EMERGENCY VEHICLE WARNING SYSTEMS AND IDENTIFICATION

2011 Preface

This paper was produced with the guidance of Dr Alec Fisher, of the University of New South Wales School of Transport (as I recall). Alec was my lecturer at the time in lighting and vision studies as part of my degree in architecture.

I corresponded extensively with both Dr Stephen Solomon, in the USA and Dr Merrill Allen at Indiana State University during the development of the paper (and subsequently to its completion). I also had the encouragement of Mr Roy Sargent, Fire Control Officer in Blactown. Roy had known of work done by Coventry Fire Brigade in the UK on fire appliance colour and safety and provided to me a paper done by Coventry FB.

A correction to the paper:

> On the advice of one reviewer, I adopted the term ‘uncial’ for lettered signs. This usage is erroneous and I was simply referring to lettering on emergency vehicles.

David Green
January 2011

EMERGENCY VEHICLE WARNING SYSTEMS AND IDENTIFICATION

A treatise examining, in qualitative terms, the ergonomics of colour and warning light signals as applied to emergency vehicles.

DAVID A. GREEN
N.S.W. Department of Public Works
May 1978

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PREFACE

The purpose of this paper is to examine Warning Systems and Emergency Vehicle Identification from an ergonomic viewpoint. That is to relate the practice of the engineering design of relevant aspects of Emergency Vehicles to the psychological and physical characteristics of human sensory systems and perceptional mechanisms.

Out of this it is intended to draw conclusions and make recommendations which will, in due cognizance of the Human Factor, allow Emergency Vehicles to optimally communicate vital information to all road users, expediting the function of the Emergency Vehicle without the incurance of a general safety penalty.

The paper is divided into four major sections followed by concluding remarks:

(i) a discussion and analysis of the problem we are considering to allow us to validly specify;

(ii) desired performance criteria;

(iii) methods of satisfying these criteria will then be discussed, and out of this

(iv) a set of recommendations will be put forward.

1. DEFINITION OF THE PROBLEM

1.1 For an Emergency Service to function effectively its vehicles must be able to travel from their turnout points to the incident scene unimpeded and safely.

1.2 While this is largely self evident, indeed a truism, and that it can only be practised by ensuring that road users are made unequivocally aware of the Emergency Vehicle and its movement, the problems encountered in this practice must be fully realized and their implications clarified.

1.3 It is necessary that to the end of 1.1 the Emergency Vehicle is considered in motion and at rest, that its nature (i.e. an Emergency Vehicle operating as an Emergency Vehicle), its location in space, its volume and shape and its direction of travel are conveyed to road users sufficiently to allow appropriate manouvres to be made in safe-time, and that attention be drawn to the vehicle, that it may be initially perceived, and then recognized as a particular type of vehicle both during daylight hours and at night, whether under artificial illumination or not.

1.4 During daylight hours (excluding twilight for simplification) fewer difficulties are presented than during the night, but the vehicle must still be temporally and spatially resolved by road users; it must be visible, and here the whole vehicle, its form and colour are the best means of achieving this. It is also not that great a problem during these hours to determine the direction of travel of the vehicle, or its nature, that is relying on colour and form. However, the use of Warning Lights necessary for special identification has problems associated with it in as much as high ambient light levels

can tend to washout any warning light signal.

1.5 Recognizing these factors then, we must consider the stationary Emergency Vehicle. It is obviously easily seen, if a road user is looking towards it, but high intensity flashing lights lose the effect they have at night in advertising the vehicle and attracting closer attention from road users. So not only is it necessary that a stationary Emergency Vehicle be seen, but that it is recognizably attending an emergency incident, which could mean extensive obstruction to the road or unusual activities in close proximity to the road.

1.6 Although at night or in lower light level conditions generally, the vehicle's special light systems are effective, they must not only draw attention to the vehicle, its nature, and define its form, but must, when it is mobile, indicate its motion to road users a reasonable distance away, again to allow ample time to evade the vehicle, by the use of lights alone. Here ambiguity of signal must be guarded against and clarity of statement achieved.

