EUROPEAN UNION ROAD FEDERATION

ERF

Towards Safer Work Zones

A constructive vision of the performance of safety equipment for work zones deployed on TEN-T roads

Contents

1. Executive Summary

The European Union Road Federation created in 2011 a dedicated Working Group to carry out a focused research on national guidelines, legislations and cases regarding equipment deployed in road work zones, in order to detect best practices, identify improvements and produce performance guidelines adapted to the state of the art.

The Working Group's first achievement has been the collection of detailed information regarding national legislation, signs, markings and other infrastructure elements used in work zones in various member states, e.g. Spain, Italy, France, Austria, Germany and Belgium.

Focused on the TEN-T road network and surveying the approach, activity and termination areas in mobile, short and long term work zones, current practices in member states and the equipment used throughout various European countries were collected and examined.

The most commonly used equipment was selected and appropriately analysed from which different types of functionality were derived, primarily information, guidance and protection.

Consequently a risk assessment was carried out by a panel of experts to verify whether the functionalities effectively contributed to the safety objectives.

Finally the Work Zone Safety Project could set forward minimum performance levels for these equipment to enable them to be effective in their own objectives regarding functionality and safety.

2. A challenge to improve safety in the EU road work zones

2.1 Background

Road maintenance activities are integral part of improving road safety conditions. Given that the majority of the current road network was built in the 1960s and being also expected to increase demands (especially from cross-border journeys) in coming years, it seems unavoidable that, in the immediate future, maintenance and upgrade works on the road network will occur on a higher frequency than in the past.

As traffic becomes more and more transnational, road users would need to benefit from transparent and harmonized measures for work zones. Nowadays, existing national regulations or guidelines can differ from one country to another. In this context, a constructive European dialogue between national authorities could have a key role to play in specifying uniform safety requirements, which would also contribute to diminishing high human, economic and social costs of accidents and also delays as consequence of road works.

Despite the overall progress being made in the area of road safety, road works remain particularly hazardous zones, as they represent an unexpected change to the usual driving environment. Drivers themselves do not regard road works as a danger. They assume to take sufficient precautions, choose the right speed, decelerate at the right moment and keep the proper safety distance from other vehicles. However, because of their actions and wrong perceptions, they put themselves, other road users and road workers in jeopardy.

Given that efficient, safe and sustainable mobility between member states is a contributing element of the Single Market, a greater harmonisation of safety requirements in road works could have a positive impact to change the situation.

In addition improving safety in work zones is becoming a major concern to road authorities and safety stakeholders. At EU level, the European Parliament, voted a resolution of 27 September 2011 on European road safety 2011-2020 which highlights work zone safety (article 59) as an action area and ***«calls on the Commission to ensure that roadwork sites are made safer through guidelines for designing and equipping sites, which should be standardised, as far as possible, at the European level, so that motorists are not faced with new, unfamiliar circumstances in each country»***.[1]

[1] EP 2010/2235 (INI), Clause 59

2.2 Sources and related Projects

Past and present EU Projects have already treated various aspects of road work zones.

Foremost, the *Advanced Research on ROad Work zone Safety standards in Europe* (**ARROWS**) project[2] 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 by the consortium was the elaboration of a consolidated Practical Handbook on 'Road Work Zone Safety' comprising among others 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 framework for the road work signaling is already provided by the Vienna Convention (Chapter 5, Article 35). In addition, more recent projects have covered the influence of road works layout on road user safety, benchmarking of roadwork safety, speed management in road work zones and harmonising work zone design.

More recently, the *Scoring Traffic at Roadworks* (**STARs**) project[3] aimed at optimizing network availability, road worker as well user safety during roadworks. Concretely, its main contribution has been the development of a methodology to score roadworks schemes and also the elaboration of a practical tool to be used by contractors and contracting authorities in planning and assessing roadworks.

To be completed by 2015, there are two other projects funded under the CEDR Transnational Road Research Programme: BROWSER and ASAP.

The *Baselining Road Works Safety on European Roads* (**BRoWSER** project)[4] addresses the issue of the safety of road workers and interaction with road users. The research seeks to significantly reduce risks to road workers with an objective of Zero Harm. The data collected by the consortium will enable national road authorities to ensure an effective safety management in work areas reducing real risks for workers. In addition, the project will elaborate a list of recommendations for harmonizing work zones layouts across Europe.

Latest project dealing with the issue is the **ASAP** Project (Speed Management in Work Zones) focused on both the road user and road worker. The consortium has gathered knowledge on effective speed management measures for road works zones through literature review, information from national expertise and practitioners, on-going research in Europe and abroad, and stakeholder consultations. The main objective of the project will be to provide practical recommendations to effectively manage speed through road work zones in terms of: engineering design and conspicuity of road works, enforcement and driver education/information.

In complement to the previously cited projects on work zones, the current ERF Position Paper **Towards Safer Work Zones** focuses 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). The completion of the document has been possible with all the data collected and information provided by experts from various member states, namely France, Germany, Spain, Italy, Belgium, Sweden, Finland, Estonia, Latvia, Lithuania, Hungary, CZ, Slovakia, Ireland, Portugal and Greece.

[2] ARROWS (1998): http://cordis.europa.eu/project/rcn/34458_en.html

[3] STARS (2013): http://www.cedr.fr/home/fileadmin/user_upload/en/Thematic_Domains/Strat_plan_3_2013-2017/TD1_Innovation/I1_Research/TGR_TPM/Transnational_calls/2011_Call_Mobility-Design-Energy/02_ENR%20Call%202011%20-%20Design/STARs/00_enr2011%20design%20project%20description%20stars.pdf

[4] BRoWSER (2015): http://www.cedr.fr/home/fileadmin/user_upload/en/Thematic_Domains/Strat_plan_3_2013-2017/TD1_Innovation/I1_Research/TGR_TPM/Transnational_calls/CEDR_Call_2012/CEDR%20Call%202012%20Safety/BROWSER/cedr%20call2012_safety_browser.pdf

2.3 Scope

The scope of the project has been delimited to the following boundaries:

Frame

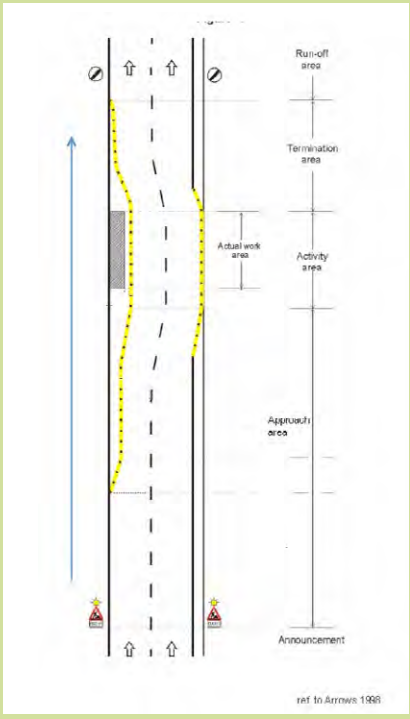
Time phase	Work zone fully installed and road works operational (Arrows Phase 4 – Operation)[5]
Placement of work zone	Uninterrupted road stretch (i.e. no exits, entries, crossroads, …)

