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CIVIL & ENVIRONMENTAL ENGINEERING | RESEARCH ARTICLE

Addressing education and training needs of road safety auditors

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Abstract: According to national (Greek) and European legislation on road infrastructure safety management, road safety auditing is mandatory for the Trans-European Road Network. This paper presents the development of a training course and educational material for candidate road safety auditors in Greece, aiming to adequately prepare them to conduct road safety audits. In particular, the principles upon which the road safety audit training course is based, the learning objectives, the course outline and the proposed framework of the curriculum are presented. The training course takes into consideration recent developments in road safety, as well as local conditions and needs. Because it places emphasis on the implementation of the Safe System and human factors in road design, it may contribute to the development of a positive safety culture among highway professionals involved in the road design and road operation process. The process of its development may be regarded as a proposal for good practice for the development of professional development training programmes, addressing the relevant training needs and achieving the relevant training objectives.

ABOUT THE AUTHOR

Sophia Vardaki PhD (Surveying Engineering) is a senior researcher on the laboratory teaching staff of the National Technical University of Athens (NTUA) Department of Transportation Planning and Engineering. She has extensive experience in elder driving performance, road safety audits, human factors in road design, surveys and field observations. The training course and the educational material were produced under the Hellenic Institute of Transport (HIT) “Development of Training Curriculum and Educational Material for Candidate Road Safety Auditors” project. The Project Leader, Evangelos Bekiaris PhD (Mechanical Engineering) is Director of HIT. His field of expertise covers road safety, clean vehicles, smart grid applications, specialised telematics applications for vehicles, public transport and maritime transport. He has great experience in accessible transportation and personalised services for disabled and elderly people. NTUA Professor Emeritus George Kanellaidis has devoted many years of academic activity to improving Greek road safety and reviewed all the project training material.

PUBLIC INTEREST STATEMENT

The Safe System model is an anthropocentric approach to road safety and the basis for road safety strategies in advanced countries. Road safety auditing is a preventive measure that is part of the Safe System approach to road safety. This article describes the development training course that leads to a certification of competency for candidate auditors. This process can be viewed as a proposal for good practice that can be applied to professional development training programmes after the necessary modifications to fit the specific training purpose. The training process for candidate auditors in private and public organisations, as well as trained freelancer highway designers must strengthen the belief that road safety is everyone’s responsibility and the common duty is to ensure that safety is an integral part of all decisions that affect the road infrastructure system.

Subjects: General Engineering Education; Sustainable Transport Engineering; Transportation Engineering; Continuing Professional Development

Keywords: Road safety audit; road design; Safety; education; survey; accreditation; learning outcomes; human factors; Professional development

1. Introduction

A key requirement to substantially upgrade road infrastructure safety is the implementation of a comprehensive programme in terms of road safety, as applies in a number of developed countries and as is institutionalised at European level by Directive2008/96/EC (EC [European Commission], 2008). Presidential Decree104/2011 (GGGR [Government Gazette of the GreekRepublic], 2011) brought Greek legislation in line with the European Directive on road infrastructure safety management, whose implementation is planned for the Trans-European Road Network of Greece.

Integrated road infrastructure safety management concerns the obligations of those responsible for road infrastructure and traffic to conduct road safety audits (during the design and construction phase), road safety inspections (during the operating phase), management of high risk sitesandroad impact assessments. These comprise the four core methodologies for identifying road safety concerns and their countermeasures in all stages of design, construction and operation of the infrastructure, both proactively and correctively (EC [European Commission], 2008).

For the implementation of integrated road infrastructure safety management, Directive2008/96/EC (EC [European Commission], 2008) and Presidential Decree104/2011 (GGGR [Government Gazette of the Greek Republic], 2011) define specific procedures related to the training and responsibilities of auditors, the data which are collected and utilised, as well as the relevant good practices that should be used to tackle the road safety issues that have been identified.

For the successful implementation of the Road Safety Audit (RSA) procedure, and in accordance with the ministerial decision approving the guidelines for road infrastructure safety management (GGGR [Government Gazette of the Greek Republic], 2012), training and follow-up courses have been planned for road safety auditors. Therefore, it is essential to develop a specific training curriculum, as well as educational material for candidate road safety auditors.

Under this framework, in October 2014, the Greek Ministry of Infrastructure, Transport and Networks assigned the elaboration of the project entitled “Development of Training Curriculum and Educational Material for Candidate Road Safety Auditors” to the Hellenic Institute of Transport (HIT) of the Centre for Research and Technology Hellas (CERTH).

1.1. Road safety auditing

Road safety auditing is a preventive measure that is part of a Safe System approach to road safety. The modern Safe System approach is the basis for road safety strategies in advanced countries e.g. Sweden (Vision Zero), the Netherlands (the Dutch Sustainable Safety vision similarly constitutes a state-of-the-art Safe System approach), Australia and several states in the USA (Belin, 2012; Kanellaidis & Vardaki, 2011; Kristianssen, Andersson, Belin, & Nilsen, 2018; Larsson & Tingvall, 2013; OECD/ITF [Organisation for Economic Cooperation and Development/International Transport Forum], 2016; PIARC [World Road Association], 2015).

