TRAFFIC CONFLICT STUDIES BEFORE AND AFTER INTRODUCTION OF RED-LIGHT RUNNING PHOTO ENFORCEMENT IN MAINE

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Year 17 (04/05)
Project No. UMER 17-10

Final Report

August 29, 2006

The New England University Transportation Center

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16. Abstract

Red-light running is a major safety concern in Maine. It can probably best be reduced by enforcement. This pilot study uses crash data, traffic conflict data, video and field observations of behavior to evaluate the potential effectiveness of photo enforcement in Lewiston and Auburn in Maine. The intent of the pilot study was to demonstrate the need for photo enforcement, to show that it can work in Maine, and to help the legislators make informed, educated decisions on legislation affecting this program, which may include a shift in policy to allow photo-enforcement activities. The ultimate purpose of the activity is to improve safety at intersections, thereby reducing fatalities and injuries.

Five signalized intersections in Lewiston-Auburn were outfitted with photographic equipment in the pilot study, which was funded by the Federal Highway Administration, Maine Department of Transportation and the Androscoggin Transportation Resource Center. The equipment vendor operated and maintained the equipment, and viewed photographic images to insure quality. The respective Lewiston or Auburn police departments reviewed each potential violation to determine whether a red light violation had occurred, and issued warning letters to the registered vehicle owners of the offending vehicles. The police were conservative when determining if a red light violation had occurred – likely more violation warning letters could have been issued. Even with some periods with the systems inoperable and the conservative approach, over 4,600 warning letters were issued during the six-month pilot project, resulting in an average of over 5 violations per day for each intersection, proving that red light running is indeed a major problem.

For a variety of reasons, the system was not operating 100% of the time. Still, it was shown that automatic enforcement can be used even during Maine's severe winter conditions. The effectiveness could be further improved with a careful maintenance program. A system that catches only 50% of all offenders would be about 2000 times more effective than today's enforcement level.

A question that has been addressed through this study is whether automatic enforcement, using video and digital camera technology, effectively can reduce red-light running frequencies even if violations only result in warning letters. (Maine law currently does not allow issuing citations based on photographic evidence, so only warning letters were issued to violators.) Observations of red-light running indicate that the violation rate dropped by around 28% between December 2004 (when the system was first installed) and May 2005, when the system had been operational for several months. But it was the infractions that occurred at low speeds and within the first second or so that were reduced. Infractions more than 3 seconds into red and at speeds above 35 mph actually increased. However, it is unlikely that the enforcement system in any way led to this increase in the more serious infractions. It is possible that weather and roadway conditions explain the higher speeds during the later months. Future studies should address that.

Conflict and crash data indicate that there were no great improvements in safety between the before period and the period when the system was in operation. Actual fines rather than warning tickets may have produced greater safety effects.

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Traffic Conflict Studies Before and After Introduction of Red-light Running Photo Enforcement in Maine

Abstract

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Acknowledgement

The red-light-running-enforcement project in Lewiston/Auburn, which is evaluated in this report, was funded with $135,900 through a $40,000 Technology Transfer Grant from the Federal Highway Administration-Maine Division (FHWA), $48,400 from the Maine Department of Transportation (Maine DOT), and $47,500 from the Androscoggin Transportation Resource Center (ATRC).

The evaluation that is presented here was funded separately by a grant from the New England University Transportation Center and funding from the Maine Department of Transportation. Separate, but close to identical, reports were delivered to these agencies.

The field-studies presented in this report were done primarily by the undersigned with help from undergraduate students at the University of Maine, primarily Jason Provencher. Background material was provided by Don Craig of Androscoggin Transportation Resource Center, and Gerry Audibert, Duane Brunell and Greg Costello of the Maine Department of Transportation, Neil Brussard and Russ Colthorpe of Peek Traffic Corporation, and Anders Norling of Sensys AB, Jönköping, Sweden. The report was written by the undersigned.

Orono, Maine in August 2006

Per Gårder

EXECUTIVE SUMMARY

Background

Red-light running is a major safety concern in Maine. The rate at which people run red lights is higher than in many other states and a high percentage of the red-light running is done intentionally (Gårder, 2004). In Maine, there are around 500 crashes every year that are caused by drivers running red lights. These crashes produce, on average, more serious injuries than other intersection-related crashes. Statewide, there are about 25 incapacitating injury crashes per year of this type. Four out of six fatal crashes at signalized intersections in the state of Maine in the three-year period analyzed involved road-users entering the intersection on red. It would obviously be desirable to reduce red-light-running frequencies. However, from a safety perspective it is especially important to reduce the number of red-light running infractions that occur at high speeds and well into the red.

There are many ways to reduce red-light running. When people run red lights on purpose, they can probably best be deterred by enforcement. Infractions that are made completely by mistake—where the driver is completely unaware that he/she is entering a signal—can probably be reduced more effectively by other means, such as bigger signal heads and better timing. However, more enforcement may have somewhat of an effect on these situations too because if drivers know that signals frequently are monitored with respect to red-light running, they may start to be more observant.

Pilot Study Conclusions

The findings of this study supported the primary goals:

- Red light running is significant in Maine. Law enforcement officials issued an average 25 red-light violations per day at the five pilot photo-enforcement intersections.
- Photo enforcement accurately captured red-light-running violators, as confirmed by police. It is clear that the system can be reliable in the sense than non-violators are not charged with violations.
- Photo enforcement can be effective. Even though only warning letters were issued in the pilot study, the number of violations decreased by an estimate of approximately 28%.
- The pilot study was too short and real fines should be levied to assess the potential effect. The University should be involved in a three-year experiment to see the long-term effect of such a program.

Pilot Study Details

This project uses crash data, traffic conflict data (near misses), as well as video and field observations of behavior to evaluate the potential effectiveness of electronic photo enforcement in Lewiston and Auburn in Androscoggin County. The Androscoggin Transportation Resource Center (ATRC), the Federal Highway Administration (FHWA) and Maine Department of Transportation (Maine DOT) together with the University of Maine through this project jointly investigated the feasibility of such a system. However, at this time, Maine law does not allow photo enforcement of red-light running. Therefore, ATRC, FHWA and Maine DOT together with the Maine Transportation Safety Coalition (MTSC) and the Cities of Lewiston and Auburn initiated the pilot project where drivers running red lights had their vehicles photographed and received a warning letter, sent to the registered owner of the violating vehicle. Since no formal citations were issued, no legislative approval was required for this experiment.

The intent of the pilot study was to show that:

1. Red-light running is a significant problem,
2. Current photo enforcement technology is feasible in Maine, and
3. Photo enforcement is effective in reducing the incidence of red light running.

Additionally the project was identified to help the legislators make informed, educated decisions on legislation affecting this program, which may include a shift in policy to allow photo-enforcement activities. The ultimate purpose of the activity is to improve safety at intersections, thereby reducing fatalities and injuries.

The ATRC volunteered to lead a pilot project because the Lewiston-Auburn area has a higher number of crashes at signalized intersections caused by drivers running red lights than any other city in Maine (Garder, 2004). One approach at each of five signalized intersections in the Lewiston-Auburn area was chosen for the study.

The study addressed whether automated enforcement, using video and digital camera technology, effectively will reduce red-light running frequencies even if violations only result in warning letters sent to owners of vehicles involved in running red lights. Manual observations of red-light running, as shown in Table 1, indicate that the violation rate dropped by around 6% between the summer of 2004 (before the system was installed) and the late spring of 2005, when the system had been operational for several months. This table includes only straight through and left-turning vehicles; right-turn-on-red vehicles were not included even if the turn was made at high speed.

Table 1 Number of violations by red-light running vehicles per 360 minutes

Location	Before (June 2004)		During (April 2005)	
	0.0-0.5 sec	>0.5 sec	0.0-0.5 sec	>0.5 sec
Center St. at Stetson Rd./Joline Street, Auburn	11	17	8	14
Center St. at Turner St. and Union St. Bypass, Auburn	8	12	8	13
Minot at Elm, Auburn*	--	--	4	10
Russell Street at East Avenue, Lewiston	6	12	7	10
East Avenue at Bartlett/Pleasant Street, Lewiston	12	10	9	14
Court Street at Main Street, Auburn*	11	9	--	--
Total	48	60	36	61

* Court Street location was changed to Minot Avenue due to City concerns with disrupting a recently-completed sidewalk project.

If we rely on information from the automatic enforcement system itself, as the data was reported by Peek, see Figure 1, the overall number of infractions per day decreased from 26.6 per day in December 2004 to 19.1 per day in May 2005, if Center Street at Stetson is excluded. This is a reduction of around 28%. The reason for excluding the Center Street/Stetson intersection is that it had no reliable observations from the first two-and-a-half months.

Figure 1 also indicates that there were much fewer infractions in January—when people were starting to become aware of the enforcement program—than in the following months. This may very well be caused by the fact that people eventually learned that the violations resulted in warning letters only. The reduction would not be caused by lower infractions during snowy/icy roadway conditions, which was a common condition in January, since a separate study conducted within this project of Center Street at Stetson/Joline in Auburn revealed the opposite; that the infraction rate goes up when it is snowing.

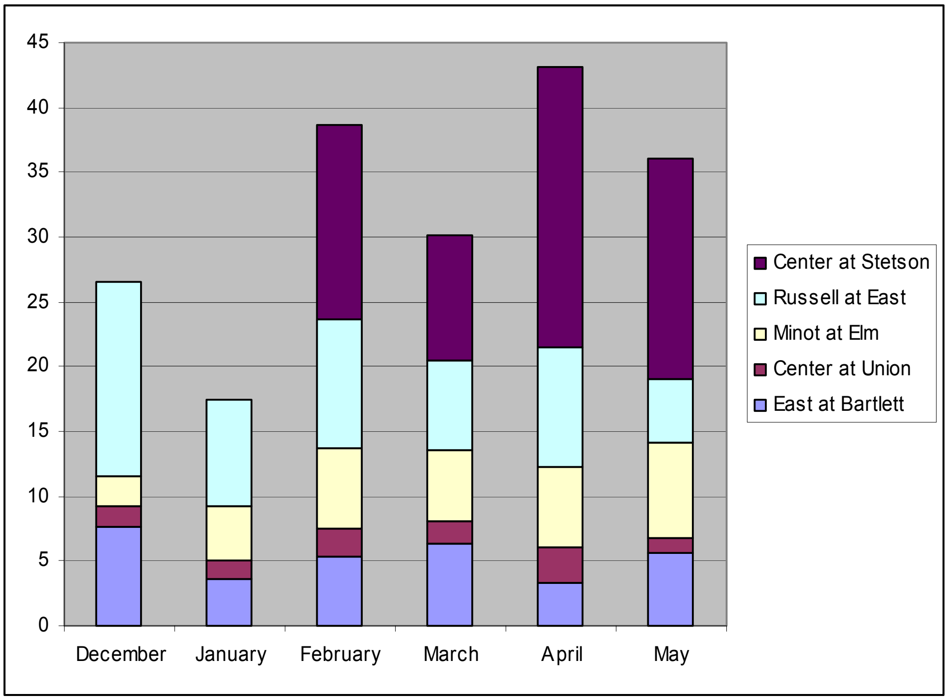

Figure 1 Infractions per day for excluding June 2005

Unfortunately—but probably not unexpectedly—it was the infractions that occurred at low speeds and within the first second or so that were reduced in numbers. Infractions more than 3 seconds into red and at speeds above 35 mph clearly increased in percentage—as seen in Figure 2—as well as in absolute numbers. However, it is unlikely that the enforcement system in any way led to this increase in the more serious infractions. It is possible that weather and roadway conditions explain the higher speeds during the later months but not the fact that people ran red lights further into the red phase.

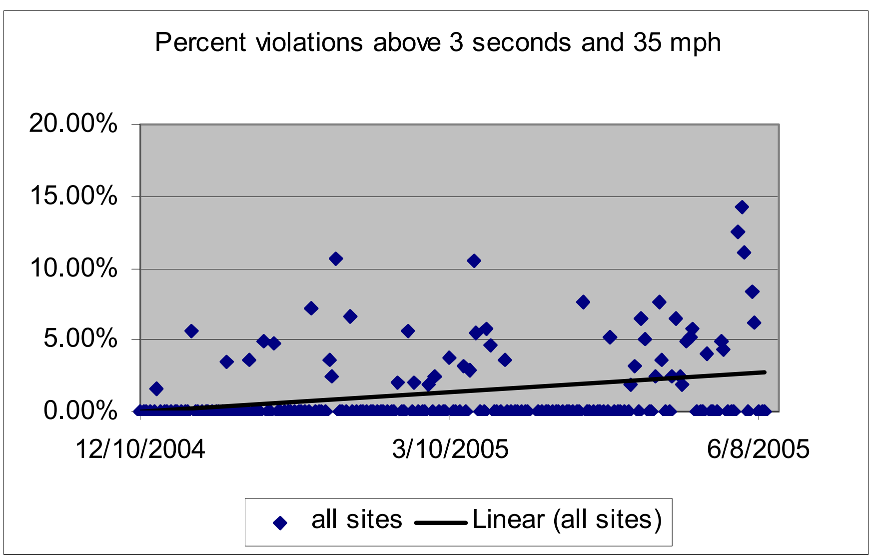

Figure 2 Percent violations more than 3 seconds into red and at speeds above 35 mph

Traffic conflict data indicate that safety was roughly unchanged between the period before the system was installed and the period when the system was in operation. However, conflict numbers are small and variations in safety would not be statistically detectable unless they were substantial. A first look at crash data may make the reader think there was a clear reduction in red-light-running crashes involving vehicles entering from the monitored approaches. However, a more in-depth analysis indicates that more or less all of this apparent improvement can be attributed to regression-to-the-mean effects. Actually, the six-month study period when the system was up and running saw nine crashes involving vehicles running red lights at the studied intersections, whereas the six-month period immediately before the installation of the enforcement system—the period not influenced by regression-to-the-mean effects—saw six such crashes. And FARS data shows that Androscoggin County sees almost exactly 50% of its most serious crashes occurring between June 15 and December 15.

It is not unlikely that the safety actually deteriorated during this experiment. Linear regression shows that infractions that occurred more than 3 seconds into red and at speeds above 35 mph went from well below 1% of all infractions in the beginning to around 3% towards the end of the experiment. This means that there at the end of the experiment were around 1.2 infractions per day at speeds above 35 mph and more than 3 seconds into the red. During the first month—December 10 through January 9—there were nine recorded infractions more than 10 seconds into red. During the month of May, that number had grown to 41 (after the intersection Center Street at Stetson had been excluded). This is a statistically significant increase ($p= 2.8 \times 10^{-6}$) of 355%. Also, the number of infractions at speeds above 40 mph grew from 57 in the first month to 78 in May (if Center Street at Stetson is excluded). Again, a statistically significant increase, $p<0.05$. If Center Street at Stetson were included, there would have been 221 infractions at speeds above 40 mph in May.

Surprisingly, only 4% of the automatically recorded infractions occurred between 10 PM and 6 AM. Manual observations were not done during the nighttime so there is no way to analyze whether the system has a lower reliability during this time. Also, Center Street at Stetson go on yellow blink from midnight until 5/6 AM.

A well-functioning enforcement system should be certain—with a high degree of reliability—to catch the worst offenders. Especially drivers who run red lights well into the red phase at high speeds. What percentage of these offenders was captured is not known. However, we know that one driver ran the red light at Center Street and Stetson on May 5 at 3[06] PM. That driver was going 46 mph 4.5 seconds into the red phase. But the violation was rejected in processing for a technicality—because the vehicle was touching the stop bar when the first image was photographed. This event was later retrieved because a collision resulted from the infraction. However, the incident would not have been reported had the crash not occurred—and it is not part of the data material presented in this report since it wasn't added to the data set until after all analyses were done. This situation may be an exception rather than a common occurrence but it is important that the more flagrant violators are caught. On the other hand, it is also important that people are not accused of being violators if they aren't. The police department needs to be conservative and fine only people that are 'proven' violators—and the lack of a photo prior to the vehicle reaching the stop bar means that such definite proof is missing. In other words, system specifications may need to be adjusted so that all truly dangerous behaviors are covered. For example, people driving extra fast cannot be excluded. Also, if someone drives out against a red light at low speeds right in front of a vehicle entering on green, then that violator ought to be caught and fined, even if the situation does not result in a crash.

Often, an assumption is made that the number of a specific type of occurrence varies around a mean according to the Poisson distribution—that is that the number of occurrences would be expected to fluctuate randomly around a mean. This results in a day-to-day variation in rates even if the underlying frequency is constant. The underlying frequency is in real life not completely constant and that complicates a statistical analysis. Still, something close to a Poisson process would be expected here unless drivers do not act independently of each other (but, for example, become more prone to run red lights at times when they see other people do it at the same place). All other stipulations for the Poisson distribution are met. However, the expected mean number of infractions (per hour or per day) may vary from day to day and hour to hour. A probability analysis indicates that it is statistically virtually impossible to get results as recorded by the automatic system if underlying violation rates were constant. Rather, statistical analysis indicates that the variation from day to day was significant, or that the system missed numerous situations on some days. If the system functioned with a reliability close to 100%, a study should be devoted to why drivers are so much more prone to run red lights on some days compared to other days. But a system does not have to be 100% reliable to act as a deterrent. Even a system that catches only 50% of all offenders would be about 2000 times more effective in catching violators than today's enforcement level.

Ideally, photo enforcement should be combined with active signal technology, for example of LHOVRA type, that keeps the red for an approach until close-by, fast-moving vehicles on conflicting approaches have stopped (Engström, 1994).

In conclusion, photo enforcement is a possible and necessary measure to assist the police in enforcing red-light running. It is an important part, but not sufficient by itself, in reducing injuries within a comprehensive engineering, education, enforcement, encouragement approach.

