ARROWS: Advanced research on road work zone safety standards in Europe

BACKGROUND

With road traffic still growing at a significant rate all over Europe, the need for maintenance and repair of road infrastructure is increasing as well. In particular, the impact of heavy vehicles combined with the sheer number of cars is contributing to the rapid deterioration of roads and related installations. The resulting need to enlarge, improve and maintain road infrastructure at ever decreasing intervals constitutes a severe safety problem for workers and users alike. An overview of the current state of practice across European countries reveals a multitude of design and signing practices for road construction sites, with diverse characteristics. Therefore harmonised safety standards are expected to be of major benefit.

OBJECTIVES

ARROWS aimed to develop a unified range of road work zone safety measures and principles that should govern the planning, design, implementation and operation of road work zones. This is to mitigate their adverse safety effects on workers and road users.

The main objectives of ARROWS have been:

to analyse road work zone typologies, present the whole range of work zone safety measures (current and innovative), and review existing national and international standards and practices on the topic;
to explore the effectiveness of road work zone safety measures in terms of their ability to achieve the desired driver behaviour, towards a safer driving and working environment;
to review the experimental methods for the evaluation of safety measures;
to develop a unified range of road work zone safety principles and measures;
to recommend a European framework for road work zone safety standards; and
to produce a practical handbook for road work zone safety, as practical guidance to network managers at all levels.

KEY RESULTS

ARROWS has:

compiled a comprehensive list of road work zone safety principles, suitable for guidance in planning, design and operation of construction sites, such as typology, standards and practices, behavioural factors, accidents and countermeasures;
performed a pilot study on accident scenario construction, after available accident studies had shown little useful information related to work zone casualties;
outlined a set of safety-related recommendations for standardised planning, implementation and operation of road work zone measures.

The major output was a consolidated Practical Handbook on 'Road Work Zone Safety' comprising the following aspects:

definition of specific construction site safety problems (awareness raising),
clear definition of typology and terminology,
an outline of road work zone safety objectives and principles,
guidance for all involved actors, i.e. road authorities, designers, contractors, site personnel and executive bodies (e.g. traffic police), on how to implement road work zone measures through all phases of the process, i.e. planning, design, installation, operation and removal,
a ready-to-use set of safety tips for the implementation phases,
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, and
provision of indicative checklists that can be used in the planning and operational phases, covering the specific details of road work zone safety such as:

- traffic and speed management,
physical design of construction sites,
work zone operation and maintenance,
safety of individual workers.

POLICY IMPLICATIONS

The ARROWS project has initiated concerted activities towards the harmonisation and standardisation of road work zones. The project findings need to be exploited by applying the recommendations in the Handbook on a pan-European level. The established dissemination forum will help to reach all relevant parties, and will enable easy access to useful tools - in particular the ARROWS Handbook - via the project web site.

RELATED PROJECTS

None

Contact details:

Project co-ordinator
Ass. Prof. George Kanellaidis
National Technical University of Athens (NTUA)
Iroon Polytechniou Street, 5
15773 Zografu-Athens
GR

g-kanel@central.ntua.gr

Project Web page:

http://www.ntua.gr/arrows/

CORDIS Web page
http://www.cordis.lu/transport/src/arrows.htm

Contents

Project Co-ordinator Prof. George Kanellaidis (NTUA). email: g-kanel@central.ntua.gr

INTRODUCTION

ARROWS Objectives

The ARROWS Project (Advanced Research on ROad Work Zone Safety Standards in Europe) is funded by the European Commission under the Transport RTD Programme of the 4th Framework Programme. It began on 18 September 1996 under the provisions of Contract No. RO-96-SC.401. The planned duration of the project is two years.

The main objectives of ARROWS include:

Development of a unified range of applicable road work zone safety measures and principles that should govern the planning, design, implementation and operation of road work zones so as to mitigate their adverse effects on the safety of workers and road users
Production of a handbook for practical guidance to network managers at all levels

Workpackage 1 Objectives

The present Deliverable 1 reports on the work carried out for Workpackage 1 of the ARROWS Project, titled Review of safety measures, standards and practices. The main objectives of Workpackage 1 were:

To concentrate the collective experience from different countries and studies in the field of road work zone safety measures
To agree on a typology for consistent use throughout ARROWS
To create a full inventory of safety measures, standards and practices for use in the subsequent evaluation, assessment and recommendation process

TYPOLOGY

The term typology is meant, in the context of ARROWS, to primarily denote a guide to classification. In addition typology is also meant to include:

a definition of what is, and what is not, a road work zone for the purposes of ARROWS;
a description of basic terms used to describe the main components of a road work zone.

Conceptual Framework

A road work zone may be defined as the part of a road facility influenced by works occurring on, near or above it. Its scope is wider than that of the immediate "work area" actually occupied by the road works, since the control measures used - such as signs, markings and protective devices - extend beyond that area.

What is usually thought of as a "typical" road work zone usually relates to roadway and structural improvements, maintenance activities (such as resurfacing), or utility work. However, varying definitions road work zones may or may not include several other types of work carried out on, beside or above the road and influencing the normal flow of traffic. Besides knowing "What" work is carried out and "How", the answers to the questions of "Where" and "When" should be all-important for classifying a road work zone.

The proposals envisaged within ARROWS should have European proposals for a harmonized road classification as a reference point, in order to allow ARROWS to contribute to the implementation of the European Common Transport Policy, in terms of systematisation, standarisation and interoperability. The road classification proposed for the TERN, distinguishing between motorways, express roads and ordinary roads, may provide a reference point for the typology to be proposed within ARROWS. For consistency purposes, however, it is important for any framework for road work zone standards to be valid for all roads whether they do or do not form part of the TERN. In addition, the ownership/operation status of the road facility should not affect applicability of recommendations.

The main considerations for building a typology included: its intended use as a tool for classifying and organizing subsequent review, analysis and, especially, the ARROWS output; the need for reaching a "proper" balance, by avoiding being over-simplifying, too case-specific, or too theoretical; its possible structure.

Classification Factors

Main classification factors can be grouped into the following categories: (a) road type, design, function and operation; (b) operation of work zone; (c) interaction between work zone and roadway. The commonest classification factors identified in a review of European and other guidelines include: the distinction between urban and rural roads (with special mention of motorways); speed (at-work zone or upstream) and traffic volume / capacity; stationary vs. mobile; long-term vs. short-term; effects of work zones on traffic,

such as narrowing, closure, diversion, contraflow, alternate traffic; special locations such as intersections / interchanges and certain off- roadway locations (shoulder, roadside, central reserve, footway or bikeway).

Selection of Typology

The basic requirements for selecting a typology included compatibility, comprehensiveness, clarity and flexibility. The selected typology features three classificication factors: road type, operation of work zone and road/work zone interaction.

Five categories regarding road type were defined:

(A) Motorway and dual-carriageway expressway

(B) Rural primary road

(C) Rural secondary road

(D) Urban main road

(E) Urban local road

In general, varying national definitions of road classes can be adequately accommodated under this broad classification of road types.

Three categories were defined regarding work zone operation:

(1) Long-term

(2) Short-term stationary

(3) Short-term mobile

The following categories were defined regarding road/work zone interaction:

(a) Lane narrowing (without reduction in the number of lanes; lane width should not fall below an acceptable lower limit)

(b) Lane closure (relevant only on multi-lane roads)

(c) Diversion (transferring all or part of the traffic from one road - "diverted road" - to another - "diversion route")

(d) Contraflow / crossover (transferring all or part of the traffic to the other carriageway or to occupy lanes from the opposite direction)

(e) Alternate one-way traffic (where only one lane remains available for the two directions of travel)

(f) Intersection / interchange (the latter term is used to denote entrance to or exit from a motorway or dual- carriageway expressway)

(g) Shoulder / roadside

(h) Central reserve

(i) Footway / bikeway

(j) Tramway

The choice of road work zone type will be denoted by a three-character abbreviation, signifying road, operation and location. For example, a long-term work zone on a motorway involving contraflow is shown as A-1-d.

Home - Documents - Top

REVIEW OF SAFETY MEASURES

Safety measures are split into two main groups:

Measures currently used at road work zones
Innovative and newly-introduced ("in the pipeline") measures

In each group, and taking into account the road work zone typology a survey has been undertaken for the following categories of items:

Adjustment of road layout
Traffic control devices (such as signs and markings)
Other road equipment (such as barriers)
Miscellaneous (e.g. information via the mass media)

In the signing field, "normal" (i.e., non-work zone) signs, as currently used in the EU countries, are additionally reviewed, in order to specify the colours actually used, as an aid for selecting such colours for road work zone signing that will not be confused with permanent road signing. Moreover, the evolution in the form and usage of the various safety measures/products is recorded in detail and, regarding the innovative measures, improvements (proven or expected) in comparison to current safety measures are emphasized. Finally, recent suggestions regarding the need for further research or improvements in the field have been identified and highlighted.

Adjustment of Road Layout

The following sections were identified for individual examination of road layout adjustment along a road work zone

advance warning area,
narrowing area,
buffer zone,

work area,
termination area,
run off area.

In case the carriageway consists of two or more traffic lanes, some additional road sections are defined:

stabilising area, situated after the narrowing area and meant for stabilising traffic flow after narrowing area,
transition area, where traffic changes position or configuration once again

Following the typology, the following are the main remarks to be made on currently-used road layout adjustments for various road work zone types:

Type A1: Lengths of individual areas differ significantly and need to be harmonized as much as possible, mainly regarding area length and lane width.
Types A2 and A3: Lengths and lane widths are more unified, thus harmonization will be much simpler.
Type B, general: Due to lower speeds allowed on this road category, some elements of work zone structure such as buffer zone are not part of work zones in most national standards. Some others, such as stabilising area and transition area, are used in only a few countries.
Type B1: Lengths and lane widths are very unified, with only slight differences.
Types B2 and B3: Nearly in the half of the observed countries special types of work zones are not defined. Schemes for long-term work zones are used instead.
Type C: Only main work zone elements such as advance warning area, narrowing area, work area, termination and run off area are used.
Types D and E: In some countries special schemes for urban roads are not presented in standards because schemes for rural roads are used.

It was not possible for the ARROWS consortium to identify innovative items on road layout adjustment, for the following main reasons:

Under the agreed classification of items, most innovative items will naturally belong to the categories of traffic control devices and other road equipment. Road layouts in work zones are, practically, standardised for many years in most countries so no real innovation exists. However, one should also note the existence of a certain common ground between road layout adjustment and certain devices (especially road equipment) which - among other things - serve the purpose of adjusting road layout.
It was decided that no strict criteria would be fixed for the distinction between currently used and innovative items. For road layout items, this meant that, since practically all of them have been used in some countries for shorter or longer times, they may be classified as currently used.

Traffic Control Devices

Currently used items in traffic control devices include the following:

Standard type traffic signs (Permanent / Non-permanent)
Traffic signs using higher-quality materials (Permanent / Non-permanent)
Traffic signs jointly used with blinkers
Traffic markings
Traffic lights

Regarding the above items, particularly interesting areas for further consideration in ARROWS include:

Usage of a specific common external background colour in road work zone signs (yellow might be suggested, as a first choice).
Usage in road work zone signs of retroreflective materials one class higher than the ones used in the specific road.
Specification of size and flashing frequency of blinkers, following a pan-European standard.
Standardization of road work zone marking colour (in conjunction with r oad work zone signing colour) and materials (considering the advantages of removable tapes).

Innovative items in traffic control devices include:

Fluorescent retroreflective traffic signs
Roll-up traffic signs
Wet reflective pavement tapes
Variable message signs (VMSs)

Regarding the subsequent consideration of the above items within ARROWS, the following remarks can be made:

Fluorescent retroreflective signs may be included as suggested work zone typical signing types.
Roll-up signs (considered as much more practical in use than normal signs) and wet reflective pavement tapes (useful for adverse weather conditions) could be mentioned for future testing.
Standard cases could be formulated in which use of VMSs could be highly beneficial for road safety and traffic operation; cases could be identified regarding not only road work zone typology but also standardized types of VMSs to be used, as well as menus of "optimal" messages to be displayed.