Road works type

Type	Definition
Mobile	Continuously moving works, eventually with intermittent stops. Repair of potholes, markings
Short term	Stationary works of limited extent and duration. Replacement of damaged RRS
Long term	Stationary works over longer periods with comprehensive logistic aspects (work vehicle traffic), mostly carrying extensive messaging and special measures to maintain traffic flow. Pavement renovation Remark: for very long term road works (several months) special arrangements could be applicable

Road works area

Area	Definition
Termination area	The stretch past the work zone where normal carriageway and traffic conditions are being restored
Activity area	The actual work zone, characterized by presence of work force and stabilised altered carriageway conditions
Approach area	The zone starting at the first advance warning and where carriageway and traffic conditions are being altered (ex.: speed reduction, lane changes). Ends at the Activity area



[5] ARROWS (1998): http://cordis.europa.eu/project/rcn/34458_en.html

Road types

Type	Definition
Motorways Highways Dual carriageway roads	High volume, high speed, multi lane carriageways (Arrows type A)
Arrows typology	**Type A** includes motorways and dual carriageway expressways. **Type B** includes rural primary roads - which are typically singlecarriageway roads, often expressways and functionally important at a national and/or international level. **Type C** includes rural secondary roads, i.e. rural roads that are functionally less important than type B. **Type D** includes urban main roads - which are typically multi-lane facilities (often arterials) with high volumes and a diverse traffic mix (which can include pedestrians, two-wheelers, and/or public transport vehicles). **Type E** includes urban local roads, serving low traffic volumes

2.4 Methodology

The process started when the ERF Working Group launched a survey to targeted member states requesting different types of safety equipment deployed in work zones areas (→ ***3 Survey of current practices for work zone equipment***).

The survey should then identify which type of equipment was commonly used in most of the EU countries. Traffic elements could consequently be categorized according to their objectives (→ ***4 Functional analysis***): e.g. restraint systems, delineators, warning lights, vertical signs, temporary markings, etc.

Following step in the process was the analysis of the requirement of each country targeted for every element (→ ***Section 5 Review per type of equipment***) having an initial clear picture in Europe to be completed by a subsequent risk analysis (→ ***6 Risk assessment***) verifying if these equipment do correspond with relevant safety functions: e.g. information, guidance and protection.

Once risk assessment has been completed and validated, the document will present a set of recommendations to ensure a minimum performance level in terms of safety for those elements following from the analysis completed by technical experts (→ ***7 Recommendations for minimum performance***).

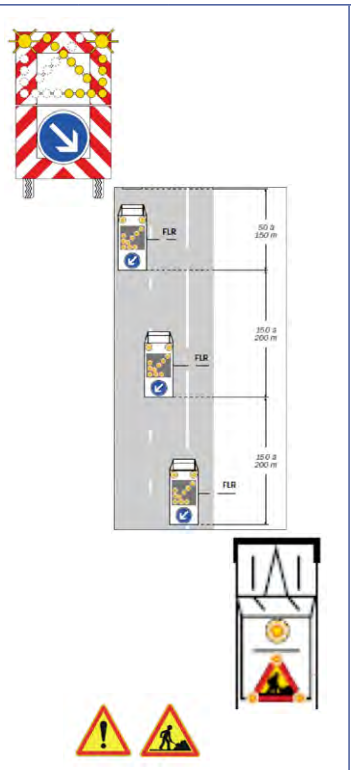
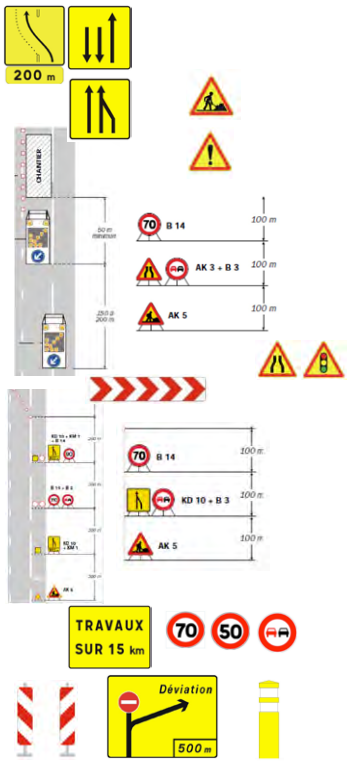
Consequently, a minimum level of performance would be required to enable the adequate fulfilment of a safety function based on specific elements such as:

- Collective expertise
- Practices in member states
- State of the art
- Feasibility
- Market acceptability
- Best practices

3. Survey of current practices for work zone equipment

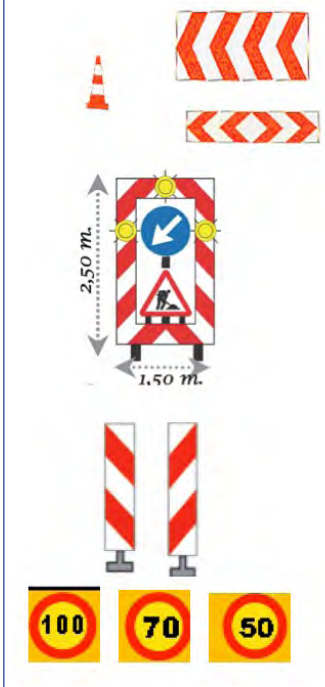
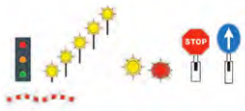
National Road Authorities have established their own rules, regulations and specifications at national or regional level regarding road works. The ERF Working Group has collected the relevant elements from various member states and summarised them graphically. Accordingly, the matrixes below represent practical examples in France, Spain and Belgium of road infrastructure elements deployed in the three types of work zones as well in various types of roads.

