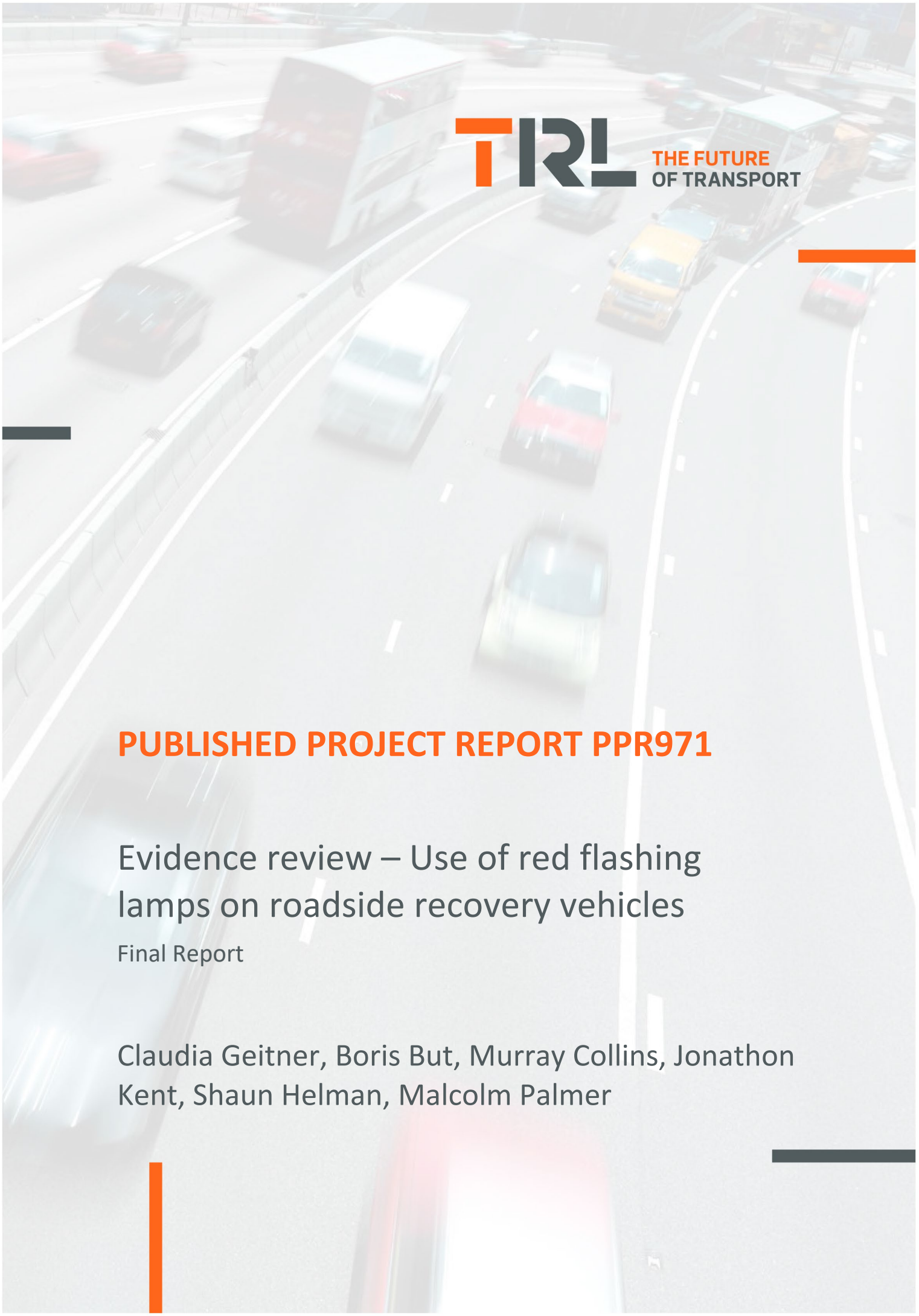

THE FUTURE OF TRANSPORT

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Evidence review – Use of red flashing lamps on roadside recovery vehicles

Final Report

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Executive summary

The roadside recovery industry employs nearly half a million workers and provides an invaluable service to stranded motorists on Great Britain's roads. When attending a vehicle breakdown, roadside recovery workers are at risk from approaching and passing traffic, and injuries and fatalities in collisions certainly occur (it is not possible to determine the numbers from existing national road casualty data or published RIDDOR[1] data).

The Road Vehicles Lighting Regulations (RVLR) 1989 prescribe the warning lamps[2] that can be used on vehicles from roadside recovery services and by other bodies such as the emergency services and the Highways England Traffic Officer Service. Currently RVLR only permits emergency service vehicles to use red warning lamps. Highways England Traffic Officer vehicles are permitted use of red flashing lamps by a section 44 Road Traffic Act 1988 Vehicle Special Order (VSO); Traffic Officers have statutory powers enabling them to direct traffic, which road recovery operators do not. There have been calls within the industry, and through the All-Party Parliamentary Group for Roadside Rescue and Recovery (hereafter APPG) to allow roadside recovery vehicles to use red warning lamps when attending to vehicle breakdowns. The reasoning given is that red flashing lamps will make roadside recovery vehicles more conspicuous (and therefore easier for approaching motorists to detect) and will also make it easier for approaching and passing motorists to identify the situation as 'dangerous' and exercise caution.

Consequently, the Department for Transport's International Vehicle Standards (IVS) Division has commissioned this review of evidence to see if a more flexible approach to the use of red flashing lamps by road recovery operators might be appropriate, taking account of their impact on the behaviour of other road users and crucially, whether there is expected to be an overarching and demonstrable road safety benefit.

In this report, three methods used to assess evidence are described. A literature review was undertaken, building on previous work in the area related to Traffic Officer Vehicles and red warning lamps (Diels et al., 2009). Furthermore, representatives from the roadside recovery industry, and wider stakeholders and academics, were consulted. Finally, a trawl of social media and an internet search was undertaken to identify further literature, data and case studies, and public sentiment around the issue.

The findings from the literature and web searches found little evidence to suggest that red lamps would help with conspicuity; there is a dearth of research specifically into the topic. The findings did suggest, however, that drivers approaching a recovery vehicle would be helped in their understanding by seeing red warning lamps, since people have an association between the colour 'red' and the concept of danger. However, the scientific evidence identified only related to that colour association. No new UK-based research was found relating to comparative trials of vehicle lamp colours.

[1] Reporting of Injuries, Diseases and Dangerous Occurrences Regulations

[2] The term 'lamps' is used throughout this document to align with lighting regulations. However, 'lights' is used where the text is a direct quote or relates to previous research

Stakeholder interviews revealed a general support for the use of red lamps on recovery vehicles, if managed properly to avoid over-use (for example when emergency vehicles are also present and displaying red lamps, or when a recovery vehicle is not attending to an incident).

Concerns were identified relating to potential over-use of warning lamps, also potentially increased warning lamps causing either discomfort or disability glare for approaching drivers. The possibility of causing confusion for drivers, should red warning lamps be used in different circumstances from existing permitted users, was also identified.

Of the five options communicated by the Department for Transport, the Regulatory Impact Assessment included in this report recommends proceeding with Option 2, to allow rear facing red flashing lamps on all roads (non-live running lane) when a road recovery vehicle is stationary. Such recommendation takes into consideration the potential benefits and disbenefits of having a red warning signal to alert upcoming traffic. However, option 2 (non-live running lanes) does not reflect the industry's concerns regarding operations in live lanes on non-motorway high-speed dual carriageways. Option 2 is also inconsistent with the current usage of red lamps by Highways England Traffic Officers.

Based on the evidence on light colour association and general stakeholder support regarding suitability of use, but acknowledging the lack of evidence comparing different light colours, the recommendations from this work are as follows:

1. An off-road comparative trial should be undertaken to gain understanding of how naïve participants perceive stationary vehicles displaying amber and amber and red warning lamps. The outcome of this trial can feed into implementation, including driver awareness campaigns.
2. Subject to the outcome from that trial, recovery vehicles should be allowed to use rear-facing red lamps in such a manner that their use does not cause confusion with current permitted use, e.g. Highways England Traffic Officers. Any implementation should be accompanied by:
    a. Dedicated stakeholder consultation with relevant industry representatives to focus on the procedures for implementation, including aspects such as: locations permitted (live lanes or off the carriageway), whether permitted only when stationary or when arriving/leaving, management of over-use and avoidance of glare.
    b. A driver awareness campaign to educate the driving public on what to do when approaching and passing recovery vehicles displaying red lamps.
3. Over the longer term, research should be undertaken to establish the boundary conditions for detectability of vehicles and people around them, and driver understanding, when vehicles are displaying different lighting combinations. This research should focus on optimising the combinations of vehicle lighting and Personal Protective Equipment (PPE).

1 Introduction

There are nearly half a million roadside recovery workers employed in different capacities in Great Britain (Deb, 2019) who offer a vital service to stranded motorists. Sometimes these roles involve working on hard shoulders, in emergency refuges on smart motorways, or in live lanes on single or dual carriageways in order to attend a broken-down vehicle. In such scenarios, the recovery vehicle must abide by certain regulations and standards. The Road Vehicles Lighting Regulations (RVLR) 1989 apply across Great Britain and cover a wide range of lighting requirements, including detailed prescription of the function, colour and use of flashing warning beacons. The RVLR currently outline the following:

- Recovery vehicles are permitted to activate amber flashing warning lamps but are not permitted to display red flashing warning lamps
- Police, fire and ambulance services are permitted to fit and use red flashing warning lamps
- Highways England (HE) Traffic Officer vehicles are permitted use of red flashing lamps by a Vehicle Special Order (VSO).

The AA (2019) reported that in the 18 months before March 2019, three people from the recovery industry died and two vehicles from the AA had to be written off[3]. All fatalities occurred on high speed roads, two on the motorway and one on a dual carriageway. After a fatality in 2017, the Campaign for Safer Roadside Rescue & Recovery was established to lobby for improved roadside safety for recovery workers.

The use of red flashing lamps is often associated with statutory power to direct traffic; it is currently reserved for the use of emergency services and Highways England Traffic Officer vehicles in live lanes. However, there are calls among road recovery industry professionals to permit the use of red flashing warning lamps on recovery vehicles, suggesting that it will improve safety in terms of detection of the vehicles by other road users, as well as the psychological effect of the colour red causing road users to assess a situation as dangerous, and be more likely to slow down.

The effects that red lamps have on other road users must be considered alongside any potential implications for vehicles that currently use red lamps. Consequently, the Department for Transport's International Vehicle Standards (IVS) Division has commissioned this review of evidence to see if a more flexible approach to the use of red flashing lamps by road recovery operators might be appropriate, taking account of their impact on the behaviour of other road users and crucially, whether there is expected to be an overarching and demonstrable road safety benefit.

The research used four methods to assess evidence:

- First, a literature review was undertaken (Section 2 of this report).

[3] Statistics on incidents with recovery workers do not exist on a national level.

- Stakeholders were consulted (Section 3); these included representatives from the recovery industry, as well as from the emergency services, and academics working in the area.
- A media trawl (Section 4) sought to identify any additional literature and establish public feeling on the issue.
- A regulatory impact assessment was undertaken (Section 6).

2 Literature review

This section of the report describes the methodology (Section 2.1) and results (Section 2.2) of the systematic literature review. Summaries of individual papers can be found in Appendix A.

2.1 Method

The literature review was conducted across the following online databases of scientific literature:

- **Google Scholar** – Google Scholar index includes most peer-reviewed online journals of Europe's and America's largest scholarly publishers, plus scholarly books and other non-peer reviewed journals. http://scholar.google.co.uk/
- **ScienceDirect** – ScienceDirect is a leading full-text scientific database offering journal articles and book chapters from more than 2,500 peer-reviewed journals and over 11,000 books. http://www.sciencedirect.com/
- **TRID** – One of the most comprehensive transport research databases available today. http://trid.trb.org/
- **TRIP** – TRIP provides an overview of in-progress and completed transport research activities at European and national levels, based around the EU research framework programme. http://www.transport-research.info/web/index.cfm
- **PubMed** – PubMed includes accident studies, safety, human factors, psychology etc. http://www.ncbi.nlm.nih.gov/pubmed/

Search terms were initially designed to be specific to the recovery industry and red flashing lamps. However, adding search terms related to "red" and "lighting" returned search results that included red light running, red traffic lights and other subjects not relevant to this work. Subsequently, "red" was dropped from the search query and replaced with the general keywords "light" and "visibility". Similarly, the search query initially included the keyword "safe", which produced many search results not relevant to the topic. Later, "safe" was replaced by other topic relevant keywords such as "visibility" and "compliance" and the more generic keyword "behav*". The recovery-vehicle-related search terms did not show any relevant results. Moving forward, "incident management" was identified as a keyword that returned more results. The keyword "incident management" showed some results related to emergency vehicles. A subsequent search replacing "incident management" with "emergency vehicles" and "work vehicle" showed the same results, therefore these were the final search terms used. The final search terms are shown in Table 1.

Table 1: Final selected search terms

Topic vehicle	Topic light	Topic behaviour and visibility
Recovery oper*	Light*	Behav*
Emergency vehicle	Rear light	Live lane
Work vehicle	Warning	Visibility
		Compliance

The search terms within the table were combined to form a query using "OR" and "AND" operators as shown below:

- ("recovery oper*" OR "emergency vehicle" OR "work vehicle") AND
- ("light*" OR "rear light" OR "warning") AND
- ("behav*" OR "live lane" OR "visibility" OR "compliance")

Only new literature published after the previous TRL report (Diels et al., 2009) on the topic of conspicuity and red lamps in 2009 is included in this review. Therewith the reports published between 2010 and 2020 were included.

The following criteria were applied to select papers for full text review:

- Published in a peer-reviewed academic journal or at a conference or referring to such evidence
- Comprising primary data collection (for example interviews, survey or simulator/on-road study) or a literature review of the same
- Clearly related to the issues of red lamps / red flashing lamps and how drivers react towards these, or relevant to this

In addition to literature identified by the above search, two papers were included from evidence sent by APPG at the request of the client. Those two papers are:

- Cook et al. (2000)
- Pravossoudovitch et al. (2014)

The literature review also includes findings from the report previously conducted at TRL in relation to conspicuity and red lamps (Diels et al., 2009).

2.2 Results of the literature review

Previous research conducted by TRL, Diels et al. (2009) evaluated the conspicuity of Traffic Officer vehicles, particularly the use of rear-facing flashing red lamps. The research consisted of a review of literature, evaluation of procedures and a simulator study.

