Night Vision: Requirements and possible roadmap for FIR and NIR systems

Jan-Erik Källhammer*
Autoliv Research, SE-447 83 Vårgårda, Sweden

ABSTRACT

A Night Vision system must increase visibility in situations where only low beam headlights can be used today. As pedestrians and animals have the highest risk increase in night time traffic due to darkness, the ability of detecting those objects should be the main performance criteria, and the system must remain effective when facing the headlights of oncoming vehicles. Far infrared system has been shown to be superior to near infrared system in terms of pedestrian detection distance. Near infrared images were rated to have significantly higher visual clutter compared with far infrared images. Visual clutter has been shown to correlate with reduction in detection distance of pedestrians. Far infrared images are perceived as being more unusual and therefore more difficult to interpret, although the image appearance is likely related to the lower visual clutter. However, the main issue comparing the two technologies should be how well they solve the driver’s problem with insufficient visibility under low beam conditions, especially of pedestrians and other vulnerable road users. With the addition of an automatic detection aid, a main issue will be whether the advantage of FIR systems will vanish given NIR systems with well performing automatic pedestrian detection functionality. The first Night Vision introductions did not generate the sales volumes initially expected. A renewed interest in Night Vision systems are however to be expected after the release of Night Vision systems by BMW, Mercedes and Honda, the latter with automatic pedestrian detection.

Keywords: Night Vision, Vision Enhancement System, FIR, NIR, Automotive, Roadmap

1. INTRODUCTION

There are two types of Night Vision technologies on the market, Far Infrared (FIR) and Near Infrared (NIR). FIR detects the radiation which all objects emit, while NIR detects the reflected illumination in a frequency just outside the visible range of a human being. The paper will analyze the requirements of a Night Vision system, how NIR and FIR today perform under the defined condition and proceed to discuss directions for future development. Development of technology has severe risks of failure if the users’ needs are not properly understood and taken into consideration, even though those needs are not always explicitly stated. A discussion of technology roadmaps should therefore start with a problem definition and a definition of what is attempted to be accomplished.

All cars today have an acceptable ‘night vision’ system. That is the high beam headlights of the vehicle. Even though they could be improved, their performances are at least acceptable. However, in many areas, high beams are of very limited use due to oncoming traffic. The insufficient night-time visibility originates in the fact that the high beam headlights are rarely possible to use. A Night Vision system must therefore be a system that increases visibility in situations where only low beam headlights can be used today. This condition will then define the criteria to evaluate the performance of any Night Vision technology proposed and the potential safety impact of such a system. Rumar provided typical realistic detection distances to vertical objects with low and high beams with and without oncoming headlights (table 1). The short detection distances for especially dark objects under low beam conditions versus the corresponding situation under high beam condition illustrate the detection distance deficiency that a Night Vision system should overcome. Safe driving speed should allow the driver to detect, react and stop in time before any obstacles on the road. However, most motorists actually drive faster than the visibility range allow with low beam headlights.

* jan-erik.kallhammer@autoliv.com
Table 1 Detection distances to dark vertical objects, typical for present realistic night driving conditions (Ref 2).

<table>
<thead>
<tr>
<th>Condition</th>
<th>Low beams with oncoming low beams</th>
<th>High beams with no oncoming headlights</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Young drivers</td>
<td>Older drivers</td>
</tr>
<tr>
<td>Dark objects</td>
<td>40 – 60 m</td>
<td>30 – 50 m</td>
</tr>
<tr>
<td>Bright objects</td>
<td>60 – 100 m</td>
<td>50 – 80 m</td>
</tr>
<tr>
<td>Dark objects with retroreflectors</td>
<td>100 – 200 m</td>
<td>80 – 160 m</td>
</tr>
</tbody>
</table>

Estimating the safety impact of Night Vision systems start with accident statistics. Pedestrian and animal accidents are found to have the highest risk increase in night time traffic fatalities due to darkness. Together, the important requirements to a Night Vision system are therefore to safely detect pedestrians, other vulnerable road users and animals while driving with low beams due to on-coming traffic. The detection of these objects in the glare of on-coming headlights is therefore more critical for the performance of the system, than the detection of these objects on an empty rural road.

