Road Workers' Safety Forum
Trials Team Report

Final

On-road Trial of the Conemaster Automated Cone Laying Machine

Contents

Executive Summary

The Road Workers' Safety Forum (RoWSaF) exists to improve the safety of road workers on all roads. As part of this work, RoWSaF has investigated and supported automation of the placement and retrieval of traffic cones.

The Conemaster system (developed by Jordan Products) is a cone placement and retrieval machine that has been evaluated by the Trials Team in previous off-road and short-term trials. The machine is semi-automatic, as it requires operatives on the rear of the traffic management vehicle to handle the cones which are delivered or retrieved from the road via a conveyor belt system. A five month on-road trial of the Conemaster system was carried out between September 2009 and February 2010 with support of one of the HA's Service Providers. The aim of this evaluation was to assess whether the Conemaster system was safe, reliable and effective for general operational service with a Service Provider.

This report presents the results of a comparison between manual cone laying and retrieval and that using Conemaster. The trials were carried out using Carillion method statements (presented in Appendix A) and should not be viewed as generic as they were undertaken by a single service provider. However the results do suggest that significant potential benefits that can be realised from automating the cone laying process. In addition, data obtained from the trial has been used to deliver the secondary trial objective of determining these potential benefits and the potential risk reductions to road workers that could be realised by automating cone laying and retrieval.

The results of the on-road trial confirmed the Conemaster system is capable of laying and retrieving cones in both relaxation and standard taper and longitudinal layouts according to the 2009 revision of the Traffic Signs Manual Chapter 8. The Conemaster system also demonstrated that it is capable of operating reliably in all weather conditions in which traffic management operatives would be expected to work and that it can also lay and retrieve cones with road danger lamps attached, provided these are of a specific type (Dorman ConeLITE). Manual handling is reduced during deployment and retrieval procedures through the use of Conemaster, which is particularly noticeable for the conveyor operator who would normally be in the cone well. The Conemaster system is required to operate behind an IPV, under the terms of the Special Vehicle Order that enables its lawful operation on-road. Although this does mean operatives are protected from live traffic by a crash cushion vehicle, it does necessitate using a minimum of four operatives are required per closure (three to operate the Conemaster vehicle and one to drive the IPV).

In this trial, the Conemaster system completed single lane closures quickly and safely with minimal time on the carriageway for operatives. The system had difficulties completing large or complicated layouts, in particular those with multiple lane closures or entry and exit slipways. If the Conemaster system is required to close more than one lane then it must be used with a second IPV to prevent any need for operatives to be on the live carriageway.

The potential benefits to road worker safety from the use of Conemaster (or similar systems) were investigated by comparing risk from the automated process against risk from the manual method of cone deployment for temporary traffic management. The results suggest that when used as per the Carillion method statement the Conemaster is optimised for deploying single lane closures on the nearside and offside, with the offside showing the greatest reduction in risk.

It is important that the findings of this report should not be taken as a generic statement of performance in the wider context of industry as many different method statements are used

within the industry to install and remove temporary traffic management on high speed roads. For example there are major differences in the use of IPVs when installing and removing lane closures; there are also significant differences in the way that cone tapers are installed and removed, with some contractors pre-placing taper cones in advance of installation.

1 Introduction

The Road Workers' Safety Forum (RoWSaF) is committed to improving the safety of road workers. The Highways Agency shares this vision and has implemented a Road Worker Safety Strategy (RWSS) with the aim of eliminating serious injuries and fatalities among its on-road work force. As part of this '*Aiming for Zero: Safety for Our Road Workers*' and other similar strategies of the major service providers, eliminating the need for road workers to be on foot on the carriageway is a key element of reducing injury risk.

The Highways Agency's '*Exposure Zero*' campaign aims to decrease risks by removing the need for road workers to be on foot on live carriageways during routine maintenance operations. One major cause of road workers being on foot on live carriageways is the placement and retrieval of traffic cones associated with lane closures. This practice exposes traffic management operatives to a risk of fatal or serious injury, as well as personal injury associated with handling the large numbers of traffic cones required for road works.

1.1 Background

The RoWSaF Steering Group led by the Highways Agency, together with representation from central and regional government, local authorities, HSE and industry has supported and encouraged development of automated cone placement and retrieval systems. The RoWSaF Trials Team has provided the performance standard for these systems under the guidance and authority of the RoWSaF Working Group.

A number of possible designs for cone placement and retrieval systems have been developed by the traffic management industry and others, which RoWSaF has evaluated via the Trials Team at various times. The ultimate aim for such devices is their routine use for the placement and removal of cones associated with traffic management, removing road workers from a potentially hazardous environment.

The technology in some of these systems is now approaching the stage where a medium-scale evaluation programme can be undertaken. On this basis it was considered by RoWSaF and the Highways Agency that a full-scale medium term on-road trial would be beneficial. This would provide an assessment as to whether automated cone placement and retrieval systems are practicable for national use.

Figure 1 - Conemaster system

One such system was the Conemaster produced by Jordan Products Ltd. The RoWSaF Trials Team previously tested the Conemaster machine in an off-road trial against the RoWSaF Evaluation of Traffic Cone Laying Machines Specification v4.11 and in a single, one day trial on the M40 in July 2006.

The Conemaster system completed the off-road trial successfully and the subsequent on-road one day trial was concluded safely and without significant issues. On this basis, a medium term on-road trial of the system with a Service Provider was proposed and approved.

This report presents an evaluation of the use of the Jordan Products Conemaster automated cone laying and retrieval machine by a Service Provider. The findings presented in this report are based on the use of Conemaster in accordance to the Carillion method statements shown in Appendix A and should not be considered necessarily as representative of industry as a whole.

The report also presents an assessment of the potential safety improvements from automating some aspects of cone laying that could help protect road workers involved in the deployment of temporary traffic management.

2 Methodology

The on-road trial took place between September 2009 and February 2010 on the M40 motorway with the support of the HA Service Provider for the M40 (Carillion plc). Operation of the machine was conducted by Carillion plc staff to ensure the use of the machine was fully representative of real-world operating conditions on the HA network.

The machine was initially operated by staff from Carillion Highway Maintenance (CHM), who were provided with full training from Jordan Products. Due to staff availability issues during the trial period, the vehicle was handed over to Carillion Traffic Management (CTM) to operate for the remainder of the trial period. It should be noted that CHM operatives were not provided with full training by Jordan Products due to operational constraints.

The system was tested by using the machine as a replacement for a standard traffic management vehicle when closing lanes for pre-planned temporary road works. This may have had implications over the optimisation of use of the Conemaster, as discussed later in this report.

The Conemaster system is a semi-automatic machine that requires operatives on the rear of the traffic management vehicle to place the cones on the conveyor belt, which then delivers the cones to the road. The system is capable of laying and retrieving cones in a taper layout and a longitudinal layout and is also capable of laying cones with road danger (cone) lamps attached. Although the Conemaster system is designed to avoid the need for traffic management operatives to work on the carriageway as per current practice, operation of the machine during the trial (using the Carillion method statement) indicated that it did not completely eliminate this requirement for the reasons that are detailed in Sections 5 - 7 of this report.

2.1 Objectives

The aim of this evaluation was to assess whether the Conemaster system was safe, reliable and effective for general operational service.

The secondary objective of the on-road trial was to determine the potential benefits from automating cone laying/retrieval through assessing the potential risk reductions to road workers that such a system could deliver.

2.2 Safe Operating Requirements

As part of the preparation work for the trial, Carillion developed method statements for the use of the Conemaster system. These are presented along with the comparable manual cone laying method statement in Appendix A, by kind permission of Carillion plc.

The Conemaster machine was prepared for use by Jordan Products by fitting it to an 18 ton vehicle. The rear overhang of the machine was such that it exceeded that permitted by Construction and Use Regulations and thus in order for the Conemaster system to be allowed to be used on the live network, a special vehicle order (SVO) was requested from the Department for Transport. This was granted and ensured that the operation of Conemaster on the road was lawful, provided it was operated in accordance with the conditions of the SVO presented in Appendix B.

2.3 Acceptance testing

The acceptance testing of the Conemaster system was intended to ensure the machine was functional, it complied with the cone placement machine specification v4.11 and performance was thus acceptable for use on the motorway network. The testing was conducted at Heyford Park in association with Carillion and Jordan Products.

The Conemaster system was fully tested against the RoWSaF Cone Placement Machine Specification v4.11 in order to determine whether the vehicle could safely lay cones on the carriageway to the required standards. The off-road assessment also gave the opportunity to rigorously measure the layouts to establish that they complied with the specification.

The Conemaster system was assessed in its ability to lay cones in both relaxation (3m cone spacings) and standard (1.5m cone spacing) taper arrangements and as longitudinal cones spaced at 9m and 18m centres. The system was also assessed for its ability to lay a right to left taper and a left to right taper, simulating nearside and offside closures.

Figure 2 - Conemaster laying taper

Figure 3 - Conemaster laying longitudinal cones

The system was also tested in its ability to retrieve the cones from the carriageway. The deployment and retrieval were observed to ensure that the system worked safely and consistently each time.

The assessment demonstrated that the Conemaster system was capable of performing the required operations, both laying and retrieving cones and cone lamps successfully and at satisfactory speeds. The acceptance testing was completed and it was indicated that the Conemaster system was acceptable for the trial.

2.4 Assessment criteria

The Conemaster system was assessed during the on-road trial by gathering different types of data on the operation of the vehicle. These data were:-

- Traffic cone arrangement against Chapter 8 of the Traffic Signs Manual for the following types of lane closure.
    - Single lane closure on the nearside
    - Multiple lane closures on the nearside
    - Single lane closure on the offside
    - Multiple lane closures on the offside
    - Complex closures including ‘splitters’ and ‘give ways’
- (Qualitative) assessment of deployment, alignment and spacing of cones in the taper.
- (Qualitative) assessment of deployment, alignment and spacing of cones in the longitudinal section.
- (Qualitative) assessment of deployment and direction of the cone lamps, both sequentially flashing and standard road danger lamps.
- Effectiveness of retrieval of the cones from the carriageway.
- Speed during deployment and retrieval of lane closures.
- Reliability over the period of the trial via breakdowns/system failures.
- Safety of the workers whilst operating the Conemaster system.
- Issues that could impact the safety of road users
- Training requirements for operatives.

2.5 Assessment method

The Conemaster system was used by Carillion Highway Maintenance (CHM) and Carillion Traffic Management (CTM) teams based on the M40. For the duration of the trial period they used the Conemaster system in place of manual traffic management deployment practices wherever practicable. All the operatives using the machine were qualified to the appropriate LANTRA Sector Scheme for their role (12A / 12B) and were experienced in manual traffic management techniques. The Carillion Highway Maintenance team were trained to use the Conemaster system by Jordan Products; staff from Carillion Traffic Management were trained in operation of the Conemaster by CHM personnel. All staff using the Conemaster were assessed by Carillion to ensure they could use the system safely and effectively and without risk to themselves or other road users.