Traffic Safety Studies Before and After Introduction of Red-light Running Photo Enforcement in Lewiston and Auburn, Maine

1 Background and Project Objectives

Red-light running is a major safety concern in the United States producing more than 100,000 crashes and approximately 1,000 deaths per year (Retting, 1999). Red-light running is also a major safety concern in Maine. The rate at which people run red lights is higher than in many other states and a high percentage of the red-light running is done intentionally. Also, half of all (six) fatal crashes at traffic signals in Maine during the 1999-2001-period were caused by someone running a red light whereas 'only' 12.2% of (the 10,163) non-fatal crashes at signalized intersections had this cause (Gårder, 2004).

A report with a good overview of the field and probably the most comprehensive study of the effectiveness of red-light-camera systems was published in 2005 by the Federal Highway Administration (FHWA) (Griffith, 2005). That study included 132 treatment sites, and derived rear end and right-angle unit crash costs for various severity levels. Crash effects detected were consistent with those found in many previous studies: decreased right-angle crashes and increased rear end ones. The economic analysis examined the extent to which the increase in rear end crashes negates the benefits for decreased right-angle crashes.

This project uses crash data, traffic conflict data (see page 25), as well as video and field observations of behavior to evaluate the potential effectiveness of photo enforcement in Lewiston and Auburn in Androscoggin County. The Androscoggin Transportation Resource Center (ATRC), FHWA, Maine Department of Transportation (Maine DOT) and the University of Maine therefore together with the Maine Transportation Safety Coalition (MTSC) and the Cities of Lewiston and Auburn initiated the pilot project where vehicles running red lights were photographed and received a warning, sent to the registered owner of the violating vehicle. Since no formal citations were issued, no legislative approval was required for this experiment. Maine law currently has no provisions for photo or electronic enforcement, so no citations were issued. The intent of the pilot study was to show that:

Red light running is a significant problem in Maine;

Current electronic photo enforcement technology is feasible in Maine's harsh winters; and

Photo enforcement is somewhat effective in reducing the incidence of red light running.

The intent of the study was also to provide information to decision-makers regarding the applicability of electronic photo enforcement in Maine. The ultimate purpose of the activity was to improve safety at intersections, thereby reducing fatalities and injuries.

The safety studies carried out in this project give an estimated crash rate before and after camera 'enforcement' is initiated. The hypothesis is that a change in risk—as assessed by traffic conflict studies and crash data analysis—is a better indicator on the effectiveness of the system than the change in rate of drivers running red lights. The legislature may not see the benefit of reducing this rate unless it is accompanied by a safety improvement. And, it would be true that, if 'all' (or a majority of) crashes were caused by drivers running lights unintentionally as opposed to doing it knowingly, the safety benefit of the photo-enforcement system would be negligible even if it reduced red-light running substantially.

1.1 Site Selection

The ATRC led the request to perform a pilot project as the cities of Lewiston and Auburn have a higher number of crashes at signalized intersections caused by drivers running red lights than any other city in Maine (Gårder, 2004). One approach at each of five representative signalized intersections in Lewiston and Auburn were chosen for the studies. The choice of locations was made jointly by representatives from Maine DOT, FHWA, ATRC, the University of Maine, and Lewiston and Auburn police departments. The selected candidate sites were reviewed by Maine DOT Traffic Engineering and by law enforcement personnel. However, for different reasons, the camera installation at one location had to have the approach arm changed to the opposing one after the before studies had been done and another location had to be replaced all together since electronic communication could not be established to the chosen site. The sites that eventually were equipped with the photo-enforcement system are described in Section 1.2.

1.2 Photo Enforcement Locations

The five sites that had cameras installed are shown in Figure 3 and described below. Aerial photos of the ones that were studied in the before and 'after' period (which ought to be referred to as the 'during' period) are shown in Figure 4.

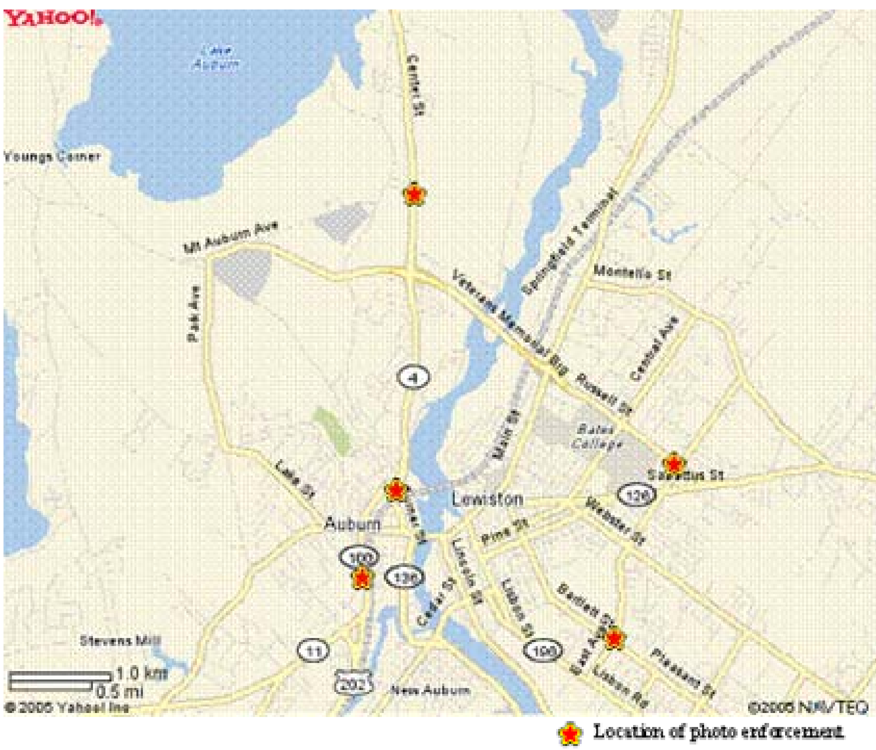

Figure 3 Locations that had cameras installed

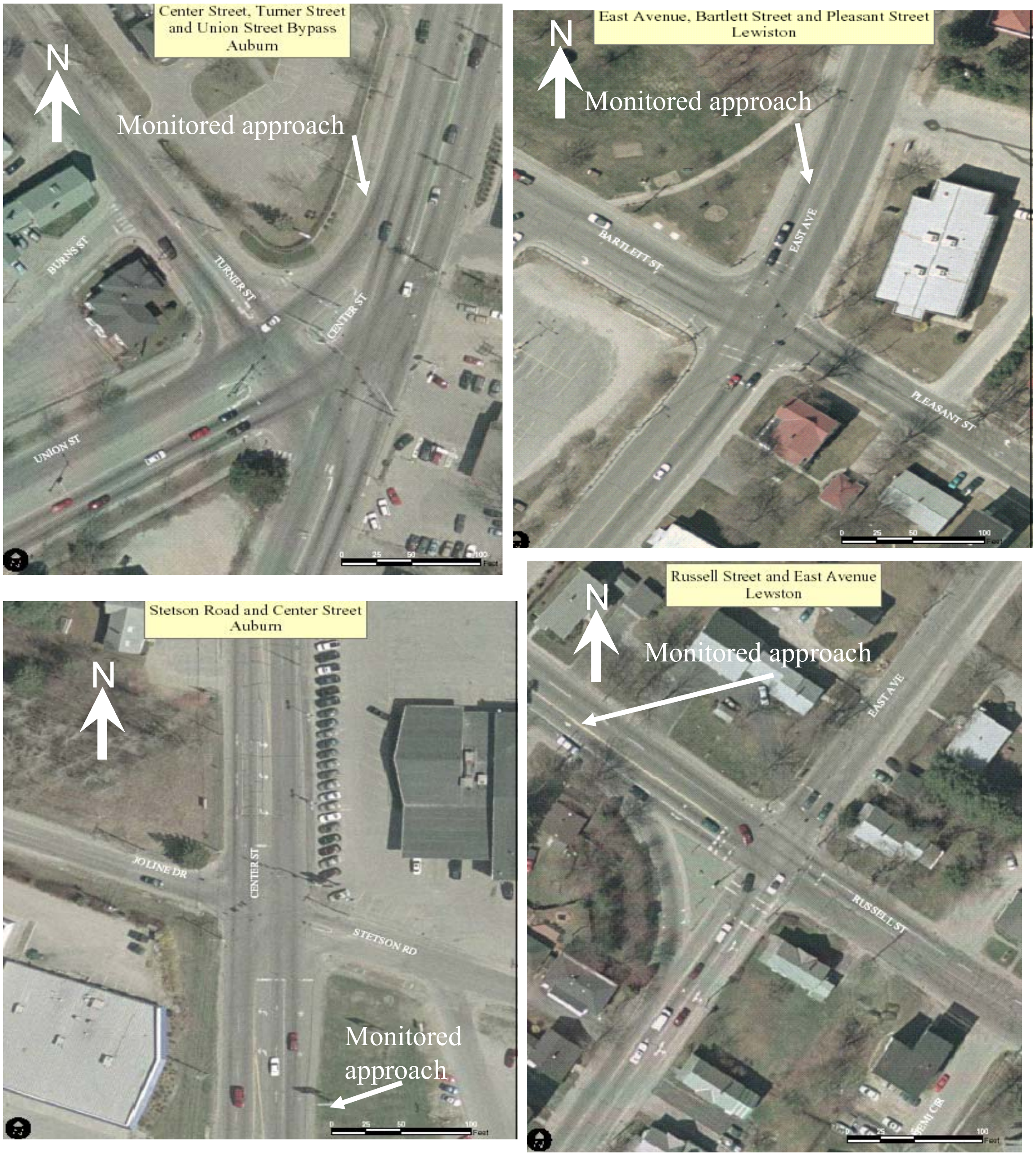

Figure 4 Aerial photos of the four locations studied in both before and 'after' study

1.2.1 <u>Auburn Sites</u>

- Center St. at Stetson Rd./Joline Street—monitoring the Center St. northbound leg
- Center St. at Turner St. and Union St. Bypass—monitoring southbound Center Street
- Minot at Elm (this location was not studied in the before period).

1.2.2 <u>Lewiston Sites</u>

- Russell Street at East Avenue—monitoring the (south) eastbound leg on Russell Street
- East Avenue at Bartlett Street and Pleasant Street—monitoring southwest-bound traffic along East Avenue (heading towards Lisbon Street).

What the cameras and video cameras look like can be seen in Figure 5. The figures following that show the intersections as photographed by the digital automatic enforcement camera.

Figure 5 Digital camera (left) and video camera at Center Street/Union Street Bypass

Figure 6 Center Street at Union Street Bypass. Left lane from behind monitored

Figure 7 Monitored approach (from behind) of Minot Avenue at Elm Street

Figure 8 Monitored approach (from behind) of Center Street at Turner and Joline

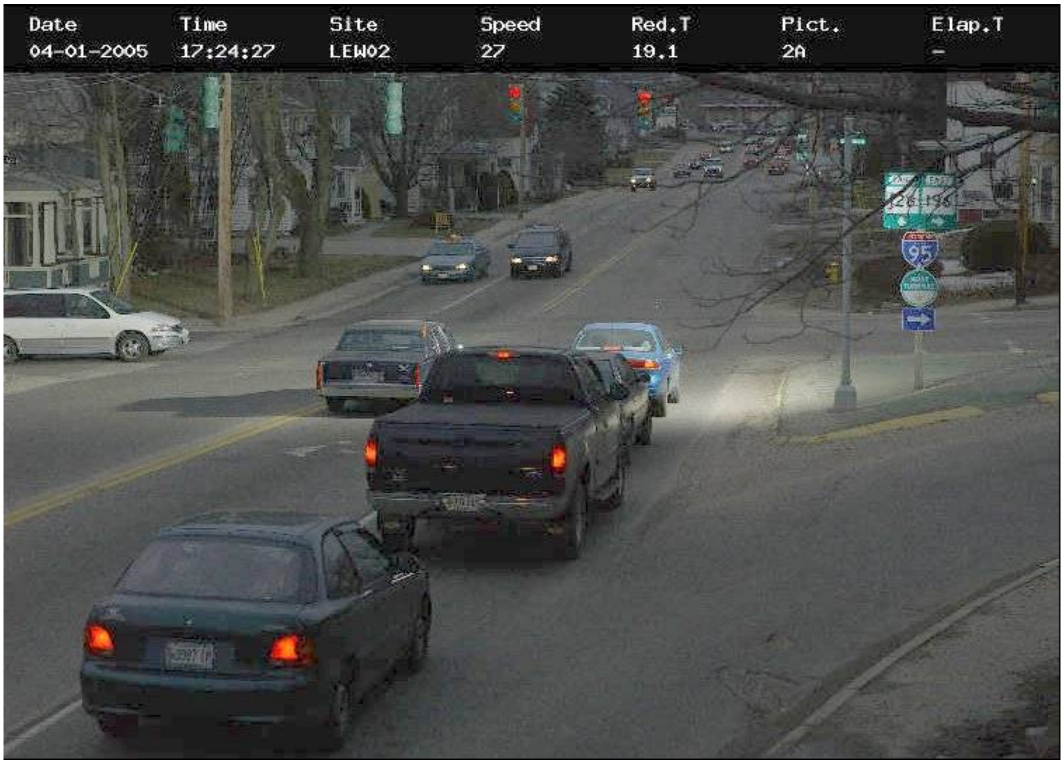

Figure 9 Monitored approach (from behind) of Russell Street at East Avenue

1.2.3 Traffic Volumes

The two-way daily traffic volumes as reported on Maine DOT's website Traffic Volume Counts—2004 Annual Report: Data collected and published by the State of Maine Department of Transportation Traffic Engineering Division in cooperation with the United States Department of Transportation Federal Highway Administration[1] are as follows:

- Center Street south of Stetson Rd. 19,680 (in 1999)
- Center Street north of Turner St. 29,140 (in 2003 north of North River Road)
- Minot at Elm (this location was not studied in the before period) with the northbound approach of Minot being equipped with the photo-enforcement equipment 19,600 (in 2001 south of Court Street)
- Russell Street west of East Avenue 22,680 (in 2004 south-east of Central Avenue, which is a better measure of traffic on the approach than that given south-east of Demi Circle)
- East Avenue north-east of Bartlett Street and Pleasant Street 18,250 (in 2003).

The studied approach volumes, excluding right-turning traffic and other lanes excluded from the analysis, are estimated from the volumes reported above and estimated percentages using those lanes from actual turning counts during the times of observation. These approach volumes are shown in Table 2.

[1] http://mainegov-images.informe.org/mdot/traffic-counts/pdf/2004finaltrafficcount.pdf

Table 2 Estimated daily entering traffic volumes for studied approaches

Approach	Estimated incoming daily volume on studied approach	Calculated as
Center Street south of Stetson Rd.	9052	0.92*0.5*19,680
Center Street north of Turner St.	6411	0.44*0.5*29,140
Minot at Elm	8526	0.87*0.5*19,600
Russell Street west of East Avenue	7825	0.69*0.5*22,680
East Avenue north-east of Bartlett/Pleasant	6570	0.72*0.5*18,250

1.2.4 Project Costs

An agreement with Peek Traffic of Palmetto, Florida, was entered, wherein they installed the system and analyzed the data at a fixed cost of $4,946 per camera per month for 6 months. The costs to the local police departments were limited to the time for verifying the infractions, researching the Department of Motor Vehicle data, entering the data into the system, and sending out letters to the violators.

1.2.5 Operation of System

The photo enforcement system is activated if a vehicle is expected to enter the intersection 0.2 seconds or more into the red phase and with a speed of at least 13 mph. A digital photograph is taken in the direction the vehicle is traveling, i.e. showing the rear of the vehicle, at a location where it still has not entered the intersection. The vehicle is then tracked by a radar system that at these locations was installed so that the vehicle was tracked from the front. A second digital photograph is taken a short while later showing whether the vehicle proceeded through the intersection or not during the red phase. A 10-second video sequence—5 seconds before the first photograph and 5 seconds after—is also stored digitally. These photos were broadcast by high-speed internet connection to Peek's office in Florida for analysis. Once a vehicle had been determined to have run a red light, the license-plate number was identified and all the information—with photos—was sent to the police in the town where the violation occurred. After the violation had been verified and registration information had been obtained and entered into the system, a warning letter was mailed to the registered owner of the vehicle. Owners of vehicles registered in other states were not contacted. System operational parameters and specifications can be summarized as:

> The selected vendor's system uses approach speed to determine if a vehicle is unlikely to stop. If such is the case, a digital photograph is taken of the rear of the vehicle prior to the vehicle crossing the stop bar. A second photo is taken of the vehicle about halfway through the intersection. An optional video was included to allow police to review extenuating circumstances prior to determining if a red light running offense had occurred.
>
> The system was set to capture violators as those who had an approach speed of at least 13 miles per hour and at least 0.2 seconds into the traffic signal red phase.
>
> The vendor operated and maintained his equipment, and the cities were responsible for the proper operation of traffic signal and communications equipment.
>
> The vendor reviewed all captured events and forwarded to the respective police department only those photos that were legible. City police officers downloaded the candidate files and then reviewed these potential cases to determine if a true violation had occurred. Right turns on red were categorically excluded.
>
> City police obtained vehicle owner information through the Bureau of Motor Vehicles from the license plate numbers and issued warning letters to the registered owners

1.3 Study Periods

The automated enforcement period spanned December 10, 2004 to June 14, 2005.

The bulk of the manual before studies were carried out in June and early July 2004. However, the intersection of East Avenue and Pleasant Street was studied in August 2004 since there was road construction interfering with the flow of traffic at this location in June and July.