2. REQUIREMENTS TO A NIGHT VISION SYSTEM

Night time traffic in densely populated areas like Japan can be as high as 40% of the total traffic volume, while typical numbers for industrialized countries are 20-25% \(^2\). Even though there is evidence showing that high beams are under used\(^4\), with high beams used less than 10% in most regions\(^5\), the core of the problem depends on the fact that there are frequent oncoming cars that prevents the use of high beams. As a consequence, the aim of a Night Vision system should be a substitution to the use of the high beams of the headlights when meeting traffic prevents their use. The system must remain efficient when facing oncoming vehicles and “system efficiency in dark country roads is not relevant because drivers would switch high beams on”\(^6\). The conclusion of these observations is therefore that the performance of any Night Vision system must be evaluated in terms of detecting pedestrians in the glare caused by the headlights of oncoming vehicles.

2.1. Risk at night

The risk in traffic is much higher at night than in the day, measured in distance traveled. The difference in crash statistics between day and night provide important information about the performance of automotive headlights and how those can be improved. However, not all of the increased risk of travel at night is due to the visibility. Other reasons include higher alcohol consumption, increased fatigue among drivers and also a different mix of drivers\(^7\). Alcohol consumption and fatigue especially influence single vehicle crashes\(^2\). Higher exposure to animals on the road in dusk, dawn and darkness increase the risk of accidents with animals. The difference in crash risk between day and night are therefore caused by several different factors. An attempt to isolate the effects of the light level on traffic fatalities was made using the US Fatality Accident Reporting System (FARS) statistics\(^8\). Assuming that activities of most people are linked to the clock time rather than the level of light, the difference in crash rates just before and just after the transition between standard and daylight savings time was compared. The results showed that only pedestrian crashes are more frequent in darkness, when the confounding factors like alcohol and fatigue are controlled. Even though there appears to
be differences in accident statistics between Europe and the US, and a similar analysis on European statistics is not known to the author, a similar relationship appears likely in Europe and other industrialized countries.

2.2. Visual guidance

Visual performance of a driver at night is based on visual guidance and target recognition. Visual guidance is mainly performed by the peripheral vision and is the function that helps the driver stay on the road, and influence the driving speed chosen by the driver. Target detection is seriously degraded at night, while the visual guidance is affected less, which is the major reason why drivers tend to drive faster than their visual ability really permit at night. Drivers select their speed based on how well they see the road, which does not decline as much as their ability to see other objects. The result is the driving speed usually exceeds the driver’s ability to detect objects. As shown above, pedestrians and other vulnerable road users are at particular risk. Improving the visibility of the road and the visual guidance provided may result in higher speed, even though their ability to see objects like pedestrians is not increased. Increasing the visibility of objects does offer a clear safety potential on the other hand.

3. FIR AND NIR NIGHT VISION SYSTEMS

Both NIR and FIR technology offer substantial benefits in different conditions. Both types of systems can also be used together with high beam headlights. The benefit of NIR systems together with high beams may be limited, as NIR systems could be compared with driving using high beams, but without blinding the other road users. The longer range of FIR systems would also make them very effective on dark roads as complements to the high beams of the vehicle. However, as concluded the previous section, pedestrian detection while facing other vehicles with oncoming headlights should be the main evaluation criteria of a Night Vision system.

3.1. Pedestrian detection using FIR and NIR systems

The ability to detect pedestrians using both a NIR and a FIR system was compared in a study by UMTRI. The results showed that the detection distance using a FIR system was significantly larger than using a NIR system, with average detection distance of 119 m for older drivers and 144m for younger drivers. Average detection distance with a NIR system was 35 and 42 m respectively, see figure 1. The interaction between system type and age was not statistically significant.

![Detection distance of pedestrians with FIR and NIR system](Ref 10)
When the system was complemented with an automatic warning function, the detection distance and the accuracy of detection increased with both systems when the driver was provided with a warning when the object was 150 m in front of the vehicle. The FIR system provided the longest detection distance at 150 m, while the detection distance with the NIR system was 110 m. The detection distance increased for the NIR system while it decreased somewhat for the FIR system, when the automatic warning was provided when the object was 75 m in front of the vehicle. Average detection distance for the NIR system was 64 m while the average detection distance for the FIR system was 119 m, see figure 2. The warning at 75 m decreased the detection distance for the FIR system, although detection was made before the warning was provided. The study suggested that some trial subjects waited for the automatic warning, when using the FIR system. Workload was rated higher by the users of the NIR system, and the addition of an automatic warning did not decrease the workload significantly.