The Conemaster system was assessed by the operatives who used the system during deployment and retrieval phases. Operatives also assessed the completed cone layout against the operational standards in the Traffic Signs Manual: Chapter 8 to ensure they were to the required standard. They also used their experience of laying and removing traffic cones manually to assess the safety of the Conemaster in comparison with the standard operational method, along with the impact of lane closure operations on road users.

2.6 Data collection

The data collected was obtained in two main formats:-

<u>Log sheets</u>

Logs were completed by Carillion operatives each time the Conemaster system was used. The log sheets contained relevant data on the operation of the machine, including:-

- Date
- Weather conditions
- Location of closure
- Type of closure (lane 1 etc.)
- Time taken to deploy taper
- Length of longitudinal
- Time taken to deploy longitudinal
- Time taken to remove closure
- Any placement or retrieval failures
- Any complete system failures
- Comments from operatives

This log provided information about the exact type of work the Conemaster system was required to do and whether the layout met the required standard in Chapter 8. Standards were assessed by LANTRA 12A/B qualified operatives who compared the results from the Conemaster system to their experience of manual cone laying operations. The information was used to determine qualitatively how the Conemaster system performed.

<u>Post use survey</u>

Responses were obtained to a post use survey with Carillion operatives after the trial had been completed. The data were collected via a guided interview with questions taken from the questionnaire presented in Appendix D. Information was collected from each operative and manager involved in the trial. Responses were collated and used to establish how well the Conemaster system performed.

2.7 Data Analysis

The quantitative data was used to provide evidence of Conemaster system performance in relation to the specifications. The timings of the deployments and retrievals were used to compare operation of the Conemaster system with the speed of current manual methods of cone placement and retrieval. Evidence of reliability of the Conemaster system was also gathered from the logs using the system failure check lists.

The qualitative data analysis used data from the interview to provide information on the use of the Conemaster system compared with current methods and identify issues with the system operations and training. These methods and the Conemaster system methods are documented in Appendix A.

3 Results

3.1 Training assessment

The Conemaster system training program follows four modules, the first being a classroom introduction. This shows a video of the Conemaster system vehicle and introduces safety instructions and operational protocol. The second module is an introduction to the Conemaster system controls where operatives are given demonstrations and hands on training. The third module is supervised training in a safe working area. This gives operatives a chance to practice with the vehicle without about the added concern of live traffic. The final recommended module is supervised operation on the network with operatives watched as they work on the network. Feedback is given on the operations carried out.

Following the trial, Jordan Products acknowledged that the training program was a “live” document that evolved during the trial; it has been reported that the current version of the Conemaster training program has been updated to include information gained from the trial described in this report.

Training was provided to operatives from Carillion Highway Maintenance (CHM) by Jordan Products. Training was delivered in several different stages, initial training being carried out during the acceptance trial at Heyford Park. Three CHM operatives were instructed in person on the day of the acceptance trial by Jordan Products. All training of CHM personnel was undertaken with Jordan Products present.

On transfer of the Conemaster to Carillion Traffic Management, training was undertaken in-house by CHM personnel. This training of CTM operatives was not as extensive as the first training sessions, due to the availability of operatives who were working night shifts and could not be released from their normal working pattern to undergo training.

3.2 Conditions of deployment

After the initial training period the Conemaster system became available for use on the network from the third week in October 2009. The trial ended on 26th February 2010. Between these dates:-

- There were a total of 70 shifts where the Conemaster system could have been used.
  - This is approximately half the total number of possible night shifts.
  - The lost night shifts were accounted for by weekends, the winter shutdown period over Christmas and poor weather during the trial period.
- Within the 70 shifts there were a total of 147 lane closure operations carried out by Carillion, at an average of just over two per night.
- The Conemaster system could only have been used on one shift per night due to the shortage of qualified staff, i.e. a maximum of 70 uses across the trial period.
- The total number of times the Conemaster system was used on the network was 26.
  - The main restriction on Conemaster system use was access to qualified staff.
  - Out of the 26 times the Conemaster system was used, there was only one incidence of failure; on the 15th December 2009, the Conemaster system failed to retrieve cones from the carriageway. It was noted in the log that the belt was damaged, which was preventing the Conemaster system picking up the cones.

3.3 Quantitative data

The quantitative data is primarily drawn from log sheets completed by Carillion. Each time the Conemaster system was used on the network a log was completed. TRL (on behalf of the RoWSaF Trials Team) received copies of these logs and used them to create a data set. The data was used to find average times to deploy closures and also remove them. Also included in the data were the types of closure and operatives comments. Other recorded data can be found in the table in Appendix E.

Some of the recorded times have been excluded from the average deployment times. The first seven deployments using the machine were not timed as the cones had to be lamped manually. This was because the compatible sequential flashing cone lamps were unavailable at that time, requiring the Carillion operatives to manually place and remove incompatible sequential flashing cone lamps.

Two of the other retrieval times were excluded as it was stated that they were walked off manually. Of the remaining exclusions only one has a time recorded. This states that it took 3 hours to complete the closure. The operator commented:- *"due to various details and ran out of cones etc. A big job for the Conemaster due to splitter and 2 give way details and length of hatching to cone off. A bit slow for such a hands on job."*

The recorded time for this deployment has been disregarded as the Conemaster vehicle has been required to leave the works site to get more cones. The time required for this part of the operation is not noted, thus, there is no certainty over how long the Conemaster system actually took to deploy the closure.

The time to deploy a taper is considered as the time taken from the deployment of the first cone of the taper to the completion of the entire run of cones, including fitting of sequentially flashing road danger lamps and installation of the two Diagram 610 arrow signs within the taper. The percentage difference in the installation time for a taper between the Conemaster semi-automatic and the current manual method was calculated and gave the following results:

- Conemaster taper deployment time: 13m 45s
- Current manual deployment time: 15m 00s
- Difference in deployment times: 1m 15s

Conemaster time saving: approximately 8.5% compared to current methods.

The 8.5% time saving should probably be viewed as a minimum start value; as the Conemaster was used within the framework of an existing method statement its use was not necessarily optimised. Optimisation of the use of automated cone laying techniques along the same lines as optimisation of current manual cone laying practices (which have been refined over many years) has the potential to enable such techniques to realise greater time savings and potentially improve the risk reductions discussed in greater detail in Section 5.

The average deployment time using the Conemaster for the longitudinal is fifteen minutes and forty-six seconds per kilometre; average time to clear an entire closure (taper and longitudinal combined) was twenty-two minutes and fifty-one seconds for a 1km closure.

3.4 Key Trial Findings

The key trial findings (taking into account responses from Carillion) are:

- The Conemaster system was capable of completing closures to the standards in Chapter 8 of the Traffic Signs Manual.
- The Conemaster system was able to deploy tapers with the correct spacing and alignment

- The Conemaster was capable of laying taper cones fitted with sequentially flashing road danger lamps, provided these were of the Dorman 'ConeLITE' type.
- The Conemaster system was able to deploy longitudinal sections with the correct spacing and standard road danger lamps attached.
- Road danger lamps were correctly deployed on top of cones. Misalignments were infrequent, but when they did happen were manually corrected.
- Cones were successfully retrieved from the carriageway except on one occasion (during this failure, cones were removed manually)
- Speed during deployment and retrieval of the closures was comparable or slightly superior to standard methods
- The Conemaster system worked reliably for the length of the project, with only one failure, which was due to the conveyor belt becoming too worn to pick up cones.
- No workers were injured or suffered manual handling injuries during the trial period whilst using the Conemaster system.

It was stated by Carillion that '*the Conemaster machine would have been more likely to have been utilised regularly had it been available for the cyclical maintenance period in August and September.'*

4 Operational Issues associated with Conemaster operation

4.1 Positive comments regarding the Conemaster system

The following positive feedback was received from the Carillion personnel involved with the trial.

- The Conemaster system can, on average, create a Chapter 8 “relaxation” taper (as typically used at night-time works) in less time than a regular traffic management crew.
- There are no operatives in the carriageway for the installation of a relaxation taper during a single lane closure on the nearside or offside.
- The Conemaster system gives a very tidy, neat run of cones. It is quick during the actual cone drop phase.
- Around 1 in 20 road danger lamps are misaligned when deployed by the Conemaster system. Badly misaligned lamps must be reoriented manually by an operative walking back along the carriageway; however, this is equally true of misaligned lamps on manually deployed cones.
- Operatives stated they felt more aware of the traffic in the adjacent lanes. This may have been due to unfamiliarity with the machine, because they were unused to the technique or because they were working behind an IPV that blocked the view of approaching traffic.
- Operatives stated they felt more aware of passing traffic. With the IPV blocking the view of oncoming traffic operatives stated they would watch the traffic more closely as reaction time would be lower due to shorter line of sight.
- The operatives’ view was that the Conemaster system would be most useful at a site where there is a generic single lane closure each night.
- The Conemaster system reduced manual handling significantly, particularly during the pick up from the carriageway. The system conveyor replaced the process whereby the cone well operative must drop cones on to the carriageway at the correct spacing when placing cones and must collect the cone from the carriageway and lift it onto the bed of the truck during retrieval.
- Operatives on the rear of the vehicle have the added protection of being strapped to the frame. If the Conemaster vehicle was hit, the operative strapped to the frame is potentially at less risk of serious injury than a cone well operative who is surrounded on all sides by rigid structures. The driver of the Conemaster vehicle also benefits from the added protection of the IPV following behind the Conemaster vehicle.
- Operatives felt less vulnerable when deploying cones. It was believed that the light arrow on the Conemaster system warned driver about returning to the outside lane too soon after the IPV, thus putting operatives at risk. During standard traffic management in the outside lane, experience suggests that vehicles are liable to return to the outside lane once they have passed the TM vehicle, which puts the road user and road worker at risk of injury.

4.2 Operational Issues associated with Conemaster operation

The following operational issues were identified with the Conemaster system.

- **Use of an Impact Protection Vehicle (IPV)**

The Conemaster system prevents a lorry mounted crash cushion (LMCC) being fitted to the traffic management vehicle being used. Current guidance from DfT (and a specific condition in granting of the Special Vehicle Order) was that the Conemaster system vehicle must always be protected by an IPV.

The IPV requires a driver with LGV qualification (either Class C or Class C+E licence) who is also a qualified traffic management operative (qualified to minimum Sector Scheme 12A/B) and holds a LANTRA IPV qualification.

The driver of the Conemaster vehicle does require a LGV licence but does not technically have to be a LANTRA 12A/B qualified traffic management operative. However, it is considered advisable that any Conemaster driver would by a qualified traffic management operative to allow for interchangeability of roles on the carriageway.

