UNECE

TEM Guidelines on Work Zone Safety

Trans-European North-South Motorway (TEM)

UNITED NATIONS

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UNITED NATIONS ECONOMIC COMMISSION FOR EUROPE

The United Nations Economic Commission for Europe (UNECE) is one of the five United Nations regional commissions, administered by the Economic and Social Council (ECOSOC). It was established in 1947 with the mandate to help rebuild post-war Europe, develop economic activity, and strengthen economic relations among European countries, and between Europe and the rest of the world. During the Cold War, UNECE served as a unique forum for economic dialogue and cooperation between East and West. Despite the complexity of this period, significant achievements were made, with consensus reached on numerous harmonization and standardization agreements.

In the post-Cold War era, UNECE acquired not only many new member States, but also new functions. Since the early 1990s, the organization has focused on assisting the countries of Central and Eastern Europe, the Caucasus and Central Asia with their transition process and their integration into the global economy.

Today, UNECE supports its 56 member States in Europe, Central Asia and North America in the implementation of the 2030 Agenda for Sustainable Development with its Sustainable Development Goals (SDG). UNECE provides a multilateral platform for policy dialogue, the development of international legal instruments, norms and standards, the exchange of best practices, and economic and technical expertise, as well as technical cooperation for countries with economies in transition.

Offering practical tools to improve people's everyday lives in the areas of environment, transport, trade, statistics, energy, forestry, housing and land management, many of the norms, standards and conventions developed in UNECE are used worldwide, and a number of countries from outside the region participate in UNECE work.

The multisectoral approach of UNECE helps countries to tackle the interconnected challenges of sustainable development in an integrated manner, with a transboundary focus that helps devise solutions to shared challenges. With its unique convening power, UNECE fosters cooperation among all stakeholders at the country and regional levels.

TRANSPORT IN UNECE

The UNECE Sustainable Transport Division is the secretariat of the Inland Transport Committee (ITC) and the ECOSOC Committee of Experts on the Transport of Dangerous Goods and on the Globally Harmonized System of Classification and Labelling of Chemicals. The ITC and its 20 working parties, as well as the ECOSOC Committee and its sub-committees, are intergovernmental decision-making bodies that work to improve the daily lives of people and businesses around the world, in measurable ways and with concrete actions, to enhance traffic safety, environmental performance, energy efficiency and the competitiveness of the transport sector.

The ECOSOC Committee was set up in 1953 by the Secretary-General of the United Nations at the request of the Economic and Social Council to elaborate recommendations on the transport of dangerous goods. Its mandate was extended to the global (multi-sectoral) harmonization of systems of classification and labelling of chemicals in 1999. It is composed of experts from countries which possess the relevant expertise and experience in the international trade and transport of dangerous goods and chemicals. Its membership is restricted in order to reflect a proper geographical balance among all regions of the world and to ensure adequate participation of developing countries. Although the Committee is a subsidiary body of ECOSOC, the Secretary-General decided in 1963 that the secretariat services would be provided by the UNECE Transport Division.

ITC is a unique intergovernmental forum that was set up in 1947 to support the reconstruction of transport connections in post-war Europe. Over the years, it has specialized in facilitating the harmonized and sustainable development of inland modes of transport. The main results of this persevering and ongoing work are reflected, among other things, (i) in 58 United Nations conventions and many more technical regulations which are updated on a regular basis and provide an international legal framework for the sustainable development of national and international road, rail, inland water and intermodal transport, including the transport of dangerous goods, as well as the construction and inspection of road motor vehicles; (ii) in the Trans-European North-South Motorway, Trans-European Railway and the Euro-Asia Transport Links projects that facilitate multi-country coordination of transport infrastructure investment programmes; (iii) in the TIR system, which is a global customs transit facilitation solution; (iv) in the tool called For Future Inland Transport Systems (ForFITS), which can assist national and local governments to monitor carbon dioxide (CO2) emissions coming from inland transport modes and to select and design climate change mitigation policies based on their impact and adapted to local conditions; (v) in transport statistics – methods and data – that are internationally agreed on; (vi) in studies and reports that help transport policy development by addressing timely issues based on cutting-edge research and analysis. ITC also devotes special attention to Intelligent Transport Services (ITS), sustainable urban mobility and city logistics, as well as to increasing the resilience of transport networks and services in response to climate change adaptation and security challenges.

In addition, the UNECE Sustainable Transport and Environment Divisions, together with the World Health Organization (WHO) – Europe, co-service the Transport Health and Environment Pan-European Programme (THE PEP).

Finally, since 2015, the UNECE Sustainable Transport Division has provided the secretariat services for the Secretary General's Special Envoy for Road Safety, Mr. Jean Todt.

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ACRONYMS AND ABBREVIATIONS

Acronym	Description
CEN	European Committee for Standardization
EAB	Electronic Arrow Board
EN	European Standard
GPS	Global Positioning System
ISO	International Organization for Standardization
ITS	Intelligent Transport Systems
LED	Light-Emitting Diode
RDS	Radio Data System
RSA	Road Safety Audit
RSI	Road Safety Inspection
TA	Traffic Announcement
TEM	Trans-European North-South Motorway
TMA	Truck (or Trailer) Mounted Attenuator
TMP	Traffic Management Plan
TS	Technical Specification
TTC	Temporary Traffic Control
TTCD	Temporary Traffic Control Devices
TTCP	Temporary Traffic Control Plan
TTM	Temporary Traffic Management
UN	United Nations
UNECE	United Nations Economic Commission for Europe
VMS	Variable Message Sign
WP	Working Party
WZSA	Work Zone Self-Assessment
WZRSA	Work Zone Road Safety Audits
WZRSI	Work Zone Road Safety Inspection

EXECUTIVE SUMMARY

Work zones pose specific risks not only to the road users driving through the complex arrangements of signs, road markings and lane changes but also to the workers who must build, repair and maintain the roads. These risks are mainly the result of the competition between workers and motorists for the limited road space available in work zones. To find the optimal work zone layout for a certain road section, different parameters must be considered and coordinated, and the speed limit must be adjusted to these factors. An overview of the current state of practice across TEM member countries revealed a multitude of design and signage practices for road work zones, with different characteristics that are often hard to understand for the road users, especially in cross border traffic.

Therefore, during the 73rd TEM Steering Committee session in Warsaw on 3 and 4 December 2019, TEM National Coordinators agreed to develop these *TEM Guidelines on Work Zone Safety*. The main focus of the *Guidelines* and their technical provisions is on the motorway network, even though the main work zone safety principles can easily be transferred to other parts of the network.

The *Guidelines* are based on a comprehensive review of the most relevant road work zone guidelines, standards, studies and projects (see Appendix 1), and address current trends, standards, technologies and equipment in road work zones on motorways in TEM member countries.

A meta-analysis of the current situation and existing national guidelines and standards for road work zones was carried out to identify good practice solutions and to develop a unified range of road work zone safety principles and measures that should govern the planning, design, implementation and operation of road work zones in TEM member countries to mitigate their negative safety effects on workers and road users. Finally, the main challenges were identified, and recommendations were prepared for TEM member countries to further improve work zone safety.

The main objectives of these *Guidelines* are:

- To identify the main areas of consideration, including longitudinal and lateral work zone components, to achieve a high degree of safety not only for road users but also for road workers and construction equipment
- To summarize methods for safety examination, risk assessment and traffic management in work zones in terms of their ability to achieve the desired driver behaviour, facilitating a safer driving and working environment
- To clearly define roles and responsibilities for all contributors in the work zone (road operators, contractors and road workers), and to identify any training needs for these parties
- To present traffic control and enforcement devices as well as work zone equipment, and to explore their effectiveness


STOP

1. WORK ZONE SAFETY IN TEM MEMBER COUNTRIES

1.1 GENERAL

To collect information on work zone safety, a questionnaire (see Appendix 3) was created and distributed to all active TEM member countries (Armenia, Austria, Bosnia and Herzegovina, Bulgaria, Croatia, the Czech Republic, Lithuania, Poland, Romania, Slovenia and Turkey). The following sections summarize the evaluation of the answers to all questions and provide important insights into the main challenges, as well as strengths and weaknesses, in work zone management in the individual countries.

1.2 ROAD SAFETY DATA FOR WORK ZONES

Reliable and accurate road safety data are needed for identifying specific problems and risks, setting targets, formulating appropriate strategies and monitoring impact. Thus, crash data should be collected, properly coded, processed, analysed, disseminated and used as a basis for evidence-based road safety work.

Even though basic general road safety data are available in TEM member countries for all types of roads, the regular collection of relevant data (at minimum crashes, injuries, fatalities) in work zones is not established. Some countries, such as Croatia and Lithuania, consistently collect work zone road safety data on motorways but not on other types of roads.

1.3 GUIDELINES AND REGULATIONS FOR WORK ZONE SAFETY

Most TEM member countries have at least some national technical guidelines, standards or manuals for work zone safety on their motorway network. However, the content and depth of these documents differ significantly.

In 2010, UNECE published two resolutions that contain material relevant for work zone safety, i.e., the UNECE Consolidated Resolution on Road Traffic (R.E.1)[1] and the UNECE Consolidated Resolution on Road Signs and Signals (R.E.2).[2] Not all TEM member countries have yet implemented these resolutions, and some are not even aware that these exist.

1.4 SAFE SYSTEM APPROACH IN WORK ZONE MANAGEMENT

While most TEM member countries have a road safety strategy or programme for their motorway network that is based on the Safe System approach, this is not true for work zone management and most national work zone guidelines. In many countries, these documents are currently not in line with the Safe System approach, especially as far as the implementation and execution of safe speeds in work zones are concerned.

1.5 WORK ZONE LAYOUTS AND RISK MANAGEMENT

Most TEM member countries define different categories for roadworks. Widely used is the differentiation by duration of the works, e.g., into short-term or long-term (lasting longer than one day). Some TEM member countries define different work zone areas in accordance with international best practice. For example, Austria differentiates the following four areas: forewarning area (length of 1,000 m for long-term works), lane change area (150 m), security area (100 m) and the actual work area (up to 5,000 m with 10,000 m under special circumstances).

As far as traffic management plan (TMP) layouts for signs and other traffic control devices for various road work situations are concerned, most TEM member countries have relevant national guidelines or standards.

When planning long-term roadworks, road safety audits (RSA) are usually performed in TEM member countries, while road safety inspections (RSI) on existing work zones are not so commonly used. In the Czech Republic, for example, RSIs on work zones are not yet implemented, while in Austria RSIs are currently used for long-term work zones only.

1 https://www.unece.org/fileadmin/DAM/trans/roadsafe/publications/docs/Consolidated_Resolution_on%20Road_Traffic_RE1_e.pdf
2 https://www.unece.org/fileadmin/DAM/trans/roadsafe/publications/docs/Consolidated_Resolution_on_Road_Traffic_RE2_e.pdf

1.6 ROLES AND RESPONSIBILITIES IN WORK ZONES

Effective work zone traffic management depends on all parties involved fully understanding their roles. Therefore, clear responsibilities for all actors in the work zone, such as the road operator, contractors and workers, are very important. This is reflected in TEM member countries, as most have written guidelines or internal procedures clearly defining duties and obligations. Furthermore, in some countries, mandatory contractual requirements for all organizations involved in undertaking or supervising the work are in place to ensure compliance with the relevant work zone guidelines or manuals.

1.7 TRAINING OF PERSONNEL

Adequate training for all actors (road operator, contractors, workers, etc.) in road work zones is mandatory in some TEM member countries, such as Austria and Croatia. In those countries where flaggers (flag persons) are still used, these persons are specifically trained to ensure their own safety.

1.8 ENFORCEMENT AND ROAD USER INFORMATION

Not all TEM member countries have uniform speed limits or speed enforcement in work zones on the motorway network. Those countries that enforce speed limits in the work zone apply control methods that are both non-automatic (e.g., handheld speed guns) as well as automatic (e.g., fixed speed cameras or section controls).

To inform road users of longer-term work zones on the motorway network, aside from advance notice by adequate signage directly on the road, social media and newsletters are widely used.

1.9 STRATEGIC GOALS AND INDICATORS

Many TEM member countries have strategic goals referring to the impact of roadworks on road users' mobility, traffic management or works efficiency (e.g., the reduction of crashes and fatalities as well as the highest possible network availability). These goals are normally defined on a national level either by the road authority or the road operator.

1.10 WORK ZONE CHALLENGES

The following main challenges in work zone safety were identified by TEM member countries:

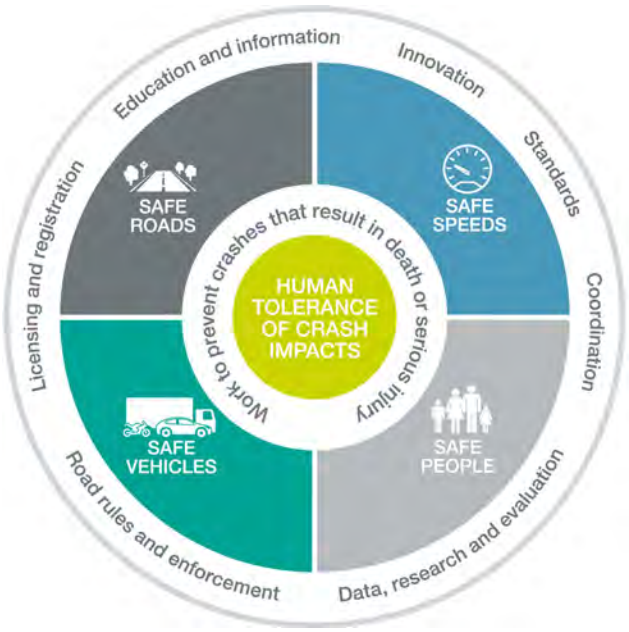
- Quality and availability of crash data
- Management of increasing traffic levels
- Organization and mapping of detours
- Increased attention to so-called low-grade work zones, such as work zones of short duration and with limited space
- Awareness of relevant political stakeholders, as well as road users and workers, of the importance of work zone safety
- Enforcement of speed limits in work zones
- Rapid provision of new technology components (vehicles, barriers, etc.) that increase work zone safety
- Quality of maintenance and repair works carried out by the private sector
- Durability and reliability of road marking equipment used during construction
- Ensuring a high degree of road safety under various road operators or concessionaires

Although not all these issues can be solved by the *Guidelines* as they are beyond the scope of this work, the provisions and findings in the following sections are an important step in trying to overcome most of these challenges.

