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An Energy-Efficient Alternative To Daytime Running Lights

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Abstract

This project investigates the feasibility of Daytime Running Lights by examining the effectiveness of these devices by conducting research and analyzing the cost-benefit relationships. Having made these investigations, the project suggests alternative ways of achieving the effectiveness of the Daytime Running Lights with less energy. One of the most energy-efficient alternatives was designed and built. The results showed that the alternative approach required the consumption of 559,000 barrels of extra gasoline in the United States per year while the energy consumption rate of the most energy efficient DRL was determined to be 56,000,000 barrels of gasoline per year.

Executive Summary

This project is based on one of the latest and most controversial topics in traffic safety. The concept of using Daytime Running Lights (DRLs) as a traffic accident reduction measure dates back to the 1960s. The effectiveness of DRLs has been extensively researched in many countries and the countries which determined that the use of DRLs reduces traffic accidents passed laws that made it mandatory to keep the headlights on at all times. In spite of all the research done, it is still not conclusive if DRLs significantly reduce traffic accidents.

In preparation for this project, extensive research has been done to uncover all the study conducted pertaining to DRLs. Several organizations including Transport Canada and National Highway Traffic Safety Administration have been contacted to request publications and the result of their studies to aid the project.

The main goal of this project was to find out the largest sources of energy consumption in our every-day lives. Having determined the sources of big energy losses, the next step was to investigate the possibilities of saving some or all of that energy being wasted needlessly.

Observing the energy requirements of the DRLs revealed the fact that these devices actually consume a lot more energy then they really need to. It was apparent that a large amount of energy could be saved if other more carefully designed devices were adopted to achieve the same goal as the DRL.

Coming up with alternative designs that would achieve similar results as the current DRL systems by using less energy was another important part of this project. It was also necessary to develop a procedure to compare the different alternatives so that one of the alternatives could be selected to replace the current DRL systems. In addition, a trade-off analysis was done to further help comparing the alternatives and the current DRL systems.

It was necessary to get the opinion of the public on the different alternatives in order to be able to determine which of the possible alternatives was more likely to be accepted in the market. Thus, a survey was conducted in the Electrical and Computer Engineering Department of Worcester Polytechnic Institute. The 74 people who participated in the survey provided invaluable input to the project that helped determine an alternative to the current DRLs.

To prove the accuracy of the hypothesis of this project, one of the alternative designs was designed and built. The results showed that, in the United States, the alternative approach would require the consumption of 559,000 barrels of extra gasoline per year while the energy consumption rate of the most energy efficient DRL was determined to be 56,000,000 barrels of gasoline per year. The alternative design was clearly at least 100 times more energy efficient than the most energy-efficient DRL system currently available.

The conclusion is that the current DRL systems are consuming an unnecessary amount of energy, which could certainly be routed to carrying out more useful and productive tasks. Thus, the design specifications of the current DRL systems should be re-evaluated and the necessary changes should be made.

1. Introduction

This project investigates the feasibility of Daytime Running Lights (DRLs) by examining the effectiveness of these devices by conducting research and analyzing the cost-benefit relationships. Having made these investigations, the project attempts to find alternative ways of achieving the effectiveness of the DRLs with less energy.

The Background section examines the history of the DRLs and the related research that has been done in that area. Additionally, this section investigates the effectiveness achieved by DRLs so far in different countries. This section also reviews the publications written by organizations working on the same project.

The next section tells the reader how the topic for this project was selected and it determines the goals for the project. In addition, four other alternatives to using DRLs are introduced.

The first part of the Analysis section discusses the procedure that needs to be established to make a logical selection amongst the possible alternatives to replace the current DRLs. Next, calculations are made to determine the amount of energy being consumed by the current DRLs so that these figures can be used to select an alternative to the DRLs which will require less energy. The final part of the section performs a trade-off analysis to come up with an alternative which is the most suited to replace the current DRLs. Lastly, the results of the survey conducted is presented.

The Implementation section carries out one of the alternative hardware designs that could possibly replace the current DRLs. It shows the hardware implementation in detail and makes the necessary calculations to show how much energy is conserved if this alternative design was applied to cars.

The final section draws conclusions from the data collected through research and the results obtained from the implementation of the alternatives.

2. Background

2.1 The Problem

Most traffic collisions are caused by driver information processing problems such as faulty visual perception, recognition errors and comprehension errors [Clayton and Mackay, 1972; Indiana U., 1975]. Common among such problems is the failure to notice another vehicle or judge its speed.

Research has shown that the ability of human eye to detect an object depends on a number of factors, but especially on the visual angle subtended by the object on the observer's retina, the luminance (brightness) of the object, and the luminance of the background [Grether, 1963].

The issue is not how well drivers can see. Good vision is critical to safe driving, and is therefore a requirement to obtain a driving license. Accidents caused by poor vision are rare in comparison with those caused by the attention problems associated with distractions, boredom, fatigue, tension and alcohol or drug impairment [Indiana U., 1975; Ontario, 1992]. These factors interfere with a driver's perception of objects and processing of visual details. For example, a driver may not perceive another vehicle if he or she is searching for street signs in an unfamiliar area, adjusting the radio, or mulling over a personal problem.

Considerable research has been carried out on the perception of objects by the human visual system. Visual perception in traffic is influenced by both visibility and cognition, i.e. the thinking process. Perception is closely related to attention level, selection, activation of memory elements, and central information processing that leads to judgment and control movements [Koornstra, 1993]. The visual detection of a target is determined by three factors – contrast of the target against its background (brightness and color), angular size and motion [Rumar, 1981]. Of these factors, visual contrast is the essential characteristic which enables drivers to perceive and monitor other vehicles in traffic. Low contrast between a vehicle and its background, which makes oncoming vehicles difficult to perceive quickly and easily, is a common driving situation, even in broad daylight [Attwood, 1981; Rumar, 1981]. Visual contrast is reduced by clouds, precipitation, low natural light and shadows (especially at dawn and dusk), similarity of vehicle and background color, and confusing or cluttered background. The increased contrast provided by DRL is designed to attract attention, thus counteracting the distractions and other causes of inattention. DRLs also have a favorable effect on the other two factors – the driver's ability to judge distance (angular size) and motion of other vehicles.

Behavioral studies have demonstrated that an observer's ability to detect the presence of a vehicle and to judge its speed and position increases when the vehicle lights are on, in daylight as well as darkness conditions [Attwood, 1975:1, 1975:2, 1976, 1981; Attwood and Angus, 1975; Dahlstedt and Rumar, 1973; Hörberg, 1977; Hörberg and Rumar, 1979; King and Finch, 1969; Olson et al., 1980; Padmos, 1988; Rabideau and Young, 1979; Ziedman et al., 1990].

DRLs have been introduced as a countermeasure to reduce daytime multiple-car accidents. DRL provide a way of producing visual contrast which enables the vehicles to be detected more effectively by other drivers. DRLs are typically either low-beam headlights full power or high-beam headlights at reduced intensity.

Several studies have been conducted by various countries all over the world to determine whether DRLs make any difference in preventing accidents. These studies have also done a cost/benefit analysis and based on the results, some of the countries in Europe, such as Norway, Sweden, Finland and Denmark, decided to make the use of DRL mandatory especially under poor weather conditions such as rainy days and winter days. In Canada, vehicles manufactured after December 1, 1989 are required to have DRLs.

Evidence concerning the effectiveness of daytime running light effects on crashes comes from two sets of studies – earlier studies (through 1986) from Scandinavia, where DRL use was increasing because of recommendations and laws, plus fleet studies in the United States, and later studies (1991-1994) primarily from Scandinavia and Canada.

2.2 Earlier Studies

A study in Finland conducted between 1968 and 1974 found that DRLs, when required on rural roads in the winter, were associated with a 21-percent reduction in daytime multiparty crash events involving more than one motor vehicle or motor vehicles colliding with pedestrians or pedalcyclists). In Sweden, a study based on two years of pre-law and two years of post-law data reported an 11-percent reduction in multiparty daytime crashes subsequent to the DRL law. A study [6] in Norway [published in Norwegian and reviewed by Koornstra] found a 14-percent drop in multiparty crashes prior to the law, during 1980-85 period when voluntary DRL use was climbing. These reported reductions occurred as the number of DRLs on vehicles increased from about 50 percent to about 97 percent in Finland, 55 percent to 98 percent in Sweden, and 35 percent to 65 percent in Norway.