The previous literature review discussed the balance of light intensity between visibility and glare effects which can reduce the detection of workers near the vehicle. Colour adds only little to visibility of the vehicle, but it aids drivers in their interpretation of the traffic scene by indicating a specific vehicle type or hazard. An interpretation of the vehicle is prerequisite for drivers to form a response. Quicker identification of a vehicle light from distance provides the driver with more time to act. Besides the benefits of light colour there is a risk factor when flashing red light is used at night. Drivers have greater difficulties to estimate the distance to the vehicle displaying red flashing light.

The simulator study showed that, although the way drivers approached the Highways England (Highways Agency at the time of the study) Traffic Officer vehicle changes with lighting, these were not statistically significant. Post-trial questionnaires identified that participants associated amber lighting more with a "slow down", the red light was associated to either "slow down" or "stop".

Those findings led to the conclusions that:

- When working in live lanes, rear-facing red flashing lights are beneficial for Traffic Officer vehicles
- When working in the hard shoulder, Traffic Officer vehicles should use amber lights

In the literature review initiated for this project, limited new literature published between 2010 and 2020 was found. Most of what was found was focused on emergency vehicles. There were two general concepts identified in the literature that are considered important alongside the main question of how drivers behave when encountering a vehicle with a flashing light; these are disability glare and discomfort glare.

Disability glare can occur when very bright light enters the eye and decreases a person's ability to detect objects in the environment (Cook et al., 2000). In a driving environment, disability glare can be created by light emitted from a vehicle and causing persons nearby the vehicle, such as roadside workers, to not be seen by an approaching driver (Cook et al., 2000).

Discomfort glare is similarly caused when bright light enters the eye (Cook et al., 2000). It can be a painful effect, but it does not reduce the ability to detect objects in the visual field. However, it can also have detrimental effects on driving safety when drivers might try to avoid looking into the bright light, leading to less observation of this area of the driving scene.

Optical consultant Hugh Barton, as stated by Tracey Crouch MP, comments that red light has a history of being used as a long-distance warning light because of the Rayleigh and Mie scattering process. At the limit of visual detection red light is seen as red, while other colours lose their colour attribute and just appear as light due to atmospheric scatter (Deb, 2019). Further, other research found that blue light is perceived as brighter, more glaring and uncomfortable compared with red light of the same intensity (Bullough et al., 2019).

A study investigating the use of different coloured lamps on emergency vehicles conducted by Illinois State Police revealed that drivers could perceive white at the greatest distance, followed by amber, red then blue. White produced the highest amount of glare, so the study recommended the use of amber lamps to be enable vehicles to be seen at the greatest distance while minimising glare for passing drivers (Howell et al., 2015). Test work conducted by Loughborough University considered distraction, flash rates, colour intensity, discomfort and disability glare of warning lamps. When colour is the only variable (intensity is held constant) red has the quickest warning beacon reaction times. However, in real world lighting white light has the highest light transmission (allowing it to be seen from the greatest distance) and amber has the quickest warning beacon reaction time, but high amounts of glare at night. As such, recommendations consist of a combination of red and amber warning lamps depending on level of conspicuity required (Cook et al., 2000).

Research has also found that red and blue light combinations had the best visibility in normal and low light conditions (Anderson & Plecas, 2010; ESRI, 2018). Red was found to be most visible during daylight and blue during night-time (ESRI, 2018). A study of more than 9,000 vehicles passing a staged right-hand lane police stop on Florida freeways revealed compliance with the move over law was higher with both blue and red warning lamps compared with the use of amber directional lamps (Carrick & Washburn, 2012).

A study using Motokawa's direct current method tested four lamps (red, yellow, green and blue) to compare the visual field of view. Values taken from the centre of vision and mid-periphery suggest that blue light may aid detection in the visual periphery while amber would offer greater conspicuity in the forward field of view (Arakawa as cited by (Cook et al., 2000)).

An analysis of accidents with first responder vehicles in the state of Florida revealed that more accidents occurred during darkness (Gray, 2020). Ambient light surrounding the vehicle during night-time was found to increase the crash risk, particularly, for police vehicles. The authors suggest that the ambient light could decrease the visibility of the first responder vehicle, but more research is suggested to understand the effect. The term "ambient lighting" is not specified or explained further in the publication. From the text it can be assumed that it refers to street lighting.

Previous research found that drivers distinguish vehicles based on colour combinations and patterns (Anderson & Plecas, 2010). Ideally the same warning lamps displayed on a vehicle would require drivers to respond similarly when approaching such a vehicle. A strong link between warning lamp colour and colour combination and the drivers' expected response enables drivers to react quickly. Confusion about the meaning of the lamps can result in delays of response or wrong responses. A study on behalf of the Texas Department of Transport investigating driver behaviour and responses to different warning light configurations revealed most participants associated yellow with highway construction or maintenance vehicles. Red was associated with emergency vehicles. Furthermore, the drivers perceived yellow-only warning lamps as less hazardous than other colours such as blue or red (Howell et al., 2015).

From a behaviour perspective, like previous research, Anderson and Plecas (2010) state that red light is associated with "danger" and "stop" across ethnicities and countries. This finding was confirmed by other research that found red to have an implicit association with danger (Pravossoudovitch et al., 2014).

Research from the United States of America found little consistency between emergency vehicle lighting specifications, including colour, among states (ESRI, 2018). The authors recommend using different light patterns for stationary and moving vehicles to help drivers to evaluate the situation and plan their response. The Kentucky Transportation Centre review of existing regulations, guidance's and practices across the United States of America recommend the use of amber and white coloured lamps for highway vehicles with asynchronous flashing pattern with a slow flash frequencies be used in order to distinguish warning lamps from headlights or brake lamps (Howell et al., 2015).

Another report discusses safety measures taken by the state of Minnesota for work zone and work vehicles (Minnesota, 2013). First, there is the move over law (OTS, 2020):

- When traveling on a road with two or more lanes, drivers must keep over one full lane away from stopped emergency vehicles with flashing lights activated — ambulance, fire, law enforcement, maintenance, construction vehicles and tow trucks
- Reduce speed if unable to safely move over a lane
- Failing to take these actions endangers personnel who provide critical and life-saving services. Fines can exceed $100

Second, blue lamps can be used by work vehicles. The design in which blue light is displayed on the vehicle is regulated (OTS, 2020). The regulation restricts use locations and scenarios to avoid overuse. Argument for its use is that blue light, due to association with emergency vehicles, provides an additional level of safety. Positive effects on speed reduction when approaching the vehicle and a higher number of drivers complying with the move over law have been observed in an on-road study (Minnesota, 2013).

The most relevant UK-based study was conducted in 2000 at the University of Loughborough (Cook et al., 2000). The authors reported that emergency operators believe the blue flashing light to be well understood but are not satisfied with driver responses. Drivers are reported to move only slowly when encountering an emergency vehicle with flashing lamps. Operators from the recovery industry believe the colour of their vehicle is not understood and complain about the proliferation of amber light. Further on, Cook et al. conducted a study to compare the conspicuity of green, blue, amber, and red flashing light of the same intensity. The authors recommend a mix of amber and red light in a warning beacon to reach best results in detection with minimal disability glare and minimal discomfort glare. Furthermore, the authors recommended the use of red light for recovery vehicles when working at an incident at a carriageway near traffic.

2.3 Literature review summary

In general, only limited new information regarding red lamps has been identified in this literature review. Some of the new literature considered red light in combination with blue light. The main new findings are:

- Ideally, the same lighting on a vehicle should require drivers to respond similarly (Anderson & Plecas, 2010)
- Drivers will react faster when there is a strong link between warning light colour or colour combination and the drivers' expected response (Anderson & Plecas, 2010; Diels et al., 2009). A study found that more drivers slowed down and moved across a lane (as required by law in Florida, US) when the vehicle displayed a blue and red light compared with an amber light (Carrick & Washburn, 2012), although this was a staged police stop
- Blue light, associated with emergency vehicles, can be used by work vehicles in Minnesota. The argument for the use of blue light is that it will offer additional protection for those vehicles because of the association with emergency vehicles (Minnesota, 2013)
- Red and blue light have the best visibility in normal and low light conditions (Anderson & Plecas, 2010; ESRI, 2018)
- Red has an implicit association with danger (Pravossoudovitch et al., 2014)

Further, besides the light colour, the literature advises that the use of warning lamps requires careful application. Cook et al. (2000) mention that the design of the light should consider disability glare and discomfort glare. Both effects can lead to reduced detection of workers besides a vehicle with a flashing light, especially if overall light levels are increased. Similarly, this was discussed by an optical consultant in Tracey Crouch's MP speech (Deb, 2019).

Summarising, the literature shows that red light has an implicit association with danger which could benefit recovery vehicles if it causes drivers approaching a scene to take more care. There is some evidence this can happen with some lighting changes; examples in the U.S. show that

drivers approach a scene more carefully when light colours on work vehicles are used that are associated with an emergency, although these studies used blue lamps, not red.

Subsequent to the completion of the literature review, a further brief search was undertaken across the main databases introducing the term “tow truck”. However, no additional research relating to vehicle lighting was identified from these searches.

3 Stakeholder engagements

Stakeholders were contacted to seek their views and invite evidence to help inform recommendations. The respondents comprised representatives from the recovery and breakdown industry, support groups, academic experts, and other stakeholders. This section describes the method (Section 3.1) and detailed findings (Section 3.2) of this work, and the findings are summarised in Section 3.4.

3.1 Method

3.1.1 Interviewees

In agreement with the client, stakeholders from emergency services, parliamentary groups, academia and the breakdown and recovery industry were selected and invited to an interview. Interviews aimed to collect viewpoints on a potential change in regulation from stakeholders who could be positively or negatively impacted, alongside viewpoints on evidence from academics. Interviewed persons were asked to answer as representatives of their organisation. Full interviews were conducted with the following organisations:

- One academic
- Two roadside recovery industry organisations
- Five other stakeholders, giving broad representation, including the police

A completed topic guide was also received from the APPG, which was included in the analysis, but a representative was unavailable for interview.

Two identified academics did not accept the invitation to participate in a full interview. One said this was because the use of red flashing lamps has not been widely explored, and the other said they had not undertaken any new research and were not aware of any new research information in this specific field since one of their reports published twenty years ago (Cook et al., 2000).

3.1.2 Design

A topic guide was created based on findings from the literature review. Interview data were analysed using thematic analysis. Responses were reviewed and key themes drawn out based on the frequency with which these emerged. These themes are summarised in the findings.

3.1.3 Topic guide

All interviews were conducted via telephone or online. Each interview was planned for a duration of 30 minutes. The following topics were covered:

- Use of red flashing lights (who, when, where)
- General use-cases of red flashing lights
- Alternatives to red flashing lights

- Non-regulated options for red-flashing lights

Two topic guides were developed. One topic guide was used for interviews with experts from academia (see Appendix B) and the other for experts from industry (see Appendix C).

3.2 Findings

3.2.1 The use of red flashing lamps

3.2.1.1 What vehicles types in the recovery industry should be allowed to use red light?

All respondents agreed vehicles attending a breakdown should be considered for use of red lamps. This was quantified by some respondents as a recovery vehicle that is attending the breakdown or recovery of vehicles. Other respondents specified that only what the industry termed *'registered recovery vehicles'* should be allowed to use red lamps. Some respondents recommended regulating the use of red lamps, by ensuring that only vehicles under the scope of PAS 43 (industry standard for safe working of vehicle breakdown, recovery and removal operation - see Survive, 2018) or registered recovery operators that have completed training in the appropriate use of red lamps be allowed to operate them.

All the respondents to this specific question commented that non-breakdown response vehicles should not be allowed to use red lamps. Examples included multi-car and lightweight car transports (used for transport operations rather than roadside recovery), and supervisory or fleet vehicles that are not used for recovery.

Highways England's statement is included in Section 3.2.6.

3.2.1.2 Locations at which recovery vehicles should use red light

Fast moving roads such as motorways, dual carriageways and some A-roads were mentioned the most by respondents as locations at which red light use should be permitted. Factors supporting this included the enhanced risk of vehicles travelling at higher speeds, and a higher number of near misses and incidents predominantly on high-speed roads where live lane working is required. Several respondents stated that it would be challenging to classify specific use cases; rather the use of red lamps should be considered in relation to the risk involved. One suggestion was that red lamps be permitted at any location where the recovery vehicle is protecting the scene, stopping or restricting the flow of traffic, or creating a hazard. Another was that dynamic risk assessments be used; requiring operators to decide if the use of a red light is appropriate based on the road scenario.

Built up urban areas or minor roads where speeds are slower were highlighted by most of the respondents as locations where red lamps should not be used. Furthermore, it was strongly suggested by most respondents that red lamps should only be used when a recovery vehicle is stationary; with amber lamps being regarded as appropriate when the recovery vehicle is approaching the scene. However, some respondents suggested that the use of red lamps should extend to include the recovery process. The recovery process would include slowing down to arrive at a disabled vehicle, being on the scene, and returning to the carriageway; it

was suggested that red lamps would then be turned off at a predetermined speed during acceleration.

It was also stated by two respondents (including one from the recovery industry) that red lamps should not be used by a recovery vehicle if it is at a controlled scene with emergency vehicles present, to avoid approaching drivers becoming distracted by too many lamps.

3.2.1.3 Road situations in which recovery vehicles should use red light

The same key themes emerged when respondents were asked to consider which road situations would be appropriate for the use of red lamps. Rather than specific use cases, respondents tended to describe any road situation where the technician or occupants are at risk at the scene of recovery as being suitable. It was reiterated by several respondents that a dynamic risk assessment should be undertaken to ensure that technicians use red lamps in appropriate situations only.

The themes of not using red lamps in a controlled scene, while moving, or on slow roads were mentioned again.

3.2.1.4 Weather conditions in which recovery vehicles should use red light

It was not considered appropriate by respondents to define specific locations based on weather. Most respondents commented that all weather conditions may be appropriate, with some references back to a risk assessment as a tool to deem if a situation requires red lamps.

3.2.1.5 Times of the day at which recovery vehicles should use red light

As with weather, most comments relating to time of day suggested that the use of red lamps could be applicable at any time. Comment on the intensity of the light was made by an industry stakeholder, suggesting the intensity of the lamps (high and low intensity) could be altered depending on time of day (and weather conditions).

3.2.2 Visibility of red light

The only location suggested by respondents for red lamps was high and to the rear of the vehicle. One respondent additionally suggested an alternating flash but suggested more research into this would be beneficial.

