

SAFER WORKING ON ROADS – HOW CAN VULNERABLE ROAD WORKERS AND ROAD USERS BE SAFER?

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ABSTRACT

Depending on interpretation, some would define road workers as vulnerable road users and some not. Some would say that as they are workers, they do not classify as road users, this is like saying that postman while walking or using bicycle or moped is not vulnerable on the road, as he is doing his job? But I believe and we can probably all agree on, that road workers are vulnerable while they are working on our roads. On this matter PIARC Technical Report “Improvements in safe working on roads” was produced, so this paper will not address the same issues. In this paper, while seeing around the world different safety approaches considering the road workers, will be addressed only 4 C's principle and how can we improve the (existing) work zones to be more conspicuous, clear, consistent and credible and with that safer for road workers and road users. We must understand that particularly in low and middle income countries (LMICs), to implement the whole concept of all improvements in safe working on roads could be difficult and challenging, that's why we must find and present immediate practical measures for our workers on the road to make them safer.

1. THE 4 C's CONCEPT

Road engineers are in general familiar with the 4 (sometimes 5) E's for road safety: Engineering, Evaluation, Education, Enforcement and sometimes Emergency services or management. For the safe, efficient and effective management of Temporary Traffic Management (i.e. TTM) it is proposed that a 4 C's principle be adopted. TTM should be designed, operated and maintained in such a way that it is: Conspicuous, Clear, Consistent, and Credible.

We can look at the 4 C's concept in combination with the 4 E's. 5th E stands for Emergency services and is used when something already went wrong and we want to prevent that. Engineering, begins when qualified and proper educated engineer has to design the TTM; Evaluation is done by qualified and proper educated staff that can evaluate the TTM design (with safety in mind) as well the evaluation of the work zone itself after being installed; Education is one of the key elements for safety of road workers, as they have to be well educated and informed of danger working on the road and under the traffic, as of special hazards in particular work zone environment. They have to know how to take care for themselves as for other workers and participants in traffic, such as: pedestrians (especially disabled people, children), bicyclists, motorists, car drivers ...; and Enforcement to exercise control over drivers regarding speed regulation and to ensure safety on the road, as well to check the road workers if they are doing everything necessary for safe working (visible clothes, proper equipment ...).

1.1. Conspicuous [1]

“The first principle is that the driver must notice the work zone – it must be conspicuous. They must be physically able to see what is coming up. The work zone must be obvious, noticeable and eye-catching to attract the attention of the driver and to start the process of encouraging them to act in the desired way with regard to speed, position of vehicle and heightened attention. The objective is to provide noticeable early warning of the need for drivers to be alert to obstructions and/or deviations in the road.”



Figure 1 - Pictures shows inconspicuous vs. conspicuous work zones and road workers (TTM on right picture enables driver to see and re-act on time)

1.2. Clear [1]

“In order for drivers to make the correct decisions about how to safely approach and pass through road works all signing, guiding and other instructions must be clear. The driver needs to be absolutely certain about what is required. Signs must be visible from far enough in advance, given the likely approach speed, for the driver to be able to understand what is required and be able to carry out those instructions in a timely fashion.”



Figure 2 - Pictures shows unclear vs. clear work zone and workers (On right picture driver knows where to drive and recognizes the workers)

1.3. Consistent [1]

“Drivers can be conditioned to behave and act in a certain way by the consistent design and operation of work zones. But if drivers encounter differing standards, layouts and arrangements in different areas they become confused and uncertain how to proceed. This

in turn can lead to poor driving and a failure to act in the required way. All this is potentially detrimental to the safety performance of the work zone.”



Figure 3 - Pictures shows the difference of consistency
(Different principles of traffic arrangements for manual traffic management just a few kilometres apart)

1.4. Credible [1]

“The final principle involves the credibility or ‘believability’ of the instructions. Drivers must believe that what they are told (e.g. the need to slow down) and that the messages they are given are a true representation of what will occur ahead.”