1.7 In all circumstances at night the existing proliferation of illuminated signals and signs must not be allowed to confuse or reduce the effectiveness of the Emergency Vehicle's special lights. It must also be recognized that the liminance of high intensity Warning Lights be reduced to avoid discomfort and disability glare that could well irritate an observing driver, impairing his ability and greatly reducing his information about the Emergency Vehicle, by either glare masking important detail or the driver diverting his eyes from the scene in consideration for his own comfort. In such situations the conspicuity of the light is ensured by the unique operation of the lamp (i.e. flashing) and its colour, and high lamp output is not required.

1.8 Special Lighting Systems, as information carriers, should be designed to allow for those people who suffer from some form of (colour) vision disability. As a great proportion of these people have disability in the red area, and as this is the major colour used in Warning Lights, the spectral composition of the red used, and lens density should be well considered in terms of the signal's perception by such persons.

1.9 Therefore, the problem is to provide for road users to receive information about Emergency Vehicles in their vicinity under all conditions of weather and light, both when the vehicle is mobile and when it is stationary.

2. DESIRED PERFORMANCE CRITERIA

2.1 Having a grasp of the problems involved in this area allows us to now set out desired performance criteria for Warning Systems and Emergency Vehicle identification, which eventually is designing to facilitate effective Emergency Vehicle functioning and afford priority of transit.

2.2 Initially, mobile Emergency Vehicles must draw attention to themselves while in motion by an audible warning alarm, conspicuous light display or vehicle colour, with emphasis on the audible alarm, as many road users may not be in a position to see the vehicle. However, useful as it is, the alarm does not locate the vehicle in space or offer any real definition of the vehicle. Research has demonstrated[1] that the occupants of a vehicle can in only very few circumstances determine the direction from which the sound of an alarm is coming. This incidence is reduced when the vehicle cabin is completely sealed - windows closed, etc. - and there is a noise source within the cabin.

2.3 Despite this, the alarm must remain as the initial alert, to cause motorists to search for the Emergency Vehicle, a search which is considerably aided by a highly conspicuous colour scheme that stands out against its background,[2] and unique lighting devices acting to give the vehicle special conspicuity, not only as an Emergency Vehicle, but as one that requires right of way at that moment. These distinctive elements are of considerable assistance to the driver in his search for an Emergency Vehicle, as with dense complex road traffic there is little time to make protracted searches, especially in poor driving conditions.

2.4 Also, while stationary, Emergency Vehicles must be obvious and conspicuous to allow their rapid perception by drivers. Therefore, they

must here too stand out against the background and draw attention to themselves, adequately demarked by lighting equipment and unique in special light displays to be seen and allow the spatial resolution of the vehicle by approaching drivers.

2.5 The fundamental criteria in this analysis are that the various visual warning systems operate without ambiguity in a fashion carefully correlated with the psychophysical and psychological behaviour of human sensory systems,[3] achieving harmony with the vehicle's configuration and normal lighting system and so designed that warning devices are visible from all around the vehicle. Vehicle colour must be similarly evaluated, the criteria being that the colour used be in the range of the eyes greatest chromatic sensitivity.

2.6 We thus have a hierarchy of warning and identification:

(i) the alarm alerting drivers to the presence of an Emergency Vehicle;

(ii) the colour scheme being such that it is easily seen when, on hearing the alarm the driver searches his surroundings, and normally, when the driver is scanning the road in a routine fashion;

(iii) Special Lighting systems in operation both heightening the vehicles conspicuity (in this sense, on a superior level to (ii) and affirming that this particular vehicle is the subject of the search.

These criteria, having been established here in general terms will now be fully discussed below in terms of actual methods of achievement.

3. WARNING SYSTEMS AND IDENTIFICATION

3.1 There are four specific elements that contribute with varying degrees of overall importance to the whole identification problem (few of which are at the moment - 1977 - correctly used). These are audible alarms, vehicle colour and colour schemes, special light systems and uncial signs and symbols.