3.1 Approach area: France

	APPROACH AREA											
	MOBILE WORK ZONE				SHORT TERM WORK ZONE				LONG TERM WORK ZONE			
	Motor-way	Primary Roads	Secundary Roads	Local Roads	Motor-way	Primary Roads	Secundary Roads	Local Roads	Motor-way	Primary Roads	Secundary Roads	Local Roads
Regulation	• Decree of Nov 24th 1967 on the Signage of Roads and Motorways (***Arreté du 24 novembre 1967 relatif à la signalisation des routes et des autoroutes***) • Interministerial Instruction on Traffic Control Devices: Temporary Devices (*Instruction Interministérielle sur la signalisation routière -Livre I, 8ème partie, Signalisation Temporaire*) • Foreman's Manual : Temporary Traffic Control Devices - vol 1 single carriageway roads (*Signalisation temporaire - Manuel du chef de chantier. Volume 1 : routes bidirectionnelles*) [6'] vol 2 dual carriageway roads, (*Signalisation temporaire - Manuel du chef de chantier. Volume 1 : routes bidirectionnelles, Volume 2 : routes à chaussées séparées*) .[6a]											
Signs												
Other elements												
Markings												
Workers	Workers must be dressed in yellow or orange with at least class 2 or class 3 high visibility clothes according to EN standard											

[6'] http://catalogue.setra.fr/document.xsp?id=Dtrf-0002340&qid=sdx_q0&n=43&q
[6a] http://catalogue.setra.fr/document.xsp?id=Dtrf-0003051&qid=sdx_q0&n=1&q

3.2 Activity area: Spain

	ACTIVITY AREA											
	MOBILE WORK ZONE				SHORT TERM WORK ZONE				LONG TERM WORK ZONE			
	Motor-way	Primary Roads	Secundary Roads	Local Roads	Motor-way	Primary Roads	Secundary Roads	Local Roads	Motor-way	Primary Roads	Secundary Roads	Local Roads
Regulation	• PG-3/75: General Technical Prescriptions for Works on Roads and Bridges from the Directorate General of Roads (last update by Orden FOM/2523/2014 of 12 December) - *PG-3/75: Pliego de Prescripciones Técnicas Generales para Obras de Carreteras y Puentes de la Dirección General de Carreteras y Caminos Vecinales (actualizado por la Orden FOM/2523/2014 de 12 de diciembre)*[7] • Guidelines with good practices on markings and signs on work zones (Minsitry of Infrastructure) - *Manual de ejemplos de señalización de obras fijas (Ministerio de Fomento)*[8]											
Signs												
Other elements												
Markings												
Workers	Workers must be dressed in yellow or orange (EN 471: 2004)											

[7] https://www.boe.es/boe/dias/2015/01/03/pdfs/BOE-A-2015-48.pdf
[8] http://www.fomento.gob.es/NR/rdonlyres/9948A902-2B36-4604-83A9-ECD47C4B2024/55751/1130600.pdf

3.3 Termination area: Belgium

	TERMINATION AREA											
	MOBILE WORK ZONE				SHORT TERM WORK ZONE				LONG TERM WORK ZONE			
	Motor-way	Primary Roads	Secundary Roads	Local Roads	Motor-way	Primary Roads	Secundary Roads	Local Roads	Motor-way	Primary Roads	Secundary Roads	Local Roads
Regulations	• National Decree regarding signnalling of Road Works and obstacles on public roads (Arrêté ministériel relatif à la signalisation des chantiers et des obstacles sur la voie publique. [A.R. 21.05.1999])[9]											
Signs												

[9] http://www.code-de-la-route.be/textes-legaux/sections/am/am-070599-werken

4. Functional analysis

National regulations present common elements as several types of equipment are deployed on a regular base and applied in typical configurations in work zones:

Type	Configurations
Barriers, fences, beacons, arrow boards, chevrons	• Lane separation • Lateral closure • Lane diversion • Buffer zone • Safety corridor • Arrays
Warning lights	• Stand-alone • Fixed on other equipment • Light arrow • Repeated
Vertical signs	• Stand-alone • VMS • Repeated
Road markings	• Lane diversion • Lane narrowing

Consequently following functions can be derived:

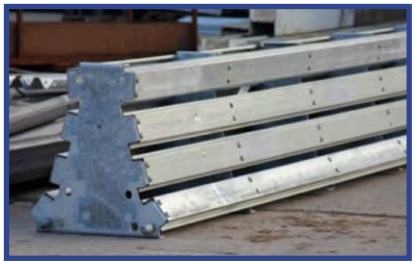
• Getting the attention, giving information and commanding:

1. Attract driver's attention (i.e. with warning lamps)
2. Telling what lies ahead (i.e. "left lane closed")
3. What must be done (i.e. "merge right")

• Physical and visual guidance and separation

• Influencing the pace, mostly speed regulation

• **Protection**



Allowing these functions, the road infrastructure equipment has been categorized in seven groups:

		Function			
		Warning, information, commands	**Guidance, separation**	**Speed control**	**Protection**
Equipment type	**Restraint systems**		■		■
	Delineators		■		
	Warning lights	■			
	Vertical signs	■		■	
	Temporary markings		■		
	Other equipment	■		■	
	Innovative solutions	■		■	

5. Review per type of equipment

This section illustrates the various types of road equipment commonly used in the member states to ensure safety in work zones.[10]

5.1. Restraint Systems

Equipment: Restraint systems	
Definition	This type of traffic equipment serves primarily to minimize or reduce the consequences of accidents involving vehicles running off the roadway. At the same time, it also fulfils the function of guiding the traffic, as well defining and physically separating the work area (closure) preventing the entrance of vehicles.
Function	• Protection • Establish transverse and longitudinal closures • Guidance • Channelize traffic
Solutions	 Steel Road Restrain Systems  Concrete Road Restrain System  Impact attenuator  Truck Mounted Attenuator

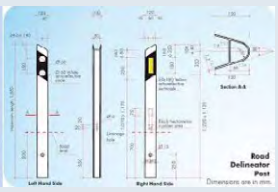
[10] Abbreviation codes: NA (not used in this work zone area), NR (No requirements), TBS (to be specified), TD (tender documents)

Example:

	Equipment	Area	Standard	Specification	Long Term	Short Term	Mobile
SWEDEN	Roadside barrier	Approach and Activity	EN 1317-2	Containment level	T2 or higher, TBS in TD	NA	
				Materials	TBS in TD		
				Working width	TBS in TD		
				ASI	TBS in TD		
			TD	Anchorage	TBS in TD		
	Impact attenuator		EN 1317-3				
	TMA	Approach	NCHRP 350	Test level	NA	NA	TL3

Normative references	Normative References EN 1317-2: Road restraint systems - Part 2: Safety barriers EN 1317-3: Road restraint systems - Part 3: Crash cushions NCHRP 350: NCHRP Report 350 - Recommended Procedures for the Safety Performance Evaluation of Highway Features

