a yellow or red light.

There are different ways to increase the likelihood drivers will stop for red lights. People in Maine believe that photo enforcement would be more effective than any other measure. The 'second' most effective way is a tie between 'longer yellow times' and 'more frequent police enforcement.

The driver was unaware that there was a red light (or even a signal) in four of the 16 crashes where the interviewee ran the red light. If, on average, 25% of all red-light running crashes have that characteristic, then improving signal visibility and conspicuity obviously could improve the safety dramatically.

Speed more than anything else determines the extent of injuries in a crash. Also, crashes are less likely to occur if all parties drive slowly. A conclusion one can draw from this study is that the posted speed should never exceed 35 mph at signalized approaches. Besides speed, the angle of collision is important in explaining injury outcomes to occupants of motor vehicles. Side impacts at a given speed are more serious than rear-end or head on collisions, though head-on collisions should always be avoided since the relative speed of the parties typically is very high. Separate, protected left-turn phasing is an important tool in reducing the number of side impacts as well as head-on collisions. We ought to also make sure that signalized intersections are safe for pedestrians, bicyclists and motorcyclists since a high portion of fatalities involve these categories.

EXTENDED SUMMARY

Traffic Signal Safety—Analysis of Red-Light Running in Maine

Introduction

The primary objective of this project is to inform Maine Department of Transportation and the public of how red-light running contributes to crashes at signalized intersections in Maine. As shown in previous research, busy intersections may handle traffic better and more safely as roundabouts than with signal control. But certainly, signalization is frequently the best overall strategy. However, crash analysis shows that the safety of signalized intersections has been declining somewhat, whereas other controls have experienced slight gains in safety. Studies by the Insurance Institute for Highway Safety (IIHS) indicate that the primary cause of this safety deterioration may be an increasing number of drivers running red lights. IIHS did not analyze what percent of red-light running crashes are caused by drivers running lights intentionally versus without knowing the light was red. Also, the IIHS did not include Maine in their studies.

This report should be seen as a supplement to the 2003 report by the Federal Highway Administration (FHWA) and the Institute of Transportation Engineers: *Making Intersections Safer—A Toolbox of Engineering Countermeasures to Reduce Red-Light Running*, which aims at assisting state and local agencies in identifying and properly addressing safety problems resulting from red-light running and guidance for using red-light cameras.

Literature Review

The first part of the project was to conduct a literature review which included over 80 documents. Among the findings of this review is that there are nationwide more than 100,000 red light running crashes (possibly over a quarter of a million) resulting in the death of about 1,000 people and close to 100,000 injuries each year.

Traditional *enforcement* of red-light running typically leads to police having to follow the violator through the red light to stop the person. That is obviously not very safe or efficient. Alternatives using *automatic surveillance* are therefore a 'natural' evolution. In 2001, automatic photo enforcement of red-light running existed in Arizona, California, Colorado, Maryland, New York, North Carolina, Washington DC and Virginia as well as in many foreign countries. Red-light violation cameras are typically activated if a driver enters an intersection more than one ½-second into red. The fine varies from jurisdiction to jurisdiction and can be over $250 besides demerit points on the driver's license. Red light cameras have been shown to reduce red light violations on an average of 40% at monitored locations. However, the effect on crashes may be substantially less than the effect on violations—maybe around 10 to 20%. Still, opinion polls have repeatedly demonstrated that the public supports automated enforcement of red-light running. Typical support levels are in the 72% to 84% range. The rates are slightly higher in cities that have cameras than in cities not having automated surveillance.

ITS technology[3] can be used to monitor vehicle and pedestrian positions, trajectories, velocities, and other data in order to predict and to warn pedestrians and drivers of real-time hazard situations. A simulated example in a reviewed paper shows that 88% of the relevant straight-crossing path crashes could be eliminated by timely warnings to violators and to drivers approaching on the side streets.

[3] ITS stands for Intelligent Transportation Systems

More *conventional technology*, such as *LHOVRA*, has been used in Sweden for over two decades and is now also used in Finland, Norway, Denmark and the Netherlands, but not in North America. LHOVRA is a control strategy for non-coordinated junctions. L stands for truck priority, H for main road priority, O for crash reduction, V for variable yellow time, R for red-light-infringement protection and A for alternative sequencing. The purpose is to improve safety and reduce delay, especially for targeted traffic such as trucks, buses or mainline traffic. The typical intersection approach is equipped with three sets of detectors. The set furthest away, approximately 300 meters (1000 ft) from the stop line, determines speeds and types of vehicles approaching. Then the vehicles are 'followed' as they approach through the other two sets of detectors. The effect of LHOVRA is a substantial reduction in the proportion of vehicles exposed to the switch from green to yellow light—from as high as 19% to around 1%. The crash reduction is typically observed to be around 25% compared to traditional signalization.

A meta-analysis of all worldwide studies of *flashing operations* shows a 55% increase in injury crashes and a 40% increase in property-damage-only crashes. It does not seem like signalized locations do well safety-wise when they are not on three-color operation.

A signal needs to be *seen* to be effective. An FHWA analysis of 306 crashes indicate that 40% of red-light running crashes happened because the driver did not see the signal or its indication. Whether a signal and its status will be seen or not depends on many factors, such as how unexpected it is, the size of the head and the intensity of the light, background illumination, shielding, and the visual environment of where the signal is located. FHWA studies indicate that 4% of red-light running crashes happened because the driver followed another vehicle into the intersection and did not see or look at the signal. A simple before and after study from North Carolina indicate that a larger size lens can lead to a substantial (47%) decline in right-angle crashes. Light emitting diodes (LEDs) can be used to produce a higher intensity light (so called high-brightness LED) and still consume less energy (80% less than incandescent lights with the same intensity). A major advantage with the energy savings is that an intersection can remain signalized longer on battery power in the event of a power failure. Another advantage with LEDs is that they last longer (over 5 years versus about one year).

Strobe lights in the red lens that emit 60 flashes of white light per minute are used at a few locations in Maine. A nationwide analysis of 22 intersections indicated that there was no consistent evidence that strobe lights are effective in reducing crashes. Rather, that study recommends the use of advance active warning signs at isolated rural or hard-to-see, high-speed locations.

A comparison of 'expected' crash frequencies at 106 signalized locations in British Columbia, some with *advance warning* flashers and some lacking them, found that overall the flashers seemed to reduce crash frequencies, but the difference was not statistically significant.

The safety effect of allowing *right turn on red* (RTOR) has been the focus of many studies. A meta-analysis of all worldwide studies in 1997 estimates the effect of allowing right-turn-on-red to be a 60% increase in injury crashes involving right-turning vehicles. However, the absolute number of serious crashes involving vehicles turning right on red is very small. Data from Maine for 1989 to 2000 shows that there were a total of 525 RTOR crashes at the analyzed 631 signalized intersections causing 6 fatalities and 117 injuries. This can be compared to the 43,398 total crashes (1.2% of the crashes) that occurred at these locations. The RTOR crashes accounted for 0.1% of all crashes statewide. Establishing separate left-turn lanes and *exclusive left-turn phasing* typically gives statistically significant reductions in crash numbers. A 1997 meta-analysis of 'all' existing studies shows that the most likely effect of introducing exclusive left-turn phasing is a 58% reduction in crashes involving left-turning vehicles. The safety effect of a permissive/protected phase was much smaller with a best estimate of 10% fewer left-turn crashes. A California Department of Transportation study found that left turn channelization by itself results in a 15% reduction in crashes but together with a separate left-turn phase there is a 35% reduction in crashes.

The 1997 meta-analysis shows that *longer evacuation times* (longer all-red phases and/or longer yellow times) on average reduce the number of crashes by 55%. However, 'habituation,' which means that people tend to adjust to the longer yellow and use more of it as part of an allowed travel phase, may make the long-term effect much smaller.

If signalized intersections are well *coordinated*, a larger percentage of people will arrive at them when the light is green. That obviously should reduce red-light running and improve safety. The 1997 meta-analysis showed that coordination, on average, reduced the number of injury crashes within the coordinated area by 19%.

Vehicle actuation as an alternative to coordination also means that a larger percentage of people will arrive at the signal when the light is green. The 1997 meta-analysis showed a 25% average reduction in the number of crashes.

Maintenance levels, awareness campaigns, countdown clocks and having the green light flash before the change to yellow are other measures discussed in the literature.

Crashes at Signalized Intersections in Maine

Official statistics provided by Maine Department of Transportation (MDOT) show that there were 10,169 reported crashes at signalized locations in Maine in the three-year period from 1999 to 2001. This means that the expected number of crashes at signalized intersections per year and per driver is around 0.0037. Assuming each crash involves two drivers, the 'average' driver will have 0.0074 crashes per year or one crash every 135 years. This may not seem like an alarming statistic but the estimated economic impact of these crashes is estimated by MDOT at $73 million per year.

Of the 10,169 reported crashes, 4203 (41.3%) were classified as intersection-movement crashes, whereas 5325 (52.4%) were classified as rear-end crashes. The remaining 6.3% of crashes were, in diminishing order, ran-off-road, head-on, pedestrian, bicycle, object in road, fire, roll-over, and animals. Of the intersection-movement crashes, 2611 were identified as left-turn crashes.

These crashes caused six fatalities, 277 incapacitating injuries, 1461 evident injuries, and 3115 possible injuries.

Three out of the six people who were killed were unprotected road users; one was a pedestrian, one a bicyclist and one a motorcyclist. The pedestrian and bicyclist disregarded the traffic-control devices. The motorcyclist collided with a vehicle making a left turn. One more person was killed in a left-turn collision where both parties entered on green 'balls.' Finally, two people were killed at high-speed locations where the parties had perpendicular through courses and one of them had run the red light. There were no fatal rear-end crashes.

The major types of crashes with respect to incapacitating injuries were intersection movements (60.8%), rear-end (18.7%), pedestrian (6.4%), bicycle (5.0%), ran-off-road (3.5%), and head-on (2.8%).

As can be seen in Table 1, driver inattention was cited as a contributing factor in more cases than disregard of a traffic-control device.

Table 1 Apparent contributing factor

Apparent contributing factor	Number of crashes	Percent of crashes
Driver inattention - distraction	3,399	31.6%
Failure to yield right of way	2,066	19.2%
Disregard of traffic control device	1,242	11.6%
Following too close	1,162	10.8%
Illegal, unsafe speed	391	3.6%
Improper turn	369	3.4%
Improper, unsafe lane change	350	3.3%
Other and unknown	1771	16.5%
Grand Total	10,750	100.0%

Fatal and Incapacitating Injury Crashes Involving People Disregarding Traffic-Control Devices

The actual police reports were analyzed for the 76 fatal and incapacitating injury crashes that involved red-light running vehicles.

An analysis by gender shows that 46 of the people disregarding the signal were men and 24 were women. This means that women here made up 34% of the violating drivers. In Maine, roughly 36% of all miles driven are driven by women, according to observations by the author and students in 1995.

An analysis by age is presented in Table 2. Numbers are small, but it is still clear there is a trend, that drivers below age 25 and drivers over the age of 70 more frequently are the offending party (running the red light). None of the 5-year age groups between 25 and 70 have ratios between offending and innocent numbers above 1.0 except for the 45 to 49 group. And the ratio for that age is far from significantly high (p=0.39). Added together, people above age 70 have a ratio that is statistically significantly higher than 1.0 (p=0.05), whereas the ratio for the group below 25 does not deviate significantly according to statistical testing (p=0.09).

Table 2 Age of at fault and innocent drivers involved in red-light running crashes

Age of driver	Drivers running red light		Drivers who did not run red light		Ratio between violating and not violating numbers
	number	%	number	%	
-19	10	14.3%	6	8.6%	1.7
20-24	8	11.4%	4	5.7%	2.0
25-29	6	8.6%	8	11.4%	0.8
30-34	5	7.1%	10	14.3%	0.5
35-39	6	8.6%	13	18.6%	0.5
40-44	7	10.0%	8	11.4%	0.9
45-49	7	10.0%	5	7.1%	1.4
50-54	4	5.7%	5	7.1%	0.8
55-59	3	4.3%	5	7.1%	0.6
60-64	2	2.9%	2	2.9%	1.0
65-69	1	1.4%	2	2.9%	0.5
70-74	4	5.7%	0	0.0%	high
75-79	2	2.9%	1	1.4%	2.0
80-84	2	2.9%	1	1.4%	2.0
85+	3	4.3%	0	0.0%	high
Total	70	100%	70	100%	1.0

We can also compare the age of the drivers running the red light to the size of populations of drivers in that age group. This comparison shows that younger drivers are clearly overrepresented not only as ‘guilty’ drivers running the red light, but also as the ‘innocent’ ones being the victim of someone else running the red light and colliding with them. This could be because there are seldom ‘truly’ innocent drivers since it is frequently possible to avoid being hit by a driver violating a right-of-way rule if one is cautious and drives defensively. It could also be that younger drivers drive more miles per capita, so that the driver population basis does not give a fair comparison of risk per mile driven.

Table 3 Age of drivers causing red-light running crashes compared to driver population

Age of driver	Drivers running red light		Drivers population, Maine		Ratio between violating number and driver population
	number	%	number	%	
-19	10	14.3%	44,313	4.7%	3.0
20-24	8	11.4%	70,934	7.5%	1.5
25-29	6	8.6%	67,642	7.2%	1.2
30-34	5	7.1%	81,684	8.7%	0.8
35-39	6	8.6%	94,548	10.0%	0.9
40-44	7	10.0%	105,348	11.2%	0.9
45-49	7	10.0%	102,073	10.8%	0.9
50-54	4	5.7%	94,020	10.0%	0.6
55-59	3	4.3%	82,099	8.7%	0.5
60-64	2	2.9%	53,443	5.7%	0.5
65-69	1	1.4%	45,745	4.9%	0.3
70-74	4	5.7%	38,701	4.1%	1.4
75-79	2	2.9%	28,161	3.0%	1.0
80-84	2	2.9%	18,554	2.0%	1.5
85+	3	4.3%	15,291	1.6%	2.7
Total	70	100%	942,556	100.0%	3.0

An analysis of vehicle types involved (see Table 4) shows that bicyclists, and probably pedestrians, frequently are at fault in crashes at signalized intersections where one party disobeys the signal. On the other hand, motorcyclists seem to be following the traffic-control device in an exemplary way, even if that does not prevent them from being injured in these crashes. These findings may not be surprising. Bicyclists frequently lack formal training in highway code. Motorcyclists are not only well trained, they also seem aware of the risks of running red lights when there is a conflicting vehicle nearby. The one finding that may be surprising when analyzing the table is that drivers of pickup trucks are much more likely to run red lights than drivers of passenger cars (p=0.03).

Table 4 Vehicle type and offense ratio

Vehicle type	Number of vehicles where driver ran red light and had a collision	Number of vehicles where driver was hit by someone running a red light	Ratio between offending and innocent numbers
2/4-door sedan	42	40	1.0
Station wagon	3	5	0.6
Van	5	14	0.4
Pickup truck	13	5	2.6
Truck	0	2	0.0
Motorcycle	0	5	0.0
Bicycle	7	0	high
Pedestrian	1	0	--
Sum	71	71	1.0

Crash times show it was daylight in 60 cases (82%), dusk in one case (1%), dark with streetlights lit in 11 cases (15%) and streetlights not lit in one case (1%). The roadway was dry in 62 cases (85%), wet in 10 cases (14%) and covered by snow or ice in one case (1%). About 10% of the crashes occurred at locations with a speed limit of 45 mph or higher while 42% of them occurred on 25 mph streets.

An analysis by town (for data see Table 22 on page 45 in the main text) shows that the communities with the highest per capita frequency of serious injury crashes caused by red-light running are Auburn (6.9 per 10,000 people), Lewiston (3.6), Winslow (2.6), Bangor (2.5), Saco (2.4) and Presque Isle (2.1).

Observations of Red-Light Running

The overall frequency of red-light running is, in the literature, reported to vary with location from a low of around 0.05% to a high of 3.9% or higher. Observations from Maine, which can be seen in Column 2 of Table 5, are all within this range.

Table 5 Red-light running frequencies

Location	over-all	of those arriving during red	of those arriving as first vehicle	of those arriving during first 2 seconds of red
Hogan Road, Bangor	0.4%	0.9%	3%	14%
Hogan at Springer	0.9%	1.2%	5%	39%
Springer Dr, Bangor	1.3%	1.6%	6%	60%
Broadway, Bangor	0.7%	1.8%	7%	22%
Center Street, Bangor	0.1%	0.2%	0.3%	3%
Union Street, Bangor	0.2%	0.4%	1%	6%
State Street, Veazie	0.2%	1.1%	1%	5%
Stillwater Ave., Orono	0.5%	1.9%	6%	19%
Western Ave, Augusta	0.9%	2.0%	18%	43%
Western Ave./Whitten	0.2%	0.3%	4%	8%
Route 202, Manchester	2.2%	5.1%	18%	97%
Congress St., Portland	0.2%	0.4%	2%	10%
Franklin Art., Portland	0.3%	0.5%	2%	10%
Main St., Waterville	0.2%	0.7%	2%	10%
Route 126, Lewiston	0.3%	0.5%	3%	8%
Arithmetic average	0.6%	1.2%	5.2%	23.6%

The overall red-light running frequency in these day-time observations vary from 0.1% to 2.2%. The highest observation (Route 202 through Manchester) was found on a 4-lane, high-speed road in a rural setting whereas the lower percentages typically were found in lower-speed urban environments. However, there are exceptions to this. For example, the reason that Springer Drive in Bangor has a high red-light running frequency may be that it is a four-phase signal with short green times and long red times and the intersection is close to capacity. This means that many drivers may have waited a long time for green and consider it their right not to have to wait for another cycle before they can enter. Few, if any other locations, ever have a phase failing to accommodate all stopped vehicles.

Interviews with Maine Drivers

Interviews of people in Maine were done by students at public locations during 2002 and 2003. Approximately 600 people were approached and 334 complete surveys were collected.

A total of 41 people had been involved in crashes at signalized intersections as a driver, passenger or pedestrian. Out of this total, 29 were driving the vehicle. Their age at the time of the crash was below 25 years in 19 cases, between 25 and 34 in five cases, and between 35 and 49 in the remaining five cases. So even though 25% of the interview subjects were older than 50, no one had been involved in a crash at a signalized intersection since they turned 50.

The behavior of drivers approaching a signal that turns yellow was examined through the following question:

> A traffic light changes to yellow so that it will just become red if you proceed at unchanged speed, do you typically slow down and stop speed up to make it before red other

The reply is shown in Table 6. It is clear that younger drivers tend to speed up in this situation whereas a majority of middle aged and elderly drivers do not.

Table 6 Behavior when light turns yellow

Behavior/age	<25	25-34	35-49	50-65	>65	Sum
Slow down and stop	35	32	52	48	13	180
Speed up	58	25	21	19	4	127
Other (write ins):						
depends, I do both	10	1	1	0	0	12
other	1	1	2	0	0	4
Not answered	7	1	1	1	0	9
Sum	112	60	77	68	17	334

The question above addresses what a driver does when he/she may be able to proceed before red. The situation is different if the light just changed to red. What a driver does at that time may be affected by what time of day it is when he/she is approaching the signal and whether or not there are other people around. To illuminate this, a subset of younger drivers, below the age of 30 (the ones who may be the most prone to run a red light in such a situation) were asked what they would do if they were approaching an intersection at 3 p.m. and the traffic light had just turned red and there was no traffic near them. The answer is shown in Table 7.

Table 7 Young drivers' behavior when no one is around

Behavior/age	Number
Definitely stop at the red and wait	40
Typically stop at red but then proceed	1
Typically slow down and proceed directly	0
Depends on how much of a hurry I am in	3
Not answered	0
Sum	44

People were asked if they could recall having run any red lights in the last year. In reality, they may have run red lights more times than they admit to. As seen in Table 8, it is obvious that younger drivers run red lights more than older drivers.

Reasons for running a light were captured through:

The last time you ran a red light, was it

Knowingly: Knew light would probably change to red just before getting to it

By mistake: Light changed to red quicker than expected

Unaware until too late to stop. Reason for not seeing the light: ………………

Completely unaware of running it until afterwards when passenger pointed it out

Other (give reason):

The response is summarized in Table 9. Note that the question did not ask about the most common reason for running a red light (which would give a biased percentage when added over the population) but about the reason for running the 'latest' red light. The main section of this report addresses why people were unaware of the light.

Table 8 People's recollection of having run any red lights in the last 12 months

Behavior/age	<25	25-34	35-49	50-65	.>65	Sum
No	26	21	43	40	13	143
Yes, once	30	16	21	14	4	85
Yes, > once	56	23	13	14	0	106
Sum	112	60	77	68	17	334

Table 9 Reason for running light

Behavior/age	<25	25-34	35-49	50-65	>65	Sum
Knowingly	32	21	9	2	1	65
By mistake	37	12	17	21	5	92
Unaware until too late	8	4	6	3	3	24
Completely unaware	5	3	1	6	0	15
Other (write ins):						
knowingly, stopped, then drove	6	1	2	0	0	9
other	3	1	3	0	0	7
Sum	91	42	38	32	9	212

People were asked if they have been stopped by police for running a red light: The responses are shown in Table 10. It is interesting to see that roughly as many people have been stopped for running a red light as the number of people who have had a crash at a signalized intersection. Obviously, people run many red lights before they are stopped for doing so, or, on average, are involved in a crash.

Table 10 Stopped by police for running red light

Behavior/age	<25	25-34	35-49	50-65	>65	Sum
No	104	48	66	61	16	295
Yes	7	11	9	7	0	34
Not answered	1	1	2	0	1	5
Sum	112	60	77	68	17	334

An analysis of the data shows that there does not seem to be a (positive) correlation between having been ticketed and not running red lights. And this lack of correlation should probably be expected. People who by nature 'like' running red lights would be ticketed more frequently than others. It also may indicate that one (or a few) ticket(s) is not a good deterrent to running red lights.

The following question aims at finding out what people think we can do to have *other* people run red lights less frequently.

> Suggest how we could make other people run red lights less frequently (mark one or several boxes)
>
> More frequent police enforcement
>
> Photo enforcement / Automatic video surveillance and ticketing
>
> Shorter red times so that it doesn't take so long to get green again
>
> Longer yellow times, so it becomes easier to stop before red
>
> Television information about risk of running red lights
>
> Other, describe:

The most common answers to the question can be seen in Table 11. For complete responses, and how the responses vary with age, see Table 44 on page 67.

Table 11 Effective measures to make other drivers run red lights less

Behavior/age	Sum
Photo enforcement/automatic video surveillance	146
Longer yellow	120
More frequent police enforcement	118
Shorter red times	66
TV info about risks	51
Other write-ins:	27
Sum	528

The next question asked was what we can do to have the interviewee himself/herself run red lights less frequently. It was an open question with no given alternative answers. The complete responses by age of respondent are shown in Table 45 on page 68. The most common answers are presented below in Table 12. Most people suggest that enforcement, either through photo enforcement or more police on the streets, would be the most effective way of having them run fewer lights. Enforcement is followed by longer yellow times and shorter red times. Vehicle actuation is also a fairly common suggestion.

Table 12 Effective measures to make the interview subject run red lights less

Behavior/age	Sum
Photo enforcement/automatic ticketing/camera boxes	31
Longer yellow phases	26
More enforcement (police) or more tickets issued	16
Shorter red-light times	12
Eliminate [some/many/most] signalized intersections	10
Vehicle actuated (rather than timed) signals	9
Higher penalties	7
I need to pay more attention when I drive	5
Longer green phases	4
Bigger signal lights/make lights more noticed	3
Coordinate (synchronize) lights for green wave	3
Have signals go on blink at night/off season	3
Have the yellow flash just before turning red	3
Have yellow light flash (throughout phase)	3
Less police	3
Others	58
Sum	196

Description of Crashes

Below is a summary of the responses by interview subjects involved in crashes at signalized intersections. The exact questions can be seen in the section starting on page 68. The individual responses from each of the 41 people is presented in the appendix starting on page 80.

Seven of the 41 people involved in crashes were passengers in vehicles, whereas the other 34 had been driving a car or pickup truck.

One question was asked to assess if anyone and if so who ran a red light and why that happened. In 25 cases, either no one or the other party ran a red light and we cannot expect detailed information from the interviewee about the mechanism that led up to the traffic control device being violated. In the remaining 16 cases the interviewee (or the driver of that vehicle) ran the light. In three of these cases (19%), the driver misjudged the timing and thought it would not change to red so quickly. In two cases (13%) the driver was unaware that the signal had changed to red. In one case (6%), the driver was completely unaware that there was a signalized intersection, and in another case the driver did not see the signal since it was blocked by a truck.

A majority of drivers (34) said they were not distracted prior to the crash. Three people did not give an answer, whereas four subjects stated they had been distracted. A young man admitted to having been looking at an attractive woman pumping gas, when the person in front stopped on flashing yellow. Another person stated, "We never saw the signal since a truck blocked it and we were distracted prior to the collision by the large truck. The driver (of our vehicle) was shouting out profanities at the truck and weaving back and forth behind it." Another person claims to have been distracted by the car behind, visible in the rear-view mirror. Finally, one person was distracted by a passenger.

Four people did not answer the question of whether injuries were sustained, whereas 25 stated that no one was injured. Seven reported minor injuries, while two reported more serious whiplash injuries.

Fifteen people answered 'yes' to the question, "Have you become more careful/changed your driving behavior as a result of this crash?" while seven gave no answer and nineteen said that they had not become any more careful.

Conclusions and Discussion

It is obvious that drivers arriving at a signal when it is green will not run a red light. Therefore, it is natural that an approach that has green for most of the cycle time should have a lower red-light running frequency than one with more red. The last three columns in Table 5 illustrate red-light running frequencies 'corrected' for such variations.

If we want to reduce the number and severity of crashes involving drivers running red lights, we need to do one or more of the following:

- reduce drivers' need to stop
- increase the likelihood drivers will stop
- reduce the likelihood of a (serious) crash if a driver runs a red light.

These goals (or strategies) are sometimes conflicting. Different avenues for reaching the goals are summarized below. It should be kept in mind that before we enforce an illegal behavior, we should make sure that it is technically possible to behave in a legal way. In other words, signals must be timed so that it is possible to stop during the yellow phase.

One way to achieve the goal of reducing drivers' need to stop is to reduce the number of signalized intersections. To convert them to 2-way stop control or to put them on yellow/red blink means that the drivers on the major road no longer need to stop. However, drivers on the minor approaches still will need to stop. Converting the intersections to roundabouts means that fewer drivers will need to come to full stops. It is therefore important to do a thorough analysis of where signals make sense from a safety perspective—and where alternatives should be found even if a signal is warranted. As seen in Table 12, ten people spontaneously suggested that we should have fewer signalized intersections and another three people suggested that signals go to flashing operation at night.

Also in the survey, three people suggested that signals be better coordinated. Coordination of signals can significantly reduce the number of drivers facing a red light if it is done well.

As indicated in the literature review, vehicle actuation is an alternative way to reduce the percentage of people facing a yellow or red light—and unless volumes are very high, vehicle actuation is often more effective at doing this than coordination of signals. In the survey, eleven people advocated for more or better actuation, whereas only three people argued for green-wave coordination.

There are different ways to increase the likelihood drivers will stop for red lights. As can be seen in Table 11 people believe that photo enforcement/automatic video enforcement would be more effective than any other measure in reducing red-light running. The 'second' most effective measure in getting people to run fewer lights is a tie between 'longer yellow times' and 'more frequent police enforcement.' "Photo enforcement" and "more police," are indicated 264 times among the 334 people who responded.

The response in Table 12 indicates what people think would be effective in making themselves run fewer lights. Not too surprisingly, they are the same three measures that are ranked in top, with photo enforcement/automatic ticketing/camera boxes/video surveillance as the most suggested one, followed by longer yellow times and then by more enforcement by police.

The conclusion is clear, based on the survey, people in Maine believe photo enforcement would be the most effective way of cutting back on red-light running. There seems to be a certain level of acceptance for such a measure since such a great majority of people indicated they believe it would be effective. Obviously, photo enforcement as well as other types of enforcement would be effective in reducing violations. However, red lights that are run completely by mistake will still be run even if enforcement and tickets may cause some drivers to look more carefully for red lights in the future.

Shorter wait times should lead to fewer people running red lights on purpose, and shorter cycle times would give shorter wait times—unless the signal reaches capacity. However, longer cycles reduce the number of times a driver will face a yellow light (and also a red light as first vehicle), meaning that the longer the cycle time, the fewer the drivers that will run the light by mistake.