![Detection distance graphs](image)

Figure 2 Detection distance when aided using an automatic warning at 150 m (long) and 75 m (short warning). The no warning condition differs between the two figures due to test set-up (from ref 10).

### 3.2. Visual clutter

Accidents with pedestrians and vulnerable road users are predominantly occurring in urban areas, where the driving scene generally is more complex with various sources of disturbance for the sensor, whether NIR or FIR. Those disturbances often will generate a more cluttered image, which will be more difficult for both a driver as well as for a computer interpreting the image.

Attempts to characterize the clutter in an image and their relationship to detection were done in a follow-up study. Figure 3 show examples of low and high clutter, as determined by human raters.
Figure 3: Sample images of low and high clutter for FIR (above) and NIR (below) images. A higher number indicates a higher rated clutter (from ref 11).

The amount of clutter should be an important parameter, as the system shall allow for detection of a pedestrian during a quick glance, at least with systems without an automatic detection function built in. The study showed that visual clutter was rated significantly higher in NIR images than in FIR images. A negative correlation was found between the rated image clutter and detection distance, meaning that detection distance was low when the rating of clutter was high. The higher rating of clutter in NIR images possibly influenced the higher rates of missed pedestrian detection for the NIR system, see table 2.

Whether the relationship between visual clutter and detection distance holds for other implementations of Night Vision systems has not been tested, but it appears reasonable that any new implementation of Night Vision with lower rated visual clutter would also produce longer detection distance among drivers. The issue should be important for both FIR and NIR Night Vision technologies.

Table 2: Number and rate of missed pedestrians for each warning type (from ref 11).

<table>
<thead>
<tr>
<th>Warning Type</th>
<th>Number of Misses (percent of cases)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>No Warning</td>
<td>8 (2.5%)</td>
<td>70 (21.9%)</td>
</tr>
<tr>
<td>Short Warning</td>
<td>8 (5%)</td>
<td>4 (2.5%)</td>
</tr>
<tr>
<td>Long Warning</td>
<td>2 (1.2%)</td>
<td>7 (4.4%)</td>
</tr>
</tbody>
</table>

### 3.3. Effects of pedestrian clothing

The fact that NIR systems detect reflected light, even though it is invisible to the human eye, also means that the performance of the system will be dependent on the reflectivity of the target. As shown in figure 4, different kinds of
clothing have varying reflectivity\textsuperscript{10}. Notice that the legs of the right-most person are hardly visible in the NIR image. An extra uncertainty on detection capability for such systems is added due to the fact that clothing of a pedestrian can vary greatly.

Figure 4 Image appearance of pedestrians with the FIR (above) and NIR (below) systems. Notice that the legs of the right-most person are hardly visible in the NIR image (from ref 10).

4. HUMAN-MACHINE INTERFACE

The population group likely to benefit the most from all the extra information provided is elderly people due to the degradation in vision this group experience with age (see table 1). However, it has also been shown that this group is less likely to accept, or utilize, the extra information\textsuperscript{2}. The Human-Machine Interface (HMI) between the system and the driver is fundamental for successful acceptance, especially among elderly drivers. Proper understanding of the required performance of the system and the expectation of the driver is a prerequisite for designing a good HMI. The primary issue should not be the type of display, but what information to provide to the driver and how it should be done.

4.1. Automatic detection of pedestrians and other vulnerable road users

Automatic detection of pedestrians and other vulnerable road users that will provide timely warnings are currently being developed. One of the intentions being to increase the efficiency of Night Vision systems and also to gain better acceptance and use especially by elderly drivers. The targeted road categories and traffic types of such a system will have significant effect on the design. There are at least two different situations - pedestrians in country roads and pedestrians in urban areas.