In the United States, a small-scale fleet study conducted in the 1960s found an 18-percent lower daytime, multiple-vehicle crash rate for DRL-equipped vehicles [8]. In a much larger fleet study conducted in the 1980s, more than 2000 passenger vehicles in three fleets were equipped with DRLs [9]. One fleet operated in Connecticut, another fleet operated in several States in the Southwest, and the third operated throughout the United States. A 7-percent reduction was found in daytime multiple-vehicle crashes in the DRL-equipped vehicles compared with control vehicles.

The early Scandinavian and United States studies have been subjected to considerable criticism with regard to their evidence of DRL effectiveness. Despite problems with the early studies, however, when they are taken together, they support a conclusion that the use of DRLs can reduce crashes.

2.3 Later Studies

The later studies add important knowledge about the effects of DRLs on crashes. A study in Norway, covering the period 1980 to 1990, examined the effects of the country's DRL law, which applied to new cars in 1985 and to all cars beginning in 1988[10]. DRL use was estimated to be about 30-35 percent in 1980-81, 60-65 percent in 1984-84, and 90-95 percent in 1989-1990, so, as in the earlier Scandinavian studies, only partial implementation of DRL was assessed. There was a statistically significant 10-percent decline in daytime multiple-vehicle crashes associated with DRLs in the study, excluding rear-end collisions.

Two studies have been conducted in Denmark evaluating the short-term and the long-term effects of the use of DRLs [11,12]. Results of these two studies were consistent. There was a small reduction in daytime multiple-vehicle crashes (7 percent) in the first fifteen months the law was in effect, with one type of DRL-relevant crash (left turn in front of oncoming vehicle) reduced by 37 percent. In the second study, which covered 2 years and 9 months of the law, there as a 6-percent reduction in daytime multiple-vehicle crashes, and a 34-percent reduction in left-turn crashes.

In a study in Canada comparing 1990 model-year vehicles (required to have DRLs) with 1989 vehicles (29 percent of which had DRLs), a statistically significant 11-percent reduction in daytime multiple-vehicle crashes other than rear-end impacts was estimated[1].

In another Canadian study, crashes of vehicles with and without DRLs in a government fleet in Saskatchewan were compared with a random sample of crashes involving vehicles without DRLs. The estimated reduction in daytime two-vehicle crashes was 15 percent[13].

In summary, although the studies of DRLs have differed in design, analysis techniques and outcome measures, the later studies agree with the earlier studies, indicating that the effect of DRLs on the reduction of motor vehicle crashes is positive. This conclusion has been reached by every reviewer of the literature [7,14,15] including the International Steering Committee on DRLs.

2.4 Effectiveness of DRLs in Canada

The prospective analysis of the effectiveness of the DRL regulation [Lawson, 1986] yielded an estimated reduction in target collisions of between 10 and 20 percent. When the measure was introduced, almost 30 percent of passenger vehicles were using either existing headlamps or some form of DRL, so the unadjusted estimate of effectiveness, at 8.3 percent, fell just below that range. Accounting for the existing daytime use of forward lighting, the resulting adjusted effectiveness of 11.3 percent was just above the lower end of the predicted range.

The reason for the apparent over-involvement in target collisions of the newest vehicles is not obvious; indeed, that is among several questions that merit further consideration. It is not, therefore, clear that an estimate of DRL effectiveness based (necessarily in the case of a motor vehicle equipment standard) on the experience of newest model year, provides a reliable estimate of the long-term effectiveness of the measure. Accordingly, the figure of 11.3 percent is to be preferred, at least for the present.

It should also be recalled that, principally for reasons of clarity of definition of the groups of collisions, those occurring in the twilight hours at dawn and dusk were excluded from the analysis reported here. That exclusion implies that the percentage reduction in daytime target collisions alone underestimates the total number of collisions avoided as a consequence of the

DRL regulation. While relatively few collisions occur in the twilight hours, taking them into account may also yield a modest increase in the effectiveness of the regulation in percentage terms. A separate analysis of the effectiveness of DRL in twilight is planned.

2.5 DRLs in United States

The DRLs show crash reduction in the countries which are at a high latitude due to the fact that countries at a higher latitude experience longer periods of twilight, low sun and low ambient illumination. However, it is still not known what the effect is when they are used in countries at lower latitudes where the brighter day conditions will allow the DRLs to provide less contrast.

The DRL concept is believed to have originated in Texas as a campaign to reduce accidents during major holidays[16]. Since that time, a number of government and private agencies have promoted 'lights-on' campaigns with conflicting results.

In support of the concept, the Grayhound Corporation reported a significant decrease in daytime collision accidents in the year immediately following initiation of a daytime running light program in the early 1960's. The overall number of accidents decreased by approximately 12 percent and in Canada a reduction of approximately 24 percent was reported.

Allen (1965) surveyed 181 U.S. companies that were known to be using running lights. Results indicated that decreases in accidents of up to 38 percent were reported after the companies installed the running lights although the reduction due entirely to the lights was, as Allen explains, probably below this figure owing to the increased accident awareness which generated the installation of the lights [17].

In 1965, the New York Port Authority (PA) modified 38 passenger cars so that parking and taillights turned on automatically with the ignition. Results after one year showed a statistically significant reduction in accident rate for the group of modified cars (Cantilli, 1965). Owing to the success of this pilot program, approximately 200 vehicles were modified by the PA in the same manner in 1967 and their accident production was compared over a one-year period with a group of approximately 400 unmodified vehicles (Cantilli, 1970). About 66 percent of the vehicles used in the 1967 study were passenger cars, 27 percent were light trucks and the remainder were heavy trucks. Vehicles from each class were assigned to the experimental groups (unmodified and modified) in about a 2:1 ratio. Approximately two-thirds of the passenger cars were black and one-third were yellow.

The researchers compared both the number and the severity of the accidents recorded in the period between dawn and dusk for each group vehicles. Only those accidents where the PA vehicle was hit by another vehicle were used to compute the accident statistics. Over the total observation period, there were about 18 percent fewer accidents per million vehicle miles (MVM) recorded for the modified vehicles as compared with the unmodified group of vehicles. Total accident severity per MVM for the modified group of vehicles was down about 66 percent from that for the unmodified group. Considering only passenger cars, the accident and severity rates for the modified group were 23 percent and 44 percent respectively below the rates for the unmodified group. Considering all types of recorded accidents, the largest reduction (45 percent) for the modified group of vehicles as in the rear-end accident rate. Only the sideswipe accident rate was higher for the modified group of vehicles. Accident and severity rates for the group of modified black passenger cars were significantly less then those for the unmodified group of black cars. The accident rate of the group of yellow modified cars (14.78 per MVM) was higher than that of the group of yellow unmodified cars (11.29 per MVM) but these differences were statistically significant.

The study, though generally demonstrating the beneficial effects of using parking lights and taillights during daylight hours, left several issues in doubt.

For example, in a recent daytime running light campaign sponsored by a community in California, a significant increase in the number of rear-end and daytime collisions was reported for vehicles which ran with their lights on. The significant increase was attributed to less visible break lights owing to a reduction in contrast between the running light and the break light in the combination taillight system.

Although the results of DRLs conducted in other northern countries cannot be directly applied to the United States, findings from other studies suggest that the effects of DRLs will also be positive in the United States. A study[18] by Environment Canada indicated that although Sweden has less daytime brightness than Canada, 40 percent of total daylight hours in Sweden were considered bright or very bright versus 54 percent in Canada, and in the Andersson and Nilsson study [4] the crash reduction effect in Sweden was about the same in high and low-ambient conditions. In the Saskatchewan study [13], DRLs were estimated to reduce crashes more during twilight than during daylight periods, but the reductions during full daylight were also substantial, leading the authors to conclude that vehicles equipped with DRLs in the United States would be expected to reduce multiple-vehicle crashes by only marginally less than 15 percent.

Finally it has been demonstrated in a test track study [19,20] that although low intensity DRLs do not improve vehicle detection in high ambient conditions, DRL intensities of 1600 candela do improve detection over a range of ambient light levels characteristic of the United States.

2.6 Other Studies Regarding DRLs

Several studies have observed typical vehicle-background contrasts and have investigated the use of running lights to increase visibility [17].

Allen and Clark (1964) measured the relative visibility of a number of light- and dark-colored automobiles. They conclude that light-colored cars are up to *40 times more visible* than some dark-colored cars.