The manual 'after' studies were completed between April 1 and May 10, 2005. Each approach was observed for 360 minutes (six hours), covering low, medium and busy times of the day—on weekdays (Monday through Friday lunch). The typical location study times were: 9:00-10:30, 11:00-12:30, 2:00-3:30 and 4:00-5:30. Traffic counts were taken and observations of green and cycle times were made during the above listed observation periods if workload allowed. Otherwise, this information was gathered adjacent to but outside the 360 minutes of observation time.

1.4 Collection of Other Material than Automatic Enforcement Data

Crash data was obtained from Maine Department of Transportation.

Traffic conflict data and other observations were collected through visual observations for a minimum of 360 minutes for each site before and 360 minutes four to six months after the photo-enforcement system was installed—while it was still in operation. The studies covered low volume, medium volume and high-volume times of the day. The 'after' studies—from here on typically referred to as 'during' studies—were done after media coverage to ensure that a majority of people knew the system had been installed. That people actually knew about the system has not been verified through formal surveys.

1.4.1 Traffic counts

Vehicle volumes for mainline AADT have been obtained from Maine Department of Transportation's website as discussed in Section 1.2.3. Turning movements (percent vehicles turning in different directions) were obtained from actual counts at the locations as described here. Vehicle flows were counted at least twice during each 90-minute observation period. Counts were taken for a minimum of six minutes exactly (or 10 or 12 minutes), and then converted to vehicles per hour. Left turns, straight through, and right turns were counted separately. The table shown in Figure 10 was used.

Location:		Date:		
Time start: Time end:	= vph	Time start: Time end:	= vph	Comment
LT				
TH				
RT				

Location:		Date:		
Time start: Time end:	= vph	Time start: Time end:	= vph	Comment
LT				
TH				
RT				

Figure 10 Extract from traffic-count sheet

1.4.2 Signal Timing

Green and cycle times were measured for through movements and left-turn movements for the studied approaches. The green time may vary from cycle to cycle so this study was done multiple times for each 90-minute period. Part of the form used for collecting this data is shown in Figure 11.

Location:				Date:	Approximate time:
Green time	starts	ends	starts again	Seconds Green	Seconds cycle time
For LT					
For TH					
Location:				Date:	Approximate time:
Green time	starts	ends	starts again	Seconds Green	Seconds cycle time
For LT					
For TH					

Figure 11 Extract from signal-timing sheet

1.4.3 Red-Light Running Counts

Besides the automatic counts that were obtained through the surveillance system, limited manual counts were taken before the system was installed and during that time. The manual red-light running counts were taken for the entire 360 minutes as listed in Section 1.3, using the form shown in Figure 12.

Location: Date: Observation time (from – to):
Fill in observation time EVEN IF NO red-light runners

Time	Movement (check)			Seconds into red (check off)				Comments (for example relate it to a conflict on separate sheet or note if high speed etc)
	LT	ST	RT (if high speed)	just at red	0.1-0.5 sec	0.6-1.5 sec	1.5 sec +	

Figure 12 Extract from red-light running sheet

1.4.4 Traffic Conflict Studies

A special conflict observation sheet was developed for this study. It is shown in Figure 13.

Conflict at location: ……………………………………………. at date: …….. time: ……..

Red-light running vehicle involved: ☐ no ☐ yes, from studied approach ☐ yes, from other

Vehicle 1: ☐ car/SUV/pickup ☐ medium/full truck ☐ pedestrian ☐ other: …………………

Vehicle 2: ☐ car/SUV/pickup ☐ medium/full truck ☐ pedestrian ☐ other: …………………

Approximate speed Vehicle 1:……….mph Approximate speed Vehicle 2:……….mph

☐ None braked/swerved ☐ Veh 1 braked ☐ Veh. 1 swerved ☐ Veh 2 braked ☐ Veh 2 sw

The vehicles would have collided had vehicle not braked/swerved? ☐ yes ☐ no ☐ maybe

If none braked or swerved but they got close, estimate time margin they passed each other with

☐ <1 sec ☐ 1-2 seconds ☐ 2-3 seconds if more, no near-miss

Sketch of what happened: Description of what happened:

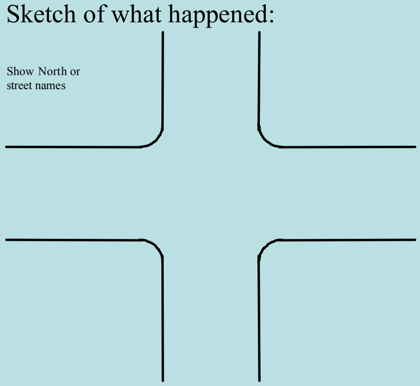

Figure 13 Traffic conflict observation sheet

2 Results Regarding Red-Light Running Frequencies

2.1 Visual Red-light Running Observations

Observations of red-light running frequencies were done visually for six hours at each site before the cameras were installed and towards the end of their installation period, in April 2005. As can be seen in Table 3, the overall number of infractions by through and left-turn vehicles was reduced from 108 to 97 (10.2% reduction) when all locations are added together. However, one location was changed between the before and after periods. The overall number was reduced from 88 to 83 (5.7% reduction) at the four locations that were studied in both periods. It can also be noted that it was only the minor infractions that were reduced. The number of infractions more than 0.5 seconds into the red was not changed. The reliability of these observations is not perfect since it is difficult for a human observer to judge if a vehicle enters 0.1 second before or 0.1 second after the red light comes on. Also, the 'after' studies were done by a different observer than the before studies. An advantage with this is that the person doing the 'after' study did not have any preconceived ideas about the frequency expectations. The disadvantage with using different observers is that the two people may systematically judge situations differently.

Table 3 Number of violations by red-light running vehicles per 360 minutes

Location	Before (June 2004)		During (April 2005)	
	0.0-0.5 sec	>0.5 sec	0.0-0.5 sec	>0.5 sec
Center St. at Stetson Rd./Joline Street, Auburn	11	17	8	14
Center St. at Turner St. and Union St. Bypass, Auburn	8	12	8	13
Minot at Elm, Auburn*	--	--	4	10
Russell Street at East Avenue, Lewiston	6	12	7	10
East Avenue at Bartlett/Pleasant Street, Lewiston	12	10	9	14
Court Street at Main Street, Auburn*	11	9	--	--
Total	48	60	36	61
Total for unchanged sites	37	51	32	51

* Court Street location was changed to Minot Avenue due to City concerns with disrupting a recently-completed sidewalk project.

2.2 Photo-Enforcement Data

Before calculating red-light-running frequencies, we need to establish how many hours of data were collected, and we should ensure that the system worked properly during those times. We know that the system for various reasons was not operational during certain 'downtimes.' Data provided by Peek regarding such 'downtimes' is presented in Table 4.

Prior to calculating red-light-running frequencies, the photo-enforcement data should probably also be analyzed to make sure the equipment was working properly during times not listed in the confirmed downtimes. The timeline plot—Figure 14—shows that at some locations there were periods without any recorded infractions and that some of those time periods are not included in Table 4. But before we go into an examination of this we will in a first analysis assume that the system never malfunctioned unless it was reported by Peek to have malfunctioned (as outlined in Table 4).

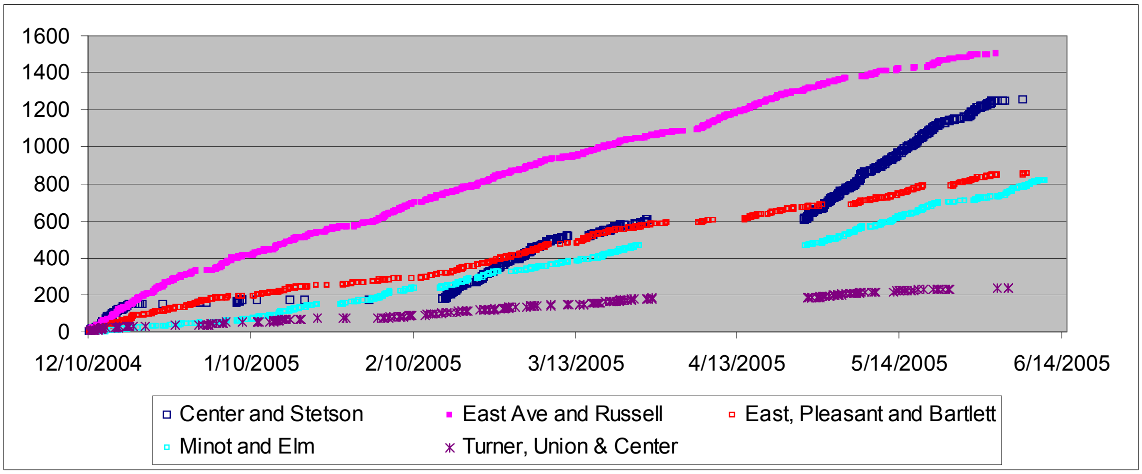

Figure 14 Timeline for accumulated number of infractions reported by site

In total, 4,665 violations were verified. The system itself, responded to 24,374 incidents but many of these incidents ended up not being violations or at least not verifiable violations. For example, all right-turning violations were excluded. But there were most likely also true violations that could not be verified, or in some instances may not even have been captured by the cameras.

Table 4 Verified downtimes

Date	Site	Downtime Hours	Reason For Downtime	Issue Related to
12/26/2004	Center @ Stetson	24	Router problems	Peek Equipment
1/13/2005	Center @ Stetson	72	RedLight Voltage Problems	City Equipment
1/18/2005	Center @ Stetson	24	RedLight Voltage Problems	City Equipment
1/21/2005	Center @ Stetson	120	RedLight Voltage Problems	City Equipment
1/28/2005	Center @ Stetson	24	Internet Connectivity Issue	Verizon Issue
2/3/2005	Center @ Stetson	24	RedLight Voltage Problems	City Equipment
2/5/2005	Center @ Stetson	72	RedLight Voltage Problems	City Equipment
3/13/2005	Center @ Stetson	48	Equipment related problems	Peek Equipment
3/23/2005	Center @ Stetson	24	Site Required Reset	Peek Equipment
3/26/2005	Center @ Stetson	728	Verizon bill not paid for service	City Issue
1/24/2005	Minot @ Elm	48	Router problems	Peek Equipment
2/6/2005	Minot @ Elm	24	Site Required Reset	Peek Equipment
2/12/2005	Minot @ Elm	48	Router Problems(Router Replaced)	Peek Equipment
3/26/2005	Minot @ Elm	730	Verizon bill not paid for service	City Issue
12/27/2004	Center @ Turner	24	Internet Connectivity Issue	Verizon Issue
1/21/2005	Center @ Turner	24	Internet Connectivity Issue	Verizon Issue
1/24/2005	Center @ Turner	48	Site Required Reset	Peek Equipment
1/29/2005	Center @ Turner	48	Site Required Reset	Peek Equipment
3/12/2005	Center @ Turner	24	Internet Connectivity Issue	Verizon Issue
3/28/2005	Center @ Turner	730	Verizon bill not paid for service	City Issue
1/21/2005	East @ Bartlett	24	Internet Connectivity Issue	Verizon Issue
1/25/2005	East @ Bartlett	48	Site Required Reset	Peek Equipment
2/8/2005	East @ Bartlett	24	Site Required Reset	Peek Equipment
3/31/2005	East @ Bartlett	72	Internet Connectivity Issue	Verizon Issue
4/3/2005	Russell @ East	24	Internet Connectivity Issue	Verizon Issue
5/2/2005	East @ Bartlett	98	Sensor required reset	Peek Equipment
6/13/2005	Center @ Stetson	165	Internet Connectivity Issue	Peek Equipment
6/13/2005	East @ Bartlett	122	Equipment related problems	Peek Equipment
6/13/2005	Russell @ East	196	Internet Connectivity Issue	Peek Equipment
Total	All Sites	3681	--	--

2.3 Analysis Assuming System Always Functioned Properly

This analysis assumes that the system never malfunctioned unless it was reported by Peek to have malfunctioned—as originally reported in July 2005. (An analysis taking later information from Peek into account is presented on page 37.) Table 5 shows that the average number of infractions varied between 0.07 per hour (1.6 per day) at Center Street and Turner Street/Union Street Bypass to 0.41 per hour (9.8 per day) at Center St. and Stetson Rd./Joline St.

Table 5 Automated Red-light running frequencies

Location	Confirmed* red-light running incidents (Dec 10, 2004 – June 10, 2005)		Reported 'downtime' (hrs)	Operational time (4392 hours minus 'downtime')	Average number of infractions per operational hour
	0.2-0.5 sec	>0.5 sec			
Center St. at Stetson Rd./Joline St	525	725	1325	3067	0.41
Center St. at Turner St. and Union	112	123	898	3494	0.07
Minot at Elm	297	525	850	3542	0.23
Russell Street at East Avenue	718	785	220	4172	0.36
East Avenue at Bartlett/Pleasant St.	437	418	388	4004	0.21
Total	2089	2576	3681	18279	0.26

* Referred to as closed in the data file provided by Peek (i.e. offence confirmed by police)

2.3.1 Daily and Monthly Variations

To try to identify if the rate of infractions varied between the early, middle and late months of the experiment one can visually inspect Figure 14. However, this does not yield clear indications of whether infraction rates were reduced over the program or not. For Russell Street at East Avenue, it looks like the rate was higher for the first few weeks than later on. For the other four sites, it is hard to distinguish such a change.

The numbers of infractions for each location separately are shown in the Figures below—Figure 15 through Figure 19.

A visual examination of Figure 15, Center Street at Stetson, suggests that the infraction rate may have gone up with time. A visual inspection of Figure 16, Russell Street at East Avenue, indicates rather the opposite, that we over time see a decrease in infraction rate. The same may be the case for Center Street at Turner/Union, Figure 19, while such trends cannot be seen for the other two locations.