Other Road Equipment

Currently used items on other road equipment include:

closure equipment (traffic cone, traffic closure, guiding beacon, mobile trailer)
warning equipment (warning light, traffic closure with warning lights, running lights, guiding traffic closure with lights, flashing arrow, running horizontal arrow, device of preliminary warning, warning tape)
guiding equipment (emphasising beacon - small / large -, guiding traffic closure, small guiding beacon, guiding hump and protective dam, guiding barrier)
protective equipment (fence, contact ledge for the blind, safety barrier)
bearing equipment (foundation plate, post, stand)
road reflectors
crash cushion - truck tyres
speed reducer in rubber - bumps

Some selected innovative devices include "two signs in one"; "UV-light"; supervision devices; cart for fold-up cassette signs; emergency cart; crash net - vehicle sustaining barrier; crash cushion - truck tyres; crash barriers; portable rumble strip; and warning tent.

Miscellaneous Items

Currently used miscellaneous items include:

flags and hand signalling devices
moving sign bridge and portable mould bridge
crash cushion or Truck Mounted Attenuator (TMA)
traffic information on radio
emergency car
retroreflective fluorescent clothing

Innovative miscellaneous items concern mainly:

automated message creation to be displayed to VMSs concerning safety issues
traffic flow channelisation for optimal flow conditions in relation to different parameters (e.g. environmental)
use of smart cards for transmission of messages to the users

Home - Documents - Top

REVIEW OF STANDARDS AND PRACTICES

Review of Standards

Complete polling of all European countries has shown that in 16 of 20 countries there are standards, directives, recommendations or similar sets of regulations which regulate the

traffic guidance systems used in the region of work zones in terms of their type, extent and road equipment to different degrees.

The fundamental intention was to base the following analysis on the classification points from Task 1.1. However more detailed consideration showed that it was necessary to take into account further viewpoints in order to permit the envisaged comparative evaluation to be carried out. As a result an expanded classification scheme was used for Task 1.3 (identifying differences from Typology as "additional information"):

Road type (see Typology, A to E)
Duration (see Typology, 1 to 3)
Traffic guidance systems (see Typology, layouts a to f, with additional information)
Location of work zone (see Typology, layouts g to j, with additional information)
Number of carriageways and lanes in without-works cross-section (additional information)
Work zone marking and method of flow separation (additional information)

Finally, nine additional items refer to the subdivision of the work zone area in the longitudinal direction; the areas identified include: (7) announcement; (8) advance warning; (9) narrowing; (10) stabilizing; (11) transition; (12) buffer; (13) activity; (14) termination; (15) run-off.

Fundamental evaluation results include the following:

The very unequal distribution observed regarding road type and duration of work (items 1 and 2) makes clear that particular attention is paid primarily to the designing of work zones on motorways and rural primary roads (categories A and B), especially to work zones which are set up in a long-term or short-term stationary manner.
Regarding work zone traffic guidance system and work zone location (items 3 and 4), it is observed that there are only very few guidelines for footways, bikeways and tramways. For motorways, certain combinations of traffic guidance system and work zone location are technically inadvisable and, thus, not defined. For rural roads, no sets of regulations exist for central reserves. For urban roads, few meaningful combinations of location and traffic guidance system exist regarding pure pedestrian / cyclist facilities.
Regarding layouts defined according to number of carriageways / lanes and marking / separation of flow (items 5 and 6), the analysis shows that very different amounts and types of information and practices exist. It is possible that the depth of regulation depends on particular local circumstances or habits. It is probable that the local degree of competence to be expected can be estimated to be in correspondence with the degree of regulation since either everything is regulated or the locally responsible person is permitted great decision-making freedom.
After examination of the safety measures foreseen for different road work zone areas, it should be stated that - in contrast to the possibilities shown in Task 1.2 - only a limited number of different objects for the securing of work zones are to be found mentioned in the different traffic guidance system plans. The very large variety of different possible variants is made use of to only a limited extent. It is probable that numerous recent products have not yet found their way into the guidelines. However, it is quite clear that the preconditions for achieving standardization are very unfavourable. Traditions and customs obviously have a considerable influence on the selection and application of the different road equipment. The proposals to be worked out in the framework of ARROWS will therefore

have to be restricted to general or framework recommendations. However, where appropriate, attention can be drawn to new developments of relevance and to areas where expenditure has been unnecessarily high up to the present time.
The example of motorway contraflow layout is used to illustrate two alternative guidance ideas:

leading the right lane's slow traffic into the fast traffic on the left lane, or
leading first the fast traffic into the slow traffic on the right lane, and afterwards lead them together to the left side of the road.

A comparative review of traffic signing used for this guidance system reveals that only few different signs are used, but on various positions and with different mass. This illustration shows a possible way for creating a harmonized framework for diverse work zone areas for all situations.

Review of Implementation of Road Work Zone Standards

Regulations, guidelines, standards and recommendations give fundamental or detailed information for the designing and setting up of such work zones in accordance with traffic flow principles. As a rule such sets of regulations are to be found primarily for the roads with the highest volume, i.e. motorways.

In the securing of work zones on or in the vicinity of roads, the maintenance of safety and of the free flow of traffic are always in the foreground. In addition to traffic signs, speed limits are often made use of for this purpose. In addition, protecting devices between lanes of traffic flowing in opposite directions are being used to an increasing extent in particular on motorways.

Noticeable in more recent regulations is the fact that increasing attention is being paid in addition to the safety of those working in the work zone and that safety devices located between the traffic lanes and the area for work are being used to a greater extent. Worthy of mention in this connection are recommendations on buffer zones at the beginning of the work zone in which there should be no equipment and in which no one should work.

The following main aspects can be identified in the guidelines:

No (or the least possible) holding up of the flow of traffic; ensuring the least possible influencing of the flow of traffic; avoiding total closing of traffic lanes as well as of entries and exits to/from motorways, where possible.
Optimization of construction work with minimum construction times including optimum construction-phase planning and shift work, as well as co-ordination of different types of work to be carried out within the same section (e.g. utility); carrying out of maintenance work at times with low traffic volume.
Achieving the acceptance of drivers by designing safety measures that are easily detectable and visible, as well as by the use of traffic signs, markings and closure devices that are in proper condition (fundamental principle: as few traffic signs as possible but as many as necessary).
Maximum possible safety for construction personnel and drivers/travellers (through setting of signs, marking, lighting, demarcating of the division between the area for traffic and the

area for work in each case in a clear manner); warning clothing should always be worn by personnel working at work zones which are open on the traffic side.
Fundamentally with motorways, the holding ready of alternative routes for use in case of severe disruptions in the region of a work zone, e.g. as a result of an accident.
Access to and opening up of work zones wherever possible from the outside and not via the road affected itself.
No empty, unmanned or abandoned work zones. As soon as the construction work has been concluded or halted, the systems disrupting traffic should be removed immediately or rapidly or at least reduced. Speed limits and in particular those imposed for the safety of those working in the work zone should be removed by covering over the relevant signs or providing indication that these do not apply outside working hours.

In order that as many as possible of these aspects can be observed, it is laid down in most countries that a plan with the traffic signs as well as the marking and safeguarding systems is prepared before work is commenced. Depending on the particular legal requirements, such plans must be checked, corrected if necessary and then prescribed for the work by in each case the responsible, official authority. Especially in the U.K., the preparation and local adaptation of safety measures is always carried out by a fundamentally competent supervisor whereby the safety measures must be additionally checked by the responsible authority in cases where a work zone will disrupt traffic to a considerable degree. Less useful, on the other hand, are framework regulations which should be followed by local experts with a greater or lesser degree of competence and where the measures are not additionally checked in a qualified manner.

Unfortunately, in a number of plans for the safeguarding of work zones, the principle "the more the better" has been followed. To be particularly mentioned in this connection is excessive use of blinking and flashing lights. In some cases the synchronizing of such lamps is required. Nevertheless priority should be given to the fundamental principle that a traffic situation, which will be unexpected and unusual for the majority of drivers, should be designed in a quiet and easily overviewed manner, instead of in a manner that - through the introduction of additional distractions - will impair drivers' abilities to master the particular situation.

Comparison of Practices Among Countries

Generally the aims of regulations, guidelines, etc. give the minimum needed signalisation on a road work zone to inform, give the way and guide road users through the work zone with:

effectiveness: best possible safety of road users and road workers.
coherence: signing must be adapted before the road works' beginning to the local situation.
clarity: guiding road users and helping them to modify and adapt progressively their behaviour to the situation requires some easy-reading and trusting signs. Signing should never give wrong or non-adapted information.

The person responsible for the safety of a work zone must be prepared to think about the individual problem and be prepared to make available what is optimally required for the drivers and other travellers; unfortunately, practical experience shows that this will only be achieved when appropriately strict checks are carried out and appropriate sanctions threatened. Obviously, the promotion of measures to ensure that the relevant contractors understand the safety aspects and feel responsible for these is an important task in connection with work zones on motorways and other roads.

Some common advice (Belgium and Germany) is presented:

Only qualified signs and materials are allowed for use.
Signing has to be clean and visible day and night.
Signing has to be installed prior to the beginning of the works, and the responsible persons should give written authorization.
A notice with the name and phone number of the person responsible for signing must be placed on the road work zone.

There are great shortcomings in the area of checking of work zones, despite relevant requirements in the regulations. Prime causes here are bottlenecks in the personnel in the different monitoring posts. As a rule the contractor is then usually found to be responsible, although the avoidance of such situations by early and intensive checks would have been more sensible. In conclusion it can be established that - in addition to the optimizing of traffic sign, marking and safeguarding plans - increased efforts must be made to creating the fundamentals for the training of contractors. More guidelines and less checks will only be effective when an appropriate level of understanding and co-operation can be expected from the side of the contractors. Here, however, no secret should be made of the fact that - if work zones are to be safeguarded in the optimal manner - the work involved must be appropriately paid for.

Review of Behavioural Studies, Accident Studies and Research Methods

Contents

Project Co-ordinator Prof. George Kanellaidis (NTUA). email: g-kanel@central.ntua.gr

OBJECTIVES

The present Deliverable 2 reports on the work carried out for Workpackage 2 of the ARROWS Project, titled Review of Behavioural Studies, Accident Studies and Research Methods. The main objectives of Workpackage 2 were:

to evaluate the potential of road work zone measures for achieving desired driver behaviour and improving the safety of both road workers and road users
to examine the methods used for testing road work zone measures

Home - Documents - Top

BEHAVIOURAL STUDIES

The main objectives of Task 2.1 were to review existing literature dealing with aspects of driver behaviour at road work zones, as well as to identify the effects thereon of various safety measures, as identified in Deliverable 1 (including layout adjustment, traffic control, other equipment and miscellaneous). To keep with the overall ARROWS project objectives, the main focus of attention in this Task should be on safety-related behavioural effects.

Procedure and Instrument

Following the task objectives, it was tried to summarise the accumulated knowledge on the topic behavioural and attitudinal aspects related to road works. The method chosen was the reviewing of available literature. Relevant reports were mainly collected via ordinary searching in computerised databases, through usage of keywords in an iterative procedure.

The summarising and reviewing process was structured in accordance with the typology (Task 1.1) and was based on a "model" developed by the partners, in the form of Review Sheet.

Results

Results are structured in two main groups, depending on whether the focus was on behavioural variables or on effects of specific safety measures.

Behavioural Variables

Several reports have been reviewed dealing with speed and lane change. A number of studies have been carried out motorways It seems justified to conclude that drivers are speeding at road works and that drivers paid greater attention to the difficulties they faced at crossover points than to those faced at the actual activity area, even though speeds were too high at the latter location as well. Additionally, the results suggest that measures intended to encourage drivers to slow down should appear before they enter the transition area.

Effect of Safety Measures

No studies have been found relating road layout arrangement to driver behaviour. Studies pertaining to other types of safety measures are presented in the following grouping: signing; delineation devices; guidance devices; and lastly, campaigns.

Informing / warning signs

According to drivers' self-reporting, their speed behaviour at work sites varies dependent on the road signs presented.

Delineation devices

From several studies carried out on motorways and primary rural roads it was concluded that steady-burn lights have little if any effect on driving behaviour, and is outperformed by the high intensity reflective sheeting. Closely-placed raised pavement markings on the other hand, were observed to provide efficient guidance and a safe driving environment at road works and were thus recommended to supplement to existing pavement striping (at transitions and detouts.)