The objective of a Safe System is to proactively identify and limit system failures (system failures can be attributed to errors by drivers, design, traffic control and combinations of these factors) (Austroads, 2015; SNRA, 2006). The application of human factors in traffic engineering and highway design practice puts the user at the centre of road systems design. The Safe System approach shares vital foundations with the human factors concept by adding biomechanical tolerance and its implications on systems design (Johansson, 2009; Larsson & Tingvall, 2013; OECD/ITF

[Organisation for Economic Cooperation and Development/International Transport Forum], 2016). In a Safe System approach, it is emphasised that even if prevention efforts are undertaken (e.g. education, surveillance), the environment may still be complex, road users will remain fallible and crashes will occur (Theeuwes, Van der Horst, & Kuiken, 2012). Research work has shown that improvements in road design are most likely to be linked to reductions in fatal outcomes (Austroads, 2018). Characteristically, using the safe road transport model developed by the Swedish Road Administration and 230 fatal crashes that occurred on Swedish roads, Stigson, Krafft, and Tingvall (2008) found that of the three components of a safe road transport system i.e. road users, road and vehicles, the road infrastructure alone was the component most often linked to a fatal outcome.

A Safe System anticipates that roads and roadsides will be planned, designed and operated to be forgiving of (inevitable) human errors and error tolerant, so that severe injury outcomes are unlikely to occur (Austroads, 2015, 2018). For that reason, there is a need for road designers to understand Safe System implementation and how to incorporate road user limitations, needs and capabilities in road system design (Austroads, 2015; Campbell et al., 2012; Johansson, 2009; Larsson & Tingvall, 2013). They also should consider the latent conditions that result in system failures (which potentially end in road crashes), e.g. associated with the decisions and actions of the “not-at-the-scene actors”, the planners, engineers and elected officials (Hauer, 2016). Latent conditions are for example the use of different design standards in the design of roads or different design standards in different sections of a road.

Road safety auditing is specifically based on the Safe System principle that the road environment and driver requirements imposed by it should be adjusted to the level that the majority of road users can cope with, thus preventing inadvertent mistakes.

Road safety auditing is a formal safety performance examination of an existing or future road or intersection by a qualified team independent of the design team. The RSA team considers the safety of all road users, qualitatively estimates and reports on road safety issues and identifies opportunities for safety improvement (e.g. Austroads, 2009; DfT (Department for Transport), 2015; FHWA (Federal Highway Administration), 2006; IHT (The Institution of Highways & Transportation), 2008; Kanellaidis, Vardaki, Mertzanis, Dragomanovits, & Laiou, 2012; Karantanos & Vardaki, 2013). In the 1980s, the RSA process started in the UK when engineers had to carry out collision reduction schemes on new roads designed and built according to existing technical standards. They realised that even on roads designed according to the technical standards, collisions still happen, and that the likelihood of collisions should be reduced before the road is used. Later, in the 1990s, RSAs were introduced in Denmark, Australia and New Zealand. The United States Federal Highway Administration (FHWA) has championed RSAs since 1996. The first RSAs were carried out in Greece in 1998. Since then, RSAs have been carried out on a limited basis on major trunk roads (Karanos & Vardaki, 2013).

1.2. Purpose of the study

The programme and the educational material (HIT, 2015) developed for the training of roadway engineers who want to be certified as road safety auditors in Greece is the first official systematic effort for the training and certification of engineers working in the private and public sector (GGGR [Government Gazette of the Greek Republic], 2016). The Greek road safety audit training course is expected to begin in late 2018.

This paper presents (i) the main results of an extensive questionnaire survey that was addressed to EU countries that have adopted Directive 96/2008/EC, and to Australia; (ii) the principles and the methodology for the development of the training course; (iii) course outlines for the initial and periodic training of auditors; (iv) learning objectives and key features of the course. The paper proposes evaluation of the training course and discusses

its characteristics, as well as its potential to develop a positive safety culture among highway designers and safety professionals.

2. Questionnaire survey

The EU Directive on road infrastructure management advises Member States to exchange good practices in the implementation of procedures relating to integrated road infrastructure safety management, including capacity building through procedures for training and certifying road safety auditors. In this respect, consistency of the Member States' training curricula is desirable.

The team responsible for creating the training curriculum and educational material for candidate road safety auditors first sent an extensive questionnaire survey to relevant agencies and services in EU Member States that had already adopted and implemented Directive 96/2008/EC, and in Australia, where RSAs have been successfully implemented for over 20 years. The questionnaire was sent to experts on road safety in agencies and organisations involved in road safety and transport infrastructure, who have knowledge of road safety audit practice in their countries. In early 2015, a total of 11 completed questionnaires were received from 10 different countries: Australia, Sweden, the Czech Republic, Hungary, Slovenia, Portugal, Italy, Switzerland, the Netherlands and Germany. An overview of the responses regarding the implementation of the directive, adoption, existence and use of guidelines, implementation of RSAs and initial training and certification for road safety auditors, RSA training courses in European countries, requirements for certification and periodic training and maintenance of competence and minimum requirements for Senior Road Safety Auditors and periodic training and maintenance of competence for Road Safety Auditors has been published elsewhere (Vardaki et al., 2016).

Selected data on good RSA training practices in European countries obtained through this survey is presented in Appendix 1. Based on a review of the survey responses, the key topics covered in RSA training courses in European countries are presented in Table 1.

3. Methods

3.1. Principles for the development of an RSA training course

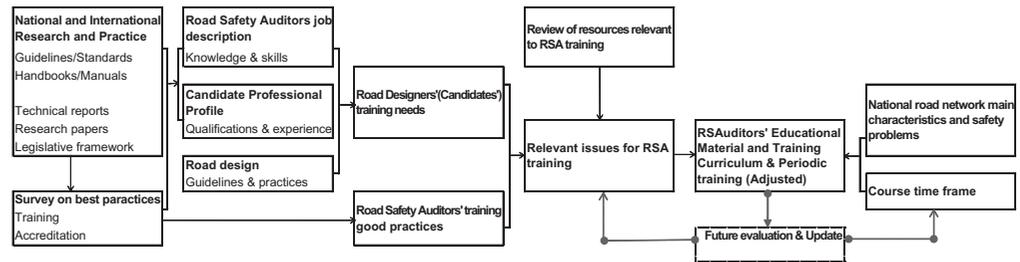
The proposed training course was developed on the basis of (a) the objectives, principles, process and scope of RSAs and duties of road safety auditors; (b) the area of expertise and the knowledge framework of the auditors, in accordance with international practice and research; (c) the provisions of the institutional framework regarding the qualifications, prerequisites and training of road safety auditors; and (d) good practice from leading countries in terms of road safety auditing.