Allen et al. (1969) examined the effect of low-beam headlights on the behavior of approaching drivers. They measured the lateral placement of oncoming vehicles when the experimental vehicle had its lights on or off during daylight hours. The results indicated that with headlights on, an apparent improvement was produced in the position of oncoming traffic in its own lane. The improvement was attributed to an increase in driver alertness and an awareness for a greater length of time of the presence and behavior of a car with lights on than when they are not displayed, (p. 36).

King and Finch (1969) recorded subjective estimates of the relative visibility of various intensities of a light which was mounted on a vehicle 600 feet away from the observers. Results indicated that, during periods of maximum background luminance, subjects reported definite improvement in visibility on at least 85 percent of the trials when the light intensity was at least 1800 candle power.

In a related study, Janoff et al. (1970) investigated the relative daytime visibility of motorcycles with and without front and rear lights on. Results showed that the experimental motorcycles, with their headlights on, were noticed by between 44 percent to 142 percent more drivers, depending on the traffic conditions. In contrast, they found that visibility of a motorcycle from the rear was not improved by using rear-lights even when the lights were modified slightly to make them more visible.

2.7 Results From Literature Review

The following comments have resulted from a review of the literature [17] related to DRLs:

i. The visibility of vehicles could be reduced considerably at typical levels of daylight illumination under certain combinations of vehicle color and background characteristics.

ii. Vehicles equipped with front running lights are generally more visible during daylight hours than those not so equipped.

iii. Significantly fewer frontal collisions occur to vehicles equipped with front running lights. Conflicting results have been reported, however, for rear-end collisions on vehicles equipped with rear running lights.

iv. To the knowledge of the author, no controlled experiments under typical driving conditions have yet been performed to determine whether vehicles equipped with front or rear running lights can be detected sooner or whether position and relative velocity can be estimated more accurately than with vehicles not so equipped.

v. To the knowledge of the author, no controlled studies have yet been conducted to determine the effect of the daytime use of *headlights* on accident production.

vi. Research indicates that factors in addition to ambient illumination control a driver's decision to turn on his lights in the daytime, but no formal survey has been conducted to determine what or how powerful these other cues might be.

vii. As yet, there is no conclusive evidence with which to rate one type of running light system relative to another. Studies indicate that the present rear lighting design may be relatively ineffective during daylight conditions.

viii. Neither government legislation on the use of driving lights nor promotional campaigns would be as effective in ensuring the daytime use of running lights as the mandatory installation of systems to automatically turn on the running lights when the vehicle is started.

National Highway Traffic Safety Administration also concluded that DRLs have not demonstrated sufficient data to be a cost-effective crash reduction method based on the fact that the Scandinavian experience with DRLs is not necessarily applicable to the United States.

2.8 Current Daytime Running Light Specifications and Regulations

DRLs are suggested for use during daytime and the National Highway Traffic Safety Administration (NHTSA) has published guidelines as to how DRLs should be operated on motor vehicles.

The NHTSA guidelines [21] regarding DRLs are as follows:

S5.5.10 The wiring requirements for lighting equipment in use are:

(a) Turn signal lamps, hazard warning signal lamps, and school bus warning lamps shall be wired to flash;

(b) Headlamps and side marker lamps may be weed to flash for signaling purposes;

(c) A motorcycle headlamp may be wired to allow either its upper beam or its lower beam, but not both, to modulate from a higher intensity to a lower intensity in accordance with section S5.6;

(d) All other lamps shall be wired to be steady-burning.

S5.5.11

(a) Any pair of lamps on the front of a passenger car, multipurpose passenger vehicle, truck, or bus, whether or not required by this standard, other than parking lamps or fog lamps, may be wired to be automatically activated, as determined by the manufacturer of the vehicle, in a steady burning state as daytime running lamps (DRLs) and to be automatically deactivated when the headlamp control is in any position, and as otherwise determined by the manufacturer of the vehicle, provided that each such lamp:

(1) Has a luminous intensity not less than 500 candela at test point H-V, nor more than 3,000 candela at any location in the beam, when tested in accordance with Section S11 of this standard, unless it is:

(i) A lower beam headlamp intended to operate as a DRL at full voltage, or at a voltage lower than used to operate it as a lower beam headlamp; or

(ii) An upper beam headlamp intended to operate as a DRL, whose luminous intensity at test point H-V is not more than 7,000 candela, and which is mounted not higher than 864 mm above the road surface as measured from the center of the lamp with the vehicle at curb weight;

(2) Is permanently marked ''DRL'' on its lens in letters not less than 3 mm high, unless it is optically combined with a headlamp;

(3) Is designed to provide the same color as the other lamp in the pair, and that is one of the following colors as defined in SAE Standard J578 MAY88: White, white to yellow, white to selective yellow, selective yellow, or yellow;

(4) If not optically combined with a turn signal lamp, is located so chat the distance from its lighted edge to the optical center of the nearest turn signal lamp is not less than 100 mm, unless:

(i) The luminous intensity of the DRL is not more than 2,600 candela at any location in the beam and the turn signal meets the requirements of S5.3.1.7; or

(ii) (For a passenger car, multipurpose passenger vehicle, truck, or bus that is manufactured before October 1, 1995, and which uses an upper beam headlamp as a DRL as specified in paragraph S5.5.11(a)(1)(ii)) the luminous intensity of the DRL is greater than 2,600 candela at any location in the beam and the turn signal lamp meets the requirements of S5.3.1.7; or

(iii) The DRL is optically combined with a lower beam headlamp and the turn signal lamp meets the requirements of S5.3.1.7; or

(iv) The DRL is deactivated when the turn signal or hazard warning signal lamp is activated.

(5) If optically combined with a turn signal lamp, is automatically deactivated as a DRL when the turn signal lamp or hazard warning lamp is activated, and automatically reactivated as a DRL when the turn signal lamp or hazard warning lamp is deactivated.

(b) Any pair of lamps that are not required by this standard and are not optically combined with any lamps that are required by this standard, and which are used as DRLs to fulfill the specifications of S5.5.11(a), shall be mounted at the same height, which shall be not more than 1.067 m above the road surface measured from the center of the lamp on the vehicle at curb weight, and shall be symmetrically disposed about the vertical centerline of the vehicle.

The Society of Automotive Engineers (SAE) also have published standards regarding vehicle lighting which can be obtained directly from SAE.

2.9 Cost-Benefit Analysis

A study [22] conducted by Transport Canada determined the costs related to the daytime running light systems as shown in Table-1 and Table-2.

Type of DRL System		Cost ($) of DRL System		Weighted Cost ($) by Type of DRL System	
		Low	High	Low	High
1	Full-Intensity Low Beam	0.61	11.26	0.10	1.88
2	Reduced-Intensity Low Beam	15.03	21.40	4.12	5.86
3	Reduced-Intensity High Beam	2.75	9.71	1.45	5.11
4	Turn signals	7.45	19.25	0.16	0.42
5	Fog Lights	5.42	5.42	0.03	0.03
6	Separate DRL	1.37	7.85	0.10	0.03
7	Increased-Intensity Parking Lts.			0.00	0.00
	TOTAL			5.87	13.34

Table-1 : Sales-Weighted Cost of Equipping A Vehicle Sold In Canada With DRL

Original Equipment Cost		Lifetime Operating Costs			Total Costs	
Low Estimate	High Estimate	Fuel Due to Added Weight	Fuel Due to Added Electrical Load	Bulb Replacement	Low	High
8		2	92	N/A	102	
	17	2	92	N/A		111

Table-2: Costs of The DRL Regulations (In $Millions)

2.9.1 Low-Cost Benefit

When the low-cost original-equipment estimate of $5.87 is used, the DRL regulation is clearly cost-beneficial, the present value of the net benefits being approximately $7 million. The regulation is clearly justified in this case.

2.9.2 High-Cost Benefit

When the high original-equipment cost of $13.34 per vehicle is used, the regulation results in net social disbenefits with a present value of approximately $3 million. However, this does not mean that the regulation is not cost-beneficial. First, the Directorate has always maintained that, given its use of minimum values in the calculation of injury-reduction benefits, a regulatory initiative would be clearly justified if the benefits outweighed the costs, but that the converse is not true. Second, not all potential benefits from this regulation have been included in this analysis. For example, there are potential collision-reduction benefits from use of DRL during twilight hours. Third, while the cost of equipping every single 1990 model-year, light-duty vehicle sold with DRL has been included in the cost-estimates, benefits accruing to those 1990 model-year, light-duty vehicles involved in multi-vehicle, daytime-frontal or side-impact collisions have not been included. Fourth, there are other potential benefits that would accrue to other road users such as pedestrians and bicyclists. All these additional benefits are currently being analyzed and will be included in an update to this preliminary evaluation.