When it comes to making themselves run fewer lights, 26 people spontaneously suggested longer yellow times. On the other hand, 120 people gave this as their option when it was given as a fixed alternative to have other people run fewer lights.[4] Longer yellow times could lead to lower capacity and longer wait times and might therefore, at busy intersections, increase irritation and thereby red-light running. However, at less busy intersections, lengthening the yellow by 2 seconds would delay people on the cross street by only those two seconds and that might be an acceptable price to pay if red-light running is decreased significantly. But it is my contention that if most intersections had long yellow times people would start using more of the yellow phase as an extension of the green phase.

The driver was unaware that there was a red light (or even a signal) in four of the 16 crashes where the interviewee ran the red light. If, on average, 25% of all red-light running crashes have that characteristic, then improving signal visibility and conspicuity obviously could improve the safety of signalized intersections. To improve the observance of signals in general, people suggest making lights more noticeable, bigger signal heads, a sign warning of an upcoming light, and lowering the light for better visibility when backlit by sun. Suggestions to make drivers note that the signal is changing from yellow to red include having the yellow light flash or add

4 It is probably not the fact that the question refers to different 'groups' that make the total number of responses differ so much, but the fact that people tend to indicate a given alternative more than they spontaneously would suggest it.

another yellow light. To increase the predictability of when the red will come on, suggestions include showing countdown in seconds before red, more warning of when yellow to red, and have the yellow flash just before turning red. To have people notice that the light has turned red, suggestions include bigger red lens than green and yellow, have red light flash[5], or an alarm in the car when a red light is run.

Traditionally, incandescent lights have been used for signals. Today, light-emitting diodes are sometimes used, and Maine DOT funds such conversion. They use 90% less energy than incandescent bulbs producing the same 'light.' However, if we want to improve their conspicuity we should use some of that energy saving to increase the emitted light intensity, especially during daytime conditions.

About 15% of the people surveyed indicate that television information about the risks of running red lights may be effective in reducing the amount of red-light running. It is my opinion that information about the risks of a crash would not influence people's behavior dramatically since, to paraphrase Leonard Evans of General Motors, few crashes are caused by drivers not knowing what to do, but many are caused by drivers doing what they know they shouldn't be doing. His conclusion is that training is often not effective, but that changing people's attitudes is important.[6] Also, it is my belief that people see the risk of a crash as so small that changing their behavior makes little sense to them, especially since they believe what they are doing is "under their full control." However, if we increased the chances of them being ticketed to be clearly higher than that of a crash[7] then information about the 'high' risks of being fined for running a red light could be effective in reducing the propensity to do so. Still, if this information was false, that the risk of a fine remained low, the campaign would probably not have a significant long-term effect.

Speed more than anything else determines the extent of injuries in a crash. Crashes are also less likely to occur if all parties drive slowly. If someone runs a red light by mistake at a low speed, he/she may be able to avoid a crash when seeing another vehicle simultaneously entering from a cross street. The speed limit of all fatal and serious injury crashes involving drivers disobeying traffic control devices is shown in Table 13. These numbers by themselves do not say much. Relating them to exposure would. But rather than try to collect exposure, rear-end and left-turn crashes at signalized locations have been used here as a proxy for exposure.

Table 13 Speed limit and crash types

Speed limit	Number of serious red-light-running crashes	Number of rear-end crashes	Number of left-turn crashes
15 mph	0	1	6
20 mph	0	0	1
25 mph	30	260	1141
30 mph	8	131	485
35 mph	20	142	913
40 mph	3	6	51
45 mph	6	10	87
50 mph	1	0	2
55 mph	0	2	2
unknown	3	77	93
sum	71	629	2781

5 Today, flashing red light means stop and then proceed. That meaning would obviously not be possible to keep parallel to a flashing red light meaning stop and wait for green.

6 Leonard Evans; *Traffic Safety and the Driver*, New York, NY: Van Nostrand Reinhold; 1991.

7 Which it today isn't based on our survey which showed that these people had been involved in 41 crashes at signalized intersections and been stopped for running a red light in 34 cases.

It can be seen that 14.7% of the serious injury crashes (with known speed limits) occurred on sections with a speed limit of 40 mph or higher, whereas these speeds accounted for only 3.3% of the rear-end crashes and 5.3% of the left-turn crashes. If we look at speed limits of 50 mph and above, the serious crashes made up about five times the percentage of the other types. If we on the other hand look at the speed limit of (exactly) 35 mph, the serious crashes were not overrepresented. For speeds below 35 mph, the serious crashes were somewhat underrepresented. A conclusion one can draw from this is that the posted speed should never exceed 35 mph at signalized approaches.

Of the six fatal crashes at signalized intersections, two occurred where the speed limit was 25 mph, two on 35-mph streets, one in a 45-mph zone and one in a 50 mph zone. Three out of the four fatalities claimed on sections with a speed limit of 35 mph or less were unprotected road users (a pedestrian, a bicyclist and a motorcyclist). In other words, there was only one fatality among "protected road-users" on streets with speed limits of 35 mph or less, even though about 95% of the reported crashes at signalized intersections occurred within such speed limits. It is obvious that we ought to not only restrict the posted speed to 35 mph at signalized intersections, we should also make sure that signalized intersections are safe for pedestrians, bicyclists and motorcyclists. This is hard to do, especially for pedestrians and bicyclists since they obey signals much less than drivers of motor vehicles. Maybe public education campaigns could improve the compliance, but it will be hard to ever get good compliance among pedestrians in particular. Again, lower speed is then the key to improved safety—as shown in the report "Pedestrian Safety in Maine," Final Report ME00-2, Maine Department of Transportation, 2002. Lower speed was also suggested by some people in the survey conducted within this project.

Besides speed, the angle of collision is important in explaining injury outcomes to occupants of motor vehicles. Side impacts at a given speed are more serious than rear-end or head on collisions, though head-on collisions should always be avoided since the relative speed of the parties typically is very high. Separate, protected left-turn phasing is an important tool in reducing the number of side impacts as well as head-on collisions.

Traffic Signal Safety
Analysis of Red-Light Running in Maine

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MAIN REPORT

1 Introduction and Objective of Study

1.1 Objective

The primary objective of this project is to inform Maine Department of Transportation and the public of how red-light running contributes to crashes at signalized intersections in Maine, why they occur and how such crashes can be made less common.

The result of the research should ultimately lead to fewer serious crashes at signalized intersections. Safety optimization obviously has to be balanced with other operational concerns such as delay and air emissions.

1.2 Technical Approach / Methodology

The project was planned to follow the tasks outlined below.

Task 1: Literature Review and Personal Contacts with Experts to identify and analyze research already conducted.

Task 2: Site Selection. Representative signalized intersections in Maine will be chosen, and their safety history and driver behavior will be surveyed. Cities and towns of different sizes will be included, and different types of signal environments selected.

Task 3: Data Collection. Crash data will typically be obtained for a minimum of three years for a site. Traffic volume data will also be collected for exposure purposes. The behavioral studies will be analyzed and compared to crash experiences at that location.

Task 4: In-depth interviews: Drivers, in particular crash-involved ones, will be interviewed. This is the major thrust of the project, and the surveying methodology will be tested through pilot studies prior to the main study.

Task 5: Analysis: The data collected in Tasks 1-4 will be analyzed. Countermeasures will be suggested, and their cost-effectiveness will, if possible, be assessed.

Task 6: Documentation of Findings. Findings from this research will be documented in a final report, presented at professional conferences and workshops, and reported in papers submitted for publication in scholarly journals.

1.3 Introduction

As shown in previous research (Persaud et al, 2001; Gårder, 1998; and Gårder, 1997), busy intersections may handle traffic better and more safely as roundabouts than with signal control. But we will continue to have signals for many years to come, and will probably see many more installed. And certainly, signalization is sometimes the best overall strategy. However, crash analysis shows that the safety of signalized intersections has been declining somewhat in recent years whereas other controls seem to have experienced slight gains in safety. National crash data from the National Highway Traffic Safety Administration's (NHTSA) Traffic Safety Facts and FARS (the fatal Accident Reporting System) for 1994 through 2001 are shown in tables in the appendix on page 94 and summarized for all reportable intersection crashes in Figure 1 below. Intersection as well as intersection-related crashes are included.

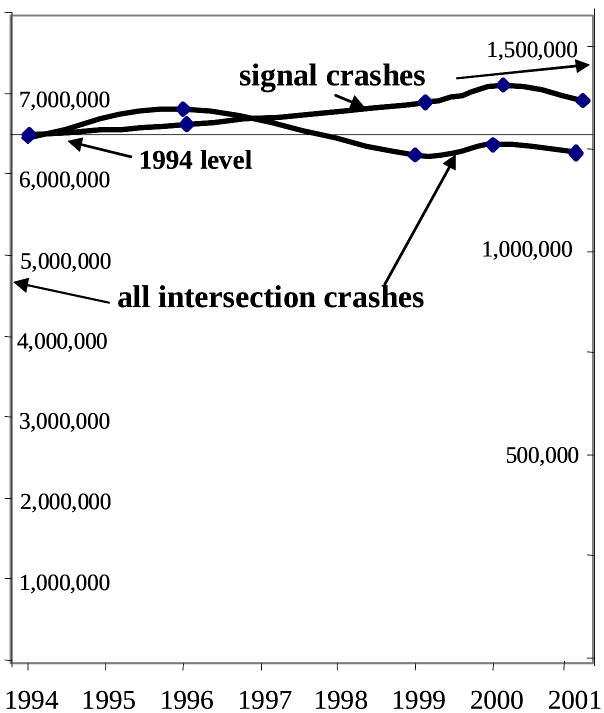

Figure 1 Number of crashes at signalized intersections versus at all U.S. intersections

Studies by the Insurance Institute for Highway Safety (IIHS, see summary on page 93) indicate that the primary cause of this safety deterioration may be an increasing number of drivers running red lights. One factor the IIHS did not analyze is what percent of serious red-light running crashes are caused by drivers running lights intentionally[8] versus without knowing[9] that the light was red. That is the core of this study. The two types of crashes obviously may need very different countermeasures.

About 45% of all intersection crashes in the United States involve left-turning vehicles (Box and Basha, 2003). In other words, to ensure safety, signalization must effectively separate left-turning traffic from through traffic. Effective separation implies that the flows are separated not only in theory, but also that people do not encroach into their red times.

The Federal Highway Administration has issued guidance to assist state and local agency managers, transportation engineers, and law enforcement officials in identifying and properly addressing safety problems resulting from red-light running and guidance for using red-light cameras. These issues are discussed on the web at the address http://safety.fhwa.dot.gov/rlcguide/index.htm.

Obviously, we run many more lights with intent (if including misjudged belief that we would just make it before red) than we do by mistake (i.e. without knowing the light was not green) but it is the hypothesis of the investigator that the more dangerous situations are the ones we are unaware of. And, as previously pointed out, different countermeasures are needed for the two situations. Sometimes it may be impossible for a driver to 'know' if a signal is green or red. When driving behind a full-sized truck it may be impossible to see the signal heads. Therefore,

8 'Intentionally' here means that drivers knew the light would be red or that it possibly could be red before they entered the intersection. In other words, there is no differentiation between where the driver 'knew' the light would change to red just before entering versus situations where the driver believed/hoped he would be entering just before the red light came on.

9 This category would encompass drivers who were completely unaware of the fact that there was a signalized intersection or they may have known that there was a signalized intersection but they were completely unaware of the light not being green until they entered the intersection or were so close that they no longer had any option but to enter it.

drivers of cars may follow trucks through signals even if the light shifted to red just when the truck entered. Obviously, drivers should not follow large trucks so closely that they cannot see the signal. Signals ideally should not turn red when trucks are at intersections. Also, signal heads should be located so that they are visible to a driver following a truck. When driving in front of trucks it may also be unsafe to stop when the signal is in the process of turning red. Serious crashes are caused by drivers stopping when a driver of a heavy vehicle following them does not stop, either because he/she decides that it is "green enough," or misses the signal altogether. Therefore, trucks should never be able to get into a dilemma or option zone, or be given yellow or red when they are within, say, 6 seconds of entering a signal. For several decades, that technology has been used in Scandinavia but it has not been used in the US. Such strategies (LHOVRA) are discussed further in Section 2.5.1.

The effect of red-light running surveillance using video or photo techniques has already been studied extensively, and a summary of these findings is provided in Section 2.4. The effectiveness of other measures is also discussed in Chapters 2 and 6.

Whether a driver will stop for red or not depends, according to Richard van der Horst, on expectations and knowledge of operations as well as estimated consequences of not stopping versus estimated consequences of stopping ("Drivers' Decision-Making at Signalized Intersections: An Optimization of the Yellow Timing," by R. van der Horst and A. Wilmink, *Traffic Engineering and Control*, 1986, pp 615-622).

1.4 Maine Definition of Red-Light Running

Applicable highway code for Maine can be found in Title 29-A, §2057. The statutes can be found on http://janus.state.me.us/legis/statutes/ and in Appendix 5. Maine Statute is current as of January 2003.

In Maine, like in many but not all states, it is legal to enter an intersection during the yellow phase even if it would have been possible to stop safely.

Right turn on red (circular ball) light is permitted after stop in all states, including Maine. Eight states, Maine, Alaska, California, Colorado, Georgia, Idaho, Minnesota and New York, plus the District of Columbia, and Puerto Rico, do not allow right turn on red even after a full stop when there is a red arrow pointing right. Some state laws do not specify the meaning of (right) red arrows, whereas other states allow right turn on red arrow after a full stop (as of January 2003).

Left turn on red light (LTOR) from a one-way road into a one-way road is permitted after stop in 42 states and Puerto Rico, but not in Maine, Connecticut, Missouri, New Hampshire, New Jersey, North Carolina, Rhode Island, South Dakota[10], the District of Columbia, or Guam.

[10] Unless authorized by a municipal ordinance

2 Literature Review

2.1 General

The literature review included over 80 documents. However, many of them were found to be of little relevance and are therefore not discussed here.

2.2 Red-Driving Habits

2.2.1 Frequency

A national survey (conducted by researchers at Old Dominion University) of over 5000 drivers in 1999, "A Nationwide Survey of Red Light Running: Measuring Driver Behaviors for the 'Stop Red Light Running' Program" found that 55.8% of respondents admitted running at least one red light out of the last 10 signalized intersections they have traveled through. That would mean that *at least* 5.58% of drivers run a red light at an individual intersection. That seems remarkable since:

> A high percentage of all driving occurs during busy times of days. During such times, typically at least 20 vehicles per lane travel through an intersection during each cycle. Observations from 22 locations in the greater Bangor area during different times of the day show that the average number of vehicles going through on green, for every person facing a red light as the front vehicle, is around nine per lane. And this (simple) average does not say everything. Let us assume that we are at an intersection between Main Street and Small Street and that Main Street has 600 vehicles per hour per lane approaching the intersection whereas Small Street has 60 vehicles per hour per lane. Let us further assume that we have a cycle time of 60 seconds with 40 seconds green time along Main Street and 10 seconds along Small Street. On average, there will be 10 vehicles per lane per phase on Main Street and one on Small Street. If few drivers run red lights, only one in ten would have the opportunity to do so along Main Street whereas 57% (one in 1.75) would have that opportunity along Small Street. (It may seem as if more or less everybody would have the opportunity to run the red light along Small Street but some people on Small Street—one in six—would get there when the signal was green and random arrivals would mean that there would be a 26% chance that two or more people would be arriving during the same green phase). If we assume that both streets have the same number of lanes, the weighted average for these two approaches would be one in 9.3 [(600 x 10 + 60 x 1.75)/660 = 9.3] rather than one in 5.9 [(10 + 1.75)/2 = 5.9]. In general, approaches with high volumes have longer green times, and the weighted average will therefore be much higher than a simple arithmetic average. So rather than using the simple average from the Bangor observations, of one in nine, one should use an average around one in 15. Assuming that 50% of those arriving first after red would run it, would mean that one in 30 or 3.3% (40% below their findings) would do so. And the assumption of 50% doing it seems high since the first vehicle often will not arrive at the stop line until several seconds after the light has turned red.

The article "Automating Safety" by Sharon Cuevas Hansen (*Traffic Technology International*, August/September 2001, p. 103) states that "on average, a motorist runs a red light every 12 minutes somewhere in the

US. During peak travel time, red light running occurs every five minutes."

For the two 'numbers' to match, there should be, on average, 12 minutes between "6% of AADT." And that would be true if the entering volume (sum of AADT for each street) was 2,000. Then, with 6% running red lights, 120 drivers would run the light per day, and over a 24 hour period, the average time between red-light running would be 12 minutes. However, the average signalized intersection in America has more than 2,000 vehicles per day entering it, so one of the 'facts' must be erroneous.

The authors of the Old Dominion report on the nationwide survey later published a paper on the same subject, "A nationwide survey of self-reported red light running: measuring prevalence, predictors, and perceived consequences" by Bryan E. Porter and Thomas D. Berry (*Accident Analysis and Prevention* Volume 33, 2001, pp 735-741). However, in this published version, only 880 drivers participated. And, 'only' 19.4% of respondents reported running one or more red lights when entering the last ten signalized intersections. About one in five certainly sounds more reasonable than 55.8% but may still be a high estimate from people misjudging their own propensity. Less than 6% of the respondents had received a ticket for running a red light and slightly more than one in ten had been involved in a red light running crash.

Furthermore, the referenced article "Automating Safety" by Sharon Cuevas Hansen may misquote the original study. Richard A. Retting, A.F. Williams and M.A. Green, "Red-Light Running and Sensible Countermeasures: Summary of Research Findings (*Transportation Research Record 1640,* 1998, pp. 23-26) gives the same violation rates, but those are not nationwide generalizations but studies of only two intersections in Virginia.

The violation rates typically span from 0.05% to 0.6% according to *Making Intersections Safer: A Toolbox of Engineering Countermeasures to Reduce Red-Light Running* (the Federal Highway Administration and the Institute of Transportation Engineers, 2003, p. 6). But one of the 13 intersections had a much higher violation rate, 3.9%.

A Norwegian study from 1997 shows that, on average, 0.8% of motorists arriving at red runs it (*Trafikksikkerhedshåndbok* by Rune Elvik, Anne Borger Mysen and Truls Vaa, TØI, Oslo, 1997, p. 308). However, 24.7% of pedestrians and 36.1% of bicyclists do it.

"Comparative Study of Advance Warning Signs at High Speed Signalized Intersections" by Prahlad D. Pant and Yuhong Xie (*Transportation Research Record 1495,* 1995, pp. 28-35) shows that locations with different types of passive and active advance warning signs have red-light running frequencies that vary between 0.24% and 0.47%.

2.2.2 Intention

'A Nationwide Survey of Red Light Running: Measuring Driver Behaviors for the "Stop Red Light Running" Program' also found that about 56.6% of red-light-running drivers did so intentionally. This finding does not necessarily mean that the other 43.4% did so without being aware that they may be running a red light if they did not stop. If a person approaches a yellow light and believes it will remain yellow until he/she goes through the intersection, but it changes to red slightly earlier than expected, then the person would typically state that he/she did not run the red light intentionally.

The study "Signal detection in conditions of everyday life traffic dilemmas" by Tova Rosenbloom and Yuval Wolf (*Accident Analysis and Prevention* Volume 34, 2002, pp 763-772) shows that not stopping for yellow lights is related to people's personality, in particular their "sensation seeking" (or thrill and adventure seeking) as defined by Zuckerman's psychometric test.

2.2.3 Detector malfunctioning

A special type of red-light running is that which people do when they do not get their green phase in a 'reasonable' time. For example, an intersection that has a protected left-turn phase—and a malfunctioning detector—may never display the left green arrow. A driver wanting to make this turn will probably make it during the through phase after waiting two or three cycles. (That driver would likely proceed only when safe to do so, however.) The problem with malfunctioning detectors has been discussed in the literature, e.g. in *NCHRP Synthesis Report 166, Traffic Signal Control Equipment: State of the Art*, 1990, pp. 17-22.

2.3 Red-Driving Crashes

In the year 2000, there were more than 100,000 red light running crashes in the United States., claiming the lives of 1,036 people and resulting in 89,000 injuries according to "Improving Intersection Safety—What's Next?" by George Ostensen, January 2003 *ITE Journal*, pp 32-39.

Similar numbers are quoted by the US Department of Transportation's Federal Highway Administration (FHWA) which tallied "more than 1.8 million crashes at controlled intersections in 2000. Red-light running accounted for 106,000 crashes, 89,000 injuries, and over 1,000 deaths. Greater than half of those fatalities were pedestrians and occupants of other vehicles hit by violating motorists." (*Traffic Technology International*, August/September 2002, p. 46).

However, the FHWA/ITE Informational Report states that, "According to preliminary estimates by the Federal Highway Administration (FHWA) for 2001, the most recent year for which statistics are available, there were nearly 218,000 red-light running crashes at intersections (1). These crashes resulted in as many as 181,000 injuries and 880 fatalities, and an economic loss estimated at $14 billion per year." (*Making Intersections Safer: A Toolbox of Engineering Countermeasures to Reduce Red-Light Running*, the Federal Highway Administration and the Institute of Transportation Engineers, 2003, p. 3). (An early presentation of this joint ITE/FHWA study—presented as *Engineering Countermeasures to Reduce Red Light Running* by Edward R. Stollof, Institute of Transportation Engineers, October 22, 2002—gave the number of crashes as 106,000. that number corresponds to the one given above. The source of the newer, higher estimates—referenced as (1) in the Informational Report—is given as "Information given by the Federal Highway Administration in September 2001." Obviously, the higher numbers are estimates since the numbers were provided well before the end of the year. However, they are most likely also closer to the true numbers since there historically is supposed to be an underestimate of the number of crashes caused by red-light running.

A study based on crash data from US-DOT by researchers from the Insurance Institute of Highway Safety estimates that drivers who run red lights are responsible for 260,000 crashes each year in the U.S. Of these, approximately 750 are fatal ("Prevalence and characteristics of red light running crashes in the United States" by Richard A. Retting, Robert G. Ulmer and Allan F. Williams (*Accident Analysis and Prevention* Volume 31, 1999, pp 687-694). One finding was that, especially among younger drivers, males are much more prone than females to be the culprit involved in red-light-running crashes in general, and fatal ones in particular. Heavy trucks make up 5% of the 'runners' and 11% of the 'non-runners' in these crashes. In two out of three crashes, it is the 'running' vehicle that strikes the other vehicle. Alcohol was involved among 35% of the runners and 4% of the non-runners. When it came to previous violations and crash history, the runners and non-runners had almost identical averages. However, the runners had more of a history of drunk driving convictions. That study is also summarized in "Reducing red light crashes" by Richard Retting (*ITS International*, May/June 2001, p. 53). The same numbers are quoted in many other articles, for example in "Automating Safety" by Sharon Cuevas Hansen (*Traffic Technology International*, August/September 2001, p. 103). Also, "motorists are more likely to be injured in a red light running crash (45%) when compared to non-red light running crashes (30%)." ("Hidden Benefits" by Rudi Gebert, *Traffic Technology International*, Annual Review 2001, p. 99).

Slightly more than one in ten respondents (10.9%) had been involved in a red light running crash according to the Old Dominion University study, "A nationwide survey of self-reported red light running: measuring prevalence, predictors, and perceived consequences" by Bryan E. Porter and Thomas D. Berry (*Accident Analysis and Prevention* Volume 33, 2001, p. 739). With 260,000 crashes per year, as estimated by Retting et al and almost 190 million drivers in the United States, 0.14% of drivers would be involved in such a crash in a given year. For 10.9% to have been involved in such a crash, the average driver would need to have driven for over 79.7 years. Many of the self-reported crashes in the nationwide survey must not have been reportable crashes, or else even the 260,000 is an underestimate.

Several European studies, including one by this author ("Pedestrian Safety at Traffic Signals: A Study Carried out with the help of a Traffic Conflicts Technique." *Accident Analysis and Prevention* Vol. 21, 1989, pp 435-444) shows that a majority of pedestrian crashes happen because one of the parties does not obey the signal. However, in a clear majority of these, it is the pedestrian that jaywalks rather than the motorist who runs the red light. Bicyclists frequently also run red lights and are sometimes hit as a result of that.

Below will follow an analysis of different measures that can improve the safety of a signalized intersection, especially with a focus on reducing red-light propensity. There are some studies that look at multiple measures such as the paper "Applying the random effect negative binomial model to examine traffic accident occurrence at signalized intersections" by Hoong Chor Chin and Mohammed Abdul Quddus (*Accident Analysis and Prevention* Volume 35, 2003, pp 253-259). They found that eleven variables significantly affect the safety of signalized intersections. These include total approach volume, number of phases per cycle, existence of a wide median, control of left-turn lane[11], and the presence of a surveillance camera. Better sight distances surprisingly led to higher crash risk. They speculate that there may be a correlation between sight distance and speeds and point out that Risto Kulmala found similar results in his Finnish study ("Safety at Rural Three- and Four-Arm Junctions: Development and Application of Accident Prediction Models, VTT, Espoo, 1995).

2.4 Photo Enforcement

Traditional enforcement of red-light running typically leads to police having to follow the violator through the red light to stop the person. That is obviously not a very safe or efficient way of stopping a large percentage of violators. Alternatives using automatic surveillance are therefore a 'natural' evolution.

2.4.1 Usage

The article "Automating Safety" by Sharon Cuevas Hansen (*Traffic Technology International*, August/September 2001, p. 104) states

[11] This study is based on Singapore data where people drive on the left. What they found was that allowing an uncontrolled left turn (right-turn-on-red in the US) significantly added to crash numbers. The existence of a right turn lane was not examined whereas the right-turn volume (left-turn in the US) was found to be correlated to crash propensity but not in a significant way (p=0.13).

that at that time photo enforcement of red-light running existed in Arizona, California, Colorado, Maryland, New York, North Carolina, Washington DC and Virginia as well as in many foreign countries.

Red-light violation cameras are typically activated if a driver enters an intersection more than 0.5 second into red. The fine varies from jurisdiction to jurisdiction and can be over $250 and can include demerit points on the driver's license ("Stopping on Red" by James Joseph, *Traffic Technology International*, August/September 2001, pp. 40-47).

Representative Dick Armey, Majority Leader of the US House of Representatives, called camera monitoring a "red light camera scam," and "Big Brother device" and backed studies suggesting that red light cameras may decrease both safety and privacy." He issued a 23-page Executive Summary, entitled "The Red Light Running Crisis: Is it Intentional?" questioning accuracy and intent of intersection camera monitoring claiming that their primary intent was to make money. This document was posted on his Web site Freedom Works in 2001 (www.freedom.gov/auto). The assertions made by Mr. Armey were immediately rebutted by the Insurance Institute for Highway Safety and the Highway Loss Data Institute, both funded by auto insurers (Stopping on Red by James Joseph, *Traffic Technology International*, August/September 2001, pp. 40-47).

2.4.2 Effectiveness

TRB's *National Cooperative Highway Research Program Synthesis Report 310, Impact of Red Light Camera Enforcement on Crash Experience* (2002) notes that red light running automated enforcement seemingly can be an effective safety countermeasure; however, the report goes on to indicate that currently there is insufficient empirical evidence based on statistically rigorous experimental design to make a conclusive statement.

The article "Automating Safety" by Sharon Cuevas Hansen (*Traffic Technology International*, August/September 2001, p. 103) states that "red light cameras have been proven to reduce red light violations on an average of 40 per cent at monitored locations." The effect varied and was as high as 92% in Los Angeles and 72% in Charlotte, NC. However, the effect on crashes may be substantially lower than the effect on violations. The article referred to here states that "San Francisco documented the 'halo effect' by measuring a 10 per cent reduction in intersection collisions citywide after six months of deploying red light cameras." A majority of the studies referenced in the article were carried out by the Insurance Institute for Highway Safety. These are also referenced in the article "Reducing red light crashes" by Richard Retting, *ITS International*, May/June 2001, p. 54).

The paper "Evaluation of red light camera enforcement in Oxnard, California" by Richard A. Retting, Allan F. Williams, Charles M. Farmer and Amy F. Feldman (*Accident Analysis and Prevention,* Volume 31, 1999, pp 169-174) reports on a before/after study of 14 intersections, nine that were equipped with cameras. Overall, the red light violation rate was reduced approximately 42% with a spillover effect to non-equipped locations. Public opinion surveys were conducted, but no crash data is presented.

The paper "Prevalence and characteristics of red light running crashes in the United States" by Richard A. Retting, Robert G. Ulmer and Allan F. Williams (*Accident Analysis and Prevention* Volume 31, 1999, pp 687-694) again stresses the importance of enforcement and recommends automated enforcement. There is no additional crash data presented.

An article originating in Singapore, "A before-and-after study of driver stopping propensity at red light camera intersections" by K.M. Lum and Y.D. Wong Williams (*Accident Analysis and Prevention* Volume 35, 2003, pp 111-120) evaluates only three sites in spite of the fact that more than 165 of Singapore's roughly 1,000 signalized intersections have surveillance cameras. The study concludes that camera enforcement of red-light running reduces the frequency of running lights, though the effect varied greatly between the three locations.