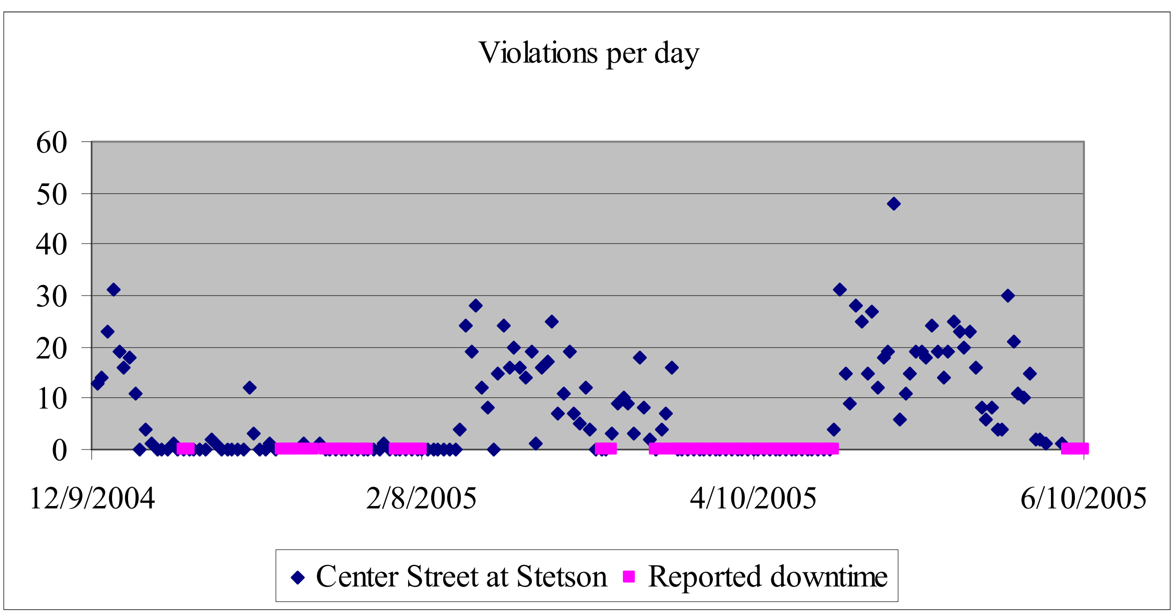

Figure 15 Center Street at Stetson Road/Joline Street, Auburn

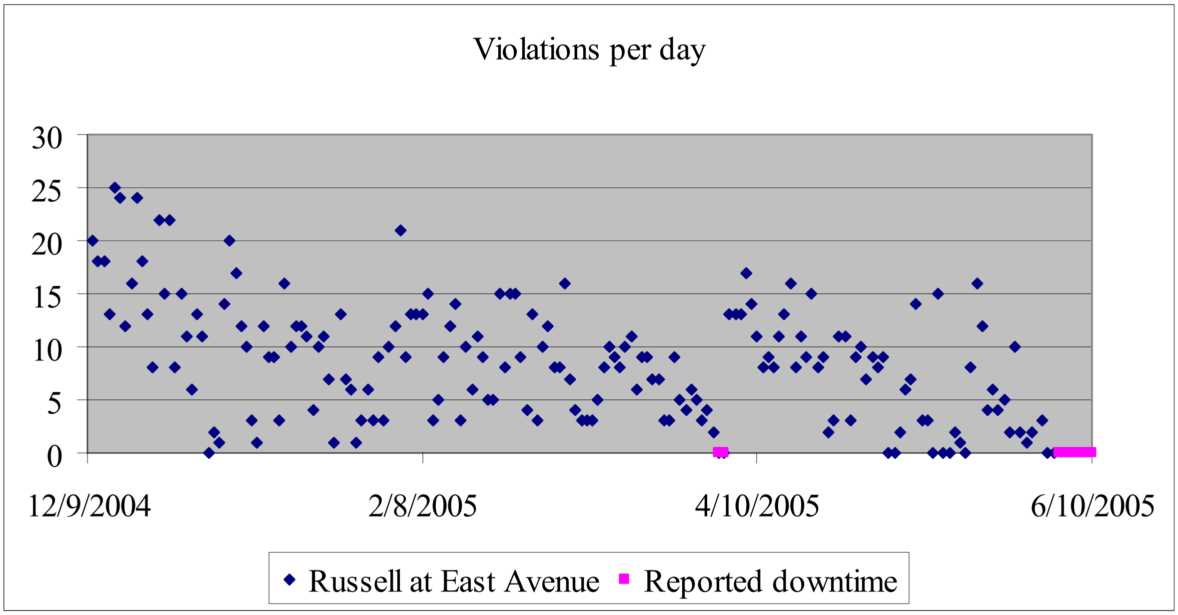

Figure 16 Russell Street at East Avenue, Lewiston

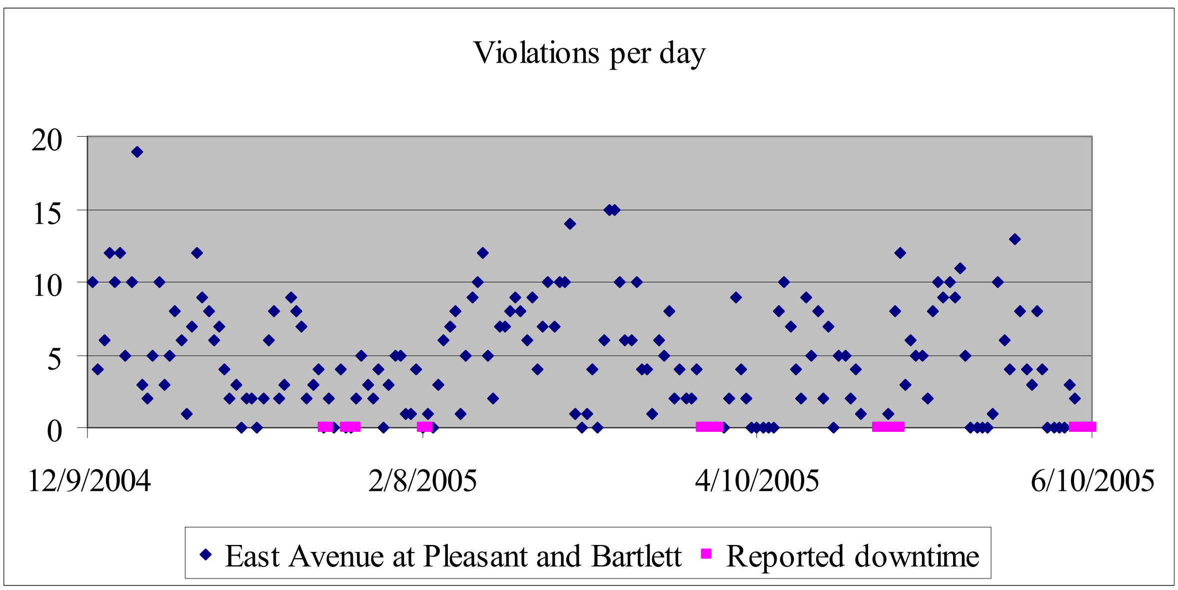

Figure 17 East Avenue at Pleasant Street and Bartlett Street, Lewiston

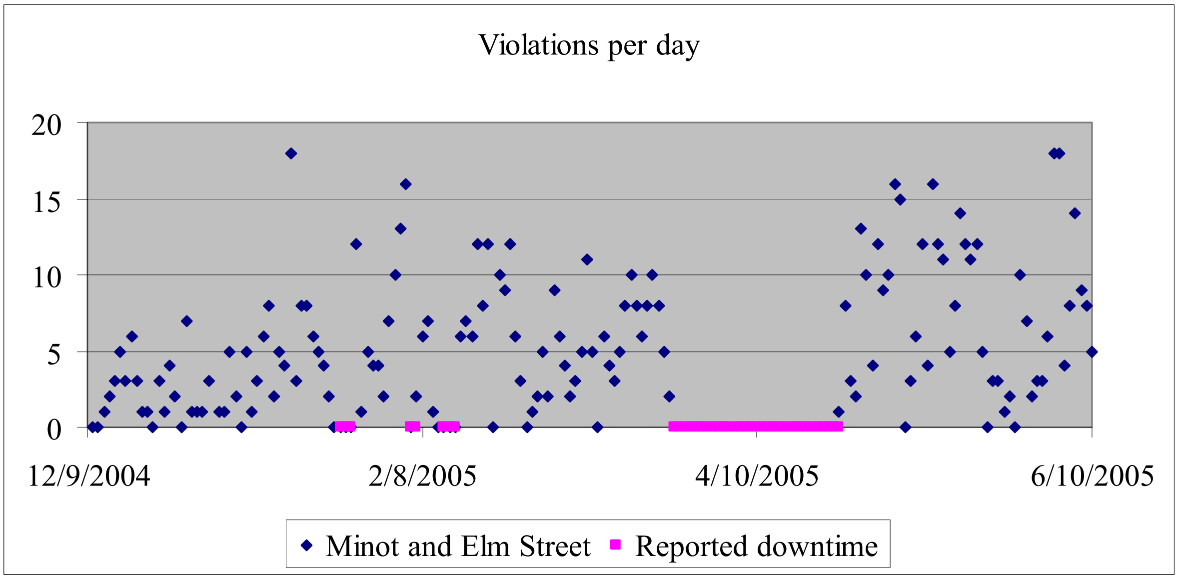

Figure 18 Minot Avenue at Elm Street, Auburn

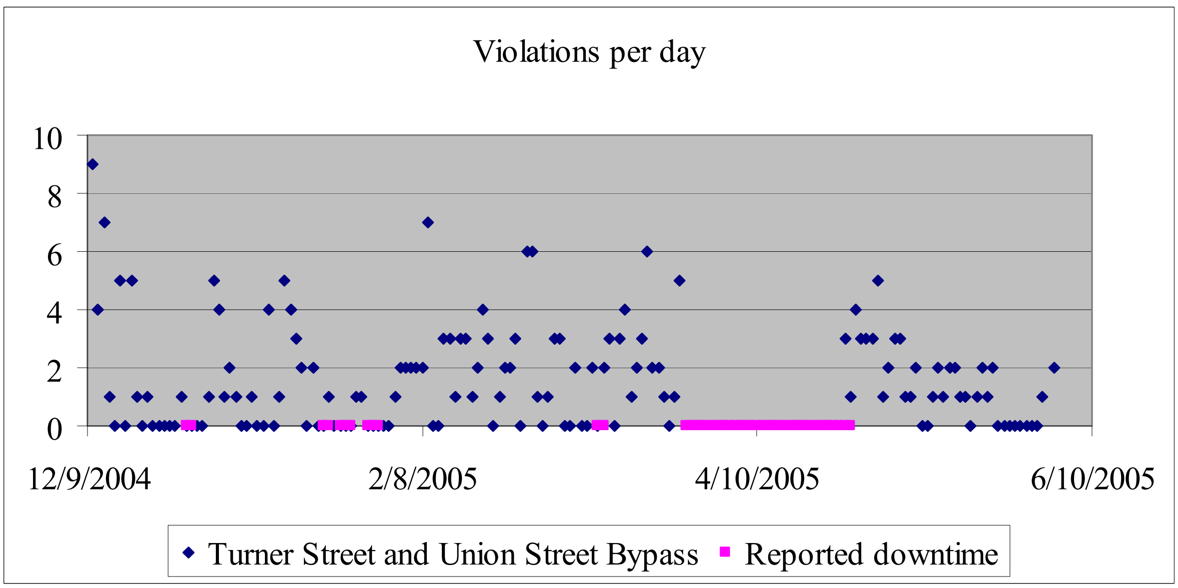

Figure 19 Center Street at Turner Street and Union Street Bypass, Auburn

Figure 20 shows trends by taking out days when the system was reported as down, and then looking at the trends for each individual site—and all sites added together—through linear-regression where the x-axis is the study day numbered from the first day of observations. Locations that had more outages will therefore have fewer observation days, and the lines therefore end at different 'days' even though all sites were monitored until early June.

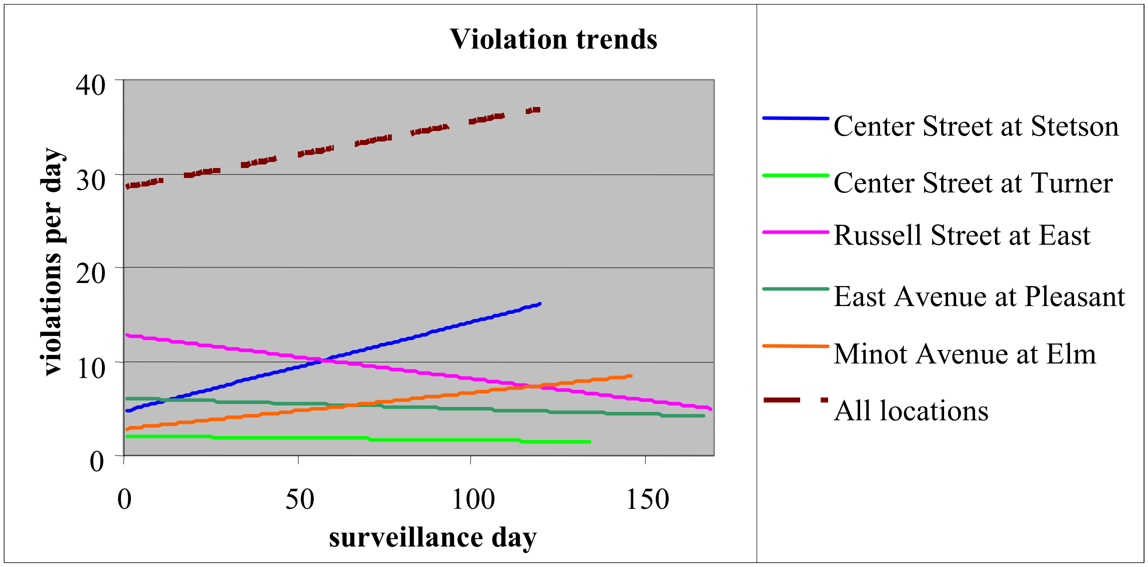

Figure 20 Violation trends for the five locations

It is clear from Figure 20, that Russell Street at East Avenue saw a clear reduction in infraction rate over time whereas Center Street at Stetson Road/Joline Street and Minot Avenue at Elm Street saw clear increases in infraction rates. A linear regression for the infraction rates for the five sites added together shows that the infraction rate went from around 28 per day in mid December 2004 to 37 per day in early June 2005—an increase of around 32%. It should be noted, however, that these results are based on the assumption that the surveillance system worked equally well all days when the system was not reported to have been down. Peek gave additional information about outage times after this analysis was completed, stating that the Center Street at Stetson data from prior to February 15 was not reliable. A new analysis taking this into account is presented on page 37. There is also an alternative analysis, starting on page 39, with assumptions that give somewhat different results.

2.3.2 Time of Day

Whether the system was malfunctioning during certain days or not is of little interest when analyzing how the number of infraction varied with time of day, as long as the system did not systematically work better during some daylight (temperature or other environmental) conditions than others. Figure 21 shows results for the five locations combined. It can be seen that infractions are common throughout the day, especially between 10 AM and 7 PM, during which time 68% of the infractions occurred. Only 4% occurred between 10 PM and 6 AM. It should be noted that one of the intersections—Center Street at Stetson—has flashing yellow/red lights between midnight and early morning.

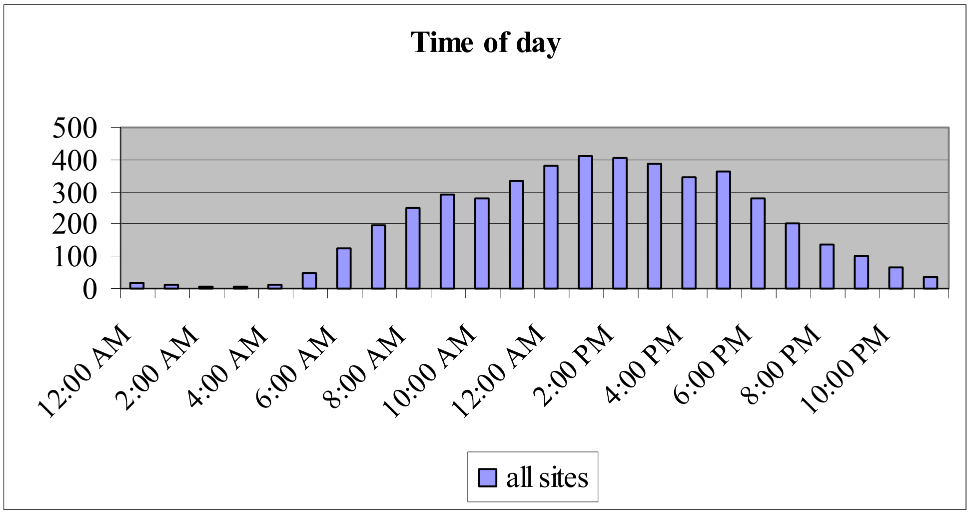

Figure 21 Violations by time of day

2.3.3 Day of Week

An analysis of weekday, as illustrated in Figure 22, shows that Friday had the most infractions with 19.4% of all reported infractions. Sunday has the fewest with 11.4%. All other days had roughly the average 14.3% or 666 infractions per day.

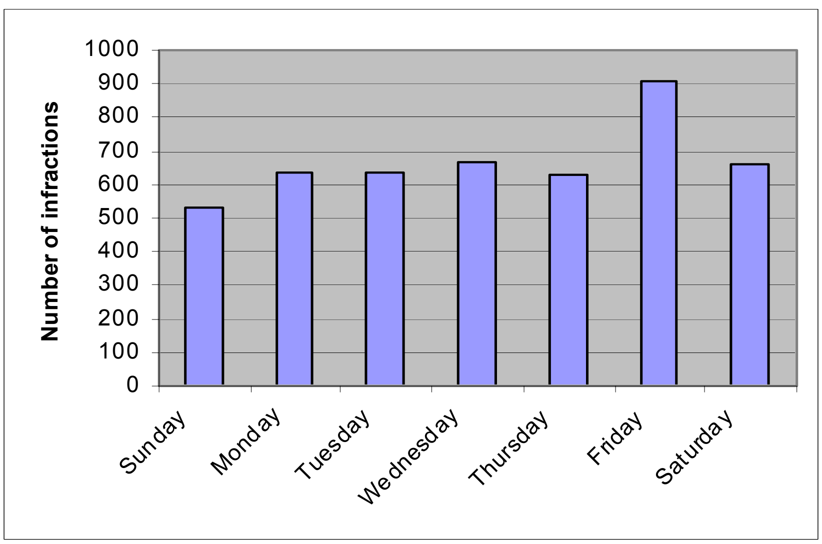

Figure 22 Infractions by day of week

2.3.4 Severity of Infractions

Table 6 shows the overall frequency of infractions by severity for the five locations combined for the entire six-month period. We can see that most of the infractions occurred at speeds above 30 mph even though the speed limit at each site is either 25 or 30 mph. We can also see that a high percentage of the high-speed infractions occurred more than one second into the red phase producing high risks of injury crashes.

Table 6 Speed and infraction times, all locations, all months

	13-20 mph	21-25 mph	26-30 mph	31-35 mph	36-40 mph	41+ mph	sum
0.2-0.5 sec	28	100	249	680	672	360	2089
0.6-1.0 sec	13	61	149	403	471	280	1377
1.1-2.0 sec	18	38	74	221	280	181	812
2.1-3.0 sec	5	13	24	34	28	23	127
3.1-5.0 sec	5	8	20	11	10	9	63
5.1-10.0 sec	4	6	21	17	9	6	63
10.1+ sec	11	10	27	44	32	10	134
sum	84	236	564	1410	1502	869	4665

Table 7 and Table 8 have been produced to see if there is a difference between the infraction frequencies and infraction severities of the first month (December 10, 2004 through January 9, 2005—a period before any letters were issued and media had made drivers aware of the photo-enforcement activity) and the last month (May 11 through June 10, 2005).

Table 7 Speed and infraction times, all locations, first month

	13-20 mph	21-25 mph	26-30 mph	31-35 mph	36-40 mph	41+ mph	sum
0.2-0.5 sec	7	25	63	145	126	55	421
0.6-1.0 sec	4	12	38	99	90	36	279
1.1-2.0 sec	5	11	18	41	47	26	148
2.1-3.0 sec	0	2	4	6	6	2	20
3.1-5.0 sec	1	1	3	2	0	0	7
5.1-10.0 sec	0	0	2	1	1	0	4
10.1+ sec	2	1	2	3	1	1	10
sum	19	52	130	297	271	120	889

Table 8 Speed and infraction times, all locations, last month

	13-20 mph	21-25 mph	26-30 mph	31-35 mph	36-40 mph	41+ mph	sum
0.2-0.5 sec	3	9	22	96	124	94	348
0.6-1.0 sec	0	6	15	65	75	70	231
1.1-2.0 sec	1	4	12	37	54	42	150
2.1-3.0 sec	0	0	2	2	10	5	19
3.1-5.0 sec	1	0	5	2	2	2	12
5.1-10.0 sec	0	1	5	6	1	3	16
10.1+ sec	3	3	8	15	12	5	46
sum	8	23	69	223	278	221	822

There were somewhat fewer infractions given out in the last month (822 is marginally significantly less than 889, p=0.055) but this is primarily caused by more outage times during the latter period—and these tables are not adjusted for that. There is certainly no tendency towards the infractions being less serious during the last month compared to the first month. Rather, high-speed infractions—above 40 mph—have clearly increased (p=0.00000002) in frequency and the number of infractions that are more than 2 seconds into red has also increased (from 41 to 93) significantly (p=0.000004). However, weather conditions (winter at beginning of study vs. summer at end) may be partially (or fully) responsible for this change. Also, the equipment possibly malfunctioned at times even when it operated to some extent, and it is possible that it had different probabilities to pick up low-speed situations at some times compared to other times. (Complete downtimes when no infractions were picked up obviously do not bias these comparisons.)