3.2 Audible Alarms

3.2.1 The function of the Audible Alarm, when hears (this is one reason for the importance of the visual aspect of Emergency Vehicles[4]), must be hopefully, to cause drivers to concede right of way, but essentially to alert him to the presence of an Emergency Vehicle which he must confirm visually, and seek further information (see 2.3).

3.3 Colour

3.3.1 General

a. By reference to spectral response curves, it can be seen that in photopic conditions the eye is most sensitive to colours in the green-yellow region of the spectrum, and markedly less sensitive to reds and blues. For scotopic conditions there is a shift in the response (the Purkinje Shift) towards the blue end of the spectrum with maximum sensitivity in the green region and total loss of sensitivity to reds and oranges.[5] (Note, most night driving is in mesopic conditions).

b. Therefore, it would appear that a colour in the green to yellow region would be the most visible and suitable for use on Emergency Vehicles. However, there are several other pertinent factors.

c. There is an important link in human perception between the visual and auditory systems. This was explored by Krovkov[6] who

discovered that high intensity sound (as in an alarm) substantially decreases the eye's sensitivity to red and attenuates the perception of orange, while heightening that of blue. Perception of green-yellow colours is unchanged by this effect. These results have recently been substantiated by Canadian researchers, cited by Chamberlain.[7]

3.3.2 Colour

a. The colour red, often used by Fire Brigades and widely considered a suitable colour for this use, thus requires a closer examination. Clearly it is not a highly conspicuous colour, especially in poor weather conditions, and is of inherent low reflectivity (apart from fluorescent materials), such that by this, and the Purkinje Shift it looses its colour value at night and is perceived as black, merging with the general dark.[8]

b. Although orange is a more luminous colour than red, it is perceived similarly, with similar qualities as red, but generally to a lesser degree.[9]

c. It is also often considered that white has value as a 'colour' for Emergency Vehicles requiring high visual impact. On examination, the salient characteristic of white is that it has a high reflectivity of white light and its attendant achromacity allows it to tend to blend with the achromatic backgrounds of many weather conditions[10] (dull, overcast sky, fog, rain, snow, etc.) and is commonly observed in reflection of daylight from polished surfaces, irrespective of colour.[11]

d. As yellow is the most easily focused colour,[12] it allows for very accurate resolution, and this with its very intense chromacity makes it an excellent attention-grabbing colour, and with the wide angle of view the human eye has for yellow and other reasons (3.3.1) it

becomes a very conspicuous colour in all weather conditions, including fog[13] (obvious allowances made), perceivable at night as a colour more readily than all colours except green, and visible at night from a distance six metres greater than for red, due to its greater light reflectance and greater relative luminosity, even in scotopic conditions.[14]

3.3.3 Street Lighting

a. Modern street lighting often has highly distinctive colour rednering characteristics which cause great changes in the apparent colour of surfaces.

b. According to studies by the Midlands Fire Service in the U.K.,[15] under Sodium Vapour and Mercury Vapour lamps, red appears grey to black, with its chromatic value reduced under fluorescent lamps. For the same conditions white is unaffected, yellow is affected only marginally or not at all. Blue and green are also affected, considerably under Sodium Vapour lamps, less so under other sources.

3.3.4 Psychological Effects of Colour

a. Red is an arousing emotive colour causing physiological changes that are associated with danger and anger, increasing restlessness and nervous tension,[16] it is also associated quite strongly with blood and fear - effects and relations that should be avoided by Emergency Vehicles,[17] coming as they do into close contact with people who are emotionally off-balance, and being driven near motorists who are placed in stressful conditions by the Emergency Vehicle's close proximity and frequent high speed. It is clear that drivers under any stress are a potential liability to that vehicle's safe arrival at its destination.

