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ROOF-MOUNTED LIGHT SYSTEMS ON POLICE VEHICLES

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ROOF-MOUNTED LIGHT SYSTEMS

ON POLICE VEHICLES

Illinois Department of Law Enforcement
Division of Administration
Bureau of Planning and Development

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EXECUTIVE SUMMARY

Tests conducted by several different agencies have indicated that removal of roof-mounted light bars (visabars) from police cars can result in reduced fuel consumption by those vehicles. Analysis of accidents involving patrol units by the California Highway Patrol and the Illinois Department of Law Enforcement have indicated that roof-mounted light bars plays no measurable role in reducing accident potential of state police patrol vehicles. Illinois State Police experience further indicates that unmarked units are actually less likely than marked units to incur accidents. For vehicles involved in accidents, the experience of marked and unmarked units is very similar with regard to a variety of factors including type of roadway, lighting conditions, accident severity, activity prior to accident, and whether or not emergency lighting systems were in use.

By removing the roof-mounted equipment from the approximately 1000 marked vehicles operated by the Illinois Department of Law Enforcement, fuel costs can be reduced by 237,000 dollars a year in terms of current fuel prices. The cost of replacement equipment would be repaid by reduced fuel consumption within four months of conversion. Removal of this equipment would also result in improved vehicle acceleration and greater top speed.

Data indicate that no increase in accident rates should result from removal of the visabars.

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I. STATEMENT OF PROBLEM

The Illinois Department of Law Enforcement (DLE), Division of State Police (DSP) currently operates 1005 vehicles which are equipped with roof-mounted emergency light systems (visabars). Fuel costs for those vehicles were approximately 2.6 million dollars for Fiscal Year 1981. Research in this area indicates that fuel costs can be reduced by removing roof-mounted equipment from patrol vehicles. The focus of this paper will be to determine whether the Illinois Department of Law Enforcement can remove visabars from vehicles and thereby decrease fuel consumption (increase average miles per gallon) without sacrificing officer safety.

The information presented in this paper will identify the level of savings, if any, which are possible; the role roof-mounted light systems play in increasing officer safety; and other related issues which should be considered in determining whether or not squad cars should be equipped with roof-mounted light systems.

II. FUEL CONSUMPTION

Some of the most sophisticated research conducted in this area has been done by the National Research Council of Canada using wind tunnel tests. Their findings indicate that the aerodynamic drag of a vehicle with roof-mounted equipment may be increased by as much as 51 percent over that of a vehicle without such equipment.[1] A reduction in aerodynamic drag would result in a reduction in fuel consumption. For example, a thirty percent reduction in aerodynamic drag for a vehicle traveling at 100 mph could represent about a twenty-five percent reduction in fuel consumption.[2]

Other tests have been conducted by various other entities including the California Highway Patrol,[3] the Energy Center at the University of Connecticut;[4] and the Transportation Research Center of Ohio.[5] Each of these entities used varying methods to measure the effect of aerodynamic drag of roof-mounted, emergency warning lights. While each set of tests concluded that some models of equipment had less adverse effect on fuel consumption than did others, there was no consensus as to which models were actually the most fuel efficient. This results, in part, from a failure by each agency to test all available equipment. Each set of tests involved different brands and models of equipment.

Tests conducted by the Energy Center and the Transportation Research Center were done under contract with manufacturers of equipment. The studies are currently cited in advertising campaigns used by the contracting firms to promote their respective products. The California study was conducted for internal purposes of the Department of California Highway Patrol. The primary purpose of each of these studies was to differentiate between various models of visabars with regard to their impact on vehicular fuel consumption. However, each of these studies as well as the Canadian research and a second study conducted by the California Highway Patrol[6] found that a vehicle without roof-mounted equipment would achieve better fuel mileage than the same vehicle with roof-mounted equipment.

Department of Law Enforcement Tests

To confirm the findings of these studies and determine exactly what level of savings would be possible for Illinois State Police vehicles, the Illinois Department of Law Enforcement conducted its own tests. The tests were completed on Interstate 72 from Milepost 1 to Milepost 11. The test procedure was conducted once in each direction with each visabar tested and with a slick roof. In all cases,

the first test was conducted eastbound between Mileposts 1 and 11, and the second test was westbound between Mileposts 11 and 1. The results of the two runs were averaged to compensate for differing wind direction and velocity as the direction of travel was reversed. The tests were conducted on August 26, 1980, between 10:30 a.m. and 2:00 p.m. The wind direction was from the southeast at 7-10 mph.[7]

Fuel consumption was measured using a Flo-Scan metering device which gives a constant read-out of fuel consumption to one one-thousandth mile per gallon. The test procedure began with the vehicle traveling at 55 mph as it passed either Milepost 1 or 11 and ended as it passed the final milepost still traveling at 55 mph. The results of the tests are shown in Table 1.[8]

TABLE 1

FUEL CONSUMPTION WITH SELECTED LIGHT BARS

Light Configuration	Fuel Consumption Rates
Slick Roof	16.584 mpg
Code III XL	15.798 mpg
Yankee 911	15.724 mpg
Federal Aerodynic	15.607 mpg
Federal Twinsonic	14.807 mpg

Like the tests cited previously, these data demonstrate two points. First, there is a difference in the fuel consumption rates of a vehicle depending on the type of roof-mounted lights with which the vehicle is equipped. Second, and more importantly, all tests reviewed indicated that a vehicle without roof-mount equipment obtains the greatest number of miles per gallon of fuel consumed.

The Division of State Police currently operates approximately 755 vehicles which are equipped with Federal Twinsonic Visabars. The data indicate that removal of this equipment would result in a 12.0 percent improvement in fuel consumption rates for those 755 vehicles. An additional 250 vehicles are equipped with Yankee systems. Removal of visabars from those vehicles would result in a 5.5 percent improvement in consumption rates. Based on a fleet wide average fuel consumption rate of 10.822 miles per gallon for patrol vehicles and fuel costs of 1.35 dollars per gallon, these figures translate into a dollar savings of 10.7 percent for vehicles now equipped with Twinsonic lights and 5.2 percent for those equipped with Yankee lights, if those systems were removed. For each Twinsonic light bar removed from a vehicle, the Department would save 271 dollars annually from reduced fuel consumption. For each Yankee light bar removed, 131 dollars would be saved annually. If the roof-mounted equipment were removed from the 1005 vehicles currently using either Federal Twinsonic or Yankee systems, savings would approximate 237,307 dollars per year at current fuel prices. (See Appendix 1 for calculations.)

There would also be some additional savings from not replacing light bars as they become inoperative or no longer fit down-sized vehicles. However, a percentage of those savings would be expended in purchasing emergency light systems which are not roof-mounted.

The study conducted by the Department of California Highway Patrol yielded similar findings. That study concluded that:

> "The removal of 780 roof-mounted light bars (685 Twinsonic and 115 Aerodynic) would result in cost savings of $988,890 based on the increase in miles per gallon for a vehicle with a use life of 85,000 miles. Additionally, the sale of 780 lightbars would achieve a revenue return of approximately $195,000 based on December 1979."[9]

The California data compared favorably with those from Illinois. DLE

tests indicate an average annual savings potential of 236 dollars per vehicle based on 20,470 miles being travelled each year. For the same number of miles, the California data indicate a savings potential of 305 dollars per vehicle from reduced fuel consumption.