A range of respondents propose the use of alternating colour, specifically red and amber, to avoid confusion with emergency vehicles and improve the performance in terms of conspicuity. An academic suggested the use of colour combinations and flash frequency to create a new learned association unique to recovery vehicles. Evidence was provided towards the use of intermittent colour based on a research report that states flashing red alongside flashing amber should provide the best compromise in relation to detection, disability glare and discomfort glare (the same Cook et al. 2000 reference picked up in the literature review). An academic also highlighted the importance of luminance, and how this will be affected in different lighting conditions. It is likely to be harder to detect red or blue under reduced light levels. If combinations of colours are used it is important to consider the luminance of both. In theory, red and amber should be equal in terms of identification if their luminance is equal,

however a driver may be more likely to take notice of red due to the cognitive association with danger. A high contrast on a dark background is required to catch attention. If the flicker is too fast the driver will not be able to see it, but if it is too slow it will not catch the driver's attention. Different rates of flicker may suggest different levels of urgency; however, the respondent was not aware of any research in this area related to driver behaviour.

Further comments by respondents from the industry and the wider stakeholder group suggest that the red light should be separate to the lightbar to ensure a positive action to turn it on is required. Some respondents believed that in order to ensure there is not misuse of red lamps, technology should be used to support regulation of their use. Concepts discussed included ensuring that the red light could not be used while moving or the red light could not be activated unless the amber light was on.

3.2.3 Driver behaviour

3.2.3.1 Response behaviour towards red light and amber light

Strong themes of 'slow down' and 'danger' emerged when respondents were asked about driver behaviour to red lamps. Most stakeholders commented on the signal of 'danger' that red represents and stated that they assumed this would make drivers more alert and prepared for an enhanced level of risk. Assumed behaviours included drivers slowing down and moving over if safe to do so. Some stakeholders discussed this as a psychological response to red, referring to studies that highlight quicker reaction times to red lamps than other lamps.

However, several respondents highlighted a concern over driver's reactions to red lamps. Respondents noted a few negative possibilities such as harsh braking or drastic action to situations which could cause vehicles to come to an excessive stop, or 'rubbernecking'.

Respondents highlighted several different themes when asked how drivers should respond to amber lamps. It was stated that amber lamps highlight slow moving vehicles. However, most respondents believed amber lamps are overused and as a result have become 'diluted' in their effectiveness. Factors mentioned as being perceived to have caused this were many use cases, such as builders' vans, milk floats, roadworks and wide load vehicles, combined with inappropriate use of amber lamps when there is no risk. An industry stakeholder suggested that while drivers associate amber with moving vehicles, they do not associate with stationary vehicles, a scenario where road recovery vehicles use them. It was highlighted that it is unclear what information amber lamps are disseminating and as a result, drivers do not change their driving behaviour.

3.2.3.2 Predicted response towards a recovery vehicle with red flashing lamp

There were no conflicting opinions when asked about driver response towards a recovery vehicle with red flashing lamps. Stakeholders commented they believe drivers should respond the same way as they do to emergency vehicles with red flashing lamps. The difference between recovery vehicles and other vehicles such as road clearance workers and road inspectors that use amber lamps was highlighted. Recovery operators are often required when traffic is at its busiest, and they are required to operate in unplanned environments. Therefore, red flashing lamps are proposed to provide an enhanced level of safety for

recovery vehicles when stationary, based on use-case examples from services that already use red flashing lamps, such as Highways England Traffic Officers and the Police.

3.2.4 Potential dilution of warning effect

3.2.4.1 Consequences for emergency services that use red light

Respondents were asked what impact, if any, would the use of red lamps on recovery vehicles have on the emergency services. They expressed no strong differences in their views.

Positive impacts suggested tended to relate to an overall improvement of road safety, and fewer dangerous situations for recovery vehicles and other road users due to the predicted benefits of red lamps. Some respondents predicted a low impact on the emergency services, with some stating that recovery and rescue vehicles should be considered an emergency service and should be afforded the same light protections.

Potential negative effects were outlined by most respondents; if red lamps are misused or used in inappropriate scenarios (while driving or at a low risk scene) the positive effect could be diluted and the information the red lamps are conveying may become confused in the minds of approaching drivers.

3.2.4.2 Overuse of amber light

Non-academic respondents commented on the overuse of amber lamps. Further references were made to the high number of use cases, the misuse of such lamps and the unclear message that amber lamps portray. It was highlighted that the primary use of amber lamps should be for wide or slow-moving vehicles; however, recovery vehicles currently use amber lamps when stationary. The academic respondent did not comment.

3.2.4.3 Alternatives to red lamps

Amber directional lamps on the vehicle, to give drivers more information and guidance to the required behaviour (e.g. slow down and move over), was suggested by one respondent.

Further suggestions to improve the information drivers receive included using smart motorway signs to make drivers aware that recoveries are in operation; for example a ‘red X’ and a directional arrow could be used to indicate to approaching drivers that a recovery is taking place ahead, and they need to slow down and/or move over and pass.

3.2.4.4 Information on incidents in the recovery industry

This question obtained little new information. Most respondents did not feel they had enough knowledge or information in order to be able to comment on incident statistics in the industry. One stated that no accurate data are available. However, some statistics were supplied by the AA, who stated that seven of their breakdown vehicles had been hit in the last 12 months on the hard shoulder in daylight.

3.2.5 National Police Chiefs Council (NPCC) statement

Independent of this research, writing to the Campaign for Safer Roadside Rescue & Recovery on behalf of Chief Constable Anthony Bangham (NPCC lead for Roads Policing), Dean Hatton (Executive Business Manager, NPCC Roads Policing) stated:

> *"Having considered your original e-mail correspondence and following consultation with operational colleagues, both within roads policing and police vehicle recovery, the NPCC view is that improving the safety of those integral to roadside rescue and recovery activity on our roads, is in line with our national strategy and something we would support, specifically:*
>
> - *We would welcome improved visual indications of recovery work in progress*
> - *We are not minded to state red flashing lights are the preserve of the police*
> - *We would seek a common minimum standard and industry guidelines concerning use of such lights*
>
> *The purpose of any change must be to improve roads safety.*
>
> *I have not looked into the safety record of roadside recovery agents and trust that you will provide evidence of the requirement for change in your update to the APPG."*

3.2.6 Highways England's current position

Separate from the stakeholder consultation exercise, a current position statement[4] was provided by Highways England:

> *"Given the evidence available to us we support the use of red lights by traffic officers for live lane incidents on our network. We do not expect recovery operatives to attend live lane incidents on our network without the support of a Traffic or Police Officer. Therefore, we are not currently supportive of any relaxation of the lighting regulations that could result in wide spread use of red lights on our network which could dilute their effectiveness."*

Supplementary to this statement, if a Highways England regional operating centre (ROC) is made aware of a break down in live lane, a Traffic Officer will attend. If that resource is not available, the ROC will notify the local police force and ask that they help.

3.3 Important considerations should red warning lamps be implemented

A virtual workshop was held, of TRL project team staff, supported by ad-hoc conversations, to consider what other legitimate reasons there might be for vehicles (other than those involved with breakdown and recovery activities) to operate on the roadside and the broader effects of red flashing lamps on those additional purposes. The workshop identified:

- A range of vehicle types which might be operating at slower speeds (i.e. below normal traffic speeds for the carriageway)

[4] Highways England. 17/06/2020. Smart Motorways Stocktake, Action 18 – Use of Red Flashing Lights.

- Types of operation, e.g. Slow / Stop-Go / Static
- Legal lighting requirements, specific marking requirements and permitted additional lighting and signing

Examples of other vehicles (not necessarily defined by regulations) operating at slower speeds, or potentially stopping on or alongside the carriageway are given in Table 2.

Table 2: Other vehicle and operation types

Vehicle type	Operation	Current provision / requirements
Home delivery vehicles	Travel at normal road speed, able to select stopping location	Hazard warning lamps may show that the vehicle is a temporary obstruction
Electric milk floats	Travel at slower speeds, able to select stopping location	Required to display flashing amber beacons if travelling slowly, if a maximum speed of 25 mph (40 km/h) or less MUST use a beacon
Post office collection	Travel at normal road speed, able to select stopping location	Hazard warning lamps may show that the vehicle is a temporary obstruction. Typically have conspicuous rear chevron markings
Farm equipment	Travel at a range of speeds	Required to display flashing amber beacons if travelling slowly, if a maximum speed of 25 mph (40 km/h) or less MUST use a beacon
Salt spreader, snow plough	Travel at normal road speed, will not stop	Typically travelling at or near normal road speeds, conspicuous markings and lighting
Abnormal loads	Travel at a range of speeds	Specific marking and escort requirements
Maintenance vehicles (e.g. road sweepers, hedge cutting)	Travel at slow speeds when operating	Required to display flashing amber beacons if travelling slowly. Permitted to display additional signing
Temporary Traffic Management vehicles	Travel at a range of speeds, may stop in or adjacent to the carriageway	Specific marking requirements and permitted additional lighting and signing
Emergency vehicles, Traffic Officers	Will stop wherever necessary, may deliberately obstruct live lanes	Have high conspicuity markings (including full retroreflective rear chevrons) and are permitted to display additional lighting

It was considered that the Temporary Traffic Management (TTM) vehicles were the only vehicle type where the use of red flashing lamps by road recovery might cause some confusion as these vehicles routinely stop in live lanes on dual carriageways where there is no hard shoulder, so there is potential for drivers to misunderstand their location. However, TTM vehicles are often preceded by temporary signs or electronic Variable Signs and Signals (VSS), typically have conspicuous markings and are permitted to display additional signs and lighting. Also, installation and removal of TTM is mainly carried out when traffic flow is low.

However, it is important to review some of aspects that were discussed with industry stakeholders during the consultation phase, and consider whether there might be longer-term implications of any change to the regulations to permit the display of red flashing lamps by the recovery industry.

3.3.1 Consequences for emergency services that use red lamps

Although the industry respondents interviewed believed that there would be a low impact on emergency services from the display of red flashing lamps by recovery vehicles, there might be adverse implications should those lamps be displayed in non-live lane situations. Industry respondents also identified that there is risk of dilution if red lamps are-over-used, potentially causing confusion to approaching drivers.

During the House of Commons debate (HC Deb 23 July 2019) on the use of red lamps there appeared to be some difference of opinion between those speaking in the debate on where it was intended that recovery vehicles would use rear red flashing lamps.

Sir Mike Penning MP stated that:

> "*They just want to be treated exactly the same as any other person working for the Government on the roadside."*

Whilst Tracey Crouch MP said that:

> *"Highways England vehicles have recently joined the fire service in being exempt from these regulations … they are permitted to use red lights in their regulation of traffic around accidents and other road incidents."*

And that:

> *"The roadside recovery industry is not calling for the use of red lights in live carriageways … It is specifically asking for the use of red lights while stationary, attending a vehicle"*.

If the Highway England's Traffic Officers are used as an example of where vehicles are permitted to display red lamps, it is important to note that Traffic Officer procedures (Highways England, 2020) (Appendix D) identify those locations where red lamps (in conjunction with amber lamps) can be used, including:

> *"Permitted usage on TOV*[5]

- *Stationary whilst dealing with an incident in a live lane.*

[5] Traffic Officer Vehicle

- *While setting out or removing ETM[6], including reversing, or if the TOV itself is used as part of live lane ETM.*
- *Stationary on a hard shoulder where hard shoulder abuse is a known issue.*
- *Moving onto a place of relative safety, such as a hard shoulder. Once on the place of relative safety rear reds will normally be extinguished."*

However, it should be noted that Traffic Officer procedures state that:

> *"To obtain the maximum protection from the warning lights it is essential that traffic officers (TOs) operate them in a proper and consistent manner."*
>
> *"Any warning light deviation is to be reported to the Regional Control Centre (RCC) as soon as practicable. The RCC are to note the deviation on the relevant incident log, or if necessary create a log. RCC are to inform the team manager for their information and any action they deem necessary."*
>
> (Highways England, 2020)

This is an Important point as, should the recovery industry follow different guidance (and use red lamps while stationary) and procedures to the Traffic Officers, this could introduce confusion for approaching drivers, and would be against the principle that the same lighting displayed colour on vehicles should require drivers to respond similarly in all circumstances.

Non-academic respondents (Section 3.2.4.2) commented that the primary use of amber lamps should be for wide or slow-moving vehicles. This would suggest that, should the recovery industry be permitted to use red lamps, then all other stationary vehicles should be similarly permitted to display red lamps.

3.3.2 'Dilution' effect

There were several comments made on the overuse of amber lamps, such as the misuse of lamps and so the unclear message that amber lamps portray. Non-academic respondents commented that amber lamps should be for wide or slow-moving vehicles but that recovery vehicles currently use amber lamps when stationary. However, it is important to recognise, as given in Table 2, that there are many other vehicles, such as roadworks vehicles and equipment, which display amber lamps and that are likely be stationary for considerable time. These vehicles and works equipment are likely to be either of the live carriageway or within closures i.e. similar circumstances to recovery vehicles operating on the hard shoulder, in an emergency refuge or within a lane closure that has been established by police or Traffic Officers.

3.3.3 Working practices

The industry was unable to provide evidence relating to the circumstances surrounding incidents that road recovery vehicles have been involved in. In addition to any implementation of red warning lamps (the focus of this report) there might be changes possible to technicians working practices that could reduce their exposure to risk from

[6] Emergency Traffic Management; signs and cones used to, for example, close live lanes

collisions with approaching and passing traffic. These might include reviewing current work procedures and compliance with them (SURVIVE, 2018) to ensure that risk is minimised and ensuring that technicians are reminded to continue to take care when near live lanes, for example when returning to the offside of their vehicle when on a hard shoulder to access the vehicle, or not undertaking any unnecessary activities while on the offside of the vehicle. Chandler and Bunn (2019) reviewed fatality rates for incident responders in the USA. One-hundred and six cases of tow truck operators being killed or severely injured (2002-2017) were identified and 41 investigation documents examined. Two major event types were identified, which accounted for 9 in 10 of the cases identified. These were 'struck-by' incidents (primarily injuries resulting from contact with traffic, rolling vehicles and equipment or other non-motorized objects) and 'caught-in or -between' incidents (primarily injuries resulting from being pinned beneath and between vehicles and being caught in moving parts). Chandler and Bunn (2019) concluded that the towing industry should provide initial and refresher safety training on vehicle loading and unloading, defensive techniques when exposed to traffic on roadways, and proper wheel chocking and braking procedures. It is not known how towing industry training in the USA compares with that in the UK; however, any implementation of red warning lamps (along with the training it will involve – see Section 6.2.1) should not be undertaken in isolation.

