D6.1 Training, education and awareness needs for VRU/URU safety in evolving mixed automated traffic

Primary Author(s)	Marilee M. Nugent | UNIFI

Related Work Package	WP6
Version/Status	1.1 | Final version
Issue date	30/11/2021
Deliverable type	**R**
Dissemination Level	**PU**

Project Acronym	SAFE-UP
Project Title	proactive SAFEty systems and tools for a constantly UPgrading road environment
Project Website	www.safeup.eu
Project Coordinator	Núria Parera | Applus IDIADA
Grant Agreement No.	861570

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

Document Distribution

Version	Date	Distributed to
1.0	29/11/2021	Coordination Team
1.1	30/11/2021	Submission in the EC System
1.1	17/03/ 2022	Approved by the EC

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

Copyright statement

Acknowledgements

We thank all SAFE-UP project partners, especially the T2.1 team, for supporting the work that led to this document. Special thanks go to Eleni Chalkia of CERTH and WP6 leader Niccolò Baldanzini for valuable contributions and unwavering support. Special thanks to Task 2.1 leader András Bálint for ongoing support and expert input for WP6 activities and for involving us in T2.1 update meetings. In addition to Andràs, many thanks also to Arturo Tejada Ruis, Volker Labenski, Ganesh Baroda Sudhakaran, Markus Koebe, Daniel Weihmayr, Leon Tolkskorf for their technical support and helpful discussions on technical aspects and T2.1 results.

Heartfelt thanks go to members of the ad hoc Safety Partner Network and members of the SAFE-UP Advisory board, Johanna Tzanidaki of ERTICO and Pedro Homem de Gouveia of POLIS for their specialist input and advice which have been critical to helping shape this document.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

Executive summary

The aim of SAFE-UP is to proactively address new road safety challenges that are expected to accompany the increasing penetration of vehicles with automated emergency and driving functions into the traffic context. New risks may emerge from changes in the interactions between vehicles and unprotected (a.k.a. vulnerable) road users (URUs). Traffic participants may need to adopt new behaviours, learn to watch out for new hazards, or exchange new cues to communicate each other's intentions. Understanding of these new situations and awareness of possible risks is important for all road users but especially with regard to keeping URUs safe while walking, pedalling a bike, pushing a wheelchair or riding a motorcycle or scooter. Operators of vehicles with automated driving and safety functions may need to acquire new competencies to ensure the systems and vehicles are used safely and for the purposes and situations for which they are designed. The role of Work Package 6 is to complement the work of SAFE-UP's technological work packages, in providing schemes for updateable Training, Educational and Awareness raising (TE&A) strategies and programs to ensure future safety for URUs as autonomous vehicle (AV) technology matures, and the traffic context continues to evolve.

This deliverable reports on the work performed in Task 6.1 *Training needs, requirements, scenarios and KPIs* to define target audiences, learning and awareness objectives and the specific needs of Knowledge Users (KUs) and road users to guide development of the strategies and materials that will be developed in T6.2 *Training & Educational programme development*. These results also inform T6.3 *Knowledge Translation, outreach and raising awareness* and set the basis for T6.4 *Evaluation of training programme and material*.

This report describes our approach to addressing TE&A to promote URU safety in future mixed automated traffic, being based on SAFE-UP results including car driver-to-URU interactions in current and future safety-critical scenarios (SCS), and expected benefits and limitations of active and connected safety systems. The approach includes a survey of trends, literature, examples, public reports, roadmaps for future mobility, driver and road user awareness and education. To support these activities, development of a Safety Partner Network (SPN) of external URU advocacy groups, future mobility and road safety stakeholders was initiated, as part of T6.3 activities. This initiative follows evidence-based best practice guidelines in planning for research impact, of which effective stakeholder engagement to aid tailoring and interpretation of results for target audiences is an essential part.

The approach outlined in this deliverable was to adapt two existing models to the realm of road safety innovation – Knowledge Translation (KT) as a best practice in planning pathways to research impact, and Constructive Alignment in educational design, from higher education research (described in detail in section 3.4 *Framework for the design of training & educational programs for future road safety)*. Within WP6 these two frameworks are nested, with outcomes from the KT process feeding into and supporting the TE&A activities. KT is the overarching methodology applied in T6.3 and has been used to support and guide Task 6.1 and will continue to support Tasks 6.2 to 6.4. The KT methodology will be reported on in detail in the forthcoming deliverable D6.2 *Knowledge Translation, outreach, safety*

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

awareness covering T6.3 activities. Final outcomes for TE&A will be reported in the second deliverable for T6.3, and evaluations on training and educational programs and materials will be reported in the deliverable for T6.4.