2. SAFE SYSTEM APPROACH IN WORK ZONES

In road safety management, the Safe System approach provides a holistic view of the road transport system. The Safe System approach considers that road users will make mistakes and thus may also have traffic crashes. The challenge is to manage the multiple and complex interactions of roads and roadsides, travel speeds, vehicles, and all groups of road users, not only to reduce crashes, but most importantly to ensure that any crashes that do occur do not result in death or serious injury thanks to a forgiving road system (Figure 1).

Figure 1: Safe System approach in road safety management at a glance



Source: Australian National Road Safety Strategy 2011–2020.

This means working holistically and collaboratively across each of the four core pillars of the Safe System approach:

- Safe road users – who are competent and follow traffic laws
- Safe vehicles – that have technology to help prevent crashes and safety features that protect road users in the event of a crash
- Safe roads – that are self-explanatory and forgiving to reduce the risk of crashes occurring and to protect road users from fatal or serious injury should a crash occur
- Safe vehicle speeds – that suit the function and the level of safety of the road to ensure that crash forces are kept below the limits that cause death or serious injury

All processes associated with roadworks must be undertaken using Safe System principles. The Safe System approach recognizes that the road user will at times make mistakes, and that work zones need to be implemented and managed so that the potential for harm can be eliminated or significantly reduced. It is also important that all road users understand what to expect and the actions they need to take when approaching a work zone. Those who are responsible for designing and installing work zones need to identify areas of potential risk and implement measures that can either eliminate the risk or reduce the severity of injury in a crash.

Managing speeds is another important aspect for a Safe System approach and should be another key concern at roadworks. Speed limits in work zones must be set for protection of the workers as well as the drivers passing through the zones, along with the requirement of managing traffic flows. These guidelines are vital in finding the balance between road worker safety and managing traffic in work zones in TEM member countries, considering the Safe System principles.

3. DEFINITIONS

The following definitions are used throughout these *Guidelines*:

Clear zone

The roadside area adjacent to the nearest traffic lane available for safe use by errant vehicles. This area must be flat, kept clear of non-frangible hazards and free of road workers.

Contractor

The organization responsible for implementing the roadworks project and providing a safe and compliant work zone.

Road operator

The organization with overall management responsibilities for the roadworks project, including design, implementation and road safety as well as for the operation and maintenance of the road network.

Road user

Any person making use of any part of a road, including pedestrians, cyclists and drivers of vehicles and public transport.

Road safety auditor

A person with road safety training and certification according to Directive 2008/96/EC of the European Parliament and of the Council on road infrastructure safety management, and Directive (EU) 2019/1936 of the European Parliament and of the Council amending Directive 2008/96/EC.

Road safety audit (RSA)

A formal safety performance examination of a road project by an independent road safety auditor or audit team. It qualitatively estimates and reports on potential road safety issues and identifies opportunities for improvements in safety for all road users.

Road safety inspection (RSI)

A systematic, on-site review of an existing road or section of road conducted by the road safety expert(s), e.g., road safety auditors, to identify hazardous conditions, faults and deficiencies that may lead to serious crashes.

Roadworks traffic control

An activity which involves directing vehicular and pedestrian traffic around a construction zone or other road disruption through the provision of directional, regulatory and warning signs, barriers, traffic cones, traffic controllers and other devices to regulate, warn or guide road users in order to attain safe and efficient movement of vehicles, pedestrians, bicyclists, workers and the general public.

Safe System approach

The Safe System approach refers to a road safety model that will compensate for human error by ensuring that road users are not subject to crash forces that result in fatal or serious injuries.

Safety barrier

A permanent or temporary concrete or steel barrier that meets minimum containment testing criteria and can provide redirection of vehicles while experiencing minimal deflection.

Safety buffer

The area provided around the actual wok zone to protect workers from traffic. No one must enter the safety buffer during the normal course of work. Materials and equipment must not be placed in this area.

Safety supervisor

Site supervisor employed by the contractor tasked with managing all temporary traffic management functions through the lifespan of the roadworks project. The safety supervisor must ensure that the temporary traffic management is safe and effective at all times.

Temporary signage

Construction safety signage installed for purposes of warning, informing and controlling the workers and the public on an ongoing construction operation.

Temporary traffic control (TTC)

Regulating, warning or guiding traffic through a stretch of road where road user conditions are changed because of a work zone or incident.

Temporary traffic control devices (TTCD)

Devices used to warn road users of hazards, to advise them of the proper path through a work zone, to delineate areas where they may not operate and to separate them from workers and opposing traffic.

Temporary traffic control plan (TTCP)

A site-specific plan or set of plans indicating the positioning and placement of temporary traffic control devices, signs and delineators in the work zone. It details how all road users will be directed around a work zone to minimize inconvenience while providing safe conditions for both the road user and those carrying out the activity. Depending on the work duration, multiple TTCP's describing the positioning and placement of traffic control devices, signs and delineators during the different stages of works (also night, day or between shifts) might be necessary. The TTCP is an important part of the Traffic Management Plan (TMP).

Temporary traffic management (TTM)

Placing, maintaining and removing of temporary traffic control devices for work zones to ensure safe, efficient and effective movement of all road users and the safety of all those working on or in the work zone.

Traffic management plan (TMP)

A site-specific document (or set of documents) that covers the management as well as the design, implementation, maintenance and removal of temporary traffic management measures during roadworks. A TMP also contains information on project details, risk assessments, emergency procedures, and project communications and other key information necessary to the safe completion of the works. An important part of a TMP is the temporary traffic control plan.

Truck (or trailer) mounted attenuator (TMA)

A shock-absorbing device mounted on the rear of a roadworks vehicle intended to protect the road users, the workforce and the truck during impact by an errant vehicle. The term also covers approved trailer-mounted attenuators.

Work zone

The area of road occupied by the work area and any additional areas of road required for advance warning signs, tapers, safety barriers, delineators, safety buffers and any other function associated with the roadworks. The work zone can be stationary or moving.

Work area

The area of the road that is occupied by the actual construction or maintenance operation.

4. CLASSIFICATION OF WORK ZONES

4.1 INTRODUCTION

Work zones may be classified in different ways considering road type, duration or length. Most common in TEM member countries is classification by the duration of the roadworks as well as by the types of roads on which they take place. The interaction between these two variables sets the context for the design of the road work, the impact on other road users and the risk to safety. Issues relating to safety will vary from work zone to work zone, and individual risk assessments that allow for the identification of location-specific risks will be required in order to develop a comprehensive approach to providing effective safety measures. However, the difficulties in dealing with unique, real-world situations can be lessened with the identification of high-level safety principles aimed at improving safety, to be applied at all stages of roadworks from planning to removal. Such principles will ensure that achieving a high level of safety is inherent in all decision-making in terms of safety measures, work zone design and operation.[3]

4.2 TYPE OF ROADWORKS

Based on their duration, the following types of roadworks can be differentiated (Figure 2)[4]:

- Long-term work – stationary construction or maintenance work that occurs in a single location over a longer period (e.g., more than seven days) with comprehensive logistic aspects
- Intermediate-term work – stationary construction or maintenance work that occurs in a single location over an intermediate period (e.g., more than one daylight period and up to seven days)
- Short-term work – stationary construction or maintenance work that lasts for a short period (e.g., more than one hour) but is completed within a single daylight period
- Mobile work – construction or maintenance work that involves continuous mobile operations or a series of periodic stops with a short duration and which are not contained in a fixed work area

4.3 TYPE OF ROADS

In terms of roadworks, five main road types can be differentiated[5]:

- Motorways – high-volume, high-speed, multi-lane carriageways
- Rural primary roads – typically single carriageway roads and functionally important at a national or international level
- Rural secondary roads – roads that are functionally less important than rural primary roads
- Urban main roads – typically multi-lane facilities (often arterials) with high volumes and a diverse traffic mix (which can include pedestrians, two-wheelers or public transport vehicles)
- Urban local roads – local roads serving low traffic volumes in urban settings

Varying national definitions of road classes can be adequately accommodated under this broad classification of road types. The focus of these *Guidelines* is on roadworks on motorways and multi-lane carriageways.

3 European Transport Safety Council, "PRAISE: Preventing Road Accidents and Injuries for the Safety of Employees", Report No. 6, May 2011. Available at: https://etsc.eu/wp-content/uploads/Report-6.pdf

4 European Commission, "Advanced Research on Road Workzone Safety Standards in Europe" (ARROWS), 21 October 2002. Fact Sheet available at: http://cordis.europa.eu/project/rcn/34458_en.html

5 Ibid.

Figure 2: Examples for short-term and long-term work zones on the Czech Motorway Network

Source: A Ředitelství silnic a dálnic ČR (ŘSD) [Road and Motorway Directorate, Czech Republic].

5. IDENTIFICATION OF THE MAIN AREAS OF WORK ZONES – WORK ZONE LAYOUT

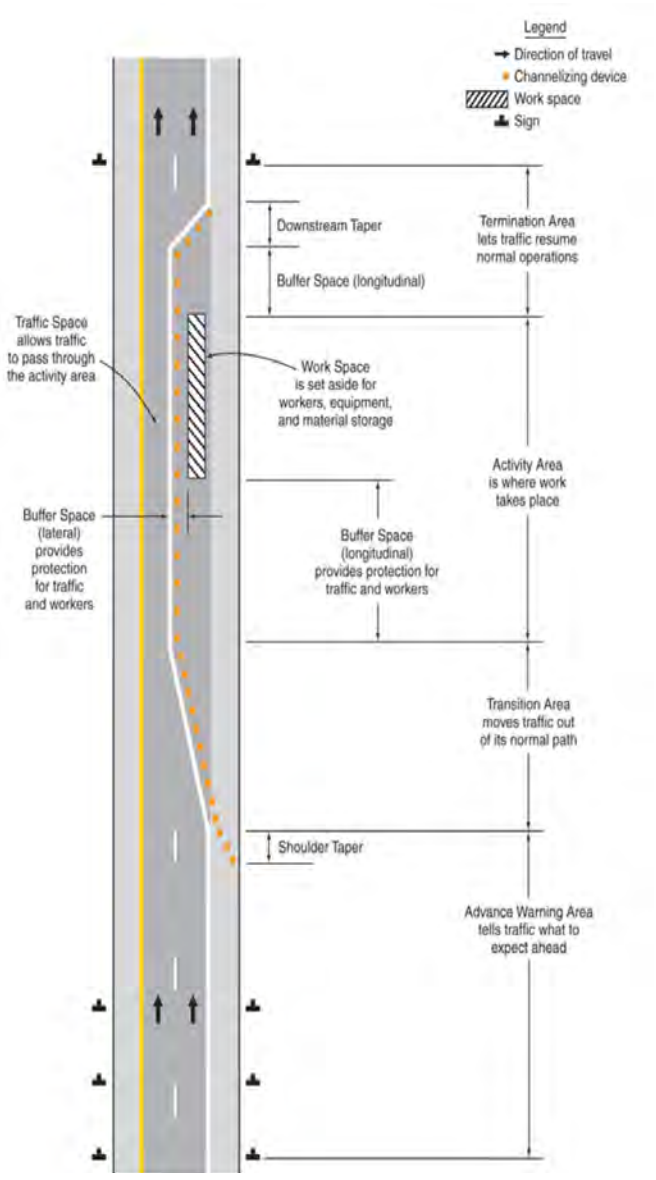
5.1 GENERAL

A work zone comprises not only the area of road occupied by the actual roadworks, but also additional areas of road required for advance warning signs, tapers, safety buffers and any other temporary traffic control device. All work zones must be highly visible and provide clear direction to all road users as well as protecting the road workers and the construction equipment.

5.2 LONGITUDINAL WORK ZONE COMPONENTS (WORK ZONE AREAS)

Based on international guidelines and best practice,[6] [7] [8] a work zone should generally comprise the following longitudinal areas: advance warning area, transition area, buffer area, work area and termination area (Figure 3). In the entrance and exit areas of work zones as well as lane crossovers and the advance warning area, the most common crashes are rear-end and single-vehicle. In addition, bad weather conditions and insufficient visibility (also at night) contribute to reduced safety in the work zone.[9]

Figure 3: Work zone areas



Source: Ibid., Federal Highway Administration, US Department of Transportation.

6 Federal Highway Administration, US Department of Transportation, "Manual on Uniform Traffic Control Devices", 2009 ed., 27 March 2020. Available at: https://mutcd.fhwa.dot.gov/htm/2009/part6/fig6c_01_longdesc.htm

7 Asian Development Bank, *CAREC Road Safety Engineering Manual 2: Safer Road Works* (Mandaluyong City, Philippines, 2018).

8 Austroads, "Guide to Temporary Traffic Management Part 3: Static Worksites", 2019.

9 G. Sorensen and others, Conference of European Directors of Roads, "ASAP – Towards a European Guideline for Speed Management Measures in Work Zones", 3 March 2015. Available at: https://www.cedr.eu/download/other_public_files/research_programme/call_2012/safety/asap/ASAP_D5_1_final.pdf

5.2.1 ADVANCE WARNING AREA

The advance warning area is the section of road where road users are informed that they are approaching a work area and are given an initial indication of any action to be taken ahead. Signs to provide advance warning, guidance or instruction are provided in this area. The type and spacing of signs to be used in this area depend on the nature of the works and the speed of approaching traffic.

The length of the advance warning area varies according to the approach speed of traffic, the type of road and whether speed reduction is being introduced as part of the works. If a temporary reduced speed limit applies within the work zone, warning of this is located in the advance warning area.

On motorways it is good practice to start placing early warning signs 1,000 m ahead of the start of the advance warning area. These signs alert drivers to the regulatory signs that commence the advance warning area.

5.2.2 TRANSITION (OR TAPER) AREA

The transition area is the area where drivers are redirected out of their normal path of travel. If a roadway needs to be partially closed, the taper that guides drivers to the new travel path clear of the work zone is provided within the transition area. It is desirable that the full length of the taper be visible to the approaching motorists. If no diversion is needed, a transition area is not necessary and the advance warning area leads straight into the buffer (approach clearance) area.