III. SAFETY

One of the principal arguments supporting the use of roof-mounted light bars is that in certain situations, when turned on, they add to the safety of officers and of the general public in emergencies. Because it is difficult to quantify something as abstract as officer safety, research conducted in this area has attempted to measure the effect of lighting systems on factors which might be associated with officer safety.[10] These have included the lighting system's impact on traffic volumes, the mean speed of traffic, and the number of vehicles which move to lanes away from the emergency vehicle.

One such study was conducted in 1971 by the California Highway Patrol in response to a legislative inquiry regarding the equipping of highway patrol vehicles with roof mounted revolving amber lights[11]. At the time of the study, California used deck-mounted amber lights on law enforcement vehicles to alert drivers that an enforcement action or roadway service was in progress. The effectiveness of test equipment was measured by its impact on vehicle speeds and traffic volumes. The study made the following conclusions relevant to this discussion:

1. Amber warning lighting has a small effect on multilane, lighted roads, reducing average speed by one or two mph at night.
2. Drivers react significantly to the warning lights at night on unlighted, undivided roadways reducing speeds by 8 to 10 mph.

3. There is no significant difference in effect between the top mounted revolving light and deck light. Speed reductions in response to either are comparable.

4. Drivers react noticeably to the presence of the black and white enforcement vehicle reducing vehicle speeds 2.5 to 6.5 mph.

5. In daylight, the presence of test vehicles (black and white enforcement units) affected traffic to a greater extent than the amber light.

These findings lead to the conclusion that a marked unit with a deck-mounted revolving light afforded a degree of safety similar to that provided by roof-mount equipment.

The study also found that:

> "During heavy volumes, traffic flow is constricted when drivers see either a black and white enforcement vehicle or tow service truck. This results in maximum capacity being reached more quickly and correspondingly, as queuing begins, volumes were reduced 10 percent for enforcement vehicles and 7 percent for tow trucks. Similar reductions did not occur for a highway maintenance pick up."[12]

This finding could have implications for deployment strategies in urban areas such as Chicago and East St. Louis.

A later study, also conducted by the California Highway Patrol, more directly addressed the issue of officer safety. The conclusions of that study stated that:

> "An analysis of the data on CHP patrol vehicle accidents between January 1, 1979 and July 1, 1980 covering 766 accidents, reveals that there appears to be no safety benefit from the use of roof-mounted light bars. The CHP driver appears to be the overriding factor rather than the operational status of warning lights and types of roadways involved. However, the Department could retain Aerodynic light bars for use on particular types of roadways (highly congested freeways without an adequate shoulder area)."[13]

Accident Analysis

To further examine the issue of safety with regard to roof-mounted visabars, an analysis was conducted of all Illinois State Police accidents involving the rank of trooper and occurring in FY81 (July 1980 -June 1981) . The rank of trooper was chosen for a specific reason. The analysis was concerned with comparing the accident experience of marked and unmarked vehicles. For ranks above trooper, unmarked units are issued in greater proportion. Also, vehicles assigned to higher ranks are driven under different conditions than those assigned to troopers. Thus, if data for all ranks were used, a large proportion of the unmarked units would have been driven under different conditions than the marked units. By restricting the analysis to vehicles driven by troopers, it can be assumed that both marked and unmarked vehicles were driven on similar assignments throughout the state.

During FY81, the Department had 239 unmarked units and 741 marked vehicles assigned to troopers. This amount would vary during the year with vehicle replacement and personnel turnover, but generally speaking, 22 to 24 percent of the vehicles assigned to troopers would be unmarked vehicles at any given time during the year. However, of the 227 accidents that occurred only 28 or 12 percent involved unmarked units. This was substantially less than the 24 percent of the vehicles which were unmarked. Examined in another way, as shown in Table 2, only twelve percent of the unmarked cars were involved in accidents, compared to 26 percent of the marked units. Marked units were 2.16 times as likely to be involved in an accident as were unmarked units.

TABLE 2

Illinois State Police
Accident Involvement*

	Accident		No Accident		Totals	
Unmarked	28	(12%)	211	(88%)	239	(100%)
Marked	199	(26%)	542	(73%)	741	(100%)
Totals	227	(23%)	753	(77%)	980	(100%)

$X^2 = 23.27$ Signif. = .01

*Data, as presented in this table, assume that each accident involves a separate vehicle. Data presented are for troopers assigned to Districts 1-19, excluding 15.

For those vehicles which were involved in accidents, there was no relationship between vehicle type (with or without light bars) and light mode (on or off). This was true for both the Illinois State Police and the California Highway Patrol as shown in Tables 3 and 4.

TABLE 3

Illinois State Police
Vehicle Type and Light Mode

	Light On		Light Off		Totals	
Unmarked	13	(39.4%)	20	(60.6%)	33	(100%)
Marked	88	(39.1%)	137	(60.9%)	225	(100%)
Totals	101	(39.1%)	157	(60.9%)	258	(100%)

$X^2 = .001$ Signif. $>.10$

TABLE 4

California Highway Patrol
Vehicle Type and Light Mode

	Light On		Light Off		Totals	
Slick Top	135	(37.3%)	226	(62.6%)	361	(100%)
Lightbar	107	(39.4%)	164	(60.5%)	271	(100%)
Totals	242	(38.2%)	390	(61.7%)	632	(100%)

$X^2 = .285$ Signif. $>.10$

The accident experience for the two agencies was remarkably similar with regard to type of vehicle and light mode. For both agencies there was no statistical relationship for vehicles involved in accidents between whether or not the vehicles were equipped with light bars and whether emergency lights were on or off; for Illinois patrol cars, 60.9 percent of all accidents occurred with red lights off and 39.1 percent with them on. For unmarked units, only 60.6 percent of the accidents occurred with lights off and 39.4 percent with them on. If only marked units are considered, the results are also very similar. Again, there was no difference between marked and unmarked units.

These data also provide additional information. An officer utilizes his red lights relatively infrequently when compared to his total working hours. There are no accurate data available on the exact amount of time red lights are used. However, nearly forty percent (39.1 percent for Illinois and 38.2 percent for California) of all accidents involving troopers occurred with the red lights on. Hypothesizing that the red lights are used ten percent of the time (48 minutes in each eight hour shift), the probability of an accident occurring is six times greater in situations for which red lights were used than for an equal period in situations which did not require red lights. If the lights are actually used less than 10 percent of the time, the probability factor would be even greater. This does not infer that officers should not use their red lights. It does indicate that during those times which troopers feel warrant the use of red lights, the danger of accident is substantially higher than the times in which he doesn't choose to use them. This increased danger may be caused by one or by a combination of factors including:

1) danger inherent in the types of situations which require the use of red lights,

2) increased incidence of driver error due to higher speeds when emergency lights are in use, or

3) a false sense of security provided by the red lights.