The outcomes of T6.1 activities are an initial set of targets, determined from project results on SCS, emerging from WP2 activities, informed by concerns of URU advocacy groups on how the problem of road safety should be addressed, and taking note of current paradigms and practice examples for promoting road safety and strategies to achieve the EU's Vision of Zero fatalities and serious injuries due to road crashed by 2050. To address acceptability, relevance and usability of the materials and programs that will result, a set of guidelines regarding needs of URU groups have been defined. In defining these targets, Translating SAFE-UP results into TE&A objectives"needs" for TE&A have been conceptualized broadly, resulting in the themes of

1) Identified safety information themes (SAFE-UP outcomes contextualised in current traffic safety knowledge),
2) Concerns and perspectives of URU advocacy and interest groups,
3) Training & educational design requirements to achieve objectives of improved safety.

In addition, audiences for targeted knowledge dissemination have been considered broadly and in two tiers: *Tier 1* being at a high hierarchical level – organizations positioned to contribute to identification of TE&A priorities and development and dissemination of tailored strategies (Safety Partner Network), and *Tier 2* including road users themselves but also educators, policy makers, planners, etc., whose activities carry the potential to translate SAFE-UP results into system-level changes.

Inputs collected from the Safety Partner Network are presented in section 4.1.1 *Stakeholder responses to SAFE-UP proposed safety innovations and TE&A aims*. The extended consultations conducted with the Safety Partner Network led to a set of concerns and issues for URUs regarding future traffic and safety in general, and in particular with regard to the application of URUs' smart devices for CITS. Key points raised included concerns for how proposed AV systems will possibly infringe on personal freedoms, provide advantages for certain segments of road users while creating additional risks or burdens for others, shifting of liability to the victim, hampering the goals of increasing active mode use and decreasing the proportion of passenger cars in pedestrian dense urban zones.

General safety content themes have been identified as understanding the interactions and behaviour failures of Car-to-URU interactions from multiple user point-of-view (POV) (systemic approach) targeting all road users; addressing training for car drivers on AV systems; informing on CITS for URU safety; and training and education for road safety innovation stakeholders to engage effectively with VRU advocacy groups. These are presented in section 4.2 *SAFE-UP TE&A target safety themes and audiences* which includes identification of initial at-risk URU groups and sub-groups to address in educational materials, as well as feasibility considering resource limitations and level of detail in WP2 analyses. Objectives for TE&A are presented in section 4.3 *Defining TE&A objectives from SAFE-UP outcomes and SPN engagement,* summarized in a table based on the KT plan,

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

which a logic pathway from the Main Messages derived from both SAFE-UP outcomes and partner inputs to target audiences to the specific KT / TE&A goals (desired changes in knowledge, behaviour, skill and practice), and likely strategies to be developed in T6.2 and T6.3 for achieving these goals. section 4.4 *Proposed Training & Learning Design framework for developing educational & learning programs for URU safety in future traffic contexts* presents a background of the Constructive Alignment framework for the design of effective educational programs proposed to be adapted for road safety innovation to address existing gaps and specific requirements of the project. Detailed key performance indicators (KPIs) for Training Education & Awareness programs consider aspects such as content, format, accessibility, acceptability and feasibility, and are provided in a table in section 4.5 *KPIs for TE&A programs.* Section 5*. Approaches to defining TE&A priorities in future SCS* presents some approaches to addressing the information on future SCS to come later in the project from T2.5 *Identification Future Safety Critical Scenarios* and from additional analyses on behavioural failures in car-to-URU interactions by WP2. Finally, section 6 *Discussion* elaborates on the considerations and approaches taken to inform T6.2 and T6.3 activiites ongoing.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