b. Not only does white lack chromacity (3.3.2), but it is a psychologically passive colour,[18] with no attention-grabbing power, lacking visual interest, and completely devoid of any compelling power.[19] White is neutral and lacks the conspicuity value of 'colours' with chromatic value.[20]

c. The psychological effects of yellow are to promote positive emotions, while advantageously retaining its association as a "caution" symbol.[21]

3.3.5 Visual Background

a. For Emergency Vehicles the background consists of the road surface, landscape and/or townscape and other vehicles. However, generally the background can be considered as a medium grey in most circumstances.

b. Although at least one author is at variance,[22] investigations by Leonard and Sleight[23] indicate that multihue colour schemes, e.g. a checkerboard pattern, can seriously reduce the conspicuity of any vehicle thus treated, often to a dangerous level. This is due to the discontinuity of colour and form, being highly disruptive, and possibly allowing a partial merging with the background - certainly at distance and if one of the colours is dark.

c. To ensure conspicuity, spatial and chromatic information most correlate, as Nuckolls indicates.[24] This, given a colour of high remission from the 550nm to 560nm region of the spectrum, would ensure that an emergency vehicle would contrast with the greatest range of background conditions.

3.3.6 Statistical Evaluations

a. It has for some time been standard practice for a number of Fire Brigades (notably in the United States and United Kingdom) to

use colours other than red for their appliances, commonly yellow or lime-yellow colours which have led to a reduction in the accident rate for these appliances; and other alternatives to red (usually white, orange or tangerine) have also given satisfactory results in this area.[25]

3.4 Warning Lights

3.4.1 General

a. To clearly communicate the Emergency Vehicle's presence and urgency of transit to road users, the particular vehicle envelope must be readily apparent to approaching and/or nearby motorists, especially at night when the vehicle is less readily specifically identified.

b. The envelope is most clearly defined by locating its corners or outermost planes so that at night the motorist is aware of the approximate size of the vehicle he must avoid, or at least, its width, and at all times, when there is obstruction between the vehicle and road user, the part most likely to be first visible - a corner or edge - is distinctly marked as part of an Emergency Vehicle.

c. However, unless there is a special means whereby the front and rear of the Emergency Vehicle may be differentiated, the effectiveness of the warning signal may be reduced from certain directions as the Emergency Vehicle will present a confusing array of rotating lights that impart no real information.

3.4.2 Conspicuity of Warning Lights

a. For conspicuity Warning Lights are wholly reliant on their uniqueness of colour and operation, and secondarily the area of the illuminated lens, more than the luminous flux of the lamp within

reasonable limits.

b. The unique colour and operation of Warning Lights: usually rotating or flashing red, provides a distinction from other light sources occurring both naturally and on the road, and attracts attention by virtue of this 'chaotic' appearance, however a balance must be struck between the degree to which this aspect is developed at the expense of a more informative display of lights in the terms of 3.4.1.

3.4.3 Vehicle Lighting and the Role of Warning Lights

a. Warning Lights serve two main purposes on an Emergency Vehicle: to signal presence and to identify the vehicle's special status. Warning Lights also serve to give a general definition of the spatial displacement of the Emergency Vehicle, giving road users clues as to what they must avoid.

b. Road users having at once had their attention attracted to the vehicle and generally informed about its size and/or shape, must be given further clear detailed information about the vehicle which is a potential obstruction and danger to safe passage. This specifically applies at night where the vehicle is stationary; when it should be demarked by sufficient use of tail-and various clearance-lamps.