Assuming the Conemaster driver is 12A/B qualified, this would requires a company using a Conemaster to provide two LANTRA 12A/B qualified LGV drivers when using Conemaster (one for the Conemaster vehicle and one with IPV qualification to operate the IPV). In some situations, such as where three lanes are required to be closed, this would require three qualified LGV drivers, two with IPV qualifications. It was felt this would present a challenge in resourcing sufficient qualified personnel, especially regarding the availability of IPV drivers.

- **Number of traffic management operatives required**

The Conemaster system requires four operatives at one time to close a lane (three on the Conemaster vehicle and one in the IPV). This is one more than currently used for traffic management operations where three operatives work from a traffic management vehicle fitted with a crash cushion. For a three lane closure, six operatives would be required (three in the Conemaster vehicle and three to drive IPVs to protect the Conemaster vehicle).

- **Driver qualifications**

As described above, the Conemaster system requires a driver with an LGV (Class C or C+E) qualification. If necessary, manual traffic management can be completed in smaller 7.5 ton vehicles which only require drivers to be qualified to Class C (often under "grandfather rights" for car licence holders who passed a driving test prior to 1997) who can be employed for lower cost.

LGV drivers are often paid more by other employers leading to industry shortages of qualified drivers and increased costs. Although the Conemaster attachment can be fitted to a 7.5 ton vehicle, the physical size of these types of vehicle is not sufficient to carry the Conemaster attachment and sufficient cones to deploy a significant length of closure.

- **Two lane closure capability**

The Conemaster system is capable of being used to close two lanes but can only close one lane at a time. When closing a second lane another IPV would have to be used to block the second lane. There is also the issue if the Conemaster system was used for a second lane that the conveyor must be reset by the operatives once the Conemaster traverses into the second lane to be closed (the Conemaster conveyor cannot traverse the full lane width in order to prevents the conveyor from extending into the neighbouring lane where traffic will still be running).

- **Cone storage**

The design of the vehicle used for the trial reduced the amount of space available to store the equipment needed for traffic management. Estimates from CHM personnel indicated the maximum practical limit for cone storage on the Conemaster vehicle was 500 cones, with this considered to be the acceptable limit of safety and practicality for the vehicle. The frame at the cab end of the Conemaster vehicle also reduced the maximum cone stack height available for cones, thus reducing the number of cones that can be placed on the vehicle; this could be increased slightly but would not significantly increase the capacity of the vehicle.

For comparison, a conventional TM truck can easily carry at least 500 cones, with room for 400 lamps and associated signs and frames. This equipment level means the vehicle is able to install a three lane closure taper (153 cones) and 4 kilometres of longitudinal coning without having to return to the depot to collect additional cones.

Figure 4 - Conemaster storage area

- **Tolerance of cone types**

There are two types of 1 metre height cones commonly in use by traffic management contractors. These cone types both conform to the relevant British Standard but one type has a thinner base. This can sometimes cause problems when they cross the conveyor joint as the thinner base cone can get stuck between the two sections.

Figure 5 – Cone stuck in the conveyor joint

There is no operational way of separating these two types of cones as they become mixed up very quickly, are interchangeable and stack together easily. The solution would be to alter the conveyor mechanism in order that the cones can no longer fall in between the sections.

- **Sequential flashing cone lamp pick up**

The Conemaster system is designed to tip the cone up from the carriageway surface in order to give its conveyor purchase when picking up the cones. When the cone is fitted with a two-battery sequential flashing lamp (of the type in widespread use on the network) this creates a taller object with a higher centre of mass. These cones have a tendency to fall over before the conveyor catches the base. Where these lamps are used, operatives must leave the vehicle to remove all sequential cone lamps before using the Conemaster system to pick up the taper.

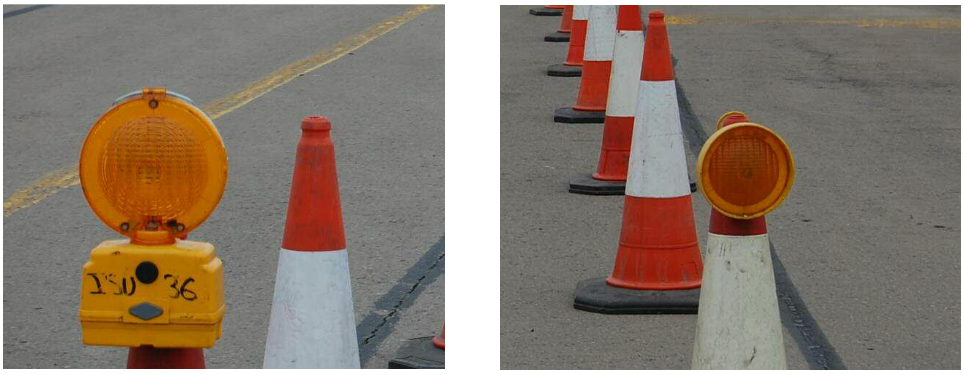

Figure 6 - Old design sequentially flashing cone lamp versus newer cone lamp shape

Figure 7 - Cone being tipped from carriageway for retrieval

The Conemaster system was designed to handle cones equipped with the single battery ConeLITE (produced by Dorman) as shown in Figure 5. The trial was able to use prototypes of a new type of sequentially flashing cone lamp that is constructed in the ConeLITE body, which enabled the Conemaster to handle cones fitted with sequential lamps. This would, however, require users to standardise on the Dorman ConeLITE sequential or standard road danger lamp.

- **Alignment of the vehicle**

The Conemaster system vehicle requires the driver to be more precise when dropping or picking up longitudinal sections of cones. The vehicle is also longer when the conveyor is in use, which requires the driver takes more care with alignment. The conveyor also sits close to the running lane when deployed in longitudinal operation and care must be taken to avoid it encroaching into live traffic.

- **Poor weather operation**

The cones deployed on the carriageway can be buffeted about by the passing of LGV's and slide across the carriageway. This occurs more frequently when conditions are wet and/or windy. This represents a problem for the Conemaster system as it does not have the flexibility to pick up cones that are grossly out of line. An operative would have to pick these cones up by hand where badly misaligned cones are outside of the tolerances which are stated in the specification (plus or minus 500mm). Wet conditions can also cause cones to slip on the conveyor and make retrieval difficult.

- **Light arrow and frame**

The Conemaster system vehicle is required by its SVO to operate with an IPV. Since the Conemaster system is operating behind an IPV then it arguably does not require the light arrow to be active. This would mean the frame for the light arrow could be removed offering greater headroom to the two rear operatives of the Conemaster system vehicle.

- **Axle weights**

Carillion operatives questioned whether the Conemaster system vehicle would be legal on axle weights. For a normal traffic management vehicle it is important that the weight is distributed evenly across the back. With the Conemaster vehicle, the weight of equipment is distributed towards the cab to make room for the Conemaster system equipment at the back and space for the operatives to work in the middle, feeding the Conemaster conveyors. This approach may result in uneven axle weight distribution.

- **Vehicle gearing**

Operatives noted that the Conemaster system vehicle gearing could be a little difficult at times. This made the vehicle occasionally liable to sudden acceleration.

- **Innovative Taper**

The Conemaster cannot currently lay the Innovative Taper layout shown in Figure 8:

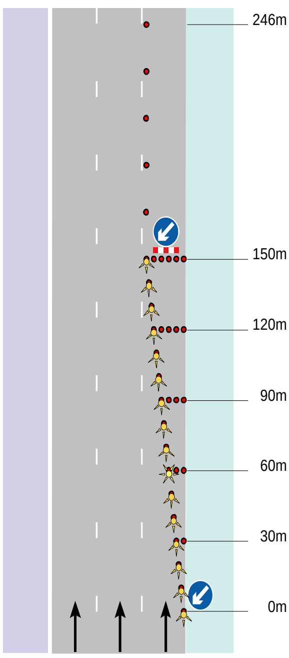

Figure 8 –Innovative Taper layout

The Innovative Taper uses fewer cones than a normal taper; the design is such that the Conemaster system is unlikely to be capable of completing it without some manual readjustment or significant increase in taper placement time. However, the Innovative Taper is an alternative to a standard taper designed to reduce time on road for TTM operations involved in lane closure. Laying a standard relaxation taper layout with the Conemaster may offer similar reductions in time comparable to the Innovative Taper but without the manual handling benefits of the reduced number of cones required.

4.3 Safety Issues associated with Conemaster operation

The following safety issues were raised associated with Conemaster operation.

- **Installing signs**

When installing the taper the operatives are still required to deploy the ‘keep left / keep right’ (Diagram 610 arrow) sign at both ends of the taper. In order to do this the operatives must exit the vehicle and deploy the signs on the side of the road and thus for the period of sign deployment the operatives must be on the carriageway. This is, in itself, not a safety concern specific to the Conemaster system but does represent a level of risk that must be considered when assessing the risk reductions from systems such as Conemaster.

- **Vehicle shape and size**

The frames on the vehicle are designed for the practicality of the light arrow display and for sign storage, but are awkward for taller operatives to work comfortably. Operatives noted that, although wearing hard hats, hitting their heads against the frame was uncomfortable and disorientating.

- **Training**

Three operatives and one main driver from Carillion Highway Maintenance received the training course from Jordan Products. None of these operatives had the opportunity to read the training manual as it was unavailable during the trial period. The operatives also felt that their training course was too brief and would have liked to train on the vehicle off-road before using it on the network under live traffic conditions. It should be noted that if the training manual is followed then off-road training is incorporated but that the training manual was unavailable until after the trial was concluded. It is acknowledged by Jordan Products that the current training manual documentation showing ‘best practice’ was evolving over the life of the trial.

- **Alignment of the vehicle**

As well as being an operational issue, this can also affect safety. The driver found aligning the vehicle to be difficult when reversing even though reversing camera systems are present. An improvised alignment device was added to the vehicle to assist with reversing, but a laser alignment device was suggested as an improvement.

- **Conveyor**

The conveyor carries the cones to the road surface and back but has the potential to act as a ramp for a vehicle colliding with the conveyor. The operatives have concerns that an errant vehicle could travel up the conveyor directly at them. The conveyor may collapse or break during an impact or remain firm. Without testing the crashworthiness of the ramp, the risk level is unknown.

- **Vehicle attributes**

Operatives commented that the rear steps to the back of the vehicle could be slippery in wet or icy conditions. Since operatives are required to get on and off the vehicle several times during lane closure operations, this increases the risk of operative injury. Again this is not an issue specific to Conemaster but the comparable risk factor for standard TM vehicles is not known.

- **Harness**

The conveyor operator is required to wear a harness attaching them to the vehicle. It was noted that this could be awkward to unclip and often had to be helped by a colleague. If the need ever arose, the conveyor operator may struggle to unclip themselves quickly without assistance.

- **Line of sight**

The operatives using the Conemaster system do not work behind an IPV during standard lane closures operations. As a result they can see oncoming traffic and its behaviour. This can work both ways as drivers sometimes pass an IPV in a lane only to immediately attempt to return to the lane they were in, which would be the work zone. The light arrow on the Conemaster vehicle may negate some of this risk by showing that there is a second vehicle behind the IPV.