Guidance devices

It is well known that pulsing lights can give an illusion of motion. The results of a study - test in a virtual environment (driving simulator) illustrate that the combination of colour, direction, and speed of the light pulses is important, and strongly influence the effect on speed.

Campaigns

The behavioural effects of a campaign among all truck drivers in Sweden was studied at a specific construction work site exposing drivers to lane narrowing. Almost all interviewed truck drivers judged the campaign as useful. But, they also said that they had not changed their behaviour, a statement confirmed by the recorded behavioural data, and that they already knew that road workers are afraid of large vehicles. A possible explanation might be that the individual drivers thought the campaign was useful for "others" but not for themselves.

Discussion and Conclusions

A cause for real concern in relation to road works is that drivers believe that they take enough caution and slow down enough when passing, while experimental studies and observations clearly show that they behave not as they claim but in an even more problematic manner than they apparently think.

Standardisation of work site areas regarding traffic guidance, alignment, and width of temporary lanes, as well as of individual signposts and guiding devices, is proposed by many referred authors and assumed to strongly contribute to the solution of the safety problem at road works. However it may also be worth considering that a uniform appearance of work sites may give the drivers a feeling of familiarity and false safety - meaning that they no longer possess an adequate sensitivity for unexpected hazardous situations that may occur.

When it comes to speed reduction measures at road works, the location of a device should be carefully decided. Thus, speed limit signs, feedback VMS, lane narrowing devices and other measures used to make drivers slow down should preferably be positioned before they enter the transition area

Based on relatively weak results (driving behaviour) and methodology, steady-burn lights are recommended to be excluded as delineation device. Behavioural adaptation occurs when closely spaced raised pavement markings supplement ordinary markings.

Compared to signed speed limits, the majority of drivers approach road work sites driving much too fast. They don't decelerate until just before an abrupt change in the conditions, like a crossover point, and then they decelerate (brake) extremely hard.

Home - Documents - Top

ACCIDENT STUDIES

Objectives

The primary objective of this task is to draw conclusions about the nature and extent of work zone accidents. To that end, existing empirical studies concerning work zone accidents, as well as literature reviews of such, have been collected and reviewed.

It has been attempted to draw conclusions about the relation between relevant accident characteristics and work zones, considering aspects such as: type of road; type and duration of works; interaction between works and road; weather; time of day; the effectiveness of safety devices; trends over time and national differences.

Limitations in Scope

This Task has very strictly limited itself to studies concerned with the analysis of traffic accidents in work zones rather than studies concerned with non-accident related work zone characteristics or road user behaviour. Reported studies have at least a minimum quality. Case studies were only considered when presented in a context meant to generalize over cases.

Procedure

Due to the limited amount of suitable research in this area, the partners in this work package agreed on a multi- pronged approach intended to ensuring that as much relevant literature as possible would be obtained. Task participants agreed to approach all ARROWS partners, as well as other sources in Western Europe and North America as well as sources in Eastern European Universities, governments, and traffic and road Institutes. Standard international computerized traffic research databases (i.e., NTIS and IRRD)were utilized in order to find literature references.

Provisions and Problems

The analysis and interpretation of work zone accidents is complicated by a number of problems. Five will be mentioned here.

First of all, the sample sizes in many of these studies are all too often quite small.
Secondly, the statistical analysis presented in many in many studies could be improved.
A third problem has to do with a lack of unambiguous data.
A fourth problem concerns itself with the design of accident investigations.
Finally, and most problematical, are the conclusions made by some authors that their data collection procedures are likely to be biased.

These problems did not affect the quality of this work which is good and reliable. However, it is deemed necessary to (subjectively) weigh the quality of the research when considering the veracity of the results.

Results

Work Zone Accidents

It seems rather well substantiated that work zones are relatively unsafe places to be. However, the estimates regarding how large the relative increase in the accident risk is in a work zone vary from a few to a several hundred percent. The source of these enormous differences are unclear, and they may never be exactly determined except by a pains-taking meta-analysis. However, one would suspect that the former number (of a few percent) is more likely than the latter.

Concerning accident severity, there is also a relative lack of uniformity: some studies indicate that work zone accident are less severe, some studies indicate that they are more severe. In any case, it has not been found that the difference in accident severity is large and well understood enough to be reliably reproduced.

The ARROWS Work Zone Typology

In the ARROWS Task 1.1 (Deliverable 1), a typology of work zones has been proposed. Much effort has been taken to relate work zone accidents to the dimensions utilized in the taxonomy of work zone themselves, realizing that the mapping is not quite perfect. The

relevant dimensions are: (duration of) operations; road type; interaction between work zone and road.

There only appears to be weak evidence relating relative accident rates to the dimensions mentioned in said taxonomy.

There is some very weak evidence that accident rates are higher for work zones of shorter duration, but one is not entirely convinced of the generality of those findings

There is ample evidence that accident rates (for both base rates and work zone rates) do differ greatly from one type of road to another. For example, there are large differences between urban roads and rural roads, and between dual and single-carriageway roads.

However, there is little incontrovertible evidence that work zones are differentially dangerous for different road types. One problem here is that some of the data needed to make such a determination is available, yet has not been adequately investigated.

Concerning work zone and roadway interaction, the results are not extensive. Some authors conclude that work zones utilizing full contraflow are especially problematical.

It is felt, however, that the only clear-cut result is that working areas located on the side of the road are relatively safe, as compared to those located on the road itself. This result seems to be reasonable.

Work Zone Structure

It is believable, yet relatively uninteresting, to conclude that road sections after a work zone are not more dangerous than a road section which is not in the vicinity of a work zone. There also is no problem in believing that the work zone proper is also relatively dangerous, as compared to an open road section. The problem is with determining whether or not approach and transitional sections are differentially dangerous. It is felt that such a differentiation has not been conclusively established.

Safety Devices

As previously stated, the ultimate goal of the ARROWS project is to reduce the frequency and/or severity of work zone accidents. One of the possible ways of achieving this is through the advocating the use of safety devices or techniques (see Task 1.2), either intended to change behaviour, or to attenuate the consequences of an accident. In the first case, one could imagine the use of variable message signs to warn drivers to slow down. In the second case, one could consider the use of guiding barriers or truck mounted attenuators (TMAs).

Only a limited and superficial literature has been found addressing the effectiveness of such devices in terms of reducing work zone accidents. This disappointing lack of findings is not surprising, for reasons such a inadequacies in standard accident registration systems, ethical reasons, and limited research funding. It is suspected that the evaluation of such devices might be founded either on functional arguments or on behavioural studies (see Task 2.1).

Contributing (Human) Factors

Enormous differences have been found between jurisdictions and between studies.

Other Characteristics

Workzone accidents tend to be fair weather, daytime accidents. Also, many authors refer to appreciable increases in the relative frequency of rear-end collisions. Interestingly, one author distinguishes between day-time (low severity), multi-vehicle, rear-end collisions and night-time (higher severity), single vehicle fixed-object collisions.

Temporal and Geographical Differences

It is somewhat surprising that not much work has been done concerning temporal trends within jurisdictions. Apart from U.S., U.K. and Germany no other country apparently has a sufficient research database to even consider temporal comparisons.

The Distribution of Accidents over Locations

One remains particularly enamored of an elaborated null hypothesis: that if you want to predict work zone accidents you need at least two variables: "exposure" to work zones (which would take operational hours into account) and pre-work zone accident rate. Only when these two (predictors) turn out to be insufficient, does one need to conjure up the unique characteristics of work zone accidents.

This view is not only simple, it is also empirically and rationally sound. In addition, it enables one to make predictions.

However, it also opens up a number of tantalizing possibilities. First of all, one could try to predict work zone accidents rates beforehand, and optimally allocate appropriate countermeasures; secondly, there is a some evidence that the distribution of accident rate increases is highly skew over locations; third of all, it explicitly recognizes that there are two sources of variation in predicting accidents: the random variation of accidents for a given location, and the variation in accident risk for different locations. The first is statistical noise, the second is what one really wants to predict.

A pan-European Accident Study

Splintered studies, with small sample sizes, limited use of analysis techniques, and possibly limited variation in national infrastructure all contribute to the present lack of focus. A well set up pan-European study, of comparable size to the large-scale American studies, would go far in remedying the present situation.

Discussion and Conclusions

It seems rather well substantiated that work zones are relatively unsafe places to be. However, the estimates regarding how large the relative increase in the accident risk is in a work zone vary from a few to a several hundred percent. The source of these enormous differences are unclear, and they may never be exactly determined except by a pains-taking meta-analysis. However, one would suspect that the former number (of a few percent) is more likely than the latter.

Concerning accident severity, it has not been found that the difference in accident severity is large and well understood enough to be reliably reproduced.

There only appears to be weak evidence relating relative accident rates to the dimensions mentioned in the ARROWS typology. There is some very weak evidence that accident rates are higher for work zones of shorter duration. There is ample evidence that accident rates (for both base rates and work zone rates) do differ greatly from one type of road to another (urban - rural, dual - single-carriageway roads). However, there is little incontrovertible evidence that work zones are differentially dangerous for different road types. Finally, concerning work zone and roadway interaction, the results are not extensive; some authors conclude that work zones utilizing full contraflow are especially problematical; moreover, working areas located on the side of the road are relatively safe, as compared to those located on the road itself.

Workzone accidents tend to be fair weather, daytime accidents. It is suspected that this finding is highly related to driving exposure to (operating) work zones. Also, many authors refer to appreciable increases in the relative frequency of rear-end collisions.

In order to predict work zone accidents, at least two variables are needed: "exposure" to work zones (which would take operational hours into account) and pre-work zone accident rate. Only when these two (predictors) turn out to be insufficient, does one need to conjure up the unique characteristics of work zone accidents. This view is not only simple, it is also empirically and rationally sound. In addition, it enables one to make predictions.

However, it also opens up a number of tantalizing possibilities. First of all, one could try to predict work zone accidents rates beforehand, and optimally allocate appropriate countermeasures. Secondly, there is a some evidence that the distribution of accident rate increases is highly skew over locations. A relatively small number of locations may suffer quite large accident rate increases. Third of all, it explicitly recognizes that there are two sources of variation in predicting accidents: the random variation of accidents for a given location, and the variation in accident risk for different locations. The first is statistical noise, the second is what one really wants to predict.

Splintered studies, with small sample sizes, limited use of analysis techniques, and possibly limited variation in national infrastructure all contribute to the present lack of focus. A well set up pan-European study, of comparable size to the large-scale American studies, would go far in remedying the present situation. Such a study should allow one to draw conclusions with more confidence, and point the way for forming more precise hypotheses. Until then, one is forced to make uncertain guesses, and tentative comparisons.

Home - Documents - Top

EXPERIMENTAL AND OTHER RESEARCH METHODS

Introduction

Task Description

The aim of this task is to present a concise overview of existing and proposed experimental and other research methods for the evaluation of safety measures and to select and define an appropriate set of experimental evaluation methods.

Task Layout

Experimental methods possible to use when evaluating layouts and safety measures at road works, as examined in this task, cover a very large variety, depending not only of the tested item but, also, of the expected level of accuracy. The choice of each specific evaluation method is influenced by the purpose, perspective and basis of the evaluation. Also, the methods applied in specific evaluation studies vary due to practical, economic and scientific demands.

Research methods are performed, as a general rule, according to the following steps, depending on the stage of evolution and the expected accuracy level of the item's characteristics assessment: Laboratory research; Scale model testing; Field testing; Road/real time testing

Methodological Framework for the Evaluation

A large number of factors and aspects are of importance and should be considered in road infrastructure evaluation. The main perspectives from which road work zone design can be evaluated are briefly the following:

effects of alternative designs and positions of the elements used to build the road work zone (signs, lights, control and closure devices etc.), as well as of alternative combinations of the elements and their positions.
effects on the different groups of people involved in road works and their various and sometimes conflicting roles.
the sometimes contradicting goals in traffic.
effects of environmental factors, like light, sight and weather conditions.
effects of varying traffic conditions (types, volumes).

ARROWS focuses on the safety aspects of road works. All the mentioned perspectives can have safety implications and are therefore of relevance for the project work.