To further examine this question, the relationship between accidents and the activity in which the officer was engaged at the time of the accident was analyzed. Activities of officers were divided into nine classifications. These are shown in Table 5. There was little difference in accident experience between marked and unmarked vehicles with regard to activity; 42.4 percent of the accidents involving unmarked cars and 41.3 percent of the accidents involving marked cars occurred while on patrol or travel status. The only activities showing any real difference with regard to vehicle type were enforcement stops and road blocks. Three percent of the accidents involving unmarked vehicles occurred during enforcement stops while 9.3 percent of the accidents involving marked cars were during enforcement stops. Nine percent of the accidents involving unmarked cars occurred while on road blocks while less than one percent of the accidents involving marked units occurred during road blocks. However, only five accidents (1.9 percent of all accidents) occurred during road blocks. Overall, by grouping cells showing less than

TABLE 5

Activity and Type of Vehicle

	Patrol and Travel	Accident Invest.	Traffic Direct	Motorist Assist	Pursuit	Emerg. Call	Enf. Stop	Road Block	Other*	Total
Unmarked	14 42.4%	3 9.1%	0 0.0%	1 3.0%	5 15.2%	2 6.1%	1 3.0%	3 9.1%	4 12.1%	33 100.0%
Marked	93 41.3%	19 8.4%	11 4.9%	10 4.4%	28 12.4%	12 5.3%	21 9.3%	2 0.9%	29 12.8%	225 100.0%
Total	107 41.5%	22 8.5%	11 4.3%	11 4.3%	33 12.8%	14 5.4%	22 8.5%	5 1.9%	33 12.8%	258 100.0%

$X^2 = .98$** Signif. $> .10$**

*Other includes "unknown".

**Chi square and significance level were computed by grouping cells showing less than 5 five accidents and applying the chi square test at the .10 level of significance, there was no statistical difference between the accident experience of marked and unmarked cars with regard to activity.

The data presented in Table 6 demonstrate that accident experience with regard to activity is completely different between accidents which occurred when emergency lights were on and those which occurred when the lights were not in use. For example, 68.2 percent of the accidents which occurred while red lights were off, occurred during patrol and travel. When red lights were on, no accidents occurred while on patrol or travel status. This is only natural since an officer would not use his red lights while engaged in patrol and travel. Thus, the discussion here is not to further demonstrate the difference between these two types of experience which may or may not be comparable, but rather will focus on the activities engaged in when accidents occurred with emergency lights in use.

Data contained in the Table demonstrate that more of the accidents which occurred when emergency lights were on took place during pursuits than in any other activity; 28.7 percent of all accidents which occurred while red lights were on, occurred during pursuits. Although not shown in the Table, this same relative proportion holds true for both marked (28.4 percent) and unmarked (30.8 percent) units. Second in frequency were enforcement stops. As shown in Table 6, 19.8 percent of all accidents occurring while red lights were on, occurred during this activity. Third in frequency were accidents which occurred during accident investigations; 17.8 percent of the accidents which occurred while red lights were on, occurred during this activity.

Accidents which occurred during these three activites (pursuits, enforcement stops, and accident investigations) constituted 66.3 percent of all accidents which occurred while red lights were in the on mode. For marked units, they constituted

TABLE 6

Activity and Red Light Status

	Patrol and Travel	Accident Invest.	Traffic Direct.	Motorist Assist.	Pursuit	Emerg. Call	Enf. Stop	Road Block	Other*	Total
Red Light On	0 0.0%	18 17.8%	9 8.9%	8 7.9%	29 28.7%	12 11.9%	20 19.8%	5 5.0%	0 0.0%	101 100.0%
Red Light Off	107 68.2%	4 2.5%	2 1.3%	3 1.9%	4 2.5%	2 1.3%	2 1.3%	0 0.0%	33 21.0%	157 100.0%
Total	107 41.5%	22 8.5%	11 4.3%	11 4.3%	33 12.8%	14 5.4%	22 8.5%	5 1.9%	33 12.8%	258 100.0%

No chi square statistic was computed for this data. The number of cells containing zero and the distribution of cells containing less than five would make combining of cells for chi square computation meaningless.

68.2 percent of the total, and for unmarked units only 53.9 percent of the total. For vehicles involved in accidents when red lights were on, the only activity in which there was a significantly higher likelihood of an unmarked unit being involved in an accident than a marked unit was in road blocks. However, as noted earlier only 1.9 percent of all accidents involved road blocks. When red lights were off, there was no significant difference between accident incidence of marked and unmarked vehicles with regard to activity.

From the information presented thus far, it can be concluded that marked units were more likely to be involved in accidents than were unmarked units. The exact reasons for this are not clear. For those vehicles which were involved in accidents there were no major differences in accident experience between unmarked and marked vehicles with regard to type of activity in which the officer was involved immediately preceeding the accident. However, the mode of the red light (on or off) was related to both accident incidence and the type activity engaged in prior to the accident. This held true for both marked and unmarked units.

The next factor to be considered is accident severity. There was no relationship between the type of unit (marked or unmarked) and whether an accident resulted in property damage only or in personal injury. None of the accidents reviewed involved fatalities. Ninety-three percent of all accidents involving troopers had property damage and only 7.0 percent involved personal injuries. These same relative percentages were true for both marked and unmarked units. However, a disproportionately large number of personal injuries resulted from accidents which occurred when emergency lights were in use. As stated previously, 39.1 percent of the accidents involving troopers occurred when red lights were on; 72.5 percent of the personal injury accidents occurred with red lights on. This same

relative percentage held true for both marked and unmarked units. Table 7 depicts these relationships.

TABLE 7

Injuries and Light Mode

	Lights On	Lights Off	Total
Personal Injury	29 (72.5%)	11 (27.5%)	40 (100%)
Property Damage	72 (33%)	146 (67%)	218 (100%)
Total	101 (39%)	157 (61%)	258 (100%)

$X^2 = 22.11$ Signif. = .01

A second measure of severity is the dollar amount of damage incurred by the DLE vehicle during the accident. Again, there was no difference in the accident experience of marked and unmarked vehicles with regard to vehicular damage. For both types of vehicles, 88 percent of all accidents resulted in damage of less than 1000 dollars. As with the other factors, there was a difference in damage levels when an accident occurred while red lights were in use than where they are not. When red lights were in use, 21 percent of the accidents resulted in damage to the DLE vehicle in excess of 1000 dollars; for accidents which occurred when red lights were not in use, only 6 percent resulted in damages in excess of 1000 dollars.

The next issue to be considered is the type of patrol assignment during which accidents occurred. The first factor to be considered is light condition. When all accidents are considered, there was little difference between marked and unmarked units with regard to this factor. The relationships are shown in Table 8. Using the .10 significance level, there was no statistical difference in the experience of marked and unmarked units with regard to light condition.

This was also true if consideration is given only to accidents which occurred when red lights were on; 38.5 percent of the accidents involving unmarked cars utilizing red lights occurred during daylight. For marked vehicles, the figure was 38.6 percent.

TABLE 8

Light Condition and Vehicle Type

	Day		Dusk or Dawn		Darkness		Dark-Lighted		Total
Unmarked	19	(57%)	0	(0%)	8	(24%)	6	(18%)	33
Marked	108	(50%)	2	(0.9%)	80	(37%)	24	(11%)	214
Total	127	(51%)	2	(0.8%)	88	(36%)	30	(12%)	247

$X^2 = 2.79$* Signif. >.10*

*For purposes of computing the chi square statistic for Table 8, column 2 was not included because both cells contained fewer than five elements.

A second factor relating to patrol assignment is the type of highway on which the accident occurs in terms of number of lanes. Three classifications were used for this analysis: non-roadway areas including parking lots and unpaved areas; roads with less than four lanes; and roads with four or more lanes. The data are shown in Table 9.