Table of Contents

1. Introduction *13*

1.1 Work Package 6 – *Training, Knowledge Translation & Awareness* – as part of the SAFE-UP holistic approach 13

1.2 T6.1 objectives and connection to other work packages 15

2. Road Safety Training, Education and Awareness raising – current practices *17*

2.1 Vulnerable (Unprotected) Road User safety 17

2.2 Driver training & licensing & AV systems 17

2.3 Current examples of training, education and awareness initiatives for road safety 18

2.3.1 LEARN! Leveraging Education to Advance Road safety Now! 19

2.3.2 The Initial Rider Training (IRT) model for motorcyclists 19

2.3.3 Online resources and examples of KT & TE&A strategies 20

2.4 Predicting safety issues and priorities in future AV-to-URU interactions 22

3. Methods & processes – Developing TE&A for road safety innovation *24*

3.1 Introduction 24

3.2 Translating SAFE-UP results into TE&A objectives 27

3.3 Development and role of the Safety Partner Network 29

3.4 Framework for the design of training & educational programs for future road safety 30

3.5 Data collection & Inputs to T6.1 30

3.5.1 Summary of current factors and issues relating to URU interactions with cars and drivers 30

3.5.2 WP2 Future Safety Critical Scenarios 33

3.5.3 WP3 Active safety systems for vehicle-URU interaction 34

4. Outcomes & Results – SAFE-UP approach to TE&A for road safety innovation *35*

4.1 Data collection results to inform TE&A objectives 35

4.1.1 Stakeholder responses to SAFE-UP proposed safety innovations and TE&A aims 35

4.1.2 WP2 Task 2.1 Initial SCS and identification of target safety themes 42

4.1.3 WP2 further analyses and Task 2.5 Future Safety-Critical Scenarios (SCS) 45

4.1.4 DEMO 4 Delivery of Timely warnings through CITS 45

4.2 SAFE-UP TE&A target safety themes and audiences 45

4.2.1 Target URU subgroups as TE&A safety priorities 47

4.3 Defining TE&A objectives from SAFE-UP outcomes and SPN engagement 48

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

4.4 Proposed Training & Learning Design framework for developing educational & learning programs for URU safety in future traffic contexts............ 55

4.4.1 Bigg's theory of Constructive alignment and application to TE&A for road safety innovation 56

4.4.2 Applying the TE&A approach to SAFE-UP outcomes 64

4.5 KPIs for TE&A programs 67

5. Approaches to defining TE&A priorities in future SCS.............................. 75

5.1 Initial training priorities in future SCS 75

5.2 URU-vehicle-AV conflicts tool for categorizing possible URU-to-car interaction risks 75

6. Discussion.. 79

7. References 86

8. Appendix Support materials for Applying the training and educational design Framework 89

8.1 Reference sheets for applying Bloom's revised Taxonomy to LOs............. 89

8.2 Behaviour change models... 94

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

List of figures

Figure 1.1 Inputs from WP2 to other WPs, showing examples of general themes that could be translated into TE&A objectives 14

Figure 2.1 The LEARN! model for developing traffic safety and mobility educational programs. Source ETSC [5] 19

Figure 2.2 Initial Rider Training model – thematic module outline. Source EU Mobility & Transport [6] 20

Figure 3.1 Identification of training, education & awareness targets through inputs from T6.3 and WPs 2 and 3 26

Figure 3.2 Simplified depiction of the steps in the SAFE-UP Knowledge Translation plan from T6.3. T6.1, T6.2 and T6.4 are embedded at different stages and processes of this plan. 28

Figure 4.1 EFA Driving Training Matrix 40

Figure 4.2 Paradigm shift in educational design models from content to desired outcomes as changes in the learner 56

Figure 4.3 GDE matrix for Driver Education. Source: EC Mobility and Transport – Road Safety 58

Figure 4.4 Bloom's revised Taxonomy of Education Objectives. Adapted from [21] 60

Figure 4.5 The three key components in course design, using the Constructive Alignment approach. 61

Figure 4.6 The behaviour change wheel: A new method for characterising and designing behaviour change interventions. Source: Michie, et al., 2011. Implementation Science [22]. 63

Figure 4.7 Nested KT & Constructive Alignment frameworks for translating SAFE-UP outcomes into TE&A programs 65

Figure 4.8 Prioritizing planned TE&A initiatives considering identified targets and feasibility. The different elements relating to target audiences and key message are used to prioritize TE&A targets but then determined strategies must be considered for feasibility. 67

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

List of tables

Table 2.1 Examples of organizations providing resources, education and awareness on road safety 21

Table 3.1 Factors influencing decision making and behaviour of URUs in interaction with cars and drivers. (Source: SWOV Safe interaction of automated vehicles with vulnerable road users, 2016) 31