- **Poor weather operation**

Poor weather causes safety as well as operational issues. The Conemaster system conveyor system sometimes had problems picking up cones. If the machine does not pick up the cones, then the operatives are required to retrieve them by hand from the carriageway. If the cones are retrieved manually then there are no safety benefits compared to manual retrieval.

4.4 Summary of issues associated with Conemaster operation

Positive benefits associated with the Conemaster identified by Carillion operatives relate to potentially quicker deployment of tapers by the automated method. The reduced manual handling associated with removing cones from the carriageway is of benefit, as is the ability of the system to provide a neat taper.

Some issues were identified during the trial that are specific to Conemaster; these centre on personnel requirements and the need for an additional IPV, vehicle capacity / weight distribution and the ability of the system to handle cones of different base thicknesses. The initial issues associated with sequential flashing cone lamps are solvable, but the Conemaster is only compatible with the use of the Dorman ConeLITE in either conventional or sequential form.

Vehicle alignment, weight and gearing were raised as issues along with on-vehicle storage design, although these and other issues such as slippery surfaces in poor weather are generally common to all types of traffic management vehicles and can be engineered out through relatively minor vehicle design changes.

The key issue from the discussion with operatives (and the trial results) seemed to be the training provided in Conemaster system operation. Repeating the training given to CHM personnel for CTM personnel could potentially have provided more qualified operatives and thus more opportunity to use the Conemaster system during the trial period.

5 Comparative risk assessment

The potential benefits to road worker safety from Conemaster use were investigated on a qualitative comparative risk assessment basis. This compared the risk for deploying traffic management (including advanced signing) using the Conemaster with the risks associated with manual traffic management.

It must be stated again that this risk assessment matrix is based on the results from the Carillion operational model and method statements; optimisation or adaptations to the operational model would undoubtedly change the assessment of risk. However, it is likely that the basic principles in this comparative risk assessment would remain valid (with minor changes) for other method statements.

The advanced signing requirements for both techniques consists of the TM vehicle stopping upstream of the works site and deploying signs warning of the road works ahead. These include the signs, shown in Figure 9 and 10 in Appendix A, preceding the works vehicles. The signs in the central reserve are walked across by the operatives along with the A-frame and sandbags. This procedure repeats for the 1 mile, 800 yards, 600 yards, 400 yards and 200 yards boards.

Deployment of the advanced signing maintains the same level of risk as both require a traffic management vehicle to stop in the hard shoulder and have operatives deploy signs on both sides of the carriageway. The Conemaster system makes no difference to procedure until it is in place to drop the first cone of the closure.

The current standard method for temporary lane closures requires operatives to manually deploy all of the required cones and signs. The operatives must drop all the cones from the side of the vehicle before walking them into the correct location. They must also deploy all of the cone lamps manually, placing them on top of the correct cones.

Where operatives are setting a taper adjacent to the hard shoulder (nearside closure), the hard shoulder represents a place of safety to which the operatives can withdraw when they are at risk from road users. When working in the centre of the road adjacent to the barrier, they may not be able to retreat to a place of safety, especially if concrete central barrier is installed. In this case, the Conemaster achieves a significant safety reduction for offside closures by providing a place of safety for the road workers, which is reflected in the risk matrix.

The Conemaster system standard operation does not require operatives to set foot on the carriageway during the cone drop phase. Conemaster is a single-stage process which is not dependent on the pre-placement of cones. When using the Conemaster system to close lanes operatives stand on the rear of the vehicle to deploy cones and lamps. They are only required to stand on the carriageway when the signs have to be deployed.

Specific issues relating to different types of closure are presented in Appendix F. Comparing the risks allows assessment of the Conemaster exposure risk against the manual method of cone deployment.

The potential benefits to road worker safety from the use of Conemaster (or similar systems) can be examined by from this comparison of risk associated with the automated process against risk associated with the manual method of cone deployment for temporary traffic management.

The risk assessment matrix below shows areas where the risk is reduced by the automated process in green, areas where there is no change in risk in yellow and areas where risk increases when using the automated process in red.

Table 2 –Risk Assessment Matrix

Risk Criterion	Single lane offside closure	Two lane offside closure	Single lane nearside closure	Two lane nearside closure	Complex closure
Speed to create taper	↓	↑	↓	↑	↔
Speed to create longitudinal	↔	↔	↔	↔	↔
Exposure to risk of operatives on carriageway	↓	↔	↓	↔	↔
Presence of "safe place" adjacent to lane being closed	↓	↓	↔	↔	↔
Risk to operatives on vehicles	↓	↓	↓	↓	↓
Number of operatives exposed to risk	↑	↑	↑	↑	↑
Accuracy of deployment	↔	↑	↔	↑	↑
Deployment and direction of cone lamps	↔	↔	↔	↔	↔
Installation of signs	↔	↔	↔	↔	↔
Retrieval of cones	↓	↔	↓	↔	↑
Safety of operatives	↓	↔	↓	↔	↑
Safety of public	↔	↔	↔	↔	↔

The overall risk reduction can be calculated based on exposure criteria represented in Table 3:

Table 3 – Overall risk change matrix

Lane closure type	**Increase in risk to road workers using automated cone laying** ←			No risk change	**Decrease in risk to road workers using automated cone laying** →			
Single lane nearside							+4	
Two lanes nearside		-2						
Single lane offside								+5
Two lanes offside			-1					
Complex lane closures	-3							

The results suggest that in terms of exposure to risk the Conemaster is optimised for deploying single lane closures on the nearside and offside, with the offside showing the greater reduction in risk. Complex closures show the most increased risk, with multiple lane closures showing a slightly increased risk. This is, however, based on the Carillion method statement; use of a different method would undoubtedly show a changed risk balance, but it is probable that the significant risk reductions achieved from single lane closures would be retained.

The single-stage process used by the Conemaster system is thus highly suited to works such as barrier repairs or cyclical maintenance where single lane closures are routinely carried out.

This assessment has not considered the resource implications of using the Conemaster system in this risk comparison, other than the need for an additional vehicle and driver to provide impact protection for the Conemaster system.

6 Conclusions and Recommendations

The Conemaster system is a semi-automatic cone placement and retrieval system that is designed to offer traffic management operatives reduced risk when installing traffic management. It is manually fed with cones by two operatives on the rear of the vehicle and is capable of placing and retrieving cones fitted with road danger lamps.

The purpose of the trial was to determine if the Conemaster system could perform reliably and consistently while reducing the exposure of road workers to live traffic situations.

Despite the length of the trial, the results taken from data gathered by the operatives are not definitively conclusive on reliability. The machine conveyor belt wore out during the early part of the trial, although it was agreed in retrospect that a new belt should have been installed by Jordan Products before going to trial.

The weather conditions and staff training problems during the trial meant that the machine was not utilised as much as had been anticipated. However, there were enough runs of the machine to assess its capabilities and limitations for use on the network.

The benefits from the use of Conemaster during the trial were identified as:

- For single lane closures the exposure of the operatives to live carriageway traffic is reduced. This is more significant for any closure where operatives need to cross the carriageway with cones. (This also applies when the other operational method is used as operatives still have to walk on the live carriageway to install a taper).
- The Conemaster system can drop and retrieve standard and relaxation tapers and longitudinal coning where cones have a lamp of the correct type placed on the top.
- There are very few misaligned cones or lamps during deployment.
- Manual handling is significantly reduced during deployment and retrieval procedures. This was noticeable for the conveyor operator who would normally be in the cone well.
- The Conemaster system must always operate behind an IPV, under the terms of the SVO, therefore operatives are protected from live traffic by a crash cushion vehicle.
- The machine can operate in the weather conditions in which a normal TM team would be expected to work.

The main issues identified during the trial were:

- The machine must always be used with a separate IPV (Impact Protection Vehicle) per lane closed with associated vehicle, driver availability and cost implications.
- The Conemaster system has difficulties completing large or complicated layouts, as it lacks flexibility of operation compared to manual cone laying methods
- More and better training in accordance with the Jordan Products Conemaster training program (which was unavailable at the time) was required for operatives
- Poor weather operations were a challenge for the system, with cones slipping on the conveyor, particularly during retrievals.

The assessment of risk and operational experience suggests that the Conemaster is highly suited for single lane offside and nearside tapers, using the Carillion method statement.

With operational experience it is felt that the opportunities to maximise the benefits from any cone laying machine could be realised into actual time and risk reductions associated with placing and removing cones for lane closures.

Following the trial, Carillion indicated that if the Conemaster system were only to be utilised for single lane closures then it would only be used a small percentage of the time as most closures are multiple lane or complex layouts. It has been suggested that it may well be of more use for cyclical maintenance work, where its use could be planned well in advance, than for reactive traffic management.

The following suggestions were made for potential improvements to the Conemaster that would improve its operational usability:

- Add a buzzer to the set up which emits an audible sound three cones before the end of the taper drop phase. This will prevent the last sequential flashing lamp being missed out.
- Installing an alignment device to the Conemaster system to assist with reversing the vehicle along the closure during the retrieval phase.
- Install a moveable floor in order for the cones to be more easily reached, by bringing them towards the operatives when they are running out.
- Increase the height of the vehicle frames above the floor, as they are currently an issue for taller operatives. i.e. bumping into the frames.
- Increase the tolerance of the Conemaster system to the different types of 1 metre cones.
- Change the harness for one that is easier for an operative to remove themselves, in case the need ever arose.
- Install an intercom for the driver to communicate with the rear operatives.

Acknowledgements

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Disclaimer

All trade names used in this report are acknowledged as the property of their respective owners.

The inclusion of any item, product or technique in this report does not equal endorsement by the Road Workers' Safety Forum, Carillion plc, the Highways Agency, TRL or the Transport Research Foundation.

Glossary of terms and abbreviations

Conemaster (system/machine)	The cone laying system (comprising the vehicle and associated equipment) produced by Jordan Products.
Offside (lane)	The right hand lane or lanes of a carriageway
Nearside (lane)	The left hand lane or lanes of a carriageway
Taper	The line of cones that angle across a lane of the carriageway
Longitudinal	The line of cones that separates the closed lane from the live lane
Carillion plc	A major company involved in construction and road maintenance; one of the Highways Agency's Supply Chain partners.
Traffic management (TM)	Operations which manage traffic flow on the highways, usually to instigate repairs to infrastructure
Impact Protection Vehicle (IPV)	A vehicle which incorporates a lorry mounted crash cushion into the rear.
Diagram 610 arrow sign	Sign number 610 from 'The Traffic Signs Regulations and General Directions 2002, Schedule 2 Regulatory signs'. (The arrow may point downwards to the right or to the left).
Sequential flashing cone lamp	A road danger (cone) lamp which flashes in sequence with others along the line of the cone taper. Used on the taper to make drivers aware of the closure of a lane
Standard cone lamp	A road danger (cone) lamp which does not flash and is used on the longitudinal section of cones.
Conveyor	Part of the Conemaster; made up of several sections, automatically transports the cones to or from the road surface
Operatives	The traffic management team of (conventionally) three members who deploy and retrieve traffic management.
Closures	A lane of the highway that is closed off the traffic, which enable work to be done in that location.
A-frames	A large metal frame with four legs which opens into an A shape and is used to display temporary traffic signs
Detail A	A '610' arrow sign with three cones in front of it placed on the hard-shoulder

Appendix A Full Methodology

A.1 Current working methods

This section describes the method statements of current practice and use of the Conemaster system.