The earlier referenced study, "Applying the random effect negative binomial model to examine traffic accident occurrence at signalized intersections" by Hoong Chor Chin and Mohammed Abdul Quddus (*Accident Analysis and Prevention* Volume 35, 2003, pp 253-259) shows that existence of a surveillance camera reduces the crash frequency more significantly than any other variable (p=0.0001). They found a regression coefficient of 0.24, which should indicate that if all other variables are held constant, the surveillance camera will reduce the crash frequency by approximately 24%.

2.4.3 Public Support of Camera Enforcement

Steven B. Gayle, International President of ITE, states in the President's Message on page 14 of the July 2001 issue of the *ITE Journal* that, "Opinion polls have repeatedly demonstrated that the public supports automated enforcement of red-light running. They realize that drivers who run red lights often cause crashes, that intersection crashes often cause injuries and sometimes death, and that police enforcement resources are insufficient. While ITE has a policy of supporting enforcement in general and automated enforcement where appropriate, we have refocused on the engineering aspects of the intersection. We realize that it is our responsibility to first make sure that the design and operation of intersections safely accommodate all users…."

Actual studies from ten cities in the United States—five with camera enforcement and five without—give uniformly high percentages of people favoring photo enforcement; varying between 72% and 84%. The rates are slightly higher in cities that have cameras ("Reducing red light crashes" by Richard Retting, *ITS International*, May/June 2001, p. 54).

The study "Evaluation of red light camera enforcement in Oxnard, California" by Richard A. Retting, Allan F. Williams, Charles M. Farmer and Amy F. Feldman (*Accident Analysis and Prevention*, Volume 31, 1999, pp 169-174) found that 76% of the respondents favor the system 6 months after it was installed whereas 18% oppose it.

2.5 ITS Measures

A report by the Intelligent Transportation Systems (ITS) Institute of the Center for Transportation Studies at the University of Minnesota presents the use of ITS to monitor vehicle and pedestrian positions, trajectories, velocities, and other data in order to predict and to warn pedestrians and drivers of real-time hazard situations. More information can be found on http://www.cts.umn.edu/pdf/-CTS_02-07.pdf.

The paper "Infrastructure Collision-Avoidance Concept for Straight-Crossing-Path Crashes at Signalized Intersections" by Robert Ferlis (*Transportation Research Record* 1800, 2002, pp. 85-91) discusses the use of sensors, processors, driver information devices, roadside-to-vehicle communication systems and on-vehicle systems. A simulated example in the paper shows that 88% of the relevant straight-crossing path crashes could be eliminated by timely warnings to violators as well as to drivers approaching on the side streets.

The paper "Inexpensive, Infrastructure-Based, Intersection Collision-Avoidance System to Prevent Left-Turn Crashes with opposite-Direction Traffic" by Byron White and

Kimberly A. Eccles (*Transportation Research Record* 1800, 2002, pp. 92-99) assesses the possibility of having "second opinion" displays at signalized intersections with permissive left turns. The system would differentiate between passenger cars and heavy vehicles making the left turn and would assess the gap in the oncoming traffic through extensive detector systems. There are no attempts to quantify the safety gains.

The paper "Development of Advanced Traffic Signal Control Strategies for Intelligent Transportation Systems: Multilevel Design" by Nathan H. Gartner, Chronis Stamatiadis and Philip J. Tarnoff (*Transportation Research Record 1494*, 1995, pp. 98-105) discusses concepts but does not give any safety assessment.

2.5.1 LHOVRA and Similar Systems

Video imaging can be used for 'immediate' safety intervention as well as for fining drivers who run red lights. "A prime advantage is the ability [of video processing] to determine vehicle speed and—given typical driver reaction-times and prevailing conditions—forecast whether a violation is likely to occur. With that prediction, it becomes possible to pre-empt normal signal sequencing and hold the cross-traffic. Although the violation is not averted, this strategy may mitigate potential disastrous consequences…." (*Traffic Technology International*, August/September 2002, p. 48).

The LHOVRA strategy is explained in the Swedish National Road Administration report 1991:51E "LHOVRA a Traffic Signal Control Strategy for Isolated Junctions." Each letter in LHOVRA stands for a strategy, but the acronym makes little sense in the English language. L stands for truck priority, H stands for main road priority, O for crash reduction, V for variable yellow time, R for red-light-infringement protection and A for alternative sequencing. The purpose is to improve safety and reduce delay, especially for targeted traffic such as trucks, buses or main-line traffic. Sometimes only some of the LHOVRA strategies are applied.

LHOVRA technology, typically based on conventional detectors rather than video detection, has been used in Sweden for over two decades and is now also used in Finland, Norway, Denmark and the Netherlands but not in North America though interest was spurred by a US field visit to Europe in 2002. That lead to Alf Peterson, of the Swedish National Road Administration, being invited to speak at the August 24-27, 2003 Annual ITE Meeting in Seattle, Washington, presenting his paper "Safer Signals Using LHOVRA."

The typical intersection approach is equipped with three sets of detectors. The set furthest away has two detectors typically located 8 meters (26 ft) apart and about 300 meters (1000 ft) from the stop line. They determine speed and type of vehicle approaching. Then the vehicles are 'followed' as they approach through the other two sets of detectors.

Rear-end collisions are reduced through extending the green time by a preset limit, say 8 seconds, above the maximum green time if the headway between vehicles is less than, e.g., 4 seconds. This means that this crash elimination feature runs out if more than three consecutive vehicles have short headways.

The variable yellow time means that yellow is reduced (to 2 seconds in a 30 mph environment) if no one is approaching in the dilemma zone, and the all-red phase is eliminated too if there is no need for it. On the other hand, if someone seems to be running a red light, the all-red phase is increased until that vehicle has passed through.

There are limits to where LHOVRA can be implemented. Obviously, main-road priority cannot be given to both roads if two arterials intersect. The same goes for truck priority.

The effect of LHOVRA is (according to SNRA Report 1991:51E, p. 12) a substantial reduction in the proportion of vehicles exposed to the switch from green to yellow light—from as high as 19% (without LHOVRA) to around 1% (with LOVRA); a substantial reduction in the number of vehicles being caught in the 'option' zone as well as in the 'dilemma' zone The crash reduction is typically observed to be around 25% compared to a traditional signalization (SNRA Report 1991:51E, p. 56).

2.6 Flashing Operation

The article "Right-Angle Crashes and Late-Night/Early Morning Flashing Operation: 19 Case Studies" by Stanley F. Polanis, April 2002 *ITE Journal* pp 26-28, concludes that right-angle crashes are more common when traffic signals are in red/yellow flash during the late-night/early-morning hours. The study found that right-angle crashes declined by 78% at the 19 locations studied after they were removed from flashing operations. However, the 19 locations may have been selected in a biased way, since:

> The author writes, "These locations were not necessarily hazardous or high-crash locations. They are simply locations where crash patterns suggested that a return to normal operations might reduce crashes." This indicates a high risk of regression-to-the-mean effects. The total number of crashes declined from 612 in 888 months[12] to 413 in 906 months. That is a monthly decline from 0.69 to 0.46 or 33%. If some of the locations where high-crash locations in the before period, regression-to-the mean effects may account for much of this effect. When it comes to right-angle crashes the situation may be similar even if the data at first looks very convincing; 156 crashes before versus 35 after. Without knowing more about the selection criteria we can not quantify the effect of having signals on flashing operations. However, most likely, the number of crashes—in particular right-angle crashes—do increase when this is done.

A meta-analysis of worldwide studies in 1997 estimates the effect of flashing operations to be a 55% increase in injury crashes (during the times of operations—with a confidence interval spanning from a 7% reduction to a 165% increase in crashes) and a 40% increase in property-damage-only crashes (with a confidence interval of 30% to 55% increase) (*Trafikksikkerhedshåndbok* by Rune Elvik, Anne Borger Mysen and Truls Vaa, TØI, Oslo, 1997, p. 308).

2.7 Signal Visibility

Whether a signal will be seen or not depends on many factors. For example, how expected it is, the size of the head and the intensity of the light, background illumination, shielding, and visual environment of where the signal is located may influence whether people will notice it and its status or not.

An FHWA analysis of 306 crashes indicate that 40% of red-light running crashes happened because the driver did not see the signal or its indication (*Making Intersections Safer: A Toolbox of Engineering Countermeasures to Reduce Red-Light Running,* the Federal Highway Administration and the Institute of Transportation Engineers, 2003, p 15).

2.7.1 <u>Visual Environment</u>

The study "Influence of Visual Environments on Visibility of Traffic Signs" by Yukiharu Akagi, Takuya Seo and Yoshitaka Motoda (*Transportation Research Record 1553*, 1996, pp. 53-58) shows that billboards, neon signs etc. compete with traffic signs for a driver's attention. It is likely that similar distractions

[12] A total of 888 months of data for the 19 intersections means that each location was covered for an average of just less than 4 years

can make drivers miss red lights, but no study was discovered that evaluated this.

2.7.2 Vehicle Blocking View

FHWA studies indicate that 4% of red-light running crashes happened because the driver followed another vehicle into the intersection and did not see or look at the signal (*Making Intersections Safer: A Toolbox of Engineering Countermeasures to Reduce Red-Light Running,* the Federal Highway Administration and the Institute of Transportation Engineers, 2003, p. 15).

2.7.3 Size and Number of Displays

There are two standard signal lens diameters, 8 in. and 12 in. MUTCD specifies when the larger size must be used and when it is recommended to be used. It is mandated, for example, when the nearest signal face is more than 120 feet away from the stop line. It is recommended where 85-percentile speeds exceed 40 mph, where signals are unexpected and where there are many elderly drivers. A simple before and after study from North Carolina indicates that the larger size lens can lead to a substantial (47%) decline in right-angle crashes. (*Making Intersections Safer: A Toolbox of Engineering Countermeasures to Reduce Red-Light Running,* the Federal Highway Administration and the Institute of Transportation Engineers, 2003, p. 22).

Besides improving the visibility of an individual light and having multiple signal heads, one can provide redundancy by providing two red-signal displays within each signal head. This can be effective in increasing conspicuity according to *Making Intersections Safer: A Toolbox of Engineering Countermeasures to Reduce Red-Light Running* (the Federal Highway Administration and the Institute of Transportation Engineers, 2003).

2.7.4 LED Signals and Strobe Lights

The Institute of Transportation Engineers (ITE) issues guidance for visual requirements. State guidelines typically follow these recommendations. The requirements can be met with different types of bulbs including light emitting diodes (LED), which have the advantage of consuming much less energy (80% less) than incandescent lights with the same intensity and lasting much longer (over 5 years versus about one year). A major advantage with the energy savings—besides the long-term cost savings—is that an intersection can remain signalized much longer on battery power in the event of a power failure. The disadvantage with LED is that they cost over ten times as much as incandescent bulbs ("Bright Future for LEDs" by James Foster, *ITS International*, July/August 2001, p. 58) but this cost difference is more than offset by reduced replacement crew costs. Some suppliers make LED 'bulbs' which screw in as a direct replacement for incandescent bulbs, obviating the need to change the original traffic signal or light head. So called "high-brightness LED" lights are brighter than traditional lights.

The paper "Evaluation of Strobe Lights in Red Lens of Traffic Signals" by Benjamin H. Cottrell Jr. (*Transportation Research Record 1495*, 1995, pp. 36-40) evaluated the Barlo strobe light that emits 60 flashes of white light per minute. The conclusion of the study—which included analysis of 22 intersections—is, "On the basis of the trend analysis, there was no consistent evidence that strobe lights are effective in reducing accidents." Rather, the study recommends the use of advance active warning signs at isolated rural or hard-to-see, high-speed locations. Also, visors and backplates can be used to improve visibility when the signal is backlit by the sun.

2.8 Advance Warning Flashers

The paper "Advance Warning Flashers—Do They Improve Safety?" by Tarek Sayed, Homayoun Vahidi and Felipe Rodriguez (*Transportation Research Record 1692*, 1999, pp. 30-38) evaluates flashers that provide drivers information about downstream status of traffic signals. The authors compared the 'expected' crash frequency of 106 signalized locations in British Columbia, some with such flashers and some lacking them, and found that overall the flashers seemed to reduce crash frequencies but that the difference was not statistically ensured. However, they found that at locations with medium or heavy flows on the minor approaches, flashers on the major approaches were clearly beneficial from a safety perspective.

"Comparative Study of Advance Warning Signs at High Speed Signalized Intersections" by Prahlad D. Pant and Yuhong Xie (*Transportation Research Record 1495*, 1995, pp. 28-35) shows that advance warning indication can lead to not only fewer drivers running red lights, but possibly also more drivers speeding up on yellow. This study presents conflict rates but no crash numbers.

2.9 Right-Turn-On-Red

The safety effect of allowing right turn on red (RTOR) has been the focus of many studies. Ezra Hauer in his textbook Observational Before-After Studies in Road Safety, pp 43-45, concludes that the safety effect on crashes involving vehicles turning right is negative. Using two different data sets from the early 1980's, his analyses show that crashes for these vehicles increased by 28% and 9% respectively.

Few people today argue that allowing right-turn-on-red will reduce crash numbers but it is frequently pointed out that the number of crashes involving vehicles turning right on red is small in comparison to the overall numbers and that the severity of these crashes is low. That is supported by the following study.

All US states and most Canadian provinces have allowed right turn on red for many years. However, Quebec was not one of those provinces. To determine whether they should conform with other jurisdictions, they commissioned a study by Dominique Lord of the Texas Transportation Institute that was delivered—and presented at the Annual TRB Meeting of January 2002—under the title "Synthesis on the Safety of Right Turn on Red in the United States and Canada." Crash data from Manitoba, Maine, Illinois and Minnesota was analyzed. The Maine data will be discussed below. Overall, the author concluded that, "RTOR is not a dangerous maneuver at signalized intersections for either vehicles or pedestrians in most circumstances."

A meta-analysis of worldwide studies in 1997 estimates the effect of allowing right-turn-on-red to be a 60% increase in injury crashes involving right-turning vehicles (with a confidence interval spanning from 50% to 70%) and a 10% increase in property-damage-only crashes (with a confidence interval spanning from 9% to 11% increase) (*Trafikksikkerhedshåndbok* by Rune Elvik, Anne Borger Mysen and Truls Vaa, TØI, Oslo, 1997, p. 308).

2.9.1 Maine Data

The data from Maine for 1989 to 2000 shows that there were a total of 525 RTOR crashes at the analyzed 631 signalized intersections causing 6 fatalities and 117 injury crashes. This can be compared to the 43,398 crashes that occurred at these locations. In other words, the RTOR crashes made up 1.2% of the crashes at these locations (or 0.1% of all crashes in the state). However, 6 fatal crashes in 12 years or 0.5 per year compared to the average number of 2 fatal crashes at signalized locations (see page 40) is a high percentage. The reason for this is that several of the crashes involved unprotected road users. Three bicyclists and one pedestrian were killed in right-turn-on-red crashes. (Data from Minnesota and Illinois also show that pedestrians are vulnerable to fatal crashes during right-turn-on-red whereas there were no fatal bicycle crashes in these states during the period of analysis.)

2.10 Separate Left-Turn Phase

The study "Effective Safety improvements through Low-Cost Treatments" by Tappan Datta, David Feber, Kerrie Schattler and Sue Datta (*Transportation Research Record* 1734, 2000, pp. 1-6) evaluated eighteen intersections in Michigan. Three sites that used to have two-phase systems got separate left-turn lanes constructed and exclusive left-turn phasing. The number of left-turn head-on crashes per 12 months were reduced from 20.67, 15 and 4 to 4.5, 3.43 and 0.63 respectively. These are all statistically significant reductions but it is possible that a substantial part of the effects were caused by regression-to-the-mean effects.

A meta-analysis of studies worldwide in 1997 shows that the most likely effect of introducing exclusive left-turn phasing is a 58% reduction in crashes involving left-turning vehicles, with a statistical confidence interval ranging from 50% to 64%. The safety effect of a permissive/protected phase was much smaller with a best estimate of 10% fewer left-turn crashes, with a confidence interval spanning from 5% to 15% (*Trafikksikkerhedshåndbok* by Rune Elvik, Anne Borger Mysen and Truls Vaa, TØI, Oslo, 1997, p. 308).

The *NCHRP Synthesis Report 225, Left Turn Treatments at Intersections*, 1996, shows (p. 4) that it is especially elderly drivers that are involved in left-turning crashes. The aging of our population may lead to an increased problem with left-turn crashes. The authors point out that prohibiting left turns—all day or during peak times—is sometimes a possibility.[13] They also point out that separate left-turn lanes reduce rear-end crash numbers in particular and recommend that left-turn lanes should be provided where more than 20% of traffic or 100 vehicles during the peak hour turn left. They also give examples of (p. 40) several jurisdictional recommendations for separate left-turn phases. Examples include when the product of left-turning vehicles and conflicting through vehicles during the peak hour is greater than 100,000, when the left-turn volume is greater than 100 vehicles during the peak hour, or when the left turn peak period volumes has more than two vehicles per cycle per approach still waiting at the end of green (for pre-timed signals). The report gives safety effects from various studies of installing a left-turn lane with a protected phase simultaneously with signalizing the location but does not give the effect of the left-turn phase installation by itself.

A California Department of Transportation study found that left turn channelization by itself results in a 15% reduction in all crashes whereas providing that together with a separate left-turn phase gives a 35% reduction in all crashes. (Neumann, T.R., *NCHRP Report 279: Intersection Channelization Design Guide*, TRB, 1985)

Separate left-turn phases can be either leading or lagging the through phase. In general, leading is considered safer, to give less delay and be less confusing ("Guidelines for Use of Leading and lagging Left-Turn Signal phasing" by Joseph E. Hummer, Robert E. Montgomery and Kumares C. Sinha, *Trans-*

[13] Based on several sources among them "Prohibition on Left Turn at traffic Signals" by ITE Committee 4N-M Informational report, ITE Journal, Volume 51, Number 2, February 1981, p. 25. However, prohibiting left-turns mid-block and allowing left turns as well as U-turns at signalized intersections may be a more effective solution according to "Effects on Safety of Replacing an arterial Two-Way Left-turn Lane with a Raised Median" by P.S. Paronson, M.G. Waters III and J.S. Fincher, Transportation Research Board, Access Management Conference, 1993.

portation Research Record 1324, 1991, pp. 11-20). However, this study concludes that lagging sequences should be recommended in a number of situations, among them at locations where there are high pedestrian volumes or the intersection has a fixed-time signal. In general, it is recommended that protected/permissive phasing is changed to permissive/protective order, unless coordination or 'blocking' speaks in favor of the reverse order.

The paper "Comparison of Left-Turn Accident Rates for Different Types of Left-Turn Phasing" by Jonathan Upchurch (*Transportation Research Record 1324*, 1991, pp. 33-40) gives further safety guidance on choice of signal strategies. Delay considerations of different options are given in "Operational Comparison of Leading and Lagging Left Turns" by Jim C. Lee, Robert H. Wortman, David J.P. Hook and Mark J. Poppe (*Transportation Research Record 1421*, 1993, pp. 1-10).

Tradeoffs between operational effects and safety are discussed in "Selection Criteria for Left-Turn Phasing and Indication Sequence" by Seth A. Asante, Siamak A. Ardekani and James C. Williams (*Transportation Research Record 1421*, 1993, pp. 11-19). The conclusion is that leading sequences are recommended at some types of locations, lagging at others, and leading/lagging at yet others.

2.11 Longer Evacuation Time

A meta-analysis from 1997 shows that longer evacuation times, probably predominantly longer all-red phase but possibly also longer yellow times, on average reduce the number of crashes by 55% with a confidence interval spanning from 40% to 65% (*Trafikksikkerhedshåndbok* by Rune Elvik, Anne Borger Mysen and Truls Vaa, TØI, Oslo, 1997, p. 308).

The earlier referenced FHWA analysis of 306 crashes indicate that 25% of red-light running crashes happened because the driver tried to beat the yellow-signal indication (*Making Intersections Safer: A Toolbox of Engineering Countermeasures to Reduce Red-Light Running,* the Federal Highway Administration and the Institute of Transportation Engineers, 2003, p. 15). This, however, does not necessarily imply that a longer yellow would be safer.

MUTCD, the "Green Book" and ITE's *Traffic Engineering Handbook* give guidance on how long the yellow phase ought to be. The recommendation typically is 3 to 6 seconds, varying with speed, grade and width of cross street. If longer evacuation times are needed, an all-red phase is recommended. Typically, a deceleration rate of 10 ft/sec^2 to 11.2 ft/sec^2 or about 0.3 to 0.35 g is recommended.

Making Intersections Safer: A Toolbox of Engineering Countermeasures to Reduce Red-Light Running (the Federal Highway Administration and the Institute of Transportation Engineers, 2003, p. 34) discusses advantages and disadvantages with longer yellow times. The stated drawbacks of longer yellow include 'habituation' which means that people tend to adjust to the longer yellow and use more of it as part of the allowed travel phase. The report does not discuss whether this could lead to a significant increase in rear-end crashes but this author's observations show that when a person stops on 'early' yellow, sometimes the person behind changes lanes and goes around and through the intersection just before the light turns red. And sometimes, the person behind may not have the chance to change lanes or be able to stop and could hit the driver who stops 'early.' That actually happened to this author's next-door neighbor on Hogan Road in Bangor. To make the option zone as short as possible without creating a dilemma zone (where it is impossible to continue and impossible to stop) seems like the 'easy' answer. However, many aggressive drivers do not mind braking with a 0.5 g or higher force, and when the dilemma zone is eliminated for the cautious to average driver, there is still a large option zone for the aggressive driver.

2.12 Coordinated Signals

If signalized intersections are well coordinated, a larger percentage of people will arrive at them when the light is green. That obviously should reduce red-light running and improve safety.

A meta-analysis in 1997 shows that coordination, on average, reduced the number of injury crashes within the coordinated area by 19% with a confidence interval spanning from 15% to 22%. Property-damage crashes were reduced slightly more than the injury crashes (*Trafikksikkerhedshåndbok* by Rune Elvik, Anne Borger Mysen and Truls Vaa, TØI, Oslo, 1997, p. 308).

2.13 Vehicle Actuation

If signalized intersections are vehicle actuated, a larger percentage of people will arrive at them when the light is green. That should reduce red-light running and improve safety similar to coordination of signals, and that is what was found in the meta-analysis of 1997, which shows that vehicle actuation on average reduced the number of crashes by 25% with a confidence interval spanning from 15% to 33% (*Trafikksikkerhedshåndbok* by Rune Elvik, Anne Borger Mysen and Truls Vaa, TØI, Oslo, 1997, p. 308).

2.14 Inclement Weather Timing

When a roadway is snowy or icy, it will be harder to stop a vehicle—unless the driver slows down 'enough'—and a longer yellow time or all-red time may be justified.

Also, when the weather is bad, drivers tend to slow down some, even if typically not enough to fully compensate for the lower braking friction. The lower speeds mean that coordinated signal systems may need retiming. This is addressed in "Modifying Signal Timing During Inclement Weather" by H. Joseph Perrin, Peter T. Martin and Blake G. Hansen, *Transportation Research Record 1748*, 2001, pp. 66-71. They found that accumulating snow and slush reduced speeds by about 30%, and increased start-up lost times by 23%. That study also recommends that yellow times be lengthened by 0.5 to 1.0 second during inclement weather, primarily because the lower speeds lead to longer clearance times and that one second is added to the all-red times. There are no actual safety evaluations presented in this paper.

Adverse weather timing of signals is also discussed in the *NCHRP Synthesis Report 172, Signal Timing Improvement Practices,* 1992, pp. 46-47.

2.15 Countdown Clock

In Maine, there are countdown clocks for pedestrian crosswalks at a few locations in Portland and Bangor. They show remaining time until cross traffic starts up, rather than remaining time until 'walk' or green. However, in the United States we do not have countdown clocks for motorists. Countdown clocks have been used in many countries for decades at subway and bus stops with the idea that people will less mind waiting when they know for how long the wait will last. That idea is transferred to numerous signalized intersections in, among other countries, China. A driver can see how many more seconds he will have to wait until green. And then the same clock is activated again to show how many more seconds of green time there is. It uses "bright dot-matrix pixels." The display is in green or red dependent in which phase it is displayed. ("Where are the countdown clocks?" by Michael L Scott, *ITS International*, July/August 2001, p. 23). Obviously, countdown clocks can not be used—at least not fully—at vehicle actuated sites, but they could be an effective help at timed locations. However, their safety effect has not been evaluated and it may be negative for similar reasons as described in Section 2.16.

2.16 Green Flashing Preceding Change to Yellow

In Canada, a green flashing light means that drivers can make a left-turn without having to yield to oncoming traffic—protected phase. In Europe, green flashing light means that the signal will soon change to yellow. A meta-analysis from 1997 shows that introducing such a phase on average increased the number of injury crashes by 42% with a confidence interval spanning from 30% to 56%. (*Trafikksikkerhedshåndbok* by Rune Elvik, Anne Borger Mysen and Truls Vaa, TØI, Oslo, 1997, p. 308)

2.17 Maintenance

It is obvious that people may run red lights if all red bulbs on an approach are broken or malfunctioning for other reasons. However, routine management other than emergency and preventive maintenance of the hardware is important to keep a signal functioning well. *The NCHRP Synthesis Report 245, Traffic Signal Control Systems Maintenance Management Practices*, 1997, points out that about 25% of all jurisdictions never redesign or retime existing signalizations unless there is a complete reconstruction. And, many of the other 75% of agencies probably update their systems far too infrequently.

2.18 Awareness Campaigns

There are many campaigns around the country to try to stop people from intentionally running red lights. For example, each year National Stop on Red Week—dedicated to educating North Americans about the dangers of running red-lights—occurs in the first week of September, from Saturday to Friday. It is sponsored by FHWA and the American Trauma Society. (*Traffic Technology International*, August/September 2002, p. 48) The effectiveness of this and other campaigns have not been comprehensively evaluated.

3 Crashes at Signalized Intersections in Maine

3.1 Overview

3.1.1 Types and Severity

Official statistics provided by the Maine Department of Transportation (MDOT) shows that there were 10,169 reported crashes at signalized locations in Maine in the three-year period 1999-2001.

In 2000, Maine had around 912,000 drivers, which means that the expected number of crashes at signalized intersections per year and driver is about 0.0037. Assuming each crash involves two drivers, the 'average' driver will have 0.0074 crashes per year.[14] This translates into one crash every 135 years. This may not seem like an alarming statistic but the economic loss of these crashes is estimated by MDOT at $73 million per year.

Of the 10,169 reported crashes, 4203 (41.3%) were classified as intersection-movement crashes, whereas 5325 (52.4%) were classified as rear-end crashes. The remaining 6.3% of crashes were, in diminishing order, ran-off-road (191 crashes), head-on (141), pedestrian (94), bicycle (91), object in road (46), fire (13), roll-over (11), animals (8), rock-thrown (1), and others (45).

The 10,169 crashes caused six fatalities, 277 incapacitating injuries, 1461 evident injuries, and 3115 possible injuries.

There were one pedestrian and one bicyclist killed in the crashes. One fatal crash was a head-on collision. The other three were classified as "intersection movement" crashes. There was no fatal rear-end crash.

The major types of crashes with respect to incapacitating injuries and fatalities were intersection movements (60.8%), rear-end (18.7%), pedestrian (6.4%), bicycle (5.0%), ran-off-road (3.5%), and head-on (2.8%).

3.1.2 Physical Condition

Typically, the driver/pedestrian was in 'normal' physical condition (20,105 out of 20,881 or 96.3% of all parties involved) but 189 (0.9%) were under the influence, 62 (0.3%) had been drinking, and 17 (0.08%) had been using drugs. Nine drivers (0.04%) had fallen asleep and 45 (0.2%) were fatigued.

3.1.3 Contributing Factors

No improper action by a driver was stated in 10,045 cases, or roughly once (0.988 to be exact) for each crash. This means that one of the parties involved in the crash was typically considered as non-contributing or 'innocent' of causing the crash. As can be seen in Table 14, there was a total of 10,187 listed factors as primary causation.

A driver was cited for disregarding a traffic control device in 1242 cases; about 12.2% of all crashes. However, a driver had disregarded the traffic control device in three of the six fatal crashes. i.e. 50%. As can be seen in Table 14, driver inattention (3399 drivers) was cited as a contributing factor in more cases than disregard of a traffic-control device. (But inattention was cited for none of the fatal crashes.) Failing to yield the right of way got 2066 citations (with one for the fatal crashes).