5.2.3 BUFFER (OR APPROACH CLEARANCE) AREA

The buffer (or approach clearance area) is a longitudinal safety buffer immediately in advance of the work area that increases protection and safety for workers and equipment. This clearance area would generally be 20–30 m long but can be extended if the work area is hidden from approaching road users (e.g., by a curve or a crest). The buffer area must always be kept clear of workers, vehicles, machinery or other activity.

5.2.4 WORK AREA

The work area is the area where works are physically being carried out and is set aside for workers, machinery, equipment and storage of materials. Vehicle speeds must be controlled through the work area to reduce the risk that a vehicle will inadvertently enter the work area. Safety barriers (not only barricades) should be used to shield the work zone both day and night.

5.2.5 TERMINATION AREA

The termination area is the area where traffic resumes normal operations after passing the actual work area. The signs that should be located in this area may include end roadwork, end detour or end speed limit as applicable. The standard length of a termination area on motorways is 100 m.

5.3 LATERAL WORK ZONE COMPONENTS (LATERAL SAFETY BUFFERS)

The lateral components of a work zone define safety buffers, which are required to provide protection to both road users and road workers as well as to allow (steel or concrete) safety barriers to function correctly. In addition, these components define the work area which road workers in general should not leave, as well as the area in which road users are permitted to travel through or around the work zone.

The workforce shall not cross this delineation or enter the lateral safety buffer at any time, including placement of any machinery or equipment overhanging into the lateral safety buffer from the work area.

The absolute minimum width of the lateral safety buffer is 1.2 m. In high-speed areas, a larger adjacent clearance area is desirable, or consideration should be given to setting a lower speed limit.

On motorways, the boundary between the lateral safety buffer and the work area should be delineated by a safety barrier adjacent to the work area to provide protection and safety for the workers.

6. ROAD SAFETY IN WORK ZONES

6.1 SAFETY EXAMINATION METHODOLOGIES FOR WORK ZONES

To ensure a successful work zone safety process, the road operator must establish the following[10]:

- Clear policies that spell out responsibilities and competencies for individuals involved in the work zone inspection programme, from the road operator to the project level
- A monitoring programme that regularly evaluates the effectiveness of agency policies and project-level actions
- A standardized procedure for programme and project deficiency identification and follow-up
- A process that integrates performance feedback into the programme as a whole

The operator should develop guiding principles, procedures and resources that form the basis upon which the programme operates. Once established, these guiding principles should be updated through process reviews and self-assessments performed on a regular basis. Detailed documentation of all relevant aspects of the process, programme or project being inspected is important. Documentation across all levels of inspection and review activities should be maintained. An effective work zone safety process involves the following activities[11]:

- Work zone process reviews – these guide a road operator through an assessment of the functionality and effectiveness of practices and procedures used to audit or inspect work zones. Process reviews can assess whether operational processes within a work zone inspection programme are consistent with established standards and expectations, if they perform effectively and efficiently, and if the practices are adequately captured and applied within the programme or across other programmes of the road operator.
- Work zone self-assessment (WZSA) – which can help road operators to manage their work zone programme. WZSA looks at the following areas: leadership and policy, project planning, project design, project construction and operation, communications, education, and programme evaluation.
- Work zone crash data trend analysis – this involves analysis of aggregated work zone crashes, with an emphasis on crash contributory factors and discussion of countermeasures.
- Crash and mobility data analysis – which evaluates current or real-time crash events and mobility issues in an active work zone. This activity is conducted as soon as practical following a crash event or serious mobility issue within the project limits. To assess mobility issues, traffic volumes should be measured prior to the start of the roadworks and compared to the road capacity during the different phases of the roadworks. It might be necessary to take additional measures to divert the traffic load into the surrounding road network. Information on crash contributory factors or serious mobility deficiency should result in immediate actions to reduce the chances of a recurrence. Sources of information on contributory factors that may have led up to the crash may be available from police reports, contractor reports or contractor or road operator witnesses. Remediation of any situation or condition that may have contributed to the event is the responsibility of the road operator. Performing crash and mobility data analysis should be a standard operating procedure for road operators. In the case of large projects, aggregation and analysis of project-related incidents may lead to identification of thematic problems. Findings from crash data analysis can help to understand the types and contributory factors of work zone crashes and to identify areas for improvement.

10 American Traffic Safety Services Association, *Safe and Effective Work Zone Inspections* (Fredericksburg, Virginia, American Road and Transportation Builders Association, 2013). Available at: https://www.workzonesafety.org/training-resources/fhwa_wz_grant/atssa_wz_inspections/

11 Andras Varhelyi and Stijn Daniels, "Road Safety Management at Work Zones – Final report", December 2019. Available at: https://www.researchgate.net/publication/339000911_Road_Safety_Management_at_Work_Zones_-_Final_report

- Work zone road safety audits (WZRSA) – these are formal safety performance evaluations performed at any stage of a planned work zone by an independent, multidisciplinary team, and consider methods of improving safety in a work zone. WZRSA should be an integral part of the work zone design process and carried out for all long-term roadworks. The independent WZRSA team is usually hired by the road operator as an integral part of the planning process of the roadworks. The difference between an RSA and a WZRSA is in the tailored RSA approach incorporated into the unique challenges of work zones. A WZRSA assesses a project's temporary elements that will eventually be removed once the active work zone phase is completed. Hence, a WZRSA team should focus on work zone safety, design and operations; it should not focus on permanent geometric design elements. WZRSAs can be performed during all project phases – from planning to an active work zone. Due to the temporary nature of work zones, the WZRSA team must record its findings and submit recommendations to the road operator in a timely fashion.
- Work zone road safety inspections (WZRSI) – these are formal reviews of temporary traffic control devices (TTCD) and safety/mobility strategies deployed according to an approved plan, standards and specifications in active work zones. Work zone inspections are done during the active work zone phase and should be applied at all long-term roadworks. Compliance and deficiencies are documented formally, using a work zone inspection sheet. Work zone inspection sheets can vary in complexity and categories, but typically identify criteria deemed most critical to the work zone (e.g., signage quality/location, whether the work zone set-up matches design plans, safety/mobility concerns, etc.).[12] WZRSIs are usually carried out by the road operator's staff.

6.2 RISK ASSESSMENT FOR WORK ZONES

Risk assessments are critical to the safety of a work zone. Construction workers and road users are all put in danger whenever risks are not adequately assessed and addressed. Risk assessment helps to take control, set standards and communicate awareness among employees. Risks in work zones can be evaluated following the methodology of EN ISO 12100.[13] The methodology for risk assessment and risk reduction is based on the following five different phases to determine if it is necessary to adopt measures to reduce risk:

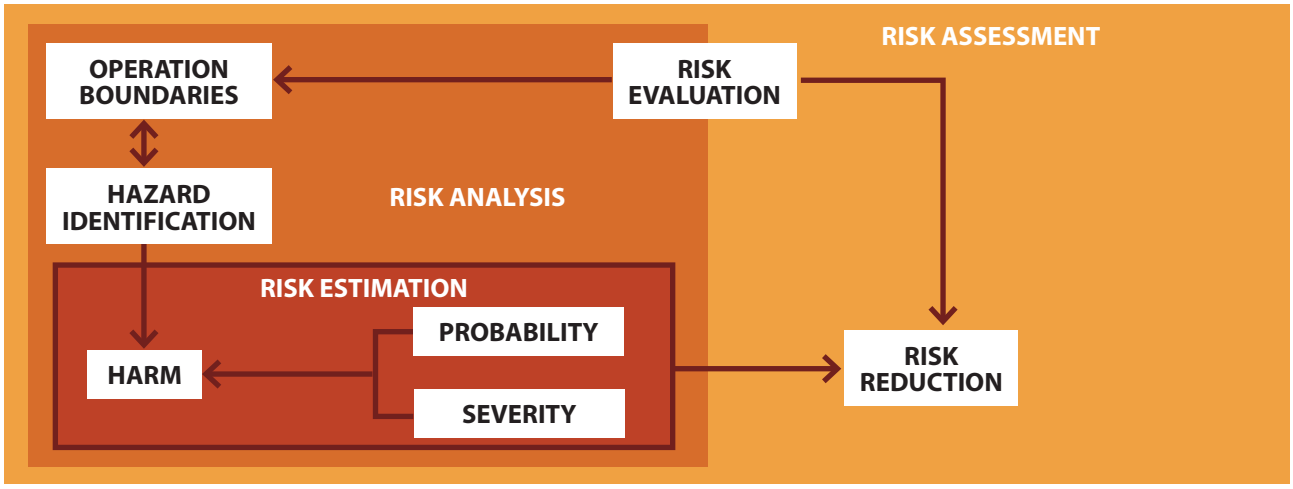
1. Determine the operation boundaries and include any reasonably foreseeable misbehaviour
2. Identify the hazards
3. Estimate the risk for each identified hazard
4. Eliminate the hazard or reduce the risk associated with the hazard
5. Re-evaluate the risk reduction

As shown in Figure 4, when estimating risks, the probability of a risk and the severity of any consequences must be considered. The likelihood of a risk includes, for example, the probability of a vehicle leaving its driving lane, the distance of a potential hazard from the driving lane and any preventative measures (such as safety barriers) employed. The severity of any consequences includes, for example, the vehicle speed and the aggressiveness of the hazard (i.e., the potential for the hazard to cause harm, such as crashing against a pole or tree).

12 American Traffic Safety Services Association, Work Zone Road Safety Audit Guidelines and Prompt Lists (Fredericksburg, Virginia, American Road and Transportation Builders Association, 2013). Available at: https://www.workzonesafety.org/training-resources/fhwa_wz_grant/atssa_wz_rsa_guide/

13 International Organization for Standardization, Safety of machinery – General principles for design – Risk assessment and risk reduction, EN ISO 12100:2010.

Figure 4: Work zone risk assessment



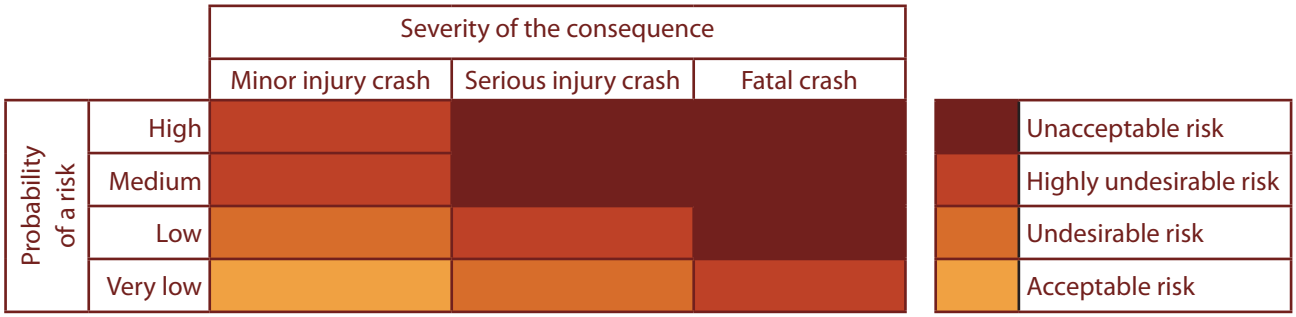
Source: European Union Road Federation, *Towards Safer Work Zones: a Constructive Vision of the Performance of Safety Equipment for Work Zones Deployed on TEN-T Roads* (Brussels, 2015).

To estimate risks, a risk matrix can be used. An example matrix is shown in Figure 5. The matrix must always be accompanied by factual statements and reasoned justification for the assigned risk level.

The provisions in these *Guidelines* describe various mitigating and control measures that can be employed to eliminate the hazards or to reduce the risk associated with the hazards in work zones.

Risk assessments should be performed primarily by someone with experience in assessing hazards, their likelihood and control measures. The risk assessors will be looking for common workplace hazards that are visible or anticipated. They will then decide who might be harmed and how they might be harmed and develop control measures that should be implemented by the contractor or the road operator.

Figure 5: Risk estimation matrix (example)



Source: Vill Ziviltechniker GmbH.

6.3 TRAFFIC MANAGEMENT PLAN (TMP)

6.3.1 PURPOSE OF A TMP

A TMP is a site-specific document (or set of documents) that covers the management as well as the design, implementation, maintenance and removal of temporary traffic management measures during roadworks. A TMP also contains information on project details, risk assessments, emergency procedures, and project communications and other key information necessary to the safe completion of the works. The TMP is made before the works commence for every work zone, including every stage of works.

An important part of a TMP is the temporary traffic control plan (TTCP), which is a site-specific plan or set of plans indicating the positioning and placement of temporary traffic control devices, signs and delineators in the work zone. It details how all road users will be directed around a work zone to minimize inconvenience while providing safe conditions for both the road user and those carrying out the activity. Depending on the work duration, multiple TTCPs describing the positioning and placement of traffic control devices, signs and delineators during the different stages of works (also night, day or between shifts) might be necessary.

The TTCP should provide a safe environment for the workers in the work zone and the public passing through or adjacent to the work zone, and should include for the following[14]:

- TTM arrangements for each stage of the roadworks considering duration and times for conducting the works (i.e., day or night operation)
- Arrangement and number of traffic controllers required, if any, for each stage of the works
- Emergency access – both for workers and any emergency services vehicles travelling through the work zone
- Use of alternative routes or detours as required
- Provisions for oversized vehicles
- TTM arrangements at the work zone outside normal working hours or when workers are not present at the work zone (aftercare)
- Arrangements to address and monitor the risk of end-of-queue collisions due to a build-up of traffic in work zones

6.3.2 GENERAL CONTENT OF A TMP

The actual information contained in a TMP normally varies according to the scale, type and duration of works, but may contain the following elements:

- Information on the proposed works (timelines, contact details for road operators, consultants and contractors) and inspection and enforcement programmes
- Overall strategy for the management of traffic in the work zone, including traffic staging methodology during various stages of the roadworks
- Temporary traffic control plan indicating the positioning and placement of temporary traffic control devices, signs and delineators in the work zone, including drawings and details for all phases of the roadworks, such as diversion route drawings, traffic management drawings and cross sections
- Implementation plan containing a method statement for implementing the traffic management arrangements, including diversion routes, descriptions and drawings of operational procedures as well as changeovers between concurrent traffic management arrangements for various project phases
- Inspection programme defining the responsibility for specific reviews and inspections throughout the duration of the works
- Clearance plan containing a method statement for decommissioning at the end of the project
- Contingency plan for unplanned and emergency events (key contacts at the road operator and emergency services), particularly for large-scale, long-term projects
- Work zone road safety audit plan (depending on the duration of the works and the impact the works will have on the surrounding network)
- Network traffic impact assessment to assess the traffic impact of work zones, including traffic analysis and modelling for each stage along the road corridor where the works are taking place as well as for the surrounding road network
- The actions to be taken to address crashes – including the requirement for root-cause analyses as a means to understand if further traffic management needs to be put in place to mitigate the risks and to help prevent that situation recurring
- Stakeholder management and communication plan detailing how stakeholders and the public will be informed throughout the work

6.3.3 PREPARATION FOR EXECUTION OF THE TMP

The TMP is generally prepared by the contractor but must typically be approved by the road operator (if necessary, involving the ministry of transport or traffic police) before it can be implemented and the works begin. If the contractor does not have suitably experienced and competent staff for preparing the TMP, they can commission another organization with adequate know-how, such as a design or engineering office. In developing the TMP, the contractor – or their commissioned organization – shall consider the staging (sequence) of the roadworks and what is to be done in each stage. This helps the contractor to identify the resources needed and to think carefully about what will happen to the traffic.