TABLE 9

Vehicle Type and Number of Lanes

	Non Roadway		One, Two or Three Lanes		Four or More Lanes		Total
Unmarked	7	(21%)	20	(61%)	6	(18%)	33
Marked	44	(20%)	147	(66%)	32	(13%)	223
Total	51	(20%)	167	(65%)	38	(15%)	256

$X^2 = .440$ Signif. > .10

The data in the Table indicate that there is no statistical difference in the accident experience of marked and unmarked vehicles with regard to type of roadway. Of course, this statement assumes that the two types of vehicles were assigned to the various types of roadways in the same relative proportions; there is no reason to believe otherwise. When only accidents which occurred while red lights were on are considered, the experience of marked and unmarked units was again the same. For both types of units, 77 percent of the accidents which occurred with lights on occurred on one, two or three lane roads. The same percentage held true for marked and unmarked vehicles.

While there was no difference in the accident experience of marked and unmarked vehicles with regard to highway type, there was a difference between whether red lights were on or off and the type of highway on which an accident occurred. As already mentioned, 77 percent of the accidents which occurred when lights were on, occurred on roadways of one, two or three lanes; only 57 percent of the accidents which occurred when lights are off, occurred on these same roadways. A much greater proportion of the accidents occurred on non-roadways when emergency lights were off than when they were on. These data are shown in Table 10.

TABLE 10

Light Mode and Number of Lanes

	Non Roadway		One, Two or Three Lanes		Four or More Lanes		Total
Lights On	5	(5%)	78	(77%)	18	(18%)	101
Lights Off	46	(30%)	89	(57%)	20	(13%)	155
Total	51	(20%)	167	(65%)	38	(15%)	256

$X^2 = 23.44$ Signif. = .01

The third and final assignment factor to be considered is type of district. For purposes of this analysis, ten of the nineteen districts were classified into 3 classifications. Districts 3 and 4 (Cook County) represent the urban classification. Districts 1, 12, 13, and 14 represent rural districts, and Districts 2, 5, 8 and 11 represent in between or suburban districts. (See Appendix 2 for map depicting districts.) The ten districts were selected because they very clearly fit into their respective classifications. Other districts might be more difficult to clearly classify. Also, none of the districts selected included new districts which were created during FY81. While these districts were selected because they fit the general classifications, this does not mean that they are representative of other districts or that the ten districts are fully representative of the state as a whole.

The data from this analysis yielded several very interesting findings. First, the data in Table 11 indicates that unmarked units were much more likely to have accidents in highly urbanized districts than in suburban or rural districts. The two urban districts were assigned 20 percent of the unmarked vehicles being considered, but those vehicles incurred 41 percent of the accidents involving unmarked vehicles. The areas classified as rural and suburban were each assigned 40 percent of the unmarked vehicles. However, in both cases they incurred only 29 percent of the accidents involving unmarked units.

TABLE 11

Accident Experience of Unmarked Units
For District Type

	Urban		Suburban		Rural		Total
Accident	7	(41%)	5	(29%)	5	(29%)	17
No Accident	22	(17%)	54	(42%)	54	(42%)	130
Total Unmarked Units	29	(20%)	59	(40%)	59	(40%)	147

$X^2 = 5.58$ Signif. = .06

This pattern did not hold true for marked units. The data in Table 12 indicate that urban districts were assigned 20 percent of the marked vehicles in the ten districts being considered, but these vehicles had 29 percent of the accidents involving marked vehicles. Similarly, suburban districts included 41 percent of the marked vehicles and 47 percent of the accidents. Looking at the data from a slightly different angle, it can be seen that 44 percent (42 of 95) of the marked vehicles assigned to the urban districts had accidents. For suburban districts this figure is 35 percent (66 of 189) and for rural districts only 19 percent (33 of 175) of the marked units had accidents. Thus, the greatest potential for accidents for both marked and unmarked units is in highly urbanized areas. Marked units are least likely to have accidents in the rural districts while unmarked units are just as likely to have accidents in rural areas as they are in suburban areas.

TABLE 12

Accident Experience of Marked Units

For District Type

	Urban		Suburban		Rural		Total
Accident	42	(29%)	66	(47%)	33	(23%)	141
No Accident	53	(17%)	123	(39%)	142	(45%)	318
Total Marked Units	95	(20%)	189	(41%)	175	(38%)	459

$X^2 = 21.26$ Signif. = .01

This same method can be used to compare the accident experience of the two types of vehicles within a classification. As already stated, 44 percent of the marked units assigned to the urban classification had accidents. In comparison only 24 percent (7 of 29) of the unmarked units assigned to troopers in the two selected urban districts had accidents. Similarly, only 8 percent of the unmarked units assigned to the suburban classification had accidents compared to 35 percent of the marked units. In rural areas, the figure is again 8 percent for unmarked units and 19 percent for marked units. In each classification, unmarked units were less likely to incur accidents than marked units which is consistent with conclusions made from data presented in Table 2.

However, when all accidents for the ten districts are compared, 30.7 percent of the marked units had accidents while only 11.6 percent of the unmarked units had accidents. Compared to the statewide data shown in Table 2, the ten districts represent a slightly more extreme situation than the State as a whole. As set forth in the beginning of this section, statewide totals for troopers show that 26 percent of the marked units and 12 percent of the unmarked units had accidents.

Summary of Safety Issue

A vast amount of information was presented in this section on safety. To provide emphasis and clarity, conclusions made in the section are as follows:

- A 1971 study conducted by the California Highway Patrol (CHP) concluded, among other things, that there is no difference in the effect on traffic between the top mounted revolving light and deck light. Speed reductions in response to either were comparable.
- A 1980 CHP study of 766 accidents involving their vehicles concluded that there is no safety benefit from the use of roof mounted light bars.
- Analysis of 258 accidents involving Illinois Department of Law Enforcement (DLE) patrol vehicles indicates that marked units are more likely to be involved in accidents than are unmarked units.
- Data from both the Illinois and California studies indicate that, for those vehicles which are involved in accidents, there is no relationship in accident occurrence between the type of vehicle (with or without light bar) and whether or not the vehicle's emergency lights were in use.

- The analysis of DLE accidents also indicates there is no significant relationship for vehicles involved in accidents between vehicle type (with or without light bar) and the activity in which the car was involved at the time of the accident, or the severity of the accident.
- While there was no relationship in accident experience between the type of vehicle (with or without light bar), activity, or severity, there were some strong differences in accident experience between light mode (on or off) and activity, severity and lighting conditions.
- There was no relationship in accident experience between vehicle type (with or without light bar) and lighting conditions or type of roadway (number of lanes).
- Data from a sample of districts grouped into three classifications - rural, suburban, and highly urban - indicated that both marked and unmarked units were more likely to incur accidents in urban areas than in either of the two other classifications. However, in each classification, unmarked units were less likely to have accidents than were marked units.

IV. OTHER ISSUES

The primary concern of this paper was with the possible savings in fuel consumption which might occur if visabars were removed from squad cars and the impact of that removal on officer safety. There are two other issues which must also be considered.