2.9.3 Conclusion

Transport Canada's Road Safety and Motor Vehicle Regulation Directorate's recently-completed retrospective assessment of the effectiveness of the DRL regulation on daytime, two-vehicle collisions involving passenger cars, light trucks and vans indicates that the use of DRL reduced such collisions by 8.3 percent. After appropriate adjustments are made for pre-regulation, voluntary DRL use and the small proportion of 1989 model-year vehicles equipped with DRL, the reduction becomes 9.3 percent.

This effectiveness translates into the prevention of 5 fatal, 454 non-fatal, and 1600 property-damage collisions for all of Canada in 1991, and a reduction of approximately 48 fatalities, 4,300 injuries and consequent property damages from the 11,800 collisions avoided over the lifetime of the 1990 model-year light-duty vehicle fleet.

An assessment of the average cost to equip a vehicle with DRL was undertaken in September 1992 concluding that the per-vehicle weighted average cost-estimate ranges from a low of $5.87 to a high of $13.34. Given 1990 model-year, light-duty vehicle sales of 1,288,973, the low estimated-cost to equip the fleet with DRL is approximately $8 million, while the high estimated-cost is approximately $17 million. The total low cost of the DRL regulation is $102 million, while the high total cost is $111 million.

Therefore, this preliminary economic evaluation of the costs and accompanying benefits of the regulation shows that when the low cost-estimate is used, the regulation is clearly cost-beneficial, the present value of the net benefits being approximately $7 million. When the high original-equipment cost of $13.34 per vehicle is used, the regulation results in net social disbenefit with a present value of approximately $3 million and, therefore, is not clearly justified. However, this does not mean that the regulation should be denied, because not all potential benefits have been included in this analysis and those that are have been conservatively estimated.

3. Goals

3.1 Deciding on a Topic

In our society, energy has a very considerable place since everything we do depends on utilizing some kind of energy. On the other hand, we do not necessarily care enough about our limited amount of useable energy resources. In fact, there have been several studies conducted to determine how much more energy we can produce from our available resources without endangering our own lives. The results indicate that it will not be long before we exhaust our reserves. Scientists are researching methods by which we might extend the life-time of our current energy resources; they are also studying other methods of safe energy-production.

Another approach to extending the life-time of our resources is to make sure that we use our available energy wisely. The purpose of this IQP is to find ways of reducing or possibly eliminating the amount of energy that is currently being wasted on various tasks.

We constantly use energy in our daily lives. Thus, the first task of this project was to find out the largest sources of energy consumption in our every-day lives. Having determined the sources of big energy losses, the next step was to investigate the possibilities of saving some or all of that energy being wasted needlessly.

3.2 Why Daytime Running Lights?

The usage of DRLs is a very hot topic which is also very controversial in the United States. Although it has been proved to some extent that DRLs are successful, that is, they save lives on the road by keeping the headlights of a vehicle on when the engine is running, they still consume a significant amount of valuable energy. Obviously, using energy to save invaluable lives is no topic of discussion, however, if it is possible to achieve the same results through the use of alternative means of increasing the contrast between a vehicle and its background, then it is very logical to adopt the more energy-friendly solution to the problem.

This project does not necessarily discuss the effectiveness of DRLs. The goal of this project is to come up with alternative ways of increasing the detectability of a vehicle and the perception of the driver by utilizing methods which require less energy than the conventional DRLs.

3.3 Alternatives to DRLs

There are many ways of making a vehicle more visible to the other drivers on the road. As mentioned before, researchers have already identified the origin of the problem to be an attention problem rather than a visibility problem. Thus, the alternative method which will attempt making a vehicle more attention grabbing does not necessarily have to use the amount of energy as do conventional DRLs. DRLs are an ease fix to the detectability problem. Since the headlights are already installed on every car, it seems to be the easiest solution to use whatever equipment is available on every car no matter how old or new it is. Even though this approach is not absolutely illogical as it is easy to implement a solution which utilizes equipment that is available on all cars, it is still very inconsiderate of many other aspects related to the issue. Obviously, it can be assumed that every car has a set of headlights. On the other hand, there will be a need for the modification of the set of headlights the vehicles have to make them turn on when the engine starts running. If modification will be necessary, then it is more logical to implement a solution which requires similarly easy installation procedures, is equally successful in making the vehicle more detectable, and is also energy efficient.

This project examines the following alternative solutions to be used in place of the current DRLs:

i. Painting the vehicle with bright colors
ii. Placing an attention-grabbing set of running lights in front of the vehicle
iii. Light-sensitive DRLs
iv. Advanced light-sensitive DRLs

Each alternative has been studied with respect to its cost, maintenance, energy consumption, visibility (visual contrast) and esthetics. A group of people from the Electrical Engineering Department of Worcester Polytechnic Institute have also been surveyed to determine the opinion of people about each alternative if any one of them was to be selected to replace the current DRLs.

4. Analysis

4.1 Selection Process of the Alternative

Several different methods of determining a reasonable alternative solution have been applied to the problem at hand in order to come up with a more energy-efficient solution which would also be readily accepted by the public.

The first step in finding an alternative solution was to weigh the different aspects of each alternative and to make logical estimates of how effective each solution would be compared to the current DRLs. The results are twofold; one way of weighing different aspects of each result depends solely on numerical calculations that do not the human factor into account while another way of doing the same evaluation makes sure that the alternative that has been selected will be readily accepted by the public. In order to satisfy both approaches, pure mathematical calculations were accompanied by a public survey.

The next step involves calculating the energy consumption levels of each alternative and comparing the results to see which alternative might be a better selection.

The final stage deals with investigating the applicability of the selected alternative to current vehicles; both new and old. The desire is that the alternative approach to DRLs should be able to be implemented on all types of vehicles with no or minimal modification to the vehicle itself.

4.2 Energy Consumption Calculations For The Current DRLs

The following calculations show how much energy is being used by the current daytime running light systems. The first part of the calculations determines how much energy 1 Liter of gasoline contains. Having calculated the total amount of energy available per liter of gasoline, the next step is to evaluate the amount of the energy a vehicle is able to obtain from the same amount of gasoline. It is known that every vehicle manufactured today is far from being efficient in extracting the available energy stored in gasoline due to the fact that during the process of energy extraction, most of the energy is dissipated to the surrounding as heat without being consumed through useful work. Due to the imperfections of the system itself, the power input to the system -the vehicle- is unfortunately not equal to the power output

The following calculations are based in part on the studies conducted by Transport Canada [23].

4.2.1 Gasoline Energy Content

1 Liter Gasoline = 115,400 Btu/gallon

$= 1.22 \times 10^8$ Joules/Gallon

$= 122 \times 10^6$ Joules/Gallon

$= 32 \times 10^6$ Joules/Liter

1 Liter Diesel Fuel = 36×10^6 Joules/Liter

4.2.2 Average Travel Speeds

In estimating the DRL energy consumption, one value of average travel speed was used for all vehicle classes, which constitutes a rather gross assumption. The value of 40.5 km/h used is based on data from a 1978-79 National Driving Survey [26], which covered drivers of light-duty vehicles. The survey gave no information about travel in heavy trucks, urban or intercity buses, the data were not collected in a form that permits a reliable calculation of the average travel speed, drivers not vehicles were sampled, and the data now are more than ten years old.

More recent and reliable data on average travel speeds for light-duty vehicles are simply not available, nor are reliable data for heavy-duty vehicles. There are, however, good reasons to believe that the average speed of urban buses is almost certainly lower than 40.5 km/h as a result of their frequent stops, while the figures for intercity truck and bus operation are subsequently higher.

For example, from data originally reported by Clayton [24], for a large convenience sample of trips by trucks in linehaul operations, Welbourne [26] has shown that their energy consumption is consistent with an overall average travel speed of about 90 km/h. Similarly, the scheduled intercity travel times for buses in Canada suggest that their average travel speed is also in the range of 90 km/h.

No comparable estimates are immediately available for urban buses. Transit system schedules could give an indication of the extent to which the average travel speed of urban busses differ from the assumed 40.5 km/h.