5.2. Delineators

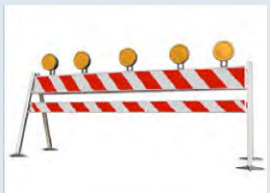
Equipment: Delineators	
Definition	This type of traffic equipment aims at establishing visual transverse and longitudinal closures, to guide and funnel/channelize the traffic, and/or to create a visual and physical separation either from opposite-way lanes or the working area.
Function	• Warning • Guidance • Creation of physical separation
Solutions	   Delineators    Beacons    Modular Plastic Lane Separators ➤ ➤ Cones and traffic cylinders 

Example:

	Equipment	Area	Standard	Specification	Long Term	Short Term	Mobile
FINLAND	Fixed delineators	Approach Activity Termination	SFS-EN 12899-3	Visual performance (posts)	Reflective part minimum 2/3 of total height		
				Visual performance (reflectors)	Daylight film		
	Portable deformable delineators		SFS-EN 13422	Height	1000 mm		NA
				Width	180 mm		NA
				Retroreflection R	R2		NA
	Cones		SFS-EN 13422	Height	NA		500-750 mm
				Weight			1,9 – 7,5 kg
				Retroreflection R			R2

Normative references	EN 12899-3: Fixed, vertical road traffic signs - Part 3: Delineator posts and retroreflectors EN 13422: Vertical road signs - Portable deformable warning devices and delineators - Portable road traffic signs - Cones and cylinders

5.3. Warnings Lights

Equipment: Warning lights	
Definition	These devices are used to draw attention and warn drivers about the presence of a disruption to the usual road conditions.
Function	• Warning • Guidance
Solutions	       Warning light configurations on work zone equipment

Example:

	Equipment	Area	Standard	Specification	Long Term	Short Term	Mobile
CZECH REPUBLIC	Lights on delineators and RRS	Approach Activity	EN 12352	Colour	yellow	yellow	NA
					L8H		
	Lights on vertical signs	Approach Activity	EN 12352	Colour	yellow	yellow	NA
					L8H		
	Lights in light arrows	Approach	EN 12352	Colour	yellow	yellow	NA
					L8H		
	Flash Lights	Approach Activity	EN 12352	Colour	yellow	yellow	NA
					L9H		

Normative references	EN 12352: Traffic control equipment - Warning and safety light devices

5.4. Vertical signs

Equipment: Vertical Signs	
Definition	These signs are used to warn and inform the drivers about the presence of a work zone area as well as about its effects on their route choice, lane choice, speed and other parameters of their behaviour.
Function	• Regulatory (e.g. speed limit) • Warning (e.g. works ahead)
Solutions	 Traffic signs and panels

Equipment: Vertical Signs	
Solutions	   Variable Message Signs

Example:

	Equipment	Area	Standard	Specification	Long Term	Short Term	Mobile
BELGIUM	Traffic Signs	Approach Activity Termination	EN 12899-1	Retroreflectivity	Type 3		
				Resistance to loads	NR[11]		
				Materials	Steel and aluminium		
	Variable Message Signs	Approach Activity	EN 12966	Colours	C2, white or yellow		
				Luminance L	L3		
				Luminance ratio R	R2		
				Beam width	B3		
		Termination	NA				

Normative references	EN 12899-1: Fixed, vertical road traffic signs - Part 1: Fixed signs EN 12966: Road vertical signs - Variable message traffic signs

[11] Belgian Road Authorities apply identical requirements both for temporary and permanent signs

5.5. Temporary Markings

Equipment: Temporary Markings	
Definition	Traffic element to delineate vehicle paths other than the lanes normally used. Temporary markings are commonly used to create deviations and relocations, eventually narrowing normal road lanes guiding traffic flow..
Function	• Warning • Guidance • Creation of physical separation
Solutions	    

Example:

	Equipment	Area	Standard	Specification	Long Term	Short Term	Mobile
SLOVAKIA	Temporary markings	Approach Activity Termination	STN 01 8020 EN 1436	Colour (W, Y1, Y2)	Orange EN 1436		NA
			STN 01 8020 EN 1436	Width	125 mm		
			STN 01 8020 EN 1436	Luminance Qd, β	Q1, B1		
			STN 01 8020 EN 1436	Retroreflectivity RL	R3		
			STN 01 8020 EN 1436	Retroreflectivity RW, RR	RW1, RR1		
			STN 01 8020 EN 1436	Durability	6 months		
			TD	Material	Preformed tape or paint		
			STN 01 8020 EN 1436	Anti-skid	S1		

Normative references	STN 01 8020: National standard on Traffic signs on roads EN 1436: Road marking materials — Road marking performance for road users

5.6. Other equipment

Equipment: Other (e.g. road studs, rumble strips)	
Definition	Roads studs are traffic devices composed of one or more integrated parts which could be bonded, anchored or embedded on the road surface. Once works are finalised, temporary studs are removed with little or no damage to the existing surface. Rumble strips are placed on the roadway to produce noise and vibration once tires of the vehicle contact them.
Function	• Warning • Guidance
Solutions	 Work Zone Road stud  Rumble strips

Example:

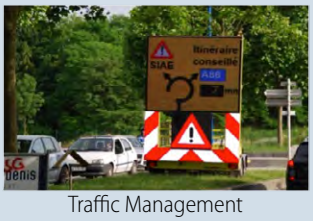
	Equipment	Area	Standard	Specification	Long Term	Short Term	Mobile
IRELAND	Road Studs	Approach Activity Termination	Chapter 8 of TSM, EN 1463 and Series 1200 of NRA Specification	Colour	Luminous Orange	NA	
				Fixing	No damage to surface		
				Inspections	Weekly		

Normative references	TSM: Traffic Safety Measures and Signs for Road Works and Temporary Situations (UK) Series 1200: NRA Specifications for Road Works (IE)

	Equipment	Area	Standard	Specification	Long Term	Short Term	Mobile
GERMANY	Rumble strips	Approach	StVO (German Law) and RSA	Colour	NA	Yelllow	NA
				Width, height	NA	200*23 *3cm	

Normative references	StVO: Straßenverkehrs-Ordnung (The Road Traffic Regulations) RSA: Richtlinien für die Sicherung von Arbeitsstellen an Straßen (Directive for safety of road work zones)

5.7. Innovative solutions

Intelligent Transport Systems	
Definition	Advance hardware and software that enable various possibilities to improve communication with driver and hence enabling safer, more coordinated and "smarter" use of transport networks at work zones areas.
Function	• Warning • Guidance
Solutions	 Traveler Information device  Traffic Management   ICT Infrastructure

Example:

	Equipment	Area	Standard	Specification	Long Term	Short Term	Mobile
THE NETHERLANDS	Information monitoring, - Jam tail distance, - Travel times , - Speed (trajectory control), - ANPR	Approach Activity	CEN TS 16157	DATEX II	TD		
	Information display		EN 12966	Colours	C2, white or yellow		
				Luminance L	L3		
				Luminance ratio R	R3		
				Beam width	B4		

Normative references	CEN/TS 16157: Intelligent Transport Systems - DATEX II data exchange specifications for traffic management and information EN 12966: Road vertical signs - Variable message traffic signs

6. Risk Assessment

To evaluate the pertinence of the equipment usually put to work regarding safety, a risk assessment has been carried out. The exercise is made on the basis of an event most obviously to be avoided, being a road worker getting hit by a vehicle.