Vehicle Speed

In addition to causing a vehicle to consume more fuel, roof-mounted equipment also causes a reduction of a vehicle's top speed. With current manufacturing trends focused on improving the fuel efficiency of vehicles, engines in new squad cars no longer have the massive horsepower of those produced just a few years ago. Consequently, many officers who drive the newer, more fuel efficient cars complain that the vehicles do not have the acceleration and top speeds necessary to respond to some emergency situations. Wind tunnel tests conducted by Kelland and Nishimura[15] found that a 1976 Plymouth equipped with a roof-mounted light system has an additional drag of 115 pounds when traveling at 100 miles per hour over that which a slick roof would have at the same speed. Approximately 31 extra horsepower is needed by a vehicle carrying the roof-mounted equipment in order for it to maintain the same speed as a comparable vehicle with a slick roof. The study found that the addition of just an open roof rack with no lights and no siren increased vehicle aerodynamic drag by 10 percent. The addition of two signal beacons increased this drag by another 5 percent, and by completing the package with a siren, the vehicle's aerodynamic drag is increased by another 20 percent for a total increase in aerodynamic drag of 35 percent over a slick roof.

The 1980 California study found that a roof-mounted light bar reduced the top speed of a patrol vehicle by 10 percent. In taking a very strong position, that report concluded that:

> "The 1980 Dodge St. Regis (318) has a top-end speed of approximately 106-108 mph without a light bar; therefore, if one is mounted on the vehicle, the top-end speed would be reduced to about 96-98 mph. The reduction of top-end speed on patrol vehicles is not a negotiable item for a Department involved primarily in traffic enforcement."[16]

Productivity

The other major rationale supporting the use of such equipment is that the equipment makes the vehicle more visible as a marked patrol unit, thereby adding to the omnipresent effect of preventive patrol.[17] Various studies and numerous articles have been completed attempting to evaluate the effect of preventive patrol. The topic is much too broad for purposes of this paper. Although Illinois State Police goals could be pursued and are, in part, pursued through preventive patrol, stated objectives indicate a heavy reliance on enforcement strategies as the

principal mechanism for pursuing those goals. Patrol primarily occurs incidental to enforcement. This balance, in favor of enforcement activities at the cost of preventive patrol activities, will continue to rise as the price of fuel increases. The issue of the effect of marked units in creating omnipresence is less relevant for an enforcement oriented approach to policing than it is for a prevention oriented approach. In fact, some would argue that feelings of omnipresence induced by strong enforcement activity using unmarked vehicles is much stronger than that produced by purely preventive patrol strategies.

This latter premise was tested by the New Hampshire State Police in 1972. Faced with a soaring rate of traffic fatalities, the New Hampshire State Police began utilizing unmarked patrol vehicles for traffic enforcement. The following year saw a sizeable reduction in the number of traffic fatalities. Although it is not possible to attribute the reduction strictly to the use of unmarked patrol units, Colonel Paul Doyon, Director of the New Hampshire State Police in 1972 has publicly stated his contention that the use of unmarked patrol cars was one of several factors which led to the reduction.[18] Colonel Doyon lists the advantages of an unmarked patrol vehicle as:

- It is better able to penetrate the defenses of the frequent, deliberate speed and law violator,
- It can more effectively monitor traffic going in two directions,
- It has a greater sphere of influence.

The International Association of Chiefs of Police holds a similar view. A study conducted by the Division of State and Provincial Police concluded:

"The tremendous spread in the use of C/B Radios by the motoring public, which hampers apprehensions of National Minimum Speed Limit (NMSL) violators, necessitates that some reasonable proportion of enforcement units be unmarked, camouflaged or aircraft."[19]

In their survey of 43 responding agencies, 63 percent (twenty seven) used unmarked vehicles. The number of unmarked vehicles used by respective agencies varied from 1 to 60 percent with a mean of 10 percent.

The I.A.C.P. in a later study conducted for the U.S. Department of Transportation regarding the productivity of various patrol vehicles in enforcing the NMSL, concluded:

- Productivity increases as the presence of officers becomes more difficult to detect, essentially through the use of unmarked patrol units and aircraft as detecting units.
- The single officer unmarked patrol car equipped with a moving radar in addition to the speedometer has the highest productivity of all patrol configurations evaluated.
- Lowering the visibility and increasing the availability of speed detecting devices increased apprehensions of passenger car violators equipped with C/B radios but not of commercial driver violators.

No analysis was conducted to determine whether Illinois troopers assigned to unmarked vehicles are more or less productive than those assigned to marked vehicles. Such analysis could be done but the results would be biased. While no formal policy exists detailing how the assignment of unmarked cars to individual troopers are made, there is general concensus among key management personnel that unmarked units are often assigned to troopers who have demonstrated superior productivity. Consequently, any analysis of existing data might be biased toward unmarked cars.

V. CONCLUSIONS

There are substantial data available which indicate that the Illinois Department of Law Enforcement has the potential to realize a first year reduction in fuel costs of approximately 237,000 dollars by removing roof-mounted equipment from patrol vehicles. As the cost of fuel continues to rise, this savings will also increase. On a per-vehicle basis, annual savings would average 236 dollars, or approximately 2900 dollars over the nine year expected life of replacement equipment (non-roof-mount) assuming an initial fuel cost of 1.35 dollars per gallon and an annual inflation factor of 8 percent. Additionally, elimination of the drag caused by the roof-mounted equipment would result in greater top speed and improved acceleration for vehicles.

Concerns over decreased officer safety resulting from the removal of such equipment appear unfounded. Analysis of accidents involving both the Illinois State Police and the California Highway Patrol indicate that the use of roof-mounted equipment does not play a role in reducing accident potential for state police vehicles.

There are also some data which support the contention that unmarked police units are more productive than marked units. The results of studies conducted by the International Association of Chiefs of Police found that unmarked units are more productive than marked units in national maximum speed limit enforcement.

Options

The Department of Law Enforcement has several choices with regard to roof-mounted equipment. They are as follows:

1. Continue with the current equipment and lighting configuration.

2. Replace currently used equipment with more aerodynamically designed roof equipment.

3. Utilize only unmarked vehicles which are equipped with grille, deck, and/or other more "covert" lighting systems.

4. Replace roof-mounted equipment with grille, deck and/or other systems which are not roof mount, but keep other vehicle markings such as stripes, emblems, and numbers on patrol units.

In addition to making an appropriate choice, an implementation program must also be developed. Different methods of implementation have varying costs attached to them depending on the alternative selected.

1. The first option is to continue with the current equipment. It offers the advantage of maintaining the existing image of the Illinois State Police patrol vehicle. The vehicle is highly visible and easily recognizable by the motoring public.

Selection of this option largely ignores data presented in this paper. While there may be some benefits from having highly visible, easily recognizable vehicles, it is not possible to put a dollar value on those benefits. Moreover, data presented indicate that these very factors (high visibility) may result in units being less productive in certain areas of enforcement than unmarked units. Selection of this alternative would result in no improvement in fuel consumption rates. In that sense, the choice would cost the Department the potential savings offered by the other options.

Further, this alternative is only a temporary solution. Expected operational life of roof-mounted equipment is estimated at nine years. Some of the light bars in use are approaching that age. Eventually, changes in the size of police vehicles may result in present equipment no longer fitting new vehicles. Thus, at some point a decision must be made on what type of equipment, if any, will be used to replace the light bars currently in use.