We could postulate a theory that drivers at first were unaware of the system, then noticed it and became more careful not to run red lights, but then later realized that only warnings were given out and became less cautious again. If this theory is accurate, we would expect to see a dip in frequency (and severity) in the middle of the six-month study period. The middle 30-day period consists of the days February 23 through March 24, 2005. Table 9 shows the results from this period.

Table 9 Speed and infraction times, all locations, February 23 – March 24

	13-20 mph	21-25 mph	26-30 mph	31-35 mph	36-40 mph	41+ mph	sum
0.2-0.5 sec	10	34	76	213	183	92	608
0.6-1.0 sec	5	15	49	113	157	86	425
1.1-2.0 sec	7	9	17	54	75	57	219
2.1-3.0 sec	0	6	9	13	3	6	37
3.1-5.0 sec	2	2	5	4	4	4	21
5.1-10.0 sec	3	0	1	3	4	2	13
10.1+ sec	5	4	5	12	6	0	32
sum	32	70	162	412	432	247	1355

It can be seen that the overall number of recorded violations were higher during the middle month than in the beginning or end of the experiment. However, this is to some extent a result of the equipment working better during the middle period. The best estimate of the actual number of violations by site can be seen in Figure 29 on page 39. However, the severity during the last month was higher (higher speeds and further into the red-phase) than in the middle month. Speeds of red-light running drivers were similar during the first month and the middle month whereas infringement times, on average, had become longer in the middle month compared to the first month. Had fines been given out, the effect may have been very different.

Figure 23 shows percent violations (by day) that are 1.1 seconds or longer out of all violations (0.2 seconds or greater). There is not any clear time trend though the percentage (1.1 seconds or longer) seems to be somewhat lower during the first few weeks compared to later time periods. Figure 24 shows the variation in percentage of violations that are 3.1 seconds or longer—the ones that occurred well into the green phase of conflicting traffic. Figure 25 shows the percent of violations that occurred at speeds of 36 mph or higher. Here we can see a clear trend over time towards an increasing percentage of the incidents being serious. Finally, Figure 26 combines speed and infraction time and shows the ones were a high risk of collision seem obvious, where people enter a red light at speeds of 36 mph or higher when the light has been red for a minimum of 3.1 seconds. The linear regression line here clearly shows a trend towards the situations becoming more serious over time.

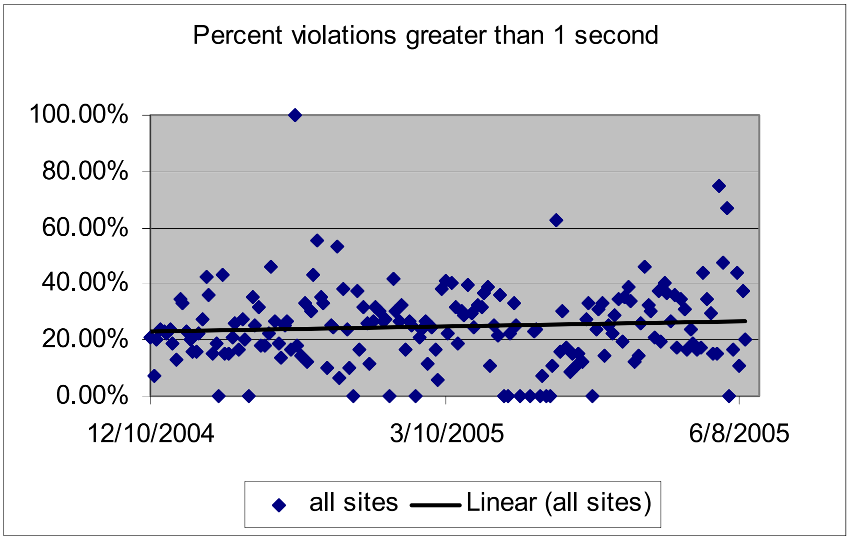

Figure 23 Percent violations greater than one second by day, linear regression

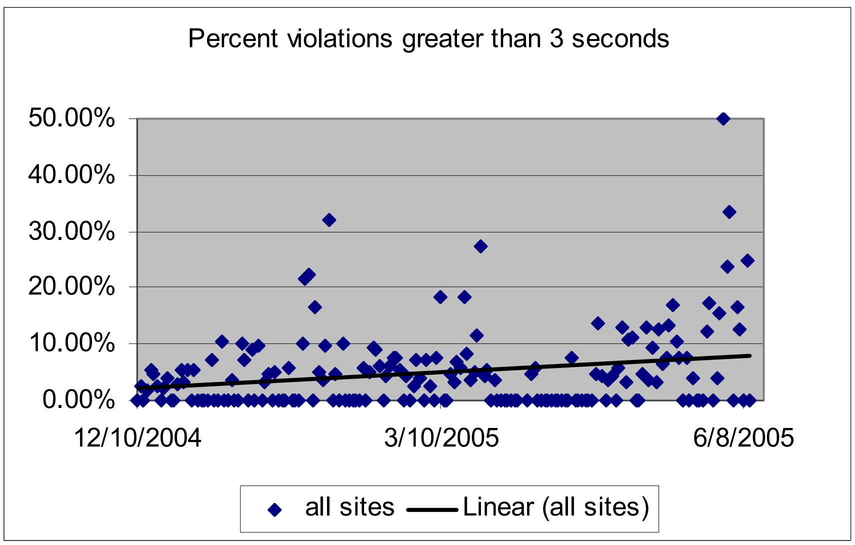

Figure 24 Percent violations greater than three seconds by day, linear regression

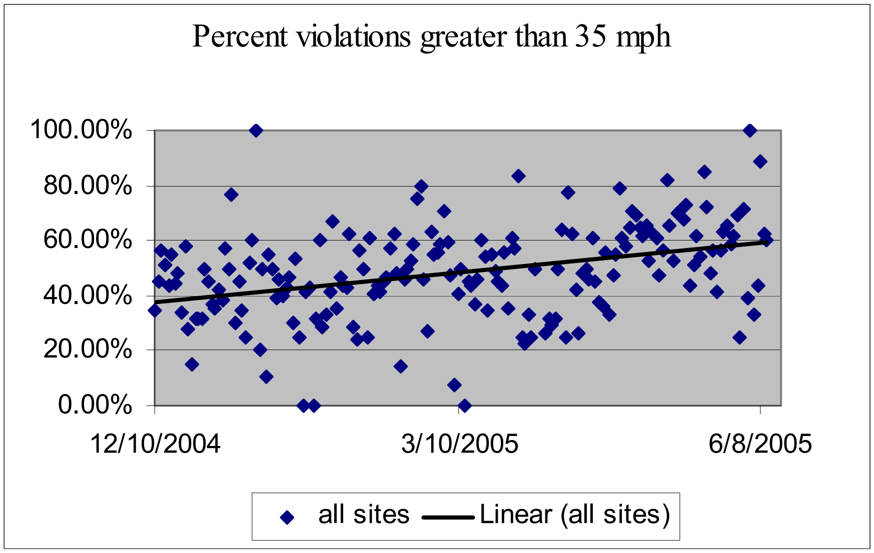

Figure 25 Percent violations at speeds above 35 mph by day, linear regression

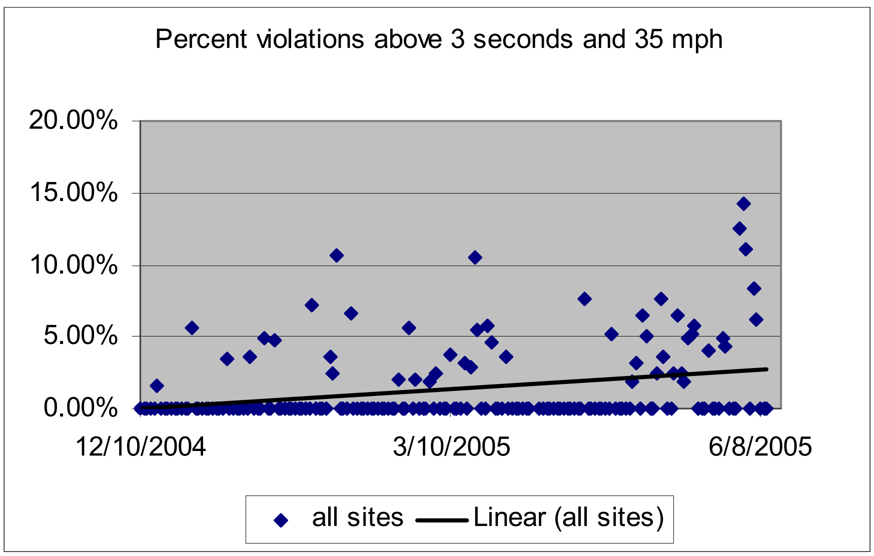

Figure 26 Percent violations more than 3 seconds into red and above 35 mph

In conclusion, the number of infractions increased over the months that the system was active (at least for the average of all sites combined), and the severity of the infractions increased significantly. Below follows an alternative analysis where it is assumed that the system at times may have malfunctioned even when the provider was not aware of it.

2.4 Analysis Taking Newer Information from Peek into Account

Information presented in a letter from Peek in August 2005 after the primary analyses were done states that with respect to Stetson and Center Street, all data prior to February 15 should be neglected. A new plot of the data, excluding days when the system was non-operational, now shows that there was no trend towards an increasing infraction rate at that location, see Figure 27.

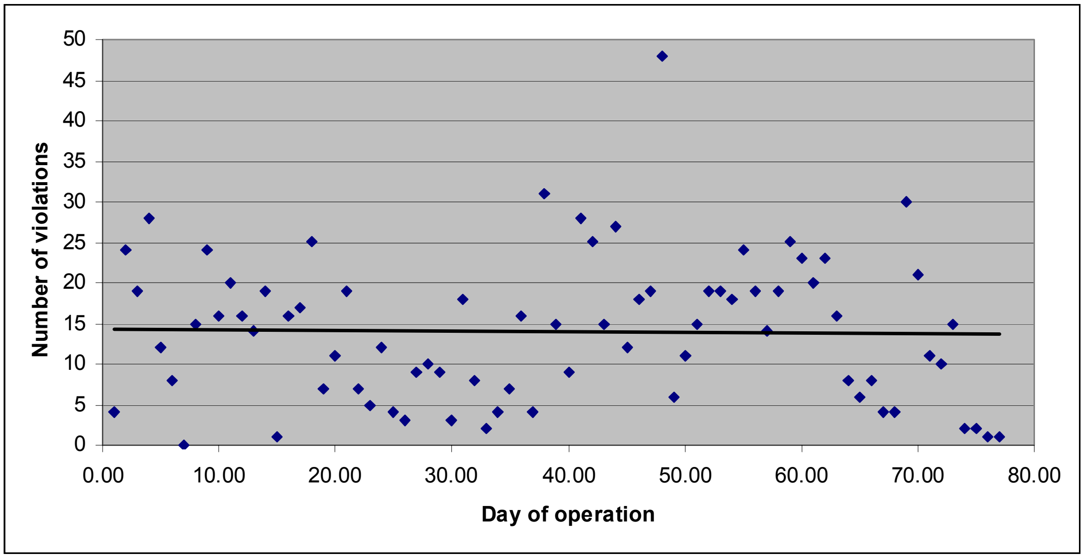

Figure 27 Violations per day at Center Street and Stetson/Joline with new information

With this added information, infraction numbers per month have been recalculated for all the locations, and are presented in Table 10 and summarized graphically after that.

Table 10 Infractions per day by the month according to Peek's final numbers

	Center St. at Stetson		Center St. at Turner/Union		Minot at Elm		Russell Street at East Avenue		East Avenue at Bartlett/Pleasant	
December	--*		35/21=	1.7	48/22=	2.2	332/22=	15.1	167/22=	7.6
January	--*		38/26=	1.5	123/29=	4.2	255/31=	8.2	102/28=	3.6
February	219/14=	15.0	61/28=	2.2	156/25=	6.2	280/28=	10.0	142/27=	5.3
March	213/22=	9.7	47/27=	1.7	137/25=	5.5	214/31=	6.9	178/28=	6.4
April	108/5=	21.6	14/5=	2.8	37/6=	6.2	268/29=	9.2	96/29=	3.3
May	527/31=	17.0	37/31=	1.2	228/31=	7.4	151/31=	4.9	161/29=	5.6
June	6/4=	1.5	2/14**=	0.1	93/14^=	6.6	3/6^^=	0.5	9/9^*=	1.0

* no data collected

** no infractions collected for last 12 of the 14 days

^ no infractions collected for the last 4 of the 14 days

^^ there were no infractions recorded after June 1 at this location

^* there were infractions recorded only during three of the days in June

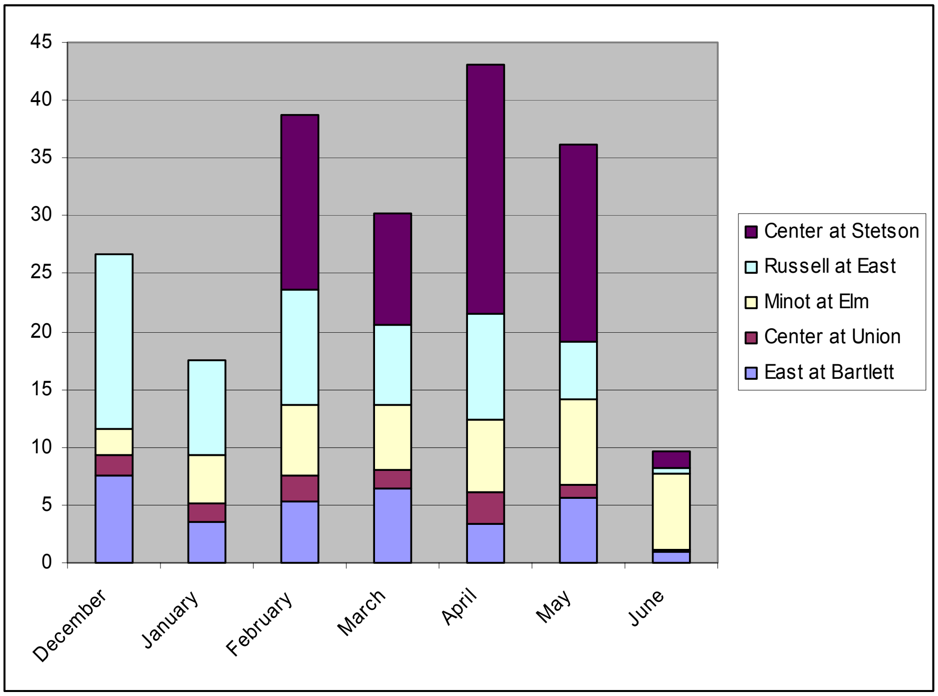

Figure 28 Infractions per day for days observed according to Peek

Since June had few days that were covered according to Peek, and many of the covered days had zero reported violations, the data is also shown for December through May, see Figure 29.

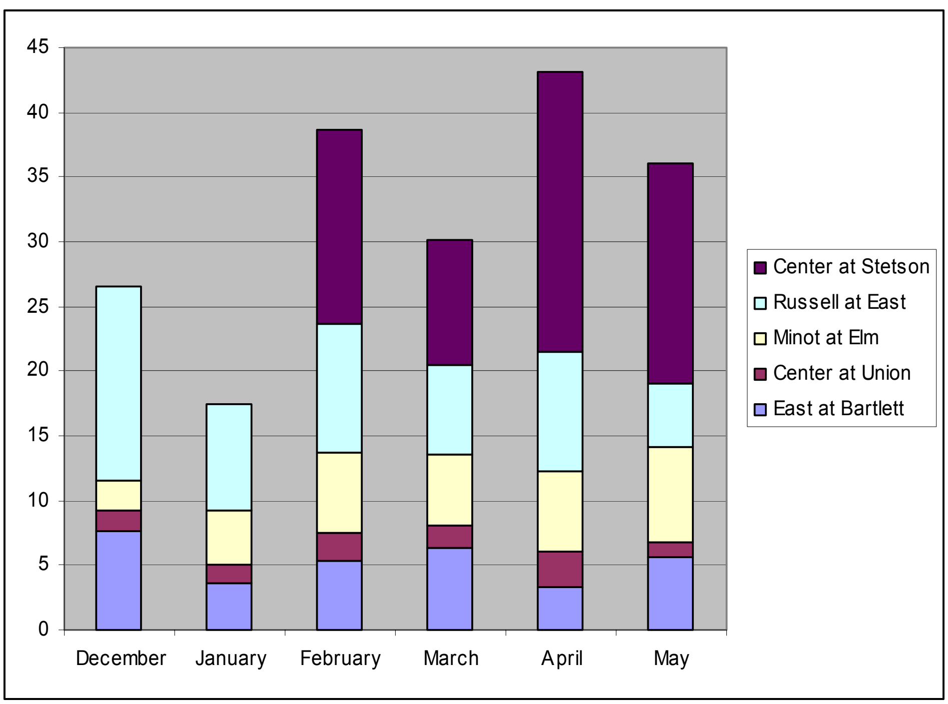

Figure 29 Infractions per day for days observed according to Peek excluding June 2005

Figure 29 indicates that December had the highest infraction rate and that—if we exclude January as well as the intersection between Center Street and Stetson Avenue—the number of infractions per day decreased gradually from around 26.6 per day in December 2004 to around 19.1 per day in May 2005—a 28% decrease.