Table 4.1 Organisations targeted for engagement in T6.1 activities 35

Table 4.2 Stakeholder concerns, issues, perspectives on TE&A for URU safety in future AV traffic 37

Table 4.3 Safety-Critical Scenarios defined in T2.1 [1] 44

Table 4.4 General themes identified for TE&A objectives 46

Table 4.5 Translating SAFE-UP results and SPN inputs into Main Messages and TE&A Goals for specific target audiences 50

Table 4.6 Course/KT strategy alignment diagnostic test. 62

Table 4.7 Detailed KPIs & indicators for TE&A programs & initiatives 68

Table 5.1 Matrix to categorize possible conflicts to prioritise TE&A objectives and targets 77

Table 5.2 Example of filled matrix for Pedestrian at designated crossing 78

Table 5.3 Example of filled matrix for Pedestrian at non-designated crossing 78

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

List of abbreviations

Abbreviation	Meaning
ABS	anti-lock braking system
ACEM	European Association of Motorcycle Manufacturers
AD	Automated Driving
AV	Autonomous Vehicles
CA	Consortium Agreement
CAV	Connected Automated Vehicles
CITS	Connected Intelligent Transport Systems
D	Deliverable
dpM	Deaths per million
EC	European Commission
ECF	European Cyclists Federation
EFA	European Driving Schools Ass**ociation**
ETSC	European Transport Safety Council
FIM	Fédération Internationale de Motocyclisme
GA	Grant Agreement
GIDAS	German In-Depth Accident Study
GV	Goods vehicle
IFP	International Federation of Pedestrians
IFZ	Institute for two-wheeled safety
ITF	International Transport Forum
IRT	Initial Rider Training
LO	Learning Outcome
KT	Knowledge Translation
KU	Knowledge User
MAIDS	Motorcycle Accidents In Depth Study
MM	Main Message
OEM	Original Equipment Manufacturer
PM	Person Month
PTW	Powered two-wheelers – motorcycles, scooters, mopeds

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

R&D	Research and Development
R&I	Research and Innovation
RSU	Roadside unit
SCS	Safety-Critical Scenario
SPN	Safety Partner Network
T	Task
TE&A	Training, Education & Awareness
TLA	Teaching and learning activity
URU	Unprotected Road User
VSV	Vlaamse Stichting Verkeerskunde
VRU	Vulnerable Road User
WP	Work Package

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

1. Introduction

1.1 Work Package 6 – *Training, Knowledge Translation & Awareness* – as part of the SAFE-UP holistic approach

On the road to achieving the EU's vision of zero road fatalities and serious injuries by 2050, implementation of connected and automated vehicles (CAVs) is identified as fundamental to reducing the catastrophic effects of human error as a main contributing factor in road crashes. Of the road users considered most vulnerable to suffering death or serious injury in crashes with cars, pedestrians experience the highest number of fatalities, with 97% of these happening in urban areas [1]. Cyclists suffer the highest number of injuries of all levels, and mostly in cities. However, the proportions of cyclists killed is about equally distributed between urban and rural cases [1]. 94% of injury-producing crashes between cars and small powered two-wheelers (PTWs) – motorcycles and scooters having engines <=50 cc – happen in urban areas, while this is 85% for large PTWs (>50 cc) [1]. Behavioural failures contributing to crash occurrence include one or both of the participants not noticing the other, sight obstructions and visibility issues, misjudgements of gap times, inattention, violations of traffic rules and failures in communication [1].

Some key technological interventions to reduce or compensate for human factors that contribute to safety-critical scenarios (SCS) are recognized widely in the road safety realm and in national and EU level roadmaps [2]. These include safety innovations such as position-sharing and warnings through Connected Intelligent Transport Systems (CITS), linking all road users and digital infrastructure, coupled with Automated Driving (AD) and emergency functions for vehicles. The increasing penetration of CAVs in the modal mix is expected to disrupt current mobility patterns with consequences for safe interaction between participants. As the traffic context evolves, road users will require new knowledge, skills and behaviours.

SAFE-UP is working to proactively address these upcoming safety challenges for CAV implementation by predicting future SCS and developing passive and active safety technologies for the coming partially and fully automated vehicles. With WP6, SAFE-UP recognizes that these challenges cannot be met through engineering solutions alone, and successful implementation requires that Research and Innovation (R&I) have coherent links with political, educational and community realms. Consequently, the SAFE-UP holistic approach includes development of training, education and awareness schemes to keep all road users up to date on how to keep ourselves and each other safe in this shifting landscape.