3.4.4 Visibility of Warning Lights

a. It is vital on Emergency Vehicles that Warning Lights be visible to road users from behind, in front of and to the sides of the vehicle. Unfortunately, it often happens on Emergency Vehicles that this obvious principle is ignored, and the usual single rotating beacon is obscured by a ladder, or other equipment, a siren, parts of the vehicle body, or in some cases by crew, depriving motorists of

important information. Thus no warning light should be obscured from any point unless another is visible from that point, preferably on the part of the Emergency Vehicle closest to the observer.

b. Now, the position of drivers immediately ahead of an approaching Emergency Vehicle must be examined. Invariably these are deprived of information to such an extent that Emergency Vehicle transit is impeded; simply by the mounting height of roof beacons and the comparatively low cut-off angle of motor car rear-vision mirrors, the driver, glancing in his mirrors on hearing the alarm, or otherwise, is given no indication as to the nature of the Emergency Vehicle behind him and, assuming that the alarm is heard, although the motorist should allow clearway, there may be confusion caused by the lack of clear visual information of the Emergency Vehicle and consequent absence of information about its position and direction of travel.

c. In amending this situation, rear mirror vision must be the primary design criteria, and that the driver spends very brief periods looking at the mirror should be taken into account. Then some sort of indication that the vehicle is an Emergency Vehicle needs to be provided at the appropriate position on the front of the vehicle - a reverse lettered illuminated sign, or flashing lights of reasonable intensity.

d. In either of these solutions it must be realized that the illumination should be of lowered intensity so as not to cause discomfort, but high enough to be distinctly recognized.

e. If a light system is opted for, it should consist of a pair of alternating flashing lights of substantial size (at least 100mm diameter) and correct optic design, placed side by side on the vehicle front.

f. Here side by side placement reduces the effect of masking glare from the headlights - especially if they are on main beam, and at the same time, with alternating flashing provides for a highly dynamic display, which would be reduced if the lights were closer to the headlamps and masked by headlight halation. If simultaneous flashers were to be used, because of the brief scans via rear vision mirrors there would be a great chance that no signal would be observed - the lamp(s) being unilluminated.

3.4.5 Colour of Light Signals

a. Red colour flashing lights and rotating beacons have long been used for warning signals, and it is felt that this is most appropriate for Emergency Vehicle identification and danger warning. Confusion with the amber lights of other service vehicles is avoided and red is strongly associated with danger, also red light is more conspicuous at night[26] than light of other colours and does not lose colour value with lowered luminance or long distance,[27] whereas, say, blue has very low luminous efficacy - a blue filter transmitting about 4% of incident light, being psychologically passive,[28] difficult to focus, and over any reasonable distance it loses its colour value.

b. The deleterious psychological effects of red, although considered a problem in vehicle colour, are outweighed here by its fulfilling of requirements for uniqueness and warning etc.

c. Cole reports[29] in this context that there are problems associated with red warning lights in as much as there is a small but substantial proportion of the population who have defective colour vision in the red area. This can be best overcome by the use of a high transmission fitter emitting a red light with a certain yellow component (BS 1376-1974).

d. Grille level flashing light installations are a special case, because of the close position of observers, the stress they are under to take decisive action and the Krovkov effect - it is probable that they would hear a loud alarm tone - it could be better to use a yellow or amber signal, despite the above, although this leads to a multiplicity of signals in terms of colour and could detract unduly from the desired effect, this indicating that red may still be the better choice in many situations.

3.4.6 Performance of Warning Lights

a. Current use of red colour beacons has two disadvantages: the Krovkov effect can act to reduce the apparent intensity of the light when a loud alarm is heard, and observations indicate that this apparent intensity reduction is great, rendering the beacon almost of no consequence; and the usually used single lamp beacons with their high speed rotation to give 90 flashes per minute produce a generally disconcerting and unpleasant effect which can distract the driver from his task and act as an excessive stimulus, possibly tending to impair rational judgement.

b. To go towards overcoming this, Ruben et al[30] recommend the use of a four lamp two colour beacon: red and clear lamps disposed in such a way so as to give successive red and white light flashes. This naturally increases the beacon size and shows the observable speed of rotation producing a far more conspicuous, and by virtue of the lower rotational speed, a less unpleasant effect.

c. It should also be mentioned here that most Warning Light installations are not in keeping with correct transportation lighting practice. To be adequately illuminated for daytime conditions, a high intensity light source is used, being at night a disabling glare source detrimental to other road users' night adapted vision. The glare

from these installations at night also has the effect of masking some important detail of the emergency incident or vehicle, depriving drivers of information that would help in decision making. With such a reduction in night-time beacon intensity, the signal uniqueness would not be lost, as contrast would still be quite high, as well as for other reasons.