The role of expectations must be considered. Pedestrians in country road settings are infrequent, but the risk of impact must be considered high, at least partially due to the driver’s lack of expectation of finding pedestrians on many of those locations. The driver should probably want to be notified of the presence of all pedestrians. The situation in urban areas can be similar to the country road case with few and unexpected occurrences. The driver would probably like to be notified of all detected pedestrians in this situation as well. On the other side, there are also many urban areas, for example inner city areas with sidewalks, where pedestrians are frequently on, or very close to the road. They are however rarely considered to be of particular risk, as long as the pedestrians remain on the sidewalk or equivalent. However, they could at any time step out in front of an approaching vehicle causing immediately high risk of impact. The system should ideally only warn the driver in the situations similar to country roads and when the driver is in
immediate risk of impact. Frequent warnings when pedestrians are walking on a sidewalk would probably generate irritation and also a lack of attention to the alarms, thus increasing the risk that the driver does not take action in the rare critical situations. Unsuitable implementation of warnings may therefore in fact even reduce the effectiveness of a system. As the majority of pedestrian accidents occur in urban areas, focus should be placed on pedestrian detection in urban areas.

A Night Vision system may operate in at least the following modes:

- Use the system as a look-ahead display to increase the preview – an extended view into the road ahead.
- Use the system as a look-ahead display combined with a warning that directs the driver’s attention to the display when a risk has been identified.
- Use the system as a look-ahead display but highlighting risky objects like pedestrians.
- Use the sensor as a data source only and provide a warning when a risk exceeds a given threshold.

The first alternative represents what is available on the market today, with one exception that would represent alternative two (see below). The choice of operating modes will greatly influence how the HMI should be done in order to produce the greatest efficiency. The intended mode of operation and the chosen technology will influence several aspects in the design of an efficient HMI.

4.2. Head Up Display versus Head Down Display

Night Vision displays can either be contact analog, or congruent, with the scene presented in front of the driver, or it can be a separate display. The separate displays are generally divided into either Head Up Displays (HUD) or Head Down Displays (HDD). The HUD systems available on the market projects an image just below the normal line of sight either directly on the windscreen or projected on a combiner that can either be transparent, or opaque. A HDD display can use either the in-vehicle navigation display or another display in the instrument cluster.

A separate display for the Night Vision, whether HUD or HDD, means that the driver has to scan both the scene through the wind shield and the display and constantly shift the gaze between those two locations. This additional scanning requirement may be an important reason for the fact that elderly drivers have been shown to use the Night Vision systems less than younger drivers. A contact analog display where the Night Vision image is completely overlaid on the windscreen view would therefore probably be preferred by elderly drivers. A contact analog display would however require that the image from the Night Vision system completely matches the view from the windshield at all times, as a contact analog display has to have, by definition, a scale factor of 1:1. Achieving a sufficiently wide field of view would therefore require very complex and expensive contact analog displays. Besides implementation difficulties, the need to cover a wider area in front of the driver for pedestrian protection purposes would therefore reduce the potential application of contact analog displays.

At first, many assume that a HUD would be preferred over a HDD, due to the fact that the image is closer to the driver’s direct field of view, and due to the fact that the image is projected further away from the driver, thereby reducing the eye accommodation time. The accommodation time saved in an eye scan cycle between the displayed image and the road for a HUD is significant. In order to preserve the time gains achieved in shorter accommodation time, the actual time viewing and interpreting the image should not go up. It is however difficult to gain the same clarity and contrast ratio in a projected image versus an image viewed in a HDD, which may increase the viewing time, especially when visual clutter is present. Much of the previous research has however not been focused directly on Night Vision images and the requirements they provide. Care therefore has to be exercised when trying to generalize results from navigation tasks, or projection of speed and other vehicle data to a Night Vision application. However, the advantages of a HUD also may have lead to some negative aspects. Cognitive capture, which means that the HUD attracts attention at the expense of detecting objects outside the display, was found to be larger for a display that was close to the driver’s central field of view than for displays that were further away. In addition, there are numerous configurations and design parameters to be considered. When comparing differences in image size ratio, lateral position and direct/indirect viewing, the results showed some differences, but they were small. Other parameters include brightness, contrasts, scale, and position.

The importance of the HMI need, however, to be emphasized. The HMI may eventually determine the market acceptance of the Night Vision technology.
5. MARKET EXPERIENCE

Night Vision systems were first introduced with the model year 2000 Cadillac DeVille (FIR) and thereafter by Lexus/Toyota in 2002 (NIR). In spite of initial consumer interest\textsuperscript{16} and initial forecasts\textsuperscript{17}, Night Vision has not generated a significant interest in the market. The supplier of the Cadillac system projected, in 2001, up to 500,000 units annually by 2006\textsuperscript{18}. Those plans did not materialize, and Cadillac is in fact no longer offering Night Vision systems.