The main inputs of other SAFE-UP WPs to WP6 relate to the first 2 pillars of the project: (i) future Safety-Critical Scenarios and (ii) new safety technologies. Therefore pillar (iii) – novel safety assessment methodologies (WP5) – will not be addressed or discussed in this

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

deliverable. However, outputs from WP5 *may* be found relevant to improving public understanding, confidence and uptake of technologies later in the project, and could be incorporated into general dissemination and awareness goals in T6.3, which is ongoing throughout the project.

Figure 1.1 summarizes the activities relating to the first two pillars, with early ideas of safety themes for Training, Educational and Awareness objectives (TE&A). Note that WP2 has a key role in providing results on SCS for the other activities.

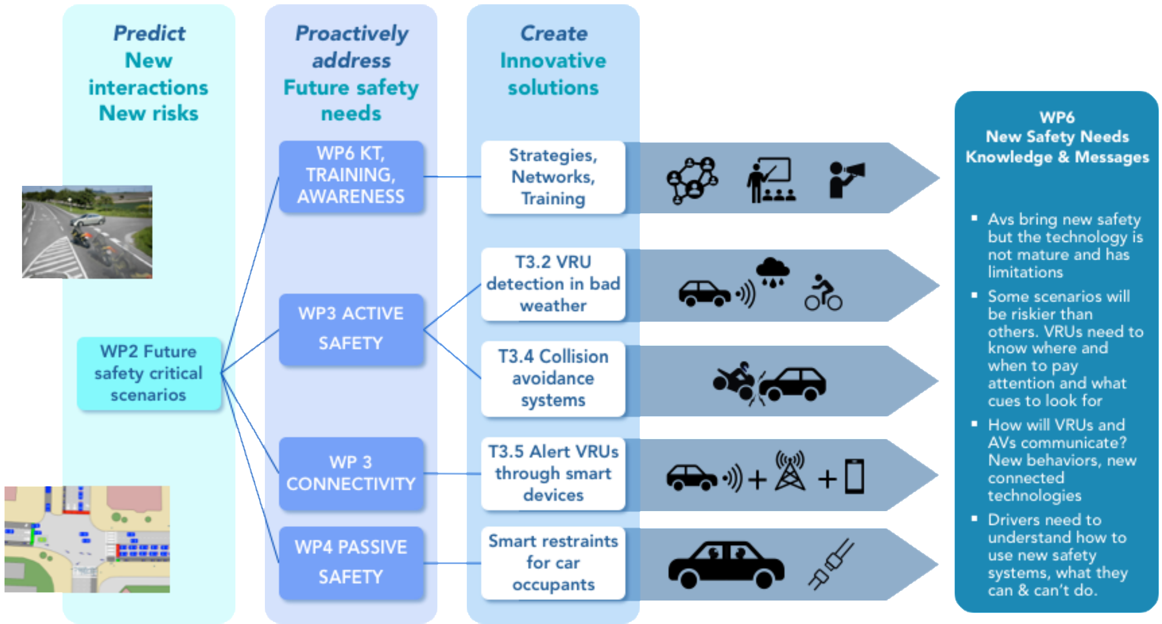

Figure 1.1 Inputs from WP2 to other WPs, showing examples of general themes that could be translated into TE&A objectives

WP6 activities commenced with *Task 6.3 Knowledge Translation, outreach and raising awareness,* in M1 of the project. T6.3 supports and feeds into all the other WP6 tasks by applying Knowledge Translation (KT) methodology (see section 3) to defining targets, goals and strategies for translating SAFE-UP results for targeted delivery to the people and groups who can use them to positively impact URU safety. These activities are supported through engagement with the Safety Partner Network (SPN) throughout the life of the project.

The rationale for this timing between tasks is to allow enough time to develop stakeholder engagement in order to collect information about potential target audiences and their needs, as inputs into T6.1. Another aim for SPN engagement is to leverage these stakeholder relationships to collaborate on tailoring any TE&A outputs to specific knowledge users and road user groups, as an efficient method for achieving diversity, and reach targets with limited resources, experience or previous networks. Additionally, stakeholder engagement is a best practice approach to ensuring relevance of TE&A outcomes and generating buy-in and interest to promote acceptance and uptake. Ongoing outreach and engagement activities are planned in T6.3 to expand the Safety Partner Network for dissemination of

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

outcomes across more organizations (horizontal) and through their respective member organizations and/or individual members (vertical). These activities will also support *T6.4 Evaluation of TE&A programme and material* for testing and assessment of usability and effectiveness of TEA strategies and materials produced.