Figure 4 - Pictures shows difference in credibility
(On left picture there are no road works after the traffic sign, while on right picture after the sign there are actual road works ahead)

1.1.1 Intertwining of the 4C concept

We must truly understand the driver and his needs when we are dealing with the 4C's concept. As seen in many figures above, we can also find other C's in the same picture. For example in Figure 4 there is an example of credibility, but we can also find an example of consistency (e.g. both signs should be set up at the same height), clearness (e.g. traffic sign on left picture is not clearly visible from far enough in advance) and conspicuousness (e.g. again the traffic sign on left picture is not conspicuous). So all C's are in a way interconnected and when understood and considered will give the driver what he needs and consecutively protect the workers.

2. ROAD ENVIRONMENTS

Sometimes we see deficiencies on the roads regarding TTM and consequently safety of road workers. Those deficiencies can be reduced or even eliminated with sufficient knowledge and effort. We also see many situations where road workers endanger themselves and other road users, thinking if they can see the drivers that mean drivers can also see them. But drivers often due to complexity of road environment and traffic tend to overlook the workers and TTM if not designed, installed and maintained properly.

2.1. Understanding the drivers needs and complexity of road environment

Many times engineers or those responsible for dealing with work zones and worker safety, blindly follow the rules and typical layouts for TTM, not understanding that if necessary work zone layout has to be adjusted according to circumstances on the road, with consideration of roads' environment and consequently the driver's needs. For example, there is a big difference in which environment is the work zone (motorway, country road or city street) in order to assure safety for road workers and road users.



Figure 5 - Road environments [2]

(Each road environment has different traffic complexity and saturation of space)

When setting up TTM and organize road workers' workspace on construction sight, responsible person for doing that should consider: complexity of traffic and road environment, traffic speed, location of existing traffic signage, basics of colour and light (e.g. time of day and season / ambient light, luminance, contrast ...) all that affects driver overall perception and influences on decision making process.

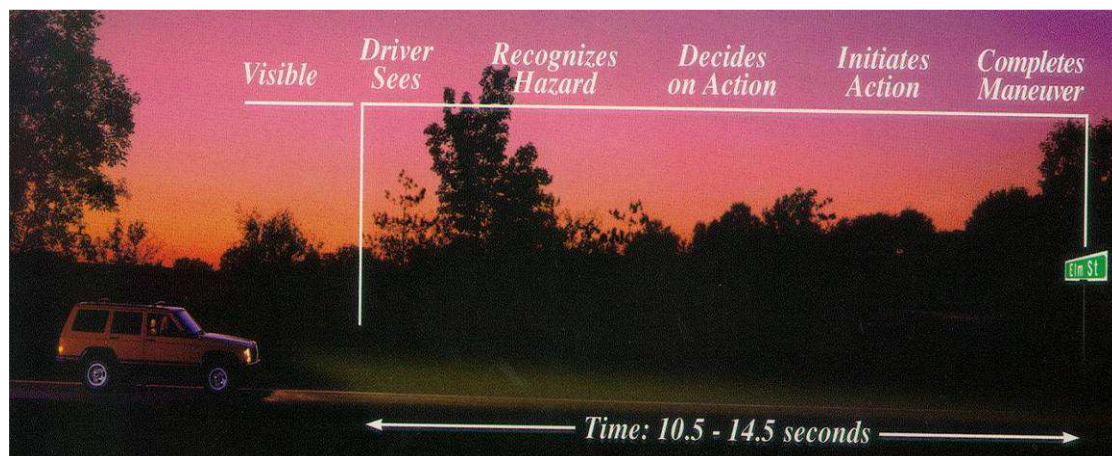


Figure 6 - Visual process [2]

(Visible does not mean the same as: seen, perceived and understood by the driver)

3. MOTORWAY ENVIRONMENT

Although motorway environment is controlled and has, generally speaking, most of the “Self-explaining” features, designing TTM on motorways is demanding. Motorways don’t have many junctions and other features like country and urban roads have, signing is minimum etc., but complexity varies depending on the environment in which the road goes thru, traffic volume, number of driving lanes etc. Drivers can experience from monotony and fatigue on strait sections to complexity, distraction and mental overload on ring roads and sections nearby or thru build up areas. High speeds, linked-up reaction time and braking distance require from workers full attention as even a small mistake, inattentiveness or distraction can lead to serious injuries or death due to severe impact collisions.