The responsibilities of the road operator and the contractor in context with the preparation, implementation and monitoring of the TMP are summarized in Section 6.5.

At least two weeks prior to the work, the road operator's responsible engineer and the contractor's safety supervisor shall meet on-site to determine the exact location of all signs, devices and delineators for the first stage of the work.

14 Christopher R. Bennett and others, *Good Practice Note: Environment and Social Framework for IPF Operations Road Safety* (Washington, D.C., World Bank, 2019).

The layouts may need to be modified in some situations to suit particular work zones or conditions. However, the underlying principles of work zone traffic management should still be applied with consideration also given to the following:

- Sign locations and spacing may need adjustment to suit road alignment, visibility, traffic speeds, etc.
- Lane tapers using cones, bollards or temporary hazard markers should be gradual and reinforced with appropriate signs
- All layouts should be driven at the expected traffic speed, both during daylight and at night, and adjustments made if necessary

To ensure that a TMP is implemented correctly, the road operator should commission work zone road safety audits and work zone road safety inspections (see Section 6.1). All the safety concerns detected in either audit or inspection are to be resolved between the road operator and the safety supervisor.

Appendix 2 contains some example layouts from TEM member countries to show the main differences.

6.4 PLANNING AND IMPLEMENTATION OF WORK ZONES

To minimize the impact of work zones along the roadways, the zones should be planned in a way that does not cause a significant increase in congestion. The delay threshold could be based on the difference between the travel times during peak hours and nonpeak hours without construction, with the goal to make sure that the travel time through a work zone or multiple work zones does not exceed (or only marginally exceeds) the travel time in the peak period when there is no construction. This could mean changing project milestones to reduce the number of combined effects of multiple work zones, or revising project designs to use detours, diversions or (partial) lane closures, as well as night-time and off-peak work.

Thus, the following points should be considered when planning and implementing work zones:

- Traffic-relevant events – e.g., consideration of the start of public holidays, end of holidays, other recurring travel days (also in neighbouring countries), popular events, truck driving bans, essential construction sites on the lower road networks
- Road operation – e.g., consideration of winter service, tunnel cleaning, etc.
- Rush hour traffic – e.g., consideration of traffic peaks (no traffic obstructions may be caused on Fridays from noon to 8 p.m.; start of roadworks is only possible on Mondays from 9.30 a.m.)
- Speed limits – e.g., roadworks should be planned in such a way that for roads where regular speed limits are 100–130 km/h at least 80 km/h should be guaranteed in work zones

6.5 RESPONSIBILITIES

An effective roadworks traffic management depends on all parties involved fully understanding their roles and responsibilities. In this context, the road operator has the major responsibility of providing work zones that are safe for all road users and road workers. The road operator needs to clearly communicate the necessary measures to increase roadworks safety to all contractors and monitor the implementation of these measures.

Work zone guidelines should be followed by all parties involved in the planning, design, approval, implementation, maintenance and decommissioning of work zones on the road network. The road operator should make compliance with work zone guidelines a mandatory contractual condition for all organizations involved in undertaking or supervising the work. Any bids for roadworks that do not include an adequate element of cost for temporary traffic management should be rejected.

6.5.1 RESPONSIBILITIES FOR THE ROAD OPERATOR

The road operator should:

- Be aware of their own role and responsibility to provide safe travelling conditions for all road users as well as safe working conditions for road workers and machinery (avoiding damage to property)
- Ensure that compliance with the work zone guidelines is a condition of all contracts
- Support the improvement of work zone safety through training and accreditation initiatives
- Ensure that all traffic management measures deployed within a roadworks project are in accordance with work zone guidelines
- Review and approve or reject – if necessary, also involving the ministry of transport or traffic police – TMPs prepared by the contractor
- For larger projects, have the TMP audited by an independent audit team
- Monitor compliance with work zone guidelines in all work zones
- Inform road users of the roadworks (for long-term work zones, information about the expected duration of the works should be posted well in advance so road users can anticipate possible effects – such as delays – and make decisions about using other routes)
- Enforce correction of non-compliance and poor work zone safety by taking appropriate action against the parties involved
- Intensify collaboration with the traffic police to increase enforcement in all work zones, and take appropriate action against the involved parties where non-compliance creates risks for road users or road workers
- Support legislation to increase enforcement (e.g., by allowing point-to-point speed control in work zones) and punishments for non-compliance with traffic rules in work zones (e.g., in case a motorist hits a worker due to speeding)

6.5.2 RESPONSIBILITIES FOR CONTRACTORS

Contractors shall:

- Be familiar with the provisions of work zone related guidelines and act accordingly
- Always prepare a TMP based on the work zone guidelines, considering the five work zone areas for approval by the road operator; for larger projects the TMP should be prepared by an independent contractor or designer
- Have appropriate reflective signs, bollards, cones and barriers to fully implement the TMP
- Have an adequate store of replacement signs, bollards or cones to use if any go missing from the work zone
- Never allow single concrete elements (e.g., New Jersey barriers), branches, rocks or other unforgiving objects to be used for delineation
- Keep construction machinery, equipment and stockpiles of materials out of the safety buffer zone that surrounds the work area
- Assign one person to be the safety supervisor who is specially trained on the content of the work zone guidelines and responsible for all occupational health and safety, as well as for road safety matters; the safety supervisor inspects the work zone twice every day and is to be responsible for repairing or replacing any missing or damaged sign or device
- Train the contractor's personnel and ensure they all wear the required personal protective equipment (especially reflective safety vests) at all times
- Train the contractor's road workers in safety methods, including signage and traffic control, and ensure they all wear the required personal protective equipment (especially reflective safety vests) at all times

6.5.3 RESPONSIBILITIES FOR WORKERS

Workers shall:

- Be familiar with the provisions relevant for workers of work zone related guidelines, and act accordingly
- Wear the required personal protective equipment provided for their own safety at all times
- Take care of their own safety by looking out for risks
- Take care of the safety of other personnel and visitors to the work zones
- Only engage in work practices that do not put themselves or any other person at risk
- Follow the lawful instructions of their employer in carrying out the requirements of work zone guidelines
- Always be courteous to the public and not be provoked
- Report immediately to the safety supervisor any incidents, deficiencies or shortcomings with the safe operation of the TMP

6.6 SAFETY AND TRAINING OF ACTORS IN WORK ZONES

Working on roads in or nearby traffic is dangerous and requires many skills. A habituation effect can often be detected in the sensitivity of workers to the existing risks, leading to a misinterpretation or less careful behaviour.[15] Inspections of work zones can increase risk sensitivity, but ideally the workers should maintain a realistic estimation of possible risks themselves and adapt their behaviour accordingly. It is the safety supervisor's responsibility that all required safety measures are met, and that workers are aware of the risks and what to do to reduce the probability of a crash.

Appropriate skills and training of personnel in work zones increase safety in all aspects – for road users and the workers themselves. Measures to enhance the skills of personnel, like definition of competences in the contract, regular awareness training within construction companies, educational measures, etc., help to improve road work safety. Evidence of training and accreditation should be kept by all professionals working within the work zone.

The provision of two training levels might be useful:

- Basic awareness training for all road workers and staff who are present in road work zones providing an overview of common road work hazards, including (simple) prevention measures. Basic trainings could be offered as online modules with a duration of 2–4 hours and should be repeated regularly (e.g., yearly).
- Advanced training modules for safety supervisors, construction site managers and others responsible for work zone design, set-up and control. For these trainings, specific curricula must be designed, depending on the type of participants and the expected outcome of the training.

The following five key principles should be respected to protect road workers[16]:

- Avoid exposure of workers to traffic
- Make workers visible to road users, both by ensuring adequate visibility for drivers and by providing suitable clothing for road workers
- Provide physical protection of workers from traffic; even in short-term work zones, buffer zones should be foreseen as a minimum
- Protect workers from collisions involving works vehicles; the movements of works vehicles should be adequately perceived by workers
- Avoid excessive work hours; European and national legal requirements regarding work hours must be observed, as fatigue can contribute to increased risk for road workers

In addition, workers should wear high-visibility clothing that is produced with high-quality materials and complies with Class 3 of EN ISO 20471.[17] Class 3 high-visibility clothing is visible at traffic speeds up to 90 km/h. Visibility – which can even be optimized by using LED technology (Figure 6) – can also greatly reduce the risk of vehicle-versus-worker crashes when working in the dark. The optimal placement of LEDs on clothing is critical to avoid confusion or blinding of the oncoming traffic while guaranteeing optimal visibility of workers.

Figure 6: LED illuminated road worker gear

Source: Bina Istra Ltd, highway operator of Croatia.

15 Catharine H. Rankin and others, "Habituation revisited: An updated and revised description of the behavioral characteristics of habituation", Neurobiology of Learning and Memory, vol. 92, No. 2 (September 2009), pp.135–138.

16 Ibid., European Commission.

17 International Organization for Standardization, *High-visibility clothing – Test methods and requirements*, EN ISO 20471:2013.

6.7 SPEED MANAGEMENT AND ENFORCEMENT

One major problem in many work zones is the lack of compliance with legal speed limits. Currently, there is no common European standard for temporary speed limits in work zones. Speed management and enforcement are necessary to reduce the risk of serious traffic crashes and incursions into work zones, with speeding being linked to the number and severity of crashes. To maximize road safety, the following issues should be considered:

- The number of lanes should be maintained, using altered layouts, narrow lanes, contra-flow or added lanes. If lanes have to be closed, at least one lane should be kept in each direction. Narrow lanes or altered layouts should be used whenever possible to avoid flow restrictions and diversions. If a lane on a motorway must be closed, it is preferable to close the faster lane(s) first and conduct traffic through the slower lane(s).
- A minimum lane width of 2.75 m for cars and 3.25 m for trucks is recommended, and excessively wide lanes should be avoided to discourage speeding in times of lower traffic volumes.
- If some extra-capacity is needed, diversions to alternative routes may be used, provided that these routes can accommodate the new traffic and are carefully controlled.
- The traffic management plan should be designed in such a way as to help drivers to make proper choices rapidly, reinforcing critical information without being excessive, while appearing credible and avoiding conflicting information. Traffic management plans should follow the evolution of the works in time and space and be removed as soon as they become unnecessary.
- Decision points for drivers should be separated to not overstress drivers.
- Any unavoidable reduction in forward visibility should be minimized, and proper warning should be provided. Signs, markings and safety devices that are consistent with intended travel paths should be used. In long-term work zones, existing signs, markings and safety devices that are inconsistent with those paths should be replaced, covered or altered. In intermediate or short-term work zones, mainly devices that emphasize the appropriate path should be used. Approach speeds should be estimated realistically, and realistic and justifiable speed limits should be chosen to be supported by accompanying measures (reduced width, police presence, stationary speed cameras or average speed control).
- Low speed limits should not be prolonged through long stretches.
- Speed limit signs should not be placed too far in advance; drivers may consider them premature and ignore them when reaching the critical point.
- An emergency plan should be part of the design. It should describe the procedures in case of crashes and define the required actions to be taken (e.g., emergency vehicles and shelter possibilities).

To achieve low speed variations within the work zone, the speed reduction prior to the work zone must be smooth. A gradual reduction of the speed limit on the approach to the work zone in many cases is reasonable to reduce the danger of rear-end crashes and to harmonize the speed level. Commonly used are decrements of 20 km/h. Usually, mandatory speed limits are applied. To ensure adherence, enforcement is crucial, which can be accomplished via police presence, stationary speed cameras or average speed control (point-to-point measurements, section control) (see Section 7.9). There is no single best method for enforcing speeds since different forms should be considered in different contexts.

Because speed limits and enforcement are strongly connected, the road operator should liaise with the police before setting a speed limit for a certain location. Police have experience and unique insights into the enforceability of speed limits that may be used to ensure that rational speed limits are applied.

Enforcement is fundamental to effective speed management in work zones. It increases safety for road users and workers, plays a vital role in educating drivers and helps to change social attitudes.

In addition to detecting offenders, one of the major roles of enforcement in speed management is deterring unsafe behaviour. The level of deterrence is related not only to the actual level of enforcement, but also to the perceived level of enforcement and the perceived deterrence value of the penalties. Publicity promoting enforcement can increase the perceived level of enforcement and thus further reduce unsafe behaviour.

General deterrence is the impact of the threat of legal punishment on the general public, influencing a potential traffic law offender through fear of detection rather than actual detection necessarily occurring. Therefore, operations employing general deterrence mechanisms target all road users irrespective of whether they have previously offended.

While general deterrence programmes have the potential to influence the behaviour of all road users, specific deterrence is the impact of punishment on those who are apprehended. Therefore, the potential impact of a specific deterrence programme may be more limited than that of programmes relying on the general deterrence mechanism.

Thus, general deterrence results from the perception of the public that traffic laws are enforced and that there is a risk of detection and punishment when traffic laws are violated. Specific deterrence results from actual experiences with detection, prosecution and punishment of offenders.