A renewed interest in Night Vision systems are however to be expected after the release of Night Vision systems in the Honda Legend (FIR) during 2004 followed by BMW 7-series (FIR) and Mercedes S-class (NIR) during 2005 and BMW 5- and 6-series (FIR) in early 2006, see promotional example in figure 5. Even though the aim of all systems is to increase the visibility range in darkness, there are many differences in approach and implementation. A relevant question must be whether the different levels of success is technology dependent, vehicle implementation, or even marketing related? Differences in the customer mix of the different vehicle types may also have an important effect.

Figure 5: Night Vision in BMW 7-series. Detecting pedestrians when facing headlights of oncoming headlights. Notice the person changing tire on the parked car to the right. (Picture source BMW AG)

The Honda “Intelligent Night Vision System”, currently is the only available system with an automatic warning function\textsuperscript{20}. The system is only available in limited numbers in Japan. Although there are restrictions in the operating conditions of the warning system, it provides field experience and feedback of market acceptance. All other systems available thus far on the market capture the video images and only display them to the driver using an in-vehicle display, or projected using a Head Up Display (HUD). Such systems will only be effective if the driver frequently scan the display for potential obstacles and other objects.

Fortune magazine wrote in a November 2004 tech special article\textsuperscript{19} that “Infrared night vision from bumper-mounted cameras never caught on when Cadillac introduced it in 2000. Now Honda has a system that specifically detects people or animals in your path”, and continued “Widely available: 2008”. As 2008 now is only two years away, the article
appears to have been early in its projection. However, there are now signs that a wider introduction is in the works, although it is too early to determine a ‘widely available’ situation.

This prompts a question, why the first introduced systems did not gain higher penetration, and if the new introductions will be more successful. The introduction by Cadillac was reported to have been the case of what could be called brand revitalization, “rev up its cars, its image--and its sales”. It may have influenced how the technology was advertised and promoted. Also, the average Cadillac buyer is in the upper age group and elderly drivers have been reported to dislike this type of HMI. The supplier of the system reported on customer’s purchase decision based on several market studies, that 35% stated Night Vision as the reason for purchasing the car. High customer satisfaction number was also reported. Such market data would be expected to lead to higher sales numbers. The reported main reasons for not buying the system were missing necessity, unavailability at the dealer and fear of driver distraction by the system. Noteworthy was that 26% of the car buyers did not order the vehicle, and instead purchased a vehicle already available at the dealer, as is customary in the US. This habit would also mean that short supply of Night Vision equipped vehicles at the dealer would translate into less sales of Night Vision. How the manufacturer promotes the product will naturally influence the public’s awareness of the technology.

Cost and value are frequently the dominating reasons. Night Vision has so far only been available as options around $2,000 and up for upper class cars, which will restrict the potential market. The issue is also whether the quality of the initial systems matched the expectations of the end customer. Improved image quality, supplemented with various detection support functions should increase customer value. Any wide spread penetration in the automotive market will always generate an intense cost reduction effort. There is no reason to expect that the situation will be different in the case of Night Vision systems.

6. DISCUSSION - A ROADMAP FOR FIR AND NIR SYSTEMS

Based on the above considerations, conclusions for the directions for future development can be made. NIR and FIR sensors have different advantages and disadvantages.

The main benefits of NIR systems are that they are cheaper. There exists synergy potential from integrating the hardware of the NIR Night Vision system with the other support functions such as lane departure warning. If successful, such ‘dual-use’ functionality is going to improve the cost advantage for NIR systems even further. Resolution of the sensors is higher, but other light source such as on-coming car causes a glare that may cause sensor blooming. NIR sensors can be mounted in a favorable location, protected behind the windshield, which translate into packaging advantages for the vehicle manufacturer. NIR systems enhance the view generally, within the range of the illuminator used. The detection range of NIR systems depend on the reflectivity, where different type of clothing can have large differences in reflectivity which means that their detection distance will be impaired.