A.1.1 Single lane closure on the Nearside or left hand/most lane

- The operatives deploy advanced signing from the hard shoulder (including ‘workforce in road’ sign) on approach to the works location on the primary carriageway and end of works signing from the traffic management vehicle.
- The traffic management vehicle travels to next junction turns around and returns to previous junction via secondary carriageway. (Traffic management vehicles are not allowed to reverse on the carriageway therefore must loop around using the other carriageway).
- The traffic management vehicle returns to the work location on the primary carriageway and stops just after the 1 mile sign on the hard shoulder. The vehicle then deploys its crash cushion.
- The TM vehicle moves to the site of the taper parks in the hard shoulder with the crash cushion deployed. The operatives deploy the first ‘610’ sign arrow.
- The operatives begin to place the taper by walking the cones into lane 1 with every third cone having an activated sequential flashing cone lamp placed on it.
- Once the taper is complete the second ‘610’ is placed on an A-frame and placed in lane 1 at the end of the taper.
- The TM vehicle then drives in to the safety zone behind the taper. The operatives then begin to add the longitudinal section of coning from the cone well of the TM vehicle.
- A works access to the closure is added by placing a ‘works access’ sign and leaving a gap in the longitudinal.
- The operatives then begin to add the longitudinal section of coning from the cone well of the TM vehicle. Cones are placed 18 metres apart with a standard cone lamp on top.
- The traffic management vehicle and operatives leave the works zone after the ‘end of works’ sign is placed at the end of the coned area.
- The operatives must then use the secondary carriageway and return to the advanced sign ‘workforce in road’ to remove it or lay it down. This is always the last sign to be removed.

A.1.2 Two lane closure on the Nearside or left hand/most lane

- The operatives deploy advanced signing (including ‘workforce in road’ sign) on approach to the works location on the primary carriageway and end of works signing from the traffic management vehicle.
- The traffic management vehicle travels to next junction turns around and returns to previous junction via secondary carriageway. (Traffic management vehicles are not

allowed to reverse on the carriageway therefore must loop around using the other carriageway).

- The traffic management vehicle returns to the work location on the primary carriageway and stops just after the 1 mile sign. The vehicle then deploys its crash cushion.
- The TM vehicle moves to the site of the taper parks in the hard shoulder with the crash cushion deployed. The operatives deploy the first ‘610’ sign arrow.
- The operatives begin to place the taper by walking the cones into lane 1 with every third cone having an activated sequential flashing cone lamp placed on it.
- The operatives continue to deploy the taper across lane 2.
- Once the taper is complete the second ‘610’ is placed on an A-frame and placed in lane 2 at the end of the taper.
- The TM vehicle then drives in to the safety zone behind the taper. The operatives then begin to add the longitudinal section of coning from the cone well of the TM vehicle.
- A works access to the closure is added by placing a ‘works access’ sign and leaving a gap in the longitudinal.
- The operatives then begin to add the longitudinal section of coning from the cone well of the TM vehicle. Cones are placed 18 metres apart with a standard cone lamp on top.
- The traffic management vehicle and operatives leave the works zone after the ‘end of works’ sign is placed at the end of the coned area.
- The operatives must then use the secondary carriageway and return to the advanced sign ‘workforce in road’ to remove it or lay it down. This is always the last sign to be removed.

A.1.3 Single lane closure on the Offside or right hand/most lane

- The operatives deploy advanced signing from the hard shoulder (including ‘workforce in road’ sign) on approach to the works location on the primary carriageway. The operatives also drop the required number of cones for the taper on the verge, then end of works signing from the traffic management vehicle.
- The traffic management vehicle travels to next junction turns around and returns to previous junction via secondary carriageway. (Traffic management vehicles are not allowed to reverse on the carriageway therefore must loop around using the other carriageway).
- The traffic management vehicle returns to the work location on the primary carriageway and stops just after the 1 mile sign on the hard shoulder. The vehicle then deploys its crash cushion.
    - o *Carillion Traffic Management operational method (which varies from the standard Carillion method for the following indented section) - The vehicle drives across to the offside lane and parks at the beginning of the taper. Operatives exit on the non live traffic side of the vehicle and deploy the lead ‘610’ arrow sign. The vehicle then drives towards the end of the taper dropping cones and cone lamps on the non-traffic side of the vehicle. Working from the start of the taper, one operative walks the cones into position, the*

other watches for errant vehicles. The end of taper ‘610’ arrow sign is deployed in the closed lane at the end of the taper.

  - The TM vehicle moves to the site of the taper parks in the hard shoulder with the crash cushion deployed.
  - (A ‘610’ arrow sign is placed in the hard shoulder with three cones at a 45 degree angle in front of it. This is a Detail A, but is only used if the carriageway is narrowed to a single running lane)
  - The operatives cross the carriageway carrying the cones in stacks of three to the central reservation. This requires a minimum of 17 crossings (both directions).
  - The operatives carry the ‘610’ sign, frame and sandbags across the carriageway and deploy the ‘610’ sign arrow. This requires a minimum of three additional crossings (with operatives finishing in the central reservation).
  - The operatives walk the cones for the taper from the central reservation into the offside lane. Every third cone has an activated sequential flashing cone lamp placed on it.
  - Approximately 100 metres of longitudinal cones are added to create a safety zone, into which the TM vehicle moves as soon as it is clear.
  - From this position cones are dropped from the TM vehicle every three metres for the first 150 metres. The cones are lamped then walked out across the next lane.
  - Once the taper is complete the second ‘610’ arrow is placed on an A-frame and placed in the closed lane at the end of the taper.
- A works access to the closure is added by placing a ‘works access’ sign and leaving a gap in the longitudinal.
- The operatives then begin to add the longitudinal section of coning from the cone well of the TM vehicle. Cones are placed 18 metres apart with a standard cone lamp on top.
- The traffic management operatives leave the works zone after the ‘end of works’ sign is placed at the end of the coned area.
- The operatives must then use the secondary carriageway and return to the advanced sign ‘workforce in road’ to remove it or lay it down. This is always the last sign to be removed.

A.1.4 Two lane closure on the Offside or right hand/most lane

- The operatives deploy advanced signing from the hard shoulder (including ‘workforce in road’ sign) on approach to the works location on the primary carriageway. The operatives also drop the required number of cones for the taper on the verge, then end of works signing from the traffic management vehicle.
- The traffic management vehicle travels to next junction turns around and returns to previous junction via secondary carriageway. (Traffic management vehicles are not allowed to reverse on the carriageway therefore must loop around using the other carriageway).
- The traffic management vehicle returns to the work location on the primary carriageway and stops just after the 1 mile sign on the hard shoulder. The vehicle then deploys its crash cushion.

- *Carillion Traffic Management operational method (which varies from the standard Carillion method for the following indented section) - The vehicle drives across to the offside lane and parks at the beginning of the taper. Operatives exit on the non live traffic side of the vehicle and deploy the lead '610' arrow sign. The vehicle then drives towards the end of the taper dropping cones and cone lamps on the non-traffic side of the vehicle. Working from the start of the taper, one operative walks the cones into position, the other watches for errant vehicles. The operatives then begin to add a section of longitudinal coning at 3 metre spacing from the cone well of the TM vehicle Every third cone has an activated sequential flashing cone lamp placed on it. The operatives walk the taper into the next lane. The end of taper '610' arrow sign is deployed in the closed lane at the end of the taper.*
- The TM vehicle moves to the site of the taper parks in the hard shoulder with the crash cushion deployed.
- (A '610' arrow sign is placed in the hard shoulder with three cones at a 45 degree angle in front of it. This is a Detail A, but is only used if the carriageway is narrowed to a single running lane)
- The operatives cross the carriageway carrying the cones in stacks of three to the central reservation. This requires a minimum of 17 crossings (both directions).
- The operatives carry the '610' sign, frame and sandbags across the carriageway and deploy the '610' sign arrow. This requires a minimum of three additional crossings (with operatives finishing in the central reservation).
- The operatives walk the cones for the taper from the central reservation into the offside lane. Every third cone has an activated sequential flashing cone lamp placed on it.
- The TM vehicle then drives in to the safety zone behind the taper. The operatives then begin to add a section of longitudinal coning at 3 metre spacing from the cone well of the TM vehicle.
- The operatives continue to walk the taper into the next lane.
- Once the taper is complete the second '610' is placed on an A-frame and placed in the closed lane at the end of the taper.

- A works access to the closure is added by placing a works access sign and leaving a gap in the longitudinal.
- The operatives then begin to add the longitudinal section of coning from the cone well of the TM vehicle. Cones are placed 18 metres apart with a standard cone lamp on top.
- The traffic management operatives leave the works zone after the 'end of works' sign is placed at the end of the coned area.
- The operatives must then use the secondary carriageway and return to the advanced sign 'workforce in road' to remove it or lay it down. This is always the last sign to be removed.

A.1.5 Retrieval procedure

- The traffic management operatives return to the 'workforce in road' sign and redeploy it.
- TM vehicle returns to the closure and enters the safety zone by the works access when the crash cushion will be deployed.

- The works access is removed. The operatives then travel to the end of the works area, the operatives exit from the non-traffic side of the vehicle and pick up the ‘end of works’ sign.
- The operatives get on the rear of the vehicle which then reverses, picking up the longitudinal cones on the move.
- The TM vehicle stops when it reaches the ‘610’ sign at the end of the taper and the operatives remove it.
- Approximately six cones are placed across the lane at a 45 degree angle. The remaining cones are moved to the longitudinal position. The TM vehicle reverses to this point picking up the new longitudinal until it reaches the 6 cone taper. (Repeat for additional lanes).
- The remaining cones and the arrow sign are loaded on to the vehicle.
- Operatives re-enter the cab from the non-traffic side of the vehicle.
- The TM vehicle leaves the site with caution and raises its crash cushion.
- The TM vehicle returns to the site via the secondary carriageway to collect advanced signing on the primary carriageway. The vehicle stops and lowers the crash cushion once more. The operatives collect the signs up to and including ‘Men at Work End’ sign.
- The TM vehicle raises the crash cushion and leaves the work area.
- The TM vehicle travels via secondary carriageway and primary carriageway to collect ‘Workforce in road’ sign. This is always the last sign to be removed.