One relevant training need might be, as identified by Helman and Palmer (2010), operatives should be mindful of glare effects from warning lighting, which can reduce drivers' detection of workers near the vehicle. Helman and Palmer (2010) identified several aspects relating to lighting:

> *"Insufficient recognition of camouflage effect with themselves and their vehicle, light flooding' at incident scenes causing glare to drivers, and a general belief amongst road workers that their own conspicuity is not important (so long as something attracts the drivers' attention):*
>
> - *Indeed it was not uncommon for road workers to believe that by being near their vehicle the light helped to illuminate them, rather than masking them.*
>
> *It was a strong recurrent theme for road workers to feel that their safety was heavily reliant on the visibility of their vehicle:*
>
> - *This lead to road workers desiring what they perceived as an 'upgrade' in lighting on the vehicle, i.e. if currently had amber then add red lights, if currently had red lights then add blue lights."*
>
> Helman and Palmer (2010)

3.3.4 Glare

Disability and discomfort glare were discussed extensively in Sections 2.2 and 2.3 and should be considered in the context of how additional lighting might be added to road recovery vehicles. If red lamps were to be used in addition to the existing amber lamps, an increase in discomfort or disability glare could occur. Should, as industry stakeholders have suggested, red lamps be permitted only when their vehicles are stationary (also potentially when arriving or leaving an incident location, when moving into a live lane), there would need to be consideration of how lighting installations would be designed, such as:

- Would amber and red be displayed simultaneously? If so, will the light intensity be suitable for conspicuity without causing glare effects?
- If red and amber are displayed alternately, will there be a sufficient 'off' period to facilitate approaching drivers identifying pedestrians adjacent to the recovery vehicle?
- If red is not be displayed (whether due to location or the vehicle being in motion), will the light intensity be suitable?

3.3.5 Conspicuity issues

Visibility and conspicuity issues should also be considered in any implementation. It should be remembered that having red warning lamps, should they be implemented, will not guarantee that road recovery vehicles and technicians will be seen or understood by approaching motorists.

'Visibility and 'conspicuity' are terms which are often used interchangeably but have distinct meanings.

Helman et al (2012) quote Lesley (1995, cited in Langham & Moberly, 2003) defining conspicuity as the extent to which an object stands out from its surroundings, with visibility being defined as the ease with which an object can be detected when an observer is aware of its location.

For drivers approaching incident such as recovery of a broken-down vehicle:

- If a driver is directed to look in the direction of the recovery vehicle and can detect it, it is visible.
- If a driver is directed to look for a recovery vehicle, but not told where it is, that is search conspicuity.
- If elements of the recovery vehicle grab the driver's attention, that is attention conspicuity.

A further development of this progression is cognitive conspicuity, which can be thought of as referring to the extent to which an object is expected by an observer (Helman, Weare, Palmer, & Fernandez-Medina, 2012). That expectation could extend to include the presence of pedestrians on, or adjacent to, the carriageway and potentially to differentiation between an obstructed live lane and an incident off the carriageway.

Drivers approaching breakdown and recovery operations must identify them, understand what they are seeing and the action required of them, and have sufficient time to take any avoiding action that is required (potentially steering around the incident, or stopping). This process was described as 'behaviour zones' by Morris (2009) in previous work by TRL relating to drivers encountering abnormal loads. As such loads are often travelling slowly relative to normal traffic speeds, they provide a valuable comparison for drivers (Triggs & Harris, 1982) approaching recovery operations. The three upstream zones identified are:

1. Hazard perception and reaction time – 3 seconds (Probst, 1985; Triggs & Harris, 1982).
2. Time from deciding to change (Probst, 1985) lanes to executing a lane change – 5 seconds (Probst, 1985; Finnegan & Green, 1960; Salvucci & Liu, 2002; Henning, Georgon,

Wunn & Krems, 2008) Time to change lanes – 5 seconds (Salvucci & Liu, 2002; Henning, Georgon, Wunn & Krems, 2008).

3. Time to stabilise after lane change – 5 seconds (Salvucci & Liu, 2002).

Using elements that had already been studied, a driver behaviour model was outlined, see Figure 1.

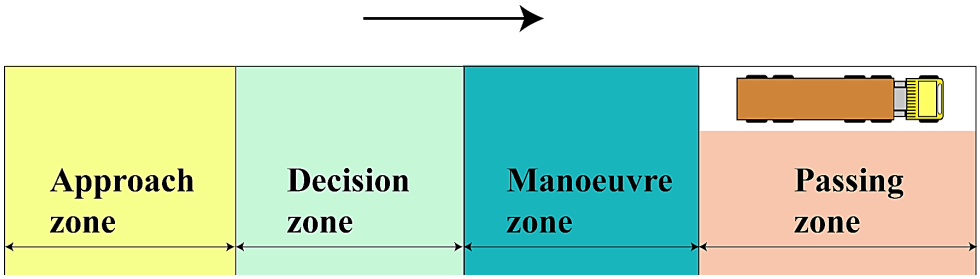

Figure 1: Driver behaviour model, showing the four zones identified by (Morris, 2009)

For the purposes of this project, the first three zones are important (Morris, 2009), with time values identified from existing research:

Approach zone – 3 seconds; the approach zone is where the driver detects the presence of "something" in, or adjacent to, their planned trajectory. In this zone, they will have time to react and process that there is a hazard that will need more attention.

Decision zone – 5 seconds; in the decision zone the driver will have processed that there is a hazard and will have time to decide on any avoiding course of action. This may also include drivers performing the necessary safety checks before executing any manoeuvres.

Manoeuvre zone – 5 seconds; the manoeuvre zone allows time for the driver to execute the course of action decided upon in the decision zone. This also includes a "stabilisation" distance to allow for exiting any manoeuvre safely. Once stabilised, it is assumed that a driver's workload will be back to normal.

The approach zones are described in terms of time rather than distance; however the drivers of vehicles travelling faster may require additional time to identify, understand and react to the lane closure ahead (due to the higher task demand with higher speeds) (Fuller, 2005). Also, if a vehicle is travelling faster it will require a longer time to stop should the driver decide to do so.

However, these approach and decision zones rely on the approaching driver having an unobstructed line of sight to the recovery vehicle, understanding what is seen, then taking appropriate action. This sequence introduces several opportunities where warning lamps may not provide the anticipated benefits, for example:

- The road recovery vehicle's lamps are not visible to an approaching driver; this might occur for several reasons, such as:
    - An additional vehicle ahead of the approaching driver, obstructing view.
    - The road recovery vehicle is positioned ahead (downstream) of the casualty vehicle and that vehicle obstructs view of the lamps.

    - Road geometry (including a bend or crest), combined with roadside infrastructure or foliage, prevents direct view.
- The approaching driver may not recognise the difference in lamp colour. This might be as a result of colour vision deficiency (stated by Tracey Crouch MP, 23 July 2019, as 1 in 12 men and 1 in 200 women).
- The approaching driver may see the warning lamps and identify the difference in light colour, but not understand the intended distinction of meaning.
- The approaching driver may see the lamps, identify the difference in light colour, and understand the intended distinction of meaning, but not estimate correctly the distance to, or location, of the incident.

3.3.5.1 Expectation

'Cognitive' conspicuity, the extent to which an object is expected by an observer (Helman, Weare, Palmer, & Fernandez-Medina, 2012), was mentioned earlier. This can relate to the level of expectation that approaching drivers have when viewing lamps and, for the recovery industry, as referring to drivers expecting to encounter breakdowns. Interviews with research participants, reported by Helman and Palmer (2010) found that most participants interviewed expected to see a broken-down vehicle when they saw vehicles at the side of the road with their flashing amber lamps on.

3.4 Results summary

Clear dissatisfaction with amber lamps for recovery vehicles was expressed by those respondents who commented, due to the misuse and overuse in different industries, alongside a lack of differentiation that an amber lamp portrays between a moving vehicle and a stationary vehicle. In general, respondents believe that red lamps will provide an enhanced level of safety by making approaching drivers more aware of stationary recovery vehicles, and by helping them respond with appropriate caution in their driving.

Respondents believe strongly that only recovery and breakdown vehicles that are attending a breakdown should be allowed to use red lamps. Most respondents believe red lamps should only be operated when the vehicle is stationary and at a breakdown, however some believe this should extend to include the recovery process (approach to, and removal from, the incident location).

Many respondents believe specific road types, time of day or weather conditions should not be defined as part of the regulations for use of red lamps. Instead, respondents tended to say that the use of red lamps should depend on risk, and that drivers should receive training in the appropriate use of red lamps to allow them to undertake dynamic risk assessments once at the scene of a breakdown.

If the use of red lamps is to be permitted, many aspects need be considered. These include glare, the dilution of effectiveness of red warning light if overused, working practices and training, and conspicuity issues. In addition, it should be noted that Highways England or the police should be able to provide lane closure support during non-motorway live lane breakdowns, and the police for breakdowns on non-Strategic high-speed dual carriageways.

If this support can be provided, there would be no requirement for attending road recovery vehicles to display rear facing red flashing lights at those incidents.

4 Media trawl

This section describes the method and results from the media trawl. The main purpose of the media trawl was to supplement the literature review, by seeing if searching social media platforms highlighted any additional relevant literature that had not already been captured. There was also an interest in gauging public opinion of the use of red lamps on recovery vehicles.

In addition, this task looked at whether any relevant cases of fatalities of serious injuries to road vehicle recovery operators could be identified by performing an internet search.

4.1 Method

4.1.1 Twitter search

The main social media platform searched was Twitter. A Premium Search Application Programming Interface (API) was purchased in order to search and analyse tweets from the whole of Twitter's archives.

The search for relevant tweets was carried out in the statistical programming software R using the following search terms, which were slightly refined from those used in from the main literature review in order to avoid having to use any wildcards:

- ("recovery operator" OR "recovery operation" OR "recovery operative" OR "emergency vehicle" OR "work vehicle") AND
- (light OR lighting OR "rear light" OR warning) AND
- (behave OR behaviour OR "live lane" OR visibility OR compliance).

The search was restricted to tweets that were created between 2010 and 2020 inclusive, in line with the timeframe used in the literature review. The results from this search were processed and a summary spreadsheet of tweets was produced, containing the following information for each tweet:

- Content of the tweet.
- Date and time it was created.
- ID and screen name of the user who created it.
- How many followers and friends the user has, and when their account was created.
- Whether or not the tweet was a quote/retweet.
- How many times the tweet was favourited, retweeted, quoted and replied to.
- Lists of any hashtags or URLs used in the tweet.

In addition to this, a summary table of the hashtags that were used across all the tweets was compiled.

4.1.2 YouTube search

Alongside the Twitter search, a smaller scale search was performed on YouTube, to identify any video content that could be relevant to the purpose of the research. Initially, this was done using the same set of terms that were used to search Twitter. However, this did not identify any content that was considered relevant. Of the videos that were returned, the focus was on the technology behind the lamps that are fitted to recovery vehicles, rather than the impact on conspicuity and road safety, or comparisons between different choices of light colour.

A second search was subsequently carried out using a much simpler set of search terms:

- “recovery vehicle” AND “red light”.

This returned one video that was relevant to the aims of the research. This is described in more detail in the results below.

4.1.3 Internet search

The aim of this search was to pick out any cases of fatalities or serious injuries to road vehicle recovery operators that had been reported in the media in recent years, in particular those where the conspicuity of the recovery vehicle was a contributory factor. To do this, the following search terms were entered into Google:

- accident AND
- "hard shoulder" AND
- ("recovery vehicle" OR “emergency vehicle”) AND
- (light OR lighting OR “rear light”).

4.2 Results summary

4.2.1 Twitter search

The Twitter search was carried out on 24th August 2020, and returned 134 tweets from Twitter’s archives, dated between 28th August 2010 and 19th March 2020. However, in practice there were only 13 unique tweets, while the other 121 tweets were either a copy of an original tweet posted by the same user or were a retweet.

Of the 13 unique tweets that were returned, eight were either clearly irrelevant to the purpose of this research, or contained a broken or outdated link, and so could not be properly evaluated.

The remaining five tweets were analysed in more detail by following the links contained in each tweet. Two of them were related to using blue LED lights to enhance the visibility of emergency vehicles, and so were considered to not be of relevance to this research, where the focus is on using red lamps. Another link was from a product manufacturer, and so was also discounted.

The first of the remaining two tweets linked to the website of Ambulance Visibility, a research organisation in Australia whose research focus is on vehicle conspicuity, livery, high-visibility

markings and warning lights (Ambulance Visibility, 2020). However, while the website does contain a list of research papers in the area of warning lamps, the vast majority of these were published before 2010, and therefore fall outside the scope of this study. There was one paper from 2012 that was of some relevance (Fischer et al., 2012) however its focus was on creating a way to measure conspicuity quantifiably, rather than comparing levels of conspicuity between different types of warning lamps.

The other tweet linked to the website of Responder Safety, an American organisation that serves as an informal advisory panel, seeking to help reduce fatalities and injuries among Emergency Responders in the country. Among their research papers is a review of agencies that have adopted new lighting and conspicuity technologies (Carrick, 2018). Regarding the choice of lighting, the report recommended that emergency vehicles should be equipped with both red and blue lights, as red lights are the most visible in daylight, but blue lights are the most visible during the night, and in fog or smoke conditions. The focus of this research (on blue and red lighting used in combination) was thus the same as the Carrick and Washburn (2012) reference identified in the literature review. It is not clear why this more recent reference was missed in the search of literature; it is possible that the publisher (Emergency Safety Responder Institute) is not one that is typically included in scientific databases.

4.2.2 YouTube search

The YouTube video (APPG, 2019) featured contributions from members of the APPG, expressing their support behind the 'Red Lights for Recovery Vehicles' campaign, part of the Campaign for Safer Roadside Rescue & Recovery (APPG, 2020). Reasons given by the APPG include:

- 'Red light means danger', and 'Anything that highlights danger is to be welcomed'.
- 'Red lights are proven to be that much safer, that people detect them earlier and move out of the danger zone'.
- 'It's really important for drivers to be able to immediately be alerted to a potential hazard'.

Thus, this video is essentially a summary statement of the known position of the APPG on the issue of red lamps on recovery vehicles.

4.2.3 Internet search

This search identified one relevant result from the website of the UK law firm Royds Withy King (Jones, 2017). The article references two collisions in 2017, one where a recovery driver was killed on the M25 by an articulated lorry, and another where a driver suffered a serious leg injury after being trapped in a collision with a 4x4. It then goes on to argue that the use of amber lights on recovery vehicles puts their drivers more at risk than those operating emergency vehicles which have flashing blue and red warning lights fitted. However, the article does not provide any more information about the nature of the collisions or mention a lack of conspicuity as being a cause of the collision. Instead, it is simply implied that this was the case.