Laboratory Research Methods

Laboratory tests are especially useful for testing separate items (signs, lights, guiding and closure devices) under static conditions. Laboratory testing methods are, mainly, used in two cases:

In earlier stages of development of a product, when dealing with a specific product or in earlier stages of the design phase, when dealing with a traffic study.
For official testing, in order to accurately measure the product's physical properties and, probably, its conformity to existing norms so that an official approval for its use may be given.

Laboratory testing is more sophisticated and leaves more room to the personal initiative when dealing with the study of human behaviour related to road design and, in our case, to road work zone design. It is on this category of laboratory testing that this task will, mainly, focus. Laboratory evaluations are preferably used for screening purposes, and alternatives fulfilling set criteria can then be further investigated under more realistic conditions.

Some of the main tools, not as an exhaustive list, used in laboratory testing, mainly when dealing with human behaviour, are the following:

Driving Simulator

In a driving simulator car drivers can drive along a route and experience and cope with included situations under controlled and as close as possible to real conditions.

Today driving simulators are frequently used for studying driver behaviour (in terms of speed, lateral position, headway, brakings and accelerations, lane change and evasive manoeuvres as well as the drivers' compliance or omission of signs, rules and other guidance)., identifying driver errors and studying vehicle dynamics, with high precision, reliability and controllability.

Traffic Simulation

This tool is closely related to the one sited above (and might be studied as one), since it deals with the operation of the simulator under specific conditions.

Scale Model Testing

Scale model testing is an intermediate test stage, used in certain cases, between laboratory and real time or test track testing. Its purpose is to give a more realistic image of the items and/or designs to be evaluated before moving to the test track or the real time evaluation. However, since road work zone design is, mainly, based in the appropriate synthesis of existing elements, scale model testing may not be very useful within this context.

Test-Track Testing

An intermediate category between laboratory testing (or scale model testing, if any) and road/real time testing is testing not in a normal road network but in a specially conceived test track. Test site evaluation is similar, in the cases of evaluation of products performance, to road testing. The most important difference relies in the fact that no special care needs to be taken regarding traffic obstructions that may be caused by experimental conditions. In addition, in a test site, some special infrastructure arrangements may be made, if necessary for the experiment, in differentiation with real-time road network that any infrastructure change for the needs of an experiment is inconceivable.

Test track testing is mainly used for investigating road works from the road users' perspective.

When testing human bahaviour aspects on a test track, drivers can be exposed to different road work designs under more realistic conditions than in the laboratory (since parts of the real driving task, like car manoeuvring and information acquisition, are included when using the test track), however there exists still a high level of experimental control (interactions with other road users are not possible to implement in a realistic way and obtained results reflect behaviour and subjective estimations of drivers being aware that they take part in an experiment).

Road / Real-Time Testing

Road/real time tests are of course the most realistic way of evaluating road works, but at the same time the method offering the lowest level of experimental control. A consequence of a larger variability (less controllability) is that more data than in more controlled environments are needed to reach the same power in the results.

In real traffic like on the test track the driving behaviour can be recorded "from outside" via observations of ordinary road users passing the road work without being aware of being involved in an experiment and/or "from inside" letting subjects drive a car carrying the appropriate on-board equipment.

Field tests can be carried out to investigate road works from the road users', road workers' or administrators' perspective. It is of special importance that safety arrangements are approved and carried out when evaluations are made in the field. Preferably, the arrangements should be described in a plan, in the same way as for the actual road work.

Some of the main tools, not as an exhaustive list, used in road/real time testing, related to the evaluation of human behaviour, are the following:

Surveys

Mail surveys make it possible to collect information (for instance, road users' knowledge, views, attitudes and experience of road works) from a large number of individuals. Investigating road works as such, the survey does not deal with a specific road work site, but simply covers the respondents experience from passing different types of road work in the past. Instead of using mailed questionnaires, the questions can be put verbally using via a telephone. If this is the case, the number of people asked will of course be less because only one individual can be asked at the time by an investigator. The survey method includes trying out the questions on a small group of individuals, before the actual survey is conducted. Road users as well as road workers can be approached and investigated using survey methods.

Interviews

Interviews are similar to surveys in general in many respects. The main difference compared to surveys based on questionnaires is that only one individual at the time can be interviewed. The main methods related to human behaviour that are actually used and may be chosen within the ARROWS project are the following:

The Conflict Technique

The Conflict Technique (LTH, 1992) is used to study traffic safety problems (conflicts) at specific sites and of specific road user groups. The method exists and is used, but so far not for safety assessment of road work designs. "Specific sites", however, may very well include road works. The type of conflicts originally considered were those occurring between different road users (and road user categories). The situations can however easily be extended to cover also conflicts with road workers. If the method is used together with counts of the traffic volume, an estimate of the accident risk can be obtained. The conflicts do not only reflect the number of accidents, but also the nature of them. The conflict technique works best in combination with other methods like behavioural studies, accident analyses, interviews with road users etc.

Dependent Variables Appropriate for Use in Road Work Zone Evaluations

Human behaviour and behavioural modification aspects, as related to the design of a road work zone and studied with the above mentioned tools or with any others, should refer to some dependent variables, unanimously known and accepted as crucial regarding their role in road safety and operation The most important of these variables that influence road traffic operation are: Speed; Lateral/ longitudinal position measurement; Acceleration / deceleration measurement; Visibility distance; Readability distance and message comprehension; Mental workload; Measurement of physical properties of materials

Home - Documents - Top

Conclusions - Definition of a Basic Set of Evaluation Methods and Propositions on Improved Sets of Safety Measures

Following the methodology issues exposed in Task 2.3, when dealing with road work zones, given that practically all items used for both their design and equipment are inherited from normal road design and equipment, no testing concerning physical properties nor model testing may be needed. It is, thus, concluded that the basic test for the experimental and research testing made in the field should be the following:

a) At first an office design, concerning both the work zone master plan and the equipment details should be performed.

b) Based on this, a simulation design and testing of the work zone performance should be conducted.

c) In cases of innovative design and/or use of innovative items in it or in cases of extremely complicated road work zones (e.g. in highways or in rural networks with heavy traffic), a test track testing should be performed to evaluate the human behaviour and behavioural modification aspects related to this design or to some critical aspects of it.

d) Finally, a road/real time testing should be performed, in cases that the proposed design is meant to become a standard to many similar road work zone layouts. In this case, the first of these layouts should be studied in detail before reaching the standardisation phase.

Following the above, it may be resumed that the appropriate individual set of experimental evaluation methods to be used in a road work zone evaluation, depending on the importance of the work zone and the expected evaluation accuracy is related to:

The importance of the road work zone
The innovations used in it
Its role in a standardisation aspect

Depending on the above, only design described in paragraph (a) earlier in this paragraph may be sufficient to a work zone of small importance, with standardised aspects and no innovative items used in it. For more important work zones and/or including some innovation aspects in them procedures in (a) should be followed by the ones in (b), for even more important and/or using more innovative aspects, procedures described in (c) should, also, be used so as in extremely important work zones and/or including many innovative items that are, additionally meant to become the basis for standardisation issues, procedures described in (d) should, also, be part of the research/experimental evaluation.

Referring to the ARROWS typology (cf. Task 1.1.), the above selection of the 4 stages of experimental and research stages proposed ((a) to (d)) can be summarised, as propositions on improved sets of safety measures, in general terms, as follows:

Stage (a): for all E types, all C-2 types, C-1 types without special implications, and all "3" types.
Stages (a)+(b): for all 2 types except the ones in the category # I., A-1, B-1 and D-1 types without special implications, and C-1 types with implications i.e. (following ARROWS typology) (c), (e) and (g).
Stages (a)+(b)+(c): for A-1, B-1 and D-1 types including special implications, i.e. (following ARROWS typology) (a), (b), (c) and (d).
Stages (a)+(b)+(d): for all # II. cases if dealing with standardisation issues.
Stages (a)+(b)+(c)+(d): for all # III. cases if dealing with standardisation issues.

It should be clarified, however, that the above proposed relation between road work zone typology and experimental methods to be used, is only indicative and should, in no way, be considered as a pre-normative issue.

Workshop on Synthesis of Improved Sets of Safety Measures

Contents

Project Co-ordinator Prof. George Kanellaidis (NTUA). email: g-kanel@central.ntua.gr

INTRODUCTION

The present Deliverable 3 reports on the work carried out within ARROWS Workpackage 3 (Workshop on Synthesis of Improved Sets of Safety Measures). The report includes a detailed record of the two-day Workshop, held in Athens (GR) on the 24th and 25th November 1997 (ARROWS Milestone III) and attended by ARROWS consortium members, the responsible officer of the European Commission, and representatives from national administrations, contractors, Universities and research institutes from all across Europe. Deliverable 3 also includes a summary of the proposed improvements to the existing state of practice that arose from the Workshop.

The Workshop consisted of the following sessions, presented in chronological order:

Opening Session: Strategy and policy aspects of road work zone safety
Session A: The designer's viewpoint: Road work zone safety measures, standards and practices
Session B: The user's viewpoint: Behavioural and safety aspects of road work zones
Session C: Effectiveness of road work zone safety measures
Supplement to Session B: Presentation of initial results of the scenario construction process
Session D: Implementation issues
Closing Session: Towards the ARROWS Framework

Each session included presentations by both ARROWS Consortium members and guest participants, followed by a round of discussion. The report is based on the audio recording of the Workshop, the presentation texts / outlines supplied by participants, and the notes taken by the sessions' rapporteurs and NTUA team members.

Home - Documents - Top

OPENING SESSION:

Strategy and policy aspects of road work zone safety

At the beginning of the Workshop, Prof. George Kanellaidis (NTUA - Project Coordinator) welcomed Workshop participants in Greece and made a brief introduction to the project concept and context and the achievements so far. It was emphasised that the Workshop - as an interactive process - was structured in such a manner as to incorporate the views of the eventual users and help reach maximum usability of the ARROWS Practical Handbook

The first presentation, made by Mr Ioannis Dimitropoulos (NTUA), was a review of the progress of the project so far (including project targets, approach, and findings) and the remaining steps to be made in order to reach its objectives. A very brief presentation was made on the main targets of the ARROWS Project and on the project background, including the review of safety measures, standards and practices (first ARROWS Work

Package). A reference was made to the tools used in ARROWS in order to ensure a fruitful output, including: definition of a common typology; the expertise of the project consortium; the Workshop - with the main objective to integrate all findings and to result in a synthesis of proposed improvements in practice and methodology; and compatibility of the final product with existing national frameworks and international agreements. The results and findings so far - integrated in the first and second ARROWS Deliverables - included: (a) established conclusions and strong evidence; (b) weak indications / missing knowledge; (c) state of the art in research methods and suggested improvements; and (d) recording and comparison of existing practices across Europe. The presentation was concluded with the structure of the Workshop, emphasizing the contribution of the Workshop to the next phases of the project - by maintaining contacts with Workshop participants and by summarizing conclusions and proposed improvements, being the basis for the principles, recommendations and the handbook.

Mr Rene Bastiaans (European Commission - DG VII/E3) made a presentation on EU Road Safety Policy and RTD Activities on Road Work Zone Safety. Although there is no explicit European policy on safety at road work zones, it is warranted to carry out research to improve safety at roadworks. The Commission Road Safety Action Programmes target both the determinants of accidents as well as measures to reduce the consequences of accidents when they occur. The strategy comprises three activity lines: (1) gathering information, information dissemination and best practice; (2) accident avoidance measures; (3) tools to reduce the consequences of accidents. The ARROWS research project can be looked at from these different activity lines. Harmonisation of road work zone safety measures should in the first place improve safety for road users and workers. It is worthwhile to investigate if "self- explaining road workzones", aiming at appropriate driver/rider behaviour, can be designed and implemented across Europe. Bringing together best practice in a handbook can be a very effective way of harmonisation. Early end-user involvement in the handbook development process, and actively getting feedback from them, is not only instrumental but essential in arriving at ARROWS' central objective: a handbook for practical guidance to road network managers.