The general assumption underlying police enforcement is that it should primarily aim for general deterrence, which is primarily achieved by increasing the subjective risk of apprehension. Covert, mobile speed camera enforcement programmes may provide a more generalized deterrent effect and may have the added benefit that drivers are less likely to know precisely when and where cameras are operating. Speed enforcement activities are best repeated frequently, at irregular intervals and with different intensities. Higher intensities generally result in larger effects.

6.8 INFORMATION MANAGEMENT FOR ROAD USERS

Timely information about roadworks enables drivers to cancel a journey, change their route or prepare themselves for possible delays.[18] The media should be engaged in increasing public awareness of planned roadworks and to enable relevant actions. Road operators should prepare a communication campaign well in advance of the works.

For roadworks with more than 4–8 weeks of traffic obstruction, an information board clearly visible to the road users should be erected no later than 14 days in advance. This board should contain the following information:

- Logo of the road operator
- Name of the project
- Expected date of completion
- Emergency contact phone number
- Message apologizing for any inconvenience

The information board should be clearly visible, allowing the public to report any safety concerns directly to the correct contact. For longer work zones, additional information should be repeatedly provided (e.g., "4 km to go"), including information on the nature of the work activity (e.g., "concrete is hardening") or road safety instructions.

The implementation of GPS navigation that includes live updates about roadworks is important in providing real-time information to drivers regarding changes to the traffic flow. Additionally, broadcasting traffic announcements (TA) on the Radio Data System (RDS) can assist road users with route planning and traffic congestion avoidance. In these contexts, increased cooperation between the road operators and relevant service providers might prove useful.

Intelligent Transport Systems (ITS) and variable message signs (VMS) should be used as much as possible for information on roadworks and in addition to temporary signs.

If possible, an indication of deviations and estimated travel times should be provided using sensors and variable message signs. If a stretch of road must be closed for roadworks or due to an incident in the work zone, the necessary deviation can also be displayed on the VMS in combination with the recalculated travel time.

18 Ibid., European Transport Safety Council.

7. TRAFFIC CONTROL DEVICES AND SAFETY EQUIPMENT

7.1 SIGNS AND MARKINGS

Road signs and markings are extremely important, highly safety-relevant devices in any work zone and thus important elements of any traffic management plan. They should be credible and used consistently and correctly on all work zones independent of their duration. The principles of signing and marking a work zone relate to good communication between the road worker and the road user. Provision of good communication requires that:

- Signs and markings are erected before work starts and placed according to the approved TMP
- Signs and markings are regularly checked for effectiveness, e.g., maintained in position, kept clean so they remain readable and visible at night (retroreflective sheeting material)
- If a sign or marking is damaged it is to be replaced immediately
- All signs and markings are removed when no longer required or when the work is finished

Effective and efficient signage and marking of a work zone includes the stages of planning, design, installation, operation and removal as described below.

7.1.1 PLANNING

The planning of road signs and markings is one of the critical elements of good work zone traffic management. When proper thought is put into the layout and planning of any work zone, the potential for crashes decreases. This is achieved because appropriate equipment, personnel and associated safety issues are considered prior to the work commencing. Such consideration leads to greater productivity and greater safety, as activity in the work zone is planned, and the issues foreseen have already been resolved. Increased situational awareness occurs because the contractor has to actively think about the work zone and methods to handle the traffic.

When planning roadworks, consideration must be given to the management of all road users. This planning needs to consider the volumes as well as the speeds of vehicles.

Subject to the nature of works being undertaken, traffic can generally be managed in one of the following ways:

- Through the work zone
- Adjacent to the work zone
- Via a detour or side track (temporary road) around the work zone

The main aims in planning are to minimize disruption to traffic as well as to the progress of the roadworks while providing a safe environment for both.

The safest approach may be to move traffic around the work zone via a temporary road or detour. This method may also be the most expensive but could generally be considered on large projects.

If the work is short-term, generally the traffic will be managed adjacent to or through the work zone. Taking traffic through the work zone is usually the most hazardous option. If traffic will be travelling through the work zone, care must be taken to ensure the safety of all people entering, leaving or being in the work zone.

7.1.2 DESIGN

Detailed design of the layout, including the choice of signs and markings to be used, is required to provide clear communication with all road users. The signs should correspond to the Vienna Convention on Road Signs and Signals (1968)[19] and the TEM Standards and Recommended Practice (2002).[20]

19 https://unece.org/fileadmin/DAM/trans/conventn/signalse.pdf
20 https://unece.org/transport/publications/tem-standards-and-recommended-practice

The contractor must ensure that all signs and road markings used in the work zone – to be effective – conform to the following six communication principles for good signage:

- Correct – the sign must contain the right information and must be correct for the situation at the work zone
- Conspicuous – the sign must be easily seen over the whole work period including at night (e.g., placing a sign behind a tree or bridge pier is not acceptable)
- Clear – the size and colour of letters or symbols need to make the sign legible and of sufficient dimensions that it can be easily interpreted at an appropriate distance
- Comprehensible – the sign needs to be understood (e.g., too many words on the sign may prevent the whole message being read by a passing motorist)
- Credible – the message conveyed by the sign must be believable to all road users, otherwise they will tend to ignore it
- Consistent – throughout the network, similar traffic situations should use the same standard sign; if signs have consistent colour, shape symbols and words, this will reduce driver reaction times, improve driver understanding and increase the level of safety

Signs need to convey the appropriate message and be placed to provide sufficient advance warning to give drivers adequate time to read the signs and react. The following sequence is suggested:

- Provide advance warning, e.g., use sign "Roadwork Ahead"
- Provide information, e.g., use sign "Lane Closed"
- Give instructions on action required, e.g., use sign "Keep Left"
- Guide drivers where to go, e.g., use traffic cones

Confusion can occur by using excessive signs, so this needs to be avoided and only the number of signs strictly necessary are to be used.

The signage layout needs to ensure that there is no doubt in the driver's mind regarding the information provided and the actions required. Colour-coding on signs by applying the same colours to the same route directions on all traffic signs can support road users' orientation in work zones (Figure 7).

Figure 7: Colour-coded signs

Source: Vill Ziviltechniker GmbH.

7.1.3 INSTALLATION

Signs must be of retroreflective sheeting material and should be placed where drivers can see them and where they will not be obstructed from view over the whole work period by vegetation or parked vehicles. They also should not:

- Cause a hazard to traffic
- Obscure a driver's vision
- Adversely affect adjacent properties or businesses
- Cause confusion or interfere with any other permanent signage – in some situations permanent signs may need to be temporarily removed or covered

All signs and delineators should be erected in accordance with the law and the approved traffic management plan, at appropriate locations and longitudinal spacing, following these steps:

- Before roadworks commence and to assist with the correct spacing of each device, all the required signs and delineators should be set out along the roadside in accordance with the approved traffic management plan.
- Next, place the advance warning and regulatory signs onto the road, starting with the signs that are at the greatest distance away from the work zone. Work inwards towards the work zone.
- Place the signs for the transition zone or the start of the work zone.
- Install all delineators required for the transition taper and the work zone.
- Place any other warning or regulatory signs, including termination and end of temporary speed zone signs.
- Cover any permanent regulatory signs that conflict with the TMP.
- After signs are erected, the safety supervisor should drive through the work zone at normal traffic speed to inspect the signage scheme and ensure the adequacy of the scheme, identifying adjustments, if necessary. Where the signage is used at night, an inspection should be done after dark with dipped headlights.

7.1.4 OPERATION

Regular inspection, cleaning and replacing of damaged signs, as appropriate, must be carried out by the contractor to ensure continued effectiveness over the whole work period.

With changing circumstances in the work zone, there may also be a need to modify or remove a sign or a series of signs. This may either be temporary or permanent removal or covering of the signs involved. For example, the warning sign for "Roadworks" should be removed or covered at the end of the workday, and then displayed again when work recommences.

The road surface on which traffic is travelling through or around the work zone also needs inspection and possible maintenance to ensure it is kept in a satisfactory operational condition.

The layout should be driven through periodically by the safety supervisor to check that the signs are still in place and still appropriate.

7.1.5 REMOVAL

Upon completion of the roadworks, signs and road markings shall be removed from the work zone and approaches to the work zone.

To maintain adequate protection for workers, signs are removed starting from the work zone, then moving out to the advance warning area in the following sequence:

- Driving instruction signs
- Other warning signs
- Advance warning signs

When removal is finished, the safety supervisor should drive through the entire work zone to make sure all signs and markings have been removed.

7.1.6 DOCUMENTATION

Supervisors shall document roadwork signs and other devices used and their positions at the work zone for future reference. Following traffic crashes, legal requests for such information may arise well after roadworks are finished.

This documentation, including times of inspections or changes to work zone arrangements, should be updated regularly.

A photographic record of the layout of signage and traffic control devices can be valuable additional information in the documentation.

7.1.7 SIGN STORAGE, MAINTENANCE, AND AVAILABILITY

To maintain signs in effective working condition, attention should be given to:

- Correct storage – under cover, preferably standing upright in catalogued racks
- Careful transport – the reflective facing is easily damaged when transported in the back of a truck
- Good installation – ensure that sign supports allow for stability and visibility, and do not damage the face of sign
- Regular maintenance – cleaning of signs and repairing bent or damaged signs

Maintenance or emergency response work groups should have ready access to commonly used signs to deal with emergency situations such as flooding, landslides or major crashes.

7.2 ELECTRONIC ARROW BOARDS (EAB)

Electronic arrow boards (EAB) displaying route deviation symbols may be located within the transition area to supplement "Keep Left" or "Keep Right" signs as well as route deviation chevron boards. Particularly on (very) high-speed roads, EABs provide high-visibility warning of route deviation, but they should not be used in place of the prescribed road signs. Electronic arrow or message boards can also be mounted on the top of a works vehicle and activated when moving slowly or when stopped to carry out works.

7.3 VARIABLE MESSAGE SIGNS (VMS)

(Electronic) variable message signs (VMS) may be used to provide road users with the following information:

- Advance notification of the start of roadworks
- Remote warning of in-progress roadworks to allow users to choose whether or not to re-route to avoid the work zone
- Information on journey times and incidents within established work zones to allow users to choose an alternative route
- Targeted messages to assist the safe management of traffic through the work zone

Normal use would be on high-speed or high-volume roads where conventional signage may be ineffective.

A VMS should never be used as an alternative to the correct placement of traffic control devices or to mitigate poor temporary road alignments that could be avoided through sufficient planning.

The VMS shall always supplement static road signs so that the static signage remains, should the VMS fail.

A VMS should be installed in a location clearly visible to the road users and according to the signage layout principles described in Section 7.1. In addition, they should not present a hazard to road users and thus should be placed outside the clear zone or behind safety barriers. Where VMSs are placed outside the clear zone, it must be ensured that they are still visible to road users.

Visibility can be affected by shade, direction of the sun, background conditions (including lighting) or oncoming headlights. These factors should be considered when positioning signs.

Messages should be kept to a maximum of three lines per frame and the message text centred. Messages shall be concise and unambiguous for driver comprehension.

Messages should comprise a maximum of two frames. The number of frames used for the VMS message affects the motorist's ability to read and understand the entire message. The number can also create a hazard as a motorist's attention may become focused on reading the message and not focusing on the road ahead. The message update shall be scrolled. Flashing or blinking of messages is undesirable.

7.4 TRAFFIC SIGNALS

Fixed or portable traffic signals should be used – whenever possible – instead of traffic controllers to control traffic at a work zone. The signals are connected and operated by cable or by radio. A battery or generator usually powers the portable traffic signals. To better inform road users and decrease the number of red-light offences, the time (in seconds) until the light changes can be displayed (Figure 8).

Figure 8: Traffic lights regulation in road work zones

Source: Bina Istra Ltd, Highway operator of Croatia.

7.5 SAFETY BARRIERS

General rules

Safety barriers of either steel or concrete (Figure 9) should be used for the separation of traffic and the protection of workers in high-speed areas or in vulnerable situations where lateral clearance between workers and moving traffic would be insufficient for adequate safety. Safety barriers should also be used for protection at a severe hazard such as a deep excavation or bridge pier. Temporary, water-filled plastic barricades are not suitable as a safety barrier for high-speed roads as they do not meet safety barrier performance criteria. Therefore, they should not be used for the purpose of protecting workers where traffic speed is likely to exceed 20 km/h.

Figure 9: Examples of concrete (left) and steel (right) safety barriers

Source: Vill Ziviltechniker GmbH.

The purpose of a temporary safety barrier is to redirect an impacting vehicle with minimal deflection according to the criteria of European Standard EN 1317 in a way that minimizes injury to the vehicle occupants.

All safety barrier systems including individual barrier units, connections, transitions and attenuation must meet the minimum performance criteria of EN 1317. All temporary barrier systems must also be installed in accordance with tested configurations and manufacturers' instructions.

Safety barriers always need to be continuous and secured together. If hit by a vehicle, unconnected units are not able to restrict penetration and can also be hazardous as an unprotected roadside object.

Even in cases where the available lane width is small, adequately slim barrier systems, e.g., made of precast concrete and a minimum design width of just 0.24 m, are available (Figure 10). Due to their light weight, these barriers are rather easy to transport and install.

Figure 10: Slim temporary safety barrier

Source: Deltabloc International GmbH.

Still, when selecting a barrier system, the required containment level and barrier deflection characteristics must always be considered. The area behind any barrier that falls within the design deflection of the barrier system must be kept clear of all road workers, construction equipment and materials. This will be fulfilled through the correct implementation of a lateral safety buffer.

End treatments

The untreated end of a safety barrier (untreated includes the use of sandbags) is extremely hazardous if hit by an errant vehicle. Therefore, the end of a safety barrier shall be tapered away to provide an offset from approaching traffic. Where an approach taper cannot be provided, a temporary crash cushion must be used as an energy absorbing device to reduce the severity of a collision by an out-of-control vehicle (Figure 11).

Figure 11: Examples of end treatments

Source: Vill Ziviltechniker GmbH.

Mobile (portable) barrier systems

If traffic density in the driving directions differs significantly throughout the day (rush hours), mobile barrier systems might be useful (Figure 12).

In periods with high traffic density, two lanes can be provided for traffic. In periods with low traffic density (night-time), only one lane can remain open for traffic, thus providing more space for the work zone at night and leading to a significant reduction in the overall time needed to complete the works.