4.2.3 Alternator Efficiency

The initial estimate of daytime running light energy consumption assumed a constant value of alternator efficiency of 55 percent. That is a reasonable figure for the overall efficiency in typical operation at moderate speeds and electrical loads. However, the overall efficiency of the regulated alternator varies markedly with both electrical load and rotational speed. Moreover, it also varies somewhat with size since larger alternators are rather more efficient, though heavier. Since the alternator is normally driven from the vehicle crankshaft by a constant ratio drive at two or three times engine speed, the alternator speed is a function of vehicle speed, transmission ratio and, for automatic transmissions, torque converter slip.

The alternator characteristic that is required in calculating the daytime running light energy consumption is not the overall efficiency, but the marginal efficiency. On the other hand, studies conducted [22] show that the resulting average marginal efficiency of the alternator differs by only some 5 percent of the absolute values. Thus, although the marginal efficiency does vary with alternator speed, it does not appear that the variation is likely to be of much practical significance.

4.2.4 Energy Conversion Efficiency of Engines

A figure of 27 percent was assumed to represent the energy efficiency of an internal combustion engine. This figure may be criticized on two grounds. It is a reasonable value for the overall efficiency of a passenger car gasoline engine under typical operating conditions. However, overall efficiency may not be the most appropriate measure of engine performance to use in estimating the energy consumption increment attributable to daytime running light use.

Provided that the effect of daytime running light use on engine power demand is not large enough to require the vehicle designer to use lower overall gear ratios, the required measure is the rate of change of output power with input power at constant engine and vehicle speed. Here, that measure is called *marginal efficiency.*

In addition to being a more accurate measure of engine performance, the marginal efficiency is found to be much more nearly independent of engine speed and load than the overall efficiency. In common with the overall efficiency, however, it strongly depends on the engine type.

Table-3 shows the marginal efficiency of selected vehicle classes together with alternator efficiencies. The figures for gasoline- and diesel-fueled passenger cars are conservative estimates derived from fuel consumption measurements on complete vehicles on the road [26].The estimate for the four-stroke diesel truck engine is derived from information supplied in confidence by a North American manufacturer for an unspecified engine. The resulting estimate is consistent with the measurements made on the final drive shaft of a Cummins diesel tractor belonging to Transport Canada [27]. Finally, the figures for naturally aspirated and turbocharged two-stroke bus engines are derived for the Detroit Diesel Allison 6V-71N and 8V-92TA engines respectively.

The engine marginal efficiencies derived have been multiplied by 0.95 to account approximately for the losses in the alternator belt drive.

	H (MJ/L)	Engine Efficiency	Alternator Efficiency
Passenger Car	32	0.27	0.55
Passenger Car (Diesel)	36	0.31	0.55
Old Urban Bus	36	0.33	0.55
New Urban Bus	36	0.43	0.55
Old Intercity Bus	36	0.33	0.55
New Intercity Bus	36	0.43	0.55
Combination Truck	36	0.45	0.55

Table-3: Marginal efficiency of Selected Vehicle Classes and Alternator Efficiencies

4.2.5 Daytime Running Light Electrical Power Demand

Existing Lamps

Cars/ Light Trucks: Approximately 200 watts

Heavy Trucks : Approximately 260 watts

Buses : Approximately 300 watts

Reduced-Intensity High-Beam Headlamps

Approximately 96 watts

Reduced-Intensity Low-Beam Headlamps

Approximately 30 Watts

4.2.6 Daytime Running Light Gasoline Requirements

(a) Average speed over all driving, from the National Driving Survey of 1978-79 is 40.5 km/h; Statistical Abstract of the United States (1997) says that the average miles per car was 19,000km, average miles per bus was 16,000km per bus and average miles per truck was 43,200km in the year 1994.

(b) Thus, average car spends 469 hours on the road, the average bus spends 395 hours on the road and the average truck spends 1067 hours on the road.

(c) Energy content of gasoline is 32.4 x 10^6 Joules/Liter.

(d) Thermal efficiency of engine = 27%; alternator efficiency = 55%; for overall efficiency of conversion of gasoline to electricity of 14.9%.

(e) Statistical Abstract of the United States (1997) says that the average number of registered vehicles for 1995 is approximately 202,000,000 (including buses, trucks and automobiles).

Existing Lamps

Cars - Light Trucks (200 watts)

200 Joules/sec x 469 hours x 60 minutes/hour x 60 seconds/minute = 338 M Joules

338 M Joules / (32 M Joules/Liter) = 10.5 Liters

10.5 Liters x (100 / 14.9) = 70 Liters of gasoline (due to the inefficiency of the engine)

Heavy Trucks (260 watts)

260 Joules/sec x 1067 hours x 60 minutes/hour x 60 seconds/minute = 998 M Joules

998 M Joules / (32 M Joules/Liter) = 31 Liters

31 Liters x (100 / 14.9) = 208 Liters of gasoline (due to the inefficiency of the engine)

Buses (300 watts)

300 Joules/sec x 395 hours x 60 minutes/hour x 60 seconds/minute = 426 M Joules

426 M Joules / (32 M Joules/Liter) = 13 Liters

13 Liters x (100 / 14.9) = 89 Liters of gasoline (due to the inefficiency of the engine)

Total

208 Liters + 70 Liters + 89 Liters = 367 Liters of extra gasoline

367 Liters * 202,000,000 = 74 x 10^9 Liters of extra gasoline per year

= 466,000,000 barrels of gasoline per year

Reduced-Intensity High-Beam Headlamps (All vehicles)

96 Joules/sec x 1931 hours x 60 minutes/hour x 60 seconds/minute = 667 M Joules

667 M Joules / (32 M Joules/Liter) = 21 Liters

21 Liters x (100 / 14.9) = 141 Liters of gasoline (due to the inefficiency of the engine)

Total

141 Liters * 202,000,000 = 29 x 10^9 Liters of extra gasoline per year

= 179,000,000 barrels of gasoline per year

Reduced-Intensity Low-Beam Headlamps (All vehicles)

30 Joules/sec x 1931 hours x 60 minutes/hour x 60 seconds/minute = 208 M Joules

208 M Joules / (32 M Joules/Liter) = 6.5 Liters

6.5 Liters x (100 / 14.9) = 44 Liters of gasoline (due to the inefficiency of the engine)

Total

44 Liters * 202,000,000 = 8.9 x 10^9 Liters of extra gasoline per year

= 56,000,000 barrels of gasoline per year

4.3 Evaluation of Possible Alternatives

Each alternative has advantages and disadvantages associated with it. The evaluation will be based on cost, maintenance, energy consumption, visibility (visual contrast) and esthetics as mentioned earlier.

4.3.1 Bright-Colored Paint

This alternative is the easiest to implement among the others. It is applicable to any car on the roads and the cost is minimal. There is no extra maintenance requirements associated with it and it is the ultimate energy-friendly alternative. It does not necessarily cause any esthetical problems and it somewhat increases detectability of a vehicle when there is enough ambient light in the environment. On the other hand, it is not a very dependable alternative due to the fact that the increase in the detectability of the vehicle depends on external lighting. Research (Cantilli, 1965) has shown that bright colored vehicles are more detectable than others, but the color of the vehicle has to be supported by other methods of increasing the attention-grabbing nature of the vehicle.

4.3.2 Running Lights

This alternative is a different approach to the concept of increasing the visibility of a vehicle. The running lights make the vehicle more visible to drivers by the attention-grabbing nature of the light emitting diodes (LEDs) positioned in front of the vehicle. The LEDs are special purpose lamps which can give out a significant amount light by using only very small amount of energy. The LEDs that are to be used for this alternative generally require about 2 Volts and about 20mA which evaluates to only 0.04 Watts of energy. Thus, this design is very energy-efficient and the LEDs are very effective in catching attention due to the motion effect they implement.

4.3.3 Light-Sensitive Daytime Running Lights

The light sensitive DRLs is another easy to implement approach. It is slightly different than the current daytime running light in that it employs a light-level sensing device which decides whether the amount of light in the environment is above the threshold value or not. If there is enough light, then the DRLs are not turned on. Otherwise, they are turned on. This approach is more energy-efficient than the conventional DRLs since the lamps will not be turned if it is a bright sunny day when the lamps only cause glare and unwanted distraction. The light-level sensing device makes sure that the lamps are on during dusk, dawn and any similar bad weather conditions.