2. The second option is to replace equipment which is now being used with more aerodynamically designed roof-mounted equipment. This alternative offers several advantages. Like the first alternative, the image of the Illinois State Police patrol vehicle would not change. It would remain a highly visible, easily recognizable unit. Tests cited in this study indicate that some models of roof-mounted equipment have less adverse effect on fuel consumption than others. For example, the tests conducted by DLE indicate that Code III XL light bars resulted in 6.7 percent better fuel consumption rates than currently used Twinsonic lights. This translates into an annual savings per vehicle of 160 dollars or 120,800 dollars for the 755 vehicles equipped with Twinsonic lights. (See Appendix 3 for calculations.) However, if purchased in large volumes, the purchase price for such equipment would be approximately 225 dollars per unit. Consequently, it would take approximately 17 months for the new, more aerodynamically designed light bars to pay for themselves in fuel savings. The Department would incur actual savings for the remaining life of the equipment. Savings which would result from switching the 250 Yankee systems would not cover the cost of

replacement equipment. Therefore, only the 755 units equipped with Twinsonic could be converted. Assuming a fuel price of 1.35 dollars per gallon, an inflation factor for fuel of 8 percent annually, and an expected life for the new equipment of 9 years, savings for the Department during the nine years are estimated at 1,764 dollars per Twinsonic unit or 1,331,457 dollars for 755 units when the cost of replacement equipment is considered. (See Appendix 4 for calculations.)

While both benefits and savings can result from this option, there are also problems which could result from it. First, projected savings are not as substantial as would result from no roof-mount equipment. This is because fuel consumption on a per unit basis would not improve as much as with no roof-mount equipment. Secondly, the purchase of new roof-mounted (225 dollars per unit) equipment is more expensive than the purchase of non-roof systems (77 dollars per unit) currently used by the Department. Also, the price of replacement equipment does not justify converting the 250 Yankee units. Therefore, only 755 units, not the full 1005, can be converted. Thus, total savings are substantially higher when non-roof-mount equipment is chosen.

3. The third option was to make all vehicles unmarked units. This would result in the greatest potential savings. As already mentioned, lighting systems for unmarked vehicles cost approximately 77 dollars per unit. With a projected annual average savings of 236 dollars per vehicle from reduced fuel consumption, new lighting systems would pay for themselves in less than four months. Again, assuming a nine year life for the equipment, a starting fuel cost of 1.35 dollars per gallon and an

annual inflation factor of eight percent for fuel; savings for the nine years could total 2,887,000 dollars or 2900 dollars for each unit replaced. This option would also eliminate the cost of various decals and stripping currently placed on marked units (approximately $70 per car for a total annual cost of 17,500 dollars).

Along with dollar savings, this alternative also offers potential for increased productivity in certain types of enforcement. However, there are also some drawbacks to this alternative. Vehicles would not be easily recognizable. Consequently, it would be difficult for motorists to identify a State Police vehicle if they needed one. Also, without markings, it would be difficult for Air Operations to identify ground units. Public acceptance of State Police having all or even a majority of unmarked units might be quite low. Lack of legislative acceptance might make the alternative unfeasible.

4. The fourth alternative is to keep the units marked but to remove roof-mounted equipment. This alternative has many of the same savings attached to it as adopting unmarked units. Conversion would cost 77 dollars per unit with an annual average savings of 236 dollars. Estimated savings for the nine year life of the equipment would be 2,887,000 dollars or an average of 2900 dollars for each unit replaced. Emblems and decals would still be purchased for vehicles.

Savings would occur and there would be no problem with vehicle recognition. Vehicle markings make the vehicle easily recognizable from either side, the rear, or from above. The vehicle would not be easily recognizable from the front, but this might serve to increase productivity in traffic enforcement. Selection of this option instead of option number three is, in essence, placing a 70 dollar value on having a car marked (easily recognizable) during its four-year expected life.

VI. RECOMMENDATIONS

The Department should adopt a policy of not equipping vehicles with roof-mounted equipment. Other markings used on State Police vehicles should remain. This change would result in a patrol vehicle which is still highly visible, easily recognizable, and acceptable to the motoring public. The vehicle would have better acceleration and a higher top speed than those equipped with roof-mounted lights. Each such vehicle would cost the Department 77 dollars in equipment costs to convert and would save the Department an average of 236 dollars in first year fuel costs for each unit converted. While the major thrust of this recommendation is for the Department to adopt a marked patrol unit that does not include roof-mounted equipment, it is also suggested that far greater flexibility be given to districts in the assignment of totally unmarked units. In summation, these recommendations are based on the following factors.

- Changing from current equipment to either more aerodynamically designed roof-mounted equipment or to non-roof-equipment would result in substantial savings to the Department in terms of reduced fuel consumption.
- Utilizing non-roof systems result in the greatest savings in fuel and lowest costs for replacement equipment. Assuming a nine year life for equipment, a fuel inflation rate of eight percent annually, and subtracting equipment cost from savings, net savings per unit would total 2900 dollars for non-roof equipment and only 1763 dollars for more aerodynamically designed equipment.

- Only 755 of the currently marked units could be converted to more aerodynamically designed roof-mount equipment. Cost of replacement equipment for 250 Yankee systems cannot be justified on the basis of the savings. Thus, total savings for converting the fleet is substantially higher for no roof-mount equipment than for more aerodynamically designed equipment.
- There appears to be no decrease in officer safety resulting from the removal of such equipment.
- The research found no available data actually supporting the use of roof-mounted equipment.
- Continuing with a marked unit (although without roof-mounted lights) will be acceptable to the public and will continue the image of the Illinois State Police as a visible police force.

With a cost of 77 dollars per vehicle for non-roof lighting systems (grille and deck lights), conversion of the 1005 marked units will cost 77,385 dollars. Since the conversions will be completed by DLE radio lab technicians, costs for installation are a part of salaries which are already being paid. First year savings in terms of reduced fuel costs will total 237,400 dollars for a net first year benefit of 160,000 dollars.

Based on an annual inflation rate for fuel of eight percent and an expected life for the new lighting systems of nine years, savings resulting from the conversion will total approximately 2.9 million dollars over the life of the equipment. Assuming only a five percent rate of inflation, total savings would equal 2.5 million dollars; and assuming that current prices continue, savings would equal 2.05 million dollars over a nine year period.

Implementation

Implementation of this recommendation can occur in one of two ways. An immediate effort can be made to convert vehicles as quickly as possible. This method would result in the greatest potential savings as described in the previous paragraph.

A second method of implementation is phased-in by converting only new vehicles. Current replacement rates for State Police vehicles are running at 200 vehicles per year. Thus, it would take five years to convert a thousand vehicles. Fuel savings utilizing this plan of implementation are estimated at 2,705,745 dollars over a nine year period, or approximately 181,255 dollars (6 percent) less than immediate implementation.

Although immediate implementation does provide greater dollar savings in terms of reduced fuel costs than does phased-in implementation, it also has some additional costs. Phased-in implementation will give the public the opportunity to adjust to the changing image of State Police vehicles. It will also pose less of a problem in terms of an implementation schedule. Limited manpower at the radio lab would make rapid conversion of all vehicles very difficult. Radio repairs, other on-going tasks, and general work routines would be greatly disrupted if all vehicles were very rapidly converted. Travel time to radio labs and vehicle down time necessary for conversion would also have costs in terms of lost trooper manhours. In addition, phased-in implementation would permit the Department to gain gradual experience with the new design and provide time to continue analysis to assure that anticipated results do, in fact, occur. Based on these factors, it is recommended that a phased-in plan of implementation be adopted. However, implementation should not necessarily be limited to just new cars.

VII. FINAL COMMENTS

This analysis discovered several very interesting facts about the Illinois State Police accident experience. In some cases, these findings can not be fully explained.