A.2 Conemaster working method

A.2.1 Nearside single lane Conemaster deployment

- The operatives deploy advanced signing from the hard shoulder (including ‘workforce in road’ sign) on approach to the works location on the primary carriageway and end of works signing from the traffic management vehicle.
- The traffic management vehicle travels to next junction turns around and returns to previous junction via secondary carriageway. (Traffic management vehicles are not allowed to reverse on the carriageway therefore must loop around using the other carriageway).
- Conemaster vehicle and traffic management vehicle meet up travel in convoy to the work location and stop just after the 1 mile sign on the hard shoulder. The TM vehicle then deploys its crash cushion to become an IPV.
- The operatives move to the site of the taper, parking both vehicles in the hard shoulder.
- IPV carefully moves into lane 1 and the Conemaster vehicle moves in front of it.
- The operatives deploy the ‘610’ arrow sign and then get on the back of the vehicle, the conveyor operator harnesses to the frame and sets the vehicle for a lane 1 (nearside) taper.
- The operatives communicate to the driver and begin deploying the taper. An activated sequential flashing cone lamp is added to every third cone.

- Once the taper is complete the second ‘610’ arrow is placed on an A-frame and placed in lane 3 at the end of the taper.
- The Conemaster system starts to add longitudinal for the safety zone.
- The IPV can join the Conemaster vehicle in the closed lane.
- A works access to the closure is added by placing a ‘works access’ sign and leaving a gap in the longitudinal.
- The operatives then begin to add the longitudinal section of coning from the cone well of the TM vehicle. Cones are placed 18 metres apart with a standard cone lamp on top.
- Both traffic management vehicles leave the works zone after the ‘end of works’ sign is placed at the end of the coned area.
- The operatives must then use the secondary carriageway and return to the advanced sign ‘workforce in road’ to remove it or lay it down. This is always the last sign to be removed.

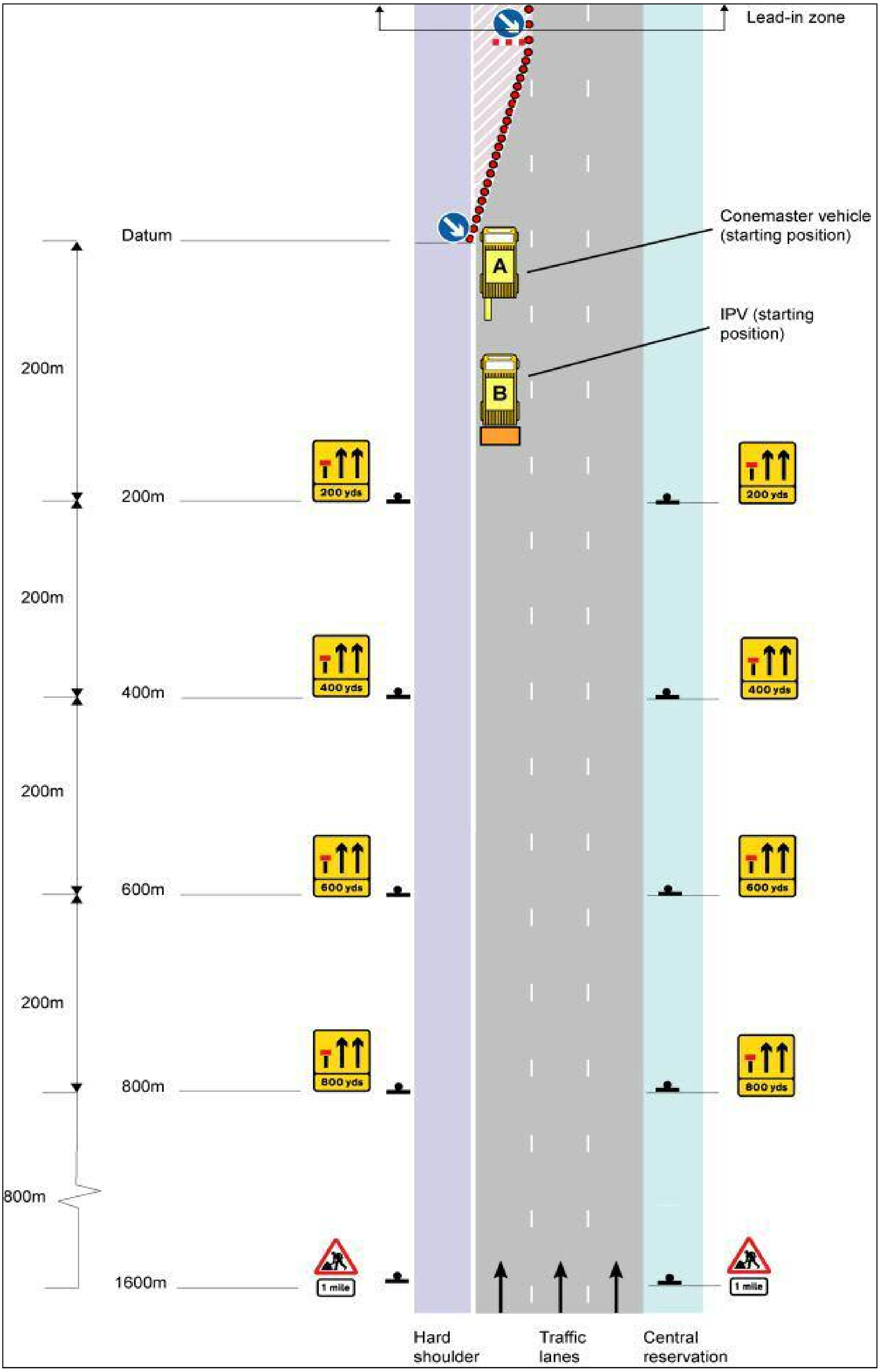

Figure 9 - Nearside Conemaster system deployment

A.2.2 *Nearside two lane Conemaster deployment*

- The operatives deploy advanced signing from the hard shoulder (including 'workforce in road' sign) on approach to the works location on the primary carriageway and end of works signing from the traffic management vehicle.
- The traffic management vehicle travels to next junction turns around and returns to previous junction via secondary carriageway. (Traffic management vehicles are not allowed to reverse on the carriageway therefore must loop around using the other carriageway).
- Conemaster vehicle and traffic management vehicle meet up travel in convoy to the work location and stop just after the 1 mile sign on the hard shoulder. The TM vehicle then deploys its crash cushion to become an IPV.
- The operatives move to the site of the taper, parking both vehicles in the hard shoulder.
- IPV carefully moves into lane 1 and the Conemaster vehicle moves in front of it.
- The operatives deploy the '610' arrow sign and then get on the back of the vehicle, the conveyor operator harnesses to the frame and sets the vehicle for a lane 1 (nearside) taper.
- The operatives communicate to the driver and begin deploying the taper. An activated sequential flashing cone lamp is added to every third cone.
- When the lane 1 taper is completed the Conemaster system deploys cones with sequential lamps at 3 metres apart on the offside of the vehicle at the edge of lane 2. These cones are then walked out to form the taper for the second lane.
- Once the taper is complete the second '610' arrow is placed on an A-frame and placed in lane 2 at the end of the taper.
- The Conemaster system starts to add longitudinal for the safety zone.
- The IPV can join the Conemaster vehicle in the closed lane.
- A works access to the closure is added by placing a 'works access' sign and leaving a gap in the longitudinal.
- The operatives then begin to add the longitudinal section of coning from the cone well of the TM vehicle. Cones are placed 18 metres apart with a standard cone lamp on top.
- Both traffic management vehicles leave the works zone after the 'end of works' sign is placed at the end of the coned area.
- The operatives must then use the secondary carriageway and return to the advanced sign 'workforce in road' to remove it or lay it down. This is always the last sign to be removed.

A.2.3 *Offside single lane Conemaster deployment*

- The operatives deploy advanced signing from the hard shoulder (including 'workforce in road' sign) on approach to the works location on the primary carriageway and end of works signing from the traffic management vehicle.
- The traffic management vehicle travels to next junction turns around and returns to previous junction via secondary carriageway. (Traffic management vehicles are not

allowed to reverse on the carriageway therefore must loop around using the other carriageway).

- Conemaster vehicle and traffic management vehicle meet up travel in convoy to the work location and stop just after the 1 mile sign on the hard shoulder. The TM vehicle then deploys its crash cushion to become an IPV.
- The operatives move to the site of the taper, parking both vehicles in the hard shoulder.
- (A ‘610’ arrow sign is placed in the hard shoulder with three cones at a 45 degree angle in front of it. This is a Detail A, but is only used if the carriageway is narrowed to a single running lane)
- IPV carefully moves into lane 2/3/4 and the Conemaster vehicle moves in front of it.
- The operatives deploy the ‘610’ arrow sign and then get on the back of the vehicle, the conveyor operator harnesses to the frame and sets the vehicle for a lane 2/3/4 (offside) taper.
- The operatives communicate to the driver and begin deploying the taper. An activated sequential flashing cone lamp is added to every third cone.
- Once the taper is complete the second ‘610’ arrow is placed on an A-frame and placed in the closed lane at the end of the taper.
- The Conemaster vehicle starts to add longitudinal for the safety zone.
- The IPV can join the Conemaster vehicle in the closed lane.
- A works access to the closure is added by placing a ‘works access’ sign and leaving a gap in the longitudinal.
- Conemaster vehicle proceeds to add required length of longitudinal.
- Both traffic management vehicles leave the works zone after the ‘end of works’ sign is placed at the end of the coned area.
- The operatives must then use the secondary carriageway and return to the advanced sign ‘workforce in road’ to remove it or lay it down. This is always the last sign to be removed.