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[14] Obviously, some of these crashes involved out-of-state drivers but we can assume that Maine drivers have an approximately equal number of crashes outside Maine as out-of-state drivers have in Maine. Also, about 3% of the crashes were single vehicle crashes, but this is probably more than compensated for having three or more parties involved in multi-vehicle collisions. Another 2% of the crashes involved non-motor vehicles, but bicyclists and pedestrians can be seen as drivers/operators too.

Table 14 Apparent contributing factor

Apparent contributing factor	Number of crashes	Percent of crashes
Driver inattention - distraction	3,399	31.6%
Failure to yield right of way	2,066	19.2%
Disregard of traffic control device	1,242	11.6%
Following too close	1,162	10.8%
Illegal, unsafe speed	391	3.6%
Improper turn	369	3.4%
Improper, unsafe lane change	350	3.3%
Unknown	331	3.1%
Other human violation factor	319	3.0%
Hit and run	140	1.3%
Other vision obscurement	140	1.3%
Unsafe backing	132	1.2%
Vision obscured - sun, headlights	110	1.0%
Driver inexperience	109	1.0%
None	87	0.8%
Improper passing - overtaking	77	0.7%
Defective brakes	68	0.6%
Physical impairment	66	0.6%
Pedestrian violation error	61	0.6%
Other vehicle defect or factor	48	0.4%
No signal or improper signal	28	0.3%
Driving left of center - not passing	25	0.2%
Vision obscured - windshield	11	0.1%
Impeding traffic	10	0.1%
Defective tire - tire failure	5	0.0%
Defective steering	3	0.0%
Defective lights	1	0.0%
Grand Total	10,750	100.0%

3.1.4 Locations with High Crash Numbers or Rates

Statistics provided by Maine DOT show that there were 401 signalized intersections in Maine with at least one reported crash in the three-year period 1999-2001 and with known traffic volumes. The list is not complete in the sense that there were other signalized intersections in Maine with reported crashes, but crash rates could not be provided for those since traffic volumes were unavailable. Together, the 401 locations had 7271 reported crashes. That gives an average of 6.0 crashes per year and intersection. The location with the most reported crashes was the intersection between Main Street and Larrabee Road in Westbrook (Cumberland County) with 84 crashes, followed by the intersection between Center St, Vietnam Veterans Bridge and Mt Auburn Avenue eastbound in Auburn (Androscoggin County) with 81 crashes and Center Street, Vietnam Veterans Bridge Westbound and Mt Auburn Avenue westbound in Auburn with 68 crashes[15]. There were another nine locations with 50 or more crashes in the three-year period. Some of these intersections have high crash rates while others carry a lot of traffic and have moderate crash rates. The three locations with the highest number of crashes have critical rate factors of 1.91 (4th highest signal in the state), 1.23 and 0.98.

The locations with the highest critical rate factors are shown in Table 15. Note that two of the three locations with the highest number of crashes do not make this list. (The two locations in Auburn have critical rate factors of 1.23 and 0.98 respectively.)

3.1.5 Detailed Analysis of Crash Reports

The actual police reports were analyzed for all fatal and those incapacitating injury crashes that involved red-light running vehicles at signalized intersections in Maine in the three-year period 1999-2001. There were a total of 76 such crashes. Besides the six fatal ones, there were 70 crashes with one or several incapacitating injuries as the most severe outcome. These crashes are analyzed in Section 3.3, and all fatal crashes are described in Section 3.2. Other overviews include analy-

[15] A new overpass on Center Street in Auburn should dramatically reduce the number of crashes at these two locations.

sis of left-turn crashes in Section 3.4, and rear-end crashes in Section 3.5.

Table 15 Locations exhibiting greatest Critical Rate Factors

Intersection	Total number of crashes	CRF	% injuries
Pleasant St & Plourde Parkway, Lewiston*	26	2.80	62%
Canal St & Cedar St, Lewiston*	57	2.32	40%
Rt 24 & Entrance to Cooks Corner & Hoyts Cinema, Brunswick	35	2.09	46%
Main St & Larrabee Rd, Westbrook	84	1.91	31%
Broadway, Strickland & Burleigh Rd, Bangor	44	1.82	57%
Civic Center Dr & I-95 South Off, Augusta	36	1.80	31%
Rt 1 & Rt 3, Ellsworth	26	?	19%
US Rt 1 & Maysville St, Presque Isle	44	1.64	27%
Rt 100 & Rt 137, Winslow	34	1.62	41%
Hogan Rd, Springer Dr & Entrance to Bangor Mall, Bangor	53	1.61	25%
North St & Elm St, Saco	42	1.59	31%
Hogan Rd, I-95 ON-OFF Ramp, Bangor	48	1.57	38%
Rt 126 & Russell St, Lewiston	53	1.50	26%
Canal St & Chestnut St, Lewiston	26	1.48	42%
Rt 4 & Center Rd, Gray	51	1.45	16%
Russell St & East Ave, Lewiston	40	1.43	45%
Rt 111 & Precourt St, Biddeford	43	1.43	19%
Westbrook St & Broadway, South Portland	50	1.43	34%
Rt 17 & Rt 90, Rockport	28	1.40	36%
State St & Spring St, Portland	36	1.40	28%
So. Main St & Easy St, Pittsfield	21	1.39	38%
Payne Rd, Exit 6 entrance & Haigis, Scarborough	32	1.36	44%
Center St, Turner St & Union St Bypass, Auburn	50	1.36	38%
Union St & I-95 South Ramp to Union St, Bangor	36	1.34	31%

* Safety improvement projects scheduled or recently completed

3.2 Fatal Crashes

During the three-year period analyzed, there were six fatal crashes. The economic loss of these crashes is estimated at $15.8 million by the Maine Department of Transportation, which is a sizable percentage of the total cost of all the crashes at signalized intersections. Each crash had one fatality. They are outlined in chronological order below:

February 2, 1999 at Route 1/Lincoln Drive/Haigis Parkway in Scarborough: A 60-year-old man was killed when he was hit by a 54-year-old woman who seems to have run a red light, though it is a bit unclear who ran the red light according to a newspaper article describing the crash. The two parties were traveling on perpendicular courses. Both were going straight. The speed limit was 45 mph. There was no alcohol involved and the roadway was dry and it was daylight.

November 3, 2000 at Rt 202/Rt 224 in Sanford: An 84-year-old man in a car was killed when he was hit by a 35-year-old man in a pickup truck. Both were traveling straight through the intersection. It appears the younger man ran the red light. The speed limit was 50 mph (according to the police report). It was daylight and dry roadway conditions. No alcohol was involved.

May 6, 2001 at East Avenue/Pleasant Street in Lewiston: Driving a pickup truck, a 77-year-old man with a lengthy violation record turned left in front of a 21-year-old male motorcyclist, who was traveling straight-through and had the right-of-way. Both parties had green balls. The speed limit was 25 mph. It was dusk and dry. The motorcyclist was killed. The (dead) motorcyclist was cited for illegal, unsafe speed.

July 6, 2001 at Main Street/Maysville/Connector Road in Presque Isle: A 63-year-old man in a pickup truck was killed in a left-turn crash involving a passenger car driven by a 23-year-old man. Both drivers faced green balls when entering the intersection. The speed limit was 25 mph. The roadway was dry and it was daylight. No alcohol.

August 4, 2001 at Franklin St South/Fox Street in Portland: A 51-year-old male bicyclist was killed when he was hit by a 39-year-old male car driver. The two parties were both traveling straight through the intersection on perpendicular paths. The bicyclist ran the red light. Daylight and dry road. The speed limit was 35 mph. No alcohol.

September 6, 2001 at Franklin/Congress Street in Portland: A taxi driven by a 30-year-old man struck and killed a 41-year-old pedestrian who ran out in front of the taxi in a marked crosswalk just after the signal turned green for the taxi driver. The view of the pedestrian was blocked by a truck, which was stopped for the light which was still red when the pedestrian walked/ran out in front of it. The taxi was traveling in a parallel lane to the truck. It was rainy. The speed limit was 35 mph. No alcohol.

In summary, three out of the six people who were killed at signalized intersections were unprotected road users, i.e., they were traveling as pedestrians, bicyclists or motorcyclists. Two out of these disregarded the traffic-control device. The third collided with a vehicle making a left turn. One more person was killed in a left-turn collision where both parties entered on green balls. Finally, two people were killed at high-speed locations where both parties had perpendicular through courses and one of them had run the red light.

3.3 Fatal and Incapacitating Injury Crashes Involving People Disregarding Traffic-Control Devices

Two of the fatal crashes discussed above did not involve anybody disregarding the signal. Rather, they were both caused by a driver not yielding the right-of-way to an oncoming through vehicle. The other four crashes are included in the analysis below as well, since those involved drivers who disregarded the lights.

3.3.1 Temporal Distribution

An analysis by year shows that 16 of the crashes occurred in 1999, 34 in 2000 and 24 in 2001. The variation between the years is somewhat skewed, with fewer crashes than expected in 1999 ($p=0.019$) and more in 2000 ($p=0.017$).

The month with the highest number is September, with eleven crashes. The winter months all have fewer crashes than the average month, but August has the very lowest number with only three reported crashes. In other words, the distribution by month does not show any clear pattern and no month stands out as clearly overrepresented. The chance that one would get eleven or more observed in a month when 6.167 per month is expected is 5.0%. That one out of 12 months would have an observation that happens once in twenty times in a random drawing is not that surprising.

An analysis by weekday shows that Saturdays (with six crashes) have fewer crashes than other days, but the difference is not significant.

3.3.2 Driver Age and Gender

There are a few crashes where we do not know who ran the red light, but we know the identity, age and gender of the parties involved in 70 of the 74 crashes. An analysis by gender shows that 46 of the people disregarding the signal were men and 24 were women. This means that women here made up 34% of the violating drivers. In Maine, roughly 36% of all miles driven are by women, according to observations by the author and students from the University of Maine in 1995[16]. Nationwide, this percentage was around 38% in 2001 according to the National Safety Council (*The World Almanac and Book of Facts*, New York, 2003, p. 79). In other words, women violated the signal almost exactly in proportion to their share. When it comes to the non-offending party, the driver being hit by the violating driver, there were 44 men and 26 women. This means women made up 37% of these drivers, still more or less exactly their share of driving.

An analysis by age is presented in Table 16. Numbers are small, but it is still clear that there is a trend that drivers below age 25 and drivers over the age of 70 more frequently are the offending party (running the red light) than the innocent party. None of the 5-year age groups between 25 and 70 have ratios between offending and innocent numbers above 1.0 except for the 45 to 49 group. And the ratio for that age is not significantly high (p=0.39). Added together, people 70 or older have a ratio of 5.5, which is statistically significantly higher than 1.0 (p=0.05), whereas the ratio for the group below 25 (which is 1.8) does not deviate significantly according to statistical testing (p=0.09).

Table 16 Age of at fault and innocent drivers involved in red-light running crashes

Age of driver	Drivers running red light		Drivers who did not run red light		Ratio between violating and not violating numbers
	number	%	number	%	
-19	10	14.3%	6	8.6%	1.7
20-24	8	11.4%	4	5.7%	2.0
25-29	6	8.6%	8	11.4%	0.8
30-34	5	7.1%	10	14.3%	0.5
35-39	6	8.6%	13	18.6%	0.5
40-44	7	10.0%	8	11.4%	0.9
45-49	7	10.0%	5	7.1%	1.4
50-54	4	5.7%	5	7.1%	0.8
55-59	3	4.3%	5	7.1%	0.6
60-64	2	2.9%	2	2.9%	1.0
65-69	1	1.4%	2	2.9%	0.5
70-74	4	5.7%	0	0.0%	(4/0)
75-79	2	2.9%	1	1.4%	2.0
80-84	2	2.9%	1	1.4%	2.0
85-89	3	4.3%	0	0.0%	(3/0)
90+	0	0.0%	0	0.0%	--
Total	70	100%	70	100%	1.0

We can also compare the age of the drivers running the red light to the size of populations of drivers in that age group in Maine in 2001 as estimated by FHWA (see http://www.fhwa.dot.gov/ohim/hs01/dl22.htm#foot1). These results are shown in Table 17. Drivers below the age of 20 are significantly overrepresented (p=0.002). None of the other (5-year) age groups are statistically overrepresented. Actually, all age groups between 30 and 79 are underrepresented. Accumulating people 80 or older into one group shows that

[16] That percentage was the average of observations on Interstates, other arterials and minor roads, in urban and rural areas of the state, for different time periods of the day. The percentage at signalized intersections may have been slightly different. A smaller study of a few signalized locations in central Maine in April 2004 showed the portion of drivers being woman varied by location from 33% to 37%.

they are overrepresented but not in a statistically significant way (p=0.11).

Table 17 Age of drivers causing red-light running crashes compared to driver population

Age of driver	Drivers running red light (in crash)		Driver population, Maine		Ratio between violating number and driver population
	number	%	number	%	
-19	10	14.3%	44,313	4.7%	3.0
20-24	8	11.4%	70,934	7.5%	1.5
25-29	6	8.6%	67,642	7.2%	1.2
30-34	5	7.1%	81,684	8.7%	0.8
35-39	6	8.6%	94,548	10.0%	0.9
40-44	7	10.0%	105,348	11.2%	0.9
45-49	7	10.0%	102,073	10.8%	0.9
50-54	4	5.7%	94,020	10.0%	0.6
55-59	3	4.3%	82,099	8.7%	0.5
60-64	2	2.9%	53,443	5.7%	0.5
65-69	1	1.4%	45,745	4.9%	0.3
70-74	4	5.7%	38,701	4.1%	1.4
75-79	2	2.9%	28,161	3.0%	1.0
80-84	2	2.9%	18,554	2.0%	1.5
85+	3	4.3%	15,291	1.6%	2.7
Total	70	100%	942,556	100.0%	1.0

If we take miles driven into account, young and elderly drivers would have even higher ratios. Maine data on miles driven by age was not available for this study but if we use U.S. data on annual miles traveled, as shown on NHTSA's website http://www-nrd.nhtsa.dot.gov/pdf/nrd-30/NCSA/RNotes/1998AgeSex 96.pdf (referencing *Crash Data and Rates for Age-Sex Groups of Drivers*, 1996 by Ezio C. Cerrelli) the overrepresentation of young and elderly drivers become very clear, as shown in Table 18. Combining people 80 or older into one age group now makes them significantly overrepresented (p=0.003). None of the age groups between 70 and 84 are by themselves statistically overrepresented (p>0.11) whereas the group 85+ is (p=0.005). The 470% overrepresentation for the age group 19 or younger is highly significant (p=0.00008) whereas the group 20-24 does not deviate in a statistically significant sense (p=0.12).

Table 18 Relative risk of causing a red-light running crash when considering miles driven

Age of driver	Number of drivers running red light	Driver population, Maine	Annual miles driven per person	Risk = ratio between violating number and exposure
-19	10	44,313	9,450	4.7
20-24	8	70,934	13,435	1.6
25-29	6	67,642	15,808	1.1
30-34	5	81,684	15,694	0.8
35-39	6	94,548	15,875	0.8
40-44	7	105,348	16,851	0.8
45-49	7	102,073	17,005	0.8
50-54	4	94,020	16,062	0.5
55-59	3	82,099	16,082	0.4
60-64	2	53,443	14,282	0.5
65-69	1	45,745	11,852	0.4
70-74	4	38,701	9,737	2.1
75-79	2	28,161	7,411	1.9
80-84	2	18,554	6,234	3.4
85+	3	15,291	4,346	8.9
Total	70	942,556	14,560	1.0

Comparing the numbers as presented in Table 16 to those of Table 17 shows that younger drivers are clearly overrepresented not only as 'guilty' drivers running the red light, but also as the 'innocent' ones being the victim of someone else running the red light and colliding with them. This could be because there are seldom truly innocent drivers. It is frequently possible to avoid being hit by a driver violating a right-of-way rule if one is cautious and drives defensively. It could also be that younger drivers drive more miles per capita, so that the driver population basis does not give a fair comparison of risk per mile driven.

3.3.3 Vehicle Type of Offending Driver

Table 19 shows what vehicle-type the operator who violated the signal was driving. In some cases it is a pedestrian, and therefore technically (or semantically) not a vehicle driver who violated the signal, but pedestrians can here be treated as a type of vehicle. In a few cases, it is unknown who ran the red light. That is a reason why the numbers in Table 19 do not always match the numbers in, e.g., Table 20.

Table 19 Vehicle type and offense ratio

Vehicle type	Number of vehicles where driver		Ratio between offending and innocent numbers
	ran red light and had a collision	was hit by someone running a red light	
2/4-door sedan	42	40	1.0
Station wagon	3	5	0.6
Van	5	14	0.4
Pickup truck	13	5	2.6
Truck	0	2	0.0
Motorcycle	0	5	0.0
Bicycle	7	0	(7/0)
Pedestrian	1	0	(1/0)
Sum	71	71	1.0

The conclusion drawn from analyzing Table 19 is that bicyclists, and probably pedestrians, frequently are at fault in crashes at signalized intersections where one party disobeyed the signal. On the other hand, motorcyclists seem to be following the traffic-control device in an exemplary way, even if that does not prevent them from being injured in these crashes. These findings may not be surprising. Bicyclists frequently lack formal training in high-way code. Motorcyclists are not only well trained, they are also aware of the risks of running red lights when there is a conflicting vehicle nearby. The one finding that may be especially surprising when analyzing the table is that drivers of pickup trucks are much more likely to run red lights than drivers of passenger cars (p=0.03).

3.3.4 Vehicle Type and Injury

Column 2 of Table 20 shows the vehicle mix in crashes in which people received incapacitating or fatal injuries.

Table 20 Vehicle type and risk of serious injury

Vehicle type	Number of vehicles where occupant		Ratio between serious injuries and not
	received fatal or incapacitating injuries	did not receive incapacitating injuries	
2/4-door sedan	45	39	1.2
Station wagon	5	3	1.6
Van	10	10	1.0
Pickup truck	3	15	0.2
Truck	0	2	0.0
Motorcycle	5	0	(5/0)
Bicycle	7	0	(7/0)
Pedestrian	1	0	(1/0)
Sum	76	69	1.1

Column 3 in that table shows the mix of vehicles where no one was seriously injured. In three crashes, occupants of both vehicles received serious injuries. That is the main reason why there were more vehicles in which people were seriously injured than not. Not surprisingly, motorcyclists, bicyclists and pedestrians are very likely to get incapacitating injuries. Also not surprisingly, occupants of heavy trucks do not easily get seriously injured. It is interesting to see that occupants of pickup trucks (and one of these is a Jeep SUV) are much less likely to get injured than occupants of a regular sedan (p=0.002). Station wagons, vans and other passenger cars do not have statistically different risks of serious injuries.

3.3.5 Light and Roadway Conditions

At the time of the crash caused by one of the parties running a red light, it was daylight in 60 cases (82%), dusk in one case (1%), dark with streetlights lit in 11 cases (15%) and streetlights not lit in one case (1%).

The roadway was dry in 62 cases (85%), wet in 10 cases (14%) and covered by snow or ice in one case (1%).

3.3.6 Speed

The speed limit at the location of the crash is shown in Table 21. About 10% of the crashes occurred at locations with a speed limit of 45 mph or higher. The table also shows what the speed limit was at the location where the four fatal crashes happened that involved disregard of a traffic signal. The two fatal crashes that occurred on 35-mph streets involved a pedestrian and bicyclist respectively.

Table 21 Speed limit (red-light running crashes)

Speed limit	Number of crashes	Number of fatal	Percent fatal
25 mph	30	0	0%
30 mph	8	0	0%
35 mph	20	2	10%
40 mph	3	0	0%
45 mph	6	1	17%
50 mph	1	1	100%
Unknown	3	0	
Sum	71	4	6%

3.3.7 Alcohol

One (or both) of the drivers were under the influence of alcohol in four cases (5% of all cases).

3.3.8 Towns and Cities

An analysis by town, as seen in Table 22, shows that the towns with the highest per capita frequency of serious injury crashes caused by red-light running are Auburn, Lewiston, Winslow, Bangor, Saco and Presque Isle. The rates are based on the night populations as reported by the Census 2000. It should be noted that daytime populations are higher in all of these municipalities since every one is a service center. It may also be more appropriate to compare rates based on vehicle-miles driven rather than population, but for community-wide comparisons, we would then need community-wide annual miles traveled or miles traveled through all signalized locations, and such values were not obtained here.

Table 22 Number of serious red-light-running crashes by community

City/town	Number of crashes	Population 2000	Crashes per 10,000 people
Auburn	16	23,203	6.9
Lewiston	13	35,690	3.6
Portland	10	64,249	1.6
Bangor	8	31,473	2.5
Saco	4	16,822	2.4
So. Portland	4	23,324	1.7
Biddeford	3	20,942	1.4
Scarborough	3	16,970	1.8
Presque Isle	2	9,511	2.1
Winslow	2	7,743	2.6
Brunswick	1	21,172	0.5
Butten	1	--	--
Eliot	1	5,954	1.7
Farmington	1	7,410	1.3
Gardiner	1	6,198	1.6
Rumford	1	6,472	1.5
Sanford	1	20,806	0.5
Westbrook	1	16,142	0.6
Windham	1	14,904	0.7

3.4 Left-Turn Crashes

The crashes analyzed in this section are identified by having one or several left turning vehicle operators. In total, 2,611 crashes were identified. Two people were killed in these crashes, 107 sustained incapacitating injuries, 464 evident injuries and 822 possible injuries. In 1,727 crashes, there were no injuries at all. The economic impact of these crashes is estimated to be $67.3 million.

3.4.1 Characteristics

What the police officer has attributed to contribute to the crash is listed in Table 23. The majority of causation factors listed are very generic and of little benefit for trying to find 'true' causation.

Table 23 Apparent contributing factors

Contributing factor	Number of crashes
Failure to yield right of way	1293
Driver inattention - distraction	635
Improper turn	243
Other vision obscurement	121
Disregard of traffic control device	117
Driver inexperience	72
Other human violation factor	65
Vision obscured - sun, headlights	32
Illegal, unsafe speed	29
Improper, unsafe lane change	29
Following too close	19
Hit and run	13
Physical impairment	9
Other vehicle defect or factor	7
Impeding traffic	5
Improper passing - overtaking	5
Defective tire - tire failure	4
Driving left of center - not passing	4
Improper parking, start, stop	2
Defective lights	1
Defective steering	1
Vision obscured - windshield glass	1

The roadway conditions are listed in Table 24. Ice and/or snow may have contributed to 6% (146/2611) of the crashes. Table 25 shows that about 70% of the crashes occurred in daylight and another 6% in dusk/dawn conditions.

Table 24 Roadway conditions—left turn crashes

Road surface condition	Number of Crashes
Dry	1941
Wet	510
Snow, slush-sanded	63
Ice, packed snow-sanded	35
Snow, slush-not sanded	30
Ice, packed snow-not sanded	18
Debris	5
Unknown	4
Oily	2
Other	2

Table 25 Light conditions—left-turn crashes

Light condition	Number of crashes
Daylight	1832
Dark (street lights on)	618
Dusk (evening)	97
Dawn (morning)	62
Dark (no street lights)	9
Other	2

The speed limit at the site is shown in Table 26. About 3% of the crashes occurred at locations where the speed limit was 45 mph or higher.

Table 26 Speed limit at sites with left-turn crashes

Speed limit (mph)	Number of crashes	Number of crashes with fatalities or incapacitating injuries	Number of fatalities and incapacitating injuries
15	6	0	0
20	1	0	0
25	1071	27	35
30	450	17	29
35	864	26	36
40	48	0	0
45	83	3	4
50	2	0	0
55	2	1	3
n/a	84	2	2
Sum	2611	76	109

3.4.2 Driver and Vehicle Characteristics

The driver was cited for being under the influence of alcohol in 23 cases (0.9%), to be drinking in six cases, using drugs in one case, fatigued in four cases and ill in three cases. The driver conditions were listed as normal in over 97% of the cases.

The age of the driver making the left turn is listed in Table 27. The table also shows the number of licensed drivers in that age group in 2001 according to FHWA (see http://www.fhwa.dot.gov/ohim/hs01/dl22.htm#foot1). The relative risk—which does not account for differences in miles driven—is calculated as the number of drivers making the left turn divided by the number belonging to that age group multiplied by 942,556/2576 to get the average relative risk of 1.0.

It is obvious that younger drivers, especially those below age 25, present very high risks ($p<1E-30$). The age group 25 to 29 was also significantly overrepresented in these crashes ($p=0.01$), whereas all 5-year age groups above the age of 35 with the exception of the 80 to 84 group, had lower than average risks. The age group 80 to 84 was significantly overrepresented ($p=0.001$).

Table 27 Age of drivers involved in crashes while turning left

Age of driver	Number making left turn	Number in age group	Relative risk
-19	434	44,313	3.6
20-24	319	70,934	1.6
25-29	216	67,642	1.2
30-34	247	81,684	1.1
35-39	215	94,548	0.8
40-44	210	105,348	0.7
45-49	179	102,073	0.6
50-54	155	94,020	0.6
55-59	123	82,099	0.5
60-64	109	53,443	0.7
65-69	92	45,745	0.7
70-74	94	38,701	0.9
75-79	73	28,161	0.9
80-84	73	18,554	1.4
85+	37	15,291	0.9
subtotal	2576	942,556	1.0
unknown	35	--	
Total	2611	--	

The comparison above does not take into account that different age groups drive different distances. If we use the same data for annual miles traveled as in Table 18, the differences in risk become even greater as shown in Table 28. Teenage drivers now have a risk which is 5.5 times the average and the group 20-24 also become even more overrepresented. But 25 to 29 year olds are no longer significantly overrepresented ($p=0.14$) since they drive more. The group 85+ also becomes clearly overrepresented in these crashes ($p=1.5E-8$). The age group 80 to 84 obviously remain significantly overrepresented but now the age groups 70-74 and 75-79 also become significantly overrepresented ($p=0.003$ and $p=3.3E-8$ respectively).

Table 28 Relative risk considering miles driven for different age groups involved in crashes while turning left

Age of driver	Number making left turn	Number in age group	Annual miles driven per person	Relative risk
-19	434	44,313	9,450	5.5
20-24	319	70,934	13,435	1.8
25-29	216	67,642	15,808	1.1
30-34	247	81,684	15,694	1.0
35-39	215	94,548	15,875	0.8
40-44	210	105,348	16,851	0.6
45-49	179	102,073	17,005	0.5
50-54	155	94,020	16,062	0.5
55-59	123	82,099	16,082	0.5
60-64	109	53,443	14,282	0.8
65-69	92	45,745	11,852	0.9
70-74	94	38,701	9,737	1.3
75-79	73	28,161	7,411	1.9
80-84	73	18,554	6,234	3.4
85+	37	15,291	4,346	3.0
subtotal	2576	942,556	14,560	1.0
unknown	35	--		
Total	2611	--		

The vehicle type making the left turn is listed in Table 29. Trucks (excluding pick- ups) made up about 7% of the left-turning vehicles. Also, medium and heavy trucks make up about 7% of all vehicle miles traveled in the US. In other words, as a first analysis, trucks do not seem either overrepresented nor underrepresented in this vehicle mix. However, trucks may travel disproportionally more miles on major highways and therefore less through signalized intersections than their average share of miles traveled, and trucks would then be somewhat overrepresented as the vehicle making the left turn.

Table 29 Vehicle type making left turn

Vehicle type	Number
Passenger car (2 or 4-door)	1669
Pickup truck	356
Van	245
Station wagon	149
Truck - before 1995	53
3 axle tractor/tandem axle semi	34
2 axle commercial bus	23
3 axle tractor/tri axle semi	12
3 axle single unit	8
Motor home	8
2 axle tractor/tandem axle semi	6
2 axle commercial bus	4
4 axle truck single unit	4
2 axle tractor/1 axle semi	3
3 and 4 axle units not listed above	3
3 axle tractor/1 axle semi	2
4 axle truck w/tandem axle semi	2
Motor home	2
School bus	2
2 axle tractor/1 ax semi 2 ax trailer	1
3 axle commercial bus	1
3 axle tractor/1 ax semi 2 ax trailer	1
6 axle std trailer tandem w/ctr axle	1
Farm vehicles/tractors	1
Unknown	21
Total	2611

3.4.3 Locations with Many Left-Turn Crashes

Table 30 lists the towns/cities with more than ten left-turn crashes. The communities with the highest per capita rates are Bangor, Auburn, Lewiston, Portland, Augusta, Scarborough, and South Portland. Again, the rates are related to nighttime populations rather than daytime ones. In absolute crash numbers, the worst cities are (in order): Portland, Bangor, Lewiston, Auburn, South Portland, Augusta, Scarborough and Brunswick—more or less the same municipalities that have the highest rates.