Figure 7 - Motorway environment
(From monotony to complexity)

Monotone environments and roads with low complexity demands little driver’s attention, that is why drivers often drive on “autopilots”, without attentive awareness of what is happening on the road. Therefore it is necessary to give a driver in advance notice of what is happening on the road. In order driver to make appropriate actions he must be stimulated several seconds before the work zone (approx. 10,5 – 14,5 sec. before as shown of Figure 6). It is very important that driver is not surprised by the situation on the road or confused. Difference in warning can be seen in Figure 8 and 9. Upper pictures in Figure 8 show warning with traffic cones and a flag on top of the vehicle and pictures below show warning with flashing lights (LED sign) on the vehicle. In Figure 9 we can see conspicuous traffic signs, so called “gate effect”, alerting driver of road works ahead. So different approaches are used according to TTM needs.



Figure 8 - Difference in the perception of work zone
(Different approaches of alerting the driver)



Figure 9 - Conspicuous traffic signs [3]
(Alerting driver of road works ahead)

Emphasized signage is also used in complex situations where ordinary traffic signage would not be conspicuous enough. As shown in Figure 10, perception of temporary traffic sign is diminished due to advertising billboards. In order to assure proper sign visibility the traffic sign has to be more conspicuous and with that predominant in drivers' field of view. This could be achieved by emphasizing traffic sign visibility with fluorescent or other contrast background or with motorway screens, also called incident screens. Screens function is to obscure the view of advertising billboards and make sign more visible.



Figure 10 - Conspicuousness of traffic sign due to billboards
(Enhance traffic sign and motorway screen as a contra measures)

Similar problem is shown in Figure 11, where beside conspicuousness there is also a problem of clearness of temporary traffic signage.



Figure 11 - Conspicuousness and clearness of traffic signage
(On right picture is shown enhance traffic signage with proper quality and maintenance)

Traffic signage requires regular maintenance especially on heavy volume roads, bad weather conditions, polluted environment etc. Signs and equipment has to be clean and conspicuous in order to be seen on time, perceived and consecutively understood and respected by the driver. As shown in upper left picture traffic signage is almost blended with the environment. In order to make it more visible / conspicuous it must be properly maintained, restored or replaced when it is worn out or damaged as shown on upper right picture.

In Figure 12 there is an example of good visibility of temporary traffic equipment on the middle road barriers. Left picture clearly demonstrates difference between left and right side of the road, where left side is marked with yellow line and clearly visible and right side is inconspicuous and has no proper markings and this could be a problem during night and poor weather condition.



Figure 12 - Conspicuousness and clearness of traffic equipment
(Good visibility of road barriers in different weather conditions)

In upper right picture there is good example of proper visibility of temporary road barrier on the left side of the road under wet conditions in comparison with right side of the road where existing road barrier is.

3.1. Road workers in motorway environment

We can divide road workers general in two categories, those who work physically on the road without any protection rather than temporary traffic equipment and those who are working with machinery with protection of a vehicle or machine frame. Road workers are also people who are driving to and from construction site or drivers and passengers surveying the road (see Figure 13).



Figure 13 - Conspicuousness of vehicles
(Visibility of vehicles and road workers safety)

In left upper picture are shown inconspicuous vehicle transporting unprotected and poorly visible workers in the back on a caisson. In the middle upper picture is conspicuous surveying vehicle and on the upper right picture are conspicuous maintenance vehicles driving on the motorway.