For small work zones, e.g., at inspection points or small-scale repairs, truck-mounted mobile barrier systems are already used for protection in the United States and the United Kingdom.

Figure 12: Truck-mounted mobile barrier system

Source: Mobile Barriers LLC.

7.6 SCREENS

Screens can be used to reduce the level of distraction of drivers created by work zones to decrease possible crashes or congestion (Figure 13). They can also be used to reduce problems with blinding from oncoming traffic or dust being blown across the road. Screens can be mounted on safety barriers or be free-standing on concrete footings behind a safety barrier (outside of the lateral safety buffer).

Figure 13: Anti-dazzle screens mounted on concrete barrier

Source: Vill Ziviltechniker GmbH.

7.7 VEHICLES

All works vehicles required to stop on the road should carry appropriate lighting and conspicuity markings to ensure they are visible to all road users and road workers, reducing the risk of collisions with other vehicles (Figure 14). In addition, a traffic sign (arrow) showing the mandatory driving direction should be mounted on the vehicle. These requirements should be mandatory for all works vehicles that are required to stop within the road or clear zone.

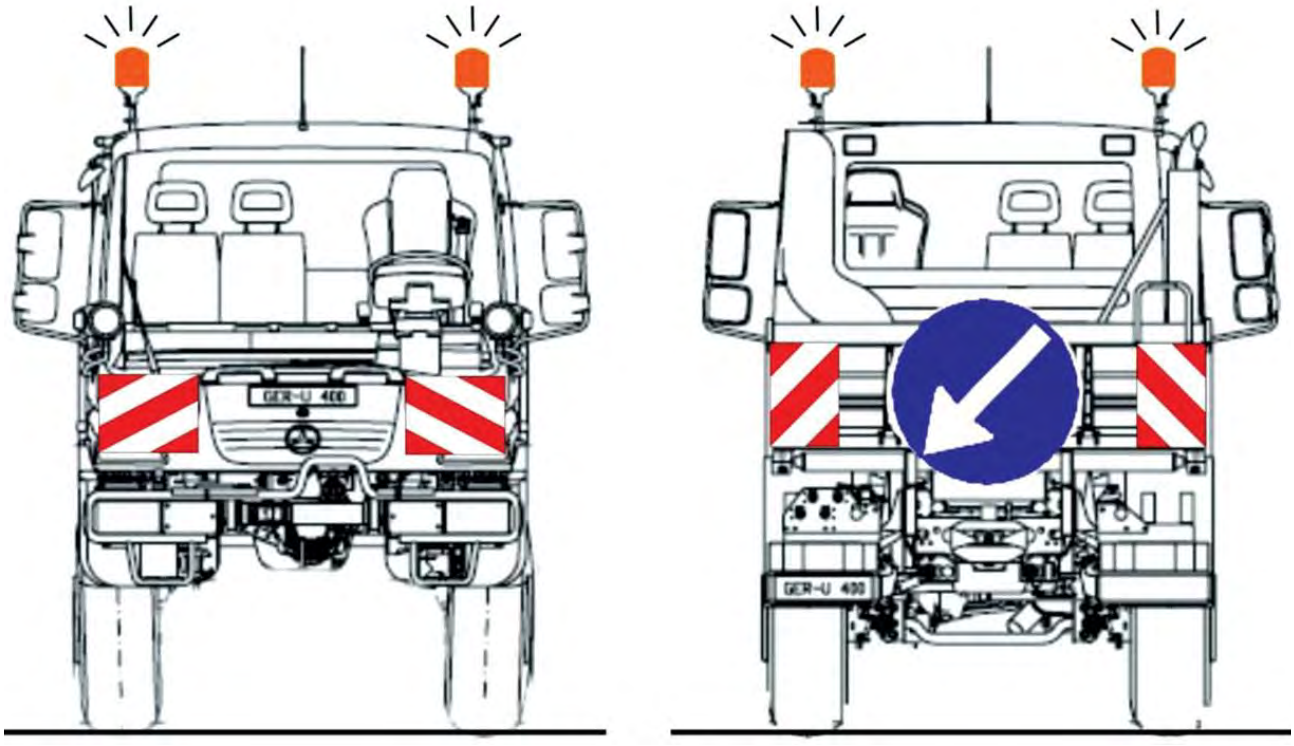
Yellow rotating or flashing lights should be mounted on top of the works vehicle and activated when moving slowly or when stopped to carry out works. The lights should be visible from both directions.

Rear retroreflective markings shall consist of either red retroreflective material covering the whole rear of the vehicle, as far as is reasonably practicable, or a series of chevron markings comprised of red retroreflective tape.

The arrow sign should be deactivated after finishing the work.

To reduce the exposure of workers to oncoming traffic, automated vehicles for works in work zones or the automation of deployment and dismantling of devices used in work zones may be employed, e.g., for cone dropping with remote control or for painting of road markings by an automated vehicle.

Figure 14: Examples of safe work vehicles



Source: Austrian Research Association for Roads, Railways and Transport, Guideline RVS 05.05.41 (left) and Bina Istra Ltd, highway operator of Croatia (right).

7.8 TRUCK MOUNTED ATTENUATORS (TMA)

Truck (or trailer) mounted attenuators (TMAs) should be used to reduce the severity of a rear-end collision with a stationary or slow-moving works vehicle (Figure 15). These devices are generally designed to manage collisions from vehicles up to 2,000 kg. Any TMA deployed should be tested and deemed compliant with relevant specifications (e.g., CEN TS 16786).

Figure 15: Example of a truck mounted attenuator

Source: Stuer-Egghe company website.

TMAs are typically used in situations where a works vehicle must be positioned or operated in a location where it is likely to be struck from the rear by a moving vehicle. Examples of these types of operations include line marking, temporary repairs to the road or placement of traffic control devices required to close a lane on a motorway.

7.9 SPEED CONTROL AND ENFORCEMENT EQUIPMENT

Enforcement of speed limits has a positive effect on road safety. There is much evidence that both average speed control and fixed speed cameras improve road safety.[21] For the enforcement of speed limits the following options are available:

- Non-automatic speed enforcement
  - Spot control – speed gun equipment alongside the road (visible or hidden)
  - Distance control – conspicuous or inconspicuous police cars
- Automatic speed enforcement
  - Spot control – fixed or mobile speed cameras (Figure 16)
  - Distance control – trajectory or section control (control between two points) (Figure 17, Figure 18)

Figure 16: Automatic speed enforcement – Spot control with fixed cameras

Source: Vill Ziviltechniker GmbH.

21 For details, see the SafetyCube Decision Support System portal, available at: https://www.roadsafety-dss.eu/#/

Figure 17: Automatic speed enforcement – Distance (section) control: starting point

Source: Vill Ziviltechniker GmbH.

Figure 18: Automatic speed enforcement – Distance (section) control: end point

Source: Vill Ziviltechniker GmbH.

Spot speed control or even mobile enforcement by the police are sensible, especially in or before crucial zones like transition zones, lane shifts, etc.

Automatic distance speed control (enforcement of mean speeds above a speed limit between two or more speed cameras) in work zones is already successfully used in some countries and – besides influencing driving speeds – leads to a homogenization of traffic flow, thus enhancing safety within the work zones.

Dynamic speed display signs showing the actual driving speed on a digital display should be used in addition as they have positive effects on speeds and on the number of crashes. The information can be combined with pictures (emoticons) or verbal messages (“‘Slow Down”). Emoticons have the advantage that they are commonly understood, and no language knowledge is necessary.

Driver speed monitoring displays (i.e., variable message signs showing the actual speed of the driver) combined with enforcement equipment were also found effective to reduce speeds and educate motorists.

8. STRATEGIC GOALS AND CRITERIA FOR WORK ZONE SAFETY

8.1 STRATEGIC GOALS

The definition of strategic goals for work zone safety is extremely important, especially for long-term roadworks. These strategic goals are usually set by the road operator in line with its general strategic objectives and the mission statement of the organization, and are agreed with the responsible road authority (e.g., ministry of transport). Different – and often conflicting – criteria might be relevant, such as safety at work and road safety (e.g., Vision Zero for work zones or zero fatalities), network availability, construction time and construction costs. These criteria should be optimized in the best possible way with a clear focus on road user needs and capabilities. These aspects are even more important for road operators that collect tolls on their roads, as road users are considered costumers.

The implementation of a work zone management system, including a work zone indicator that represents a key Figure for the availability and risk of congestion of a specific work zone, can support the road operator in monitoring and evaluation of the work zone safety goals as well as defining measures to reach these goals. The indicator should be determined for each relevant construction phase, should be defined for all intermediate and long-term work zones, and might consider the speed reduction due to the roadworks, the risk of congestion in peak hours as well as the traffic volume.

8.2 ROAD USER CRITERIA

Basic road user (customer) criteria may be based on the road operator's experience or studies of actual road user behaviour and acceptance; these criteria might include the following aspects[22]:

- Loss of time, e.g., work zone-related time loss of a maximum 5 minutes per 100 km
- Continuous length of a work zone, e.g., a maximum continuous length of 10 km for speed limits of 80–100 km/h; a maximum continuous length of 6 km for speed limits of 60 km/h
- Total length of work zones, e.g., maximum combined length of work zones limited to 20 km per 100 km (equivalent to a 5-minute time loss with an average speed reduction in the work zones
- Number of work zones, e.g., maximum number of work zones limited to 2 in 100 km

Additional criteria might be useful for roads with high degrees of commuter traffic during rush hours.

22 ASFINAG, "Handbook on Work Zone Coordination", 2019. (Internal document of the Austrian highway operator).

9. WORK ZONE CHALLENGES AND RECOMMENDATIONS

The following chapter summarizes the main challenges linked to work zone safety in TEM member countries and presents recommendations regarding possible solutions to overcome these challenges.

Challenge	Recommendation
Inadequate crash data for work zones	Standardized collection and evaluation of crash data for all work zones on motorways and on other roads as a basis for data-driven and evidence-based work zone safety management
Lack of knowledge of relevant UNECE resolutions (R.E.1 and R.E.2)	Increase awareness of UNECE consolidated resolutions and their impact on work zone safety
Insufficient implementation of Safe System approach in work zones	Review and – where necessary – adaptation of existing national work zone guidelines/standards/manuals to be in line with the Safe System approach
No systematic investigation and evaluation of work zone implementation schemes	Full implementation of road safety audits for (long-term) work zones
No systematic investigation and evaluation of active work zones	Full implementation of road safety inspections for (long-term) work zones
Lack of training of actors in the work zone	Compulsory training of all actors (road administration, contractors, workers, etc.) – also as a contractual requirement
No common standards for uniform speed limits	Definition of appropriate uniform speed limits for all road work zonesx
Insufficient enforcement of speed limits	Increase (automated) enforcement in all work zones (use of section control where possible)
Signage and road markings not in line with the capability and receptivity of the road users	Continuous application of the 4C concept for all signs and road markings to achieve a comprehensible guidance system
Large variety of work zone standards and layouts across TEM member countries	Creation of a TEM working group for harmonization of basic work zone frameworks and procedures

10. LITERATURE

The most relevant literature is covered in this chapter. All useful resources are summarized in Appendix 1 – Literature Review.

- American Traffic Safety Services Association, *Safe and Effective Work Zone Inspections* (Fredericksburg, Virginia, American Road and Transportation Builders Association, 2013).
- American Traffic Safety Services Association, *Work Zone Road Safety Audit Guidelines and Prompt Lists* (Fredericksburg, Virginia, American Road and Transportation Builders Association, 2013).
- Asian Development Bank, *CAREC Road Safety Engineering Manual 2: Safer Road Works* (Mandaluyong City, Philippines, 2018).
- Australian National Road Safety Strategy 2011–2020.
- Austroads, "Guide to Temporary Traffic Management Part 3: Static Worksites", 2019.
- Bennett, Christopher R. and others, *Good Practice Note: Environment and Social Framework for IPF Operations Road Safety* (Washington, D.C., World Bank, 2019).
- European Commission, "Advanced Research on Road Workzone Safety Standards in Europe" (ARROWS), 21 October 2002.
- European Union Road Federation, *Towards Safer Work Zones: a Constructive Vision of the Performance of Safety Equipment for Work Zones Deployed on TEN-T Roads* (Brussels, 2015).
- European Transport Safety Council, "PRAISE: Preventing Road Accidents and Injuries for the Safety of Employees", Report No. 6, May 2011.
- Federal Highway Administration, US Department of Transportation, "Manual on Uniform Traffic Control Devices", 2009 ed., 27 March 2020.
- International Organization for Standardization, *High-visibility clothing – Test methods and requirements*, ISO 20471:2013.
- International Organization for Standardization, *Safety of machinery – General principles for design – Risk assessment and risk reduction*, ISO 12100:2010.
- Rankin, Catharine H. and others, "Habituation revisited: An updated and revised description of the behavioral characteristics of habituation", *Neurobiology of Learning and Memory*, vol. 92, No. 2 (September 2009), pp.135–138.
- Sorensen, G. and others, Conference of European Directors of Roads, "ASAP – Towards a European Guideline for Speed Management Measures in Work Zones", 3 March 2015.
- Varhelyi, Andras and Daniels, Stijn, "Road Safety Management at Work Zones – Final report", December 2019.

APPENDIX 1 – LITERATURE REVIEW

In the following sections, the main contents and findings of the most relevant literature on work zone safety are summarized. More detailed information is available via the weblinks provided for each document.

A.1 UNECE DOCUMENTS

A.1.1 UNECE CONSOLIDATED RESOLUTION ON ROAD TRAFFIC (R.E.1) (2010)

Link: https://www.unece.org/fileadmin/DAM/trans/roadsafe/publications/docs/Consolidated_Resolution_on%20Road_Traffic_RE1_e.pdf

The Consolidated Resolution on Road Traffic (R.E.1) was prepared by the Working Party on Road Traffic Safety (WP.1) of UNECE. Chapter 14 of R.E.1 covers safety in the area of roadworks and includes recommendations on the safety of road users and road maintenance workers as well as on sensitization measures. The recommendations on the safety of road users include, e.g., the positioning of appropriate information panels, signs and signals; the setting of speed limits and their control; as well as user information in real time, in particular by means of dynamic information panels or by radio. Recommendations for road workers include the use of fluorescent and retroreflective clothing and the positioning of emergency vehicles. As far as sensitization measures are concerned, the recommendations include adequate training for road workers, especially on the need to be seen by road users, on the risks they face and on measures to prevent crashes. Furthermore, awareness among road users should be raised about risks they face in roadworks areas, specific speed limits and safety distance between vehicles.