Figure 1 depicts a diagrammatic representation of the methodology and the process for the development of the Greek road safety audit training course and the educational material.

Table 1. Key topics covered in RSA training courses in European countries participating in the survey

	DE	NL	IT	PT	SI	HU	CZ	SE
Road safety audit process	▪	▪	▪	▪	▪	▪	▪	▪
Safety management and regulatory framework	▪	▪	▪	▪	▪	▪	▪	▪
Human factors in road design	▪	▪			▪	▪	▪	▪
Safe System approach		▪		▪	▪	▪	▪	▪
Road design/Design standards	▪		▪			▪	▪	
Accident analysis countermeasures	▪		▪		▪	▪	▪	▪

Figure 1. Methodology for the development of the road safety audit training course and the educational material.



The content of the educational material and the related course topics were formulated to meet the following requirements:

- To reflect the role and job description of road safety auditors.
- To be adapted to candidates' professional profiles regarding their knowledge background and skills, especially regarding their formal education and the way they practice their profession (e.g. use of guidelines).
- To cover modern international scientific literature and practice, in line with good European training practices for road safety auditors as revealed by the results of the questionnaire survey (Table 1).
- To be the components of the training curriculum (i.e. institutional framework of road safety management; road safety audits; human factors; identification and improvement of hazardous locations; review of existing design guidelines; signing; roadside safety; vehicle restraint systems) that must work together as a combined unit delivered within a certain time, i.e. approximately 30 h (the hours of individual preparation are not included).
- To enhance workforce understanding and application of traffic safety culture and a commitment to road safety, placing emphasis on the implementation of the principles of the Safe System approach and human factors in road design.
- To be effectively delivered.

3.2. Road safety auditors job description

In RSAs, emphasis is placed on the proactive assessment of hazards or hazardous situations that might increase crash risk if they are left untreated. A road safety audit is not a check of compliance with the design guidelines and is not a substitute for design checks. RSAs aim at improving safety for all, and in particular, vulnerable road users. Importantly, auditors should see things from the perspective of all users, especially those who are most at risk (IHT [The Institution of Highways & Transportation], 2008; DfT [Department for Transport] 2015).

The implementation of a road safety audit from the initial stages of road design is an opportunity to support safe user behaviour by design, ensuring safer road design adjusted to road user characteristics.

During the evaluation of a road design or the inspection of an existing road, the road safety auditor should address the following issues (IHT [The Institution of Highways & Transportation], 2008):

- Who might be injured in an accident on the specific section of road, and why? How might this happen?
- What types of accidents/collisions might occur?
- How might the likelihood of an accident be reduced or its consequences mitigated?

These questions should be answered by professionals with experience in road safety engineering and collision investigation and good background knowledge of highway and traffic engineering (Austrroads2009; IHT [The Institution of Highways & Transportation], 2008).

3.3. Road safety auditor skills

The road safety auditor is a trained professional engineer who evaluates the design of the road (conducted by another engineer) with the main criterion being the safety of all road users.

For the development of the training course, the following requirements related to road safety auditors (Austrroads, 2009; IHT [The Institution of Highways & Transportation], 2008; DfT [Department for Transport] 2015; FHWA [Federal Highway Administration], 2006; Belcher, Proctor, & Cook, 2015) have been taken into account:

- (1) Professional experience. Professional experience and knowledge in the area of road safety engineering and accident analysis and thorough understanding of safety principles and human factors in road systems. Up-to-date knowledge and experience regarding the RSA process while having experience in other areas of road safety engineering as well.
- (2) Road safety culture. Road safety auditors must be characterised by self-criticism and positive road safety attitudes that determine their behaviour and ability to investigate the road project in depth and in detail.
- (3) Independence. Auditors cannot conduct RSAs on designs in which they have participated.
- (4) Training. Road safety auditors need training that complements experience in road safety engineering and road safety auditing, and contributes to the development of the desired knowledge and skills. In addition, periodic re-training is essential for auditors to stay up to date with modern practices in accident investigation and recent research in road safety engineering, including issues from the point of view of driver behaviour, as well as the latest technological developments in addressing the resulting risks to road users.
- (5) Other skills. Road safety auditors should have good knowledge of the design guidelines and control data, and also be capable of: preparing clear concise reports; forming a clear picture of the on-site project from the design drawings and from the point of view of all road users; understanding complex layouts and paying attention to detail; assessing the likely frequency and severity of crashes and errors resulting from localised risk factors; discussing and defending their point of view in a constructive and consensus-seeking way, without being arrogant, overbearing or intolerant; examining innovative solutions.

3.4. Directions for training as laid down in the institutional framework

As stated in the EU Directive (EC [European Commission], 2008), the initial training “*should ensure that practitioners get the necessary up-to-date knowledge*” and “*that where road safety auditors carry out functions under this Directive, they undergo an initial training resulting in the award of a certificate of competence, and take part in periodic further training courses.*”

The provisions of the European (EC [European Commission], 2008) and Greek institutional framework (GGGR [Government Gazette of theGreekRepublic], 2011; GGGR [Government Gazette of the Greek Republic], 2012), and the relevant manuals and guidelines emphasise the importance of new and up-to-date knowledge. Auditors should therefore keep abreast of the latest developments in road safety research, road design, and issues concerning the human factor (Austrroads, 2009; IHT [The Institution of Highways & Transportation], 2008; DfT 2015; FHWA [Federal Highway Administration], 2006).