2.5 Alternative Analysis—Assuming More Downtimes

Based on the average number of infractions per site and day, one might expect at least one infraction per day for each of the locations. However, if we look at the dates when none of the five locations had any time periods of 24 hours or longer without any infractions, we get data from only nine days. Those days were Wednesday February 16 when the five locations combined had 49 infractions, Friday March 4 with 52, Saturday March 19 with 29, Sunday March 20 with 40, Monday March 21 with 35, Tuesday March 22 with 22, Wednesday March 23 with 23, Wednesday April 27 with 24, and Thursday April 28 with 28. Besides noting that three of the days had the same number of infractions as the day of the month, it seems like there may be a trend from more infractions in February and early March to fewer later on. However with these few days with the equipment definitely operational at all sites it is difficult to draw any conclusions with respect to trends.

As earlier pointed out, the numbers of infractions for each location separately are shown in Figure 15 through Figure 19. There seems to be day-to-day variations that are much greater than random. That the true variation from day to day is much greater than random can obviously be considered as reasonable. The variation may, for example, depend on weather conditions and also vary considerably with day of the week. In addition, if a police car happens to be parked at the intersection, one would expect very few if any infractions on such days. The true variation could in theory also be smaller than random if there is a small number of people always running the red light whenever they get the opportunity.

Figure 30 shows an alternative attempt to quantify trends by taking out days when the system was reported as down or when there were no reported infractions, and then looking at the trends for each individual site with the x-axis being observation day numbered from the first day of observations. Locations that had more outages will have fewer observation days, and the lines therefore end at different 'days' even though all sites were monitored until early June, just like in Figure 20.

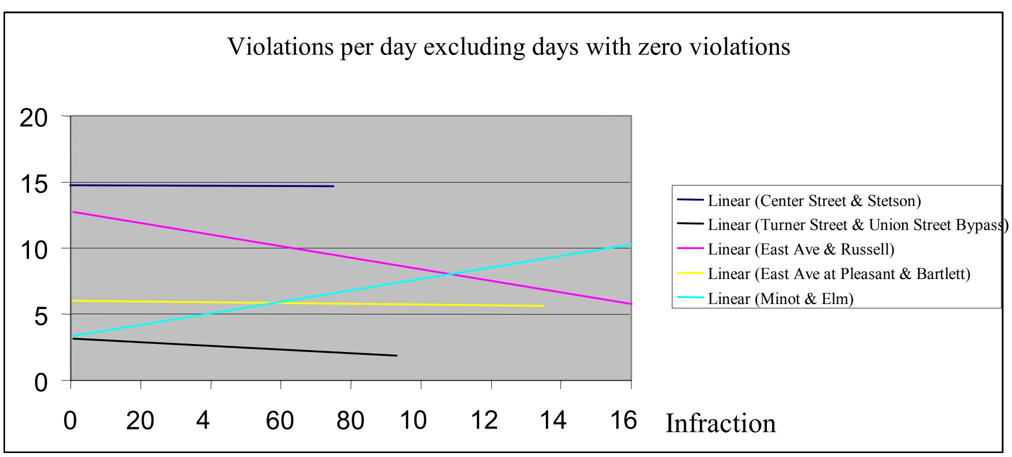

Figure 30 Violation trends for the five locations excluding days with zero infractions

The results are not drastically different than those found in Figure 20 on page 32. However, there is now a slight trend towards a decrease in the number of infractions. The textbox below shows what periods have no reported infractions.

> Periods longer than 24 hours without any infractions can be noted at *Center at Stetson* from 12/17/04 at 9:10 PM until 12/19/04 at 1:31 PM, from 12/20/04 8:06 AM until 12/24/04 10:03 AM, from 12/24/04 at 10:03 AM until 12/31/04 9:41 AM, from 12/31/04 11:16 AM until 1/1/05 3:25 PM, from 1/1/05 3:25 PM until 1/7/05 7:33 AM, from 1/11/05 9:45 AM until 1/17/05 3:40 PM, from 1/17/05 3:40 PM until 1/20/05 10:17 AM, from 1/20/05 10:17 AM until 2/1/05 7:34 PM, from 2/1/05 7:34 PM until 2/15/05 6:19 PM, from 2/20/05 3:32 PM until 2/22/05 7:01 AM, from 6/1/05 7:34 AM until 6/2/05 5:25 PM, from 6/3/05 8:24 AM until 6/6/05 6:41 PM, and 6/6/05 6:41 PM until the end of the study period on 6/10/05.
>
> Periods longer than 24 hours without any infractions can be noted at *Russell* at *East Avenue* from 12/30/04 3:32 PM until 1/1/05 2:02 PM, from 1/1/05 2:32 PM until 1/2/05 4:37 PM, from 1/8/05 12:43 PM until 1/9/05 2:55 PM, from 1/22/05 5:48 PM until 1/23/05 9:32 PM, from 1/28/05 4:02 PM until 1/29/05 5:45 PM, from 2/10/05 10:29 AM until 2/11/05 3:05 PM, from 2/14/05 5:00 PM until 2/15/05 7:41 PM, from 3/8/05 2:41 PM until 3/9/05 9:29 PM, from 4/2/05 5:47 PM until 4/5/05 4:52 AM, from 5/3/05 7:16 PM until 5/6/05 6:47 PM, from 5/11/05 12:19 PM until 5/13/05 9:04 AM, 5from /13/05 8:09 PM until 5/16/05 5:39 PM, from 5/17/05 4:09 AM until 5/19/05 6:57 AM, from 5/24/05 8:34 AM until 5/25/05 8:45 AM, from 5/25/05 4:52 PM until 5/26/05 5:28 PM, from 5/29/05 12:10 AM until 5/30/05 10:27 AM, from 5/30/05 11:31 PM until 6/1/05 8:45 AM, and from 6/1/05 11:44 AM until the end of the study period on 6/10/05.
>
> Periods longer than 24 hours without any infractions can be noted at *East Avenue at Pleasant/Bartlett Street* from 1/5/05 7:52 PM until 1/7/05 3:23 PM, from 1/8/05 1:09 PM until 1/10/05 2:32 PM, from 1/18/05 5:34 PM until 1/19/05 6:13 PM, from 1/20/05 8:47 PM until 1/22/05 1:02 PM, from 1/22/05 3:01 PM until 1/24/05 3:12 PM, from 1/24/05 5:32 PM until 1/27/05 3:37 PM, from 1/31/05 2:46 PM until 2/2/05 10:42 AM, from 2/5/05 12:25 PM until 2/6/05 12:43 PM, from 2/7/05 9:15 AM until 2/9/05 5:08 PM, from 2/9/05 5:08 PM until 2/11/05 12:58 PM, from 3/8/05 6:46 AM until 3/10/05 8:29 AM, 3/10/05 8:29 AM, until 3/11/05 1:25 PM, from 3/11/05 6:08 PM until 3/13/05 8:52 AM, from 3/17/05 2:23 PM until 3/18/05 2:55 PM, from 3/28/05 9:27 AM until 3/29/05 12:45 PM, from 3/30/05 3:36 PM until 4/5/05 12:20 PM, from 4/8/05 12:01 PM until 4/14/05 8:01 AM, from 4/17/05 1:59 PM until 4/18/05 6:14 PM, from 4/23/05 8:34 PM until 4/25/05 7:40 AM, from 4/29/05 6:01 AM until 5/4/05 8:32 PM, from 5/10/05 7:05 PM until 5/11/05 8:43 PM, from 6/1/05 3:50 PM until 6/6/05 12:40 PM, and from 6/7/05 10:43 AM until the end of the study period on 6/10/05.

2.5.1 Missed Observation Periods

If there is a ‘long’ gap between two recorded infractions, is it because no one ran a red light during this period or because the equipment malfunctions? If Peek reported a problem, then we know that the equipment did not function but how do we know that they caught all equipment problems? How likely is it that no one ran a red light in a 24-hour period? How likely is it that the system malfunctioned without Peek knowing about it?

To look at one example: Is it likely that there would be infractions at East Avenue and Pleasant/Bartlett Street on Monday, March 7 at 6:01 AM, 8:11 AM, 9:17 AM, 11:35 AM,

12:06 PM, 1:42 PM, 1:46 PM, 2:56 PM, 3:34 PM, 5:26 PM, 5:30 PM, 5:37 PM, 8:15 PM, 9:59 PM and then again infractions about once an hour on Friday, March 11 starting in the early afternoon, but only one single infraction on Tuesday March 8 (at 6:46 AM), no infractions on Wednesday March 9 and only one infraction on Thursday, March 10 (at 8:29 AM) and no infractions on Friday morning? That could be possible—for example, because people are more in a hurry on Mondays and Fridays than other weekdays—but if we look at the following week, we note that there were 15 infractions recorded at that site on Tuesday, March 15 and ten on Wednesday, March 16. It may be that the equipment did not work properly from the early morning of Tuesday, March 8 until around noon on Friday, March 11. Still, there was one recorded infraction on Thursday, March 10. If using a 24-hour 'cut-off' we may conclude that the system worked if there is one infraction in the middle of a period when the system malfunctions. We could use even shorter periods than 24 hours as our criterion for malfunction.

Let us look at the location with the fewest infractions. That is the intersection of Minot and Elm Street. An example of the frequency of 'confirmed' photo-enforcement infractions from this location shows that there was an infraction at 8:22 PM on Tuesday May 3, 2005 and then the next one was at 8:52 the following morning followed by infractions at 10:19 AM, 10:26 AM, 11:29 AM, 2:21 PM, 2:50 PM, 2:57 PM, 3:22 PM, 3:52 PM, 5:28 PM, and then there was again a gap of about 12 hours until 5:45 AM on Thursday May 5, followed by infractions at 7:53 AM, 7:57 AM, 8:08 AM, 11:03 AM, 11:07 AM, 2:09 PM, 2:19 PM, 2:23 PM, 2:33 PM, 3:15 PM, 3:54 PM, 4:35 PM, 5:44 PM, 7:15 PM, 8:06 PM, followed by a gap of about 10 hours until 6:07 AM on Friday May 6. If we use gaps of 12 hours as an indication of malfunctioning, it seems likely that we may get false signals of malfunctions. However, during the days studied here, there were ten infractions on May 4 and sixteen on May 6. If we look at the week from Saturday, April 30 through Friday, May 6 for this intersection, we have a total of 76 infractions or 10.86 per day. If the number of infractions varied randomly around this number, the chance that we would have 0 infractions in a 24-hr period would be less than one in 50,000. If we studied the intersection with the least infractions, we would need to be there approximately 52,000 days (or 142 years) before we would expect to have no infractions in a 24-hour period. Even if the rate of infractions varies from day to day, and varies with weather conditions, it is very unlikely that there would be no infractions at any of these sites in a 24-hour period.

What about if the system functions with a reliability of around 50% or any other percentage? If the true number of infractions is twenty per day but only every second is recorded, then we would 'never' know, except that we could compare the photo observations to those in Table 3. It is likely, from the observations described above, that the system at times does not either function fully or not function at all. At times it seems to record only a fraction of the actual infractions—or possibly, the police or some other human intervener rejected cases so that all recorded infractions were not reported for this analysis.

The total study time, from December 10, 2004 just after midnight until June 10, 2005 just before midnight, would have encompassed 4392 hours for each location if the system had not malfunctioned at all. That means that we would have had 21,960 hours of observations in total. Table 11 shows likely malfunctioning times. The malfunctioning times reported by Peek add up to 3681 hours or 16.8% of the available time. However, as stated above, it is statistically very unlikely that there would be no infractions in an 18-hour period. Using this as the cutoff, means that the system malfunctioned during 11245 hours or 51.2% of the time.

Most likely, it also malfunctioned partially during other times. If we were to be more conservative, and use no infractions in a 24-hour period as our criterion for malfunction, the system would be completely out during 9461 hours or 43.1% of the time.

Table 11 Downtime estimates

Location	Reported down-time (hrs)	Total time with no in-fractions within 48 hrs (hrs)	Total time with no in-fractions within 24 hrs (hrs)	Total time with no in-fractions within 18 hrs (hrs)	Total time with no in-fractions within 12 hrs (hrs)
Center St. at Stetson Rd./Joline Street	1325	2355	2497	2622	2949
Center St. at Turner St. and Union St.	898	2426	2904	3396	3856
Minot at Elm	850	1156	1738	2193	2945
Russell Street at East Avenue	220	479	878	1107	2077
East Avenue at Bartlett/Pleasant St.	388	1015	1444	1927	2849
Total	3681	7431	9461	11245	14677

2.5.2 The Influence of Winter Weather

Speeds as well as traffic volumes may be influenced by weather conditions. Climatology data from the National Weather Service Forecast Office[2] in Gray was therefore gathered. Gray is located 16 miles away from the downtown areas of Lewiston/Auburn. Detailed data is presented in Enclosure A at the end of the report.

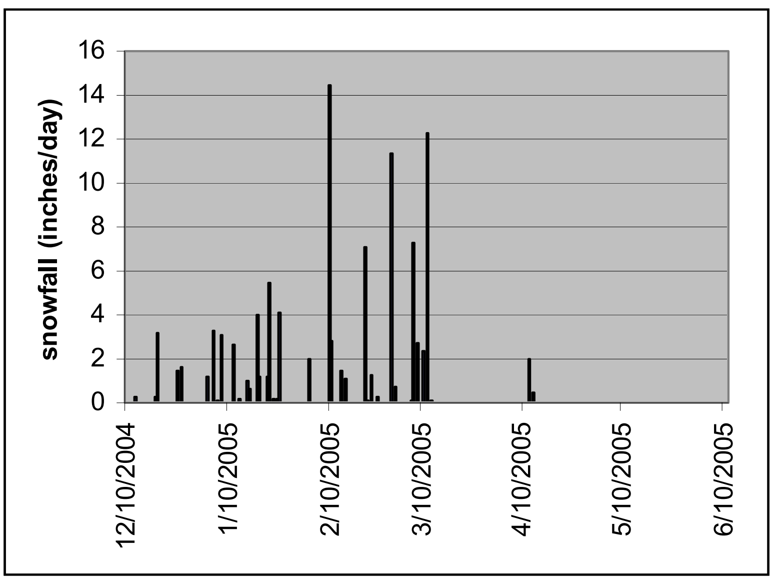

Figure 31 Snowfall amounts during study period

Analysis of red-light-running numbers for the four locations that had the system operating during the winter months, shows that for days with more than two inches of snowfall, the average number of vehicles running the light was 11.5 per day (as the sum of the four locations). That is clearly less than the average number of infractions for the winter months. However,

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[2] National Weather Service Forecast Office on 1 Weather Lane, Route 231, Gray, ME 04039 available at their website: http://www.weather.gov/climate/observed.php?wfo=gyx

the number of days with zero infractions at a given location does not seem to be overrepresented. In other words, the system seems to have operated during days with heavy snowfall, but either it missed some infractions or people were more cautious during days with heavy snowfall, and therefore ran the light less frequently these days.

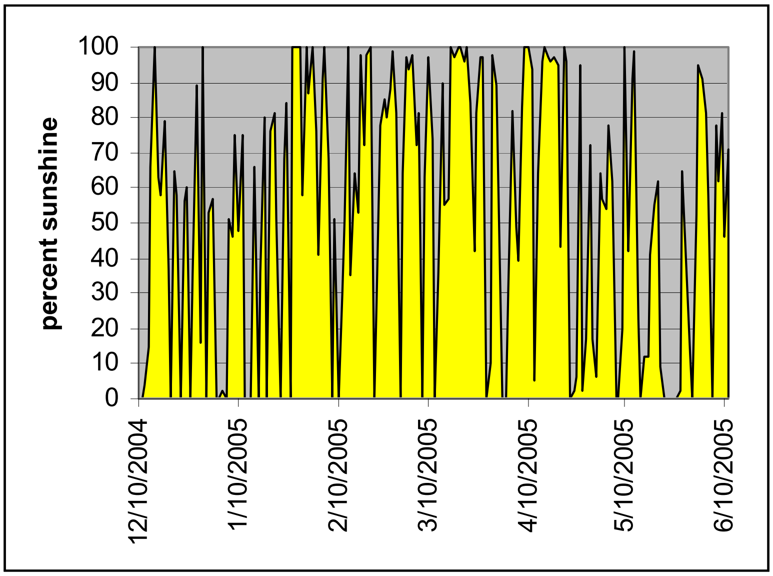

Figure 32 Percent of daylight hours with sunshine/clear sky

No attempts have been done to correlate red-light-running frequencies to sunshine/cloud data.

2.5.3 Comparison between Before and 'During' Rates

There is no before data available for red-light running frequency other than that from the visual observations presented in Table 3 and crash reports. However, data from the 'during' period is available from the automatic video/photo-surveillance system itself as well as from the manual observations. The video data could in theory be used for reliability assessment of the visual observations from the time period which is referred to as 'during' period in Table 3. However, the visual observations did not exclude infractions less than 0.2 seconds or at speeds below 13 mph. Also, most of the visual studies were done during the time when the photo-enforcement system clearly malfunctioned—because Verizon had terminated the connection to three of the five locations. It can be noted that the [visual] observer—during the times observed—did not seem to have missed a single infraction recorded through the photo-enforcement system (though the times recorded were sometimes a few minutes off and it is impossible to always tell if it was the same situation that was picked up) but that there were numerous infractions recorded visually that could not be verified through the photo-enforcement system. Whether this is because the observer identified situations that were not true infractions or whether it was the photo-enforcement system that missed them (or excluded them because the speed was too low, it occurred during the first 0.2 seconds of red time, or it seemed to involve a right-turning vehicle, etc). Overall, the infraction rate per hour of visual observation was around 3.2 per hour. The automatic system recorded, as seen in Table 12, on average 0.37 infractions per hour over the 24-hour day. The visual observations were done between 9 AM and 5:30 PM. Overall, 65% of the photographed red-light running incidents were recorded between 9 AM and 5:30 PM. If 65% of the incidents occur during these 8-1/2 hours, the average 'automated' frequency during this time becomes 0.68 infractions per hour. Still, the manually observed frequency is much higher than that. But if we eliminate the 0.0 to 0.2 second infractions and the ones occurring at speeds below 13 mph, the difference would become considerably smaller. Also, at Center Street at Turner Street and Union Street Bypass, the manual observations included all four lanes of the fork whereas the automatic enforcement excluded the two lanes that forked to the right, as well as the sharp right turn onto Turner Street where right-turn-on-red is allowed. And again, there is no way to tell what the true infraction rate was. All automatically recorded incidents are verified to be true infractions but the system may have missed a certain percentage. Also, the manual observer may have misjudged a high percentage of the situations.