4.3.4 Advanced Light-Sensitive Daytime Running Lights

This alternative is a more sophisticated version of the light-sensitive DRLs. The light-level sensing device is programmed to determine the amount of light around the vehicle so that even if it is a bright day, if the vehicle is in the shade, the DRLs will be turned on to ensure the safety of the vehicle. This alternative is based around a microcontroller system which continuously monitors the amount of light in the environment around the vehicle and takes appropriate action. Thus, even though it is a more precise and safer approach, the system requires very fine tuning to function properly.

4.4 Trade-Off Analysis

Table-4 summarizes the advantages and disadvantages associated with each alternative discussed in the previous section. In the table, '1' is associated with the least wanted asset and '5' is associated with the most wanted asset.

Alternatives	Cost (5%)	Maintenance (10%)	Aesthetic (10%)	Energy Consumption (30%)	Visibility (35%)	Score
Painting the car to bright colors	5	5	3	5	2	325
Runinng lights in front of the car	4	4	1	4	3	295
Regular DRLs	3	3	5	1	5	300
Light Sensitive DRLs	2	2	5	2	5	315
Advanced Light Sensitive DRLs	1	1	5	3	5	330

Table-4: Trade-Off Analysis

Directly looking at the scores for each alternative on the trade-off analysis table might be misleading since each alternative has different pros and cons. For example, it seems as if the conventional DRLs are a better option than the running lights, however, the running lights use far less energy, they are easier to maintain and they cost less. On the other hand, the running lights are esthetically less pleasant than the DRLs which is a big drawback for many customers. The comparisons of this nature could be extended and it is very obvious that making a selection is very hard due to the different limitations of each alternative.

4.5 Survey

This survey has been conducted to determine the opinion of the public on different alternatives available in place of the current DRLs. 74 people participated the survey which was conducted at the Electrical and Computer Engineering Department of Worcester Polytechnic Institute via e-mail.

4.5.1 Goals of the Survey

The survey consists of seven short-answer questions. The questions look for answers to the following issues:

i. For how long the participant drives his/her car per week.

ii. The participant's awareness of the DRLs.

iii. The participant's opinion on the DRLs.

iv. The participant's opinion on the different alternatives to the DRLs.

v. The participant's opinion on the importance of each asset which is used to choose an alternative to the DRLs.

Table-5 through Table-12 show the results of the survey. They present the individual number of responses received for each question.

	Number of People
No Car	6
1 hour	6
2 hours	8
3 hours	9
4 hours	7
5 hours	12
7 hours	6
8 hours	5
10 hours	7
15 hours	4
25 hours	4

Table-5: For how long people drive their cars per week

	Number of People
Seen	73
Not Seen	1

Table-6: Have people seen the cars with their headlights on during the daytime?

	Number of People
Noticeable	68
Not Noticeable	5
Undecided	1

Table-7: What people think about the noticeability of DRLs

	Number Of People
Yes, Disturbing	27
No, Not Disturbing	47

Table-8: Do people find the DRLs disturbing?

	Number of People
Yes	24
No	50

Table-9: Would people buy a car if it was only sold in colors of white or metallic gray?

	Number of People
Unpleasant	46
Pleasant	15
Undecided	13

Table-10: Would people find it unpleasant if their car had to have *moving* lights?

	Number of People
I would buy	15
I would not buy	46
Undecided	13

Table-11: Would people willingly buy a car having *moving* lights?

	Cost	Maintenance	Aesthetics	Energy Consumption	Visibility
1	31	19	17	6	1
2	20	14	11	15	3
3	18	22	10	20	9
4	5	8	18	22	15
5	1	4	13	9	45

Table-12: How people rate the different assets of a car (1-most wanted, 5-least wanted)

4.5.2 Analysis of the Survey

The first question resulted in a variety of answers due to the fact that the people in Electrical Engineering Department have very different backgrounds. Most of the participants of the survey are students whom have cars. Some of the upperclassmen have jobs and they commute everyday whereas some of the other students simply drive their cars to come to school from their off-campus houses. Very few of the participants do not own a car and very few of the participants, most of whom are professors, drive long hours due to the fact that they live in a nearby city.

All the participants, except for one, said that they saw cars equipped with DRLs on the road and the one person who was not aware of the DRL-equipped cars does not own a car. Almost all the participants agreed that DRLs are noticeable. They also noted that DRLs are noticeable especially in bad weather conditions.

Only one-thirds of the participants mentioned that DRLs are disturbing when they are driving. On the other hand, all the participants agreed that DRLs that use the high-beam and halogen lamps are very disturbing when a vehicle equipped with this kind of DRL lights is headed towards the car of the participant.

One-third of the participants reported that they would agree to buy cars that are sold only in colors of white or metallic gray. Those participants said that they did not worry about the color of their car. Instead, they were interested in the performance and safety of the vehicle. The rest of the participants claimed that they should not be denied their right to choose the color of the car they are buying. They also added that light-colored cars tend to get dirty much more easily and quickly than dark-colored cars.

Three-quarters of the participants did not like the idea of installing a set of running lights in front of their cars due to the reason that they found the device aesthetically unpleasant. Moreover, some of the participants were concerned that installing running lights in front of a vehicle would be too distracting for the other drivers on the road and thus might even cause accidents. The rest of the participants agreed to have the device installed on their cars as long as the device made the car safer and the car had a good performance.

The answers to the last question of the survey are summarized in Table-12. Table-12 displays what people think is important when they are purchasing a car.

4.5.3 Conclusion

First of all, majority of the participants completing the survey reported that the DRLs are noticeable and effective especially in bad weather conditions such as rain and fog, but a significant number of participants pointed out that some of the DRL equipment on installed on some vehicles cause too much glare and disturb the drivers. Even though NHTSA has guidelines for the intensity of the light produced by the DRL system, it is apparent that not all the DRLs follow the standards.

The survey results also reveal the fact that the trade-off analysis performed in Section 4.4 was not accurate enough in estimating the opinion of the public about the importance of the different aspects of a vehicle. The results obtained from the trade-off analysis certainly brings a lot of insight to determining a reasonable and more efficient solution to the problem at hand, however, the survey has shown that the trade-off analysis fails to anticipate the opinion of the public on the selection process of an alternative approach to the current DRLs. According to the survey, the cost of a car is the most important asset. The participants also agree that the maintenance of a car is very important to consider. An interesting result of the survey is that very few people are concerned about the energy consumption levels or the visibility of their cars. Another result obtained from the survey is that the looks of the car is almost as important as its cost.

Taking all this data into consideration, certain adjustments should be made to the alternatives that are being examined to replace the current DRLs. It is very unlikely that the use of certain colors to increase the detectability of a vehicle will be successfully simply because the customers would like to be able to decide for themselves. Since cars are very personal items, almost nobody would agree to be forced to buy a car that is of a certain color. The running light method is very effective except for the aesthetics. If it were to be expected to be successful, the *looks* of the device would have to be improved. Light sensitive DRLs and advanced light sensitive DRLs have a lot of potential to be successful. The only design consideration is that the control circuits used to sense the light level around the vehicle should be cheap and they should require minimal amount of maintenance.

5. Implementation of Alternative Solutions

Another approach to selecting an alternative to the current DRLs is to actually build all the possible alternatives and compare them with each other to physically see which design works better. The problem with this approach is that the timeline for completing this project does not allow to build all the possible hardware designs being examined for this project. Thus, only the running lights, which is the easiest-to-implement and most energy-efficient hardware design, was built.

5.1 Running Lights

This is an alternative hardware-design option to the conventional DRLs. The circuit is very easy to build and it uses very commonly found TTL-type integrated circuits. The design makes use of 32 special light emitting diodes (LEDs) which are much brighter than regular LEDs so that they are very noticeable, yet they are designed as *markers*. Since they are not designed to emit light to make the environment visible, they do not cause any glare problems. The specific data for the LEDs is as follows:

23,000 mcd typical luminosity
Operates on 1.9V - 2.5V @ 20mA
10mm InGaAIP Yellow
590nm peak emission wavelength

This design uses far less energy than the current DRLs, and yet it is able to achieve the same detectability effect.

5.2 The Design

Figure-1 shows a block diagram of the circuit. The circuit is based on an up/down counter integrated circuit (IC) which is driven by a timer device. The design utilizes Large Scale Integration (LSI) type of integrated circuits which minimizes the amount of components necessary while the complexity of the circuit is kept at a minimum. A 555 timer IC is used to supply the required clock signals to drive the counter ICs. It has been observed that running lights were considered to be dangerous since they are too distracting. In order to solve this problem, the design could be modified to include a switch to alter the frequency of the timer IC. In return, this would adjust the speed of the running lights. The schematic for the circuit and the data sheets for the ICs used are provided in the Appendix.