Table 30 Towns/cities with more than ten left-turn crashes, listed by rank

City/town	Number of crashes	Population 2000	Crashes per 10,000 people
Bangor	260	31,473	82.6
Auburn	163	23,203	70.2
Lewiston	243	35,690	68.1
Portland	395	64,249	61.5
Augusta	112	18,560	60.3
Scarborough	99	16,970	58.3
South Portland	135	23,324	57.9
Randolph	11	1,911	57.6
Rockport	17	3,209	53.0
Westbrook	81	16,142	50.2
Ellsworth	32	6,456	49.6
Presque Isle	47	9,511	49.4
Winslow	35	7,743	45.2
Brunswick	93	21,172	43.9
Kittery	40	9,543	41.9
Saco	66	16,822	39.2
Brewer	35	8,987	38.9
Farmington	28	7,410	37.8
Rockland	28	7,609	36.8
Gray	19	6,820	27.9
Biddeford	57	20,942	27.2
Skowhegan	24	8,824	27.2
Sanford	55	20,806	26.4
Waterville	41	15,605	26.3
Falmouth	24	10,310	23.3
Fairfield	15	6,573	22.8
Waterboro	12	6,214	19.3
Windham	28	14,904	18.8
Old Town	15	8,130	18.5
Wells	17	9,400	18.1
Hampden	11	6,327	17.4
Kennebunk	15	10,476	14.3
Lisbon	13	9,077	14.3
Gorham	19	14,141	13.4
Orono	12	9,112	13.2
Topsham	11	9,100	12.1

The three largest cities have not only the highest absolute numbers but also high rates. Intersections within these communities with at least ten left-turn crashes, listed in alphabetical order for each city, are:

Portland

- Forest, Bedford, Baxter Boulevard
- Franklin Arterial, Congress Street
- Park Avenue, High Street
- Preble Street Extension, Baxter Blvd
- Rte 22, Park, St John Street
- Rte.25, Colonial, Columbia
- State, Spring Street
- Warren Avenue, Riverside Street

Lewiston

- Canal Street, Cedar Street*
- College Street, Russell Street*
- East, Bartlett, Pleasant
- Pleasant Street, Plourde Parkway
- Rte 126, Horton Street, College
- Rte 126, Russell Street
- Rte 196, South Avenue*
- Russell Street, East Avenue

Bangor

- Broadway, Center, Earle
- Broadway, N. Park Street
- Broadway, Strickland, Burleigh
- Haskell, Hogan Road
- Hogan Road, Ramp On/Off I-95n
- Hogan Road, Ramps On/Off I-95s
- Hogan, Springer Drive, Bangor Mall
- Union Street, Ramp I-95s to Union
- Union Street, Godfrey Drive, Airport Mall
- Union Street, Main Street

3.5 'Unprovoked' Rear-End Crashes

A list of locations was developed by identifying crashes where all vehicle units had the pre-crash action of "Following Roadway". In a three vehicle crash, if only units 2 and 3 (or 1 and 3) were listed as following roadway, the crash would not be included in this analysis since the missing unit is presumed to have made a turn, stopping, slowing, etc. This procedure may have omitted some crashes, or in some cases incorrectly included some based on the dynamics of the query. If instead all crashes identified by the reporting officer as rear-end crashes were to be included, a greater total would be found but the analysis

* Safety improvement scheduled or recently completed

here aims at finding locations where some drivers stop whereas other drivers (behind them) decide to continue without stopping.

Of course, it may also be that the following driver is unable to stop because it is icy or snowy and he/she is going faster than the driver ahead (or has worse tires). But an analysis of the roadway conditions shows that the roadway was dry in 74% of the crashes and wet in 19% of the crashes. That leaves 7% of the crashes to snow/ice. The roadway was just slushy in a majority of these crashes, and in over half of them, the roadway had been sanded. This leaves less than 1% of all crashes to ice or packed snow/not sanded conditions.

Eight of the drivers were under the influence of alcohol. That means that about 3% of the crashes can be attributed to OUI.

The speed limit was unknown in 12% of the crashes, 25 mph in 41%, 30 mph in 21%, 35 mph in 23% and 40 mph or higher in 3% of the crashes.

There were no fatal or incapacitating injuries in any of these crashes. There was at least one person receiving evident injuries in 69 of the 629 vehicles (11%) involved in these crashes and possible injuries to occupants of 127 vehicles (20%).

3.5.1 Locations with High Numbers of Rear-End Crashes

Towns with more than one of these types of crashes are listed in Table 31. Note that the number for South Portland includes an intersection on the town line with Portland.

Three cities stand out has having not only higher absolute numbers than any others, they also have higher rates per capita than any of the other communities. Again, these are the three most populous municipalities in Maine.

Table 31 Towns with multiple ‘unprovoked’ rear-end crashes, listed by rank

Town name	No. of crashes	Population 2000	Crashes per 10,000 people
Portland	117	64,249	18.2
Lewiston	39	35,690	10.9
Bangor	34	31,473	10.8
Rockland	7	7,609	9.2
Skowhegan	6	8,824	6.8
Ellsworth	4	6,456	6.2
Rockport	2	3,209	6.2
Auburn	14	23,203	6.0
Westbrook	9	16,142	5.6
Kennebunk	5	10,476	4.8
Scarborough	8	16,970	4.7
Waterville	7	15,605	4.5
Brewer	4	8,987	4.5
Wells	4	9,400	4.3
South Portland	9	23,324	3.9
Winslow	2	7,743	2.6
Topsham	2	9,100	2.2
Saco	3	16,822	1.8
Brunswick	3	21,172	1.4
Sanford	3	20,806	1.4
Augusta	2	18,560	1.1

Portland locations with multiple rear-end crashes of the type discussed here were:

- Bates, Veranda, Washington, Sb & Nb
- Brighton, Taft Avenue
- Congress Street, High Street, Free Street
- Congress Street, Forest Avenue
- Congress Street, Stevens Avenue
- Congress, Frost Street
- Congress, Sewell, Whitney
- Congress, Sewell, Whitney
- Forest Ave, Revere Street
- Forest Ave, Riverside Street
- Forest Deering, Woodford
- Forest, Allen Avenue
- Forest, Bedford, Baxter Blvd
- Forest, Ocean, Saunder Street
- Forest, Steven Ave, Bishop
- Franklin Art, Congress Street
- Franklin Art, Cumberland

- High Street, Cumberland Avenue
- High, Spring Street
- Oxford, Preble Street
- Riverside Street, Brighton Avenue
- Rte 22, Park, St John Street
- Rte 25, Rand Rd, Cabot Street
- Rte.25, Falmouth Street
- Rte.26, Presumpscot Street
- State, Congress Street
- State, Danforth Street
- State, Forest, Marginal Way
- State, Spring Street
- Stevens Ave, Woodford Street
- Stevens, Brighton Avenue
- Washington, Allen Avenue
- Washington, Ocean Avenue

Lewiston locations with multiple rear-end crashes of the type discussed here were:

- Canal St, Cedar Street[*]
- Cedar Street, Lincoln Street
- East Ave, Webster Street
- Rte 11, Bates Street
- Rte 11, Park Street
- Rte 11, Russel Street, L&A Cir
- Rte 11, Russel Wb, Mem.Br Wb
- Rte 126, Randall, Old Green
- Rte 126, Russell Street
- Rte 126, Sylvan Ave, Campus

Bangor locations with multiple rear-end crashes of the type discussed here were:

- Broadway and Cumberland Street
- Broadway, Strickland, Burleigh Street
- Center and Cumberland Street
- Hancock, State, Otis Street
- Hogan Rd, Ramp On, Off I-95 north
- Hogan, Springer, Bangor Mall
- Industrial Spur, I-395 W, Odlin Road
- Main Street, Dutton Street
- Union, Godfrey, Airport Mall

In Bangor, two arterials stand out as having more of these crashes than any other: Broadway with nine crashes and Hogan Road with six. Union Street has four and (the 4-lane section of) Main Street has three whereas Stillwater Avenue and State Street each have two crashes of this type. Observations of red-light running therefore include locations along Broadway and Hogan Road (see Chapter 4).

[*] Safety improvements planned or recently completed

4 Observations of Red-Light Running

4.1 General

Observations of how frequently drivers in Maine run red lights are presented in this chapter. Section 4.2 focuses on through and left-turning traffic. Section 4.3 describes right-turn-on-red behavior. Finally, Section 4.4 presents serious conflicts that were observed during the observations of red-light running behavior. The observations were made in the daytime since over 80% of the state's serious red-light running crashes occur then, as noted in Section 3.3.5 on page 45.

4.2 Through Traffic

This section focuses on through traffic but includes in some instances left-turning traffic as well, where the two share the same lane and/or phase. The study methodology is described in detail for one of the observational sites, in Section 4.2.1. The other studies followed the same methodology unless otherwise pointed out. If not otherwise noted, all through traffic red-light running is done as 'high-speed' entry. Among left-turners, there may be people who have stopped, waiting for oncoming traffic that enters on red after oncoming traffic has stopped. Such cars are counted as red-light runners if they enter the intersection on red but not if they entered on green and stopped and waited inside the intersection and don't proceed until red. An emergency vehicle running a red light during an emergency call is here not counted as red-light running. Pedestrians and bicyclists are not considered in the observations.

4.2.1 Hogan Road, Bangor—4-lane Arterial—Daytime

According to Section 3.5, Hogan Road in Bangor is one of the (minor) arterials in the state with the most rear-end crashes where the vehicle hit from behind was going straight through the intersection. This is an indication that some people run red lights so far into the cycle that the vehicle in front of them has already stopped. Observations of red-light running behavior were made on the morning of June 28, 2003 (a Saturday) of traffic arriving at the intersection with Haskell Road. This intersection has fairly random arrivals in the northbound direction (from Eastern Maine Medical Center towards the Interstate) since it is fed by traffic from Route 2 and from Mount Hope Avenue as well as in the southbound direction where Hogan Road is fed from the northbound off ramp of I-95 as well as from the mall area.

Here, Hogan Road has two through lanes in both directions and separate left-turn lanes. Observations were done for 120 minutes, from 9:30 to 11:30. The northbound flow (excluding right-turning vehicles but including left-turning ones) was around 600 vph and the southbound flow (also excluding right-turning traffic) was around 830 vph. In other words, a total of about 2,860 vehicles along Hogan Road were observed.

The signal here has a fixed time cycle that varies over the day. At the time of the observations, the cycle time was 100 seconds, with the red phase starting at the same time in both directions of Hogan Road. The red phase was preceded by three seconds of yellow and then followed by two seconds of all red before the eastbound traffic on Haskell road got green. The 'complete' red phase for traffic on Hogan Road lasted for 32 seconds when a left-turn green arrow came on. The southbound through phase had red for another 10 seconds, and the northbound through-phase had a slightly later onset of green. The southbound green phase lasted for 55 seconds and the northbound for a couple of seconds less. The left-turn from Hogan Road is protected/permissive, meaning that the green arrow is followed by a yellow arrow and then a green ball allowing left-turn throughout the green phase. Left-turning traffic was included in the study at this site because the left-turn lane is short and was not well marked at the time of the study so that through traffic and left-turners approach the intersection in the 'same' lane until very close to the stop line.

There was not a single through vehicle or left-turning vehicle going through more than two seconds into the red phase during the observation period. There were five northbound and two southbound vehicles entering the signal at high speed during the first two seconds of red, the all-red phase. There was also one straight-through driver in the left of the two through lanes, who was stopped at red who started up when the left-turn arrow came on and people in the lane next to him started up. Cross traffic had red at this time and there happened not to be any opposing left-turning vehicles. There were another three left-turning southbound vehicles (exiting eastbound) that were stopped when the light turned red and that entered the intersection during this phase. Eleven vehicles running the red light out of 2,860 equals 0.39%, and a majority of these entered during the first second of red.

About 45% of the cycle time was red for the through traffic. This means that out of those arriving during red, about 0.9% ran the red light.

In total, 72 cycles were observed. This means that the six lanes (two through and one left-turn per direction) would have a total of 432 vehicles arriving as first vehicle on red. But the left-turn lane was frequently blocked by a stopped vehicle at the time the signal changed to yellow and then red, so let's analyze the through movement only. There would be 288 of them. Since eight vehicles ran red lights (at high speed when approaching the light), this means that 3% did so. In no case during the observation period did a second vehicle follow the first one through on red. However, there were not 432 vehicles arriving during the first two seconds of red. It is hard to determine exactly when a vehicle would have gone across the stop line had the driver not slowed down and stopped. If vehicles arrived completely randomly, 2/100 of them would have arrived during the first two seconds of red. That would be a total of 57 vehicles. My estimate is that this is a realistic number of actual arrivals as well. Using this number and 8 going through on red, gives us a portion of people running the red light, out of those arriving when it has just turned red, as 14%.

Similar studies were done on Tuesday July 22, in the late morning, at the intersection with Springer Drive/Bangor Mall Boulevard. The cycle time for this 4-phase signal was 88 seconds, with 22 seconds green, 4 seconds yellow and 63 seconds red in the southbound direction, towards the Interstate. The traffic flow was 450 vph, excluding right turners. 0.9% of the vehicles ran the red light. This means that about 1.2% of those arriving on red and 39% of those arriving during the first two seconds of red ran the light.

Studies were also done on traffic entering Hogan Road at the same intersection in the westbound direction—on Springer Drive from Shaw's/Wal-Mart. The green time here was 12 seconds followed by 4 seconds of yellow. The arrival rate was 370 vph excluding right turners. In total, 10 vehicles ran the red light during 120 minutes of observations. This means that 1.3% ran the red light. About 1.6% of those arriving on red ran the light and, statistically, almost 60% of those arriving during the first two seconds of red ran it.

4.2.2 Broadway, Bangor—2-lane Arterial

Another place with many rear-end crashes is the intersection between Broadway and Cumberland in Bangor. Broadway here has one lane in each direction but widens enough at the intersection to accommodate separate left-turn lanes. Observations were made for two hours on Thursday August 21, 2003. The traffic flow was 504 vph in the northbound direction (towards the Interstate) and 558 vph in the southbound direction (towards the CBD). The cycle time was fixed at 68 seconds with a 25 second red phase along Broadway. In total, there were 14 vehicles along Broadway (sum of both directions) running red lights. Eleven of these ran it in the normal way, within two seconds of the onset of red, whereas two drivers ran the light more than two seconds into the red phase by entering late at high speed. The remaining driver stopped for the red light (a pickup truck with two men around age 35, dressed as construction workers). They seemed to be waiting for green when they suddenly, in the middle of the red phase, started up and drove straight through the intersection just in front of a crossing vehicle.

The total red-light running makes up 0.66% of all vehicles or 1.8% of those arriving on red. Out of the first one arriving on red, 6.6% ran the red light. Theoretically, out of those arriving during the first two seconds of red, about 22.4% ran the red light.

4.2.3 Center Street, Bangor—2-lane collector

Center Street is a 25-mph two-lane collector wide enough for two vehicles to parallel each other at the approaches to Cumberland Street. Observations were done in the afternoon of Friday July 11, 2003. Center Street carried 240 vph in the northbound direction (away from downtown) and 246 vph in the southbound direction, excluding right-turning traffic. The signal is vehicle actuated with an average green time along Center street of 22 seconds followed by a 3 second yellow time and 24 seconds of red. This means that traffic along Center Street has red about 49% of the time. During two hours of observation time, one vehicle ran the red light. It did so within the first two seconds of red time. This gives a red-light running frequency of 0.1%, or 0.2% of those arriving during red. There were approximately 147 cycles observed, and typically vehicles arriving in both directions during the red phase. This means that 0.3% of first arriving vehicles ran the red light. Assuming random arrivals, approximately 40 vehicles would have arrived during the first two seconds of red. Out of these, one or 3% ran the red light.

4.2.4 Union Street, Bangor—4-lane Arterial

Union Street is an “other principal arterial” with a speed limit of 35 mph at the intersection with Godfrey Drive/Airport Mall. Observations were done in the afternoon of Friday July 11, 2003. Union Street carried 306 vph in the eastbound direction (towards downtown) and 390 vph in the opposing direction. The major approaches have protected/permitted left turns from the left land of the two approach lanes. The average green time for through traffic was 25 seconds followed by 3 seconds of yellow and sometimes preceded by a short green left-turn arrow. The average red time was 29 seconds. A total of three through vehicles ran the red light during two hours of observations. This means that 0.2% of the vehicles ran the red light. About 0.4% of those arriving during red ran the red light. About 1% of first arriving vehicles ran the red light. Assuming random arrivals, about 6% of those arriving during the first two seconds of red, ran the light.

4.2.5 State Street (Rte 2), Veazie

State Street through Veazie is a two-lane minor arterial that widens up to two unmarked lanes on the intersection approaches with Chase Road. The signal is vehicle actuated. Studies were done in the afternoon of Thursday, July 10, 2003. The average cycle time was 58 seconds with a green time along State Street varying between 15 and 168 seconds (average 45 seconds) followed by 3 seconds of yellow and 9 to 13 seconds of red. This means that the traffic faced red only 17% of the time. The southbound vehicle flow was 264 vph excluding right-turn vehicles. The northbound flow was 270 vph. During an observation period of two hours, there was one person running the red light in the northbound direction and one in the southbound direction. Both entered within the first two seconds of red. This gives a red-light running frequency of 0.2% per arriving vehicle or 1.1% of those arriving when it is red. Approximately 124 cycles were observed and a maximum of 248 vehicles were first arrivals. About 1% of first-arriving vehicles ran the red light. Assuming random arrivals, approximately 37 vehicles would be arriving during the first two seconds of red. Out of these, two or 5% ran the red light.

4.2.6 Stillwater Avenue, Orono

Stillwater Avenue is a four-lane arterial where it passes by the University Mall just northeast of I-95 in Orono. Traffic from Old Town traveling in the southwesterly direction was observed for two hours during the daytime of Friday August 22, 2003. There is no left-turning traffic at the main entry to University Mall. About ten percent of the vehicles turn right, and the right-hand lane ends at the northbound ramp of the Interstate. Most through vehicles use the lane adjacent to the centerline. The through flow was 564 vph at the time of the observations. A total of six through vehicles ran the red light during the two hours which means that 0.5% of all vehicles ran the light. All of these did so within the first two seconds of red. The signal is vehicle actuated and traffic has 'continuous' green unless there is conflicting traffic—opposing left turn or traffic from the mall area (from the right). On average, the cycle time was 70 seconds during the time of observations with 20 seconds of red time preceded by four seconds of yellow. The percentage of cars running red of those arriving during red would be around 1.9%. Out of those arriving first on red—in the lane that carries the vast majority of through traffic—about 5.8% ran the light. Statistically, out of those that arrive during the first two seconds of red, 18.6% ran the light.

4.2.7 Western Avenue, Augusta—4-Lane Arterial

Western Avenue is the major connector between the Interstate and downtown Augusta. At the intersection with Orchard Street/Meadow Drive, it carried 1488 vph in the eastbound direction during the time of observations, late morning on Monday July 14, 2003. The speed limit is 35 mph. Only about 1% of traffic turns off Western Avenue at this slightly staggered intersection. The signal is of fixed-time type and had at the time of observations a green time of 52 seconds followed by a 3 second yellow phase and 43 seconds of red. During two hours of observation, there were 26 vehicles that ran the red light. Three of them were about 3 seconds into the red phase when they entered whereas the other 23 entered during the first two seconds of red. In total, 0.9% of the drivers ran the red light. Out of those arriving when it was red, about 2.0% ran the red light. Out of those arriving as first vehicle, about 18% (26/148) ran the red light. (Actually, a few of the red-light runners were second vehicles arriving on red.) Out of those that arrived during the first two seconds of red, about 43% ran the red light.

Observations of traffic along Western Avenue were also done for one hour at Whitten Road on the other side of the Interstate. Again, only traffic towards downtown was observed. Only through vehicles were included. This flow was 1680 vph. The cycle time here was 88 seconds with 37 seconds green and 48 seconds red. A total of 3 vehicles ran this light, all within the first two seconds of red. This gives us an overall red-light running frequency of 0.2%. Out of those arriving when the light was red, about 0.3% ran the light. Out of those arriving as first vehicle, about 4% ran the light and out of those arriving during the first two seconds, statistically about 8% ran the light. (This percentage would have been much higher had right-turning drivers been included.)

4.2.8 Route 202, Manchester

Western Avenue in Augusta continues westwards with the same name through Manchester though it is here also designated as US 202 and Route 100. Studies of red-light running frequencies were carried out at the intersection with Route 17 (Readfield Road) for two hours on the early afternoon of Tuesday August 26, 2003. Only the westbound direction was observed. Traffic here moves at high speeds, typically around 45 mph in the local 35 mph speed limit. The signal is vehicle actuated and the cycle time varies quite a bit depending on volumes and if left-turn phases are activated or not. The average cycle time was around 88 seconds with 38 seconds red time for westbound through traffic. The through flow was around 660 vph, distributed over two through lanes though a majority of passenger vehicles uses the left lane. In total, 29 vehicles were observed running the red light in the 120 minutes observed. Three of them ran the light at least three seconds into the red phase. This means that the overall percentage of red-light runners was 2.2%. Out of those arriving during red, 5.1% ran the light. There would be 164 vehicles arriving first to the red light during the observed 82 phases. This means that 18% of the first arrivals ran the light. Statistically, about 30 vehicles would have arrived during the first two seconds of red. Since 29 ran the red light, about 97% of those arriving during the first two seconds of red ran the light. (In reality, some people running the light arrived more than two seconds into red, so less than 97% of the people arriving during the first two seconds of red actually ran it.)

4.2.9 Congress Street, Portland—4-Lane Arterial

A majority of the northbound traffic on this section of Congress Street turns left onto Franklin Arterial. However, Franklin Arterial has a wide grass median here, and there are two separate signals along Congress Street. Observations were made of cars entering the first of these two. There people have a choice of going straight or turning right but since a majority of drivers will turn left shortly thereafter, through traffic is moving slowly here, slower than the speed limit of 25 mph, especially during congested time periods as was the case on Monday afternoon between 3 and 5 pm on July 14, 2003. The through traffic flow was 816 vph. The signal showed green for 27 seconds, yellow for 3 seconds and red for 55 seconds. Four drivers were seen entering the signal on red—all during the first two seconds of red. This means that 0.2% of the drivers ran the red light. Approximately 0.4% of those arriving during red ran the light. And about 2.4% of those arriving first to the light ran it. Statistically, about 10% of those who arrived during the first two seconds ran the light.

4.2.10 Franklin Arterial, Portland—4 Lanes

Franklin is a four lane arterial that widens up to three lanes in each direction at the intersection with Marginal Way. The speed limit is 35 mph. Observations were made in the westbound direction (traffic heading towards Interstate 295). It carried 828 vph in this direction. Through traffic has green for an average of 24 seconds per cycle followed by 3 seconds of yellow and 41 seconds of red. During the red phase, left turning traffic has green for 6 seconds. Observations were made for 120 minutes and 5 vehicles ran the red light, all within the first two seconds of red. This means that 0.3% of all vehicles ran the red light. Out of those arriving during red, 0.5% ran the light. For the 106 cycles observed, 212 vehicles would be arriving as first vehicle on red. Out of those, 2.4% ran the red light. Approximately 48 vehicles would be expected to arrive during the first two seconds of red. Out of these, 10.4% ran the light.

4.2.11 Main Street, Waterville—4-Lane Arterial

The signalized intersection observed is the first one when going from I-95 towards downtown Waterville, before getting to Armory Road. Only southbound traffic was observed. The cross road to the right is a driveway that leads into the parking lots of Governor's restaurant, Ruby Tuesday and Bangor Savings Bank among other businesses. To the left is a minor driveway with a protected turn that is activated only when vehicles are detected. The cycle time varied and was on average around 96 seconds during the observations on the afternoon of Thursday July 24, 2003. The signal was green for 63 of these seconds, yellow for 3 and red for 30. Excluding turning traffic, the two through lanes carried 708 vph. During two hours of observations, there were three cars that ran a red light, all within the first two seconds of red, as well as an emergency vehicle that is excluded from the analysis. This means that 0.2% of the cars ran the red light. Out of the ones arriving during red, about 0.7% ran the red light. And, theoretically, during the 75 cycles observed, 150 cars arrived first to the red light and three of them, or 2.0%, ran the light. Out of the ones arriving during the first two second, about 10% ran the light.

4.3 Right-Turn-on-Red Where Not Permitted

Studies of right-turn-on-red where it is allowed—after a full stop—were not performed in this project. However, it can generally be observed that a high percentage of drivers do not come to a full stop before they proceed. The percentage that do not stop obviously varies with conflicting traffic volume among other factors. The studies presented in Section 4.3.2 here can possibly be seen as representation of what people do where it is legal to turn right on red.

Studies of right-turn-on-red behavior where it is not allowed were done at two sites. One with a red arrow but no sign, the other with a red ball and a sign prohibiting right-turn-on-red. Both sites are located in Bangor to minimize variation in driver populations.

4.3.1 Rte 126, Lewiston

Route 126 (Sabattus Street) is a 2-lane, urban street with a gas station, a church and stores surrounding the 5-leg junction with College Street and Horton Street. Two hours of observations were made of eastbound traffic along Route 126 on the afternoon of Friday August 29, 2003. The through flow was 558 vph. The signal is vehicle actuated. The average cycle time was 59 seconds with 32 seconds of red along Route 126. There were three drivers of motor vehicles running the red light, which means that 0.3% ran the light. Out of those arriving during red, about 0.5% ran the light. Out of the first arriving vehicle on red, 2.5% ran the light. And, out of those arriving within the first two seconds of red, approximately 7.9% ran the light.

4.3.2 Red-Arrow Indication

The first study covered 4.5-hours of observation during the afternoon of Wednesday June 11, 2003 at the intersection between Stillwater Avenue and the I-95 off-ramp from Exit 48A in Bangor. There is no sign prohibiting the right-turn-on-red at this location. The meaning of the red arrow is expected to be understood by the drivers. The weather was mostly overcast but without precipitation. A total of 646 vehicles were observed arriving from the off-ramp when the signal indicated a red arrow to the right.

The results of the observations are shown in Table 32. It can be noted that only 77 of the 646 (12%) drivers obey the law, and

47 of those who did 'obey' had a continuous flow of vehicles to yield to from the left, so they may not have obeyed the prohibition had they had a chance to start up before the light turned red on Stillwater Avenue and people came to a stop there.

It is possible that many drivers are not aware that right-turn-on-red is prohibited by the signal display since it is a fairly recent change in MUTCD and State law. If right turn on red had been allowed, then at a minimum, an additional 39 drivers (6%) would have obeyed the stop and yield rule that applies at typical signalized intersections in the state. Another 267 drivers (41%) came to a (more or less) full stop, but they may have done so only because they had to yield to traffic along Stillwater Avenue.

Table 32 Right-turn behavior where right-turn-on-red prohibited by red arrow but no sign

Traffic Situation	Driver behavior	Number of drivers
No conflicting vehicles	Stops and waits for green light	30
	Stops and then makes an illegal right turn-on-red	39
	Slows down to a rolling stop	206
	Makes high-speed turn	52
Conflicting vehicles (when getting to signal)	Stops and waits for sufficient gap	267
	Enters road so that cars must slow down	4
	Enters road causing a conflict	1
Continuous flow of conflicting vehicles	Stops and waits for light to turn green (no alternative available)	47

A total of 327 drivers arrive at the signal when there is a sufficient gap to enter and turn right without waiting for traffic to pass. Out of these, 206 drivers (63% or 32% of the total) slow down but never come to a full stop. They drive as if there was a yield sign regulating their movement. This may still be considered a reasonably safe behavior even if it is clearly illegal. What is probably less safe is making the turn at a high speed, around 12 to 15 mph, which is the approximate speed people make the turn at when the light is green. What is definitely unsafe, is to not only fail to stop when the light is red but also to fail to yield to through traffic on Stillwater Avenue. Five drivers (0.8%) entered Stillwater Avenue in such a way that through drivers had to brake or at least slow down to not collide with them shortly downstream from the intersection. Two of these entering vehicles were heavy trucks (18-wheelers) One of the through vehicles on Stillwater Avenue had to brake hard to avoid a collision.

4.3.3 Red Ball and Sign

These studies were done at the intersection of State Street, Exchange Street and Harlow Street in downtown Bangor. The studies were done on Tuesday June 24, 2003. In total, 68 red phases were surveyed during approximately 2.5 hours of observation. At least one vehicle would arrive in the westbound direction of State Street during 66 of these red phases. In 63 of these occasions, there was a gap long enough to allow the driver to make a right-turn-on-red without considerable interruption to the traffic along Exchange/Harlow Street. Only in three of these 63 cases did someone make a [clear] right turn on red. Two of the three drivers came to full stops before making the turn whereas the third driver made a low-speed turn. There were an additional five drivers making the right turn when the signal had just changed to red. They approached the signal on yellow and it turned to red within the last two seconds before they crossed the stop bar. All of them made "high-speed turns." (There were approximately 20 vehicles approaching the signal in similar situations who did stop rather than run the signal. This means that about 20% of people who would enter the intersection within the first second or two elect to do so.) Overall, the portion of drivers out of those who have the opportunity to make unlawful turns at this location who actually do that is about seven in 63 or 11%. Out of these, a majority are people who 'almost' made the light before it turned red. Out of those that clearly have a red light when they approach the signal, 5% make the right-turn-on-red.