d. In multi-beacom installations attention should be paid to the fact that invariably the beacons are incoherent in their rotation - revolving at fractionally different speeds. Thus it is difficult for the brain to interpret that both beacons are a part of the one system and therefore is confused in the evaluation of this information. To effect a clear signal, all warning lights, revolving or flashing, on any vehicle should be synchronized and correctly phased to be interpreted by the brain as identifying one particular vehicle, particularly essential where a number of vehicles are at the one location.

3.4.7 Traffic Signal Lamps

a. On Emergency Vehicles it is not only important to give adequate signals of the type discussed above, but to ensure that normal traffic signals are clearly communicated; that is that turn indicator lamps, stop lights, tail and parking lights and reversing indicators should all be given careful optic and ergonomic design, and although discussion of this is beyond the scope of this paper, it will suffice to mention here that a major factor in lamp visibility is size as well as lamp flux (3.4.2).

b. We can, however, make some comment on the problem of obstruction. The use of normal traffic signal lamps is frequently of limited effectiveness on Emergency Vehicles due to the obstruction of these simply by

following traffic, an important factor when it is considered that Emergency Vehicles frequently need to make unusual traffic movements which should be well indicated to all traffic, especially that following.

3.5 Uncial Signs

3.5.1 General

a. In the hierarchy of Warning Systems, uncial signs - as verbal communicators - give information that is not necessary to the vehicle's Warning Systems in the terms previously discussed. The purpose of these signs, although considered by some as part of the Visual Warning System, is usually to give simple "low-key" information for the use of field controllers, Emergency crews, etc. and others who may need confirmative evidence as to the type of Emergency Vehicle or the organization that it belongs to. It may also be of some use that motorists are informed as to the type of Emergency Vehicle. However, there is no evidence or opinion for either case on this point.

b. However, it must be pointed out that any element that requires reading or invites an observor to read cannot be considered to be a warning device in the terms of this paper. All such features should be eliminated from any schedule of warning devices. Particularly in this classification are steady or flashing illuminated signs.

c. The most serious aspect of illuminated signs on emergency vehicles is that, because of various factors, they only become legible in what may be termed supra-threshold conditions. At threshold there are usually problems in determining the form of the characters, although their illumination is apparent. Thus information transfer

is delayed although the sign is perceived, and the driver is diverted from his task until he can understand the sign. Synchronized flashing coloured lights avoid this problem, information being simultaneous with initial perception, even at threshold distances and luminances with red colour lights.

4. RECOMMENDATIONS

4.1 General

a. In designing Warning Systems, each particular Emergency Vehicle must be treated on its merits and nothing can be said that will cover all situations in detail with any validity.

b. All that can be set out are the general principles that have emerged from Section 3 and can be applied in essence, if not in letter, to a large variety of Emergency Service Vehicles.

4.2 Colour and Colour Schemes

a. Basically this paper points to the need for universal use of a highly conspicuous colour for all emergency vehicles, with the colour standardized internationally if possible. From the evidence presented, using ergonomic criteria, this colour - in either fluorescent or conventional form - should be in the yellow green to yellow range. It is considered that an appropriate colour then would be that equal to Munsell colour No. 2.5GY 8.5/8.0, subjectively experienced as a greenish yellow.

b. This colour not only satisfies our requirements but is perceivably different from the yellow hues that are to varying degrees in common use on motor vehicles, thereby giving emergency vehicles as special distinctiveness.

c. It is very important that there be no dilution of the visual uniqueness of Emergency Vehicles, which means that only the Emergency Vehicles of Emergency Service bodies be given special treatment, and the use of such colour schemes be restricted by regulation to those vehicles.