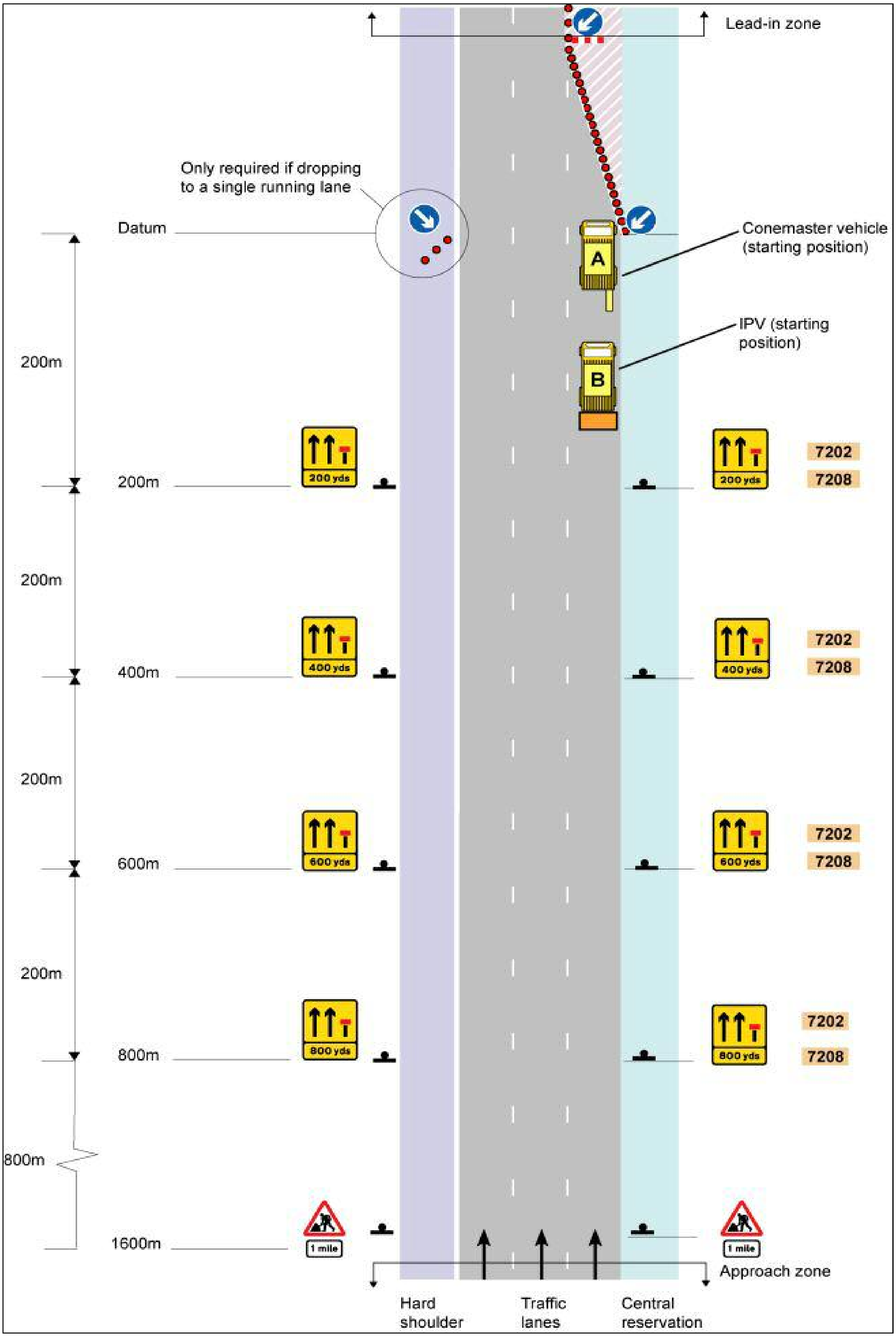

Figure 10 - Offside Conemaster system deployment

A.2.4 Offside two lane Conemaster deployment

- The operatives deploy advanced signing from the hard shoulder (including 'workforce in road' sign) on approach to the works location on the primary carriageway and end of works signing from the traffic management vehicle.
- The traffic management vehicle travels to next junction turns around and returns to previous junction via secondary carriageway. (Traffic management vehicles are not allowed to reverse on the carriageway therefore must loop around using the other carriageway).
- Conemaster vehicle and traffic management vehicle meet up travel in convoy to the work location and stop just after the 1 mile sign on the hard shoulder. The TM vehicle then deploys its crash cushion to become an IPV.
- The operatives move to the site of the taper, parking both vehicles in the hard shoulder.
- (A '610' arrow sign is placed in the hard shoulder with three cones at a 45 degree angle in front of it. This is a Detail A, but is only used if the carriageway is narrowed to a single running lane)
- IPV carefully moves into lane 2/3/4 and the Conemaster vehicle moves in front of it.
- The operatives deploy the '610' arrow sign and then get on the back of the vehicle, the conveyor operator harnesses to the frame and sets the vehicle for a lane 2/3/4 (offside) taper.
- The operatives communicate to the driver and begin deploying the taper. An activated sequential flashing cone lamp is added to every third cone.
- When the offside lane taper is completed the Conemaster system deploys cones with sequential lamps at 3 metres apart on the nearside of the vehicle at the edge of the next lane. These cones are then walked out to form the taper for the second lane.
- Once the taper is complete the second '610' arrow is placed on an A-frame and placed in the closed lane at the end of the taper.
- The Conemaster system starts to add longitudinal for the safety zone.
- The IPV can join the Conemaster vehicle in the closed lane.
- A works access to the closure is added by placing a 'works access' sign and leaving a gap in the longitudinal.
- Conemaster vehicle proceeds to add required length of longitudinal.
- Both traffic management vehicles leave the works zone after the 'end of works' sign is placed at the end of the coned area.
- The operatives must then use the secondary carriageway and return to the advanced sign 'workforce in road' to remove it or lay it down. This is always the last sign to be removed.

A.2.5 Conemaster single lane retrieval procedure

- The operatives return to the 'workforce in road' sign and redeploy it.
- The Conemaster vehicle returns to the closure and enters the safety zone by the works access.

- The works access is removed. The operatives then travel to the end of the works area, the operatives exit from the non-traffic side of the vehicle and pick up the ‘end of works’ sign.
- The operatives get on the rear of the vehicle which then reverses, picking up the longitudinal cones on the move.
- The TM vehicle stops when it reaches the ‘610’ sign at the end of the taper and the operatives remove it.
- The IPV moves into position at the front of the taper.
- The Conemaster vehicle reverses along the taper picking up the cones and lamps, then raises the conveyor into the park position.
- The operatives remove the ‘610’ arrow sign.
- Operatives re-enter the cab from the non-traffic side of the vehicle.
- The Conemaster vehicle and IPV leave the site with caution.
- The TM vehicle returns to the site via the secondary carriageway to collect advanced signing on the primary carriageway. The vehicle stops and lowers the crash cushion once more. The operatives collect the signs up to and including ‘Men at Work End’ sign.
- The TM vehicle raises the crash cushion and leaves the work area.
- The TM vehicle travels via secondary carriageway and primary carriageway to collect ‘Workforce in road’ sign. This is always the last sign to be removed.

A.2.6 Conemaster two lane retrieval procedure

- The operatives return to the ‘workforce in road’ sign and redeploy it.
- The Conemaster vehicle returns to the closure and enters the safety zone by the works access.
- The works access is removed. The operatives then travel to the end of the works area, the operatives exit from the non-traffic side of the vehicle and pick up the ‘end of works’ sign.
- The operatives get on the rear of the vehicle which then reverses, picking up the longitudinal cones on the move.
- The TM vehicle stops when it reaches the ‘610’ sign at the end of the taper and the operatives remove it.
- The Conemaster vehicle then moves into the next closed lane.
- The Conemaster operatives get off the vehicle and walk the taper to the edge of the lane. The Conemaster operatives get on the vehicle again and reverse the vehicle picking up the new longitudinal.
- The IPV moves into position at the front of the taper.
- The Conemaster vehicle reverses along the taper picking up the cones and lamps, then raises the conveyor into the park position.
- The operatives remove the ‘610’ arrow sign.
- Operatives re-enter the cab from the non-traffic side of the vehicle.
- The Conemaster vehicle and IPV leave the site with caution.

- The TM vehicle returns to the site via the secondary carriageway to collect advanced signing on the primary carriageway. The vehicle stops and lowers the crash cushion once more. The operatives collect the signs up to and including ‘Men at Work End’ sign.
- The TM vehicle raises the crash cushion and leaves the work area.
- The TM vehicle travels via secondary carriageway and primary carriageway to collect ‘Workforce in road’ sign. This is always the last sign to be removed.

Appendix B **Special Vehicle Order (SVO)**

Order of the Secretary of State for Transport under Section 44

The Secretary of State for Transport, in exercise of his powers under Section 44 of the Road Traffic Act 1988, hereby authorises the use on roads of the motor vehicle described in the Schedule hereto notwithstanding that, when fitted with a cone laying device, it does not comply with Regulation 11 of the Road Vehicles (Construction and Use) Regulations 1986 S.I. 1986 No. 1078 as amended, subject to the following conditions:-

- The vehicle shall be operated only by or on behalf of Jordan Products Limited.
- When the vehicle is used on the roads without the Cone Laying Device fitted, Regulation 11 of the said Regulations shall apply.
- When equipped with the Cone Laying Device The vehicle shall only be used for and in connection with deployment of traffic cones (and road danger lamps).
- When stowed the Cone Laying Device shall be positioned centrally and the requirements of regulations 81 and 82 shall apply as if the device were regarded as part of a load or apparatus projecting beyond the rear of the vehicle.
- When being operated on the roads with the Cone Laying Device in the deployed position, the rear of the vehicle shall be protected by a sufficient number of suitable vehicles fitted with rear mounted crash cushion(s).
- Red reflective tape shall be applied as far as practicable on the rearward facing surfaces of the cone laying device.
- When deployed, the device shall be regarded as a trailer for the purposes of compliance with the Road Vehicles Lighting Regulations 1989 No. 1796, as amended.
- The vehicle shall comply in all aspects with the Road Vehicles Lighting Regulations 1989 No. 1796, as amended.
- Notwithstanding that the vehicle does not comply at all times with Regulation 11 of the Road Vehicles (Construction and Use) Regulations 1986,as amended, it shall comply with all other requirements of those regulations.

Appendix C **Conemaster System images**








Appendix D **Guided Interview Questionnaire**

Questionnaire – Cone Laying Machines

Section A

Q1 – What training qualifications do you currently have relating to work on the roads?

Q2 – How would you normally complete a lane closure on the motorway? Describe the differences if you were to install different types of closure. (i.e. lane 1 closure, lane 3,2 closure)

Q3 - How long would it take to install a taper using this method?

What are the differences in operating methods between normal lane closures and cone laying machine methods?

Q4 – Could you describe the training you received in order to operate the cone laying machine?

Who trained you and how long did it take?

Q5

(a) - Was the training adequate for you to perform your job?

Yes	No

(b) Could the training be improved in any way?

Yes	No

(c) Do you have any suggestions for improving the training?

(d) How does the training differ between the cone laying machine and standard methods of lane closure?

<u>Q5</u> - What role does the IPV take in the cone laying machine deployment?

Describe any differences in the role of the IPV between normal lane closure operations and cone laying machine methods.

<u>Q6</u> – Which operating position were you employed in during the trial? i.e. driver etc.

Driver	Conveyor	Stacker

What is your normal operating position?

Driver	Other	Stacker

What are the cone laying machine's advantages?

What are its disadvantages?

<u>Driver related Question's</u>

<u>Q7</u> - Please could you describe the process of a using the cone machine as from a driver's perspective.

<u>Q8</u> - Could you describe any issues that you encountered while operating the vehicle?

<u>Q9</u> - *Are there any improvements which you think could be made to the machine?*

Yes	No

Are there any improvements that could be made to the operating methods of the machine?

Yes	No

<u>Q10</u> – Safety

What safety briefings did you receive for the cone laying machine?

Did the risk assessment adequately cover the operating procedures of the machine?