According to the legal framework (GGGR [Government Gazetteof theGreekRepublic], 2011, GGGR [Government Gazette of the Greek Republic], 2012) and guidelines for road infrastructure safety management in Greece, candidate auditors must have the necessary qualifications in terms of formal education and experience, i.e. they must be Civil Engineers or Rural and Surveying Engineers

(disciplines related to the qualifications requirement for background and experience in road safety engineering) with at least 5 years' experience in design, road safety engineering, and accident analysis. After successfully completing an appropriate training course and examination, candidate auditors will be able to conduct RSAs. The minimum requirements needed to gain accreditation as a Road Safety Auditor and a Senior Road Safety Auditor are presented in Appendix 2.

3.5. Extent of training topics

The extent of the training topics was largely based on the available time frame. In this regard, the emphasis was placed on specific characteristics and safety problems of the Greek road network (NTUA, 2011), such as the low-maintenance level of the network, roads serving multiple functions with coexistence of different operational and design characteristics, poor speed management, and the presence of work zones on an extensive part of the Trans-European Road Network. A future extension of the duration of the course (if deemed necessary, e.g. as a result of course evaluation) may result in the expansion of the topics in order to include more roadway design, and operational and risk management issues.

Course topics and educational material should aid and augment the judgement and complement the experience of highway designers and traffic engineers through presentation of relevant information and insights from the scientific literature. For example, human factors principles and concepts for the training of candidate auditors were based on a review of available modern guides, publications, and references that reflect the current trends of a holistic and anthropocentric approach to road safety (Kanellaidis & Vardaki, 2011; Larsson & Tingvall, 2013).

Until now, experienced roadway and traffic engineers have been educated in the context of traditional road design courses and road design guidelines (Gross & Jovanis, 2008). The road and roadside infrastructure design guidelines were developed several years ago and do not include discussion of concepts that reflect the new holistic and anthropocentric approach to road safety which, in turn, imposes requirements on the qualifications of civil and surveying engineers (Angelides & Loukogeorgaki, 2005).

The fact that the course is designed and is expected to be implemented by academics, as well as professionals/field experts with expertise in road safety, road design, human factors, and hands-on experience in road safety auditing is likely to be crucial for its effective delivery.

4. Framework of training course

4.1. Purpose

Road safety auditors (as defined internationally) are trained professional engineers specialising in road safety engineering issues who understand the mechanisms of road accidents, know how to deal with them, and are thus able to carry out road safety audits. The proposed training course has been designed so that an experienced engineer can be brought up to date with the latest developments in road safety research, road design and human factor concerns. During the process of its configuration, good training practices found in EU Member States were also considered (Table 1). The concept behind the Greek training RSA programme is in agreement with current trends in the field of road safety as expressed by international platforms, such as the International Road Federation and World Road Association, which play a vital role in the exchange of knowledge and techniques. IRF's continuing education programmes (IRF [International Road Federation], 2018), including training courses on Road Safety Audits and accreditation programmes for senior auditors, and PIARC's deliverables, e.g. technical reports, manuals, seminars (PIARC [World Road Association], 2017; PIARC [World Road Association], 2015), promote the new thinking in road safety, i.e. the implementation of the Safe System and the application of human factors principles.

The project aimed to deliver original educational material that will be appropriate for training professionals with experience in road design and road safety. The educational material will be given to the trainees as a 300-page manual.

The safety principles considered in the development of the training curriculum and educational materials result from the modern international scientific literature and practice in the field of road safety engineering.

The design of the road and the road environment in accordance with these safety principles is different to a design that merely follows the formal design guidelines, e.g. AASHTO design guidelines (AASHTO (American Association of State Highway and Transportation Officials), 2011a) or AASHTO guidelines for achieving flexibility in highways (AASHTO 2011b), and involves compliance with control design values (Austroads, 2015, 2009; Belcher et al., 2015; IHT [The Institution of Highways & Transportation], 2008; Kanellaidis, 1999; Professional Engineers Ontario, 1997).

For the enrolment in the RSA course, emphasis is put on the prerequisite of experience in road safety engineering (GGGR [Government Gazette of the Greek Republic], 2011, GGGR [Government Gazette of the Greek Republic], 2012; Austroads, 2009; IHT [The Institution of Highways & Transportation], 2008; Belcher et al., 2015). Road safety engineering aims at creating a road and traffic environment that informs, guides, warns and controls road users and at the same time is “forgiving” of their errors. It should be noted that there is no substitute for the application of sound road safety engineering experience and judgement, which form the basis of safety principles (Austroads, 2009, 2015; Kanellaidis & Vardaki, 2011; Professional Engineers Ontario, 1997).

The training curriculum addresses specific learning outcomes in terms of the knowledge, skills and competence of the candidate road safety auditor. Due to the time frame of the course, the course topics and the educational material do not cover all issues relevant to RSA training in detail. Provision has been made for candidates to be made aware of guides, publications and references providing more detail on issues, such as human factors in the design and operation of road systems, vulnerable road users, crash risk assessment and management, as well as hazard management approaches (e.g. AASHTO [American Association of State Highway and Transportation Officials], 2010; Campbell et al., 2012; Brewer, Murillo, & Pate, 2014; Austroads, 2008; Austroads, 2009; Austroads, 2010; Austroads, 2012; Austroads, 2014; Austroads, 2015).