First, marked units were 2.16 times more likely to have accidents than were unmarked units. This finding resulted even though only the accident experience for the rank of trooper was considered. There are several possible reasons for this. Drivers of marked units may develop a false sense of security from the fact that their cars are marked. This sense of security may make them less careful when driving or even when parking their vehicles.

Other possible reasons deal with the difference in the number of marked and unmarked vehicles in the fleet. Roughly 76 percent of the vehicles considered in the analysis were marked. It may very well be that these units, because they are present in greater numbers, do incur proportionately more accidents. That is, the probability of any single vehicle being involved in an accident may increase as the number of vehicles of that type in the fleet increase. If such is the case, the 76 percent of the fleet which is marked would have more than 76 percent of the accidents. However, that type of relationship cannot be identified until experience is gained under a more balanced fleet in terms of marked and unmarked vehicles. Also, this numerical difference may result in an assignment bias. Marked units may be assigned to accidents, traffic direction or other details because there are more of them or because they are marked. For example, if both a marked and an unmarked car are patroling the same area, the marked car may be assigned an accident because it is marked whereas the unmarked car is left to run radar because it is unmarked.

Another factor which may also contribute to difference in accident rates for marked and unmarked vehicles is the experience of the driver. Analysis indicates that while 31 percent of ISP troopers have five or fewer years of experience, this same group incurred 55 percent of the accidents. For those with six to eleven years of experience, 24 percent of the officers incurred 27 percent of the accidents. Similarly, the 24 percent of the officers who had twelve to seventeen years of experience incurred only 8 percent of the accidents. However, the distribution, with regard to seniority, of troopers assigned unmarked cars is different than the distribution of troopers generally. For example, as already stated, 31 percent of the troopers have less than six years of experience but only 20 percent of the unmarked units are assigned to troopers in this group. Similarly, the group which had the lowest accident rate, those with 12 to 17 years of experience, included 24 percent of all troopers but 33 percent of the troopers assigned to unmarked units. Thus, it is possible to conclude that there is a relationship between accident involvement and seniority, or perhaps age. This relationship may be one factor contributing to the difference in accident rates between marked and unmarked units. Conversely, it is also possible that the difference in accident rates for the two types of vehicles and the difference in distribution of those vehicles are contributing to the seniority pattern of accidents. Available data does not permit identification of the cause-effect relationship, it merely identifies that relationship exists.

Another major issue set forth in the analysis was the difference in accident experience between when emergency lights are in use and when they are not. The potential for accidents, the vehicular damage, and the injuries resulting from accidents were all greater for instances when red lights were in use. Also, the distribution of accidents occurring with emergency lights on was different with regard to type of roadway and lighting condition than it was for accidents which occurred when lights were not in use. The reasons for these differences cannot be established by analysis of the type done for this paper. However, the analysis has identified that differences do exist. Analysis of the type done in accident

reconstruction should be completed for Department accidents. Such analysis should identify factors associated with accident causation for each type of accident. If possible, training and policy should be developed to reduce the accident potential for instances when emergency systems are being utilized. Although such accidents constitute only a minority of all Department accidents, they involve the greatest proportion of personal injury and high property damage accidents.

FOOTNOTES

1. Y. Nishimura, J. Friedel, and S. R. Gwilt. Aerodynamic Drag of Automobiles With Roof-Mounted Equipment. (Ottawa, Canada: National Aeronautical Establishment, National Research Council Canada, May 1980), page 4.

2. Ibid., page 17.

3. Department of California Highway Patrol, "Fuel Consumption Test of Patrol Car With Various Roof light Bars," October 23, 1980. (Unpublished report.)

4. Winthrop E. Hilding, "Preliminary Report to Whelen Company on the Investigation of increased Aerodynamic Drag and Resultant Loss of Fuel Economy Caused by Installation of Light Bars on a 1979 Ford LTD Police Cruiser" (Storrs, Connecticut: Emergy Center, University of Connecticut, 1979 Unpublished Report.)

5. Kelly Dearivestes, "A Test of Light Bar Fuel Economy", (East Liberty, Ohio: Transportation Research Center of Ohio, 1978, Unpublished Report.)

6. Department of California Highway Patrol, "Emergency Warning Light Systems: Gasoline Consumption and Safety", 1981. (Unpublished Report.)

7. This information is reproduced from an internal Illinois Department of Law Enforcement memorandum produced by the Bureau of Logistics, August 26, 1980.

8. Ibid.

9. Department of California Highway Patrol, "Emergency Warning Light Systems: Gasoline Consumption and Safety", 1981. (Unpublished Report.)

10. See: Department of California Highway Patrol, "Sequential Light Study", 1974 (Unpublished Report); Department of California Highway Patrol, "Blue Light Study", 1973 (Unpublished Report); also, Department of California Highway Patrol, "Twinsonic Light Study", 1973 (Unpublished Report).

11. Harold Sullivan, Warning Light Study (Washington, D.C.: U.S. Department of Commerce, (1971).

12. Ibid.

13. Department of California Highway Patrol "Emergency Warning Light Systems: Gasoline Consumption and Safety", 1980 (Unpublished Report) page 8.

14. Ibid., page 6.

15. H. H. Kelland and Y. Nishimura, "Aerodynamic Drag of Automobiles With Roof-Mounted Equipment". Equipment Technology Center Bulletin, 1979, pages 3-5.

16. "Emergency Warning Light Systems: Gasoline Consumption and Safety", page 8.

17. O. W. Wilson and Roy C. McLaren. Police Administration, (New York: McGraw-Hill Company, 1972) pages 320 and 342.

18. Paul Doyon, "New Hampshire State Police: Unmarked Traffic Patrol" Law and Order, 21 (August 1973) page 79.

19. International Association of Chiefs of Police, Final Report: National Maximum Speed Limit Enforcement Practices and Procedures (Washington, D.C.: U.S. Department of Transportation, 1977).

20. International Association of Chiefs of Police, National Maximum Speed Limit Enforcement Practices and Procedures: Phase II, (Washington, D.C.: U.S. Department of Transportation, 1978).

APPENDIX 1

Calculation of Fuel Savings

	Twinsonic	Yankee
Slick Roof MPG	16.584	16.584
Current Equipment MPG	-14.807	-15.724
	1.777	.860
	÷14.807	÷15.724
Improvement	12.00%	5.47%