Ms Maria Sakki (CEN/TC 226 and COST 331 representative for Greece) made a presentation on CEN/TC 226 and COST 331. The first part of the presentation dealt with the standardization work of the CEN Technical Committee TC 226 for the work zone safety devices. This work is being done on the basis of six essential requirements: (1) mechanical resistance and stability; (2) safety in case of fire; (3) hygiene, health and environment; (4) safety in use; (5) protection against noise; (6) energy economy and heat retention. Ten of the standards already prepared for road equipment are related to the road work zone safety devices and mainly refer to the: horizontal signalisation; cones and cylinders; temporary signal systems; warning and safety light devices (danger lamps); variable messages etc. The second part of the presentation was related to the research Programme Cost 331: "Requirements for road markings", whose basic purpose is to provide a scientific basis on which to harmonise the quality and design of road markings and thus to promote a uniformly high level of safety throughout the European road network. The application field of the Action is limited to interurban roads and would cover road markings (white and yellow) such as: long lines (continuous and broken); retroreflective studs; directional arrows; and chevrons.

Home - Documents - Top

SESSION A:

The designer's viewpoint: Road work zone safety measures, standards and practices

An overview of the safety measures which have been inventorised in ARROWS Task 1.2 was presented by Mr Nicolas Poriotis (3M / Poriotis Consultants). The presentation included items used in road work zones to improve traffic safety and traffic flow characteristics. It is worthwhile to mention that within Task 1.2 the existing state-of- the-art in items used in road workzones have been presented without a mention of the specific way in which they should be used in each case (which was the object of subsequent tasks), i.e. Task 1.2 presented what exists but not how it should be used.

Dr Wolfgang Schulte made a presentation on the review of standards and practices, which was the objective of ARROWS Task 1.3. A pan-European review revealed that, in the standards, directives, recommendations or similar sets of regulations applicable, attention is paid primarily to the designing of work zones on motorways, highways, and non-urban roads and - additionally - to work zones which are set up in a permanent manner or ones which are operated in an interrupted manner. Only a limited range of different measures for the securing of work zones are to be found mentioned in the different layouts; it seems that numerous recent products have not yet found their way into the guidelines. The example of motorway contraflow layout was presented as a candidate standardisation case: depending on the traffic volume, two alternative concepts for guidance can be used for the diverted flow, in both of which only few different signs are used, but on various positions and in different quantities. The review of implementation of work zone standards revealed that, in the more recent regulations, increasing attention is being paid to the safety of those working in the work zones; in addition, both safety and traffic-flow considerations are important in guidelines. Depending on the particular legal requirements, work zone plans (featuring signs, markings and safeguard systems) have to be prepared, checked, corrected - if necessary - and then applied by the responsible official authority.

Mr John Boender (CROW) made a presentation on Harmonisation and Standardisation issues. He presented some items that could be proposed by ARROWS for European uniformity such as: colour of the traffic markings and traffic signs; devices and design elements for each work zone section; minimum sizes and quality indicators for the size; visibility and reflectance of the material of the traffic signs; minimum requirements for the use of protective barriers which will also serve traffic guidance.

Ms Sophie Jehaes (CRR) made a presentation on the interoperability and harmonisation principles and explained how these principles - as important "thought tools" - can be used in the outputs of the project and particularly in the Practical Handbook. The interoperability principle can be linked to: layouts (allowing to reduce the number of different layouts in the handbook); and material (possibility of using a same type of material for as many different types of workzones as possible). Harmonisation is the first step of standardisation; in the ARROWS project this principle has been applied in the creation of a typology, giving a common basis and a work tool for realisation of the subsequent stages.

Dr Manuel Romana (UPM) presented how work zone safety is dealt with in Spain. The good experience of ten years of relevant legislation shows the importance of bringing in all actors involved, as well as of the use of separate documents with procedures. These issues should be considered when dealing with the ARROWS Handbook. The importance of dissemination and the value of a flexible and simple Handbook were also emphasized.

The issues raised during discussion concerned mainly the harmonisation proposal of ARROWS, in particular the role and context of the Practical Handbook. Concerning the safety measures to be included in the Practical Handbook, a further screening should be made of what has been written in Task 1.2, focusing on safety measures that are more important to road work zones. Innovative and new equipment has been inventorised: this is common in use but not found in national regulations. However, an ARROWS proposal, including new things and ideas, will have to face the fact that lengthy procedures are needed for changing standards.

It was stressed that it is important to produce a Handbook flexible and not too rigid, to be applied by the different Member States but not to be limited to current technology. TERN motorway standards might be a good basis for harmonisation proposal of ARROWS. For example, one harmonisation issue is the colour of the background of the traffic signs. A major issue that was raised from the discussion is, given that many of the regulations have been based on "religion" more than on scientific results, how much "religion" should be injected to ARROWS proposal, since it is not acceptable to change regulations without research. Furthermore, CEN standards introduce a legislative aspect in addition to the previous question. On the other hand, ARROWS has to rely on "best common practice" and research.

It was also agreed that, concerning the Handbook, ARROWS can give a proposal for harmonised signing and layouts. It is, however, more important to include general underlying principles - concerning, for example, implementation or procedures - than concrete and too detailed proposals of specific dimensions or layouts. It was also mentioned that increasing attention is being paid recently to the safety of pedestrians, as well as that research is being carried out looking for new technologies and methods aiming at a safer working environment for road workers. Finally, it was agreed that quality and reliability in signing is of great importance.

Home - Documents - Top

SESSION B:

The user's viewpoint: Behavioural and safety aspects of road work zones

A significant portion of Session B was dedicated to the Accident Scenario Construction exercise, which is to be reported separately in Task Report 4.1. The presentations made prior to the exercise highlight behavioural and safety aspects, based on the reviews carried out within ARROWS Workpackage 2.

Ms Lena Nilsson (VTI) presented the methodology and findings of Task 2.1 (behavioural studies). The information was obtained from reviewing available literature and analysing it by means of a classification "model". Certain limitations, such as inconsistent terminology, poorly described factors and conditions and relative lack of statistical testing, made it difficult to draw clear and generalizable conclusions. One consistent (and expected) finding was that drivers speed at roadworks (commonly 20 km/h above the limits, often by a lot more) and usually change (reduce) their speed abruptly. Speed-reducing devices are more effective when positioned prior to the transition area, although it is noted that mental overloading (through use of too many devices) may lead to accidents even when speeds are reduced. Standardization is usually assumed to contribute to safety, although concern is expressed for familiarity potentially leading to "false safety" and lack of alertness. Most

behavioural studies were carried out in the United States; the direct transfer of proposed safety measures may not always be advisable. It is suggested that attitudinal surveys of road users as well as more investigations on non-motorway roads will be useful in the future. Little is specified about the type of road-to-work zone interaction in studies reviewed, with contraflow being most common. Additional evaluation problems were caused by (a) the lack of mentioning the specific safety measures used, or (b) the incremental placement / testing of safety devices. Finally, apart from speed and lateral position, few other behavioural variables were considered.

Mr Chad Gundy (SWOV) made a presentation on road work zone accident studies, noting that the problems mentioned by Ms Nilsson were not unique for behavioural studies but also came up in accident-related reports: small sample sizes, ambiguous data and definitions, lack of good experimental controls, biased data collection, relative non- use of statistical methods (or use of them to test the wrong hypotheses). Some of the main findings from the analysis of reviewed studies are: (a) work zones are more dangerous than non-works sections, usually by a few tens of percent; (b) no hard conclusions can be derived on the relative risk of different work zone types or parts - apart from the finding that the run-off area is safer than the rest of the work-zone; (c) future studies could focus on testing the "augmented null hypothesis" (via measurement of the relative accident rate beforehand and of the exposure at the time of road works) and on performing innovative analyses such as pan-European studies, meta- studies or accident scenario construction. However, the findings from existing studies do not allow for a lot of hard conclusions useful for the handbook.

Next, Mr Gundy proceeded with an introduction to the accident scenario construction exercise. The rationale for accident scenarios lies in the fact that not enough is known about accidents at work zones, thus expert "guessing" could be useful for constructing a shared image of these. Accident scenario construction consists of four phases: preparation; brainstorm / discussion (part of the Workshop); survey; and analysis. For the brainstorm, the Workshop participants would split into six working groups, each dealing with a separate question - and, time permitting, identifying relations between the factors identified. Brainstorm results would be summarized in the supplement to this Session.

Home - Documents - Top

SESSION C:

Effectiveness of road work zone safety measures

The session started with an overview of research methods used and proposed for the evaluation of road work zone safety measures (ARROWS Task 2.3), presented by Mr Nicolas Poriotis (3M / Poriotis Consultants). The different possible perspectives of evaluation (e.g. effects of alternative designs; effects on different groups of people involved; contradicting goals in traffic, etc.) and the diversity and multitude of methods were noted. The main steps identified were: laboratory research; scale model testing; field testing; and road /real traffic conditions testing. Each step was described as to their purpose, domain of application and other characteristics, and a number of dependent variables commonly measured (speed, lateral / longitudinal position, acceleration / deceleration, etc.) were identified. Eventually, a basic set of experimental methods was proposed, consisting of: (a) office design, (b) simulation design for the more important

work zones, (c) test track testing for innovative design or complicated work zones, (d) road testing for purposes of standardization.

Mr Graham Coe (TRL) analysed two measures used in the U.K. for the purpose of reducing speed. One is the use of speed cameras, as an enforcement measure. Their use is not equally spread through the country, due to different attitudes of local police forces. Where used, there are commonly about six dummy units for each real camera. The measure has proven to be effective in reducing speeds, especially for lorries. The other method is the "convoy working technique", which is useful in areas where the width of the carriageway is not enough for provision of the required lateral buffer space. The method can be used with either one or several works vehicles, driven at a given low speed and thus physically forcing the traffic (following behind on single file) to travel at that same speed through the work zone. For the success of this measure, it is important to make it understood to drivers by careful use of signs / signals.

In the last presentation for this session, Prof. Anthony Stathopoulos (NTUA) spoke about telematics applications for road work zones. Telematics is used as a tool with the main purpose of introducing observation of the traffic flow, not just the individual behaviour of each driver. In addition, time dependency can be introduced in the operation of work zones (e.g. for reassigning lanes to opposite directions in urban road work zones, depending on time of day). Information provision will be enhanced when the RDS traffic message channel project is materialized. Notions such as cooperative driving are expected to become part of future motorways, reducing the driving task requirements. Finally, telematics allows one to have a comprehensive control of the road environment and to test alternative scenarios concerning work zones.

In the round of discussion that followed, the following main points were made:

commercial traffic may be a first field for application of telematics
acceptance of automated systems is related to their reliability
optical "tunneling" of the lanes (gateway treatment) may be effective in reducing speeds without being restrictive; however, questions could be raised about the duration of the speed-reduction effect
cultural differences can affect the effectiveness of speed-reducing measures (e.g. markings)
acceptability of safety measures by authorities / decision-makers depends on perceived concrete benefits
appropriate signing was found to have a positive influence on proper merging behaviour
consistent signing is also helpful in use of cameras, by rationalizing use of police resources
speed limits are not effective without enforcement
the number of road signs is important - there is the challenge of the "self-explanatory road work zone"
road workers are a "forgotten group" when it comes to education / rules of behaviour
general testing, as opposed to special testing for work zone conditions, is usually sufficient; however, when the worst solutions are screened away, driving through the road work is important at the end

SUPPLEMENT TO SESSION B:

Presentation of initial results of the scenario construction process

Mr Chad Gundy (SWOV) introduced the presentation of initial results of the six brainstorms that took place at the last part of session B. The group at Table 1 had to find a list of external factors that influence traffic exposure / accident rates. The group at Table 2 dealt with unsafe acts, defences and psychological precursors. The group at Table 3 dealt with latent failure types. Table 4 worked on actors, their goals, resources and strategies. Table 5 looked into risk factors, and Table 6 discussed accident types.

Home - Documents - Top

SESSION D:

Implementation Issues

Session D dealt with implementation issues and covered the application in Central / Eastern European countries, the viewpoint of construction managers and the viewpoint of public road administrations.