FIR systems have a superior range and pedestrian detection capability, but can not be placed behind the windshield, or any other glass. FIR images are perceived as being more unusual and therefore more difficult to interpret, although the image appearance is likely related to the lower rate of visual clutter, which was shown to correlate with pedestrian detection distance. Despite frequent misconceptions to the contrary, objects with the same temperature as ambient scene are in fact visible due to differences in emissivity. Their low contrast versus the surrounding ambient scene make them however more difficult to detect as compared with objects like pedestrians and animals that have a different temperature than the ambient scene.

The main issue should however be how well the different technologies solve the driver’s problem with insufficient visibility under low beam conditions, especially of pedestrians and other vulnerable road users. Both technologies can be improved. Clear is though that FIR has a head start with currently superior pedestrian detection performance. System cost is the main obstacle for wide spread market penetration of FIR systems.

The conclusion drawn from the finding on visual clutter is that all attempts that will reduce the visibility of all other objects than pedestrians and animals will reduce the visual clutter and hence improve the detection of pedestrian and
animals. The conclusion is equally valid for both FIR and NIR, although the current level of clutter is low in FIR systems. Attempts to make the FIR images appear more ‘natural’ in appearance could therefore be counter productive for achieving easier pedestrian detection\(^\dagger\). Instead, a possible preferred way of visualizing could be to reduce details and replace it with more symbolic representation, like replacing the road with a line, or contour information. Suitable image processing could also offer important improvements in image appearance, where the NIR images should have to most to gain. Whether the higher degree of clutter in NIR images can be eliminated with image processing remains to be shown. With sufficient automatic pedestrian detection performance, the image may not need to be visible all the time, and the increased clutter level in NIR systems may then no longer be an issue.

As NIR and FIR systems have complementing functionality in some cases, the conclusion may be that the optimal system would be a fusion between NIR and FIR images. The cost would, however, have to come down substantially to allow any significant market penetration. A lower resolution FIR sensor may be acceptable as the FIR information would only be used for automated pedestrian detection functions, and not presented directly to the driver. Lower resolution FIR systems allow a cost reduction by the reduction of sensor size, sensor packaging, optics and image processing power. Such an attempt is underway as a means of fulfilling the new EU pedestrian protection directive\(^\dagger\). 

7. CONCLUSION

The insufficient night-time visibility originates in the fact that the high beam headlights are rarely possible to use. Pedestrian and animal accidents are found to have the highest risk increase in night time fatalities. A Night Vision system should therefore be designed to enhance the visibility of pedestrians, other vulnerable road users and animals.

The detections distance of pedestrians using a FIR system has been shown to be superior to the detection distance using a NIR system. A study showing that visual clutter was rated significantly higher in NIR images than in FIR images showed correlation between decreased detection distance and increased visual clutter in the image. This suggests that visual clutter may be an important explanation of the difference in performance between the two system types. It also shows that image processing that would reduce the visual clutter in the images could offer important improvements in detection distances of pedestrians.

The emphasis of the system HMI should focus on how the system aim of detecting pedestrians and animals could be improved. With the addition of automatic pedestrian detection functionality, there are different strategies possible for the HMI that need to be carefully evaluated.

The previous low market penetration may be reversed by a renewed interest, initiated by the introduction of Night Vision systems by Mercedes and BMW. The Honda introduction of a Night Vision system with automatic pedestrian detection will provide field experiences and feedback of market acceptance that will provide directions for future developments.

A fundamental issue in the comparison between FIR and NIR systems should be whether there will remain any significant reasons to prefer FIR over NIR, if an automatic detection aid of pedestrians and animals can be made with sufficient performance. Logically, the answer should be no. The condition though is that the image processing actually can achieve sufficient reliability for both systems and that there will not be any remaining performance reasons to favor FIR. NIR systems have the benefit of higher resolution, but the disadvantage of shorter range and problem with the glare from headlights of oncoming vehicles. Until the development of such an automatic detection function is completed, the superior pedestrian detection capability of FIR should make it the preferred technology. The main problem and focus should be on cost reduction of FIR system components.

ACKNOWLEDGEMENT

The author is indebted to Professor Kåre Rumar and Prof Erik Hollnagel for fruitful contributions and discussions prior and during the preparation of this paper. Autoliv is the supplier of the FIR based Night Vision system that was introduced in the BMW 7-series in September 2005.
REFERENCES


17. E. Johnson, Thermal imaging lights up darkened highways, Gannet news service, Retrieved for the world wide web on February 14, 2006: http://www.sadcom.com/night/night1.htm