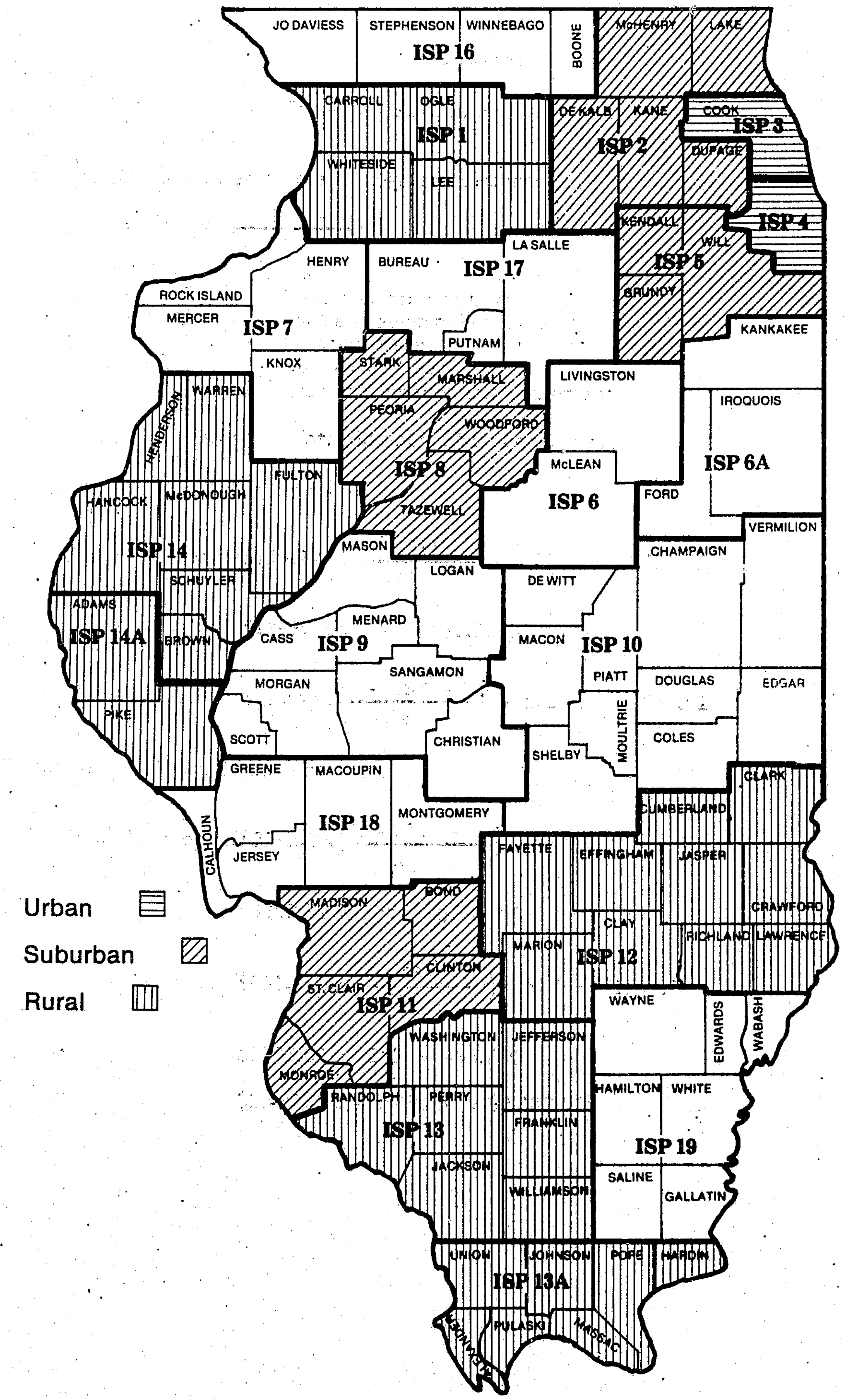
	Twinsonic	Yankee
Fleet Average MPG	10.882	10.882
Improvement	x 1.120	x1.0547
Expected MPG	12.188	11.477

	Twinsonic	Yankee
Average Annual Miles/Vehicle	20,470	20,470
Expected MPG	÷ 12.182	÷11.477
Gallons Per Year	1680.35	1784
Cost/Gallon	x$ 1.35	x$ 1.35
Cost/Year Without Lights	$2268.45	2408.40

	Twinsonic	Yankee
Current Average Fuel Cost Per Year	$2539.47	$2539.47
Cost Without Lights	- 2268.45	-2408.40
Savings Per Unit	$ 271.02	$131.07
Number of Units	x 755	x 250
Sub-Total Savings	$204,620	$32,767

	$ 204,620
	+ 32,767
Total Savings	$ 237,387
Number of Units	÷ 1,005
Average Saving Per Vehicle Per Year	$ 236.21

APPENDIX 2



APPENDIX 3

Code III XL Fuel Savings

	Twinsonic	Yankee
Code III XL MPG	15.798	15.798
Current Equipment	-14,807	-15.724
	.991	.074
	÷14.807	÷15.724
Improvement	6.69%	0.47%
Fleet Average MPG	10.8820	10.8820
Improvement	x 1.0669	x1.0047
Expected MPG	11.6100	10.933
Annual Average miles	20,470	20,470
Expected MPG	÷ 11.610	÷10.933
Gallons Per Year	1763.13	1872.31
Cost/Gallon	x$ 1.35	x$ 1.35
Expected Cost/Year	$2380.23	$2527.62
Current Average Fuel Cost Per Year	$2539.47	$ 2539.47
Expected Cost/Year	-2380.23	-2527.62
Savings/Unit	$ 159.24	$ 11.85
Number of Units	x 755	x 250
	$120,226	$ 2962

	$ 120,266
	+2,962
Total Savings	123,228
Total Units	÷ 1,005
Average Saving Per Unit	$ 122.62

APPENDIX 4

Projected Savings For Nine Year Period

Computations are based on the following equations:

$$TS_u = \left(S_1 \times \frac{(1+I)^N - 1}{I} \right) - C$$

where: TS_u = Total Savings Per Unit
S_1 = 1st Year Savings Per Unit
I = Inflation Rate
N = Number of Years
C = Cost of Replacement Equipment

Total Fleet Savings = Total Savings x Number of Units

To CODE III XL (Alternative #2)

From Twinsonic: $\left(\$159.24 \times \left(\frac{(1+.08)^9 - 1}{.08}\right)\right) - \$225 = \$1763.52$

$\$1763.52 \times 755 = \$1,331,457$

From Yankee: $\left(\$11.85 \times \left(\frac{(1+.08)^9 - 1}{.08}\right)\right) - \$225 = (-)\ \$77.02$

To Non-Roof-Mount Equipment

From Twinsonic: $\left(\$271.02 \times \left(\frac{(1+.08)^9 - 1}{.08}\right)\right) - \$77 = \$3307.38$

$\$3307.38 \times 755 = \$2,497,070$

From Yankee: $\left(\$131.07 \times \left(\frac{(1+.08)^9 - 1}{.08}\right)\right) - \$77 = \$1559.74$

$\$1733.00 \times 250 = 433,250$

$\$2,497,070 + \$389,936 = \$2,887,006$

APPENDIX 5

Calculation of Nine Year Savings
Based On Phased-In Implementation To Slick-Roofs

Calculations are based on the following equations.

$$TS = U \left[\left(S_1 \times \frac{(1+I)^N - 1}{I} \right) - C \right]$$

where: TS = Total Savings
U = Number of Units Converted
S_1 = 1st Year Saving Per Unit*
I = Inflation Rate
N = Number of Years
t = Costs for Replacement Equipment*

$$200 \left[\left(\$271 \times \frac{(1+.08)^9 - 1}{.08} \right) - \$77 \right] = \$661,426$$

$$200 \left[\left(\$293 \times \frac{(1+.08)^8 - 1}{.08} \right) - \$83 \right] = \$606,706$$

$$200 \left[\left(\$316 \times \frac{(1+.08)^7 - 1}{.08} \right) - \$90 \right] = \$545,921$$

$$200 \left[\left(\$341 \times \frac{(1+.08)^6 - 1}{.08} \right) - \$97 \right] = \$480,910$$

$$200 \left[\left(\$368 \times \frac{(1+.0)^5 - 1}{.08} \right) - \$105 \right] = \$410,782$$

Total $2,705,745

*The first year savings and the cost of replacement increases at the same rate as fuel.

END