5 Summary of findings from Work Package 1

The aim of this Work Package 1 was to undertake a review of evidence to inform consideration of the use of red lamps on road recovery vehicles. A literature review, stakeholder engagement exercise, and media trawl were completed. In this section the findings from all these activities are summarised and then recommendations are made.

5.1 Summary of findings

This research built on a previous literature review (and simulator research) undertaken by Diels et al. (2009), which was focused on the use of red lamps on Highways England's Traffic Officer vehicles. That earlier work concluded that there was little conspicuity or visibility benefit to using red lamps, but due to the inherent association drivers have between 'red' and 'danger' there would be an advantage to Traffic Officer vehicles using red lamps while operating in a live lane.

Taken as a whole, the findings from the more recent literature and social media content uncovered in this report provides little in the way of *conclusive* evidence that red lamps *should or should not* be used on recovery vehicles. In terms of the impact lighting colour has on visibility and conspicuity of the vehicle, there is almost no direct evidence relating to the use of red lamps versus other colours, although the basic physics at play (Rayleigh and Mie scattering process) does suggest that red will 'hold its colour' at longer distances. There is little work in the UK context that is relevant since Diels et al. (2009). Work from other countries and from laboratory studies does suggest that on balance, red lighting will produce less discomfort glare than some other colours at the same intensity (notably blue – Bullough et al., 2019). Lighting colour by itself does not appear to alter the detectability of people in the area around lit vehicles, with light intensity being the main factor driving this 'disability glare' effect. Some work does find an impact of different colours on behaviour, but again this has not looked specifically at 'red versus others', and much of it has been done in different legislative conditions to those in the UK; one example is the work of Carrick and Washburn (2012) which looked at blue and red light combined (versus amber), and in the context of Florida's 'move over' law.

The one thing that does seem to come through clearly in the literature is that drivers have an established understanding of the fact that the colour red means 'danger' and that 'slow down, prepare to stop or stop' are compatible behavioural responses.

Feedback from stakeholders broadly seems to suggest two things. First, stakeholders seem to agree that the use of red lamps by road recovery vehicles is acceptable, if undertaken with care and in line with proper risk assessments at the scene (for example avoiding use if an emergency vehicle is present, as this may confuse drivers); the considerations discussed in Section 3.3. will help to ensure that implementation is done with care. Second, it is clear from academics working in vision sciences and in the applied setting under investigation here that there is an urgent need for properly controlled research to inform implementation. There has simply not been the detailed research required, addressing the specific research questions here, in the last two decades; given the proliferation of LED lighting with its different characteristics (Bullough et al., 2019) this research gap should be closed.

6 Initial Regulatory impact assessment

Title: Use of red warning lamps by recovery vehicles **IA No:** **RPC Reference No:** **Lead department or agency:** **Other departments or agencies:**	**Impact Assessment** **Date: 23/09/2020** **Stage: Option recommendation** **Source of intervention: Domestic** **Type of measure: Secondary legislation**

Cost of Preferred (or more likely) Option (in 2019 prices)			
Total Net Present Social Value --	**Business Net Present Value** -£132,065	**Net cost to business per year** £15,343	**Business Impact Target Status** Qualifying provision

What is the problem under consideration? Why is government action or intervention necessary?

Roadside recovery operations are exposed to traffic collision risks. Unlike emergency service vehicles permitted to use red flashing warning lamps, roadside operators can currently only use amber. The use of red flashing lamps by roadside operators has been suggested as a protection measure. However, there were concerns that red flashing lamps could become overused and cause a proliferation of the use of other lamps such as blue. These could dilute the benefit of such use by those currently permitted. There are also concerns over whether allowing recovery operators to use red flashing lamps would present benefits or disbenefits.

What are the policy objectives of the action or intervention and the intended effects?

The use of red flashing lamps by roadside operators has been debated in Parliament to make recovery work safer. Currently, vehicles at roadside attendance can use only amber flashing lamps to warn upcoming traffic. Red lamps have been proposed as a stronger signal of danger to drivers approaching from behind. The primary objective of the study is to carry out a review of available evidence, in the context of the existing regulations on red flashing lamps, to determine whether a more flexible approach might be appropriate. The study included a literature review, media trawl and a stakeholder engagement exercise conducted by TRL. The study concluded that red lamps have the potential to provide safety benefits for roadside recovery operators. Recommendations about the implementation of the use of red lamps by roadside operators were also provided.

What policy options have been considered, including any alternatives to regulation? Please justify preferred option (further details in Evidence Base)

1. **Do Nothing**. Opportunities to appraise ways to better protect the roadside recovery industry are missed.
2. Allow **rear facing red flashing** lamps on **all roads** (non-live running lane) when road recovery vehicle is stationary.
3. Allow **rear facing red flashing** lamps on **all motorways** (non-live running lane) when road recovery vehicle is stationary.
4. Allow **red warning beacons** with 360 degrees on **all roads** (non-live running lane) when road recovery vehicle is stationary.
5. Allow **red warning beacons** with 360 degrees on **all motorways** (non-live running lane) when road recovery vehicle is stationary.

Option 2 is recommended, as non-motorways also present danger to operators. Moreover, the purpose of flashing lamps is to warn upcoming traffic, hence rear facing red flashing lamps are preferred. The cost is the same across options two to five.

Will the policy be reviewed? It **will/will not** be reviewed. **If applicable, set review date: Month/Year**

Does implementation go beyond minimum EU requirements?		N/A		
Is this measure likely to impact on international trade and investment?		No		
Are any of these organisations in scope?	**Micro**Yes	**Small**Yes	**Medium**Yes	**Large**Yes
What is the CO_2 equivalent change in greenhouse gas emissions? (Million tonnes CO_2 equivalent)		**Traded:**	**Non-traded:**	

I have read the Impact Assessment and I am satisfied that, given the available evidence, it represents a reasonable view of the likely costs, benefits and impact of the leading options.

Signed by the responsible SELECT SIGNATORY: ..... Date: .....

6.1 Evidence base

This section briefly summarises the evidence base for the assessment of costs and benefits. The detailed discussion of evidence can be found in earlier sections of this report.

6.1.1 Problem under consideration

The problem under consideration is whether a more flexible approach to rear warning lamps might be appropriate for safety of the roadside recovery industry. Roadside recovery operators are integral to the safety of stranded and at-risk motorists. Their work carries risk and it is therefore important that they have the right set of tools to keep themselves and other motorists safe. Over the years, there have been fatal collisions involving roadside recovery operators as reported by media and the industry. A range of potential data sources to help quantify the scale of the issue is explored in Section 6.3.

The use of red flashing lamps was suggested within the roadside recovery industry as a possible solution to help drivers of vehicles approaching a recovery vehicle to better detect and understand the situation.

Without government intervention and changes in legislation, roadside recovery operators would be excluded from considering the use of red flashing lamps. If there is enough evidence that demonstrates and justifies such use by specific vehicles, the government can instigate secondary legislation to allow such use under certain circumstances. This Impact Assessment takes into account the benefits and costs of the range of options.

6.1.2 Rationale for intervention

There are potential benefits and disbenefits related to allowing the use of red flashing lamps by recovery operators. Potentially, there are benefits associated with changes to the conspicuity of roadside operators and from giving appropriate warning to oncoming drivers to avoid excessive speed and ultimately collisions with roadside operators. However, there are potential disbenefits associated with the possible proliferation of red flashing lamps and possible dilution of their effectiveness in signalling the danger present, particularly if they conflict with warnings given by other users of red lamps.

6.1.3 Policy objective

The policy objective is to enhance the safety of roadside operators and the safety of all road users more generally. To this end, the use of red lamps by recovery vehicles under a range of circumstances is considered.

Another objective of the review is to identify the business impacts the use of red flashing lamps would bring. These highlight the need for roadside operators to understand any amended guidelines applicable to the use of warning lamps at attendance. The aim of any recommendations from this impact assessment is also to impose the minimum regulatory costs required to enhance safety for roadside operators attending incidents.

6.1.4 Description of options considered

Option 1 – Recovery vehicles remain unable to display red flashing lamps.

Option 2 – Allow **rear facing red flashing** lamps on **all roads** (non-live running lane) when road recovery vehicle is stationary.

Option 3 – Allow **rear facing red flashing** lamps on **all motorways** (non-live running lane) when road recovery vehicle is stationary.

Option 4 – Allow **red warning beacons** with 360 degrees on **all roads** (non-live running lane) when road recovery vehicle is stationary.

Option 5 – Allow **red warning beacons** with 360 degrees on **all motorways** (non-live running lane) when road recovery vehicle is stationary.

6.2 Monetised and non-monetised costs of each option (including administrative burden)

6.2.1 Cost types

Option 1

There are no costs associated with option 1 as there would be no changes to the current requirements of recovery vehicles, other emergency vehicles and staff operating those vehicles. Option 1 is also the baseline against which options 2 to 5 are compared.

Do Something (Options 2 to 5)

All the Do Something options involve changes to existing, or the creation of new, legislation. This impact assessment lays the general principles when considering the costs of such intervention and considers all costs as monetisable.

It is therefore important to note the two main types of costs relating to such interventions. The first arises due to the requirements themselves. If businesses are mandated to follow certain safety guidelines, the relevant costs of creating and sustaining that safety environment for customers and staff would need to be considered. Similarly, recovery vehicles being required to fit and install equipment enabling red warning lamps are a cost to businesses.

The second type of costs relates to the familiarisation and transition into a new regime. That would typically involve retraining of existing staff and extra training of new joiners. For instance, the fitting of red warning lamps capability itself would not fulfil a requirement to display them. Operators' know-how is part of the costs for which businesses are responsible.

As far as the options hereby considered are concerned, the first cost type is nil. This is because all of options 2 to 5 only propose to allow for the use of red warning lamps under various circumstances. These uses are currently not allowed according to regulations. Such allowance neither forces the fitment of relevant equipment onto recovery vehicles nor requires operators to deploy such capability. No businesses are forced to install red warning lamps.

6.2.2 Familiarisation costs

Nevertheless, there is a cost to considering and understanding the proposed regulations and the operation of deploying the newly allowed warning signals. Since the roadside recovery industry campaigned for the use of red warning lamps for safety, it is reasonable to expect a 100% uptake in familiarising with the regulatory options. This will therefore be a cost to the roadside recovery industry. As shown in the stakeholder engagement exercise, there are several suggested pre-requisites for the red warning lamps to be used.

The first suggestion is that the vehicle must be stationary or just about to arrive at or leave a scene. The second is that some options only permit the use of red warning lamps on certain road types. This further adds to the operational know-how requirement. It is therefore reasonable to expect the roadside industry to have to invest in training existing staff considering this new requirement. Roadside service providers would also need to add to their training curriculum for new joiners.

The starting point for modelling familiarisation costs is the amount of time required to train operating staff so that they understand the requirement. One stakeholder has helpfully provided the outline of a relevant training course concerning the use of red warning lamps. The level of knowledge and complexity suggest the time required to familiarise with rear facing red flashing lamps and red warning beacons (options 4 and 5) is similar. Moreover, we gathered from the stakeholder engagement exercise that the amount of training time required will also be similar across the range of locations allowed. A potential training course provider also did not differentiate among the required options. Options 2 to 5 are therefore taken to place the same level of training burden on recovery operators.

6.2.2.1 Training time

The stakeholder engagement exercise TRL conducted with the roadside recovery industry and consulting groups revealed some useful information. From the interviews, it appeared reasonable to expect new regulations to take industry participants, including technicians and inspectors, on average 15 minutes each of their productive time to familiarise with any proposed regulations.

6.2.2.2 Cost of time

The next consideration is the cost of time. We take the median wage of technicians (£29,867 per annum) and inspectors (£26,715 per annum) (Indeed, 2020). Given a typical 37-hour work week, this translates to £14.70 per productive hour. Going beyond 2020, this hourly rate is projected in line with Consumer Price Index (CPI) inflation forecasts by the Office for Budget Responsibility (2020) up to 2023 and then extended beyond at the same rate. The hourly rate profile is summarised below in Table 3:

Table 3: Projected hourly rate of roadside operators

2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
£14.70	£14.98	£15.28	£15.58	£15.89	£16.21	£16.53	£16.87	£17.20	£17.55

This is forecast to grow in accordance with the guidance outlined in the Treasury's Green Book (HM Treasury, 2018). Gross wage rates should be used in accounting for familiarisation costs. This is because tax and national insurance contributions made from employees' gross earnings are part of the output produced by the workforce. Were these proposed regulations not to come into force, the industry could spend the time in other productive activities.

6.2.2.3 Recovery workforce size

The estimation then reviews the size of the workforce. The AA, for instance, employs 6,313 operational employees as of 2020 (AA, 2020a). Applying AA's estimated market share of 40% in the UK (AA, 2020b), the UK roadside industry workforce is estimated to be at 15,783. Going forward, the same staff are not expected to need this familiarisation again. However, new joiners could be expected to undergo this training.

There is no available data on recovery industry staff turnover specifically. We therefore rely on the official employee turnover rates statistics (Office for National Statistics, 2019). The

'wholesale, retail and repair of vehicles' industry appears to match most closely the recovery industry. The corresponding turnover rate is 33% per annum. On top of that, it is recognised that not all this turnover would require training again on changing jobs. If they stay within the industry, skills would be transferable, and time would not have to be invested again in training on the use of red warning lamps. There is no available data on the split of those joining the industry and changing jobs within the industry. It appears reasonable, however, to assume that half of the turnover involves new operators.

In addition, the Department for Transport's Vehicle Licensing Statistics Table VEH0101 shows the year-on-year change in total vehicles in the UK average at 1.2% between 2018 and 2019 (Department for Transport, 2020). As the population is forecast to grow and as a result the number of cars, it appears reasonable to expect the recovery industry to grow within the standard, 10-year appraisal period in accordance with the Treasury's Green Book. This growth is therefore applied to the appraisal period of 2020-2029.

The impact of Covid-19 also needs to be considered. It is recognised that although vehicle registration decreased in quarter 1 of 2020, some have opted for car ownership to avoid public transport. The long-term assessment is therefore to not account for this fluctuation. The recovery workforce is therefore grown by the annual factor of 1.2% for 10 years based on the car ownership trends – extrapolating the existing vehicle registration growth rate. The turnover rate is then applied to the workforce from 2021 and they will be the forecast numbers of operators who would require training concerning the use of red warning lamps. The figures are summarised in Table 4 below.