4.3.4 Conclusions

It is obvious that the no-turn-on-red sign is respected to a much greater degree than the signal display observed in Section 4.3.2. An informational campaign should probably be initiated to teach Maine drivers about the meaning of a red, right arrow, or a "No Turn on Red" sign should be installed..

4.4 Serious Conflicts

Traffic conflict studies, focusing on serious conflicts only, were carried out parallel to the observations of red-light running behavior. There were relatively few really serious conflicts observed.

The most serious conflict involved a car, Vehicle A, whose driver was proceeding north along Hogan Road through Haskell Road at approximately the speed limit. A southbound left-turning car, Vehicle B, (from the Interstate onto Haskell Road) turned left so that the northbound through driver seemed to think that he must move from the right to the left lane in order not to hit Vehicle B. Vehicle A's driver did that and braked some too to avoid a collision with B but a second left-turning car, Vehicle C, followed the first one, possibly either thinking that Vehicle A was staying in the right hand and would pass in front of C, or thinking that A was stopping because his light must have turned red. The result was that the driver of Vehicle A had to brake hard, and he locked his wheels and the car skidded partially sideways towards Vehicle C. This became a close call and it would have resulted in a crash had the driver of Vehicle A braked a fraction of a second later.

Another very serious conflict happened at the intersection between Broadway and Cumberland Street in Bangor. It involved two passenger vehicles. It was preceded by a car (Vehicle A) arriving at a red light along Cumberland and coming to a full stop and then making a right-turn-on-red. The vehicle behind him (Vehicle B) came to a full stop behind Vehicle A. It seems as if the driver of Vehicle B assumed that the light had changed to green when Vehicle A started up. Vehicle B proceeded straight through the intersection, and a driver of another passenger car (Vehicle C), coming from the right, braked hard to avoid hitting Vehicle B.

A much less serious conflict also involving a driver running a red light in the middle of the red phase occurred at the same intersection—Broadway and Cumberland in Bangor. This time, it was a driver of a pickup truck that ran the light. It seems as if he just got frustrated at waiting and when there was a reasonable gap available in cross traffic he went straight through the intersection. Cross traffic probably never had to brake to avoid a crash but a driver did brake as a precaution. It is possible that the driver of the pickup forgot that he was at a signalized intersection and thought there was a stop sign there, or that the light was at red flash like most signals operate at night in Bangor. However, this happened in the middle of the day, so it probably was a purposeful violation.

A serious conflict involved a truck turning right onto Stillwater Avenue at Exit 48A. A passenger car traveling northbound along Stillwater Avenue had to brake to not collide with the truck.

A somewhat serious conflict involved a bicyclist—a man in his 20's—running a red light along Route 126/Sabbatus Street through the intersection with College and

Horton Streets in Lewiston. A car from the right, with a green light, braked and yielded to him.

A serious conflict involved a north-bound car making a right-turn-on-red from College Street onto Sabbatus Street/Route 126 in Lewiston. He made the turn after deciding that the car from the left was turning right onto College. However, the car from the left proceeded straight ahead to make the right turn onto Horton Street, the 5th leg of the junction. This driver had to brake to not run into the driver making the right-turn-on-red.

5 Interviews with Maine Drivers

5.1 General

The interviews of people in Maine were done by students at public locations throughout the state of Maine, but with a majority of interviews done in central Maine. A total of approximately 600 people were approached. About 25% of the people never even slowed down to see what the survey was about. Another 15 to 20% refused to participate (or stopped participating partially through the interview) after they had been told the purpose of the study. Out of those that participated, some were reluctant to admit to crashes and/or running red lights. A few subjects even accused the interviewer of being an undercover cop. Such interviews were discontinued and the results are not included here. However a majority of subjects were very cooperative and had an attitude of wanting to help make our intersections safer. Also, some people did not give their age. The interviewer sometimes estimated their age, and in other cases that was not done. A total of eleven surveys had blank ages, and since all analysis below is done by age, these forms were also discarded. The results of the remaining 334 surveys are presented below. An analysis by gender is not presented since women and men in general had similar behaviors and opinions.

5.2 Questions and Answers

The questions that were asked are here presented woven into the result sections below. The order of the presentation reflects the order at which the questions generally were asked. The survey that was typically used is presented on page 91. Some questions were not given to all subjects. That is the major reason why the number of responses do not always total the same for each question.

5.3 Safety Concern with Red-Light Running

A pilot study showed that essentially all middle aged and older people consider red-light running to be a major safety concern. The question:

> Do you consider the fact that some people run red lights a major safety concern?
> yes, definitely   yes, probably   no, there are many more important safety issues

was therefore asked only of younger drivers—below the age of 25, and a subset of these. A total of 45 people responded to the question. Out of these, 31 (69%) checked the box, "yes, definitely," 9 (20%) answered, "yes, probably," and 5 (11%) checked the alternative, "no, there are many more important safety issues."

5.4 Crash Involvement at Signalized Intersections

Everybody was asked the question:

> Have you ever (as a passenger, driver or pedestrian) been involved in a motor vehicle **crash** at a SIGNALIZED intersection?"
>
> □ yes, once
>
> yes, more than once, **each** incident is described below on separate sheets
>
> no

If they answered 'yes' to this question, they were asked follow up questions for each crash they had been involved in. The response to this initial question is shown in Table 33. The responses to the follow-up questions are presented in the section starting on page 68. The age at the time of the crash is presented in Table 34. Five people did not report an age at the time of the crash, and seven were not drivers of motor vehicles, which means that the sum becomes less than 41.

Table 33 Crash involved driver's age at time of interview

Behavior/age	<25	25-34	35-49	50-65	>65	Sum
no	97	48	68	63	17	293
yes, once	15	12	9	5	0	41
yes, > once	0	0	0	0	0	0
Sum	112	60	77	68	17	334

Table 34 Age at time of crash (if reported and driver of motor vehicle[17])

Age	<25	25-34	35-49	50-65	>65	Sum
	19	5	5	0	0	29

5.4.1 Validation of Survey Question

Whether or not the surveyed people represent Mainers at large, at least with respect to crash frequency, can be evaluated by comparing the reported crash frequency to the average reported number of crashes in the state.

At signalized intersections, we have according to page 38 about 3,390 reported crashes per year in the state of Maine; or 0.74% of all Maine drivers involved in a crash for a given year.

The surveyed people are on average 37.2 years old. That means that they, on average, have driven for approximately 20.5 years. With 0.0074 crashes per year, the surveyed people should have had about 0.15 crashes per person at signalized intersections; and the 334 people surveyed should have a total of 50 crashes if the crash frequency had remained constant during the period covered. However, some of the surveyed people have very long driving records, and signalized intersections have become much more common in the state in the last decades than they were earlier on, so a somewhat lower number than 50 would be expected. The reported number, 41 people involved in crashes and 34 of them as drivers, may be a bit lower than expected but is not unreasonable especially considering the fact that a couple of people declined participating in the survey when they found out that they were to be questioned about crashes at signalized intersections.

5.5 Behavior When Light Turns Red

Drivers who approach a signal when it is green typically maintain their speed if they are going straight through the intersection. Some cautious drivers, commonly elderly, slow down when they approach a green light. There could be at least two reasons for this behavior; they slow down because the intersection is a complicated environment where they may have to yield to someone who turns in front of them, or they slow down because the light may turn to yellow, and it will make for a more comfortable stop if that happens when the speed is lower. The opposite behavior can be observed in some drivers. They speed up (as early as a quarter of a mile away) when they see that the light is green, to "make it" before it changes to red.

Drivers who approach a light that is red have fairly uniform behavior even if some drivers slow down earlier than others.

What is of more interest to study is the behavior of drivers approaching a signal that turns yellow when they are reasonably close by. There are intersections with such short yellow times that a dilemma zone is created. That means that a driver is too close to stop when the light turns yellow but so far away that they will not be able to go through the intersection (or even enter it) before the light changes to red. There are formulas for calculating minimum yellow times to avoid creating a dilemma zone, but acceptable deceleration rates, etc. vary from driver to driver, and eliminating a dilemma zone on paper typically creates a long option zone for more aggressive drivers, a zone where they have the option of stopping but also an option of continuing to drive without facing a red light.

[17] Five people did not report their age, and seven were passengers rather than drivers of the vehicle involved in the crash.

Many drivers utilize this option zone by continuing driving. Some drivers may even lengthen this option zone by accelerating to higher speed so that they enter on yellow rather than red. By mistake they may then enter the intersection not only too late but also with a higher speed than they would typically drive. This is one of the aspects aimed for by asking the following[18] question:

A traffic light changes to yellow so that it will just become red if you proceed at unchanged speed, do you typically slow down and stop speed up to make it before red other

Table 35 Behavior when light turns red

Behavior/age	<25	25-34	35-49	50-65	>65	Sum
Slow down and stop	35	32	52	48	13	180
Speed up	58	25	21	19	4	127
Other (write ins):						
depends, I do both	10	1	1	0	0	12
stops if safe—if no one on my tail	0	0	1	0	0	1
try to maintain speed	0	0	1	0	0	1
speed up & lay on the horn	0	1	0	0	0	1
depends, if long red phase I go	1	0	0	0	0	1
Not answered	7	1	1	1	0	9
Sum	112	60	77	68	17	334

It is very clear that younger drivers tend to speed up in this situation whereas a majority of middle aged and elderly drivers do not.

An analysis of the data shows that a vast majority of people who have been fined for running red lights speed up rather than stop. It does not seem people take lessons from getting one or two tickets over their lifetimes. People who are aggressive drivers continue to be so whereas people who have never received a ticket may always have been more defensive drivers. Whether or not more intensive surveillance would make the more aggressive drivers slow down rather than speed up cannot be analyzed with our data.

The question above addresses what a driver does when he/she may be able to proceed through a signal. The situation is slightly different if the light changed to red a few seconds earlier. What a driver does at that time may be affected by what time of day at which he/she is approaching the signal and whether or not there are other people around. To illuminate this, the following question was asked to a subset of younger drivers, below the age of 30, the ones who may be the most prone to run a red light in such a situation.

(Imagine that) You are approaching an intersection at 3 p.m. The traffic light has just turned red. At this time you notice that there is no traffic near you. You are to proceed straight. What would you do?

Definitely stop at the red and wait until the light turns green

Typically stop at red but then proceed through the red light

Typically slow down and proceed directly through the red light

Depends on how much of a hurry I am in

The answer to this question is shown in Table 36 and Table 37.

Table 36 Young drivers' behavior when no one is around

Behavior/age	Number
Definitely stop at the red and wait for green, though see Table 37 as well	40
Typically stop at red but then proceed	1
Typically slow down and proceed directly	0
Depends on how much of a hurry I am in	3
Not answered	0
Sum	44

[18] Some of the respondents got a slightly differently worded question, "When the light changes to yellow close to you but far enough for you to stop, do you typically slow down and stop speed up to make it before red other:….. The two questions have been tabulated together here.

Table 37 Comments among people answering that they definitely would stop and wait

Behavior/age	Number
I would stop and wait, but if the light seemed to be malfunctioning, I would proceed when the way was clear	1
I would go through past midnight, but not during the day	1
Make it 3 AM and I would pick second choice	1
Sum	3

5.6 Propensity to Run Red Lights

The question asked was

> As far as you can recall, have you run a red light in the last 12 months? no If no, go to Question 16. yes, once yes, more than once

Go to Question 16 means they skip the next few questions and go to the question in Section 5.8

Table 38 Proportion of people who ran a red light in the last 12 months

Behavior/age	<25	25-34	35-49	50-65	.>65	Sum
No	26	21	43	40	13	143
Yes, once	30	16	21	14	4	85
Yes, > once	56	23	13	14	0	106
Sum	112	60	77	68	17	334

It is obvious that younger drivers run red lights more than older drivers.

An analysis of the data also shows that there does not seem to be a (positive) correlation between having been ticketed (see Section 5.8, page 66) and not running red lights. And that should be expected. People who by nature 'like' running red lights would be ticketed more frequently than others. But it also shows that a ticket is not a good deterrent to running red lights, just like it was not a good deterrent to speeding up to try to make the light before red.

One person points out that he cannot recall running a red light, but that he may very well have done so. Also, other people say that a passenger made them aware of it. Most of the time there is no passenger in the car when people drive, and when there is, they may not observe red-light running either, so the actual percentage of people running red lights is probably somewhat higher than reported here.

5.7 Reasons for Running Red Light

> The last time you ran a red light, was it
>
> Knowingly: Knew light would probably change to red just before getting to it
>
> By mistake: Light changed to red quicker than expected
>
> Unaware until too late to stop. Reason for not seeing the light: ………………
>
> Completely unaware of running it until afterwards when passenger pointed it out
>
> Other (give reason):

The answer to the question is shown in Table 39. Note that the question did not refer to the most common reason for running a red light—which would give a biased percentage when added over the population—but the reason for running the red light the latest time that was done. Even this does not give an unbiased 'average' unless the individual answers are weighted according to how frequently each person is running red lights.

Table 40 gives the reasons for why people did not see the red light until it was too late to stop. Some people did not give a reason.

Table 41 gives reasons for why some people knowingly ran a red light after having come to a full stop.

Table 39 Reason for running light

Behavior/age	<25	25-34	35-49	50-65	>65	Sum
Knowingly	32	21	9	2	1	65
By mistake	37	12	17	21	5	92
Unaware until too late, reason (see Table 40)	8	4	6	3	3	24
Completely unaware	5	3	1	6	0	15
Other (write ins):						
completely unaware until after crash	0	0	1	0	0	1
completely unaware of new light until after running it	1	0	0	0	0	1
green besides it for other lane	0	1	0	0	0	1
icy road—not enough time to stop	0	0	1	0	0	1
not enough yellow time to stop commercial vehicle	1	0	0	0	0	1
car behind seemed not able to stop	1	0	1	0	0	2
knowingly, stopped, then drove (see Table 41)	6	1	2	0	0	9
Sum[19]	91	42	38	32	9	212

Table 40 Reasons for not seeing the light until too late to stop

Reasons/age	<25	25-34	35-49	50-65	>65	Sum
Baby screaming	0	1	0	0	0	1
Distracted by children in car	0	0	2	0	0	2
Distracted by passengers/talking	1	0	1	0	0	2
On my cell phone*	0	0	0	0	0	0
My vision	0	0	0	0	1	1
Blinded by sun	0	0	1	0	0	1
Large truck in front of me	1	0	0	0	0	1
Traffic	1	0	0	0	0	1
Vegetation blocking sight	1	0	0	0	0	1
Not familiar with area	0	0	0	1	0	1
Not paying attention	0	1	0	0	0	1
The red didn't register in my mind	1	0	0	0	0	1
Distracted (not specified how)	0	0	1	0	0	1
Sum	5	2	5	1	1	14

* No one gave this as a reason for not seeing the light. The alternative was included in this table because the author was surprised to see that it did not occur.

Table 41 Given write-in reasons for, "Knowingly stopped, then drove"

Reason	Age & gender
"Red light but no one in sight anywhere on road so why should I wait"	21-year-old male Orono resident
"Knowingly, no one around intersection."	29-year-old male
"It was like 2:30 in the morning and it seemed like the light was not going to change. Impatient and no sense to wait for light to change"	37 year-old female from Bangor
"No other cars around and I know how the light operates so I went through on red"	25-year old male from the Portland area

19 Note that the total in Table 39 does not add up to match the number of people indicating they have run a red light in the Question presented in Table 38. Some people answered this latter question even though it—to their recollection—was somewhat more than 12 months since they last ran a red light

To find out if people act differently when they are alone in their car, as opposed to when driving with children or with other people in their car, they were asked:

Were you alone in the car when you ran it?
yes no, with …. children and …. adults

As Table 42 shows, about two thirds of the drivers were alone when they ran the red light. Very few admit to doing it with children in the vehicle.

Table 42 Alone or with passengers in the vehicle

Behavior/age	<25	25-34	35-49	50-65	>65	Sum
Alone	63	29	22	18	4	136
With child(ren) only	1	1	4	0	1	7
With adult(s) only	10	8	5	4	4	31
With adults *and* children	0	0	2	2	0	4
With adults/children	8	2	4	8	0	22
Not answered	6	0	1	0	0	7
Sum	88	40	38	32	9	207

5.8 Police Enforcement

The following question was asked:

Have you ever been stopped by police/ticketed for running a red light?
yes no

The responses are shown in Table 43. Around 10% of drivers have been stopped and fined for running a red light. One more person (around age 60) stated that he was once stopped and the officer maintained that he had run a red light, but he disputed it saying he did not and he eventually prevailed (not stated if that was in court or if the officer decided to let it go). It is interesting to see that roughly as many people have been stopped for running a red light as the number of people who have had a crash at a signalized intersection. Obviously, people run many red lights before they are stopped for doing so or, on average, have a crash.

Table 43 Stopped by police for running red light

Behavior/age	<25	25-34	35-49	50-65	>65	Sum
No	104	48	66	61	16	295
Yes	7	11	9	7	0	34
Not answered	1	1	2	0	1	5
Sum	112	60	77	68	17	334

Of the 34 people who indicated they had been stopped by a police officer or fined for running a red light, six had had a crash at a signalized intersection. That also means that only six of the 41 people having had a crash at a signalized intersection had been ticketed for running a red light. Eleven of the 41 involved in these crashes had been the offending party running a red light and one of the respondents clearly indicated that the ticket was issued for that incident. Several of the other people may also have been ticketed only for their one crash—and not in a regular red-light running police stakeout. Unfortunately the survey instrument used here does not show whether the ticketing was from the crash event or not. But even if all remaining five people were ticketed in unrelated events, the ratio of five crashes among 33 people (being ticketed for unrelated events), 15.2%, is certainly not significantly higher than the average crash rate of 41 crashes among 334 respondents (12.3%) or the crash rate among those not ticketed (35 crashes among 301 drivers = 11.6%) (p=0.21). And, if just one of the remaining five crashes was the reason for a ticket, then the percentage of "otherwise ticketed drivers involved in crashes" would be reduced to 4/32 = 12.5%.

5.9 Suggestions for Stopping Red-Light Running

5.9.1 Among Other People

This question aims at finding out what we can do to have *other* people run red lights less.

Suggest how we could make other people run red lights less frequently (mark one or several boxes)

More frequent police enforcement

Photo enforcement / Automatic video surveillance and ticketing

Shorter red times so that it doesn't take so long to get green again

Longer yellow times, so it becomes easier to stop before red

Television information about risk of running red lights

Other, describe:

The answer to the question can be found in Table 44.

Table 44 Effective measures to make other drivers run red lights less

Behavior/age	<25	25-34	35-49	50-65	>65	Sum
More frequent police enforcement	44	21	29	20	4	118
Photo enforcement/automatic video surveillance	55	28	30	28	5	146
Shorter red times	31	12	8	12	3	66
Longer yellow	39	17	29	31	4	120
TV info about risks	10	9	16	13	3	51
Write-ins:						
Eliminate signals	2	1	0	0	0	3
Vehicle-actuate timed signals	1	1	0	0	0	2
Better timing of signals	0	1	0	0	0	1
Higher penalties	1	0	1	0	0	2
Add another yellow light (two lenses)	0	1	0	0	0	1
Yellow light should blink first	0	0	0	1	0	1
Show countdown of seconds of yellow before red	0	0	1	0	0	1
Standardize yellow time	0	1	1	0	0	2
Sufficiently long green times so everybody gets thru	0	1	0	0	0	1
Longer all-red time between red and opposing green	1	0	0	0	0	1
Coordinate signals better	0	1	1	0	0	2
Warning lights at set distance ahead of signal	0	1	0	0	0	1
Improve educational effort in addition to TV info	1	0	0	1	0	2
Better education on what 'yellow' means	0	0	1	0	0	1
More instructions: right-turn-on-red allowed or not	0	0	0	1	0	1
Don't like any option. Not big on more police…	0	0	0	1	0	1
Don't like any. People can regulate themselves	0	0	1	0	0	1
Difficult; human nature a) challenge, b) right to run	0	0	1	0	0	1
Public hangings	0	0	0	1	0	1
Kids should be 18 to get license	0	0	0	1	0	1
Sum	185	95	119	110	19	528

5.9.2 Among Themselves

This question asks what we can do to have the interviewee himself/herself run red lights less frequently.

Suggest how we could make YOU personally run red lights less frequently:

(Open question—there were no given alternatives)

The responses are shown in Table 45.

Table 45 Effective measures to make the interview subject run red lights less

Behavior/age	<25	25-34	35-49	50-65	>65	Sum
Longer yellow phase / 2-3 sec. longer yellow	8	3	7	7	0	25
Longer yellow phase especially when snow/ice	0	0	1	0	0	1
Shorter yellow phase	1	0	0	0	0	1
Assure 'clearance' phase is correct for travel speeds	0	0	0	1	0	1
Standardize yellow time	0	1	1	0	0	2
Longer green phase (for each movement during peak, so less rush)	1	1	2	0	0	4
Shorter red-light time	6	2	1	3	0	12
Time the lights better	1	0	0	0	0	1
Coordinate (synchronize) lights for green wave	2	0	1	0	0	3
Not to change too quickly (= longer cycle time)	0	0	2	0	0	2
Shorter cycle time (so shorter red)	1	0	1	0	0	2
Vehicle actuated (rather than timed) to minimize red when no cars	5	2	1	1	0	9
Make detectors more sensitive so they don't miss cars	1	1	0	0	0	2
Not change to yellow when vehicle in 'dilemma' zone (early or late ok)	1	0	0	0	0	1
Make all lights I come to green	0	1	0	0	0	1
Have the yellow flash just before turning red (better predictability)	0	2	0	1	0	3
Have yellow light flash (throughout phase) /flashing strobe yellow	1	1	0	1	0	3
Add another yellow light (two lenses)	0	1	0	0	0	1
Make sure the signal is clearly for that lane (not parallel lane)	0	1	0	0	0	1
Show countdown of seconds (of yellow?) before red	0	1	1	0	0	2
More warning to let you know when 'yellow to red'	0	0	1	0	1	2
Bigger signal lights/Make lights more noticed	1	0	0	1	1	3
Bigger red light than green/yellow lenses / red stand out more than g/y	0	1	1	0	0	2
Have red light blink	1	0	0	0	0	1
Lower the light for better visibility when backlit by sun	1	0	0	0	0	1
Alarm in car that goes off when you run a red light	0	0	0	1	0	1
Simpler intersections (phasing or layout?) allow secondary conflicts	1	1	0	0	0	2
Paint perpendicular lines to give an illusion of acceleration	1	0	0	0	0	1
Install signals only where fully warranted	0	0	0	1	0	1
Eliminate [some/many/most] signalized intersections	6	2	0	1	0	9
Have signals go on blink at night/off season	2	1	0	0	0	3
Photo enforcement/automatic ticketing/camera boxes	17	4	6	4	0	31
More enforcement (police) or more tickets issued	12	1	2	1	0	16
Higher penalties (make me pay more) (larger fines)	4	1	1	1	0	7
Make people more aware of consequences	1	0	0	1	0	2
Capital punishment / Electroshock if you run red light (not serious?)	2	0	0	0	0	2
Award points 'back' to people who have no red-light violations	1	0	0	0	0	1
Less police / Make Veazie cops less strict	1	1	1	0	0	3
I don't need help	0	0	0	1	0	1
Better brakes	1	0	0	0	0	1
Lower speed limits/lower speeds	0	1	1	0	0	2
Sign showing my speed	0	0	0	0	1	1
Make me stop instead of speed up when yellow	1	0	0	0	0	1
Not much will help when I'm late I tend to push it	1	0	0	0	0	1
I need to pay more attention when I drive	2	2	1	0	0	5
Make me aware of the fact I am running a red light	0	1	0	0	0	1
Have passengers help me watch where I am going	1	0	0	0	0	1
Signs warning of upcoming lights	0	0	0	1	0	1
Active signs warning of upcoming lights, flashing if stop req.	0	0	0	1	0	1
Fewer distractions in vehicle	0	0	1	0	0	1
No idea since it is by mistake	2	0	0	0	0	2
TV information about risks	0	1	0	0	0	1
Have me be more patient / accept being late	1	0	1	0	0	2
Revoke my driver's license / take my keys	0	2	0	0	0	2
Reduce stress and pressure on working people / on students	1	0	1	0	0	2
Wake me up early enough to get to work on time	1	0	0	0	0	1
≈ I try to not run red lights, seldom do—so not a big problem	1	1	1	0	0	3
Pay drivers for not running red lights	0	0	0	1	0	1
Sum	91	37	36	29	3	196

Most people, according to Table 45, suggest that enforcement—either through photo enforcement or more police on the streets—would be the most effective way of having them run fewer lights. Enforcement is followed by longer yellow times and shorter red times. Vehicle actuation is also a fairly common suggestion. One person, whose answer cannot easily be summarized in the table, wants longer green phases "for each movement so that people in the morning peak won't rush the lights to get through" but also wants shorter red times so that people do not need to wait so long if they miss the green (The solution that meets these criteria may be adding more lanes to each approach). Another suggestion, "Have the yellow flash just before turning red," was followed by "that would encourage stopping." Obviously yellow is not seen as 'stop if you can.' The suggestion, "Assure 'clearance' phase is correct for travel speeds" was suggested by a traffic engineer. Two of the respondents of this survey were DOT employees, all other people were 'random' lay-people. A 69-year-old man stated as a response to this question, "I do not run red lights. But I am very concerned about the people who do. The numbers of red-light runners is increasing."

5.10 Description of Crashes

Below are the questions and summary responses of the people involved in a crash at a signalized intersection. The individual responses from each of the 41 people who replied that they had been involved is presented in an appendix starting on page 80.

Were you driving? yes, a car yes, a …..
no, I was a passenger no, I was ….

As stated in Section 5.4, seven of the 41 people were passengers in vehicles, whereas the remainder of people had been driving a car or pickup truck.

What year did it happen? ……

See the appendix for answers.

Where did it happen? (Give town and State and exact street names if you remember)

See the appendix for answers.

Did you (the vehicle you were in) or the other party run a red light? (Check the alternative that fits best)

No, no one did

No, the other party did

It is uncertain who ran the red light. I believe I did not

Yes, it changed to red just before I entered the intersection and I thought it might change

Yes, it changed to red just before I entered the intersection but I thought it would not

Yes, the light must have changed to red but I was unaware of it

Yes, but I never saw the signal since it was blocked by a (truck or)………………………

Yes, but I was completely unaware that there was a signalized intersection there

Yes, other (describe):

The response to this question is shown in Table 46. In 25 cases, either no one or the other party ran the red light and we cannot expect detailed information from the interviewee about the mechanism that led up to the traffic control device being violated. In the remaining 16 cases the interviewee (or the driver of that vehicle) ran the light. In three of these cases (19%), the driver misjudged the timing and thought it would not change to red so quickly. In two cases (13%) the driver was unaware that the signal had changed to red. In one case (6%), the driver was completely unaware that there was a signalized intersection and in another case, the driver did not see what the signal displayed since it was blocked by a truck.

Table 46 Party running red light

Ran red light	reason	number
no one	left turning/through vehicle	1
other party	(various reasons)	10
uncertain	I believe I did not	0
interviewee	thought it might change	0
interviewee	thought it would not change	3
interviewee	was unaware it changed	2
interviewee	never saw signal since it was blocked by truck	1
interviewee	completely unaware there was a signalized intersection	1
interviewee	could not stop because of ice (not rear-end)	1
interviewee	made a right-turn-on-red	3
other party	ran red flashing light while interviewee had yellow flashing	2
(other party)	rear-ended by someone	12
(interviewee)	rear-ended someone because of inattentiveness	2
(interviewee)	rear-ended someone who stopped for flashing yellow	1
(interviewee)	rear-ended someone because of ice/snow	2
sum		41

Were you (the driver) distracted just prior to the collision by something? No Yes, by:

A majority of drivers (34) said they were not distracted. Three people did not give an answer, whereas four subjects stated they had been distracted. A young man admitted to having been looking at an attractive woman pumping gas, when the person in front stopped on flashing yellow to let a car out that had flashing red. Another person states, “We never saw the signal since a truck blocked it and we were distracted prior to the collision by the large truck. The driver (of our vehicle) was shouting out profanities at the truck and weaving back and forth behind it.” Another person claims to have been distracted by the car behind, visible in the rear-view mirror. Finally, one person was distracted by a passenger.