Regarding Central / East European Policy, the document "Proposal for Harmonisation of TEM Motorway Traffic Signing: Proposals for Temporary Signing" describes Central / East European policy and practice. In a presentation by Mr Pavel Tucka (CDV), the following were the main points:

As a basis for the formulation of safety requirements, work zone closures are classified into three categories: long-term closures and traffic restrictions, short-term closures, mobile closures.
For long-term closures, guidelines refer to the distance for the traffic sign installation, traffic channeling, the lane width, the separation of traffic lanes of the same and opposite direction, the transverse closures, the longitudinal closure, the maximum speed.
A basic principle at short-term closures is the avoidance of firm closing devices and the employment of operative means such as mobile trailers combined with cone markers.
At mobile closures, the provision of road work machines/vehicles with warning facilities (such as special warning lights, flashing lights, running arrows) and the use of mobile trailers is specified.

On the contractors' role, a presentation was made by Mr Rene de Groene (Traffic Service van Strien BV).

Mr de Groene gave an account of the history of safety measures and standards in the Netherlands. Referring to the current practice he mentioned that Dutch work zone policy aims at "zero accidents". The development of the national policy was based on the following principles: collective (by both authorities and contractors) development and implementation of lines of action; placing more responsibility on contractor for safety; increasing the level of control by the authority; introducing new systems for road works. Regarding the contractors' role, he noted that in the Netherlands the planning of safety measures is entirely assigned to special contractors, whose role is: to formulate the specifications (for each application) in consultation with the principles and the other parties

involved; to decide on the safety measures required for the particular application (preparation of drawings/plans, description of work); to realise the safety measures (in the field) and to check up during the execution; to provide employees with the necessary training; and to rent the safety equipment.

Regarding the administrators' viewpoint, presentations were made by Mr Jan Boone (Rijkswaterstaat) and Mr Peter Behrman (Swedish National Road Administration).

Describing the Dutch policy, Mr Boone referred to three requirements that were set: minimising the delays, maximising the safety of road users, maximising the safety of road workers. Among the measures specified in the Dutch guidelines, those suggested for improving safety of workers include: formulation and implementation of guidelines for the layout of work sites; the organisation of a road work (the application of temporary systems); the use of technical equipment; education and training for road workers; giving briefings before starting a work. Finally, examples of rules of the Dutch practice include: the (traffic arrangements and measures used for the) 3-1 system; the introduction of a 60-cm free space/zone between machines/vehicles (of the work site) and the barrier or other separating element; the provision of a buffer zone between the lane closure and the starting point of the workzone; the definition of the required lane width (especially in contraflow systems); the mandatory use of lane signalling in the case of lane closure; the use of a special type of crash attenuators in temporary situations and mobile lane closures.

Referring to Swedish practice Mr Behrman noted that the target of the Swedish national traffic policy is "vision zero". Safety is considered at two levels: safety for road workers and safety for road users. The basis of the policy is training at all levels. Training is compulsory for workers and road managers. Swedish practice also includes: the use of mass media to increase public awareness and inform about particular problems related to road work zones; giving greater responsibility to the site manager; carrying out unannounced spot checks. Regarding the safety measures (for class A roads), Swedish standards specify the utilization of sturdy, energy-absorbing physical barriers, the removal of non-anchored heavy objects in support signs at road sites, the use of class 2 high-reflective material on all road signs at work sites and the mandatory use of approved high-visibility fluorescent clothing that fulfil special requirements.

Regarding the procedures, a traffic arrangement plan is drawn up by the contractor before the commencement of the road works, specifying the location of road signs and additional safety devices. The plan is checked and approved by the road manager. The contractor is also responsible for maintaining the round the clock function of the signs and keeping accurate records of any changes.

Actions towards the improvement of current practice include collection of relevant rules in a single document, gaining knowledge on accident causation at work zones through accident studies, raising the status of the workers, enhancement of the quality of the traffic arrangement plans, and promotion of uniformity of work site marking throughout the country.

The following are some of the main issues raised in the ensuing discussion:

Prioritisation of safety aspects: The key words in prioritising safety aspects are 'training' and 'controlling'.

The use of colour in differentiating work zone signing: An aspect of harmonisation is the use of a specific colour for work zone marking/signing, to indicate the presence of a work zone. In deciding on the introduction of a uniform background colour for the WZ signs throughout Europe, two are the main factors: the cost of changing the colour of the signs; and introducing signs of a particular colour and the potential usefulness and effectiveness of this measure.
Handbook contents: A good and fast method for producing a practical handbook is to agree on some major recommendations for each distinct area of the work zone separately, based on the results of research, gained experience and expertise in each country. New / innovative measures, not very well studied but currently in use, could be included in the handbook.
Contraflow systems: In some countries there has been some speculation about the maximum length of contraflow systems, which seem to get longer and longer. Relevant research in Germany indicated that contraflow system length is related to lane width. German regulations specify the required lane width for a given length of contra-flow system.
Accident data collection: The starting point of every effort for harmonisation should be the creation of a very sound, common data base for accidents. In order to achieve this, the use of standardised data collection methods should be considered. In deciding on a common data collection system/method, the importance of analysing the accident data in a structured way - making figures from the various counties comparable - should be acknowledged and elements/facts (such as "what preceded the accident") should be considered. Some ideas on how to proceed in the future towards the creation of such a system could be formulated within ARROWS.

Home - Documents - Top

CLOSING SESSION:

Towards the ARROWS Framework

The ARROWS Workshop was foreseen as a crucial milestone, marking the mid-term of the project's life-cycle. To this end, the Workshop was meant to provide an initial sketching of the Handbook in broad terms by identifying the fundamental principles for its structure, content and style. The final session, titled "Towards the ARROWS Framework", was specifically dedicated to the sketching of the end-product of the project. To this end, two presentations were provided, by Mr Pavel Tucka (CDV) and Dr Wolfgang Schulte (BAST) respectively. Both presentations dealt with the issues of the content and structure of the handbook and of the necessary amendments (innovations) to the current state-of-practice. They identified certain key points concerning the layout and the signing of Road Work Zones, paying particular attention to the issues of:

achieving a satisfactory level of driver acceptance through the use of the necessary number and type of signs, markings and guidance devices;
achieving safety for working personnel and for the other user categories (e.g. pedestrians, cyclists);
avoiding the setup and maintenance of work zones at occasions where they can be removed;
education and training of those involved in Road Work Zones, and
achievement of interoperability and standardisation.

The session and the Workshop ended with an exercise involving all the participants. This exercise was targeted to the sketching of the "Practical Handbook" and, within that, the participants were asked to freely fill in two lists as briefly as possible. The lists were entitled "What the handbook should be" and "What the handbook should not be".

The unstructured and brief type of the participants' input was commanded by the necessity to record all the views stemming from people with different expertise and representing different bodies with varying perspectives. After having filled in the aforementioned lists, the entries of the "should be" list were classified in three entities, dealing with format, concept and content. A basic underlying principle for the aforementioned classification was the unanimous belief that the handbook will in any case be a pre-normative tool and thus had to be flexible to achieve an acceptable degree of usability among the European countries - under the principle of subsidiarity. The "should not be" list entries were also classified into four entities, namely: quantity of contained text; format of presentations of the respective safety measures; content topic; and innovative character.

The concept of flexibility mentioned above was fully confirmed by the nature of the entries, where the participants proposed a handbook which would be: brief, containing many explanatory pictures and layouts, portable, user- friendly, comprehensive, accessible and modular. Moreover, it is envisaged to provide adequate details for the implementations of the proposed measures, to cover (in the sense of guidelines) the identified training gap (especially concerning the road workers), to provide a "Quality Control" check list and to allow for procedures of the "ask yourself" type.

In conclusion, it was mentioned that the two-day Workshop revealed certain "white holes" in the current state-of- the-art and state-of-practice, and the need for actions - in the sense of targeted research projects to cover the gaps - was emphasized.

Road Work Zone Safety Practical Handbook

Contents

Project Co-ordinator Prof. George Kanellaidis (NTUA). email: g-kanel@central.ntua.gr

VOLUME I

Summary

The ARROWS handbook, aimed at improving the safety of road users and workers at road work zones, is intended for highway authorities, designers, contractors and other individuals and organizations responsible for traffic safety at roadworks. It is a product of the ARROWS research project, funded by the European Commission.

The handbook is a pre-normative framework of recommendations - i.e., it is not intended to replace or supersede existing national official standards. The main focus of the handbook is the introduction of a common "best practice" for road work zone design and operation.

The handbook features detailed examples of the most commonly encountered work zone cases, with recommendations on the selection and placement of safety measures. The recommended values are proposed on the basis of the following criteria:

firstly, to ensure a high level of safety;
secondly, to harmonize between the standards of European countries - provided that the first criterion is not violated.

In addition, the handbook presents principles, procedures, tips and checklists for the safe implementation of work zones. The general recommendations given in the handbook can be useful in the implementation of road work zone cases that are not covered by a specific detailed example, either in national standards or in this handbook.

Moreover, the handbook's recommendations may be used as a starting point for the development, modification and/or amplification of national guidelines. This could be especially useful for countries whose road work zone safety standards cover only a specific type of road (e.g. motorways) - or only a small number of work zone cases.

When applying this handbook, the user must take not to violate either national legal requirements or international conventions/agreements. The handbook presents recommendations on the safety measures to be used at different work zone types, as well as on the procedures and responsibilities in the process of implementing a road work zone. Even though the recommendations are largely the result of harmonization between European national standards, they are not "normative" or "legislative".

In many cases the recommendations will differ from the national standards for road work zone safety in European countries. Moreover, the handbook should be consulted in cases where procedures and responsibilities are not adequately defined in national standards. National authorities are advised to take into account the handbook's recommendations in the process of revising their standards.

The handbook includes:

A description of road work zone safety objectives and principles

An outline of procedures and responsibilities for all stages of road work zone implementation
Practical recommendations in the form of "safety tips"
An illustrated glossary of safety measures
Recommended layouts for the most common road work zone types
Indicative checklists

Home - Documents - Top

Volume II

INTRODUCTION

The present Deliverable 4 - Volume II reports on the work carried out within ARROWS Workpackage 4 (Practical Handbook). It constitutes a Background Report to the ARROWS Practical Handbook, which is produced as Deliverable 4 - Volume I. The Workpackage consisted of the following Tasks:

Task 4.1 - Safety Principles. The initial objective of this Task was to propose a set of safety principles for the proper planning, design, implementation, operation and follow-up/assessment of road work zones across Europe. This is reported in Chapter 1 of the present volume. During the course of the project, the subtask of Accident Scenario Construction was added to this Task, with the objective to complement the conclusions from behavioural and accident studies through analysis of expert-generated data on "virtual work zone accidents". The procedure and results are reported in Chapter 2 of the present volume. Furthermore, Appendices 1 through 9 present detailed information about the accident scenario pilot study's inputs and outputs.
Task 4.2 - Recommendations and Compatibility. The objective of this Task was to formulate recommendations of sets of measures (layout, traffic control devices, other road equipment, and other measures) for all types of road work zone, as well as to determine possibilities for harmonisation of national guidelines and compatibility with relevant European agreements (such as TERN, CEN, and TEM). The work carried out for this Task is reported in Chapter 3 of the present volume.
Task 4.3 - Practical Handbook. The practical handbook is the key output of ARROWS and constitutes Volume I of this Deliverable. Itemisation of the cases selected as layout examples, as well as identification of safety issues - including "tips" and "checklists" - was largely based on the material of Tasks 4.1 and 4.2. Moreover, recommendations for the road worker are presented in Annex I to this volume, and a discussion of issues related to the management of road work zones appears in Annex II to this volume.

Home - Documents - Top

CHAPTER 1

Chapter 1 is a compilation of safety principles, derived from the work which has been conducted in the ARROWS project, which can be used for the planning, design, implementation and operation European road work zones.

This compilation is primarily based on the compiled and original findings of previous phases of the ARROWS project. To this end, each of the involved partners was asked to

prepare a contribution, based on a specific ARROWS Task report. Those sub-task assignments were:

Typology (CROW)
Measures (3M)
Standards and Practices (BAST)
Behaviour (BAST)
Accidents (3M)
Methods (3M)
Synthesis of Improved Sets of Countermeasures (3M).

All partners were also encouraged to freely contribute as they saw fit. The possibility of incorporating existing guidelines from each partner's country was also stimulated.

The idea was that, to the extent that previous ARROWS work was systematic, complete, and unambiguous, then (some) principles should be extractable in a structured way. To the extent that these conditions did not obtain, then less structured contributions could also be useful.