Table 4: Number of UK roadside recovery operators who would require training

2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
15,783	2,635	2,667	2,699	2,731	2,764	2,797	2,831	2,865	2,899

6.2.2.4 Resulting costs

The resulting time cost is therefore a quarter of the hourly rate for each of the operators assumed to be economically productive elsewhere if not in training. All costs are re-based to 2019 prices in line with Green Book guidance. In so doing, GDP deflators forecasts only go up to 2023 and an extrapolation method similar to CPI inflation extension is applied. The rate of forecast GDP change between 2022 and 2023 is used in extrapolating to 2029. Whereas the cost for 2020 is regarded as transition costs, subsequent years involve only new joiners to undertake relevant training. Therefore, the time costs from 2021 to 2029 are treated as annual costs. Table 5 below presents the resulting costs.

Table 5: Training costs in 2019 prices

2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
£56,853	£9,480	£9,577	£9,686	£9,795	£9,906	£10,019	£10,132	£10,247	£10,363

The recommended discount rate is 3.5% per annum for the 10-year appraisal period as per standard. Table 6 below presents these costs discounted back to 2020 using the 3.5% discount rate.

Table 6: Training costs discounted to 2020 in 2019 prices

2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
£56,853	£9,159	£8,941	£8,736	£8,536	£8,341	£8,150	£7,964	£7,782	£7,604

The Present Value Cost (PVC) is therefore calculated as £132,065, discounted to 2020 and in 2019 prices. It is further noted that there is a business impact as a result of this policy. Therefore, the costs are also calculated as part of the Business Net Present Value (Business NPV). Furthermore, since all roadside recovery operators would need to know about this proposed change in the regulations, this impact is direct. Therefore, the costs would also be part of the Equivalent Annual Net Direct Costs and Benefits (EANDCB). Section 6.3 will discuss these in turn and arrive at the Business Impact Target (BIT).

6.3 Monetised and non-monetised benefits of each option (including administrative burden)

6.3.1 Benefit sources

Option 1

There are no benefits associated with option 1 as there would be no changes to the level of safety for recovery vehicles, other emergency vehicles and staff operating those vehicles. Option 1 is also the baseline against which options 2 to 5 are compared.

Do Something (Options 2 to 5)

The rationale for intervention concerns 1) the improved safety of roadside recovery operators and 2) that of other road users. Depending on the availability of data and evidence, these safety benefits can be considered separately or collectively. Part of the roadside industry's purpose is to assist stranded motorists in the event of a vehicle breakdown. If operators' safety improves, it is likely that the safety of road users would also be improved. This section explores whether there is enough evidence available on this issue.

6.3.1.1 Department for Transport's Road Accident Statistics

The Department for Transport publishes road accident statistics since 1979 for Great Britain and provides details at various levels. These include the severity, vehicle type, region, road type, contributory factors and casualty age. The Reported Road Casualties Great Britain Annual Report summarises trends and how these data are categorised (Department for Transport, 2018). See Table 7 below for more detail.

Table 7: Road accident data by the Department for Transport

Road Accident Statistics (RAS) code	Coverage
RAS10	Accidents
RAS20	Drivers and vehicles involved
RAS30	Casualties
RAS40	Combined accidents, casualties, vehicles
RAS41	Former Strategic Framework for Road Safety outcome indicators
RAS50	Contributing factors
RAS51	Reported drink-driving
RAS54	Survey data on road activities
RAS55	Hospital admissions as a result of road accidents
RAS60	Accident and casualty costs

Published annually, these data provide a broad analytical basis for understanding the trend in road safety as well as the economic cost of collisions. Nevertheless, it is clear from the above that collisions involving roadside operators have not been flagged in the database. As a result, it is also impossible to draw conclusions based on these data whether red warning lamps could have avoided a number of these collisions from upcoming traffic.

This view was shared among stakeholders in the dedicated engagement exercise to gain insight into the knowledge that the industry, related charities and academics might have access to. But all the contacts who helpfully provided information regarding the use of red warning lamps stated that they were not aware of any data source that singles out casualties related to or arising from roadside operations.

6.3.1.2 STATS19

As most of the statistics mentioned in the Department's statistics come from STATS19, the benefits estimation effort then turned to the collisions reported to the police. STATS19 is a database compiled by the Department for Transport with input from local police forces. The data include accidents reported by or to the police regarding collision circumstances including vehicles involved, resulting casualties and contributory factors.

The vehicle and casualty types in STATS19 do not indicate recovery vehicles or operators. However, the enhanced vehicle data, based on matching Vehicle Registration Marks (VRMs) with DVLA database, includes 'recovery vehicle' as a body type. However, recovery vehicles may be coded as other vehicles types. Casualties are coded according to the vehicle they were an occupant of at the time of the collision (if the operator was outside their vehicle then they would be classified as pedestrians linked to the vehicle that hit them).

There also does not appear to be a system in place to specifically record whether the lack of warning lamps could be a contributory factor. The only contributory factors concerning lamps within the form are factor 202 'Defective lights or indicators' and factor 506 'Not displaying lights at night or in poor visibility'. Neither would have picked up incidents of interest if roadside operators did correctly use the lamps at their disposal.

To exhaust all avenues before coming to the conclusion that it is not feasible to attempt to quantify the benefit of allowing operators to use red warning lamps, we discuss the Road Accident In-Depth Studies (RAIDS) to understand whether relevant investigations might be of help.

6.3.1.3 Road Accident In-Depth Studies (RAIDS)

Created in 2012, RAIDS is a more detailed investigation than STATS19 on a subset of road collision cases. TRL works closely with police forces and medical staff to record extensive data. These include new information at the scene of road collisions and gather data from retrospective investigations of accident involved vehicles to evaluate their crashworthiness performance. This resource is used to understand the causes and consequences of road traffic collisions. It provides highly detailed evidence to help identify countermeasures that have the potential to reduce the number of deaths and injuries on the UK roads. Nevertheless, the RAIDS project does not contain sufficient data, rather it allows investigators to develop an in-depth understanding of the collision dynamics and other relevant circumstances.

6.3.1.4 Information provided by the recovery industry

One stakeholder representing a recovery provider said in the interview that there were seven incidents of road recovery vehicles being hit in the last 12 months. These were reported to have happened during daytime. This suggests such operations are dangerous, but it is difficult

to estimate the national picture based on this source. It is claimed, however, that if the use of red warning lamps could have avoided some of the accidents and not contributed to other potential danger, the benefits could be appropriately considered.

6.3.2 Health and Safety Executive's Reporting of Injuries, Diseases and Dangerous Occurrences Regulations (RIDDOR)

Despite the difficulty in such estimation, we researched the Health and Safety Executive's RIDDOR database and consulted the industry stakeholders on the usefulness of accessing relevant data. The database holds record of reported incidents at the workplace. Reportable incidents include the death of anyone from a work-related accident, specified injuries and over-seven-day incapacitation of a worker (Health and Safety Executive, 2020).

The consulted stakeholders in the recovery industry expressed that there were incidents related to roadside recovery operations that do not get recorded in RIDDOR. Such cases included road traffic collisions. Even though operators were at work, because collisions involved third parties, most likely vehicles which collided from behind, the incidents could be recorded via STATS19 rather than RIDDOR. The participants failed to recall the percentage splits of those incidents recorded via either channel. Without this estimate, it is unlikely the national picture of fatalities and injuries related to recovery operations could be appropriately projected. A review of publicly available RIDDOR data found that incidents involving roadside recovery technicians would be included in the "wholesale and retail trade; repair of motor vehicles and motorcycles" category. There was no further breakdown of industry categories, although type of incident included "struck by moving vehicle". However, the RIDDOR data did not differentiate between those incidents occurring on the public highway and those in other workplaces.

6.3.3 Qualitative assessment of benefits

All the above discussions point to the difficulty of attempting to quantify the baseline safety level of operators using amber warning lamps, let alone the potential benefits of being able to use red warning lamps. Nevertheless, the literature review earlier in this report explored the evidence relating to red warning lamps, which support the view that red is perceived by most people as related to 'danger' and the need to slow down or stop. This suggests that red lamps might work to some degree to enhance operators' safety.

The baseline option 1 of Do Nothing would not allow the use of red warning lamps. The warning lamps operators can use currently are amber.

6.3.4 Red 360-degree warning beacons versus rear red flashing lamps

Options 2 and 3 allow for rear facing red flashing lamps while options 4 and 5 allow for red warning beacons with 360 degrees coverage. Section 8 discussed the cost considerations and concluded that the familiarisation cost is identical across options 2 to 5 based on the amount of training time required.

In terms of benefits, the qualitative assessment of our stakeholder engagement exercise lends more support towards rear facing red flashing lamps. This is because the main danger recovery technicians face at breakdowns is from upcoming traffic. Stakeholders have

overwhelmingly indicated that recovery vehicles in motion (except possible on immediate approach and leaving a scene) should not use rear facing red flashing lamps. And those within the core recovery industry also highlighted the importance of only using rear facing amber flashing lamps when stationary. It therefore seems logical that the design of any new regulations focuses on warning the traffic from behind. This led to the assessment in favour of options 2 and 3.

6.3.5 All roads versus motorways

Evidence and stakeholders' views have not been perfectly aligned on the circumstances under which red warning lamps should be allowed. Some stakeholders emphasised on the importance of risk factors rather than specific locations. Others have expressed a need for clear guidance that should exclude low risk places such as car parks.

Industry participants and associations have highlighted the danger of many motorways and A-roads. They also underlined the differences in risk levels of different A-roads, which can run from single-digit (e.g. A3) to less strategic four-digit (e.g. A3013 which covers a 30 mile-per-hour high street). It is recognised that in less dangerous locations, red flashing lamps would not be appropriate. Nevertheless, restricting the use of red flashing lamps to motorways risks missing out on protecting operators in high-risk non-motorway locations at the national speed limit.

The impact assessment therefore suggests that roadside recovery operators can only use red flashing lamps in locations where amber flashing lamps are currently permitted. The option closest to this reasoning, from those suggested, is option 2. If this option is taken to implementation, the considerations such as glare, over-use, where and when to use and so-on need to be taken into account and potentially consulted on further.

6.3.6 Disbenefits assessment

The benefit assessment must be taken in conjunction with the potential disbenefits. These include overuse of warning lamps, glare and so-on. The stakeholder engagement exercise indicated the possibility of non-compliance on the implementation of the above options.

In case of proliferation, emergency workers might feel the need to distinguish themselves from roadside recovery vehicles. This could lead to more aggressive uses of warning lamps on the roads. We recognise that it is impossible to predict what would happen if the recovery industry is allowed to use red flashing lamps. It is harder still to quantify this potential disbenefit, but we acknowledge this potential disbenefit. Interviewees from police forces have helpfully set out how detailed guidance and an enforcement regime would benefit recovery workers and not compromise the warning signals police can use.

Industry participants further expanded on how the use of red warning lamps should be allowed. A proper enforcement system to ensure red warning lamps are used appropriately is key to the successful implementation of the recommended option. The Association of Vehicle Recovery Operators (AVRO) raised that red warning lamps should only be used on trunk roads and dual carriageways. This is due to the low speed limit on other road types and hence less need for a more intrusive colour that can also be overused.

Nevertheless, the recovery industry has commented on the importance of adequate training to ensure the correct lamps are displayed at the right time. There does not seem to be available data on existing non-compliance and resulting legal action against operators who fail to observe pertinent rules. It is hence difficult to estimate the compliance aspect that would arise from the implementation. Given the lack of current data, this impact assessment does not attempt to get into the wide array of possible scenarios about compliance and enforcement if red lamps are allowed.

6.4 Specific impacts tests

6.4.1 Statutory equality duties

We have considered whether statutorily protected groups would be impacted through the implementation of the Do Something options. It is concluded that the proposed changes would have no impact on these groups.

6.4.2 Economic impacts

The main specific group affected is the roadside recovery industry. Industry participants range from micro and small businesses to large corporations. The time required to understand the legal requirement is relatively brief. It is concluded that the impact will be small.

6.4.3 Environmental impacts

The energy consumption from the use of red flashing lamps is relatively small, and the policy is not expected to generate environmental concerns.

6.5 Summary (including preferred option)

This impact assessment exercise proposes to proceed with Option 2 (of the options suggested), to allow **rear facing red flashing lamps** on **all roads** (non-live running lane) when a road recovery vehicle is stationary. This comes at a net cost to business per year of £15,343 which is also referred to as the Equivalent Annual Net Direct Costs and Benefits (EANDCB). This is obtained by dividing the Business Net Present Value of £132,065 by the annuity factor. The latter is 8.6 for the appraisal period of 10 years.

The Business Impact Target (BIT), which concerns the economic impact of regulation on businesses, is calculated for the lesser of the expected duration of the current Parliament (2019-2024) and the period of regulatory changes being put in place. Therefore, the Business Impact Target (BIT) for this impact assessment is 5 times the net cost to business per year, or £76,713.

It is important to note that this impact assessment has not produced quantitative calculations of the potential safety benefits and disbenefits. The literature has explored the evidence relating to red warning lamps, supporting the view that red is perceived by most people as related to 'danger' and the need to slow down or stop. However, disbenefits could arise from overuse and proliferation of high-level warning lamps. If an appropriate regime is put in place, either mechanically to disallow the switching on of red flashing lamps whilst in motion (possibly over a certain speed) or through enforcement, benefits are likely to outweigh disbenefits.

We therefore opted to show the Business Net Present Value as a cost and the net cost to business per year, but not the Total Net Present Social Value. This recognises that the change in policy only needs to reduce injury marginally to 'break even'. For reference, the costs per fatality and serious injury based on 2018 prices and values were £2.0 million and £0.2 million respectively. Even if these figures were to be brought back to 2019 prices and 2020 values, preventing one single case of either casualty type would bring about a positive Total Net Present Social Value.

7 Recommendations

On balance, the evidence covered in all the activities in this report suggests that if red flashing lamps were used on recovery vehicles there would be no obvious disadvantages so long as, through careful implementation, disability glare, discomfort glare and operational confusion with emergency service vehicles were avoided.

Although red flashing lamps are unlikely to have a major impact on visibility and conspicuity, the fact that red is a colour associated with danger by most drivers may provide an advantage in terms of driver understanding of the behavioural response required (slow down, prepare to stop, or stop). The only scientific evidence identified related to that colour association and no new UK-based research relating to comparative trials of vehicle lamp colours was found.