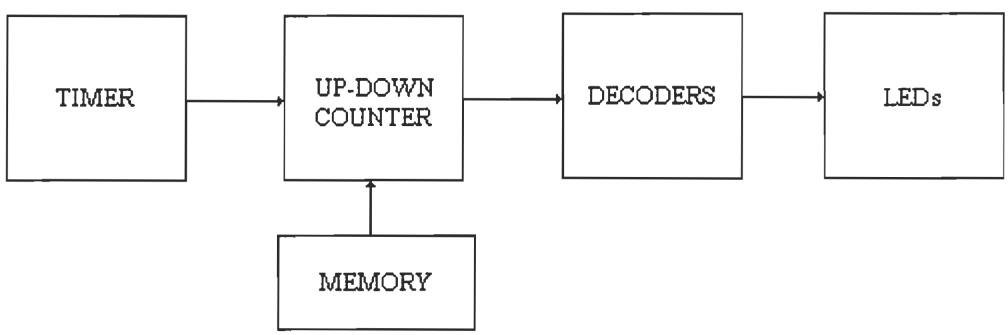

Figure-1: Block Diagram of the Running Lights Circuit

5.3 Conclusion

The circuit uses 60 mA of current maximum and it requires 5 Volts to work. The following calculations show that the circuit needs only 0.3 Watts of power.

I = 60mA   V = 5 Volts

P = V x I

P = (0.06 A)(5 V) = 0.3 W

The following calculations show how much gasoline would be consumed if this circuit was being used in place of the current DRLs:

0.3 Joules/sec x 1931 hours x 60 minutes/hour x 60 seconds/minute = 2.1 M Joules
2.1 M Joules / (32 M Joules/Liter) = 0.066 Liters
0.066 Liters x (100 / 14.9) = 0.44 Liters of gasoline (due to the inefficiency of the engine)

Total

0.44 Liters * 202,000,000 = 89 x 10^6 Liters of extra gasoline per year
= 559,000 barrels of gasoline per year

This result is 100 times better than the result achieved by the use of low-beam DRLs.

6. Conclusions

The project has very clear results in that the calculations speak for themselves. It is very obvious that the current DRL systems are very ignorant of their energy consumption rates. Even though officials and car manufacturers, such as General Motors and Volkswagen, claim that running DRLs has a minimal cost attached to the invaluable benefits, the author has proved his point in the previous sections through intensive research, mathematical calculations and design implementation.

6.1 Energy Consumption Comparisons

Table-13 compares the energy requirements of the different DRL systems and the related extra gasoline amount that is consumed due to the extra load.

DRL System	Power Requirements (Watts)	Extra Gasoline Consumed (Barrels/Year)
Regular Car Lamps	200	90 Million
Regular Heavy Truck Lamps	260	264 Million
Regular Bus Lamps	300	113 Million
Reduced Intensity High-Beam Lamps	96	179 Million
Reduced Intensity Low-Beam Lamps	30	56 Million
Running Lights	0.3	0.56 Million

Table-13: How people rate the different assets of a car (1-most wanted, 5-least wanted)

It can be observed that even in the best case scenario of the current DRL systems, the reduced-intensity low-beam headlights require 30 Watts of power whereas the running lights need merely 0.3 Watts. Thus, the implemented alternative approach to the current DRL systems perform -at least- 100 times better, saving millions of barrels of gasoline per year just in the United States.

6.2 Feedback from the Survey

The feedback from the survey conducted reflected the fact that only 20 percent of the participants were interested allowing a modification like the running lights to be made to their cars. This result suggests that if running lights were to be mass-manufactured and if they were built in to the new generation cars, approximately one out of every five people would buy that car. Therefore, providing the running light approach as a standard feature in the new generation cars would result in a catastrophe. If another company was to consider manufacturing add-on running lights systems for old model cars, it is very likely that it would face the same catastrophe.

However, it should be pointed out that running lights were chosen to be designed and built amongst the other alternative merely because of the time limitations of this project. It could certainly be argued and proved that all of the four alternatives discussed in this project out-perform the current DRL system with respect to their energy efficiency.

Furthermore, the running lights design implemented in this project could certainly be improved in terms of its aesthetic assets by employing professional designers and modelers to give it a fancier look. The appearance of the design is not necessarily very appealing as built for this project, however, it is absolutely open to modifications and improvements that would make it less pleasant or even attractive for the vehicles it is placed in.

6.3 Final Conclusion

This project certainly met the goals previously established. the existence of much energy-efficient methods of increasing background contrast of vehicle was demonstrated successfully and the demonstration was supported by mathematical calculations, conducted research and design implementation. It was proved that millions of barrels of gasoline could be saved by utilizing smarter designs in DRL systems currently being used in vehicles on the road.

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Appendix-A

The Survey

This survey is being conducted to aid an IQP, which investigates the feasibility of Daytime Running Lights (DRL). DRL is an additional lighting system for cars. It is activated as soon as the engine starts running. It turns on whether it is day-time or night-time and it cannot be turned off manually. Thus your external lighting system of a car that has a DRL system is always on during day-time and night-time.

DRL has been introduced as a requirement in many countries as a method of traffic accident prevention. It has been justified by a number of countries that DRL reduces day-time multiple-car collisions. The IQP is investigating alternative ways of achieving the same visibility the DRL system provides.

Please take the time to fill out the following short survey. The questions require short answers, however, please feel free to answer in as much detail as you wish.

Thank you very much.

Emrah Diril

* For approximately how long do you drive your car per week?

* Have you noticed the cars with their lights turned on on the road during day time?

* Do you think they are noticeable?

* Do you think they are disturbing or annoying?

* Would you be interested in buying a car that comes in colors of either white or metallic gray only?

* Would you find it aesthetically unpleasant if your car "had to" have moving lights in front of it or around its head-lights and back-lights? If you had the choice, would you actually buy such a car?

* Please number the following items from 1 to 5 with respect to the importance of each item for you (1 being the most important, and 5 being the least important)

_ Cost of a car

_ Maintenance of a car

_ Aesthetics of a car

_ Energy Consumption of a car

_ Visibility of a car at different weather condition and during different times of the day