Did someone get injured? No Yes, but only minor injuries Yes, describe:

Four people did not answer this question, whereas 25 stated that no one was injured. Seven reported minor injuries, while two reported more serious whiplash injuries. One person got a fractured arm, another one a broken arm and shoulder, and finally one person reported broken ribs.

Have you become more careful/changed your driving behavior as a result of this crash? No Yes, describe how:

Fifteen people answered ‘yes’ to this question while seven gave no answer and nineteen said that they had not become any more careful.[20] Out of the fifteen saying yes, ten described how they have changed their behavior to be more careful. One admits to being more careful especially on ice/snow. Another person said, “Sometimes the other person should look even when it is green. Trucks can’t stop on a dime.” Someone else answered, “Yes, I watch out for other vehicles at intersections.” Other answers were, “Yes, I look each direction at stop lights,” “Yes, paying more attention,” “Yes, I now check both ways before

[20] It may surprise the reader that so many people claim not to have changed behavior as a result of their crash. But the literature (for example, “What Surviving Drivers Learn from a Fatal Road Accident” Sirpa Rajalin & Heikki Summala, *Accident Analysis and Prevention* Volume 29, Number 3, May 1997, p. 277-283) supports this. The referenced study shows that even being involved (and surviving) a fatal crash will for most people only affect behavior for a short time period. People rarely change basic behavior and the their future accident frequency and number of recorded violations were not affected by the involvement. The conclusion of this may be that crash rates which have been shown to drop with experience are less influenced by a few serious incidents than from many “near misses.”

going through a signalized intersection," "Yes, I now check multiple times at intersections and I don't trust blinkers," "Yes, I pay more attention," "Yes, more careful at lights, I now take more time to look," and "Yes, I try not to gaze out the side window."

Describe briefly what happened, preferably with a sketch (what caused the crash?)

The individual crashes are described in the appendix starting on page 80.

6 Conclusions and Discussion

6.1 General

The overall frequency of red-light running is, in the literature, reported to vary with location from a low of around 0.05% to a high of 3.9% or higher. Observations from Maine, which can be seen in Column 2 of Table 47, are all within this range.

Table 47 Red-light running frequencies

Location	over-all	of those arriving during red	of those arriv-ing as first vehicle	of those arriving during first 2 sec-onds of red*
Hogan Road, Bangor	0.4%	0.9%	3%	14%
Hogan at Springer	0.9%	1.2%	5%	39%
Springer Dr, Bangor	1.3%	1.6%	6%	60%
Broadway, Bangor	0.7%	1.8%	7%	22%
Center Street, Bangor	0.1%	0.2%	0.3%	3%
Union Street, Bangor	0.2%	0.4%	1%	6%
State Street, Veazie	0.2%	1.1%	1%	5%
Stillwater Ave., Orono	0.5%	1.9%	6%	19%
Western Ave, Augusta	0.9%	2.0%	18%	43%
Western Ave./Whitten	0.2%	0.3%	4%	8%
Route 202, Manchester	2.2%	5.1%	18%	97%*
Congress St., Portland	0.2%	0.4%	2%	10%
Franklin Art., Portland	0.3%	0.5%	2%	10%
Main St., Waterville	0.2%	0.7%	2%	10%
Route 126, Lewiston	0.3%	0.5%	3%	8%
Arithmetic average	0.6%	1.2%	5.2%	23.6%

* Note: The percentage "red light-running frequency of those arriving during the first 2 seconds of red" is here calculated as the total number of vehicles running the red light divided by the number arriving during the first two seconds of red. In other words, the 97% observation does not mean that only 3% of drivers facing this situation stop since there are people running the light arriving more than two second into the red.

The overall red-light running frequency in these day-time observations vary from 0.1% to 2.2%. The highest observation (Route 202 through Manchester) was found on a 4-lane, high-speed road in a rural setting whereas the lower percentages typically were found in lower-speed urban environments. However, there are exceptions to this. Western Avenue at Whitten Road, just west of I-95 in Augusta, has fairly high speeds and is in a semi-urban rather than an urban environment, and still the red-light running frequency was low—at least at the time of these observations. And the observations on Broadway in Bangor were done in an urban environment where the speeds are fairly low—still, the red-light running frequency was above the average. The reason that Springer Drive in Bangor has a high red-light running frequency may be that it is a four-phase signal with short green times and long red times and that the intersection is close to capacity which means that many drivers may have waited a long time for green and consider it their right not to have to wait for another cycle before they can enter. Few if any of the other locations ever had a phase failing to accommodate all vehicles stopped before the light turned red.

It is obvious that drivers arriving (at the stop line) when the signal shows green will not run the red light. Also, it is natural that an approach that has green for most of the cycle time should have a lower red-light running frequency than one where most drivers face red. The three right-most columns in Table 47 illustrate red-light running frequencies 'corrected' for such variations. Accounting for red-time portion, the intersection in Manchester still has the highest percentage of red-light running. Statistically, almost everyone arriving just after the light turned red, ran it at this location. In reality, not everyone did, because there were several people who ran the light more than two seconds into the red phase. And also, the actual number of people arriving just when the light changed to red may have been higher than randomly expected, which was assumed here.

6.2 Ways to Reduce Red-Light Running

If we want to reduce the number and severity of crashes involving drivers running red lights, we need to do one or several of the following:

- reduce drivers' need to stop
- increase the likelihood drivers will stop
- reduce the likelihood of a (serious) crash if a driver runs a red light.

These strategies are sometimes conflicting. Different avenues for reaching these 'goals' will be summarized below. It should be kept in mind that before we enforce an illegal behavior, we should make sure that it is technically possible to behave in a legal way. In other words, signals must always be timed so that it is possible to stop during the yellow phase.

6.3 Reduce Drivers Need to Stop

One way to achieve the goal of reducing drivers need to stop is to reduce the number of signalized intersections. To convert them to 2-way stop control or to put them on yellow/red blink means that the drivers on the major road no longer need to stop. However, drivers on the minor approaches still will need to stop. Converting the intersections to roundabouts means that much fewer drivers will need to come to full stops. It is therefore important to do a thorough analysis of where signals make sense from a safety perspective—and where alternatives should be found even if a signal is warranted. Roundabouts are definitely underutilized in the state of Maine. As seen in Table 45, ten people spontaneously suggested that we should have fewer signalized intersections and another three people suggested that signals go to flashing operation at night.

Also in the survey, three people suggested that signals be better coordinated. And coordination of signals can significantly reduce the number of drivers facing a red light if the coordination is well done. But 'bad' coordination has been observed throughout the state and reported in the media. There are examples where traffic starting up at one signal will reach the next signal just when that light habitually turns red. People driving there regularly may be encouraged to run the (second) red light or speed up to illegal speeds to get there just before the yellow turns red.

As indicated in the literature review, vehicle actuation is an alternative way to reduce the percentage of people facing a red light—and unless volumes are very high, vehicle actuation is often more effective at doing this than coordination of signals. In the survey, eleven people advocated more or better actuation, whereas only three people argued for green-wave coordination.

6.4 Increase the Likelihood Drivers Will Stop

There are different ways to accomplish this dependent on if the driver is running the light on purpose or by mistake.

6.4.1 Enforcement

As can be seen in Table 44, people believe that photo enforcement/automatic video enforcement would be more effective than any other measure in reducing red-light running. The 'second' most effective measure in getting other people to run fewer lights is a tie between 'longer yellow times' and 'more frequent police enforcement.' If we add photo enforcement and more police, those are indicated 264 times among the 334 people who responded. Obviously, the public being interviewed are just speculating about what would be effective. They are neither experts in the area nor do they know how other people will react. The only person the interviewee truly knows is himself/herself. The response in Table 45 indicates what people think would be effective in making themselves run fewer lights. It is, maybe not too surprising, the same three measures that are ranked in top, with photo enforcement/automatic ticketing/camera boxes/video surveillance that comes in as the most suggested one, followed by longer yellow times and then more enforcement by police.

The conclusion is clear, based on the survey, people in Maine believe photo enforcement would be the most effective way of cutting back on red-light running. And, there seems to be a certain level of acceptance for such a measure since so many people indicated that they believe it would be effective. Obviously, photo enforcement as well as other types of enforcement would be effective in reducing violations that people are aware of when they make them. Lights that are run completely by mistake would still be run even if the enforcement and tickets following that may lead to drivers looking more carefully for red lights in the future.

6.4.2 Timing

Shorter wait times ought to lead to fewer people running red lights on purpose, and shorter cycles would give shorter wait times—unless the signal reaches capacity. However, longer cycles reduce the number of times a driver will face a yellow light (and also a red light) as first vehicle meaning that the longer the cycle time, the fewer the drivers that will run the light by mistake. Few people in the survey had any opinion on how the cycle time ought to be changed. But many people suggested shorter red times and others suggested longer green times. Obviously, it will be hard to accommodate those wishes for traffic on all approaches.

When it comes to making themselves run fewer lights, 26 people spontaneously suggested longer yellow times, as can be seen in Table 45. On the other hand, as can be seen in Table 44, 120 people gave this as their option when it was given as a fixed alternative to have other people run fewer lights. (It is probably not the fact that the question refers to different 'groups' that make the total number of responses vary so much, but the fact that people tend to indicate given alternatives more than they spontaneously would suggest it.) Longer yellow times could lead to lower capacity and longer wait times and might therefore, at busy intersections, increase irritation and thereby red-light running. However, at less busy intersections, lengthening the yellow by 2 seconds would delay people on the cross street by only those two seconds and that might be an acceptable price to pay if red-light running is decreased significantly. Representative Dick Armey's report (see page 27) recommends longer yellow times as the solution to red-light running. And, he claims to have 'proof' that it works ("Stopping on Red" by James Joseph, *Traffic Technology International*, August/September 2001, pp. 40-47). However, his proof is limited to one intersection in Virginia where lengthening the yellow time from 4.0 to 5.5 seconds almost eliminated the problem. It is this author's contention, that if most intersections had that long yellow times, people would start using more of the yellow phase as an extension of the green phase.

6.4.3 Signal Visibility and Conspicuity

Based on Table 46, the driver was unaware that there was a red light (or even a signal) in four of the 16 crashes where the interviewee ran the red light. If it is true that 25% of all red-light running crashes have that characteristic, then improving signal visibility and conspicuity obviously could significantly improve the safety of signalized intersections.

To improve the observance of signals in general, people suggest:

• make lights more noticed/better, 3 people

• bigger signal heads, 3 people

• sign warning of upcoming light, 2 people

• lower the light for better visibility when backlit by sun, 1 person

Suggestions to make drivers note that the signal is changing from yellow to red include:

• have the yellow light flash/strobe, 3 people

• add another yellow light, 1 person

To increase the predictability of when the red will come on, suggestions include:

• show countdown in seconds before red, 2

• more warning of when yellow to red, 2

• have the yellow flash before turning red, 1

To have people notice that the light has turned red, suggestions include:

• bigger red lens than green and yellow, 2

• have red light flash[21], 1 person

• alarm in car when you run a red light, 1

The size of signal heads are important especially for elderly drivers. The question to be answered is where do we need larger heads? These studies do not necessarily suggest that the recommendations in existing guidelines are not adequate.

Traditionally, incandescent lights have been used for signals. Today, light-emitting diodes are sometimes used, and Maine has a program to help communities switch to LED. LED use 90% less energy than incandescent bulbs producing the same 'light.' However, if we want to improve their conspicuity we should use some of that energy saving to increase the emitted light intensity, especially during daytime conditions.

[21] Today, flashing red light means stop and then proceed. That meaning would obviously not be possible to keep parallel to a flashing red light meaning stop and wait for green

6.4.4 Public Information Campaigns

According to Table 44, about 15% of the people surveyed indicate that television information about the risks of running red lights may be effective in reducing the amount of red-light running. It is this author's opinion that information about the risks of a crash would not influence people's behavior dramatically since, to paraphrase Leonard Evans of General Motors (one of the premier human factors experts in the world), few crashes are caused by drivers not knowing what to do, but that many are caused by drivers doing what they know they shouldn't be doing. His conclusion is that training is often not effective, but that changing people's attitudes is important.[22] Also, it is the belief of the author of this report that people see the risk of a crash as so small that changing their behavior makes little sense. Especially since they believe what they are doing is "under their full control." However, if we increased the chances of them being ticketed to be clearly higher than that of a crash—which it today isn't based on the survey, which showed that people had been involved in 41 crashes at signalized intersections and been stopped for running a red light in 34 cases, then information about the 'high' risks of being fined for running a red light could be effective in reducing the propensity to do so. Still, if this information was false, that the risk of a fine remained low, then the campaign would probably not have a significant long-term effect.

6.5 Reduce the Likelihood of a (Serious) Crash When a Light is Run

Speed more than anything else determines the extent of injuries in a crash. Also, crashes are less likely to occur if all parties drive slowly. If someone runs a red light by mistake at a low speed, he/she may be able to avoid a

[22] Leonard Evans; *Traffic Safety and the Driver*, New York, NY: Van Nostrand Reinhold; 1991

crash when seeing another vehicle simultaneously entering from a cross street.

The speed limit of all fatal and serious injury crashes analyzed here involving drivers disobeying a traffic control device is shown in Table 48. These numbers by themselves do not say much without relating them to exposure. Rather than try to collect exposure, rear-end and left-turn crashes at signalized locations can be used as a proxy for exposure. These numbers are also shown in the same table. It can be seen that 14.7% of the serious injury crashes (with known speed limits) occur on sections with a speed limit of 40 mph or higher, whereas these speeds account for only 3.3% of the rear-end crashes and 5.3% of the left-turn crashes. If we look at speed limits of 50 mph and above, the serious crashes make up about five times the percentage of the other types (1.5% versus 0.4% and 0.2% respectively). If we on the other hand look at the speed limit of (exactly) 35 mph, the serious crashes were not overrepresented. They made up 29.4% of the serious crashes, whereas the 35-mph crashes made up 25.7% of the rear-end ones and 34.0% of the left-turn ones. For speeds below 35 mph, the serious crashes are somewhat underrepresented. A conclusion one can draw from this is that the posted speed should never exceed 35 mph at signalized approaches.

Of the six fatal crashes at signalized intersections, two occurred where the speed limit was 25 mph, two on 35-mph streets, one in a 45-mph zone and one in a 50 mph zone. Three out of the four fatalities claimed on sections with a speed limit of 35 mph or less were unprotected road users (a pedestrian, a bicyclist and a motorcyclist). In other words, there was only one fatality among "protected road-users" on streets with speed limits of 35 mph or less, even though about 95% of the reported crashes at signalized intersections occur within such speed limits. It is obvious that we ought to not only restrict the posted speed to 35 mph at signalized intersections, we should also make sure that signalized intersections are safe for pedestrians, bicyclists and motorcyclists. This is hard to do, especially for pedestrians and bicyclists since they obey signals much less than drivers of motor vehicles do. Maybe public education campaigns could improve the compliance, but it will be hard to ever get good compliance among pedestrians in particular. Again, lower speed is then the key to improved safety—as shown in the report "Pedestrian Safety in Maine," Final Report ME00-2, Maine Department of Transportation, May 2002. Lower speed was also suggested by some people in the survey conducted within this project.

Table 48 Speed limit and crash types

Speed limit	Number of serious red-light-running crashes	Number of rear-end crashes	Number of left-turn crashes
15 mph	0	1	6
20 mph	0	0	1
25 mph	30	260	1141
30 mph	8	131	485
35 mph	20	142	913
40 mph	3	6	51
45 mph	6	10	87
50 mph	1	0	2
55 mph	0	2	2
unknown	3	77	93
sum	71	629	2781

Besides speed, the angle of collision is also important in explaining injury outcomes to occupants of motor vehicles. Side impacts at a given speed are more serious than rear-end or head on collisions, though head-on collisions should always be avoided since the relative speed of the involved parties typically is very high. Separate, protected left-turn phasing is an important tool in reducing the number of side impacts as well as head-on collisions.

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Appendix 1. Description of Crashes

Crash 1 --38-year-old gender unknown (but handwriting indicates male), around age 32 at time of crash

Were you driving? yes, a car

What year did it happen? 1997

Where did it happen? In Bangor

Did you (the vehicle you were in/someone else) run a red light, and if so which alternative fits best: Yes, it changed to red just before I entered the intersection but I thought it would not and I had been drinking

Were you (the driver) distracted prior to the collision by something? No

Did someone get injured? Yes, but only minor injuries

Describe briefly what happened, preferably with a sketch: n/a

Have you become more careful/changed your driving behavior as a result of this crash? No

Crash 2 -- 28-year-old female

Were you driving? yes, a car

What year did it happen? n/a

Where did it happen? Brewer, Maine

Did you (the vehicle you were in/someone else) run a red light, and if so which alternative fits best: No, the other party did

Were you (the driver) distracted prior to the collision by something? n/a

Did someone get injured? No

Describe briefly what happened, preferably with a sketch: n/a

Have you become more careful/changed your driving behavior as a result of this crash? Yes, describe how: n/a

Crash 3 – 58-year-old female

Were you driving? No, passenger of a car

What year did it happen? n/a

Where did it happen? Vermont

Did you (the vehicle you were in/someone else) run a red light, and if so which alternative fits best: No, the other driver did (or would have if we hadn't blocked his path)

Were you (the driver) distracted prior to the collision by something? No

Did someone get injured? No

Describe briefly what happened, preferably with a sketch: We stopped for a light and the car behind us did not.

Have you become more careful/changed your driving behavior as a result of this crash? No

Crash 4 – about 30-year-old male

Were you driving? No, passenger of a car

What year did it happen? n/a

Where did it happen? n/a

Did you (the vehicle you were in/someone else) run a red light, and if so which alternative fits best: I slid into the intersection because the road was not properly plowed and sanded

Were you (the driver) distracted prior to the collision by something? No

Did someone get injured? Yes, I got whiplash (spelled wipelash)

Describe briefly what happened, preferably with a sketch: (unclear whether it was rear-end or perpendicular and who ran the red light))

Have you become more careful/changed your driving behavior as a result of this crash? N/a

Crash 5 – 24-year-old male (about 23 when crash happened)

Were you driving? Yes, a car

What year did it happen? 2001

Where did it happen? Bangor

Did you (the vehicle you were in/someone else) run a red light, and if so which alternative fits best: No, the other driver did

Were you (the driver) distracted prior to the collision by something? No

Did someone get injured? Yes, broken arm/shoulder

Describe briefly what happened, preferably with a sketch: A van coming from a perpendicular street ran right through the red light

Have you become more careful/changed your driving behavior as a result of this crash? No

Crash 6 – 25-year-old female (passenger in vehicle)

Were you driving? No, passenger

What year did it happen? 1989

Where did it happen? Bangor (downtown)

Did you (the vehicle you were in/someone else) run a red light, and if so which alternative fits best: We never saw the signal since a truck blocked it

Were you (the driver) distracted prior to the collision by something? Yes, by the large truck. And the driver (of our vehicle)was shouting out profanities at the truck and weaving back and forth behind it

Did someone get injured? Yes, the driver of the other car was "crushed" into the steering column and broke some ribs

Describe briefly what happened, preferably with a sketch: We were traveling at fast speeds until we got stuck behind the truck. We were right up his ass, therefore we did not see the light change red

Have you become more careful/changed your driving behavior as a result of this crash? No, we still tend to drive too close to other drivers

Crash 7 – 26-year-old male (about 24 when crash happened)

Were you driving? Yes, a car

What year did it happen? 2000

Where did it happen? South Portland, ME; on Western Avenue

Did you (the vehicle you were in/someone else) run a red light, and if so which alternative fits best: No, no one did [but I may have if the other car had not been there]

Were you (the driver) distracted prior to the collision by something? No

Did someone get injured? No

Describe briefly what happened, preferably with a sketch: I was going too fast and ran into the back of another car at red light on icy road when I tried to stop

Have you become more careful/changed your driving behavior as a result of this crash? Yes, more careful in ice and snow

Crash 8 – 23-year-old male (unknown when crash happened)

Were you driving? No, passenger of a car

What year did it happen? n/a

Where did it happen? Brunswick/Topsham

Did you (the vehicle you were in/someone else) run a red light, and if so which alternative fits best: No, the other driver did

Were you (the driver) distracted prior to the collision by something? n/a

Did someone get injured? n/a

Describe briefly what happened, preferably with a sketch: n/a

Have you become more careful/changed your driving behavior as a result of this crash? n/a

Crash 9 – 30-year-old male (unknown when crash happened)

Were you driving? Yes, a car

What year did it happen? n/a

Where did it happen? Bangor (?)

Did you (the vehicle you were in/someone else) run a red light, and if so which alternative fits best: Yes, it changed to red just before I entered the intersection but I thought it would not

Were you (the driver) distracted prior to the collision by something? Yes, by a passenger

Did someone get injured? No

Describe briefly what happened, preferably with a sketch: n/a

Have you become more careful/changed your driving behavior as a result of this crash? Yes

Crash 10 – 24-year-old male (22 when crash happened)

Were you driving? Yes, a car

What year did it happen? 2000

Where did it happen? Colorado Springs, Co.

Did you (the vehicle you were in/someone else) run a red light, and if so which alternative fits best: No, no one did

Were you (the driver) distracted prior to the collision by something? No

Did someone get injured? No

Describe briefly what happened, preferably with a sketch: I was driving way too fast and could not stop fast enough so I crashed into rear of stopped car

Have you become more careful/changed your driving behavior as a result of this crash? No

Crash 11 – 35-year-old male (young when crash happened)

Were you driving? Yes, a truck

What year did it happen? 1980s

Where did it happen? Skowhegan, ME

Did you (the vehicle you were in/someone else) run a red light, and if so which alternative fits best: Yes, it changed to red just before I entered the intersection but I thought it would not

Were you (the driver) distracted prior to the collision by something? No

Did someone get injured? No

Describe briefly what happened, preferably with a sketch: n/a

Have you become more careful/changed your driving behavior as a result of this crash? Yes, some. Comment: "Sometimes the other person should look even when it is green. Trucks can't stop on a dime."

Crash 12 -- 34-year-old female from Hallowell, about 24 at time of crash

Were you driving? yes, a car

What year did it happen? 1992

Where did it happen? Downtown intersection, Gardiner, Maine

Did you (the vehicle you were in/someone else) run a red light, and if so which alternative fits best: No, no one did

Were you (the driver) distracted prior to the collision by something? No

Did someone get injured? No

Describe briefly what happened, preferably with a sketch: Other car hit me while I was stopped at the red light.

Have you become more careful/changed your driving behavior as a result of this crash? Yes, describe how: I watch out for other vehicles at intersections

Crash 13 -- 21-year-old male, about 20 at time of crash

Were you driving? yes, a car

What year did it happen? 2001

Where did it happen? Western Avenue, South Portland, Maine

Did you (the vehicle you were in/someone else) run a red light, and if so which alternative fits best: No, no one did

Were you (the driver) distracted prior to the collision by something? No

Did someone get injured? No

Describe briefly what happened, preferably with a sketch: I had a rear-end collision with a stopped car on an icy road

Have you become more careful/changed your driving behavior as a result of this crash? n/a

Crash 14 -- 20-year-old female, about 17 at time of crash

Were you driving? yes, a car

What year did it happen? 1999

Where did it happen? Intersection of Union Street and Vermont Avenue in Bangor, Maine

Did you (the vehicle you were in/someone else) run a red light, and if so which alternative fits best: No, the other party did

Were you (the driver) distracted prior to the collision by something? No

Did someone get injured? No

Describe briefly what happened, preferably with a sketch: I was turning left from Vermont Avenue onto Union Street. I had a green light. The other vehicle was going at a high speed and ran the red light, coming from my right. As I was about halfway through the intersection, the other car crashed into the front passenger-side (right-side) [door] of my car

Have you become more careful/changed your driving behavior as a result of this crash? n/a

Crash 15 -- 22-year-old male, about 16 at time of crash

Were you driving? yes, a car

What year did it happen? 1997

Where did it happen? Waterville, Maine

Did you (the vehicle you were in/someone else) run a red light, and if so which alternative fits best: Yes, the light must have changed to red but I was unaware of it

Were you (the driver) distracted prior to the collision by something? No

Did someone get injured? No

Describe briefly what happened, preferably with a sketch: I thought the left-turn light was green but it was red. Oncoming straight-through car hit us

Have you become more careful/changed your driving behavior as a result of this crash? n/a

Crash 16 -- 56-year-old male, unknown at time of crash

Were you driving? yes, a car

What year did it happen? n/a

Where did it happen? n/a

Did you (the vehicle you were in/someone else) run a red light, and if so which alternative fits best: No, the other party did

Were you (the driver) distracted prior to the collision by something? n/a

Did someone get injured? n/a

Describe briefly what happened, preferably with a sketch: I entered the intersection on green light and other driver ran the red light striking my vehicle in left-rear panel. Other vehicles on the multi-laned approach, which was violated, were stopped for the red light before I entered the intersection

Have you become more careful/changed your driving behavior as a result of this crash? n/a

Crash 17 -- 31-year-old female, in the mid to late 20's at time of crash

Were you driving? yes, a car

What year did it happen? Late 1990's

Where did it happen? In Clinton, Maine, Bangor Road and Baxter Street, I think

Did you (the vehicle you were in/someone else) run a red light, and if so which alternative fits best: No, no one did (or the other one may have)

Were you (the driver) distracted prior to the collision by something? no

Did someone get injured? no

Describe briefly what happened, preferably with a sketch: I was rear ended

Have you become more careful/changed your driving behavior as a result of this crash? no

Crash 18 -- 27-year-old male, around 26 at time of crash

Were you driving? yes, a car

What year did it happen? 2001

Where did it happen? In Oakland, Maine

Did you (the vehicle you were in/someone else) run a red light, and if so which alternative fits best: No, the other party did

Were you (the driver) distracted prior to the collision by something? no

Did someone get injured? Yes, but only minor injuries

Describe briefly what happened, preferably with a sketch: There was barely a collision, but my airbag inflated

Have you become more careful/changed your driving behavior as a result of this crash? no

Crash 19 -- 47-year-old female, about 47 at time of crash

Were you driving? yes, a van

What year did it happen? 2002

Where did it happen? Rt 90 and Rt 17 in Rockland, Maine

Did you (the vehicle you were in/someone else) run a red light, and if so which alternative fits best: Yes, I did. I did not see it and did not even know that the stop light was there; it was new

Were you (the driver) distracted prior to the collision by something? Yes, by car behind, in rear-view mirror

Did someone get injured? Yes, but only minor cuts

Describe briefly what happened, preferably with a sketch: Perpendicular courses. I got clipped towards the rear

Have you become more careful/changed your driving behavior as a result of this crash? no

Crash 20 -- 35-year-old female, unknown at time of crash

Were you driving? yes, a car

What year did it happen? I don't remember

Where did it happen? In Orono, Maine

Did you (the vehicle you were in/someone else) run a red light, and if so which alternative fits best: Yes, the light must have changed to red but I was unaware of it

Were you (the driver) distracted prior to the collision by something? no

Did someone get injured? Yes, I fractured my left arm

Describe briefly what happened, preferably with a sketch: I was sideswiped. The other car came from the right. [The sketch indicate that the two vehicles entered on perpendicular courses and that the other car struck the passenger side of the one driven by the subject

Have you become more careful/changed your driving behavior as a result of this crash? Yes. I look each direction at stop lights

Crash 21 -- 65-year-old male from Winterport, 40's at time of crash

Were you driving? yes, a car

What year did it happen? 1980's

Where did it happen? In Rumford, Route 2, Maine

Did you (the vehicle you were in/someone else) run a red light, and if so which alternative fits best: no, no one did (or the other guy would have)

Were you (the driver) distracted prior to the collision by something? no

Did someone get injured? no

Describe briefly what happened, preferably with a sketch: I stopped for red and was rear-ended

Have you become more careful/changed your driving behavior as a result of this crash? no

Crash 22 -- 21-year-old female currently living in Orono, about 18 at time of crash

Were you driving? No, passenger

What year did it happen? 1999

Where did it happen? In Ventura, CA, intersection of Petit and Telephone

Did you (the vehicle you were in/someone else) run a red light, and if so which alternative fits best: no, no one did

Were you (the driver) distracted prior to the collision by something? no

Did someone get injured? no

Describe briefly what happened, preferably with a sketch: My mom stopped to turn right waiting for a pedestrian and then started up but stopped again to let a vehicle come out of a driveway from a parking lot. The vehicle, a van, behind us saw us start moving but didn't stop when we did. The driver of the van smashed into the back of our car.