Based on the evidence on light colour association and apparent stakeholder agreement regarding suitability of use, but the lack of evidence comparing lamp colour, the recommendations from this work are as follows:

1. An off-road comparative trial should be undertaken to gain understanding of how naïve participants perceive stationary vehicles displaying amber and amber and red warning lamps. The outcome of this trial can feed into implementation, including driver awareness campaigns.
2. Subject to the outcome from that trial, recovery vehicles should be allowed to use red flashing lamps in such a manner that their use does not cause confusion with current permitted use, e.g. Highways England Traffic Officers. Any implementation should be accompanied by:
    a. Dedicated stakeholder consultation with relevant industry representatives to focus on the procedures for implementation, including aspects such as: locations permitted (live lanes or off the carriageway), whether permitted only when stationary or when arriving/leaving, management of over-use, and avoidance of glare.
    b. A driver awareness campaign to educate the driving public on what to do when approaching and passing recovery vehicles displaying red lamps.
3. Over the longer term, research should be undertaken to establish the boundary conditions for detectability of vehicles and people around them, and driver understanding, when vehicles are displaying different lighting combinations. This research should focus on optimising the combinations of vehicle lighting and Personal Protective Equipment (PPE).

Of the five options communicated by the Department for Transport for consideration in the initial regulatory impact assessment, the report recommends proceeding with Option 2, to allow rear facing red flashing lamps on all roads (non-live running lane) when a road recovery vehicle is stationary. Such recommendation takes into consideration the potential benefits and disbenefits of having a red warning signal to alert upcoming traffic as well as the fact that operations on non-motorway A roads can also be dangerous to recovery operators and other road users. However, option 2 (non-live running lanes) does not reflect the industry's concerns regarding operations in live lanes on non-motorway high-speed dual carriageways.

8 References

Ambulance Visibility (2020). *Website* [online]. [Accessed August 2020]. Available from World Wide Web: http://ambulancevisibility.com/

Anderson GS and Plecas DB (2010). The science of warning lights. *The Journal of Criminal Justice Research*, 1(2).

APPG (2019). *Red Lights for Recovery Vehicles - A No-Brainer!* [online]. [Accessed August 2020]. Available from World Wide Web: https://www.youtube.com/watch?v=BAGNKSNEHmE

APPG (2020). *CSRRR website* [online]. [Accessed August 2020]. Available from World Wide Web: https://www.csrrr.co.uk/

APPG (2020). *Data on CSRRR website*. [online]. [Accessed August 2020]. Available from World Wide Web: https://www.csrrr.co.uk/campaign/data/

Arakawa Y (1953). Quantitative measurements of visual fields for colors: with a direct-current method. *American journal of ophthalmology*, 1594-1601.

Bullough J, Skinner N and Rea M (2019). *Impacts of flashing emergency lights and vehicle-mounted illumination on driver visibility and glare*. SAE Technical Paper 2019-01-0847. doi:10.4271/2019-01-0847

Carrick G and Washburn S (2012). *The Move Over Law Effect of Emergency Vehicle Lighting on Driver Compliance on Florida Freeways.* Transportation Research Record, 2281(1), 1-7

Carrick G and Washburn SJ (2018). *Study of Protecting Emergency Responders on the Highways and Operation of Emergency Vehicles.* Cumberland Valley Volunteer Firemen's Association – Emergency Responder Safety Institute.

Chandler, MD and Bunn, TL (2019). *Motor vehicle towing: an analysis of injuries in a high-risk yet understudied industry*. Journal of safety research, 71, pp.191-200.

Cook S, Quigley C and Clift L (2000). *Motor vehicle and pedal cycle conspicuity: part 1-vehicle mounted warning beacons. Summary report.* DfT Report; 9/33/13.

Deb H (2019). *Roadside Recovery Vehicles: Red Lights*. [online]. [Accessed August 2020]. Available from World Wide Web: https://hansard.parliament.uk/commons/2019-07-23/debates/6F0D4798-3D63-46D8-BC77-C94436CDA00F/RoadsideRecoveryVehiclesRedLights

Department for Transport (2018). *Reported Road Casualties Great Britain: 2018 – Annual Report* [online]. [Date accessed: 5 September 2020]. Available from:

https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/864873/rrcgb-2018-print-ready-version.pdf

Department for Transport (2020). *Vehicle Licensing Statistics: Table VEH0101* [online]. [Date accessed: 5 September 2020]. Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/896222/veh0101.ods

Diels C, Palmer M, Sterling T and Rillie T (2009). *Conspicuity of red lights on traffic officer vehicles (CPR1051)*. Crowthorne: Transport Research Laboratory.

ESRI (2018). *Study of protecting emergency responders on the highways and operation of emergency vehicles – A review of first responder agencies who have adopted emergency lighting and vehicle conspicuity technology.* Report by the Cumberland Valley Volunteer Firemen's Association – Emergency Responder Safety Institute (ESRI).

Finnegan, P., & Green, P. (1990). *The Time to Change Lanes: A Literature Review*. University of Michigan Transport Research Institute.

Fischer J, Krzmarzick A, Menon A and Shankwitz C (2012). *Performance Analysis of Squad Car Lighting, Retro-reflective Markings, and Paint Treatments to Improve Safety at Roadside Traffic Stops.* Intelligent Vehicles Laboratory, Department of Mechanical Engineering, University of Minnesota, Intelligent Transportation Systems Institute, Center for Transportation Studies, University of Minnesota: Minneapolis.

Fuller, R., 2005. Towards a general theory of driver behaviour. *Accident analysis & prevention*, 37(3), pp.461-472.

Gray J (2020). *Analysis of crashes involving first responder vehicles.* MSc Thesis, Embry-riddle Aeronautical University, Daytona Beach, Florida, United States of America.

Health and Safety Executive (2019). *Injuries - Last updated 10/19 [online]. [Date accessed: 27 October 2020].* Available from: https://www.hse.gov.uk/statistics/tables/index.htm#riddor

Health and Safety Executive (2020). *Types of reportable incidents [online]. [Date accessed: 2 October 2020].* Available from: https://www.hse.gov.uk/riddor/reportable-incidents.htm

HC Deb (23 July 2019). vol. 663, col. 523WH. Available at: https://hansard.parliament.uk/Commons/2019-07-23/debates/6F0D4798-3D63-46D8-BC77-C94436CDA00F/RoadsideRecoveryVehiclesRedLights (Accessed: 20 September 2020).

Helman, S & Palmer, M. (2010) *Road Worker Conspicuity Daytime & Night Time.* CPR1001. Crowthorne: Transport Research Laboratory.

Helman, S., Weare, A., Palmer, M., & Fernandez-Medina, K. (2012). *Literature review of interventions to improve the conspicuity of motorcyclists and help avoid 'looked but failed to see' accidents.* Published Project Report PPR638. Crowthorne: Transport Research Laboratory.

Henning, M., Georgeon, O., Wynn, T., & Krems, J. (2008). *Modelling Driver Behaviour in Order to Infer the Intention to Change Lanes*. In European Conference on Human Centred Design for Intelligent Transport Systems (pp. 113 - 120). Lyon, France: HUMANIST Publications.

Highways England (2020) *Highways England Traffic Officer Manual*

HM Treasury (2018). *The Green Book: central government guidance on appraisal and evaluation*. Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/685903/The_Green_Book.pdf

Howell B, Pigman J and Agent (2015). *Work Vehicle Warning Lights: Color Options and Effectiveness.* Kentucky Transportation Center.

Indeed (2020). *The AA Salaries in the United Kingdom* [online]. [Date accessed: 5 September 2020]. Available from: https://www.indeed.co.uk/cmp/The-Aa/salaries

Jones (2017). *We need to talk about roadside workers* [online]. [Accessed August 2020]. Available from World Wide Web: https://www.roydswithyking.com/need-talk-roadside-workers/

Langham, M., & Moberlerly, N. (2003). Pedestrian conspicuity research: a review. *Ergonomics*, 46, 345-363

Minnesota (2013*).* *Impact of work zone warning light configurations on driver behaviour.* Minnesota Department of Transportation, Office of Maintenance.

Morris, B., Cooper, J., Mitchell, J., Morris, L., & Weekley, J (2009) Li*ghting, Marking, Signage and Safety Equipment for Abnormal Loads and Self Escort Vehicles Final Report*. CPR286. Crowthorne: Transport Research Laboratory.

Office for Budget Responsibility (2020). *Inflation [online]. [Date accessed: 5 September 2020].* Available from: http://obr.uk/forecasts-in-depth/the-economy-forecast/inflation/#cpi

Office for National Statistics (2019). *Employee turnover levels and rates by industry section, UK, January 2017 to December 2018* [online]. [Date accessed: 5 September 2020]. Available from:

https://www.ons.gov.uk/employmentandlabourmarket/peopleinwork/employmentandemployeetypes/adhocs/10685employeeturnoverlevelsandratesbyindustrysectionukjanuary2017todecember2018

OTS (2020). *Move over law* [online]. [Accessed July 2020]. Available from World Wide Web: viewed July 2020 Available from: https://dps.mn.gov/divisions/ots/move-over-law/Pages/default.aspx

Pravossoudovitch K, Cury F, Young SG and Elliot A (2014). Is red the colour of danger? Testing an implicit red-danger association. *Ergonomics*, 57(4), 503-510. doi:10.1080/00140139.2014.889220

Probst, T. (1985). Thresholds for Detection of Changes in Headway are Elevated During Car Ride. In A. Gale, M. Freeman, C. Hasslegrave, P. Smith, & S. Taylor (Eds.), *Vision in Vehicles* (pp. 157-166). Nottingham, UK: Elsevier.

Salvucci, D. D., & Liu, A. (2002). The time course of a lane change: Driver control and eye-movement behavior. *Transportation Research Part F: Psychology and Behaviour*, 5(2), 123-132.

SURVIVE (2018). *BEST PRACTICE GUIDELINES v4/18*

SURVIVE (2018). PAS 43. *Specification for the safe working of vehicle breakdown and recovery operations*

The AA (2019). *The all-party parliamentary group for roadside rescue and recovery - First inquiry: safety concerns within the roadside rescue and recovery industry.*

The AA (2020). *AA plc Annual Report and Accounts 2020.* Reported dated 6 May 2020

The AA (2020). Investment Case [online]. [Date accessed: 5 September 2020]. Available from: https://www.theaaplc.com/investors/investment-case

Triggs, T., & Harris, W. (1982). *Reaction Time of Drivers to Road Stimuli.* Monash University.

Appendix A Literature review - summary of papers

Pravossoudovitch et al. (2014): Is red the colour of danger? Testing an implicit red–danger association

Study evaluating the association between red and danger. First experiment used words with either a meaning representing safety or danger. All words were presented randomly in either red, green, or grey, but with the same chroma and lightness. Results showed that words representing danger were faster detected when they were presented in red. The second experiment was conducted similarly to the first experiment but employed symbols. Again, a strong association between red and danger was observed. The results suggest that the hue red may have an implicit link with danger and that seems to be the optimal colour leading to fast reactions in dangerous situations. In consequence from the results, the authors suggest utilising red to communicate danger in various contexts beyond formal signage or signal systems.

Cook et al. (2000): Motor vehicle and pedal cycle conspicuity: part 1- vehicle mounted warning beacons

Study to evaluate conditions for warning lights to increase detection. Colour among others is one of the assessed conspicuity criteria of the warning light. A second objective was to evaluate the conspicuity of vehicles with amber warning beacons in the context where other vehicles with amber lights could be present.

The document cites The Road Vehicle Lighting Regulation 1989. The regulation prescribes the use of blue light beacons solely to emergency vehicles indicating the urgency or to warn of a hazard. Amber light beacons similarly are prescribed to be used at the scene of an emergency warning of a vehicle or hazard. Recovery vehicles are specifically mentioned. They are allowed to use amber light in the vicinity of an accident or a breakdown or when they tow a broken-down vehicle.

Interviews with different emergency responders were conducted, e.g., ambulance services, police, and fire officers. All emergency providers experience that other road users could respond more mindfully to warning beacons. For example, there is the opinion that a blue warning beacon is well understood, however road users tend to react rather slowly when they encounter one in a traffic scenario. Recovery operators and break down services raised the opinion that there is a lack of understanding of amber warning beacons. It is stated that this might be because of the proliferation of use of amber light beacons. Recovery operators stated that the situation could be improved with another colour used in conjunction with amber in their light beacon. They agreed to keep blue and green restricted to be solely used by emergency services and suggested using red or magenta.

The project involved tests, for example, to evaluate the conspicuity of a warning colour. Those tests were conducted in laboratory and test track conditions. The study compared blue, green, amber and red warning beacons at the same intensity. Amber had the poorest detection time (day and night). Contrasting, red had the quickest reaction time (night), with the least

discomfort glare (day and night). However, the domes of the warning beacons filter light and therewith change their intensity in real world conditions. A second study was conducted under real world conditions. The study under real world conditions showed that amber beacons led to the quickest detection time (day and night), but also the greatest disability glare (night). Red minimised effects of disability glare (night).

Further, the study found that using another colour alongside an amber light beacon (e.g., red, white or blue) improves detection time compared to using an amber only warning beacon. The authors suggest that a combination of amber and red would be the best in terms of detection and a minimal disability glare and minimal discomfort glare.

The authors recommend the use of red lights for recovery vehicles, when personnel are working at an incident on a carriageway, e.g., closet to approaching traffic.

Anderson and Plecas (2010): The science of warning lights

Anderson and Plecas (2010) conducted a literature review investigating optimal settings for a warning light. In a general finding they suggest that it would be beneficial to use the same warning lights on vehicles that require other drivers to react in a comparable way. A strong association between warning light colour and colour combinations and the drivers' expected response enable drivers to react in a timely manner. Thereby the authors describe that it is not the colour as such that determines the identification of a vehicle type but rather colour combinations / patterns. The drivers' interpretation of vehicle lighting is based on previous experiences and knowledge. Confusion about the interpretation can lead to a delay in response or an inappropriate response.

The authors cite a source from 1998 which describes that two police agencies in Illinois worked in the same area but one used blue lights and the other red lights. This led to inappropriate responses by some drivers, failing to pull over.

Yellow lights are found to be linked with driving at a slow speed and/or maintenance vehicles and readiness for a merge. Because a different response, e.g., directing the traffic, is expected for emergency or law enforcement vehicles, amber lights were not found to be suitable. Instead blue and red light has been found favourable. The colour red as such is strongly associated with "stop", "danger", and "emergencies" across ethnicities and countries. Further, literature found red light and blue combinations to have the best visibility in normal and low light conditions, and also in adverse weather.