Candidates will be informed about existing databases of effective road safety measures, as well as tools to identify hazardous locations. When carrying out an RSA, auditors should base their comments on sound engineering safety experience. They should use their critical judgement to determine who is most at risk and suggest an improvement that has previously been demonstrated to be effective based largely on available/relevant control data, and also on role-played safety needs of each road user in relation to likely conflicts. Candidates are advised that when they use control data for problem identification and recommendation they should consider whether these data are relevant to the particular scheme (IHT [The Institution of Highways & Transportation], 2008; Belcher et al., 2015). Furthermore, they will have group discussions on quantitative approaches that may support road safety management decisions. Praticò, Catalfamo, and Lanciano (2016) propose such a quantitative method for assessing the safety level of a road/road section, as well as for ranking of road sections based on their characteristics.

4.2. Structure

The Greek road safety audit training course consists of two parts: theoretical and practical. The theoretical part includes three main sections: road safety policy and the institutional framework (Section 1), road safety audit issues (Section 2), and road safety engineering (Section 3). The practical part involves RSA training and examination. Since successful performance in the

examination results in the acquisition of a certificate of competence, applicants will be tested on their technical ability to apply knowledge and skills in conducting RSAs.

A key feature of the training process is its dynamic character, since besides the lectures and presentations of the different topics by trainers, provision is also made for the active participation of trainees in terms of collaboration, discussion, exchange of knowledge and experiences, etc.

4.3. Learning outcomes

A set of learning outcomes has been specified for each section/subsection. These learning outcomes represent the knowledge, skills and competences that candidates with sound road safety engineering experience should acquire through their participation in the training course for the award of a certificate of competence; they also allow the evaluation (on the basis of expert judgement) of the extent to which the candidates have achieved them. During the course, candidates will be presented with examples of RSA implementation in all design stages, as well as on existing roads using real examples. In the practical part, the course will include case studies and site visit(s), where the participants will have the chance to be trained in the field and apply in practice what they have been taught in the classroom. The certification of competence is awarded to candidates who prove their knowledge, understanding and ability to undertake a road safety audit at any stage.

4.3.1. Section 1: Road Safety Policy and Institutional Framework

Candidates will become aware of issues of strategic road safety planning and regulatory framework for road safety management (such as ISO 39001:2012 (<https://www.iso.org/standard/44958.html>)); they will also have an understanding of the Safe System approach as the basis of a national road safety strategy.

4.3.2. Section 2: Road Safety Audit Issues

Candidates will understand what a road safety audit is and the benefits associated with RSAs. They will have an understanding of the requirements associated with road safety audit procedures (phases); they will understand the RSA process, objectives and tasks, and will be able to apply methods associated with the road safety audit at any design stage of a project. They will understand auditing principles, roles and responsibilities; the relationship of road safety audit and design standards; how to identify safety problems; the use of checklists; and how to structure an RSA report. Candidates are expected to understand the benefits of conducting audits in the early design stages of a project. Candidates are also expected to understand the essential difference between inspection as part of regular maintenance practice and the road safety audit of an existing road; the differences and complexities of auditing project(s) at different design stages or theme Audits (RSA that focus on specific road users, e.g. pedestrians, cyclist, motorcyclist, heavy vehicles, etc.), or issues (e.g. land use planning audits) which guide the selection of the audit team members (in terms of expertise and/or experience); and the importance of the audit brief for an effective audit (project scope, details and history). They will be expected to assess the level of risk associated with an identified problem, as well as the treatment approach. Moreover, they will be expected to know how to make realistic and constructive recommendations.

4.3.3. Section 3: Road Safety Engineering

4.3.3.1. Identification and improvement of hazardous locations. Candidates will understand and apply various methods for accident analysis and investigation techniques. They will know how to identify risk using crash data; how to select appropriate road safety remedial measures and monitor the effectiveness of measures. They will be aware of factors associated with each type of accident and the contribution of road design elements to risk (Camacho-Torregrosa, Pérez-Zuriaga, Campoy-Ungría, & García-García, 2013); criteria for the selection of measures (Park & Abdel-Aty, 2017); measures with proved effectiveness for each type of road and type of accident; and the effect of different infrastructure treatments on safety outcomes. Furthermore, they will be aware of how to apply road safety impact assessment and the use of crash modification factors.

4.3.3.2. *Human factors in safe road design.* Candidates will understand the requirements for the implementation of the safety principles of the Safe System approach in relation to roads, vehicles and road users. They will understand how to apply human factors principles in designing roadway elements, such as curves, intersections, interchanges, work zones and rural-urban transitions (Charlton et al., 2010) and traffic engineering elements (signing, markings); and how to apply positive guidance principles in a road safety audit. They will have an understanding of the driving task, the needs, capabilities, and limitations of road users and how they operate in the driving environment (Bella & Silvestri, 2015). They will understand how the design influences driving behaviour and how the environment contributes to driver errors and collisions; how to apply task analysis and the effects of demands imposed on drivers by the driving environment; individual differences, such as age; how to consider the needs of vulnerable road users in design; and how design consistency affects driver expectations, which in turn influence driving behaviour (including speed selection).

4.3.3.3. *Road safety, road design and design guidelines.* Candidates will become aware of the current road design principles and guidelines (Easa, 2017; Mollashahi, Khajavi, & Ghaeini, 2017); they will have an understanding of important issues of road design, e.g. sight distance, horizontal alignment, cross section, vertical alignment, 3-D road design and road surface operational characteristics, such as friction and evenness; they will understand and apply safety principles in road design. They will also be aware of issues regarding functionality and categorisation of roads (Mackie, Charlton, Baas, & Villasenor, 2013); they will know how to identify and deal with problems associated with transit through roads in built up areas (Moreno & García, 2013),

4.3.3.4. *Road safety and signing.* Candidates will be aware of key elements in signing. They will understand and apply safety principles in signing, including work zone signing (Lyu, Lin, Wang, & Yang, 2017).