This may be caused by the worker entering the traffic or by the vehicle entering the work zone. Cause-to-effect diagrams are given below:

Figure 1: Ishikawa for Road User

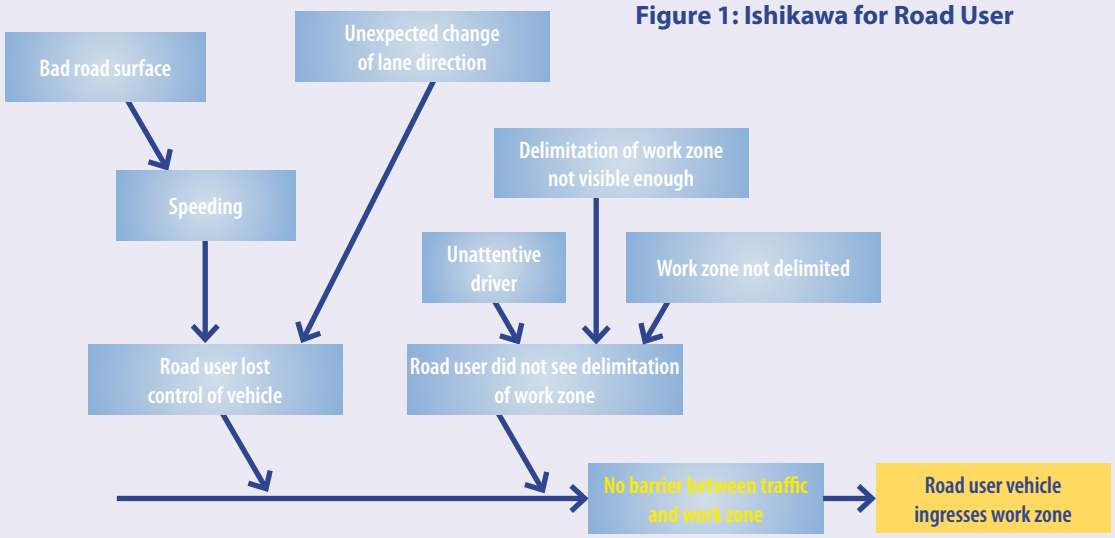
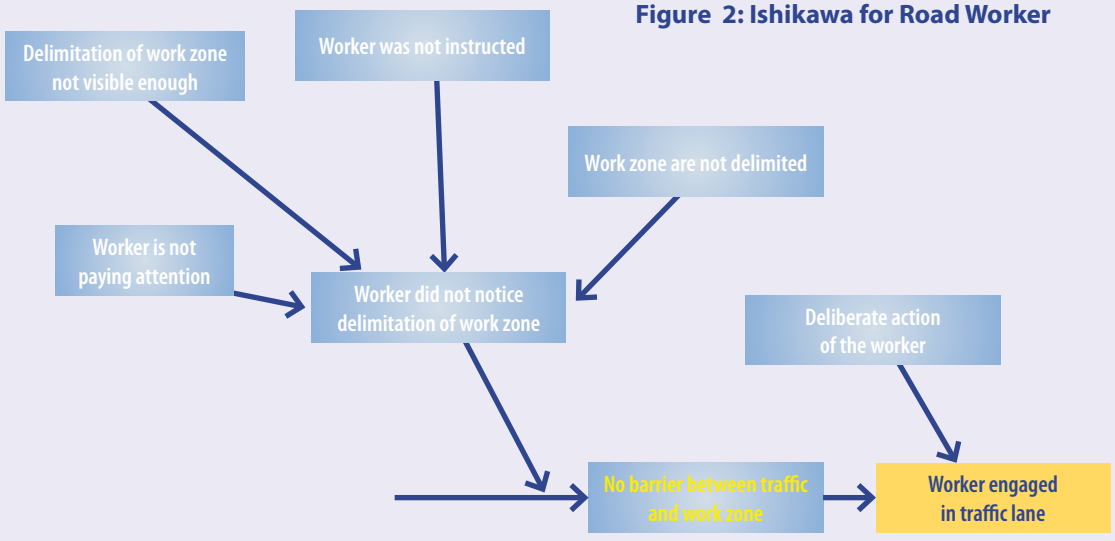


Figure 2: Ishikawa for Road Worker



In both cases risks are evaluated following the methodology of the EN ISO 12100. This methodology is schematized in Appendix 1: RISK ASSESSMENT METHOD on page 31.
The risk assessment is then carried out and described in the Figure 3: Risk assessment table on p.22.

Figure 3: Risk assessment table

			Risk evaluation (Procter)						Step 1 (Protective measures)	Step 2 (information for user)	Step 3 (Information for user)	Reassessment of the risk						
			LO	FE	DPH	NP	HRN	Risk level				LO	FE	DPH	NP	HRN	Risk level	Addressing residual risk
Causes	Hazards (5.4)	Harm																
WORKER																		
Worker engaged in traffic area	Worker being hit by road user vehicle	All degree of injured	8	5	15	2	1200	Unacceptable	Plan safety perimeter	Indication of perimeter (cones, delineators, ...)	Instructions to the workers	2	5	15	2	300	High	Instructions to the workers
									Plan work zone and traffic in separate areas	Physical separation (barriers)	Instructions to the workers	1	5	0	2	0	Negligible	Instructions to the workers
ROAD USER																		
Road user vehicle ingresses work zone	Worker being hit by road user vehicle	All degree of injured	8	5	15	2	1200	Unacceptable	Plan work zone and traffic in separate areas			1	5	0	2	0	Negligible	Equipment performance
									Organise a fixed safety perimeter	Separation markers (beacons, cones, cilinders, delineators, barriers, fences,...)	Conspicuous separations	1	5	4	2	40	Low significant	Equipment performance
									Lower traffic speed	Humps	Speed limitation signs	5	5	4	2	200	High	Conspicuous speed enforcement, equipment performance
									Channelise traffic (if a fixed safety perimeter is not practicable)	Delimitation markers (beacons, cones, cilinders, delineators, barriers, fences,...)	Conspicuous separations	2	5	15	2	300	High	Equipment performance
									Organise driver awarness		Advance signs, warnings	2	5	15	2	300	High	ITS

7. Recommendations for Minimum Performance

After the description of the road equipment deployed in work zones areas in the EU, as well the explanation of the risk assessment methodology, this section presents a set of minimum requirements for the reviewed safety equipment. Normative references for fixed equipment are used given that most (if not all) TC226 standards can be applied both on permanent and temporary equipment.