Table 12 Automated red-light running numbers

Location	Confirmed* red-light running incidents (Dec 10, 2004 – June 10, 2005)		'Downtime' with no recordings in 24 hrs or more (hrs)	Operational time (4392 hours minus 'downtime')	Average number of infractions per hour
	0.2-0.5 sec	>0.5 sec			
Center St. at Stetson Rd./Joline St	525	725	2497	1895	0.66
Center St. at Turner St. and Union	112	123	2904	1488	0.16
Minot at Elm	297	525	1738	2654	0.31
Russell Street at East Avenue	718	785	878	3514	0.43
East Ave at Bartlett/Pleasant St.	437	418	1444	2948	0.29
Total	2089	2576	9461	12499	0.37

* Referred to as closed in the data file provided by Peek

Table 12 shows the 'automated' infraction rates with the assumption that times with no recorded infractions in 24 hours were downtimes and that the system was fully operational during other times. Russell Street at East Avenue, which had the highest number of reported infractions, has the second highest infraction frequency. Center Street and Stetson Road had the highest frequency. One reason Center Street at Turner had a low infraction rate is that traffic towards the Union Street Bypass was not monitored.

If we take traffic volumes into account, as presented in Table 2, and calculate the average number of infractions per day as 24 times the number of infractions per hour as presented in Table 12, we get infraction rates per approaching vehicle as shown in Table 2.

Table 13 Red-light running rates

Approach	Average number of infractions per day	Estimated incoming daily volume on studied approach	Infractions per incoming vehicle
Center St. at Stetson Rd./Joline St	15.83	9052	0.00175
Center St. at Turner St. and Union	3.79	6411	0.00059
Minot at Elm	7.43	8526	0.00087
Russell Street at East Avenue	10.27	7825	0.00131
East Avenue at Bartlett/Pleasant St.	6.96	6570	0.00106
Average	8.96	7677	0.00117

We can see that the violation rate calculated this way varies between 0.06% (on Center Street at Turner and Union) and 0.18% (on Center Street at Stetson). These violation rates are lower than what typically has been observed through manual observations around the state (Garder,

2004) where intersections saw rates vary from a low of 0.1% to a high of 2.2%. Some of that discrepancy can be explained by infractions less than 0.2 seconds not being included here.

3 Safety Analysis

3.1 Conflict Data

The 360 minute observations at each site before the system was activated and another 360 minutes in April of 2005 gave results as presented in the figure below. The 'after' study was done by a different person to ensure that the results would not be biased by expectations from the before period.

Table 14 Number of definite traffic conflicts per 360 minutes

Location	Before		During	
	Red light	Not red light	Red light	Not red light
Center St. at Stetson Rd./Joline Street, Auburn	2*	0	0	0
Center St. at Turner St. and Union St. Bypass, Auburn	1	0	0	0
Minot at Elm, Auburn	--	--	2**	1
Russell Street at East Avenue, Lewiston	1	1	1	0
East Avenue at Bartlett/Pleasant Street, Lewiston	0	3	0	1
Court Street at Main Street, Auburn	0	1	--	--
Total	4	5	3	2

* One right-turn-on-red vehicle is almost rear-ended after turning onto Center Street. The other conflict involved a northbound red-light running vehicle

** One of the red-light runners did and one did not come from the monitored approach

The main conclusion of these studies is that the numbers are too small for any firm safety conclusions to be drawn. However, if anything, there seems to be a reduction in conflicts rather than the opposite.

3.2 Other Dangerous Situations

The situations presented in Table 15 did not result in traffic conflicts because there was no conflicting car on collision course close enough to trigger a conflict. However, with a little less luck these situations could also have developed into conflicts and potentially crashes as well. But there is no established link between situations that are deemed "somewhat dangerous" and crashes, and different observers have different criteria for selecting what they feel are dangerous, so comparisons between before and after studies are of no value (as opposed to conflict studies that follow strict protocols) and 'during' studies of "other dangerous situations" were therefore not performed.

Table 15 Number of other serious red-light running incidents per 360 minutes

Location	Before	
	Red light	Not red light
Center St. at Stetson Rd./Joline Street, Auburn	4	1
Center St. at Turner St. and Union St. Bypass, Auburn	3	1
Russell Street at East Avenue, Lewiston	4	1
East Avenue at Bartlett/Pleasant Street, Lewiston	2	5
Court Street at Main Street, Auburn	1	4
Total	14	12

3.3 Crash Data

Police reported crashes only have been used for the basis of this analysis.

3.3.1 The Five Test Sites

Crashes were studied in detail with respect to movements and exact location for the six-month study period and for a before period of six-month duration a year prior to the study period (for the same months). Results are shown in the two tables below. Vehicles rear-ending stopped vehicles are not categorized as red-light runners; and they shouldn't be unless the second vehicle crossed into the intersection (on red) before the crash occurred. (On the other hand, sudden stops for red lights—sometimes caused by the enforcement program—could cause rear-end crashes.) One crash, involving a vehicle which had a wheel break off while turning (in May 2005 on Russell Street in the camera direction) is excluded altogether from the analysis as presented in these tables since no other party was involved in the crash—and it was deemed unrelated to the control of the intersection.

Table 16 Crashes involving red-light running vehicles from specified direction

Location	Before (Dec 10, '03-June 10, '04)		During (Dec 10, '04-June 10, '05)	
	Camera direction	Other directions	Camera direction	Other directions
Center St. at Stetson Rd./Joline Street, Auburn	5	1	1	0
Center St. at Turner St. and Union St. Bypass, Auburn	5*	1	1	0
Minot at Elm, Auburn	0	0	2	0
Russell Street at East Avenue, Lewiston	1	1	2	1
East Avenue at Bartlett/Pleasant Street, Lewiston	1	0	0	2**
Total	12	3	6	3

* For one of these, the police report notes both parties as failing to obey the signal though only one of them ran a red light, possibly the one in the camera direction (as assumed in this tally). Another one of the five collisions involved a right-turn-on-red vehicle in the camera direction. In a third situation, the driver was proceeding so slowly that he may have entered on green

** One of these involved a right-turn-on-red vehicle

Table 17 Crashes that do not involve red-light running vehicles

Location	Before (Dec 10, '03 - June 10, '04)		During (Dec 10, '04 - June 10, '05)	
	Camera direction	Other directions	Camera direction	Other directions
Center St. at Stetson Rd./Joline Street, Auburn	0	1	0	0
Center St. at Turner St. and Union St. Bypass, Auburn	1	2	2	0
Minot at Elm, Auburn	0	2	3	2
Russell Street at East Avenue, Lewiston	1	1	2	2
East Avenue at Bartlett/Pleasant Street, Lewiston	4	2	2	1
Total	6	8	9	5

Overall for the five locations, the numbers of crashes that do not involve red-light running vehicles were constant at 14 for the two time periods. Red-light running crashes on the non-monitored approaches were also constant, at 3 for each period. However, the number of crashes involving red-light running vehicles on the monitored approaches went from 12 to 6. At first, this may seem like a significant reduction[3] but it is likely that much of the reduction in crashes was due to regression-to-the-mean effects since the locations that were equipped with cameras were picked because they had 'many' disregard-of-traffic-control-device crashes in the near past. For comparison, Table 18 shows the intersections in Maine with the most red-light running crashes in 2003, the ones with five or more such crashes that year. Without anything specific being done to a great majority of these locations, the number of red-light running crashes were, on average, reduced by 44% in the following year, and if we look at the three with the most crashes—eight or more in the 12-month period, we see a 64% reduction. That we at our studied locations would se a 50% reduction—even without any change in enforcement level—is not that surprising, especially since two of the locations had five red-light-running crashes each in a six-month period. This gives a frequency of 10 crashes per year (for a single approach!) placing them among the ones with the very highest observed crash frequencies in the whole state. The expected crash frequency over a longer time period is almost always lower than the short-term observed one, if one looks at locations with exceptionally high crash rates in that short time period.

[3] The raw numbers, using a binomial test, shows that the reduction is not quite statistically significant, with p=0.12

Table 18 Crash reduction caused by regression-to-the-mean for high-crash locations

Node identifier	Town name	Disregard of traffic control device crashes in 2003	Disregard of traffic control device crashes in 2004	Apparent crash reduction "regression effect"
41293	Bangor	19	7	63%
3690	Auburn	12	4	67%
15528	South Portland	8	3	63%
10087	Brunswick	7	9	-29%
5003	Auburn	6	7	-17%
15532	South Portland	6	1	83%
18519	Portland	6	5	17%
3391	Lewiston	5	2	60%
4580	Auburn	5	2	60%
5007	Auburn	5	2	60%
19250	South Portland	5	4	20%
30503	Rockland	5	3	40%
39690	Brewer	5	4	20%
	Sum	94	53	44%

What is also of interest when looking at Table 18, is that so many of the locations in the state that had five or more red-light-running crashes in 2003 were located in the Lewiston Auburn region.

A statewide analysis, see Table 19, shows that there was a small (6%) overall reduction in the number of red-light-running crashes between 2003 and 2004. But most locations with more than average number of crashes saw much bigger reductions in numbers while locations with no red-light-running crashes in 2003, frequently saw one or more such crashes in 2004. That is what regression-to-the-mean refers to.

Table 19 Statewide number of crashes at traffic signals

	1998	1999	2000	2001	2002	2003	2004	Sum
# total crashes	3619	3497	3356	3372	3081	3283	2860	23068
# disregard-of-traffic-control-device crashes	440	456	532	504	503	513	482	3430
% disregard crashes	12.2%	13.0%	15.9%	14.9%	16.3%	15.6%	16.9%	14.9%

One way of eliminating systematic regression-to-the mean effects is to analyze before-period crashes from only the time period after the decision was made to include that site. Such an analysis is presented in Table 20—though the intersection of Minot and Elm should probably be excluded from this analysis since it was chosen after June 10, 2004 as a replacement location. The weakness of this analysis is that the two six-month periods cover different seasons. Still, it is most likely a less biased comparison than that presented in Table 16.

Table 20 Crashes involving red-light running vehicles from any direction

Location	Before (June 10, '04 - Dec 9, '04)	During (Dec 10, '04 - June 10, '05)
Center St. at Stetson Rd./Joline Street, Auburn	1	1
Center St. at Turner St. and Union St. Bypass, Auburn	1	1
Minot at Elm, Auburn	2	2
Russell Street at East Avenue, Lewiston	1	3
East Avenue at Bartlett/Pleasant Street, Lewiston	1	2*
Total	6	9

* One of these involved a right-turn-on-red vehicle

As seen in this analysis (Table 20), there is no reduction in crashes as a result of the photo-enforcement program. Rather, there is an increase from 6 to 9 crashes at these intersections. But this increase is far from statistically significant ($p = 0.30$) so there is certainly no proof that the situation has gotten worse. An analysis by direction was not undertaken here since the actual crash reports indicating directions of travel were not provided for the six-month before period analyzed here.

3.3.2 Crashes Caught on Video

In total, as indicated in Table 16, there were six crashes involving red-light running vehicles in the camera direction during the "during" phase. Five of these ought to have been caught by the automated system. The sixth involved a vehicle taking the middle leg out of the intersection, and only the left-most was monitored. However, only two crashes were caught captured by the automatic surveillance system. A third was also filmed but rejected.

The collision at Center Street and Stetson Road is (based on the police report) classified as "disregard of signal" for the driver along Center Street even if this driver claimed that he entered on yellow. There is no mentioning in the police report of this incident being analyzed on video. The collision is reported to have occurred at 3:10 pm on May 23, 2005. The nearest infraction happened at 2:59 PM and was 0.2 seconds into red with a speed of 40 mph. At that speed, it would be impossible for a driver to collide with a driver who starts up from Stetson Road after the light turns green in that direction as was reported by a witness in a vehicle behind the one coming from Stetson Road. It must be concluded that the collision was not captured by the system even though there were infractions captured earlier and later that day. A later analysis by Peek showed that the situation had been filmed but was rejected: "According to cameras the crash occurred at 3:06. The violation was rejected in processing for a technicality (because the vehicle was touching the stop bar in the first image) even though clearly a violation because the vehicle was going 46 mph 4.5 seconds into the red phase. Rain on camera glass makes video difficult to see. NOTE - 4 minutes difference between reported time and camera actual time. Camera Trigger Speed: 16 mph."

The collision on Center St. at Turner St. and Union St. Bypass occurred at 1:31 PM on February 25, 2005. This infraction occurred on the monitored approach but in a lane that was not monitored as explained above.

Of the two collisions along Minot Street, one was caught on video. That one occurred on March 22nd. The red-light-running car was traveling at 36 mph, 19 seconds into the red phase. The collision involved two four-door sedans (a 1993 Ford and a 1990 Pontiac) and the damages to the vehicles were estimated at $600 and $900 respectively. An 'identical' collision, involving two SUVs, at 11:36 on January 2nd was not caught by the automated system even though the police report clearly states that it was the driver along Minot Avenue who ran the red light and this collision caused damages of $7,300 and $5,500 respectively, so speeds must have been well above 15 mph for at least one of the vehicles. It is possible—but unlikely—that the violating driver was going below 15 mph. It is also possible that the police erred in determining who ran the red light. Rather, it seems likely that the system was not functioning properly at this time even though there was a red-light running infraction caught later that day, especially since there was a period longer than 24 hours without any infractions from 12/31/04 11:05 AM until 1/2/05 6:29 PM. Comment from Peek: "Minot & Elm, 1/2/05 11:36 am - no nearby incident in time. The next image taken by the camera at 12:15 pm shows the accident already completely cleared only 39 minutes later. Is that possible with almost $13,000 in damage? Camera Trigger Speed: 18 mph."

There were two collisions on Russell Street at East Avenue that should have been caught on the video if the police reports are accurate. One of them was. That one occurred on April 1, 2005. The other one is reported to have happened at 8:17 AM on January 27. The automated system did not pick up any infractions at this location between 8:55 PM the previous evening and 11:23 that morning. It seems likely that the automated system should have picked up this crash. The police report is very clear with respect to who ran the light in this serious crash causing $25,000 worth of property damages and a possible injury in one of the three vehicles damaged. It is possible but not likely that the violator was going below 15 mph and thereby not triggering the surveillance camera.

In conclusion, two out of five crashes that ought to have been captured were captured by the automatic system and a third was filmed but rejected. One of the missed ones occurred during a time when the system seemed to have malfunctioned even though no problem was reported by Peek while the remaining two occurred at locations where other infractions were picked up within a few hours before and after the collision. Without an in-depth study of these crashes, it is impossible to know whether the violating vehicle was going at a speed which should have triggered the systems. However, what seems to be absolutely clear in both of these crashes is that a driver ran a red light and caused a serious crash as a result of this. It would have made sense that drivers behaving in this way are fined for running red lights no matter what their speed is. Still, we can not criticize the provider of the system for this—if the speeds truly were below the triggering thresholds—since that is what the system specifications called for.

3.3.3 Lewiston-Auburn Area

A similar analysis for Auburn as that presented for the whole state in Table 19 is shown in Table 21. And data for Lewiston is shown in Table 22.

Table 21 Number of crashes at traffic signals in Auburn

	2000	2001	2002	2003	2004	Sum
# total crashes	248	211	233	237	197	1126
# disregard-of-traffic-control-device crashes	67	56	45	49	43	260
% disregard crashes	27.0%	26.5%	19.3%	20.7%	21.8%	23.1%

Table 22 Number of crashes at traffic signals in Lewiston

	2000	2001	2002	2003	2004	Sum
# total crashes	337	301	286	280	270	1474
# disregard-of-traffic-control-device crashes	57	64	66	46	49	282
% disregard crashes	16.9%	21.3%	23.1%	16.4%	18.1%	19.1%

Both Lewiston and Auburn have a trend towards a decreasing number of crashes caused by drivers running red lights. Still, the percentage is high, and clearly higher than the statewide average presented in Table 19.

3.3.4 Comparison Areas

It is obviously possible that red-light running is not a specific Lewiston/Auburn problem but a problem in many other urbanized areas of the state. A comparison therefore ought not to be done just against the statewide average but also against other urban and urbanized areas. One such comparison can be to look at what percentage of crashes at traffic signals are "disregard of signal." This is shown in Figure 33. This comparison may not reflect the absolute problem with red-light running since a city where drivers are cautious in general (or where signals are designed well) may have a low number of other types of collisions at signalized intersections. Still, the indication here is that Lewiston and Auburn in the last few years aren't deviating from the other urban areas.