4.3 Warning Light Systems

a. As mentioned in the text, there should be two levels of Warning Lighting - attention-grabbing rotating and flashing red beacons mounted on the upper parts of the vehicle to approximate the position of the vehicle's extremities, and a secondary system of steady demarking (clearance) lamps specifically located so as to define the vehicle in detail with full and correct use of tail and parking lamp and side marker lamps, particularly on van and truck based vehicles.

b. Concerning the primary Warning Lights above, Emergency Vehicles of motor car size and type need only use grille mounted lights and have the outer side planes of their envelopes defined (i.e. the width of the vehicle must be indicated to road users) and therefore there is a requirement for two roof mounted beacons, one either side of the turret roof, or equipment such as integral Warning Bars. Any further use of roof mounted beacons or lights would be both redundant and confusing and not to be considered.

c. Large van and truck type Emergency Vehicles present a different problem, as the size and bulk of the vehicle may obstruct roof mounted beacons for close observers as may, as on Fire Appliances, various pieces of equipment - ladders, monitors, turntable ladders and hydraulic platforms. Thus here and often elsewhere the configuration of the vehicle is a prime determinate in Warning Light design, but basically, what is called for on this type of vehicle is a pair of rotating beacons over the cab roof, and a pair of alternating flashing beacons to the rear of the body, with grille mounted alternating flashers also fitted.

d. It is recommended that recommendations in the report by Ruben et al be accepted and the opportunity afforded used to code the

Warning Light systems of Emergency Vehicles, with a selected service perhaps using the alternate Red/White lamp in a single beacon dome. Further developments could perhaps be made in this direction.

e. Obstruction of Traffic Signal Lights - notably those at the rear of the vehicle - is a serious problem, as is the comparative 'invisibility' of some. It is recommended that this be overcome in part by deploying repeater lamps at a high position on the rear of the vehicle, and empirically ensuring that all such lamps are visible in all conditions.

4.4 Summary of Recommendations

a. Colour: It is recommended that greenish yellow - as specified - is the most suitable colour for Emergency Vehicles.

b. Warning Lights: It is recommended that for smaller vehicles, beacons be displayed so as to indicate the width of the vehicle and that grille level beacons be used for the benefit of motorists ahead of the Emergency Vehicle.

For large vehicles it is recommended that as well as the above, additional Warning Lights be displayed where necessary to ensure visibility of some warning signal to any observer. For large vehicles it is also recommended that rotating beacons be used towards the front of the vehicle and flashing (alternating) lights to the rear.

It is recommended that all Warning Lights on a vehicle be designed to operate in a synchronous fashion - all lights being in phase to give clear information that is unambiguous, ensuring that the light display is recognized as that of a single vehicle.

5. CONCLUSION

5.1 In the application of these principles by Emergency Service organizations in the design of Warning Systems and colour schemes for particular vehicles it must be remembered that all such design must be carried out with an awareness of the problems and potential of the vehicle under consideration.

5.2 Lighting systems must be set out with regard for the shape and configuration of the vehicle, its use, and the lighting equipment already fitted. Warning Light equipment must be co-ordinated with standard lights on the vehicle, and the correct operation of this by users should be ensured.

5.3 Planning the vehicle's colour scheme is also important and it must be carefully considered with due regard for the vehicle's use, the particular nature of common background conditions and any colour coding scheme that is developing.

5.4 To speak in summary then, by the ergonomic design and use of Emergency Vehicle colour schemes, Warning Lights and signs, much can be done to allow the Emergency Vehicle to make a clear visual statement to road users that provides unambiguous information related to the vehicle's presence, function and urgency of transit, which the safety of the Vehicles and their crew and their contribution to general road safety can only be beneficial, in that the emergency service provided by way of the Vehicle will be expedited. Thus, through the straightforward recommendations in this paper it is expected that the performance of Emergency Services will, as a consequence, be improved.

5.5 Although these recommendations are not absolute, for the time, on the basis of the State of Knowledge in this field, they are considered to be an optimum ergonomic solution and to provide a standard by which further design work and ergonomic studies may proceed.

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