Unprotected road workers need the most attention and care in order to be safe in their working environment. Workers who set up and maintain temporary signage and equipment are exposed to greatest risk. That is why workers have to be highly visible / conspicuous from sufficient distance in advance. It is also very important that circumstances (weather, traffic conditions etc.) are favourable, that means are allowing good sight distances and visibility.



Figure 14 - Conspicuous road workers in high visible clothing
(Driver can detect workers from a distance)

In the work zone, within the worksite, workers do their job and do not pay attention to traffic since their mind is set up on work. Because of that it is essential for them to be physically separated from traffic.



Figure 15 - Buffer zone and side distance
(Protection of workers with a traffic trailer with buffer zone and side distance provided by traffic cones)

It is important to have a buffer zone between the beginning of the work site and place when work is going on. Beside the buffer zone physical protection is also at great importance. Physical protection can be done by vehicles, trailers, road barriers, road equipment or even with a pile of sand. It depends on construction site, traffic situation and TTM. When protecting road workers it is important that with worker protection we do not endanger other road users.



Figure 16 - Physical protection for the road workers and traffic guidance
(Variety of ways to protect the workers by separating and calming down traffic)

To ensure safe speeds, speed limits have to be credible and if necessary physical measures and enforcement has to be introduced in TTM.

Proper (credible and consistent) traffic guidance is important as well and all of the time of TTM, so the drivers are not confused or unclear which way to go or which lane to take.

4. COUNTRY ROAD ENVIRONMENT

Country road environment differs depending on the terrain and could be very monotonous or dynamic and complex. Speeds vary as well, from very low speeds on gravel roads and mountain roads to high speeds on straight long and wide road sections. In some circumstances, we could compare it to motorway road environment as it could be monotonous in combination with higher speed and in this situation advanced notice has to be given to drivers to divert them from monotony and stimulate their attention. This kind of pre-warning signs can be similar as on motorways (in a concept) to provide consistent traffic information (see Figure 17). The concept can be consistently used on all roads, depending on the situation.



Figure 17 - Pre-warning traffic signs for road works
(Variety of traffic signs: white, yellow and fluorescent yellow background)

In addition to temporary traffic signs road operators and designers of TTM also make use of information signage to give drivers pre-information of road works ahead (see Figure 18). Regardless of whether the information provided is a traffic sign or information sign we must always strive to make information 4C. In next figure there is an example of emphasized information board with white background and fluorescent yellow frame.



Figure 18 - Pre-warning traffic information for road works ahead
(Emphasized traffic information: white background and fluorescent yellow frame)

In Figure 19 is shown difference of unclear vs. clear information to the driver. To make information clear designer or responsible person for setting up TTM have to consider that "Less is more". In upper three pictures are traffic signs that are covering each other (warning signs for road works, signs for speed limit and signs for prohibition of overtaking) are confusing and creates unclear information to the driver. Beside the cluster of all the signage, driver is not informed of a road worker that manually manages traffic.



Figure 19 - Clear information of road works ahead
(Cluster of traffic signs vs. clear and credible information)

In bottom three pictures (upper figure) there are reduced traffic signs, properly relocated with additional sign for manual traffic management and traffic cones. Traffic sign for warning and speed limit are relocated (traffic sign for speed limit could also be set up with traffic sign for manual traffic management – depends on the concept of consistency of TTM in the country as well credibility), approximately 100 m in front of the worker for manual management of traffic is posted new traffic sign for manual traffic management. Sign for prohibition of overtaking is already posted as existing traffic sign so there is no need for additional one and sign for direction of travel (driving / passing by) is relocated closer to worker, to additionally with traffic cones alert and slow down drivers.

While working on the road under actual weather conditions which are unpredictable and are changing during the day, it is a challenge to provide clear and conspicuous information to a driver all of the time. Shown in Figure 20 there is an example of how can incline of a traffic sign and time of a day (position of the sun and angle of light) make sign due to a glare almost invisible.