Even though there are (some) gaps, ambiguities and overlap between principles, every principle and/or argument mentioned in this paper can be profitably considered.

Home - Documents - Top

CHAPTER 2

Chapter 2 deals with accident scenario construction. The ARROWS consortium is interested in gathering and organising scientific knowledge concerning work zone traffic accidents, in order to produce suggestions for pan- European guidelines for implementing work zones. One effort to that end was not as illuminating as originally hoped, due to limitations in the scientific literature. In addition, there were no funds available for gathering data from actual work zone accidents, nor for analysing the data that already exists in (inter-)national databases.

To cover this lack, it was suggested that if we had no access to actual accidents then it might be useful to extract the intuitions of the ARROWS consortium about work zone traffic accidents. To this end, we asked these experts to consider virtual accidents, which we further treated as if they were real.

It was also the intention to include experts form outside the consortium, who represented other groups of stakeholders in the area of work zone safety: policy makers, police officials, contractors, etc.

This could have allowed a broader view of the problem area, contributed to the overall acceptance of the consortium's efforts, provided a common forum for a pan-European discussion of the subject, and allowed for comparisons of differences and similarities between viewpoints.

Due to a number of limitations, a more modest pilot study was conceived, which would make use of a session of the ARROWS Workshop in Athens in 1997 as the kickoff. This author prepared six discussion papers, which were to presented to six parallel working groups of 5 workshop participants each . Each group attempted (by means of a brain-storming procedure) to consider possible answers to central questions poised in the discussion papers.

The results of these working groups were then combined with existing accident forms, information found in previous ARROWS deliverables, and other relevant sources of information, to produce a "virtual" work zone traffic accident registration form. Eight copies of said form were sent to all participants of the Athens Workshop with the request to consider a concrete work zone traffic accident (either real or imagined) and to fill in an accident form in order to describe that accident. This was done for a total of eight times. 5 times subjects were given a road type of which the said accident had to occur, 3 times the subjects could freely determine the road type themselves.

About 2/3 of the subjects responded, and their returned accident registration forms were entered into the computer and analysed by means of non-linear Principal Component Analysis.

This process has resulted in very simple and clear results. Namely, the variability in the characteristics of work zone traffic accidents, as studied in the present report, can be reduced to three underlying, basic dimensions:

the type of road on which the work zone is located, with motorways being contrasted with urban local roads;
the duration of the work zone, varying from short-term and ad hoc to long-term and more-extensively organised.
the time-of-day cycle. It is only this last dimension which is clearly associated with different types of accidents.

These results may then be used as starting points for developing checklists and guidelines, which may then be incorporated in a practical handbook.

Home - Documents - Top

CHAPTER 3

Chapter 3 deals with recommendations and compatibility. Before planning of work zone and before decision of the technique of ensuring the concrete work zone the designer should collect as much as possible information about planning activities on roads (e.g. detailed description of appropriate road segment, range of planned work zone, current traffic signs and devices on this road segment, possibly supposed diversion and its length and direction and contingently order of phases of traffic lights).

The design of work zone measures should follow possible stages of activities, its possible combinations, types and duration.

It is evident that the different level of work zone ensuring (measures) will be designed for appropriate type of work zone. Therefore during the planning phase is necessary respect the location of work zone i.e. on urban roads (main, local), on rural roads (primary, secondary) and on motorways or expressways, farther its duration - long-term or short-term (stationary and mobile) - only during day light, and also take heed to possible concurrence of works.

If the ensuring of work zone with short term duration shows as insufficient from the point of view of road safety (i.e. gross fog or rain, snow etc.), it is necessary to use the same purpose of measures as on work zone with long term duration.

The purpose of ensuring of concrete work zone should come out from the appropriate model traffic scheme mentioned in practical handbook.

The form of work zone ensuring is necessary to decide on the base of local conditions (partial or complete road enclosure, diversion). The basic principle is to keep as far as possible the same number of lines on road or to find the traffic solution, which makes possible to keep traffic in both directions.

In case there is only one line in the work place area for both traffic directions it is necessary to decide on the basis of a local situation and traffic intensity whether it is possible to lead traffic on the basis of the intermittent traffic, with help of traffic signal or to set up a diversion. It is also possible to use the both way combination (for instance to set up diversion for particular vehicles, particular time or for one traffic direction only).

If the traffic intensity is too high and there is no possibility to set up diversion it is necessary to think of making provisional diversion road in the work area.

In the case of partial or complete road enclosure is necessary to consider the ensuring of cyclist and pedestrians, too. In the case of works on foot-paths or on cycle tracks is necessary to provide alternate and safe way of transportation for this vulnerable traffic participants.

Complete road enclosure for all kinds or same kinds of traffic is a big interference with organisation of traffic, because it means to set up a diversion.

In case a diversion road is used for longer time it is good to sign it up as a main road particularly if the traffic on important and busy road is turn away. Except interference into a giving way rule changes there may be also an importance of temporally speed decrease limit in area, which is unsuitable for temporally increase traffic. A diversion must be signed by traffic signs in advance for all drivers to make possible to get use to those traffic changes. It is useful to inform about a diversion in media.

Some main aspects for installing work zones are:

Choose time and duration of work zones in correspondence to traffic requirements and volume.
Adhere the number of lanes as far as possible.
Govern the design of the work zone (alignment, lane width and length).
Determine uniform layouts with signs as few as possible but as many as necessary.
Make work zones consistent during working and cancel them after the work is finished.

Use high quality materials for signing and marking.
Maintain traffic signs, markings and safety devices in a proper form all the time.
Train personnel in regard to their responsibility and their own safety aspects.

Workplan

ARROWS through its workplan will :

Analyse road work zone typologies, present the whole range of applicable work zone safety measures (current and innovative), and review existing national and international standards and practices on the topic;
Explore the effectiveness of road work zone safety measures in terms of their capability in achieving desired driver behavior, towards a safer driving and working environment;
Review the experimental methods for the evaluation of safety measures;
Develop improved sets of road work zone safety measures;
Recommend a European Framework for road work zone safety standards;
Produce a practical handbook for road work zone safety aiming to provide practical guidance to network managers at all levels;

Objectives

ARROWS aims to:

Develop a unified range of applicable road work zone safety principles and measures;
Produce a practical handbook for the assistance of network managers at all levels;
Initiate concerted activities towards the harmonisation & standarisation on road work zones;
Create a dissemination forum to all involved actors;

European Roadway System experiences a high increase in traffic volumes. This fact along with the budget shortage for building new infrastructure opts for an enhanced maintenance of the existing infrastructure. An overview of the current state-of-practice across the European countries reveals a multitude of design and signing practices with respect to workzone sites with diversified characteristics. This diversification undermines to a large extend the concept of a Common European Transport Policy (CTP) and requires a concerted effort towards workzone harmonization and standardization at a pan-European level.

Road RESEARCH: ARROWS

Project Acronym:
ARROWS
Type of contract:
Shared Cost
Project title:
ADVANCED RESEARCH ON ROAD WORKZONE SAFETY STANDARDS IN EUROPE
URL:
http://www.ntua.gr/arrows/
Main contractor:
NATIONAL TECHNICAL UNIVERSITY OF ATHENS
Type organisation:
Education
Country:
GR
Start date & duration:
1996-09-17 - 26 months
Area:
Road
Relevant tasks:
7.4.29
Total cost in kECUs:
1203
Total EU contribution in kECUs:
684

Objectives of research

Main objectives:

The ARROWS project aims to reach its key objectives of: 1) Developing a unified range of applicable road workzone safety measures and principles that should govern the planning, design, implementation and operation of road workzones so as to mitigate their adverse safety effects on workers and road users, and 2) producing a practical handbook aiming in the practical guidance to network managers at all levels. ARROWS will achieve this through a series of four complementary work packages designed to: - Analyse road workzone typologies, present the whole range of applicable workzone safety measures (current and innovative), and review existing national and international "standards and

practices" on the topic. - Explore the effectiveness of road workzone safety measures in terms of their capability in achieving desired driver behaviour, towards a safer driving and working environment. - Review the experimental methods for the evaluation of safety measures. - Develop improved sets of road workzone safety measures. - Recommend a European framework for road workzone safety standards. - Produce a practical handbook for road workzone safety aiming to provide practical guidance to network managers at all levels.

Demo Sites:

None

Links with other projects, tasks, areas, programmes, policy actions:

Participants

Organisation
Type
Country
NATIONAL TECHNICAL UNIVERSITY OF ATHENS
Education
GR
SWOV - INSTITUTE FOR ROAD SAFETY RESEARCH
Research Organisation
NL

BUNDESANSTALT FÜR STRASSENWESEN
Research Organisation
DE

SWEDISH NATIONAL ROAD AND TRANSPORT RESEARCH INSTITUTE
Research Organisation
SE

3M HELLAS LIMITED
Industry
GR
BELGIAN ROAD RESEARCH CENTRE
Research Organisation
BE

CENTRE FOR RESEARCH AND CONTRACT STANDARDISATION IN CIVIL AND TRAFFIC ENGI NEERING
Research Organisation
NL

CENTRUM DOPRAVNIHO VYZKUMV S.A.
Research Organisation
CZ

ZAVOD ZA GRADBENISTVO SLOVENIJE (ZAG)
Research Organisation
SI

Coordinator's name: Ass. prof. George KANELLAIDIS
Address: NATIONAL TECHNICAL UNIVERSITY OF ATHENS
Iroon Polytechniou Street, 5
15773 Zografou-Athens
GR
Tel: +30-1-7780559
Fax: +30-1-7781796
E-mail: g-kanel@central.ntua.gr

European Commission Contact Point

Name: Mr. René BASTIAANS
Tel: +32-2-2994115
Fax: +32 -2-2968350

ARROWS - Final Summary Report

Advanced Research on Road Work Zone Safety Standards in Europe

Project Coordinator:
NTUA - National Technical University of Athens (GR)
Department of Transportation Planning and Engineering

Partners:
SWOV - Institute for Road Safety Research (NL)
BAST - Federal Highway Research Institute (DE)
VTI - Swedish National Road and Transport Research Institute (SE)
3M - 3M Hellas Limited (GR)
CRR - Belgian Road Research Centre (BE)
CROW - Information and Technology Centre for Transport and Infrastructure (NL) qCDV - Transport Research Centre (CZ)
ZAG - Slovenian National Building and Civil Engineering Institute (SI)

Project duration:
17 September 1996 to 16 November 1998

Date:
January 1999

CONTENTS

PARTNERSHIP

The ARROWS project has been carried out by a Consortium consisting of the following partners:

The National Technical University of Athens [NTUA], based in Athens (GR), who co-ordinated the project.

The SWOV Institute for Road Safety Research [SWOV], based in Leidschendam (NL).

The Federal Highway Research Institute [BAST], based in Bergisch-Gladbach (DE).

The Swedish National Road and Transport Research Institute [VTI], based in Linköping (SE).

3M Hellas Limited [3M], based in Athens (GR).

The Belgian Road Research Centre [CRR], based in Brussels (BE).

The Information and Technology Centre for Transport and Infrastructure [CROW], based in Ede (NL).

The Transport Research Centre [CDV], based in Brno (CZ).

The Slovenian National Building and Civil Engineering Institute [ZAG], based in Ljubljana (SI).

The above nine partners had the status of Contractor. There were no Associated Contractors. Poriotis Consultants (GR) were subcontractors to 3M. The Engineering Company for Public Roads (SI) and the University of Ljubljana (SI) were subcontractors to ZAG.

NTUA, SWOV, BAST, VTI and 3M were the leading partners in the twelve Tasks into which ARROWS was subdivided. Tasks were grouped into Workpackages. Each Workpackage resulted in a Deliverable, compiled by NTUA, which contained the corresponding Task Reports.

ARROWS was supervised by the European Commission, Directorate-General for Transport (DG VII), Division E-3.

OBJECTIVES

The ARROWS Project (Advanced Research on ROad Work Zone Safety Standards in Europe) was funded by the European Commission under the Transport RTD Programme of the 4th Framework Programme. It began on 17 September 1996 and finished on 16 November 1998 under the provisions of Contract No. RO-96-SC.401.