4.3.3.5. *Roadside hazard management and vehicle restraint systems.* Candidates will be acquainted with key terminology of the EN1317 standard (<http://www.rrs.erf.be/index.php/en-1317>), e.g. containment level, impact severity, working width, and performance classes; they will be aware of issues resulting from the mandatory application of EN1317. Candidates will be acquainted with the key elements to be considered for identification, prioritisation and treatment of roadside hazards (providing forgiving roadsides, effective selection and placement of safety barriers). They will understand which parameters are the basis for decision-making on the use of road restraint systems and on which properties/performance parameters of road restraint systems the choice of the appropriate system is based.

4.3.3.6. *RSA applications.* Candidates will assimilate the theoretical knowledge and obtain initial experience in conducting RSAs.

4.4. Content of the theoretical part

Based on the desired learning outcomes, the proposed theoretical part of the training course (HIT, 2015), which is 20 h' duration, includes the following sections and subsections:

Section 1: Road safety policy and institutional framework (2 h)

Subsection 1.1: Road safety policy in Greece and worldwide

Subsection 1.2: Institutional framework for road safety management in Greece

Subsection 1.3: Good European practices for road safety management

Subsection 1.4: Introduction to ISO 39,001:2012

Section 2: Road safety audit issues (2 h)

- Road safety audit process
- Preparation of a road safety audit report

- RSA roles and responsibilities
- RSA team membership
- Differentiating road safety audits (audit in design stages, on existing roads, on work zones, related to particular road user groups)

Section 3: Road safety engineering (16 h)

Subsection 3.1: Identification and improvement of hazardous locations

Subsection 3.2: Safety by design

- Definition and analysis of the Safe System approach; Safe System principles and human factors in safe road design
- Road safety, road design and critical analysis of the design guidelines and safety practices in Greece
- Road safety and road signing
- Roadside hazard management and vehicle restraint systems

4.5. Content of the practical part

The practical part of the training course includes RSA case studies. Eight hours are devoted to case studies on the following:

- RSA case studies at various stages of the project (preliminary design, detailed design, pre-operation) and road safety inspection on an existing road. At this point, organisational issues related to RSA are also tackled (discussion, individual preparation)
- On-site visits and study of material (individual preparation)
- RSA findings and writing of report (individual participation)
- Individual/group presentation of RSA findings.

The above applications cover the RSA procedure from its start to the presentation of the findings and will contribute to the assimilation of theoretical knowledge and the acquisition of initial experience in conducting RSAs.

The practical part will also cover key features of successful RSAs, as well as lessons learned from the application of RSAs in Greece so far.

4.6. Assessment

An effective performance in the examination process by a candidate with the necessary qualifications in terms of formal education and experience will lead to a certificate of competence. Candidates will be examined on their technical ability to perform as road safety auditors. Once this last process has been successfully completed, the candidate will become a certified auditor.

During the examination process (Appendix 3), the performance of the candidates will be taken into account in terms of the following:

- Knowledge of the curriculum
- Conducting RSAs

Candidates who pass the exam will have demonstrated competence to perform road safety audits. The necessary competence in each skill area/domain per subject, as well as the exact examination process will be determined by experts (academics, as well as professionals/field experts) and outlined in the exam blueprint. Specifically, successful candidates are expected:

- to answer a sufficient number of test questions correctly, demonstrating at least a minimum level of knowledge and skills in each subject as laid down by experts. The test questions of the theoretical examination will measure the acquired knowledge and skills and assess them in relation to the expected candidate learning outcomes. They will cover all topics/skill areas but their contribution to the total score will reflect the importance/criticality of the measured skills as outlined by the exam blueprint.
- to conduct an RSA demonstrating a sufficient level of knowledge and skills based on the engineering judgement of experts (academics and field professionals).

4.7. Periodic training course

Continuing education of road safety auditors aims at the exchange of knowledge and experience in addressing road safety concerns (whether common, more particular, or exceptional cases), as well as procedural issues (collaboration with main contractors, the competent authorities and designers). Furthermore, a periodic training course provides an opportunity for interaction between professionals and thus it is considered important in delivering improved designs, as well as updating the design guidelines.

The validity period of the certificate of competence in Greece is 3 years. Road safety auditors are required to undertake a refresher course and participate in at least one road safety audit to retain their accreditation (GGGR [Government Gazette of the Greek Republic], 2012). The one-day periodic training course covers the following issues:

- New developments in design guidelines (self-explaining roads, functionality of the road network, recognisability of roads, design classes)
- Roundabouts
- RSAs on urban roads
- RSAs on motorways at the design stage
- RSAs in work zones
- Specific issues/Experience exchange (organised)

5. Conclusions

The training course presented in this paper, which involves both initial and periodic training of road safety auditors, is the first systematic effort in Greece for the training and certification of engineers according to the guidelines set by the European and national legal framework.

The proposed training course reflects the objectives of road safety auditing, principles of road safety engineering, as well as duties of road safety auditors and their area of expertise according to international research, practice and legislation. Furthermore, its structure (i.e. theoretical and practical parts, written exams) and key topics (road safety audit process, institutional/regulatory framework, human factors in road design, road infrastructure safety management, road safety impact assessment, Safe System and self-explaining roads, accident analysis and countermeasures) are in line with good road safety audit training practices as established by the questionnaire survey. The process of its development can be viewed as a proposal for good practice that can be applied to professional development training programmes after the necessary modifications to fit the specific training purpose.

The training course, which leads to the certification of competency of candidate auditors, takes into consideration recent developments in road safety, as well as local conditions and needs in terms of road safety level, road design guidelines and road safety practices. Upon completion of the course, candidates are expected to be able to apply accident investigation techniques, human factors and safety principles in road design, to undertake a road safety audit, and to identify the potential for collisions or a safety problem and propose appropriate remedial measures.