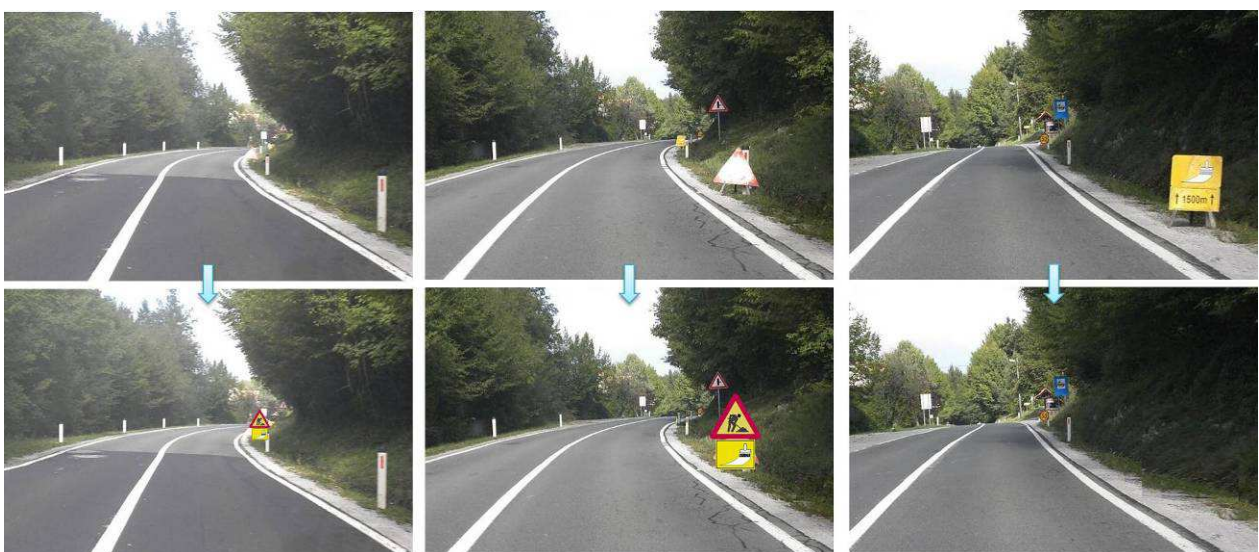


Figure 20 - Unclear information due to sun glare
(Difference of signs visibility due to incline and position of signs)

In figure above there is an example of visibility of traffic signs due to incline of signs and consequently sun glare. When sun position is in high zenith it is better to set up signs more upright to avoid sun glare. It is also better to set additional panel under the sign and therefore give improved and on time information to the driver about road marking works in progress. By combining compatible information we provide more accurate information by that reduce number of signage and consequently improve visibility of other signs (in this case the sign for speed limit).

4.1. Road workers in country road environment

In conjunction with Figure 20 we can see on Figure 21 the effect of sun glare (ambient light, luminance, contrast) on road workers and machinery.



Figure 21 - The effect of sun glare on visibility
(Sun glare can reduce the visibility and conspicuousness of signage, workers etc.)

In those situations, especially road marking works, safety of workers depends particularly on their own knowledge and experience. Workers have to be constantly alert and watch for each other. In those kinds of circumstances it is recommended to have, in addition to signs, extra workers to alert and slow down drivers (see Figure 22), especially before bends, road inflection point etc.



Figure 22 - Workers for manual management of traffic [4]

(Workers for alerting and slowing down traffic and for manual alternating of traffic)

It is at most importance that worker for manual traffic management never turn his back to the traffic, his eyes must constantly monitor traffic and what is happening on the road.

Occasionally, it is necessary to resort to measures to prevent vehicles to drive on or thru the work zone, so available resources can be used. In Figure 23 is shown how by using available resources driver are dissuade to drive on the newly build road and by that workers are safer as well.