Could you communicate with your colleagues adequately using the cone laying machine?

Did you feel more or less safe while using the machine compared to normal? Why?

More safe	Less safe	Same

Did you feel your colleagues were more or less safe while using the machine? (Give reasons for your answer.)

More safe	Less safe	Same

<u>Q11</u> – Driving the machine

Was the cone laying machine easier or more difficult to operate than a standard TM vehicle?

Easier	More difficult	Same

<u>Q12</u> – What extra demands does driving the cone laying machine place on the driver compared to a standard vehicle?

<u>Q13</u> – Standard method replacement

If your company was to obtain one, would you feel comfortable using it instead of standard traffic management methods? (What reasons do you have for your opinion?)

Comfortable	Uncomfortable	Same

Q14 – Improvements

Are there any improvements which you think could be made to the machine?

Yes	No

Q15 *- Are there any improvements that could be made to the operating methods of the machine?*

Yes	No

Q16 - Replacement

If your company was to obtain one, would you feel comfortable using it instead of standard traffic management methods? (What reasons do you have for your opinion?)

Yes	No

Conveyor Operator/ Stacker Questions

Q17 - Please could you describe the process of a using the cone machine as a from an operator's perspective.

Q18 - Could you describe any issues that you encountered while operating the vehicle?

Q19 – Improvements

Are there any improvements which you think could be made to the machine?

Yes	No

Are there any improvements that could be made to the operating methods of the machine?

Yes	No

Q20 – Alignment of cones

Was the taper consistently well aligned?

Yes	No

Was the longitudinal consistently well aligned?

Yes	No

If either are no answers, what specific problems were encountered?

Q21 – What is the current procedure for placing cone lamps on cones? How does this differ when using the cone laying machine?

Q22 - *If cone lamps were put out by the machine were they positioned and aligned correctly? If not, what was wrong with them?*

Q23 - How were the cone lamps taken in? Does this differ from standard practice?

<u>Q24</u> – Safety

What safety briefings did you receive for the cone laying machine?

<u>Q25</u> - *Did the risk assessment adequately cover the operating procedures of the machine?*

<u>Q26</u> - Could you communicate with your colleagues adequately using the cone laying machine?

<u>Q27</u> - *Did you feel more or less safe while using the machine compared to normal? Why?*

More safe	Less safe	Same

Did you feel your colleagues were more or less safe while using the machine? (Give reasons for your answer.)

More safe	Less safe	Same

<u>Q28</u> - Does the cone laying machine take more or less time to complete a closure than standard TM?

<u>Q29</u> – *If your company was to obtain one, would you feel comfortable using it instead of standard traffic management methods? (What reasons do you have for your opinion?)*

Comfortable	Uncomfortable	Same

Appendix E **Table of Results**

Date	Weather conditions	Location	Type of closure	Time to deploy taper (mm:ss)	Length of longitudinal (m)	Time to deploy longitudinal (mm:ss)	Time to remove closure (mm:ss)	Placement and retrieval failures?	Complete system failures	Comments by operatives
13/10/09		M40 J8-9								Cones lamped manually due to unavailability of new style cone lamps.
14/10/09		M40 J8-9								"
15/10/09		M40 J9-10								"
16/10/09		M40 J9-10								"
21/10/09		M40 J5-4								"
22/10/09		M40 J9-10								"
23/10/09		M40 J9-10								"
29/10/09	Dry	M40 116/5 A c/w	Lane 1	3:13	2000	17:00	21:55 (including signs)	None	None	Went very well, all happy
4/11/09	Damp - rain moved in	M40 B c/w, 67/7	3 + 2	3:50 per taper	1400	16:00	37:00 (including signs)	3 lamps fell off	none	Picked up very well when very wet
5/11/09	Damp	M40 A c/w 65/3	3 + 2	4:12 & 4:00	300	7:31	18:00 (including signs)	None	None	very well, had a good crew on the cone layer
10/11/09	Damp, light fog	M40 A c/w 140/0	Lane 1	4:19	2000	16:28	28:00 (including signs)	Dropped 2 cones together 3 times	none	Belt making funny noise
26/11/09	Dry	M40 B c/w 44/6	Lane 3 + 2	2:50 & 3:19	1200	8:06	20:00	None	None	None
7/12/09	Damp	M40 42/3 to 41/6	Lane 4 + 3	2:22 for first taper, no timing for second taper	300	5:00 (including w/accots)	14:35 (including internal plate)	Dropping out tapers @ 200m instead of 150m. Also missed 3 cones in taper at different intervals.	None	Enjoyed using machine
8/12/09	Damp	M40 A c/w, 93/4 to 95/8	Lane 1	5:30	400	6:20	18:20 (including internal plate)	Leaving gaps in taper on layout. Top bar knocking cones over on layout of run. Taper light not going out after 150m	None	Conemaster not stopping at 150m on taper. Phoned manager and informed him. Also cones sticking on conveyor belt dropping out.
9/12/09	Damp	M40 B c/w, 67/7 to 66/7	Lane 3 & 2	6:41 for first taper, unable to time second taper	700	10:40	20:15	Cones stuck in conveyor belt at bottom on taper 3 times, and on longitudinal run. Belt on top badly worn on join.	None	Played up installing closure. Cones sticking on taper and longitudinal. Picked up no problem.
10/11/09	Dry, patchy fog	M40 B c/w, 99/0 to 98/4	Lane 1	2:20	400	2:30	19:30 (Done next day as walk off)	None	None	All good

15/12/09	Dry	M40 46/2 to 44/0	Lane 3 & 2	2:59 (for first taper - the second had to be done manually)	1900	28:42	40:00	During installation cones jamming on belt. During removal belt catching due to damage. *Removed taper manually.*	None	Belt damaged to the point of not being able to use. Needs repair before next use.
04/01/10	Dry (cold)	M40 B c/w 73/9 to 71/5	Lane 3 & 2	3:15 1st taper, 2nd taper by hand	2100	32:28	35:00	None	None	Went fine, all ok
01/02/10	Dry	M40 B c/w 110/7 to 110/0	Lane 3 & 2	3:25	400	15:00 inc. w/a, w.e & ends	15:20	None	None	Good run
02/02/10	Dry	M40 A c/w 126/6 to 125/9	Lane 1	3:35	350	8:00	15:00	None	None	Good run again. Had a couple of cones not spaced right on taper, but all fine apart from that.
03/02/10	Dry	M40 76/9 to 80/8	Lane 1 & 2	3:35	5000	-	-	None	None	Good. Missed a couple of cones on taper. Built splitter & give way with c/cushion
04/02/10	Dry	M40 B c/w 107/7 to 103/4	Lane 1 & 2	4:22	4000	3:00:00	-	A few cone missing on taper	None	A big job for the Conemaster due to splitter & 2 give way details & length of hatching to cone off. A bit slow for such a hands on job. due to various details & ran out of cones etc.
25/02/10	Wet	M40 106/9 to 104/8	Lane 3 & 2	-	1800	-	-			

Appendix F **Comparative Risk Assessment**

Single lane nearside closure

Deployment of the taper varies as per the method statement. For Conemaster system the operatives stand on the rear of the vehicle and deploy cones from there. The standard method involves the operatives having to walk the taper into the carriageway from the hard shoulder. This gives the operatives a place of safety away from traffic into which they can retreat if vehicles pose a threat to their safety.

The Conemaster system method requires an IPV vehicle and driver to park in the live lane. Both methods require operatives to leave the back of the vehicle to deploy signs. Both methods are comparable for deploying the longitudinal, as operatives deploy cones from the vehicle. The Conemaster system method reduces manual handling for the operatives, mostly for the conveyor operator during the retrieval phase. Instead of having to swing cones from the carriageway to the vehicle bed, this operative only has to take cones from the conveyor and pass them to the operative behind.

Single lane offside closure

Deployment of the taper varies significantly in this case as per the method statement. Conemaster vehicle parks in the offside lane behind an IPV. Operatives only have to stand on the carriageway to deploy the signs. The standard method involves operatives having to cross the carriageway repeatedly to carry all the equipment needed to complete the taper.

When cones are being placed manually, operatives have no guaranteed place of safety away from traffic into which they can retreat if vehicles pose a threat to their safety. This is particularly true if there is concrete central reserve barrier in place at the taper location.

The Carillion operational method requires operatives to deploy cones from the side of the vehicle and then walk the cones into the live carriageway, along with the signs, from the central reservation.

Two lane nearside closure

The standard deployment method is similar to the single lane closure. Operatives walk out the taper for the first nearside lane then do the same for the second lane.

The Conemaster system method is the same as the single lane closure. When it reaches the second lane it deploys a longitudinal section, which is then walked in to the second lane of the carriageway by the operatives. Since the operatives are on the carriageway, there is no safety benefit from this method of operation. As well as walking out the second lane taper, operatives must make manual adjustments to the end of the first taper so that it joins with the second taper. To operate with the Conemaster system closing both lanes, a second IPV would have to stop in the second lane, then redeploy the Conemaster vehicle behind it. Staff and vehicle issues prevented this method from being used as two IPV’s are required and five staff. The manual readjustments to the end of the tapers would still be required.

Two lane offside closure

The standard deployment method is similar to the offside single lane method. Operatives must repeatedly cross the carriageway with all the equipment required for an offside single lane closure. Operatives install the taper then the TM vehicle moves into the closure. Cones are dropped from the vehicle in a longitudinal and then walked into the next lane to extend

the taper.
The Carillion operational procedure is similar to the single offside lane procedure. Operatives deploy the first taper by walking it into the offside lane. They will then set out another 150 metres of cones on the opposite lane edge. Then they must go back and walk these out into the next lane to close it.

The Conemaster system procedure is the same as for a two lane nearside closure. The Conemaster system deploys one taper, then a longitudinal at 3 metre centre cones. Operatives then walk the taper into place. As with the two lane nearside closure two IPV's must used to avoid operatives having to complete a full lane taper on the carriageway, but some manual adjustment would still be required. Staffing issues, as above, would prevent this method being used. This would mean the operatives walking out the second closure by hand from the carriageway, therefore providing little safety benefit.

Three lane closures

If three lanes were closed then procedures apply as above. For each extra lane with the Conemaster system, an extra IPV is required otherwise operatives must work on the carriageway unprotected. When this happens the standard method of operation and the Conemaster system method are little different from each other.

Complex closures

The Conemaster system is capable of completing complex closures which involve slip road entrances and exits. These often involve a large quantity of cones and signs which the Conemaster vehicle is unable to carry. It is also very likely that operatives would have to leave the vehicle to finish sections that the Conemaster system is unable to complete in these closures.

If the Conemaster system was to be used it is likely to take multiple runs of the vehicle through the closure area to complete. It is also likely that it would have to return to the depot for more cones and signs. (example within log table)

A standard TM vehicle is capable of carrying more cones and can complete more complex closure without the need to leave the site to collect more cones.