The main objectives of ARROWS were:

Development of a unified range of applicable road work zone safety measures and principles that should govern the planning, design, implementation and operation of road work zones so as to mitigate their adverse effects on the safety of workers and road users
Production of a handbook for practical guidance to network managers at all levels

TECHNICAL DESCRIPTION

The work content of ARROWS has been organized into five Workpackages and twelve Tasks as follows:

Workpackages
Tasks

0. Project Management
0.1 Project Management

1. Review of Safety Measures,
Standards and Practices
1.1 Typology

1.2 Safety Measures

1.3 Standards and Practices

2. Review of Behavioural and
Accident Studies and
Research Methods
2.1 Behavioural Studies

2.2 Accident Studies

2.3 Experimental Methods

3. Workshop on Synthesis of
Improved Sets of
Safety Measures
3.1 Preparation and
Implementation of Workshop

3.2 Synthesis of Improved Sets

4. Framework for European
Standards and Production of
Practical Handbook
4.1 Safety Principles

4.2 Recommendations and Compatibility

4.3 Practical Handbook

Each of the ARROWS Deliverables was based upon the corresponding Task Reports.

ARROWS Workpackages 1 and 2 were dedicated to the review of road work zone safety issues.

Workpackages 1 and 2 comprised:

concentration of the collective experience from different countries and studies in the field of road work zone safety measures
agreement on a typology for consistent use throughout ARROWS
creation of a full inventory of safety measures, standards and practices for use in the subsequent evaluation, assessment and recommendation process
evaluation of the potential of road work zone measures for achieving desired driver behaviour and improving the safety of both road workers and road users
examination of the methods used for testing road work zone measures

The Workshop on Road Work Zone Safety (Workpackage 3) was meant to aid in the development of improved sets of road work zone safety measures, through innovative insights provided by experts in the field - both ARROWS contributors and invited specialists. Directly linked to the outcome of the Workshop was the formulation of an adequately justified inventory of improved sets of safety measures categorised by type of road work zone. The emphasis were on highlighting the improvements that may be proposed in relation to existing practices and on specifying the arguments for these.

The work carried out for ARROWS Workpackage 4 provided the main background to the Practical Handbook, namely:

a proposal of a set of safety principles for the proper planning, design, implementation, operation and follow-up/assessment of road work zones across Europe (safety principles)
complement to the conclusions from behavioural and accident studies through analysis of expert-generated data on "virtual work zone accidents" (accident scenario construction)
formulation of recommendations of sets of measures (layout, traffic control devices, other road equipment, and other measures) for all types of road work zone, as well as to determine possibilities for harmonisation of national guidelines and compatibility with

relevant European agreements - such as TERN, CEN, and TEM (recommendations and compatibility)

The ARROWS handbook was the key output expected of the ARROWS project based on a review of formats, colours, texts and other conventions used in similar handbooks and incorporation of findings from ARROWS Tasks related to safety principles and recommendations. It aimed at improving the safety of road users and workers at road work zones. It is intended for highway authorities, designers, contractors and other individuals and organizations responsible for traffic safety at roadworks. The Practical Handbook featured an itemisation of cases selected as layout examples, as well as identification of safety issues - including "tips" and "checklists". The handbook is a pre-normative framework of recommendations - i.e., it is not intended to replace or supersede existing national official standards. The main focus of the handbook is the introduction of a common "best practice" for road work zone design and operation.

RESULTS AND CONCLUSIONS

The work carried out for ARROWS consisted of:

Reviews of road work zone safety issues
An interactive international workshop
Compilation of safety principles and recommendations of a framework for European standards on road work zone safety

ARROWS Workpackages 1 and 2 were dedicated to the reviews of road work zone safety issues.

The review phase resulted in:

a typology consisting of three main classification factors (road type, work type, and interaction between road and work zone)
an inventory of currently-used and innovative safety measures, classified into road layout arrangement, traffic control devices, other road equipment, and miscellaneous
an overview of the provisions of European standards regarding the usage of safety measures
the identification of main behavioural effects of road work zones
results on the accident situation at different types of road work zones
a critical review of research methods for assessing the effectiveness of safety measures at road work zones

The ARROWS Workshop (Workpackage 3) took place in Athens in November 1997, with the participation of ARROWS partners, the European Commission, as well as representatives from international initiatives (CEN/TC), national road administrations, research institutes, Universities and contractors from several European countries. The Workshop included six thematic sessions, consisting of presentations, discussion and interactive work (brainstorms). The main ideas presented, discussed and generated were recorded and taken into consideration during preparation of the ARROWS Practical Handbook, which was the key output of the project. An inventory of main ideas presented at the Workshop was produced on the basis of the above record, categorized by the following "thematic units", i.e. groups of topics: (I) research and policy; (II) format, concept and context of handbook; (III) safety measures for inclusion in handbook.

The work carried out for ARROWS Workpackage 4 provided the main background to the Practical Handbook.

The ARROWS handbook, aimed at improving the safety of road users and workers at road work zones, is intended for highway authorities, designers, contractors and other individuals and organizations responsible for traffic safety at roadworks. The handbook is a pre-normative framework of recommendations - i.e., it is not intended to replace or supersede existing national official standards. The main focus of the handbook is the introduction of a common "best practice" for road work zone design and operation.

The general recommendations given in the handbook can be useful in the implementation of road work zone cases that are not covered by a specific detailed example, either in national standards or in this handbook. Moreover, the handbook's recommendations may be used as a starting point for the development, modification and/or amplification of national guidelines. This could be especially useful for countries whose road work zone safety standards cover only a specific type of road (e.g. motorways) - or only a small number of work zone cases.

EXPLOITATION AND DISSEMINATION PLANS

NTUA intends to exploit the ARROWS results as follows:

Contribute to the improvement of Greek standards and to the promotion of roadworks safety concepts in Greece
Apply, test, fine-tune and adapt ARROWS recommendations to Greek conditions
Play a leading role in follow-up initiatives, at a national and/or European level

In the Netherlands both CROW and SWOV are involved in ARROWS. Dissemination activities will be joint efforts of these organisations. The policy makers and designers will be informed about the existence and contents of the practical handbook through dissemination. Through articles published in the magazines, the people concerned with road work zone safety will be informed. If they have questions they can contact the authors of the report and they can order a copy of the report by SWOV or CROW.

BAST acts as scientific advisor to the Federal Ministry on technical matters and transport policy. Therefore it plays a leading role in the formulation of specifications and standards as well in work zone regulations. In so far, BASt has additionally the task to inform the different Ministries of the so called "Laender" of the Federal Republic of Germany. In Germany, the current version of regulations for work zones on all types of roads is published in 1995. Additionally, special rules for execution of contracts about signing of road work zones are prescribed since 1997. Due to the described situation, the results of ARROWS shall by distributed and discussed in relevant working groups of the Federal Republic and the Laender to prepare the platform for further develop of the existing regulations: Technical Committee for the Traffic Law and the Police; Technical Committee for Traffic Technology.

VTI's intention is to publish the final ARROWS deliverables in the VTI series "EC-research". Reports in the VTI series will be announced and some selected ones will also be referred to in a periodical which is distributed by VTI to about 5000 "subscribers" in

Sweden and the Nordic countries, and to a smaller number of subscribers in other countries. It is possible to order reports using a form in the periodical. Abstracts of reports in the VTI series are/will also be available on VTI's Internet homepage and included in databases. Finally, VTI will also distribute the deliverables (at least the Handbook) to the Swedish Road Administration (cental and regional offices).

3M's main objective is the adoption the soonest possible and to the largest degree of the proposals by the Greek State, followed by the upgrading of 3M's status in the signing field, as the innovative supplier of top quality signing products that effectively contribute to road safety. 3M is willing to actively participate in an effort to revise/upgrade respective national standards so that they incorporate the project proposals. A workshop with the participation of NTUA is proposed to be held within the first quarter of 1999. The invited parties will come from academia, the ministry, the association of construction contractors and other parties interested in road work zone safety. Finally, 3M Helllas plan to diffuse the project findings to 3M's European subsidiaries through regular reporting, internal newsletters and personal contacts.

CRR has already contacted the Flemish and Walloon governments to exploit more completely the output of the ARROWS project. An exploitation at the European level could be the study of the implementation of the handbook in the different European countries (how to modify the current national standards) or in the study of specific safety measurements through a COST action. By the way of presentation during international conference, the aims and the outputs of the ARROWS project were already disseminated and this action will continue in the next years. A paper in the CRR's newspaper (called Bulletin) will describe the aims and the results of the project, in March 99. A such paper will be the first step for a dissemination through the contractors and the ministers. At the same time, the Deliverables and the handbook will be disseminated through the country. The next step is to give courses to the work zone chiefs and official persons (at the Federal, Regional and local level) in Belgium and to the government members in other countries in the framework of international exchange with non-European countries.

CDV's main aim is to transmit and discuss results of this project on governmental level and used for formation of new Transport Policy (schedule: first on the end of 1998) and for editing of Czech standards and technical principles (schedule: continuously). Scientific exploitation will take place through traditional routes, such as: the presentation at national conferences together with introducing new standards and technical principles for national road administrators and for police traffic engineers; the presentation at educational courses for Road Safety Auditors; the presentation of papers at major national conferences and the production of papers for magazines. Information about this project will be published on the CDV World Wide Web home page (www.cdv.cz) (schedule: continuously).

The results of the project will be disseminated by ZAG at national level through targeting of recipients by the participating experts to the responsible institutions. Dedicated meetings will be held to update practicing engineers at all levels of road authority. It is expected that results of the project should reach the engineers that design the work zone areas and produce the plans for the road closures at all levels of road authority. These activities will lead to standardisation and/or other way of regulation and implementation of the result of this project. National Research Institutes and Universities will be involved in these activities. The aims and the outputs of the ARROWS project were already disseminated

during national conferences or symposiums, and this action will continue in the next years. Information about this project will be published on the ZAG home page (www.zag.si)

NAMES AND ADDRESSES OF THE ARROWS CONSORTIUM MEMBERS

Partner
Name
Contact
Person
Postal
Address
Telephone
Number
Facsimile
Number
E-mail Address
Home page

NTUA
Dr. George KANELLAIDIS
Iroon Polytechniou 5,
GR-15773 Zografou -
Athens,
Greece
+30-1-7721283
-7721282
-7721331
+30-1-7721327
g- kanel@central.ntua.gr
http://www.ntua.gr

SWOV
Mrs. Marjan HAGENZIEKER
P.O Box 1090, 2260BB Leidschendam, The Netherlands
+31-70-3209323
+31-70-3201261
hagenzieker@swov.nl
http://www.swov.nl

BAST
Dr. Wolfgang SCHULTE
P.O Box 100150,
D-51401
Bergisch Gladbach
Bruederstrasse 53,
D-51401
Bergisch Gladbach
Germany
+49-220-443540
+49-220-443750
+49-220-443159

schulte@bast.de
http://www.bast.de

VTI
Ms. Lena NILSSON
Olaus Magnus Vaeg 37,
S-58195 Linköping,
Sweden
+46-13-204140
+46-13-141436
lena.nilsson@vti.se
http://www.vti.se

3M
Mr. Frank HANIOTIS
20 Kifissias Ave,
Maroussi - Attiki GR - 15125,
Greece
+30-1-6842902
+30-1-6843281
fhaniotis@mmm.com
http://www.mmm.com

CRR
Mrs. Sophie JEHAES
Blvd. de la Woluwe 42,
Brussels 1200,
Belgium
+32-2- 7660344
+32-2- 7671780
S.Jehaes@brrc.be
http://www.brrc.be

CROW
Mr. John BOENDER
P.O Box 37,
Galvanistraat 1,
Ede 6710 BA,
The Netherlands
+31-318-620410
+31-318-621112
boender@crow.nl
http://www.crow.nl

CDV
Mr. Jozef MIKULIK
Vinohrady 10,
P.O.Box 22,
CZ - 639 00 Brno,
Czech Republic
+420-543- 215050

+420-543- 211215
jmikulik@cdv.cz
http://www.cdv.cz

ZAG
Mr. Bojan LEBEN
Dimiceva 12,
Ljubljana 1000,
Slovenia
+386-61- 1888100
+386-61- 1888484
bojan.leben@zag.si
http://www.zag.si

Last Updated: 04-10-1999