Figure 23 - Preventing driving by using available resources
(Placed stones prevent driving on newly laid asphalt and ensure workers safety)

Stones also form an obstacle, especially for motorcycles, so by setting up traffic cones as additional guidance improves safety. Similar concept is also used for traffic calming and warning like tactile road equipment shown in Figure 24. As other road equipment it can also be used on other roads.



Figure 24 - Warning ramp / tactile road equipment [5]
(Traffic equipment for warning and slowing down drivers)

5. URBAN ROAD ENVIRONMENT

Urban road environment has its own specialities. Usually in urban environment speeds are not hi, except major city roads, but complexity of traffic is great. Because of its complexity, TTM has to be adjusted. Usually there is not enough space or distance to set up as many temporary traffic signs in advance as on country roads and motorways, but those which are set up have to be conspicuous among other C's. In Figure 25 is shown one of the solutions for emphasizing the traffic signs. Beside the panels also other measures can be used for emphasizing traffic sign (different colour, contrast panels and backgrounds, flashing lights).



Figure 25 - Conspicuousness of temporary traffic signs and ensuring width for pedestrians

Special care has to be given to other road users to enable them to safely pass by or thru work zone. Traffic equipment or work zone must not represent an obstacle or even endanger road users. When posting traffic signs there must always be enough space for pedestrians (handicapped people, prams etc.) to pass by, as shown in Figure 25.

Setting up TTM in urban environment represents challenge as there is often not enough space to implement all signage needed considering typical layouts. By adjusting the signage we must be innovative and adjust them in a way to ensure driver needs. In Figure 26 we can again see that “less is more” and what can be done with proper usage of temporary traffic signage. The leftmost and rightmost pictures show excessive use of signage, while the middle picture gives a driver enough information to safely pass by the construction site. Firstly we should consider driving rules in accordance with the law and then set up only necessary traffic signage.



Figure 26 - Clear and comprehensive temporary traffic signage
(Driving rules state that in this kind of situation vehicle with obstacle on its way has to give priority to oncoming traffic so additional sign “priority of oncoming traffic” is not required)

5.1. Road workers in urban road environment

In urban road environment we should also not neglect the importance for conspicuousness of road workers and their safety. No matter the environment road workers have to be visible all the time, also during the night and in poor weather conditions. If necessary also work zones / construction sites have to be visible and properly illuminated during the night, but not in a way to dazzle road users, especially drivers, as seen in Figure 27.



Figure 27 - Illumination and visibility of road worker during the night
(Improper illumination dazzles drivers and does not assure the visibility of a road worker)

Now even in poor weather conditions new technology made it possible for workers to be visible even without direct light (retro-reflectivity) with additionally illuminative safety equipment. That's why engineers must also be well acquainted with what the industry / market has to offer, but at the same time be very careful and prudent.

6. CNCLUSION

Road environments vary as and with those also basic principles of TTM. In general there are no strict boundaries between the approaches. As shown in this paper we can use and apply basic principles in all road environments. In general we have to understand the drivers and workers needs and how to provide Conspicuous, Clear, Consistent, and Credible information to road users. Learning from each other, exchanging knowledge and improving mistakes will help us to be better and to design TTM in safest way feasible. We shall constantly educate road workers, engineers, designers and road users and cooperate with enforcement when necessary. Collaboration with decision makers is also very important, so they can help us with improved legislation and to provide support for professional / expert solutions, which will lead to safer roads and working on roads.

There are still many things that were not described in the paper as road safety and safe working on roads are very extensive and can go into smallest details, which at the same time gives us plenty of possibilities to improve. At the end I would like to conclude with the sentence and appeal: "Respect our road workers. Roadworks are a place of work, and the people there deserve just as much respect as you would expect at work. On busy roads, day and night, in all weathers, they risk their lives improving our highways. Keeping them open. When you see roadworks, reduce your speed, drive with more care and keep them safe". [6]

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