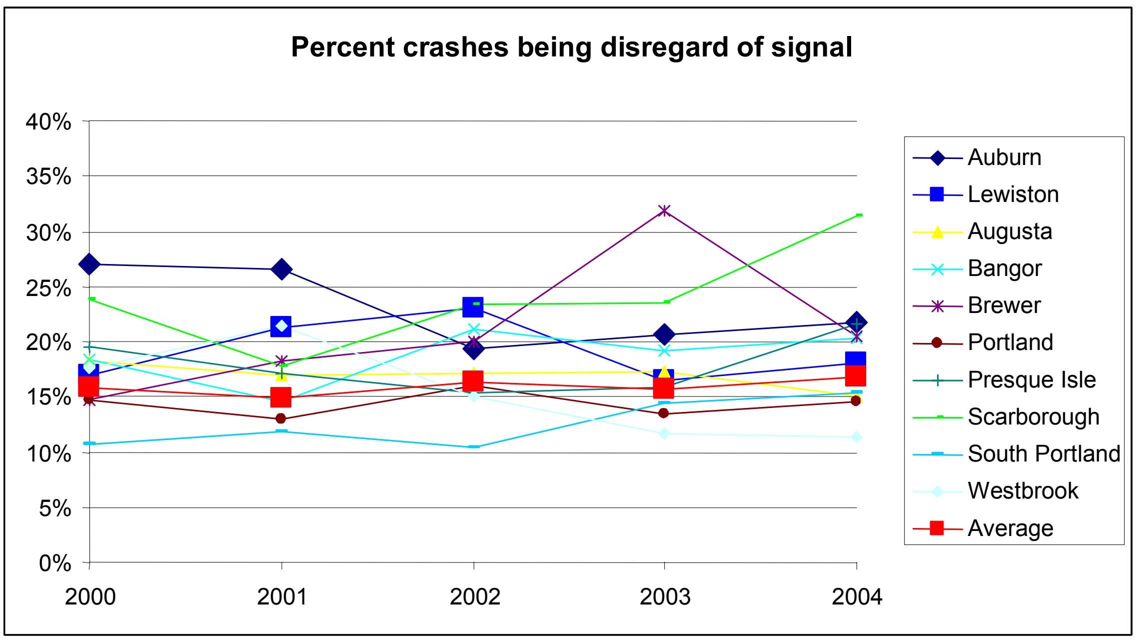

Figure 33 Percent crashes at signals being caused by drivers disregarding signal

In absolute numbers, red-light running crashes for the years 1998 through 2004 are shown in Table 23. Census populations are shown in the same table. Daytime population is in most of these cities much greater than nighttime population, so this comparison may also not be 'fair.' However, without taking that into account, red-light-running crash rates are higher for Auburn and Lewiston than for other cities. If analyzed in relations to million entering vehicles, the crash rate is also higher for Auburn than for any other city listed. Bangor and Lewiston follow with rates that are higher than other cities. Also, as shown in Garder (2004), the average crash severity of red-light-running crashes seems to be higher in Auburn and Lewiston than in the other urban areas.

Table 23 Red-light-running rates for Maine cities

City/Town	Number of red-light running crashes '98 - '04	Population 2000 (nighttime)	Million entering vehicles (MEV) at traffic signals	Red-light-running crashes per year and 10,000 residents	Red-light-running crashes per year and MEV
Auburn	346	23,203	231	21.3	0.187
Lewiston	414	35,690	384	16.6	0.135
Portland	549	64,249	824	12.2	0.083
Scarborough	184	16,970	228**	15.5	0.101
South Portland	216	23,324	308	13.2	0.088
Westbrook	107	16,142	127	9.5	0.105
Bangor	332	31,473	289	15.1	0.144
Brewer	59	8,987	68	9.4	0.108
Augusta	154	18,560	224	11.9	0.086
Presque Isle	49	9,511	--*	7.4	--*
Statewide	3,430	1,274,923	--*	3.8	--*

* MEV for several signalized locations missing

** MEV from two out of 25 signalized locations missing—assumed to have the same flow as the average

It is from the table obvious that the urbanized areas saw much higher population rates than the non-urban parts of Maine. And that is not surprising since signals are concentrated to the urban areas.

4 Findings and Observations

In Maine, there are around 500 crashes every year that are caused by drivers running red lights. These crashes produce, on average, more serious injuries than other intersection-related crashes. There are about 25 incapacitating injury crashes per year of this type. Four out of six fatal crashes at signalized intersections in the state of Maine in the three-year period 1999 through 2001 involved road-users entering the intersection on red. It would obviously be desirable to reduce red-light-running frequencies. However, from a safety perspective it is especially important to reduce the number of red-light running infractions that occur at high speeds and well into the red.

There are many ways to reduce red-light running. Reducing travel speeds may be the most effective way—but that is politically and practically difficult. Red-light running done on purpose can probably best be reduced by enforcement. Infractions that are made completely by mistake—where the driver is totally unaware that he/she is entering a signal—can probably be reduced more effectively by other means, such as bigger signal heads and better timing. However, more enforcement may have somewhat of an effect on these situations too because if drivers know that signals frequently are monitored with respect to red-light running, they may start to be more observant.

The main question addressed through this study is whether automatic enforcement, using video and digital camera technology, effectively will reduce red-light running frequencies even if violations only result in warning letters sent to owners of vehicles involved in running red lights. The answer to that question is "probably not," but we are uncertain. Manual observations of red-light running indicate that the violation rate dropped by around 6% between the summer of 2004 (before the system was installed) and the late spring of 2005, when the system had been operational for several months. The automatic enforcement system itself, indicate that the number of infractions per day decreased by around 28% between the very beginning and end of the experiment.

The manual observations were done during similar times of year and with similar weather situations. The 'early' automatic recordings however were done in the early winter whereas the 'late' observations were done during summer conditions. This may have lead to different driving behaviors. But the fact that there were much fewer infractions in January—when people were starting to become aware of the enforcement program—than in the following months is likely to have been caused by the fact that people eventually learned that the violations resulted in warning letters only. It would not be caused by lower infractions during snowy/icy roadway conditions. A study in Auburn initiated by this project revealed the opposite; that the infraction rate goes up when it is snowing.

Also, traffic volumes may be higher during the summer months than in the winter—even if Lewiston Auburn is not in a tourist district, winter volumes tend to be lower, as illustrated by the urban line in Figure 34, from Maine Department of Transportation's website, Traffic Volume Counts, 2004 Annual Report, page 8.

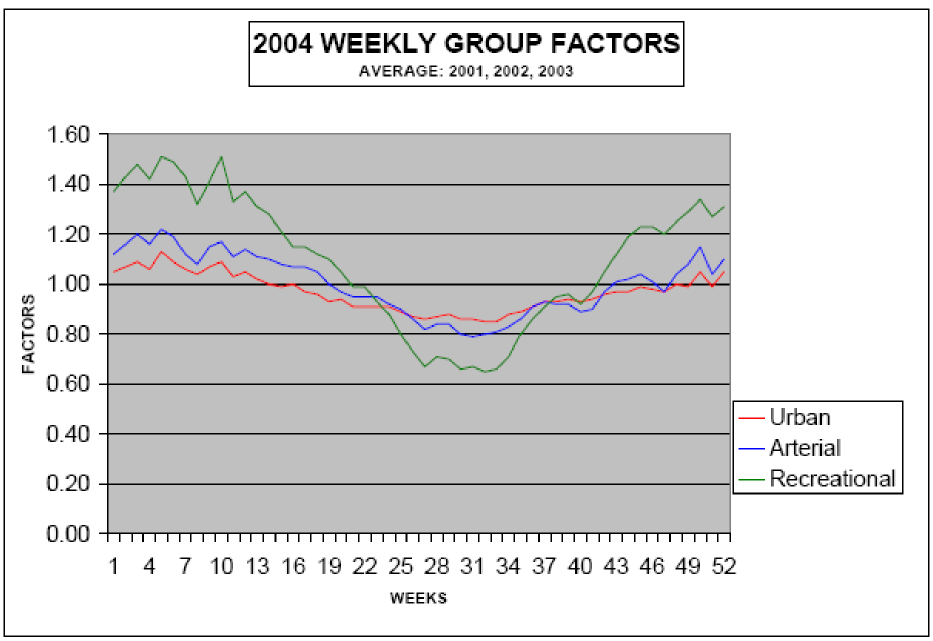

Figure 34 Traffic volume variations in 2001-2003 for the state of Maine

Unfortunately—but probably not unexpectedly—it was the infractions that occurred at low speeds and within the first second or so that were reduced in numbers. Infractions more than 3 seconds into red and at speeds above 35 mph clearly increased in numbers. However, it is unlikely that the enforcement system in any way led to this increase in the more serious infractions. It is possible that weather and roadway conditions explain the higher speeds during the later months. Also, if citations had been issued, the number of infractions may (or may not) have been reduced.

With respect to the safety analysis, conflict data indicate that safety was roughly unchanged between the before period and the period when the system was in operation. However, conflict numbers are small and small variations in safety would not be statistically detectable. A first look at crash data may make the reader think there was a reduction in red-light-running crashes involving vehicles entering from the monitored approaches. However, a more in-depth analysis indicates that more or less all of this apparent improvement can be attributed to regression-to-the-mean effects. Crash numbers are too small to calculate numerical effects for perpendicular versus rear-end collisions.

It is likely that safety deteriorated during this experiment. Linear regression shows that infractions that occurred more than 3 seconds into red and at speeds above 35 mph went from well below 1% of all infractions to around 3% towards the end of the experiment—that is to around 1.2 daily infractions at speeds above 35 mph and more than 3 seconds into the red. And, during the first month, there was in total 10 recorded infractions more than 10 seconds into red. During the last month, that number had grown to 46—a statistically significant increase ($p= 6.2 \times 10^{-7}$) of 360%. Also, the number of infractions at speeds above 40 mph grew from 120 in the first month to 221 in the last month (again a statistically highly significant increase, $p=2.4 \times 10^{-8}$).

Surprisingly, only 4% of the automatically recorded infractions occurred between 10 PM and 6 AM. Manual observations were not done during the nighttime so there is no way to analyze whether the system has a lower reliability during this time. (One of the intersections—Center Street at Stetson—is on yellow/red blink between midnight and 5/6 AM but the other ones operate on green/yellow/red phasing all night.

A well-functioning enforcement system should be certain—with a high degree of reliability—to catch the worst offenders. Especially drivers who run red lights well into the red phase at high speeds. What percentage of these offenders was captured is not known. However, we know that one driver ran the red light at Center Street and Stetson on May 5 at 3[06] PM. That driver was going 46 mph 4.5 seconds into the red phase. But the violation was rejected in processing for a technicality—because the vehicle was touching the stop bar in the first image. This situation was later retrieved because a collision resulted from the infraction. However, the incident would not have been reported had the crash not occurred—and it is not part of the data material presented in this report since it wasn't added to the data set until after all analyses were finished. This situation was likely an exception rather than a common occurrence.

System specifications may also need to be adjusted. Truly dangerous behaviors should be covered. For example, if someone drives at low speed against a red light right in front of a vehicle entering on green, then that violation ought to be captured, even if the situation does not result in a crash.

Often, an assumption is made that the number of a specific type of occurrence varies around a mean according to the Poisson distribution—that is that the number of occurrences would be expected to fluctuate randomly around a mean. This results in a day to day variation in rates even if the underlying frequency is constant. Though the underlying frequency is in real life often not completely constant. The Poisson process would be expected here unless drivers do not act independently of each other (but, for example, become more prone to run red lights at times when they see other people do it at the same place). All other stipulations for the Poisson distribution are met. However, the expected mean number of infractions (per hour or per day) may vary from day to day and hour to hour. A probability analysis indicates that it is statistically virtually impossible to get results as recorded by the automatic system if underlying violation rates were constant. Rather, statistical analysis indicates that the variation from day to day is significant. For example, the approach on Center Street at Stetson had typically around 16 recorded infractions per day. But, the automated system captured no infractions on several days. In total, there were 76 days with no infractions, but the system was reported as non-operational on 48 of those days. In other words, there were 28 days when the system was operating that it saw no infractions. And, a specific day with no infractions would have an underlying infraction frequency of no more than 3.0 per day ($p<0.05$) according to the Poisson distribution. That there would be 28 days out of 171 with no infractions if the underlying rate was 3.0 would have a very low probability. The underlying rate must be around 1.8 or lower for that to happen. There were also 32 days with 18 or more infractions. The underlying rate must statistically ($p<0.05$) be above 12.4 for 18 to occur at a single site. Also, there was one day with 48 infractions. For this to happen, the underlying rate must be at least 38.0 ($p<0.05$). In other words, either the system at this location missed numerous situations on some days, or the underlying infraction frequency was at least 21 times higher some days than on other days. If the latter is the case, a study should be devoted to why drivers are so much more prone to run red lights on some days compared to other days.

Ideally, every offender should be caught by the automatic system. However, the deterrence will not be lost even if a certain percentage is missed. And, that percentage can probably be fairly large before the deterrence is completely lost. If the chance that you are caught and fined is 50%, few people will run a red light on purpose. Earlier studies (Gårder, 2004) show that historically in Maine, people have been stopped by the police and fined for running red lights, on average, once every 2.5 million miles (34 people had been stopped out of 334 people interviewed after an average driving career of 20.5 years). Also, that report showed that roughly 0.6% of all drivers entering a signalized intersection run the red light. If the average person travels through ten signalized intersections per day, 365 days a year, they would go through roughly 4400 signals on red before they were stopped the first time. In other words, an automated system getting 50% of the offenders would be 2200 times better than today's system.

As concluded in the earlier report by Gårder (2004), photo enforcement should ideally be combined with active signal technology, for example of LHOVRA type, that keeps red on an approach until close-by, fast moving vehicles on conflicting approaches have stopped. If one can prevent a collision, it makes little sense to detect that a vehicle is going to run a red light, wait for it to have the collision, and then send a fine (or warning) to the offending driver (or vehicle owner). The LHOVRA technique, from being an experimental initiative by the Swedish National Road Administration in the early 1970's, has become a more or less standard technique at Swedish signal controlled junctions. The LHOVRA is no longer only a technique used in rural roads but is widespread in urban areas. An outline of the LHOVRA functions, its geometric design, and its traffic safety and mobility effects are given in "10 years with LHOVRA - what are the experiences?" by A. Engström of Peek Traffic.

5 Conclusions

The findings of this study supported the primary goals:

- Red light running is significant in Maine. Law enforcement officials issued an average 25 red-light violations per day at the five pilot photo-enforcement intersections.

- Photo enforcement accurately captured red-light-running violators, as confirmed by police. It is clear that the system can be reliable in the sense than non-violators are not charged with violations.
- Photo enforcement can be effective. Even though only warning letters were issued in the pilot study, the number of violations decreased by an estimate of approximately 28%.

In conclusion, photo enforcement is a possible and necessary measure to assist the police in enforcing red-light running. It is an important part, but not sufficient by itself, in reducing injuries with a comprehensive engineering, education, enforcement, encouragement approach.

References

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Gårder, Per. "Traffic Signal Safety—Analysis of Red-Light Running in Maine, Technical Report ME02-1, Maine Department of Transportation, May 2004

Griffith, Michael. "Safety Evaluation of Red-Light Cameras," FHWA-HRT-05-048, the Federal Highway Administration, April 2005

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Enclosure A: Weather Data

Table 24 Percent of daytime with sunshine for Gray, Maine

Day	Dec '04	Jan '05	Feb '05	March '05	April '05	May '05	June '05
1	-	53	87	0	32	6	52
2	-	57	100	64	0	64	95
3	-	0	76	97	0	57	91
4	-	0	41	94	31	54	81
5	-	2	91	98	82	78	58
6	-	0	100	72	49	62	0
7	-	51	68	81	39	0	78
8	-	46	0	0	83	0	62
9	-	75	51	63	100	20	81
10	0	48	0	97	100	100	46
11	0	75	30	74	94	42	71
12	4	0	51	0	5	91	26
13	15	0	100	36	64	99	35
14	66	0	35	90	96	23	0
15	100	66	64	55	100	0	0
16	63	0	53	57	97	12	0
17	58	36	98	100	96	12	0
18	79	80	72	97	97	41	9
19	37	0	98	100	95	55	88
20	0	76	100	100	43	62	100
21	65	81	0	96	100	9	93
22	58	51	28	100	96	0	53
23	0	0	78	84	0	0	82
24	56	68	85	42	2	0	89
25	60	84	80	81	6	0	90
26	0	0	88	97	95	0	69
27	35	100	99	97	2	2	74
28	89	100	81	0	17	65	57
29	16	100	-	10	72	37	43
30	100	58	-	98	17	13	11
31	0	100	-	89	-	0	-

Table 25 Snowfall for Gray, Maine

Day	Dec '04	Jan '05	Feb '05	March '05	April '05	May '05	June '05
1	-	0	0	11.4	T	0	0
2	-	T	0	0.7	0	0	0
3	-	0	T	0	0	0	0
4	-	1.2	2	0	0	0	0
5	-	0	0	0	0	0	0
6	-	3.3	0	0	0	0	0
7	-	0.1	0	0.1	0	0	0
8	-	3.1	T	7.3	0	0	0
9	-	T	0	2.7	0	0	0
10	T	T	14.5	0	0	0	0
11	0	0	2.8	2.4	0	0	0
12	T	2.6	0	12.3	2	0	0
13	0.3	0	0	0.1	0.5	0	0
14	0	0.2	1.5	0	0	0	0
15	0	0	1.1	T	0	0	0
16	0	1	T	T	0	0	0
17	T	0.6	0	0	0	0	0
18	0	0	T	0	0	0	0
19	0.3	4	0	0	0	0	0
20	3.2	1.2	0	0	0	0	0
21	0	0	7.1	0	0	0	0
22	0	1.2	0.1	0	0	0	0
23	0	5.5	1.3	0	0	0	0
24	0	0.2	0	0	0	0	0
25	0	0.2	0.3	0	0	0	0
26	1.5	4.1	0	0	0	0	0
27	1.6	0	0	0	0	0	0
28	0	0	0	T	0	0	0
29	0	0	-	0	0	0	0
30	0	0	-	0	0	0	0
31	0	0	-	0	-	0	-