Appendix-B

Data Sheets for 74LS74A

Appendix-C

Data Sheets for 74LS138

Appendix-D

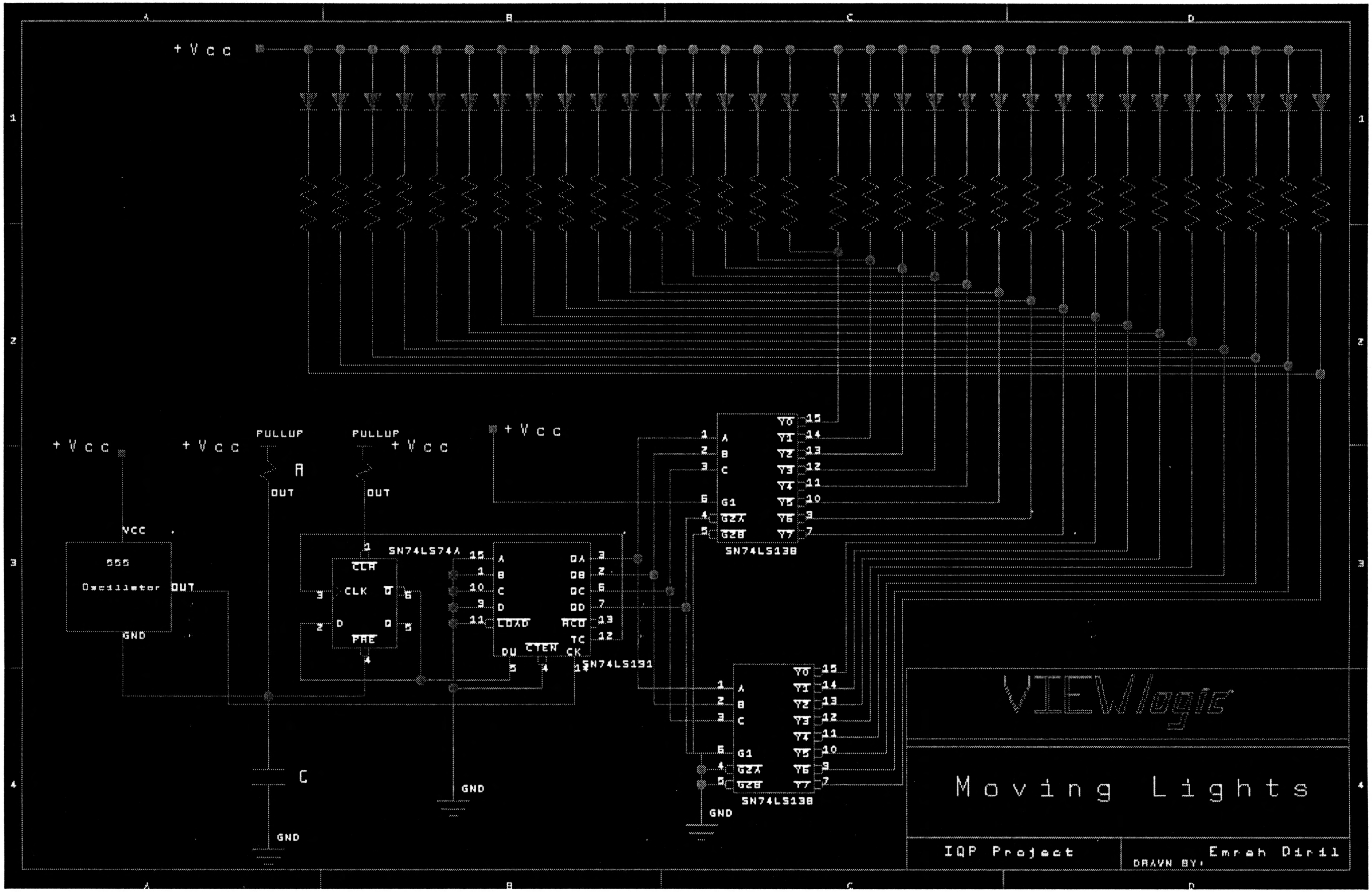
Data Sheets for 74LS191

Appendix-E

Data Sheets for LM555

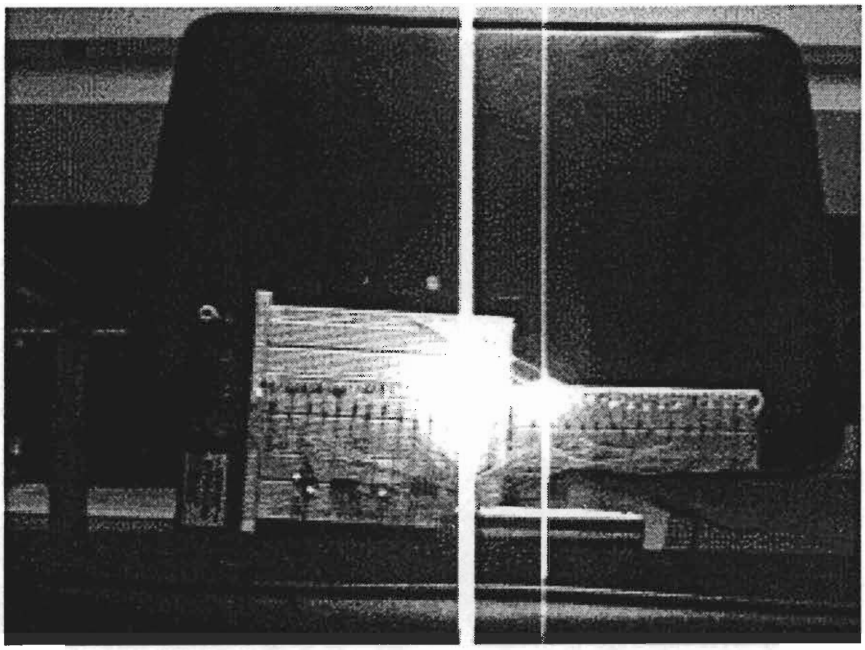
Appendix-F

Schematic for the Running Lights

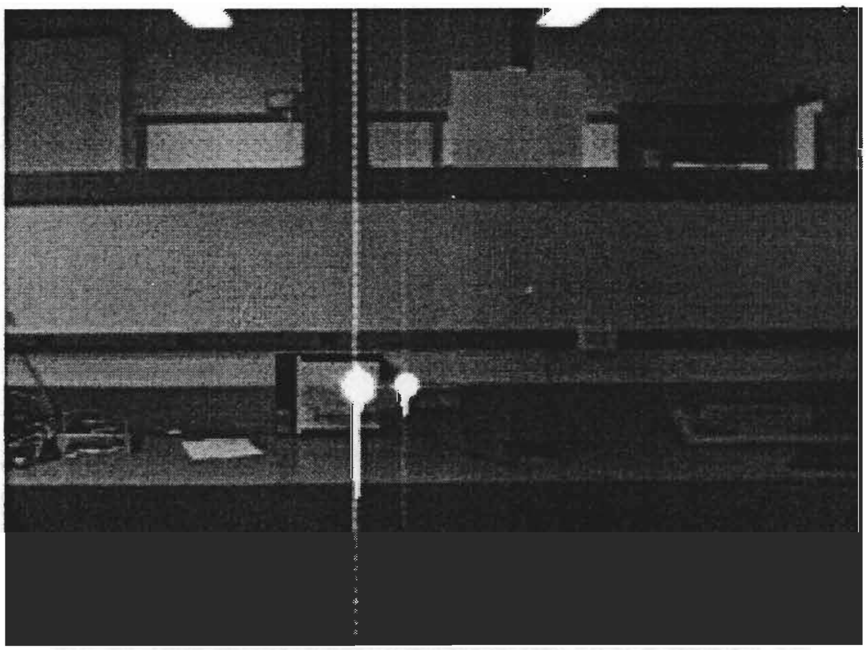

+Vcc
PULLUP
PULLUP
R
OUT
OUT
VCC
555
Oscillator
OUT
GND
SN74LS74A
CLR
CLK
D
PRE
SN74LS191
A
B
C
D
LOAD
QA
QB
QC
QD
RCO
TC
CK
DU
CTEN
SN74LS138
SN74LS138
G1
G2A
G2B
Y0
Y1
Y2
Y3
Y4
Y5
Y6
Y7
C
GND
VIEWlogic
Moving Lights
IQP Project
DRAWN BY:
Emrah Diril

Appendix-G

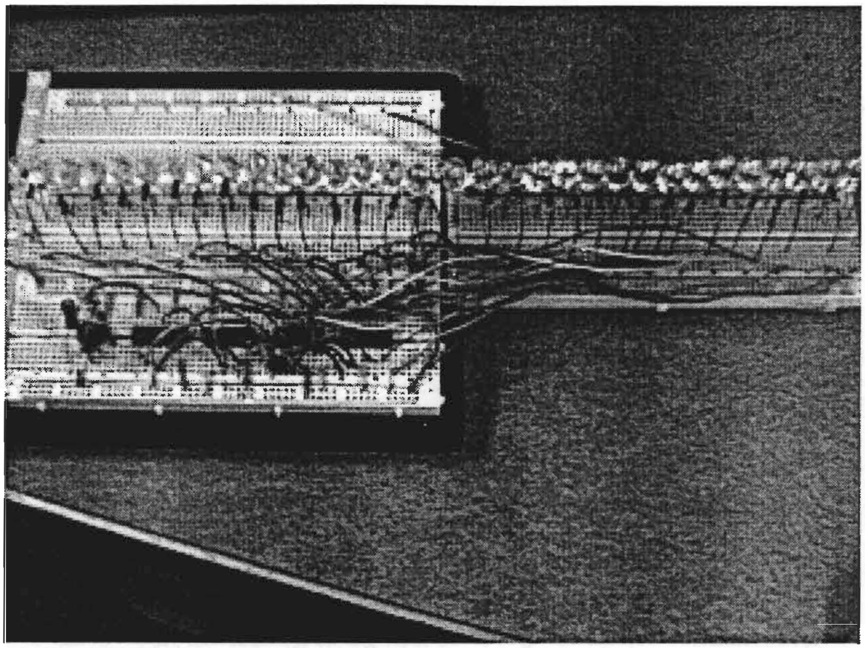
Photograph of the Running Lights Circuit



Running Light Circuit From 1.5m Away



Running Light Circuit From 4m Away



Top View of the Running Light Circuit