A Safe System approach is central to the training curriculum. Candidate road safety auditors are expected to understand Safe System principles and the need to apply them in road design. Implementation of Safe System principles is integrated throughout the course and the educational material.

Other qualities of the course include positive guidance principles and approach; a critical analysis of road safety practices and design guidelines in Greece; discussion of challenges to providing positive guidance identified in work zones in operation; recommendations to mitigate these challenges; and the human factors section that includes implementation issues of human factors in road design and traffic engineering, which actually represent a new area of knowledge for highway and traffic engineers in Greece.

In the RSA training course, emphasis is placed on key features of successful implementation of RSAs and lessons learned from the implementation of RSAs so far. The Greek road safety audit training course and educational material include examples of road safety audits on the national road network, i.e., problems identified, as well as challenges in implementing RSA recommendations (Vardaki, Papadimitriou, & Kopelias, 2014). The inclusion of a practice session in the course provides the opportunity for candidates to link theoretical knowledge acquired in the course with practical skills. We expect successful outcomes from team teaching (Kim, Jackson, & Keiller, 2016), i.e. educators being academics, as well as field experts with hands-on experience who can contribute to training that promotes ready-to-use knowledge in the areas of RSA and human factors and eventually in achieving the learning outcomes (Vardaki et al., 2016). Through such training, candidates may increase their professional potential and employability, assets that are particularly important to those willing to work abroad in times of economic uncertainty (Lambropoulos, Pantouvakis, & Marinelli, 2014).

Road safety audit training is not a static process. Improvement of road and traffic engineer practices requires training that keeps pace with changes in the science of road safety, as well as changes in the professionals' background. The course is expected to be reviewed regularly in the light of new information, research and developments in the area (such as the effectiveness of RSAs undertaken by certified auditors), and also on the basis of the trainees' and the trainer's course evaluation, (e.g. in regard to duration and/or content). The topics of both the training course and the educational material are expected to be updated in order to supplement basic knowledge by broadening the subjects and/or adding detailed information on specific aspects of road design or system development, and to include lessons learned from the experience in road safety audit implementation.

Examining the extent to which highway designers accept the application of the RSA to their design is crucial for the successful implementation of the process in a country. In their research on attitudes of Greek highway designers to the RSA, Karantanos and Vardaki (2013) found that highway designers in Greece had a positive attitude towards the RSA process and they explicitly recognised their own share of responsibility for road safety problems. Nonetheless, almost 50% of the designers agreed with the prevalent view, according to which "*compliance with standards equals a safe design*". The authors (Karananos & Vardaki, 2013) stressed in their discussion that this result was revealing of the need for further education and training on road safety issues

The safety provided by a road design depends on the extent to which it allows road users to make good decisions. Experienced road designers may understand that design is not the application of specific dimensions for road features, but is actually a process that involves using their judgement to combine design elements with the aim of providing a high level of safety performance. Beyond being a prerequisite for accreditation of road safety auditors, the training course may be an important tool for professional development, augmenting the engineering judgement and experience that already play a significant role in a successful road design. As far as road safety auditing is concerned, other necessary assets are the ability to exercise self-criticism, independent evaluation, in-depth investigation and great attention to every detail in order to define hazards that might have been ignored or not

noticed (Austrroads, 2009; Professional Engineers Ontario, 1997). Training should assist them to develop these essential assets for their profession. Due to the emphasis placed on the implementation of Safe System principles and human factors in road design, the Greek road safety audit training course and educational material may contribute to the development of a positive safety culture among highway professionals involved in the road design and road operation process, and among highway engineers in the public sector (ministries, regional and local authorities) (Austrroads, 2009; Kanellaidis & Vardaki, 2011; TZD [Toward Zero Deaths: A National Strategy on Highway Safety], 2014). The training process for candidate auditors must strengthen the belief that road safety is everyone's responsibility and the common duty is to ensure that safety is an integral part of all choices/decisions that affect the road infrastructure system. Appropriate training is essential for successful road safety audits and in turn could be a catalyst for improving other road design projects and design guides. Importantly, it should enable road designers and managers to be aware of and attentive to latent conditions that result in failures, and to be able to build defences to avert these failures or mitigate their effects. With trained personnel in private and public organisations, as well as trained freelance highway designers with a positive safety culture, safety can be made inherent to the decision-making process, thus positively affecting road system safety in all phases of design and operation.

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Conflict of interest

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Appendix 1. Selected data on good RSA training practices in European countries

Initial Training and Certification for Road Safety Auditors

As part of the questionnaire survey, information regarding the content of the training programme for candidate road safety auditors was collected. The longest programmes in terms of duration, with a relatively broad range of issues, are provided in Germany, Italy and Hungary.

The majority of these programmes deal with the institutional framework, i.e. EU and national legislation (Italy, the Czech Republic, Portugal, the Netherlands, Germany and Sweden), human factors (Slovenia, Hungary, the Netherlands, the Czech Republic and Germany), road infrastructure safety management (the Czech Republic, Slovenia, Hungary, Italy and Sweden), as well as road safety impact assessment (Slovenia and Hungary). Furthermore, contemporary approaches to addressing road safety are also covered, namely the Safe System and self-explaining roads (Austroads, 2009), (Theeuwes et al., 2012), (the Netherlands, the Czech Republic, Sweden, Portugal, Slovenia and Hungary), as well as accident analysis (the Czech Republic, Sweden, Hungary and Germany). Key topics covered in RSA training courses of European countries according to the survey responses are presented in Table 1.