Recommendations are applicable to performance in use.

Scope

TEN-T: Motorways / Heavy traffic dual carriageway roads

Criteria for levels of performance

- Collective expertise
- Practices in member states
- State of the art
- Feasibility
- Market acceptability
- Best practices

Criteria for assessment of high/medium/low costs

High	Additional equipment. Substantial influence on the budget for this function. It requires modification of WZ design and layout
	Example: closing carriageway and constructing bypass lanes or road
Medium	Noticeable influence on the budget for this function. It may require other type of equipment. No modification of WZ design and layout required.
	Example: replacement of delineators by solid barrier
Low	No additional equipment. Technical and budgetary upgrade of usual equipment.
	Example: upgrading reflective material on signs

7.1. Restraint systems

Best Practice for Restraint Systems: Roadside barrier						
Equipment	**Area**	**Standard**	**Specification**	**Long Term**	**Short Term**	**Mobile**
Roadside barrier	Approach Activity	EN 1317-2	Containment level	H2 at diversions T3 at parallel lanes	NA	NA
			Materials	NR		
			Working width	H2 and T3: W2 to W5 depending on the space on the installation		
			ASI	A or B		
		TD	Anchorages	Comply with test records		
Feasibility	High					
Cost	Low/Medium depending on duration of the works (availability mostly on rental basis)					

Best Practice for Restraint Systems: Impact attenuator						
Equipment	**Area**	**Standard**	**Specification**	**Long Term**	**Short Term**	**Mobile**
Impact attenuator	Approach	EN 1317-3	Performance level	80/1	NA	
			ASI	A or B		
			Anchorages	Comply with test records		
Feasibility	High					
Cost	Medium					

Best Practice for Restraint Systems: TMA						
Equipment	**Area**	**Standard**	**Specification**	**Long Term**	**Short Term**	**Mobile**
TMA	Approach	NCHRP 350	Test method	NA	TL3	
Feasibility	High					
Cost	Low/Medium depending on duration of the works (availability mostly on rental basis)					

Normative References	EN 1317-2: Road restraint systems - Part 2: Safety barriers H2 and T3 account for the amount of collision energy involved. H2 are typical for roadside barriers, T3 for lane separators. W indicates the deformation of the barrier under test conditions EN 1317-3: Road restraint systems - Part 3: Crash cushions Performance level 80/1 requires tests with 900 and 1300 kg car at 80 km/h. NCHRP 350: NCHRP Report 350 – Recommended Procedures for the Safety Performance Evaluation of Highway Features. Level TL3 requires four tests (one with 900 kg car, three with 2000 kg car) at 100 km/h. Note: This American recommendation will be superseded in 2016 by a European Technical Specification TS 16786. ASI: Acceleration Severity Index is used to evaluate the occupant risk in full-scale crash tests involving roadside safety hardware. Levels A (ASI ≤ 1,0) and B (1,0 < ASI ≤ 1,4) are deemed acceptable.

7.2. Delineators/ Guidance

Best Practice for Delineators						
Equipment	**Area**	**Standard**	**Specification**	**Long Term**	**Short Term**	**Mobile**
• Cones	Approach Activity Termination	EN-13422	Height	min. 750 mm	NA	
			Weight class	W2		
			Retroreflection R'	Class R2A		
Feasibility	High					
Cost	Medium					

Best Practice for Cones						
Equipment	**Area**	**Standard**	**Specification**	**Long Term**	**Short Term**	**Mobile**
Delineators on lane separators	Approach Activity Termination	EN 12899-3	Visual performance (reflectors)	Pass		NA
Feasibility	High					
Cost	Low					

Best Practice for Delineators						
Equipment	**Area**	**Standard**	**Specification**	**Long Term**	**Short Term**	**Mobile**
• Mobile delineators • Beacons[12]	Approach Activity Termination	EN 1342[13]	Height	min. 750 mm		NA
			Weight class	W2		
			Retroreflecion R'	Class R2A		
Feasibility	High					
Cost	Low					

Best Practice for Delineators						
Equipment	**Area**	**Standard**	**Specification**	**Long Term**	**Short Term**	**Mobile**
Modular Plastic Lane Separators	Approach Activity Termination	TD	Height	≥ 750 mm		NA
		TD	Width	≥ 250 mm		
		EN 12899-3	Retroreflectors	Pass		
Feasibility	High					
Cost	Low					

[12] Beacons meaning portable vertical panels (featuring sergeant stripes, chevrons, …)
[13] As a reference only. Product is not described in this standard but characteristics can apply.

Normative References	EN 12899-3 Fixed, vertical road traffic signs - Delineator posts and retroreflectors Reflectors type D4 (delineator posts for fixing to structures (fixed), e.g. bridges, crash barriers and guard rails): Visibility characteristics: chromaticity, luminance and retroreflection EN 13422 - Vertical road signs - Portable deformable warning devices and delineators - Portable road traffic signs - Cones and cylinders Weight class W2 is 4 kg when height ≥ 750 mm and < 900 mm Retroreflection Class R2A is comparable with RA2 in EN 12899-1

7.3. Warning lights

Best Practice for Warning Lights						
Equipment	**Area**	**Standard**	**Specification**	**Long Term**	**Short Term**	**Mobile**
Lights on RRS	Approach Activity Termination	EN 12352	Colour	yellow C1		
			Class	L6/L7		
Lights on delineators			Colour	yellow C1		
			Class	L6/L7		
Lights on vertical signs			Colour	yellow C1		
			Class	L6/L7		
Lights on VMS			Colour	yellow C1		
			Class	L6/L7		
Lights in light arrow			Colour	yellow C1		
			Class	L8M (day) / L8L (night)		
Flash Lights			Colour	yellow C1		
			Class	L9H		
Feasibility	High					
Cost	Medium					

Normative References	EN 12352 Traffic control equipment - Warning and safety light devices: Colour: according to the CIE-chromaticity diagram Class: categorised by the area of light emitting surface, angle ranges and luminous intensity. Classes range from L1 to L9H

7.4. Vertical signs

Best Practice for Signs						
Equipment	**Area**	**Standard**	**Specification**	**Long Term**	**Short Term**	**Mobile**
Traffic Signs	Approach Activity Termination	EN 12899-1	Retroreflectivity	Class 3		
			Resistance to loads	NR		
			Materials	Fluorescent Yellow. If white, fluorescent backing board. Temporary direction signs in fluorescent yellow[12]		
Feasibility	High					
Cost	Low					