Have you become more careful/changed your driving behavior as a result of this crash? no

Crash 23 -- 54-year-old male currently living in Old Town, 30 at time of crash

Were you driving? Yes, a car

What year did it happen? 1978

Where did it happen? Exit ramp from I-95 in Maine

Did you (the vehicle you were in/someone else) run a red light, and if so which alternative fits best: no, no one did, but the other person might have

Were you (the driver) distracted prior to the collision by something? no

Did someone get injured? yes, but only minor injuries

Describe briefly what happened, preferably with a sketch: Young operator ran into rear of my vehicle while I was stopped at red light

Have you become more careful/changed your driving behavior as a result of this crash? no

Crash 24 -- 31-year-old female currently living in Orono, 29 at time of crash

Were you driving? Yes, a car

What year did it happen? 2000

Where did it happen? Lee, New Hampshire, Route 12S

Did you (the vehicle you were in/someone else) run a red light, and if so which alternative fits best: no, no one did, but I might have

Were you (the driver) distracted prior to the collision by something? no

Did someone get injured? no

Describe briefly what happened, preferably with a sketch: cars were stopped at red light and I did not slow down fast enough and I bumped into the last car that was stopped in front of me

Have you become more careful/changed your driving behavior as a result of this crash? yes, paying more attention

Crash 25 -- 34-year-old female currently living in Orono, 30 at time of crash

Were you driving? Yes, a car

What year did it happen? 1998

Where did it happen? Corner of State Street and Union, Boston, Mass

Did you (the vehicle you were in/someone else) run a red light, and if so which alternative fits best: no, the other party did

Were you (the driver) distracted prior to the collision by something? no

Did someone get injured? yes, but only minor injuries

Describe briefly what happened, preferably with a sketch: I was hit from the side (my passenger side) as I traveled straight through the light. It was approximately 11 pm and the driver of the other vehicle, a big truck, was drunk

Have you become more careful/changed your driving behavior as a result of this crash? n/a

Crash 26 -- 37-year-old male currently living in Hermon, 21 at time of crash

Where you driving? Yes, a car

What year did it happen? 1986

Were did it happen? Troy, NY

Did you (the vehicle you were in/someone else) run a red light, and if so which alternative fits best: no, the other party ran a red flashing light. I had a yellow flashing light

Were you (the driver) distracted prior to the collision by something? no

Did someone get injured? no

Describe briefly what happened, preferably with a sketch: Cadillac ran a blinking red light. I had a blinking yellow light

Have you become more careful/changed your driving behavior as a result of this crash? yes (no details)

Crash 27 -- 46-year-old male currently living in Brewer, 36 at time of crash

Were you driving? Yes, a pickup truck

What year did it happen? 1993

Where did it happen? Hermon/Bangor Interstate 95

Did you (the vehicle you were in/someone else) run a red light, and if so which alternative fits best: no, the other party did

Were you (the driver) distracted prior to the collision by something? no

Did someone get injured? yes, but only minor injuries

Describe briefly what happened, preferably with a sketch: Not described at all

Have you become more careful/changed your driving behavior as a result of this crash? yes (no details)

Crash 28 -- 41-year-old female currently living in Smithfield, 39 at time of crash

Where you driving? Yes, a car

What year did it happen? 2000

Were did it happen? Oak Street and High Street; Oakland, ME

Did you (the vehicle you were in/someone else) run a red light, and if so which alternative fits best: no, but the other party may have

Were you (the driver) distracted prior to the collision by something? no

Did someone get injured? yes, but only minor injuries

Describe briefly what happened, preferably with a sketch: I was driving down High Street when the signal was changing to red and I had ample of time to stop, but the man behind me rear-ended me. He said I stopped too soon

Have you become more careful/changed your driving behavior as a result of this crash? no

Crash 29 -- 20-year-old female currently living in Orono, 18 at time of crash

Were you driving? Yes, a car

What year did it happen? 1999

Where did it happen? Vermont Avenue and Union Street, Bangor, ME

Did you (the vehicle you were in/someone else) run a red light, and if so which alternative fits best: no, the other party did

Were you (the driver) distracted prior to the collision by something? no

Did someone get injured? no

Describe briefly what happened, preferably with a sketch: Vermont Street is the third leg of a T-intersection. I had a green light when turning left from Vermont onto Union Street. The other driver was traveling straight along the curb of Union Street. They ran the red light and struck my car in the front right as I was entering the street.

Have you become more careful/changed your driving behavior as a result of this crash? Yes. I now check both ways before going through a signalized intersection

Crash 30 -- 61-year-old male currently living in Sidney, ME, 49 at time of crash

Were you driving? Yes, a car

What year did it happen? 1990

Where did it happen? Waterville, ME

Did you (the vehicle you were in/someone else) run a red light, and if so which alternative fits best: it is uncertain who ran the red light. I believe I did not (But description make it seem like both drivers made right turns on red)

Were you (the driver) distracted prior to the collision by something? no

Did someone get injured? no

Describe briefly what happened, preferably with a sketch: I made a right-turn on red. A car pulled up in the breakdown lane for right turn beside me. A 90 year-old man

Have you become more careful/changed your driving behavior as a result of this crash? Yes. (not specified)

Crash 31 -- 23-year-old male currently living in Sidney, ME, 19 at time of crash

Were you driving? Yes, a car

What year did it happen? 1998

Where did it happen? N. Maine and Center Street, Old Town, ME

Did you (the vehicle you were in/someone else) run a red light, and if so which alternative fits best: (Seems as if subject made a right-turn on red)

Were you (the driver) distracted prior to the collision by something? no

Did someone get injured? no

Describe briefly what happened, preferably with a sketch: I approached the intersection along North Main Street and made a right turn onto Center Street. Collided with through vehicle along Center Street approaching from my left. (It seems as if the subject made a right-turn-on-red and thought that the other car may turn left. But the other car may have run a red light too)

Have you become more careful/changed your driving behavior as a result of this crash? Yes. Check multiple times at intersections. Don’t trust blinkers.

Crash 32 -- 24-year-old male currently living in Sidney, ME, 20 at time of crash

Were you driving? Yes, a car

What year did it happen? 1998

Where did it happen? Kennedy Memorial Drive and West River Road, Waterville, ME

Did you (the vehicle you were in/someone else) run a red light, and if so which alternative fits best: Yes, I stopped and then made a right-turn on red

Were you (the driver) distracted prior to the collision by something? no

Did someone get injured? no

Describe briefly what happened, preferably with a sketch: I made a right-turn on red and was hit by a through vehicle along Kennedy Memorial Drive, a rear-end crash

Have you become more careful/changed your driving behavior as a result of this crash? Yes. I pay more attention.

Crash 33 -- 21-year-old male currently living in Orono, ME, 17 at time of crash

Were you driving? No, a passenger

What year did it happen? 1998

Where did it happen? Spring Street intersection, Saco, ME

Did you (the vehicle you were in/someone else) run a red light, and if so which alternative fits best: The signal was flashing red/yellow. The other driver had the red.

Were you (the driver) distracted prior to the collision by something? no

Did someone get injured? no

Describe briefly what happened, preferably with a sketch: Four-way intersection. I stopped at blinking yellow light and then proceeded through the intersection and got hit from the side. (This shows the danger of having some signals go onto flashing red/red and others onto yellow/red since a driver approaching a yellow/red intersection, entering from an approach with flashing red may assume it is a flashing red/red intersection, especially when another driver stops for blinking yellow…)

Have you become more careful/changed your driving behavior as a result of this crash? Yes, more careful at lights. I now take more time to look.

Crash 34 -- 23-year-old male currently living in Orono, ME, 20 at time of crash

Were you driving? yes, a car

What year did it happen? 1999

Where did it happen? In front of Sam's Club on Hogan Road, Bangor, ME

Did you (the vehicle you were in/someone else) run a red light, and if so which alternative fits best: I was rear-ended

Were you (the driver) distracted prior to the collision by something? no

Did someone get injured? no

Describe briefly what happened, preferably with a sketch: I was stopped at red light when car behind me was rear ended and pushed into me (3-car crash)

Have you become more careful/changed your driving behavior as a result of this crash? no

Crash 35 -- 42-year-old female currently living in Orono, ME, 24 at time of crash

Were you driving? yes, a car

What year did it happen? 1985 or so

Where did it happen? Washington DC

Did you (the vehicle you were in/someone else) run a red light, and if so which alternative fits best: I was rear-ended

Were you (the driver) distracted prior to the collision by something? no

Did someone get injured? yes, I got whiplash

Describe briefly what happened, preferably with a sketch: I was stopped at red light when car behind me struck me from behind. The driver claimed that her accelerator stuck.

Have you become more careful/changed your driving behavior as a result of this crash? no

Crash 36 -- 44-year-old female currently living in Old Town, ME, unknown at time of crash

Were you driving? yes, a car

What year did it happen? unknown

Where did it happen? unknown

Did you (the vehicle you were in/someone else) run a red light, and if so which alternative fits best: I was rear-ended

Were you (the driver) distracted prior to the collision by something? n/a

Did someone get injured? n/a

Describe briefly what happened, preferably with a sketch: I was rear-ended by another car while stopped at a red light.

Have you become more careful/changed your driving behavior as a result of this crash? n/a

Crash 37 -- 27-year-old female currently living in Bangor, ME, 19 at time of crash

Were you driving? yes, a truck

What year did it happen? 1996

Where did it happen? Main and Pine Street, Orono

Did you (the vehicle you were in/someone else) run a red light, and if so which alternative fits best: I rear-ended a person who stopped during flashing yellow to let someone out who had flashing red.

Were you (the driver) distracted prior to the collision by something? Yes, I was looking at an attractive woman pumping gas, when the guy in front of me stopped to let a car out of Pine Street

Did someone get injured? no

Describe briefly what happened, preferably with a sketch: I rear-ended a person who stopped during flashing yellow to let someone out who had flashing red. I saw it late and tried to swerve around him but oncoming traffic forced me to clip him. I was only going @ 5mph on impact

Have you become more careful/changed your driving behavior as a result of this crash? I try not to gaze out the side window.

Crash 38 -- approx. 21-year-old male currently living in Falmouth, ME, 19 at time of crash

Were you driving? yes, a truck

What year did it happen? 2001

Where did it happen? Washington Avenue in Portland, ME, near DMV at the double streetlights

Did you (the vehicle you were in/someone else) run a red light, and if so which alternative fits best: I was rear-ended

Were you (the driver) distracted prior to the collision by something? No

Did someone get injured? No

Describe briefly what happened, preferably with a sketch: I was stopped at a red light when a car didn't slow down in time and crashed into the back of me.

Have you become more careful/changed your driving behavior as a result of this crash? No

Crash 39 -- 20-year-old male currently living in Machias, ME, 17 at time of crash

Were you driving? Yes, a car

What year did it happen? 2001

Where did it happen? In St Stephens, NB, Canada

Did you (the vehicle you were in/someone else) run a red light, and if so which alternative fits best: no, the other party did

Were you (the driver) distracted prior to the collision by something? No

Did someone get injured? No

Describe briefly what happened, preferably with a sketch: The other car ran a red light and hit me on the driver side. We were both going straight on perpendicular courses. (It looks like the subject started up on early green with a parallel car blocking him from the car running an early red.

Have you become more careful/changed your driving behavior as a result of this crash? No

Crash 40 -- 20-year-old male currently living in Orono, ME, 13 at time of crash

Were you driving? No, passenger of a car

What year did it happen? 1996

Where did it happen? South Portland

Did you (the vehicle you were in/someone else) run a red light, and if so which alternative fits best: We were rear-ended

Were you (the driver) distracted prior to the collision by something? No

Did someone get injured? No

Describe briefly what happened, preferably with a sketch: We were stopped at a red light when a driver didn't pay attention and crashed into us (rear-end illustration)

Have you become more careful/changed your driving behavior as a result of this crash? No

Crash 41 -- approx 30-year-old male currently living in Orono, ME, around 22 at time of crash

Were you driving? yes, a car

What year did it happen? 1986

Where did it happen? Ohio Street and 14th Street, Bangor, ME

Did you (the vehicle you were in/someone else) run a red light, and if so which alternative fits best: No one did

Were you (the driver) distracted prior to the collision by something? No

Did someone get injured? No

Describe briefly what happened, preferably with a sketch: I turned left in front of a straight through oncoming cars

Have you become more careful/changed your driving behavior as a result of this crash? No

Appendix 2. Questionnaire

MAINE SIGNAL SAFETY PROJECT

We are conducting a brief survey for the University of Maine and Maine Department of Transportation on behalf of traffic-safety educators. To participate you must hold a driver's license and be at least 18 year old. There are no risks with participating in this study. Your responses will be kept confidential. You can get more information about this study from Dr. Per Garder, tel. (207) 581-2177, e-mail Garder@Maine.edu

1. Do you consider the fact that some people run red lights a major safety concern?

   yes, definitely   yes, probably   no, there are many more important safety issues

2. Have you ever (as a passenger, driver or pedestrian) been involved in a motor vehicle **crash** at a SIGNALIZED intersection?   yes, once   yes, more than once, **each** incident is described below on separate sheets   no   If no, go to Question 11

3. Were you driving?   yes, a car   yes, a …. …   no, I was a passenger   no, I was ….

4. What year did it happen? ……………………………..

5. Where did it happen? (Give town and State and exact street names if you remember)

6. Did you (the vehicle you were in) or the other party run a red light? (Check the alternative that fits best)

   No, no one did

   No, the other party did

   It is uncertain who ran the red light. I believe I did not

   Yes, it changed to red just before I entered the intersection and I thought it might change

   Yes, it changed to red just before I entered the intersection but I thought it would not

   Yes, the light must have changed to red but I was unaware of it

   Yes, but I never saw the signal since it was blocked by a (truck or)………………………

   Yes, but I was completely unaware that there was a signalized intersection there

   Yes, other (describe):

7. Were you (the driver) distracted just prior to the collision by something?   No   Yes, by:

8. Did someone get injured?   No   Yes, but only minor injuries   Yes, describe:

9. Have you become more careful/changed your driving behavior as a result of this crash?
   No   Yes, describe how:

10. Describe briefly what happened, preferably with a sketch (what caused the crash?)

11. (Imagine that) You are approaching an intersection at 3 p.m. The traffic light has just turned red. At this time you notice that there is no traffic near you. You are to proceed straight. What would you do?
    - Definitely stop at the red and wait until the light turns green
    - Typically stop at red but then proceed through the red light
    - Typically slow down and proceed directly through the red light
    - Depends on how much of a hurry I am in

    Comment:

12. A traffic light changes to yellow so that it will just become red if you proceed at unchanged speed, do you typically   slow down and stop   speed up to make it before red   other:

13. As far as you can recall, have you run a red light in the last 12 months?

    yes, once   yes, more than once   no   <u>If *no*, go to Question 16</u>

14. The last time you ran a red light, was it
    - Knowingly: Stopped for red but no one around so why wait
    - Knowingly: Knew light would probably change to red just before getting to it
    - By mistake: Light changed to red quicker than expected
    - Unaware until too late to stop. Reason for not seeing the light: ………………………
    - Completely unaware of running it until afterwards when passenger pointed it out
    - Other (give reason):

15. Were you alone in the car when you ran it?   yes   no, with ….children and .… adults

16. Have you ever been stopped by police/ticketed for running a red light?   yes   no

17. Suggest how we could make *other people* run red lights less frequently (mark one or several boxes)
    - More frequent police enforcement
    - Automatic photo enforcement and ticketing
    - Higher penalties for people caught running red lights
    - Shorter red times so that it doesn't take so long to get green again
    - Longer yellow times, so it becomes easier to stop before red
    - Television information about risk of running red lights
    - Other, describe:

18. (If you have run a red light in the last year or so) Suggest how we could make YOU personally run red lights less frequently:

19. Gender: male   female

20. Age ………….

21. Currently living in (town, Maine):   …………………………………..………, Maine

22. Are you a parent?   yes, my youngest child is ….. years old   no

23. Approximately how many miles do you drive per year? ………………. miles

Thank you, this concludes our study

Appendix 3. Characteristics of U.S. Red Light Running Crashes

This appendix is provided as a supplement to the study from Maine. It is to be used for comparing the situation in Maine to that of other states. The information is in its entirety taken from: http://www.tf.org/tf/lib&data/redlight.shtml (accessed on May 21, 2004). The website belongs to the Trauma Foundation, a part of the San Francisco General Hospital. The only referenced literature is: Retting RA, Ulmer RG, and Williams AF. Prevalence and characteristics of red light running crashes in the United States. *Accident Analysis and Prevention*, 31:687-694, 1999. It is this author's opinion that that article has been accurately summarized.

According to a recent national study, in the United States in 1996, there was a total of 257,849 traffic crashes in which someone ran a red light. These red light running crashes accounted for:

- 4% of all police-reported crashes;
- 5% of all injury crashes; and
- 7% of all injury crashes on urban roads.

47% of red light running crashes involved injuries, as compared with 33% of other crashes.

Of all red light running crashes in the U.S. in 1996:

- 15% involved fatal or incapacitating injuries, and
- 31% involved non-incapacitating injuries.

72% of these red light running crashes occurred during the day (between 6:00 a.m. and 5:59 p.m.).

Red light running injury crashes in 1996

In 208,355 red light running injury crashes, (1) the crash involved two drivers, each of whom was going straight (not necessarily in the same direction) prior to the crash, and (2) only one driver met the definition of a red light runner (in other words, this subset avoids problems with assigning fault by excluding left-turn crashes and those involving more than two vehicles). This subset represented 61% of red light running injury crashes in 1996. Of drivers in this subset:

- 43% were younger than age 30, as compared with 33% of drivers in non-red light running crashes ("non-runners");
- 58% were male, as compared with 54% of non-runners;
- 5% were reported to have been drinking any amount of alcohol, as compared with less than 1% of non-runners (these rates are for both daytime and nighttime crashes);
- 12% in nighttime crashes (6:00 p.m. to 5:59 a.m.) were reported to have been drinking any amount of alcohol, as compared with 1% of non-runners in nighttime crashes.

Fatal red light running crashes between 1992 and 1996

Between 1992 and 1996, there were 3,753 fatal red light running traffic crashes, resulting in 4,238 deaths. These fatal red light running crashes accounted for 3% of all fatal crashes. Of fatal red light running crashes:

- 97% involved two or more vehicles, and 3% involved pedestrians or bicyclists;
- 86% occurred on urban roads;
- 57% occurred during the day; and
- 91% occurred during "good weather conditions."

In 2,229 fatal red light running crashes, (1) the crash involved two drivers going straight (not necessarily in the same direction) prior to the crash, and (2) only one driver met the definition of a red light runner. This subset accounted for 59% of fatal red light running crashes between 1992 and 1996. Of drivers in this subset:

- 43% were younger than age 30, as compared with 32% of non-runners;
- 74% were male, as compared with 70% of non-runners; and
- police-reported alcohol consumption was much higher than that reported for non-runners: 34% for red light runners, as compared with 4% of non-runners.

Characteristics of fatal red light running crashes differed by age group:

- Red light running crashes peaked during the day for drivers aged 70 and older, and around midnight for drivers aged 20-69.
- Police-reported alcohol consumption was similar for drivers younger than age 20 and drivers aged 20-69, but was rarely reported for drivers over age 70.

Appendix 4. National Crash Data

Signal

Year	1994	1996	1999	2000	2001
All crashes	1,268,000	1,295,000	1,347,000	1,391,000	1,353,000
Injury	464,000	489,000	493,000	505,000	493,000
% injury	36.6%	37.8%	36.6%	36.3%	36.4%
Fatal	2,791	2,812	2,803	2,785	2,925
% fatal	0.22%	0.22%	0.21%	0.20%	0.22%

Stop

Year	1994	1996	1999*	2000	2001
All crashes	725,000	745,000	286,000	699,000	691,000
Injury	267,000	277,000	91,000	259,000	247,000
% injury	36.8%	37.2%	31.8%	37.0%	35.8%
Fatal	3,117	3,453	3,623	3,424	3,408
% fatal	0.43%	0.46%	1.27%	0.49%	0.49%

All controls, all locations

Year	1994	1996	1999	2000	2001
All crashes	6,492,000	6,842,000	6,279,000	6,394,000	6,323,000
Injury	2,092,000	2,227,000	2,054,000	2,070,000	2,003,000
% injury	32.2%	32.6%	32.7%	32.4%	31.7%
Fatal	36,223	37,494	37,043	37,409	37,795
% fatal	0.56%	0.55%	0.59%	0.59%	0.60%

* The 1999 data for stop-controlled intersections seem suspect but is still included since these are the officially reported numbers.

Appendix 5. Maine Statute

Title 29-A: MOTOR VEHICLES (HEADING: PL 1993, c. 683, Pt. A, @2 (new); Pt. B, @5 (aff))
Chapter 19: OPERATION (HEADING: PL 1993, c. 683, Pt. A, @2 (new); Pt. B, @5 (aff))
Subchapter 1: RULES OF THE ROAD (HEADING: PL 1993, c. 683, Pt. A, @2 (new); Pt. B, @5 (aff))

§2057. Traffic-control devices

An operator shall obey a traffic-control device, unless otherwise directed by a law enforcement officer. A traffic-control device conforming to the requirements for these devices is presumed to comply with this chapter. [1993, c. 683, Pt. A, §2 (new); Pt. B, §5 (aff).]

1. Lighted devices. A traffic-control device may emit only the colors green, red and yellow, except for a pedestrian signal carrying a legend. The lights have the following meanings.

A. A green light:

(1) If circular, means the operator may proceed straight through or turn right or left, unless a sign prohibits either turn; or

(2) If an arrow, alone or in combination with another indication, means the operator may cautiously enter the intersection only to make the movement indicated by the arrow or other movement as is permitted by other indications shown at the same time.

Notwithstanding the light, the operator must yield the right-of-way to a vehicle or pedestrian lawfully within the intersection or crosswalk. [1993, c. 683, Pt. A, §2 (new); Pt. B, §5 (aff).]

B. A yellow light:

(1) If steady and circular or an arrow, means the operator must take warning that a green light is being terminated or a red light will be exhibited immediately; or

(2) If showing rapid intermittent flashes, means the operator may proceed only with caution. [1993, c. 683, Pt. A, §2 (new); Pt. B, §5 (aff).]

C. (TEXT EFFECTIVE UNTIL 7/1/04) A red light:

(1) If steady and circular, means the operator must stop and remain standing until an indication to proceed is shown.
An operator may cautiously enter the intersection to make a right turn after stopping, unless prohibited by an appropriate sign such as "NO RIGHT TURN ON RED."
An operator executing a turn shall yield the right-of-way to pedestrians on a crosswalk and to a vehicle having a green signal at the intersection;

(2) If a steady arrow, means the operator may not enter the intersection to make the movement indicated by that arrow; or

(3) If showing rapid intermittent flashes, means the operator must stop and then proceed as if at a stop sign.
[1993, c. 683, Pt. A, §2 (new); Pt. B, §5 (aff).]

C. (TEXT EFFECTIVE 7/1/04) A red light, if steady and circular, means:
(1) The operator must stop and remain stationary until an indication to proceed is shown; or

(2) The operator may cautiously enter the intersection to make a right turn after stopping if:
(a) Not prohibited by an appropriate sign such as "NO RIGHT TURN ON RED"; and

(b) The operator executing a turn yields the right-of-way to pedestrians on a crosswalk and to a vehicle having a green signal at the intersection.

[2003, c. 452, Pt. Q, §36 (rpr); Pt. X, §2 (aff).]

C-1. (TEXT EFFECTIVE 7/1/04) A red light, if a steady arrow, means the operator may not enter the intersection to make the movement indicated by that arrow. [2003, c. 452, Pt. Q, §37 (new); Pt. X, §2 (aff).]

C-2. (TEXT EFFECTIVE 7/1/04) A red light, if showing rapid intermittent flashes, means the operator must stop and then proceed as if at a stop sign. [2003, c. 452, Pt. Q, §37 (new); Pt. X, §2 (aff).]

D. Red and yellow illuminated together, means the operator may not enter the intersection, as the intersection is reserved for the exclusive use of pedestrians. [1993, c. 683, Pt. A, §2 (new); Pt. B, §5 (aff).]

[1993, c. 683, Pt. A, §2 (new); Pt. B, §5 (aff); 2003, c. 452, Pt. Q, §§36, 37 (amd); Pt. X, §2 (aff).]

2. Basis for prohibiting turn. A municipality or the Department of Transportation, in determining whether to prohibit a right turn on a red light, must consider at least the following factors:

A. The proximity to that light of schools, fire stations, residences or institutions for the blind; [1993, c. 683, Pt. A, §2 (new); Pt. B, §5 (aff).]

B. The number of pedestrians using the intersection; and [1993, c. 683, Pt. A, §2 (new); Pt. B, §5 (aff).]

C. The complexity of the intersection. [1993, c. 683, Pt. A, §2 (new); Pt. B, §5 (aff).]

[1993, c. 683, Pt. A, §2 (new); Pt. B, §5 (aff).]

3. Lane direction control devices. When lane direction control devices are placed over the individual lanes, an operator may travel in a lane over which a green signal is shown, but may not enter or travel in a lane over which a red signal is shown. [1993, c. 683, Pt. A, §2 (new); Pt. B, §5 (aff).]

4. Located other than at an intersection. If a traffic control device is located at a place other than an intersection, this section is applicable except as to those provisions that by their nature can have no application. [1993, c. 683, Pt. A, §2 (new); Pt. B, §5 (aff).]

5. Pedestrians. Unless otherwise directed by a pedestrian control signal, a pedestrian facing:

A. A green signal, except when the sole green signal is a turn arrow, may proceed across the way within a marked or unmarked crosswalk; [1993, c. 683, Pt. A, §2 (new); Pt. B, §5 (aff).]

B. A steady circular yellow or yellow arrow signal, may not start to cross the way, as there is insufficient time to cross before a red indication is shown; or [1993, c. 683, Pt. A, §2 (new); Pt. B, §5 (aff).]

C. A steady circular red signal or a steady red arrow, may not enter the way. [1993, c. 683, Pt. A, §2 (new); Pt. B, §5 (aff).]

[1993, c. 683, Pt. A, §2 (new); Pt. B, §5 (aff).]

6. Pedestrian control devices. When a pedestrian control device exhibiting the words "walk" and "don't walk" is used, it indicates as follows.

A. A pedestrian facing a "walk" signal may proceed across the way in the direction of the signal and must be given the right-of-way. [1993, c. 683, Pt. A, §2 (new); Pt. B, §5 (aff).]

B. A pedestrian may not start to cross a way in the direction of a "don't walk" signal, but a pedestrian who has partially completed crossing may proceed to a sidewalk or safety island. [1993, c. 683, Pt. A, §2 (new); Pt. B, §5 (aff).]

[1993, c. 683, Pt. A, §2 (new); Pt. B, §5 (aff).]

7. Stop signs. Unless directed to proceed by a law enforcement officer or traffic control device, an operator of a vehicle approaching a stop sign shall stop and:

A. Yield the right-of-way to a vehicle that has entered the intersection or that is approaching so closely as to constitute an immediate hazard; and [1993, c. 683, Pt. A, §2 (new); Pt. B, §5 (aff).]

B. Having yielded, an operator may proceed. All other operators approaching the intersection shall yield the right-of-way to the vehicle so proceeding. [1993, c. 683, Pt. A, §2 (new); Pt. B, §5 (aff).]

[1993, c. 683, Pt. A, §2 (new); Pt. B, §5 (aff).]

8. Place of stop. A stop must be made before entering the intersecting way as follows:

A. Where the intersection is regulated by a traffic control device, at a sign or marking on the pavement indicating where the stop is to be made or, in the absence of a sign or marking, at the device; or [1993, c. 683, Pt. A, §2 (new); Pt. B, §5 (aff).]

B. Where the intersection is regulated by a stop sign, before entering the crosswalk or, in the absence of a cross walk, at a marked stop line; but if there is no stop line, at a point nearest the intersecting way where the operator has a view of approaching traffic. [1993, c. 683, Pt. A, §2 (new); Pt. B, §5 (aff).]

[1993, c. 683, Pt. A, §2 (new); Pt. B, §5 (aff).]

9. Evidence. The placing of a traffic control device in a position approximately conforming to this chapter is prima facie evidence that the device has been placed by the official act or direction of lawful authority. [1993, c. 683, Pt. A, §2 (new); Pt. B, §5 (aff).]

10. Failure to yield. A person commits a Class E crime if that person operates a vehicle past a yield sign and collides with a vehicle or pedestrian proceeding on the intersecting way. [1993, c. 683, Pt. A, §2 (new); Pt. B, §5 (aff).]

11. Avoidance of traffic control device prohibited. An operator may not operate a motor vehicle through a parking area to avoid obeying or conforming to the requirements of a traffic control device. [1999, c. 183, §9 (new).]

Section History:
PL 1993, Ch. 683, §A2 (NEW).
PL 1993, Ch. 683, §B5 (AFF).
PL 1999, Ch. 183, §9 (AMD).
PL 2003, Ch. 452, §Q36,37 (AMD).
PL 2003, Ch. 452, §X2 (AFF).

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