Minnesota (2013): Impact of work zone warning light configurations on driver behaviour

The report describes measures employed to influence driver behaviour when approaching a work vehicle / work zone to increase the safety of workers. One measure taken by the state of Minnesota was to require drivers to move at least one lane away when they need to pass any of the following vehicles with activated warning lights: emergency vehicle, freeway service patrol vehicle, road maintenance vehicle or construction vehicle. The report notes that many drivers do not comply.

Another measure taken by the state of Minnesota is that "blue lights may and may not be used". The light bar on an equipped vehicle should not be more than 50% blue and blue lights must be installed on the passenger side. This blue light equipment is, for example, frequently used by maintenance supervisor or superintendent vehicles when they are managing unscheduled incidents on roadways or shoulders and also by Freeway Incident Response Safety Team (FIRST) vehicles. Due to the close association with emergency vehicles blue lights are assumed to increase safety. The report states that the use is limited to avoid overuse and loss of alerting effect. Further, it is stated that positive effects on vehicle speed and lane choice, though, those effects would need to be proven in a formal evaluation.

The report includes a study in which effects of light configurations on top of the vehicle on driver behaviour (speed and lane choice) were tested. Driver reduced their speed only a small amount, most 5.8 mph with the amber blue without lowers bar lighting. The amber blue lighting combination with lower light below the light bar was most effective to engage drivers to move a lane (99% in the left lane).

Bullough et al. (2019): Impacts of flashing emergency lights and vehicle-mounted illumination on driver visibility and glare

Bullough et al. (2019) investigated the visibility of an officer besides a police car with red and blue flashing lights at night-time. The vehicle lighting was installed on a scale model police car and was presented in different intensities and optical power (intensity x duration). Participants were asked to detect the officer as fast as possible and rate the light, e.g., glare. Participants perceived blue light as brighter, more glaring, and more uncomfortable compared to a red light of the same intensity. The authors found the intensity of the light influences the detection of the officer; higher intensity makes it less likely to correctly detect the worker. However, colour was not found to have an influence on the detection.

ESRI (2018): Study of protecting emergency responders on the highways and operation of emergency vehicles

The report is a literature review about emergency response vehicle lighting and conspicuity. Recommendations are made at the end of the report. The authors found little consistency between the emergency vehicle lighting specification, including colour, among states. The authors recommend using different light patterns to help drivers differentiate between and respond correctly towards a vehicle that is moving (calling for right of way) and one that is stationary (blocking right of way). The differentiation could be implemented by strobe pattern, light pattern, and light colour.

Red and blue lights were found to be most visible (red in daylight, and blue at night). The authors recommend that emergency vehicles should be equipped with both red and blue light for optimal effectiveness. Red might be used during daytime and blue lighting during night-time.

Gray (2020): Analysis of crashes involving first responder vehicles

Gray (2020) analysed crashes involving first responder vehicles in the state of Florida between 2016 and 2018. Darkness was identified as a factor that increased the crash risk. The crash risk increased even more when the accident occurred at night in an environment with ambient light compared to darkness only. Further, the study found that police vehicles were particularly at risk to be involved in an accident in those conditions, compared to ambulances and fire engines. At night emergency lights of first responder vehicles might be obscured by existing ambient light. The authors suggest more research in vehicle lighting.

Note: The term “ambient lighting” is not specified or explained further. From the text it can be assumed that it refers to street lighting.

Diels et al. (2009): Conspicuity of Rear Red Lights on Traffic Officer Vehicles Final Report

Study consisted of three elements; a literature review, evaluation of TOS procedures and simulator trials. The literature review identified that there is little benefit to be gained by increasing physical conspicuity (visibility) in isolation. This suggests that the use of conspicuity aids needs to be considered not from the point of view of the user but from the point of view of the approaching driver as it will contribute to the driver’s response to the situation ahead. The authors state that seeing and understanding are generally guided by a driver’s expectation of what is ahead and that it is likely that drivers do not understand what flashing lights mean.

Driver response to various lighting configurations and parking orientations, under simulated night-time and daytime conditions, was evaluated in a driving simulator. The simulator trials demonstrated that the presence of an unlit TOS vehicle on the hard shoulder (LBS1) or in lane 1 (LBS2) will influence the speed and course approaching drivers select, but that lighting and parking orientation (parallel, fend in, fend off) will cause further changes, although none of the variations between the lighting conditions were found to be statistically significant. However, post-trial questionnaires identified the understanding drivers have of the varying colours of lighting displayed and the actions drivers they would take in response to the different roof bar configurations, that amber is largely understood to indicate drivers to “slow down and red is understood to require drivers to either “slow down” or “stop”. Drivers indicated a poorer understanding in the red plus amber configuration, which suggests they are less familiar as to the meaning and required actions of this configuration compared to the red only or amber only configurations.

The authors recommended that Traffic Officer vehicles on the hard shoulder should display amber lights only, as there was no conspicuity benefit from the use of red plus amber lights, and vehicles in live lanes that are presenting a rear aspect or fend aspect to traffic should display rear-facing red flashing lights only. Also, they recommended that rear-facing red flashing lights should be reserved for use in live lanes only, so that drivers will make an association between red flashing lights and Traffic Officer vehicles in live lane situations

Appendix B Topic guide academic stakeholders

Topic Guide: Red flashing lights

Project objective: To gather evidence about the use of flashing red lights, particularly for recovery vehicles and their impact on other road users

As an academic expert in the areas of vehicle lighting and/or driver behaviour, the following topic guide has been created to prompt understanding in these areas. You may write answers to the following questions ahead of the engagement; however, this is **optional.** If you complete the topic guide prior to the engagement, please email it prior to the engagement to allow for questions to be prepared. If you do not complete the topic guide prior, we will be able to discuss it during the engagement.

Please complete the topic guide and the interview as a representative of your organisation.

Topic	Question	Answer
Visibility of red lights	Have you conducted studies comparing the visibility of red flashing light with other colours? If yes, what were the findings?	
	According to studies you have done, or are aware of, in which conditions are red flashing lights more visible, less visible or no different when compared with other colours? (Please share any articles where possible/relevant)	

Topic	Question	Answer
	Have you compared glare effects of red flashing lights to those of other colours? If no, are you aware of studies where this has been done?	
	How do you think red flashing lights on vehicles from the recovery industry will affect their conspicuity to other road users, if at all?	
Effects on driver behaviour	According to studies you have done or are aware of, did driver behaviour differ when they approached a vehicle with red flashing lights compared to a vehicle with amber flashing lights?	
	If drivers encounter a recovery vehicle with red flashing lights, how do you think they will respond? How would this be different to encountering a recovery vehicle with amber flashing lights?	
	Could drivers get confused when encountering a recovery vehicle displaying red flashing lights?	
	Do you have recommendations how the red flashing lights should be displayed on recovery vehicles to differentiate them clearly from other vehicles (e.g. emergency vehicles)?	

Topic	Question	Answer

	Do you have research recommendations, from a driving safety perspective, that should be considered during the development of a regulation for the use of red flashing lights on recovery vehicles?
	
	Please name factors, if any, that could determine when the use of a red flashing light should be **mandatory** for recovery vehicles.
	- Locations
	  - E.g., hard shoulder, trunk road
	- Road situations
	  - E.g., towing start to merge into traffic, recovery vehicle merging into traffic
	- Weather conditions
	  - E.g., ice, <100m visibility
	- Times of day
	  - E.g., daytime, night-time
	
	Please name factors, if any, that determine when a recovery vehicle operator is **advised** to use a red flashing light.
	- Locations
	  - E.g., hard shoulder, trunk road
	- Road situations	

Topic	Question	Answer
	- E.g., towing start to merge into traffic, recovery vehicle merging into traffic - Weather conditions - E.g., ice, <100m visibility - Times of day - E.g., daytime, night-time Please name factors, if any, when a red flashing light **should <u>not</u> be used** for recovery vehicles. - Locations - E.g., hard shoulder, trunk road - Road situations - E.g., towing start to merge into traffic, recovery vehicle merging into traffic - Weather conditions - E.g., ice, <100m visibility - Times of day - E.g., daytime, night-time	
Incidents	Are you aware of any statistics about incidents involving recovery vehicles?	

Topic	Question	Answer
	If yes, would it be possible to share the data?	
	According to studies you have done, or are aware of, what are the main risk factors for incidents involving recovery vehicles? (Please share any articles where possible/relevant)	

Appendix C Topic guide industry stakeholders

Topic Guide: Red flashing lights

Project objective: To gather evidence about the use of flashing red lights, particularly for recovery vehicles and their impact on other road users

The following topic guide has been created to prompt understanding in these areas. You may write answers to the following questions ahead of the engagement; however, this is **optional.** If you do not complete the topic guide prior, we will be able to discuss it during the engagement.

Please complete the topic guide and the interview as a representative of your organisation.

Topic	Question	Answer
Use of red lights **(who, when, where)**	What vehicle types in the recovery industry should **be allowed** to use red flashing lights?	
	What vehicle types in the recovery industry should **not be allowed** to use red flashing lights?	
	In which **locations** should red flashing lights for recovery vehicles **be allowed**?	
	Are there **locations** in which a red flashing light should **not be allowed** for recovery vehicles?	

Topic	Question	Answer
	In which **road situations** should red flashing lights for recovery vehicles **be allowed**?	
	Are there **road situations** in which a red flashing light should **not be allowed** for recovery vehicles?	
	In which **weather conditions** should red flashing lights for recovery vehicles **be allowed**?	
	Are there **weather conditions** in which a red flashing light should **not be allowed** on recovery vehicles?	
	At which **times of the day** should red flashing lights for recovery vehicles **be allowed**?	
	Are there **times of day** at which a red flashing light should **not be allowed** for recovery vehicles?	
	How do you think the vehicle lighting should be displayed if red flashing lights are used by recovery vehicles?	

Topic	Question	Answer

	Do you have research recommendations, from a driving safety perspective, that should be considered during the development of a regulation for the use of red flashing lights on recovery vehicles?
	
	Please name factors, if any, that could determine when the use of a red flashing light should be **mandatory** for recovery vehicles.
	- Locations
	  - E.g., hard shoulder, trunk road
	- Road situations
	  - E.g., towing start to merge into traffic, recovery vehicle merging into traffic
	- Weather conditions
	  - E.g., ice, <100m visibility
	- Times of day
	  - E.g., daytime, night-time
	
	Please name factors, if any, that determine when a recovery vehicle operator **is advised** to use a red flashing light.
	- Locations
	  - E.g., hard shoulder, trunk road	

Topic	Question	Answer
	- Road situations - E.g., towing start to merge into traffic, recovery vehicle merging into traffic - Weather conditions - E.g., ice, <100m visibility - Times of day - E.g., daytime, night-time Please name factors, if any, when a red flashing light **should <u>not</u> be used** for recovery vehicles. - Locations - E.g., hard shoulder, trunk road - Road situations - E.g., towing start to merge into traffic, recovery vehicle merging into traffic - Weather conditions - E.g., ice, <100m visibility - Times of day - E.g., daytime, night-time	

Topic	Question	Answer
Expected driver responses	How **should drivers respond** when they see a **red** flashing light on a vehicle which are currently permitted to display them?	
	How do you think **drivers actually respond** when they see a **red** flashing light on a vehicle?	
	Do you think drivers would respond the same if the vehicle was a recovery vehicle? If not, why not?	
	How **should drivers respond** when they see **amber** flashing lights on a vehicle?	

Topic	Question	Answer
	How do you think **drivers actually respond** when they see **amber** flashing lights on a vehicle?	
Potential overuse of red lights	What impact, if any, would it have for emergency services if recovery vehicles were able to use red flashing lights? Any positive impacts? Any negative impacts?	
	Do you think amber lights have become overused? If yes, please give examples?	
	Do you think other vehicles using red flashing lights should be clearly distinguishable from emergency vehicles?	
Incidents	Are you aware of any statistics about incidents involving recovery vehicles? If yes, would it be possible to share the data?	

Topic	Question	Answer
	According to studies you have done, or are aware of, what are the main risk factors for incidents involving recovery vehicles? (Please share any articles where possible/relevant)	

Appendix D Highways England Traffic Officer Manual

The tables below, from the Highways England Traffic Officer Manual (Highways England, 2020), Safety and Welfare, Traffic Officer Vehicles and Equipment, describe key operating requirements and the appropriate use of vehicle mounted warning lights

Table 8: Vehicle mounted warning lights and their use

Lights illuminated	Permitted usage on TOV
Rear Ambers and Rear Reds	• When carrying out a rolling road block. • Stationary whilst dealing with an incident in a live lane. • While setting out or removing ETM, including reversing, or if the TOV itself is used as part of live lane ETM. • Stationary on a hard shoulder where hard shoulder abuse is a known issue. • Moving onto a place of relative safety, such as a hard shoulder. Once on the place of relative safety rear reds will **normally** be extinguished.
Rear Ambers	• Stationary in a place of relative safety • Stationary whilst directing traffic on foot at Junction or roundabout. • Escorting abnormal loads (front ambers are also to be illuminated when approaching and passing junctions and interchanges). • Escorting other vehicles e.g. slow ambulances. • Reversing on a hard shoulder.

Table 9: Work instruction: TOV VMP, lighting and vehicle checks, Key operating requirements:

Work instruction: TOV VMP, lighting and vehicle checks
Key operating requirements:
2. Warning lights - vehicle mounted a) All warning lights are programmed in accordance with a national lighting scheme and are not to be altered. b) TOs are to ensure they are fully conversant with which button operates which light or set of lights. c) To obtain the maximum protection from the warning lights it is essential that traffic officers (TOs) operate them in a proper and consistent manner. d) Lighting displayed is to be changed as necessary when the circumstances of the incident change eg moving onto the hard shoulder after clearing an incident off the carriageway will **normally** require rear reds to be extinguished. e) Any warning light deviation is to be reported to the Regional Control Centre (RCC) as soon as practicable. The RCC are to note the deviation on the relevant incident log, or if necessary create a log. RCC are to inform the team manager for their information and any action they deem necessary.

Evidence review – Use of red flashing lamps on roadside recovery vehicles

The Department for Transport required a review of available evidence, in the context of the existing regulations on red flashing lamps, to determine whether a more flexible approach might be appropriate to their use by road recovery operators. This review considered existing evidence and identified more recent research to assess whether there are potential benefits and any detrimental effects on road safety. The review included a literature search, media trawl and stakeholder interviews. An Initial Regulatory Impact Assessment compared four options against the default do nothing option. The results from the review include recommendations and identified potential limitations of the increased use of red flashing lamps.

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