Regarding the duration of the programmes, significant variation can be found. In most cases, the length ranges from 3 to 8 days, or 24 to 48 h, except in Italy, where the training programme lasts 180 h. In Germany, the duration is 7–11 days in classes plus extra hours of individual preparation. In Hungary, the training hours are spread over a 3-month period, while in Slovenia the test is performed 2 weeks after completion of the programme. Australian training programmes have a duration of 2–3 days.

Most countries (Germany, the Netherlands, Hungary, Sweden and Italy) state clearly that the successful completion of the RSA training procedure is usually evaluated through written exams. Reference is also made to practical exercises (Portugal, Australia and Hungary), oral examination (Italy), as well as examination on RSA issues at the final stage of road design. In

Australia, depending on the state, the evaluation varies between exercises during the programme and presentation of inspection findings in a group of participants, or a combination of the two.

The minimum requirements for certification to conduct RSAs in the European countries surveyed are:

- Qualifications: Civil engineers or traffic engineers or those with a background in technical or natural sciences (Sweden) with expertise in road safety and design. In Portugal, auditors must be registered with a professional chamber.
- Experience: Mainly in road design, road safety engineering and accident analysis. In most countries, the minimum period is 5 years, with the exception of Slovenia (10 years) and Portugal (3 years).
- Successful completion of the training programme.

The first two requirements are usually a precondition for participating in a training programme.

In Australia, all accredited road safety auditors need to have successfully completed an RSA training course, have generally had a pre-set number of years of professional experience (although some states may not have this requirement), and have been part of an RSA team for a specified number of audits.

The training bodies vary. They are often universities (Italy), research institutes (Portugal, Hungary, the Czech Republic), professional organisations (Switzerland, Hungary) or private firms (the Netherlands, Sweden). In Australia, depending on the state, RSA training is offered by members of the competent authority, universities, research institutes (e.g. Australian Road Research Board, ARRB) or recognised consultancy firms. In every case, the competent authorities (ministries) in European countries and Australia are responsible for approving the training programmes. Ministries are training providers in Italy, Switzerland, Slovenia and the Netherlands.

Regarding the roles and responsibilities of bodies involved in the training and certification of candidate auditors, in most cases (70%) training bodies also provide certificates of competence (Germany), in collaboration (Switzerland) or after authorisation by the competent authority/ministry (Australia, Italy). The competent authorities are responsible for the inspection/supervision and approval of the evaluation and certification process. In Portugal, Sweden and the Netherlands, the certificate is given by the competent ministry/authority.

The certificate of competence (in most of the countries that responded to the relevant question) is valid for a certain time period, namely: 3 years in the Netherlands, Portugal, Slovenia, Italy and the Czech Republic, 5 years in Hungary and 1 year in Australia. In Switzerland, the relevant validity period is indefinite and Sweden has not set a specific time period. It should also be noted that in four countries (the Netherlands, Germany, the Czech Republic and Australia) the certificates of competence to conduct RSAs issued in other states are not valid. By contrast, these certificates are valid in Slovenia, while in Portugal and Sweden, specific additional conditions are set in relation to the profession and experience of the auditor.

Periodic Training and Maintenance of Competence for Road Safety Auditors

In European Directive 96/2008/EC (EC [European Commission], 2008), it is stated that road safety auditors, after being awarded the certificate of competence, should participate in further periodic training courses (e.g. participation in shorter educational courses). The conditions for maintaining the competence to conduct RSAs vary in the countries that took part in the questionnaire survey. In general, this is associated with periodic training.

Regarding the content of periodic training courses, the survey revealed that in all countries that took part, emphasis is placed on new advances in the institutional framework, in

regulations and in road design. Furthermore, innovations in RSA, road safety management (Italy, Slovenia) and road safety measures (Italy) are presented, as well as relevant experience from European states (Slovenia), national and European directives and guidelines (Slovenia), special issues and specific design cases, e.g. roundabouts, pedestrian safety (Hungary), case studies prepared by the participants (Hungary), examples of road safety improvement measures (Slovenia) and workshops (Hungary and Slovenia). A key element of training is the exchange of experiences, as well as the interactive training process with the involvement of auditors in discussions and workshops (the Netherlands, Germany, Hungary and Slovenia). In Hungary, there is RSA “simulation”: a role-playing game where the auditor, the client and the designer express their arguments regarding the RSA proposals.

Appendix 2.

The minimum requirements needed to gain accreditation as a Road Safety Auditor and a Senior Road Safety Auditor are as follows:

A Road Safety Auditor is required to:

- have been awarded a certificate of competence following a successful undertaking of a road safety audit training programme,
- have had a minimum of 5 years professional experience in road design, road safety engineering and accident analysis.

In order to retain accreditation, a Road Safety Auditor is required to have undertaken a refresher course.

A Senior Road Safety Auditor is required to:

- have been awarded a “certificate of competence” following the successful undertaking of a road safety audit training programme,
- have a minimum of 8 years of experience in road design, road safety engineering and accident analysis, 8 years since the acquisition of university degree,
- have participated in at least two Road Safety Audits within the validity period of the last certificate of competence (3 years) and have successfully completed a minimum of one training course,
- have undertaken a refresher course approved by the Ministry.

Appendix 3. Examination of candidate Road Safety Auditors

The examination will start with a knowledge test. The planned duration of the knowledge test is 2 h. The second part of the exam will include a road safety audit on a project at the design stage and an RSA on an existing road section or intersection/interchange.

The performance in the examination will be successful if the candidate receives a score of $n_t \geq 60/100$ in the theoretical and $n_p \geq 60/100$ in the practical examination. The final grade is determined by the following formula:

$$N = 0.50 n_t + 0.50 n_p$$

Where

n_t = score in theoretical examination (knowledge test)

n_p = score in practical examination

N = final grade



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