A.1.2 UNECE CONSOLIDATED RESOLUTION ON ROAD SIGNS AND SIGNALS (R.E.2) (2010)

Link: https://www.unece.org/fileadmin/DAM/trans/roadsafe/publications/docs/Consolidated_Resolution_on_Road_Traffic_RE2_e.pdf

The Consolidated Resolution on Road Signs and Signals (R.E.2) was prepared by the Working Party on Road Traffic Safety (WP.1) of UNECE. Chapter 4 of this resolution covers roadworks and defines general and technical requirements for safe road work zones. Furthermore, it contains basic information on road signs in the advance warning and the work areas, vertical delineation, temporary horizontal markings, diversion signing, end of restrictions, traffic light signals and the removal of unnecessary restrictions.

A.2 EUROPEAN AND INTERNATIONAL PROJECTS AND INITIATIVES

A.2.1 EUROPEAN PROJECTS AND INITIATIVES

A.2.1.1 ARROWS – Advanced Research on Road Workzone Safety standards in Europe (1998)

Link: http://cordis.europa.eu/project/rcn/34458_en.html

This project was funded by the 4th Framework Program of the European Commission and aimed at developing a unified range of road work zone safety measures and principles that should govern the planning, design, implementation and operation of road work zones. The major output was the formulation of a consolidated *Practical Handbook on Road Work Zone Safety* comprising, among other things, guidance on the layout of road work zones with respect to traffic control, information and warning equipment, guiding and protective elements on the road, and safety equipment for workers.

A.2.1.2 PRAISE – Preventing Road Accidents and Injuries for the Safety of Employees (2011)

Link: https://etsc.eu/wp-content/uploads/Report-6.pdf

The project was co-funded by the European Commission and implemented by the European Transport Safety Council (ETSC). It aimed at advancing all work-related road safety management issues, such as in-vehicle safety equipment, fitness to drive, safer commuting to work and minimizing in-vehicle distraction. One part of the project covered road safety in work zones and summarized the state-of-the-art in terms of planning, installing, removing and managing a safe work zone using case studies from ETSC member States.

A.2.1.3 STARs – Scoring Traffic at Roadworks (2013)

Link: https://www.cedr.eu/stars-project-results

This project was funded by the 7th Framework Program of the European Commission (ERA-NET ROAD II) and aimed at optimizing network availability and road worker as well user safety during roadworks. A methodology to score road work schemes was developed, and a practical tool to be used by contractors and contracting authorities in planning and assessing roadworks was elaborated.

A.2.1.4 BRoWSER – Baselining Road Works Safety on European Roads (2015)

Link: https://www.cedr.eu/call-2012-safety

This project was funded by the Conference of European Directors of Roads (CEDR) Transnational Road Research Program and addressed the safety of road workers and their interaction with road users, with the aim to significantly reduce risks to road workers as well as an objective of Zero Harm. The data collected should enable national road authorities to ensure effective safety management in work areas, reducing real risks for workers. In addition, the project formulated a list of recommendations for harmonizing work zone layouts across Europe.

The BRoWSER project also contained a part dedicated to data collection and storage. A European Road Worker Casualty (EuRoWCas) database was developed to help national road authorities to take an evidence-led approach in managing road worker safety and to allow benchmarking of safety.

A.2.1.5 ASAP – Appropriate Speed Saves All People (2015)

Link: https://www.cedr.eu/call-2012-safety

This project was funded by the CEDR Transnational Road Research Program and looked at recommending the best methods for controlling speed through road work zones. The project analysed and graded 24 different speed-reducing measures and developed recommendations for both long- and short-term roadworks, both on motorways and rural roads. The project consortium gathered knowledge on effective speed management measures for road work zones through literature review, information from national expertise and practitioners, ongoing research in Europe and abroad, and stakeholder consultations. The main objective of the project was to provide practical recommendations to effectively manage speed through road work zones in terms of design and conspicuity of road work zones, enforcement, and driver education and information.

A.2.1.6 IRIS – Incursion Reduction to Increase Safety in road work zones (2019)

Link: https://www.cedr-iris.eu/en/deliverables-publications/#recommendations_final_report

This project was funded by the CEDR Transnational Road Research Program and aims to share best practices on traffic management in work zones with national road authorities in Europe for short-, medium- and long-term roadworks. The project covers data analysis of existing practices, regulations and future developments, a review of scientific literature on human factors, as well as interviews with road authorities and inspectors. Furthermore, existing inspection and audit requirements are assessed and best practices to prevent incursions are catalogued. The main findings of the projects are presented in a short webinar available on the project website.

A.2.1.7 ERF – Position Paper *Towards Safer Work Zones: a Constructive Vision of the Performance of Safety Equipment for Work Zones Deployed on TEN-T Roads* (2014)

Link: https://erf.be/wp-content/uploads/2019/07/Towards_Safer_Work_Zones_EN_FINAL.pdf

The European Union Road Federation (ERF) focuses in this position paper on the performance of the safety equipment used for securing road work zones (i.e., restraint systems, delineators, warning lights, vertical signs, temporary markings and other equipment). Focused on the TEN-T road network and surveying the approach, activity and termination areas in mobile, short-term and long-term work zones, information on current practices in member States and the equipment used throughout various European countries was collected and examined. The most commonly used equipment was selected and appropriately analysed, from which different functions were derived – primarily information, guidance and protection. Consequently, a risk assessment was carried out by a panel of experts to verify whether the functions effectively contributed to the safety objectives.

A.2.2 INTERNATIONAL PROJECTS AND INITIATIVES

A.2.2.1 PIARC – Technical Report "Improvements in safe working on roads" (2012)

Link: https://www.piarc.org/en/order-library/18274-en-Improvements%20in%20safe%20working%20on%20roads.htm?catalog&catalog-sort=title&catalog-size=

The focus of this report is on the safety of both workers and road users in road work zones. For the safe, efficient and effective management of work zones, it is proposed that a 4Cs principle be adopted. Work zones should be designed, operated and maintained such that the works are conspicuous, clear, consistent and credible. The report addresses the roles and responsibilities in work zones, planning and design of work zones, safe and efficient operations of work zones, personnel guidance in work zones, typical work zones layout, as well as checklists for work zone safety.

A.2.2.2 Austroads – Guide to Temporary Traffic Management (2019)

Link: https://austroads.com.au/latest-news/new-guide-will-improve-safety-of-road-workers-and-users-across-australasia

The 10-Part Guide to Temporary Traffic Management (AGTTM) was created by the collective of the Australian and New Zealand transport agencies (Austroads) to improve the safety and efficiency of temporary traffic management in road work zones across Australia and New Zealand. In addition to improving the safety of workers, the guide seeks to improve consistency and safety for all road users, including protecting vulnerable road users such as pedestrians, bicycle riders and motorcycle riders. Specialized planning and design guidance are provided for static work zones, mobile work zones and short-term, low-impact work zones. The guide consists of the following parts:

- Part 1: Introduction
- Part 2: Traffic Management Planning
- Part 3: Static Worksites
- Part 4: Mobile Works
- Part 5: Short-Term, Low-Impact Worksites
- Part 6: Field Staff – Implementation and Operation
- Part 7: Traffic Controllers
- Part 8: Processes and Procedures
- Part 9: Sample Layouts
- Part 10: Supporting Guidance

A.2.2.3 NCHRP – Estimating the Safety Effects of Work Zone Characteristics and Countermeasures: A Guidebook (2018)

Link: http://www.trb.org/Main/Blurbs/177154.aspx

The guidebook published by the Transportation Research Board's (TRB) National Cooperative Highway Research Program (NCHRP) provides practitioners who develop phasing and staging plans for temporary traffic control through work zones with guidance to evaluate the safety impacts of their plan decisions. There is limited data on work zone crashes and fatalities that address trends, causality and the best use of resources to improve work zone safety. This guidebook provides clearer guidance to encourage the use of a data-driven, comprehensive, collaborative planning approaches for the selection and implementation of effective countermeasures to improve work zone safety.

A.2.2.4 NCHRP – Analysis of Work Zone Crash Characteristics and Countermeasures (2018)

Link: http://www.trb.org/Main/Blurbs/177155.aspx

The report published by the Transportation Research Board's (TRB) National Cooperative Highway Research Program (NCHRP) contains the results of multiple analyses focused on developing an improved understanding of work zone crash characteristics and countermeasure effectiveness.

A.2.2.5 FHWA – Work Zone Management Listing

Link: https://ops.fhwa.dot.gov/publications/fhwahop18081/ch4.htm

The Federal Highway Administration (FHWA) of the US Department of Transportation provides a complete listing of currently available work zone management resources by mitigation strategy (work zone planning and analysis tools and modelling; crash data collection and performance measure reporting; congestion data collection and performance measure reporting; process reviews; and work zone safety audit). The listing contains guidelines, podcasts, field guides, trainings (instructional and web-based) as well as analytical tools (research-based simulation, modelling, analysis and other tools developed to help agencies or practitioners mitigate work zone impacts and select appropriate safety strategies).

A.2.2.6 CAREC – Road Safety Engineering Manual 2 – Safer Road Works (2018)

Link: https://www.adb.org/publications/carec-road-safety-engineering-manual-safer-road-works

The manual published by the Asian Development Bank (ADB) explains good practices for work zones on Central Asia Regional Economic Cooperation (CAREC) roads and provides clear and simple guidance for national road authorities to improve road safety in work zones. It provides full information about the six-zone process; how to plan, design, implement and operate a TMP; and how to manage road safety for road users and road workers alike.

A.2.2.7 IRF – Statement of Policy "Mandating Safer Work Zones Globally" (2018)

Link: https://www.irf.global/docs/committees/IRF-Policy-Statement-to-Mandate-Safer-Global-Work-Zones-180406.pdf

In this paper, the International Road Federation (IRF) calls for coordinated efforts to foster a safety culture in road work zones, encourages road authorities to develop and update national guidelines that incorporate best practices, and sets a "level playing field" for the private sector. Contractors should be held accountable for training their crews on safety best practices. For work zones of a certain scale, an independent road safety audit should be mandatory to ensure safety standards are met and maintained.

A.3 LEGAL FRAMEWORK

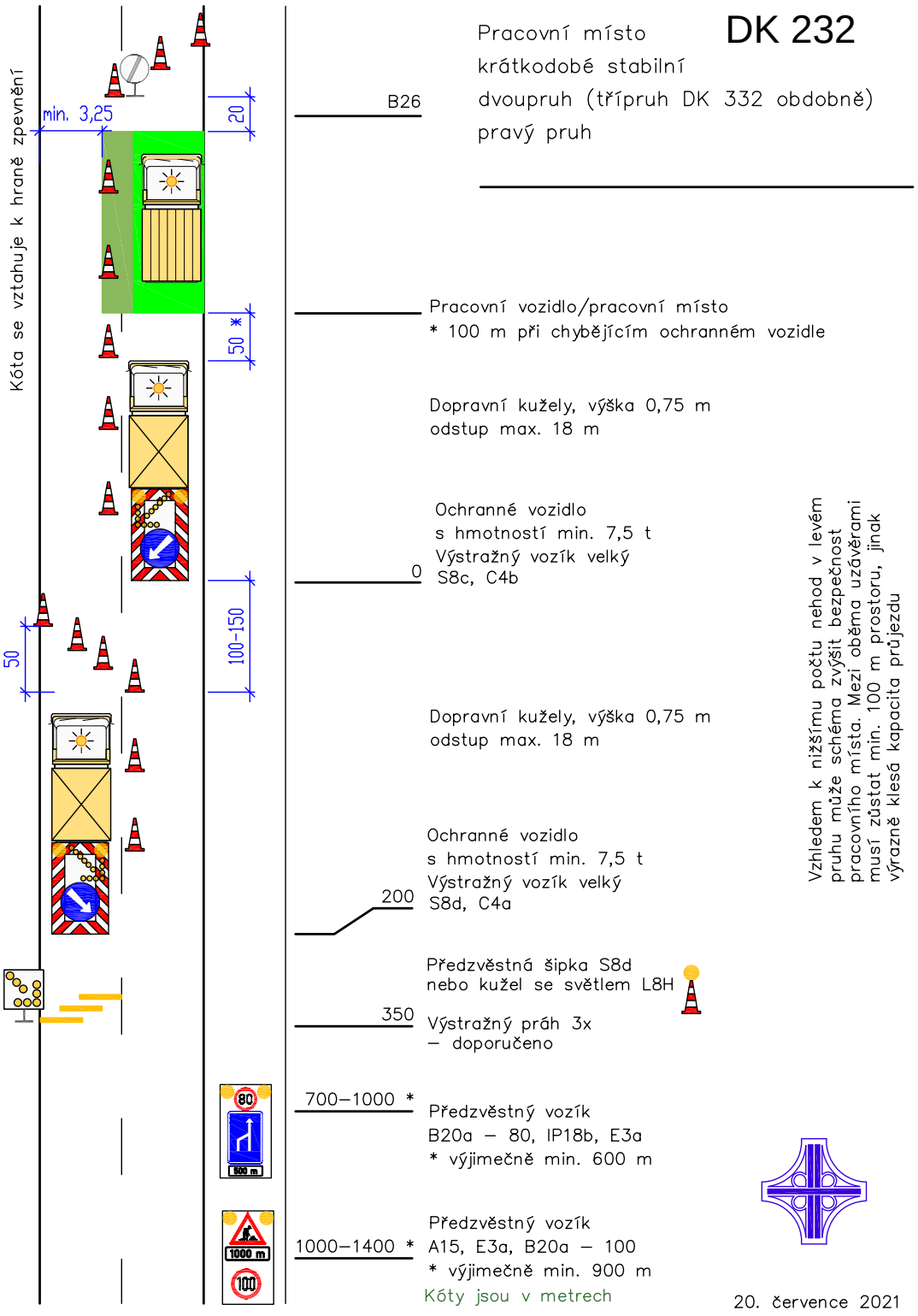
A.3.1 DIRECTIVE (EU) 2019/1936 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL OF 23 OCTOBER 2019 AMENDING DIRECTIVE 2008/96/EC ON ROAD INFRASTRUCTURE SAFETY MANAGEMENT

Link: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019L1936&from=EN

Annex IIa of the Directive covers indicative elements of targeted road safety inspections. In this context roadworks are mentioned explicitly.