Best Practice for VMS						
Equipment	**Area**	**Standard**	**Specification**	**Long Term**	**Short Term**	**Mobile**
Variable Message Signs	Approach Activity Termination	EN 12966	Colours	C2, white or yellow		
			Luminance L	L3		
			Luminance ratio R	R3		
			Beam width B	B4		
Feasibility	High					
Cost	Medium					

Normative References

Vienna Convention
EN 12899-1 Clause 4.2:
Prismatic reflective sheeting obtain EU declaration according to European Technical Approval (ETA)
EN 12966 Road vertical signs - Variable message traffic signs

Class designation:

Colour (C)	C1, C2 (C2 is the more restrictive) Red, orange, yellow, white, green and blue are defined.
Luminance (L)	L1, L2, L3 (L3 has the highest luminance)
Luminance ratio (R)	R1, R2, R3 (R3 has the highest luminance ratio)
Beam width (B)	B1, B2, B3, B4, B5, B6, B7 (B7 has the widest beam)

[12] Vienna Convention for Road Signs (Annex 3):
http://www.unece.org/fileadmin/DAM/trans/conventn/Conv_road_signs_2006v_EN.pdf

7.5. Temporary markings

Best Practice for Temporary Markings							
Equipment	**Area**	**Standard**	**Specification**	**Road Trials**	**Wear Simulator**	**Short Term**	**Mobile**
Temporary road markings	Approach Activity Termination		Colour	Y2	Y2	NA	
		TD	Width	150 mm			
		EN 1436	Luminance Qd, β	Q2	Q2		
		EN 1436	Retroreflectivity RL	R4	R4		
		EN 1436	Retroreflectivity RW	RW3	RW4		
		EN 1436	Skid resistance	S1	S2		
		EN1824 or EN13197	Durability of road marking materials	T2	P6		
		EN 1790 or EN 1871	Preformed or non-preformed material depending on the phasing and nature of the works	Tested materials + Removability	Tested materials		
Feasibility	High						
Cost	Low						

Normative References	EN 1436 Road marking materials – Road Marking performance for road users Daytime visibility : Luminance Factor β or Qd → Qd Class Q1 to Q3 Night-time visibility (Retroreflectivity) Dry surface : RL →Class R1 to R5 : Type I (Before Rain) Wet surface : RW → Class RW1 to RW6 : Type II (During Wetness After Rain) Rain conditions : RR → Class RR1 to RR6 : Type II (During Rain) Colour (x, y) : Yellow for Temporary Markings → Class Y2 is intended for Temporary Markings Skid Resistance Test (SRT) = Pendulum Test Value (PTV) → Class S1 to S5 EN 1824 Road marking materials - Road trials The roll-over classes T0, T1 and T2 are intended for temporary road markings EN13197 Road marking materials – Wear simulator Turntable EN 1790 Road marking materials – Preformed road markings Removability to be tested according to EN 1824 Annex F EN 1871 Road marking materials – Paints, thermoplastic and cold plastic materials Removability to be tested according to EN 1824 Annex F

7.6. Other equipment

Best Practice for Road Studs						
Equipment	**Area**	**Standard**	**Specification**	**Long Term**	**Short Term**	**Mobile**
Road Studs	Approach Activity Termination	EN 1463-1	Perm/Temp	Type T	NA	
			Height	TD		
			Retroreflectivity	TD		
			Colour	TD		
Feasibility	High					
Cost	Low					

Normative References	EN 1463-1 Road marking materials - Retroreflecting road studs - Part 1: Initial performance requirements Type T = Temporary road stud (self-adhesive or bonded) Height: 4 classes: HO, H1, H2, H3 (H0 = no requirement) Retroreflectivity: 3 types: R1, R2, R3

7.7. Intelligent Transport Solutions (ITS)

Best Practice for Intelligent Transport Systems (ITS)						
Equipment	**Area**	**Standard**	**Specification**	**Long Term**	**Short Term**	**Mobile**
Information Management Devices	Approach Activity	CEN TS 16157	DATEX II	TD		
Information Display Devices		EN 12966	Colours	C2, white or yellow		
			Luminance L	L3		
			Luminance ratio R	R3		
			Beam width	B4		
Feasibility	High					
Cost	Medium					

Normative References

CEN/TS 16157: Intelligent Transport Systems - DATEX II data exchange specifications for traffic management and information
Main usage areas:
- road network management
- traffic management
- traffic information systems
- information exchange between individual vehicles and traffic management
- information exchange between management systems
- interoperability: multiple operator cooperation and exchange of data

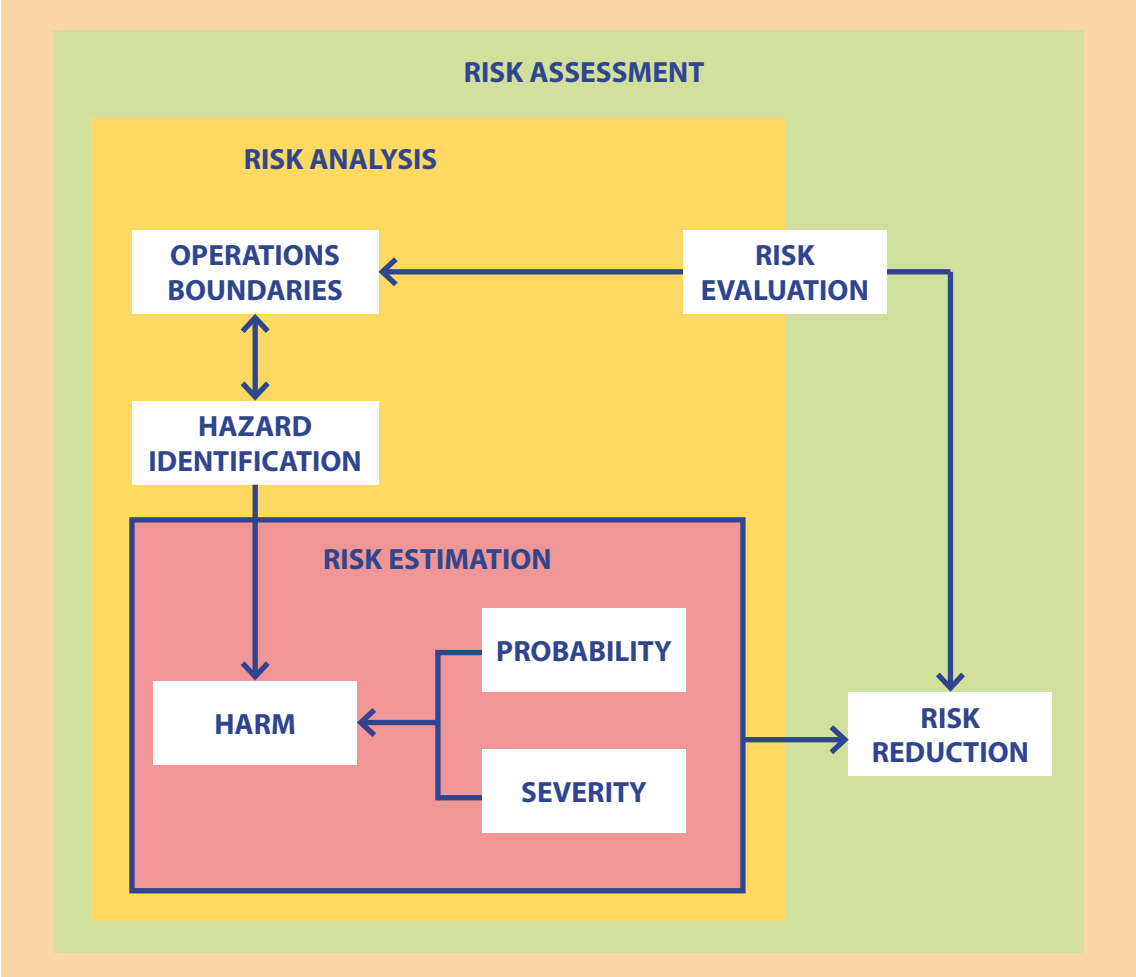
EN 12966: Road vertical signs - Variable message traffic signs