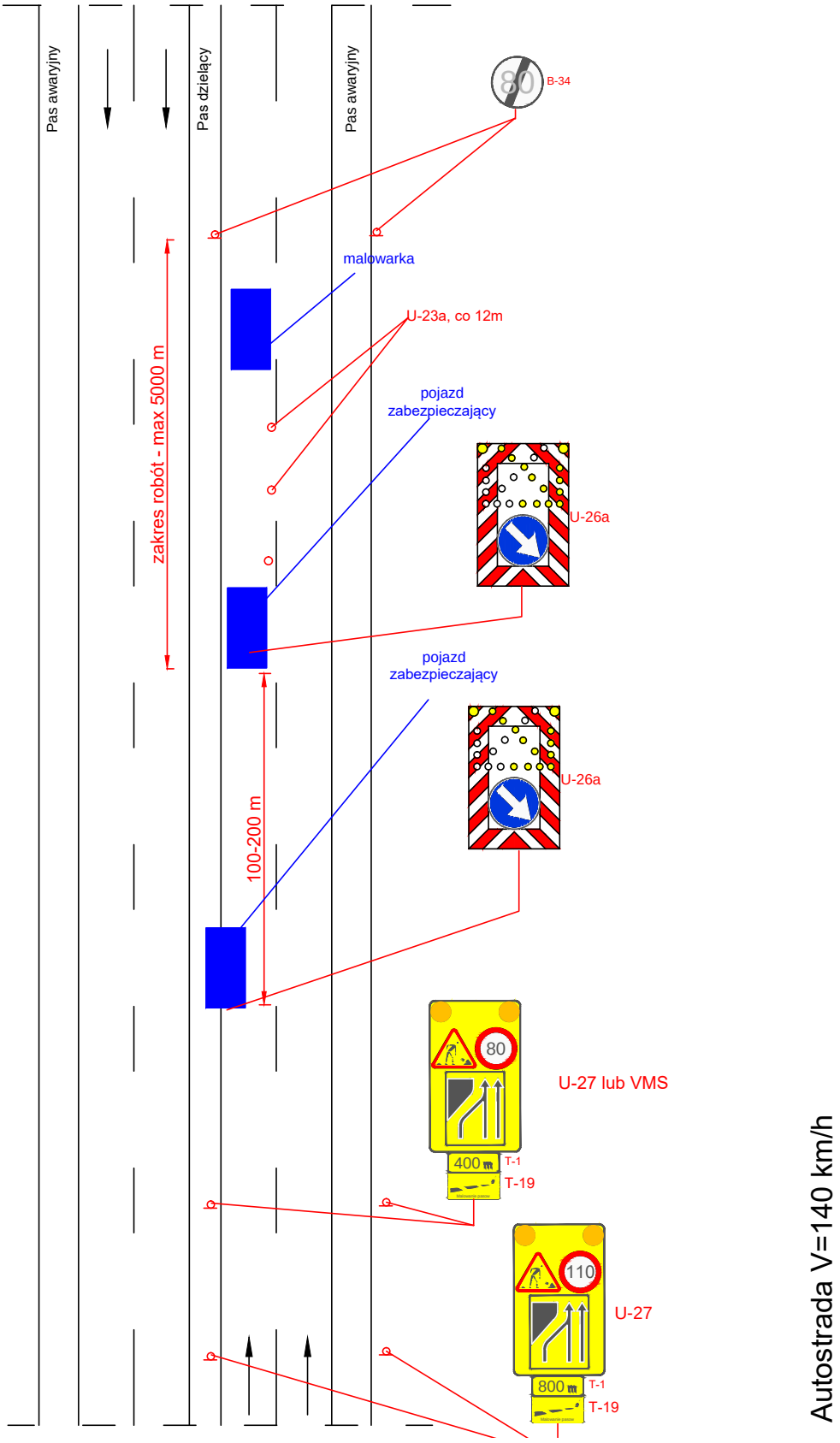
APPENDIX 2 – EXAMPLE LAYOUTS FROM TEM MEMBER COUNTRIES

A.1 SHORT-TERM ROADWORKS ON MOTORWAY



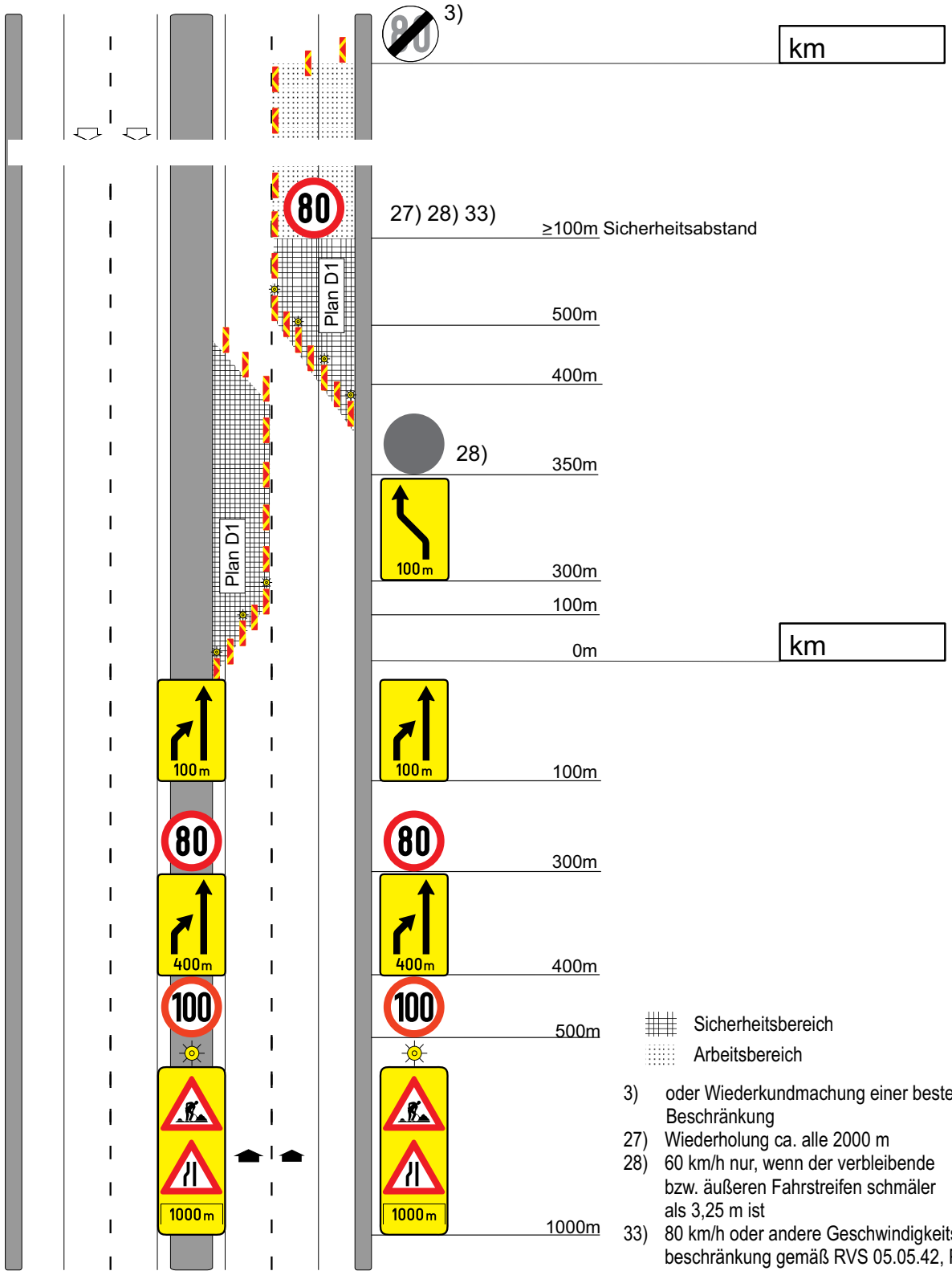
Source: Ředitelství silnic a dálnic ČR (ŘSD) [Road and Motorway Directorate, Czech Republic].

A.2 SHORT-TERM ROADWORKS ON MOTORWAY – CLOSURE OF THE (INNER) LEFT LANE



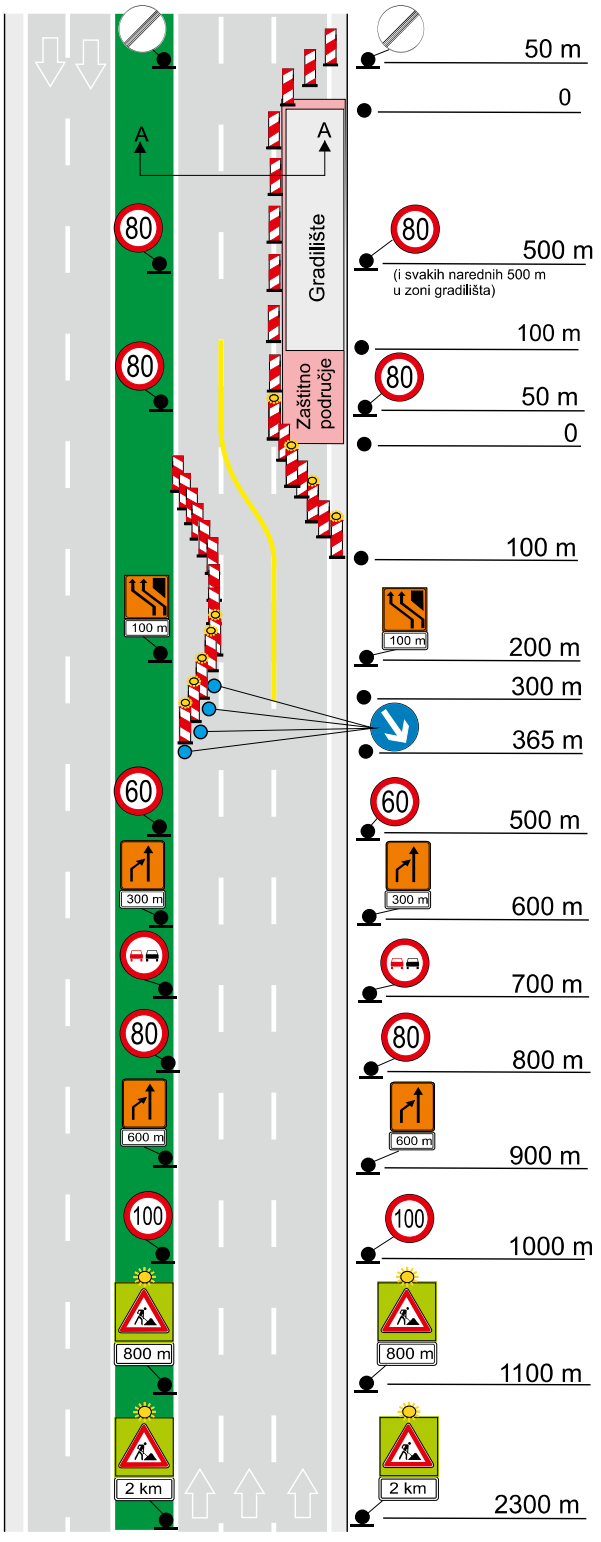
Source: Generalna Dyrekcja Dróg Krajowych i Autostrad [General Directorate of National Roads and Motorways, Poland].

A.3 LONG-TERM ROADWORKS ON MOTORWAY – CLOSURE OF THE (OUTER) RIGHT LANE



Source: Austrian Research Association for Roads, Railways and Transport, Guideline RVS 05.05.42.

A.4 LONG-TERM ROADWORKS ON MOTORWAY – CLOSURE OF THE (OUTHER) RIGHT LANE

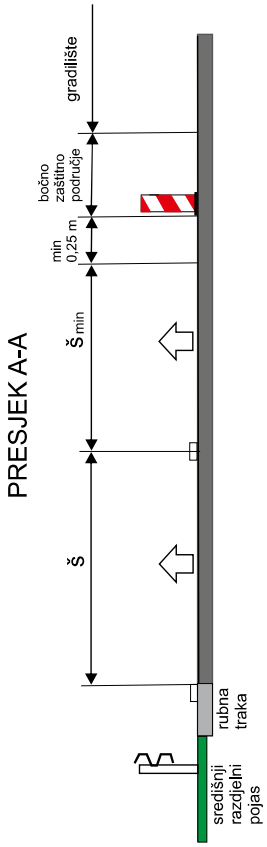


PRIVREMENA REGULACIJA

A - 4

NAMJENA:

Privremena regulacija prometa na dijelu autoceste kada se radovi izvode na zaustavnoj traci i dijelu prometne trake uz osiguranje prometovanja na dvije vozne trake u području radova.
U području regulacije autocesta ima tri prometne trake na području kolničke trake gdje se izvode radovi.



PRIMJER

Source: Ministarstvo Mora, Prometa i Infrastrukture [Ministry of the Sea, Transport and Infrastructure, Croatia].

NOTES

TEM Guidelines on Work Zone Safety

The Trans-European North-South Motorway (TEM) Project was initiated to facilitate road traffic in Central, Eastern and South-Eastern Europe, and to assist with the process of integrating European transport infrastructure systems.

Major infrastructure projects which are implemented to improve the efficiency, safety and environmental performance of the TEM Backbone Network are often accompanied by risks during construction, rehabilitation and maintenance works. Work zones pose specific risks not only to the road users driving through complex arrangements of signs, road markings and lane changes, but also to the workers conducting the road works. These risks are mainly the result of the competition between workers and motorists for the limited road space available in work zones.

An overview of the current state of practice across TEM member countries revealed a multitude of design and signage practices for road work zones, with different characteristics that are often hard to understand for road users – especially for cross border traffic. These Guidelines are based on a comprehensive review of the most relevant road work zones guidelines, standards, studies and projects, addressing current trends, standards, technologies and equipment in road work zones on motorways in TEM member countries.

These Guidelines identify good practice solutions and present a unified compilation of road work zone safety principles and measures that should govern the planning, design, implementation and operation of road work zones in TEM member countries, mitigating many of the risks to both road workers and users.

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