Colour (C)	C1, C2 (C2 is the more restrictive) Red, orange, yellow, white, green and blue are defined.
Luminance (L)	L1, L2, L3 (L3 has the highest luminance)
Luminance ratio (R)	R1, R2, R3 (R3 has the highest luminance ratio)
Beam width (B)	B1, B2, B3, B4, B5, B6, B7 (B7 has the widest beam)

8. Appendix 1: RISK ASSESSMENT METHODOLOGY

The methodology for risk assessment and risk reduction is based on five different phases:

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 (4 steps);
5 Re-evaluate the risk reduction



First step will focus on the **operation boundaries** in:

- use (only traffic related hazards / workforce, road users, emergency teams, media, authorities / awareness level of parties involved),
- time (before, during, after),
- space (work area, carriage way, (de)congestion area, neighbourhood) and
- other factors (local work area during short term WZ, extended work area in longer term WZ, dust, mud, rain, fog, darkness).

Next, the process will also **identify the hazards** to work force, road users and traffic.

The **risk estimation** will be assessed using a mathematical risk assessment method (Kinney or Procter). Here the Risk Assessment Calculator by Procter Machine Guarding has been used, based on the requirements of the European standard EN ISO 12100:2010 (Safety of machinery).[13]

LO (Likelihood of Occurrence)		
0,033	Almost impossible	Only in extreme circumstances
1	Highly unlikely	Though conceivable
1,5	Unlikely	But could occur
2	Possible	But unusual
5	Even chance	Could happen
8	Probable	Not surprising
10	Likely	To be expected
15	Certain	No doubt

FE (Frequency of Exposure)	
0,5	Annually
1	Monthly
1,5	Weekly
2,5	Daily
4	Hourly
5	Constantly

HRN	Risk
0-5	Negligible
5-50	Low, significant
50-500	High
Over 500	Unacceptable

HRN = LO x FE x DPH x NP

DPH (Degree of Possible Harm)	
0,1	Scratch or bruise
0,5	Laceration or mild ill-effect
2	Break of minor bone or minor illness (temporary)
4	Break of major bone or major illness (temporary)
6	Loss of one limb, eye, hearing (permanent)
10	Loss of two limbs or eyes (permanent)
15	Fatality

NP (Number of Persons at risk)	
1	1-2 persons
2	3-7 persons
4	8-15 persons
8	16-50 persons
12	50+ persons

Source: Pilz Guide to Machinery Safety, 6th Edition

Lookup table according to Procter

Once risk has been identified and accordingly rated, coming step will focus on its **reduction** following 4 steps:

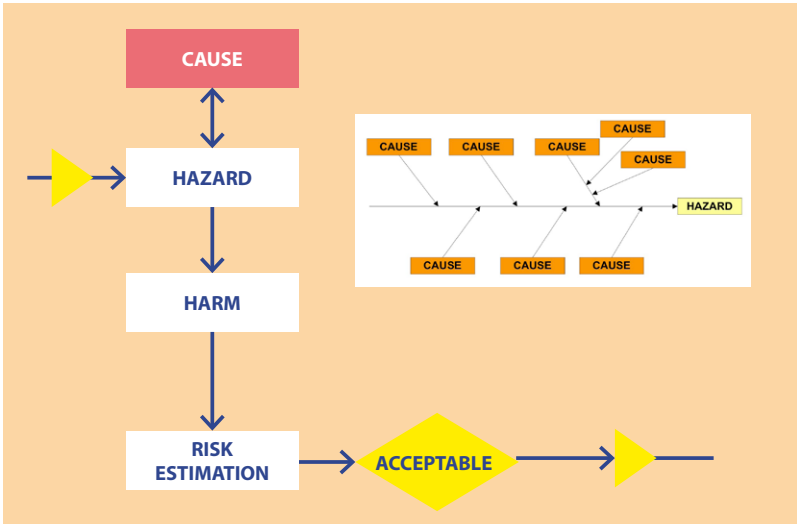
- Step 1 "Inherently safe design measures": Design inherently safe measures to eliminate hazards or to reduce the associated risks by a suitable choice of features, meaning taking precautions in the design phase;
- Step 2 "Safeguarding and/or complementary protective measures": Taking into account the intended use and the reasonably foreseeable misuse, apply appropriately selected safeguarding and complementary protective measures;
- Step 3 "Information for use (warnings, signals)": Where residual risks remain, despite steps 1 and 2, declare these risks in the information to the user;
- Step 4"Enforcement": Install procedures to enable in-service monitoring and evaluation.

See Figure 3: Risk assessment table, page 22.

[13] http://www.machinesafety.co.uk/

Last phase is based on the **risk evaluation**. Adequate risk reduction is achieved when (see detailed picture below):

- All operating conditions and all intervention procedures have been considered;
- Hazards have been eliminated or risks reduced to the lowest practicable level;
- Any new hazards introduced by the protective measures have been properly addressed;
- Parties involved are sufficiently informed and warned about the residual risks;
- Protective measures are compatible with one another;
- Sufficient consideration has been given to the consequences that can arise from the nonprofessional context;
- Protective measures do not adversely affect the working conditions of the parties involved.



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[15] http://portal.liikennevirasto.fi/sivu/www/e
[16] http://www.yme.gr/index.php?tid=531
[17] http://www.central.ntua.gr/
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[19] http://www.mdcr.cz/en/HomePage.htm
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