1.2 T6.1 objectives and connection to other work packages

The overall purpose of Task 6.1 is to define TE&A objectives (e.g. changes in awareness, knowledge, capacity, behaviour) intended to address potential risks to URUs in the evolving mixed and automated traffic context. The main subtasks for T6.1 include:

- Set Training, Educational and Awareness objectives for URU safety based on new knowledge and innovations from SAFE-UP.
- Identify specific knowledge user (KU) groups (target audiences) as priorities.
- Develop a Framework for guiding the development of educational content & training programs.
- Define key performance indicators (KPIs) to evaluate the potential effectiveness, use and acceptance of strategies created to achieve TE&A objectives.

Note that KU groups considered, range from 'end users' (people interacting in traffic, road users, consumers) to 'next Knowledge Users', for example road safety associations, pedestrian, cyclist and motorcyclist advocacy groups, policy makers, other researchers – any entity who can use the knowledge produced in SAFE-UP in their work to positively impact URU safety in current and future traffic.

From the expected outcomes to be generated by SAFE-UP, the following safety information themes will provide the knowledge content on which to base TE&A objectives:

(i) WP2 – The initial and future Safety-critical Scenarios developed in WP2 provide knowledge on the evolving risks to URUs in interactions with passenger cars. Objectives could include updates to *hazard perception practices* or *traffic participation* behaviours, including possible changes to how users communicate intentions to one another, or exchange cues with AVs whose occupants may not be performing the driving task.

(ii) WP3 Demos 2 & 3 – information on the new safety technologies, such as enhanced sensors for bad weather and automated emergency avoidance manoeuvres. Objectives could include knowledge and understanding of intended use cases, proper use and system capabilities and limitations in operating domain and response characteristics which could have safety implications for both occupants and unprotected road users outside the vehicle.

iii) WP3 Demo 4 – gaps in and promotion of increased road user connectivity associated with increasing AV penetration and future implementation of CITS systems to support crash avoidance and URU safety.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

2. Road Safety Training, Education and Awareness raising – current practices

2.1 Vulnerable (Unprotected) Road User safety

WP6 was created on the prediction that future traffic patterns and driving behaviours will require new training, educational and awareness raising initiatives to complement the implementation of new safety technologies and CITS uptake. Any proposed road safety innovation should be safe to use, intuitively understood and should not produce unintended negative consequences. Further, the European Commission (EC) specifies in the report on "Ethics of Connected and Automated Vehicles Recommendations on road safety, privacy, fairness, explainability and responsibility", that "*CAVs should, among other things, adapt their behaviour around vulnerable road users instead of expecting these users to adapt to the (new) dangers of the road*" [3]. Nevertheless, we can expect that all road users will increasingly find themselves in unfamiliar traffic interactions due to the increasing mix of automated and conventional driving functions. The safety implications will be particularly important for unprotected road users.

At the time of writing the SAFE-UP grant proposal, there was no existing EU standard for road safety education for URU safety that could be adapted for training on risks related to the introduction of CAVs and resulting mixed traffic contexts. Consequently, to the best of our knowledge there are no existing standardized methods.

2.2 Driver training & licensing & AV systems

The need for hazard perception training for motorcycle riders is a continuing theme both in the research and expressed by promoters of motorcycle and transport safety. Many high-quality post-license training programs exist throughout Europe, particularly in Northern EU countries like Germany. The European Association of Motorcycle Manufacturers (ACEM) and the DVR launched their European Training Quality Label for PTW rider training in 2016 to recognize and promote the best post-license schemes in the EU. Despite the existence of such programs, the proportion of riders who take advantage of post-license training is very small. Some manufacturers, for example Ducati and KTM offer training courses for new owners, highlighting the correct use and benefits of the advanced safety technologies. Such a marketing strategy may have a positive safety effect, as it is important to ensure customer confidence in using systems which are shown to work well and enhance safety (e.g. anti-lock braking system (ABS)).

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

Recommendations from the implementation of Directive 2006/126/EC on driving licences from 2017 [4] include improving PTW rider training for risk awareness. The report also indicates the need to include driver training and testing on Advanced Driver Assistance Systems (ADAS) as well as on e-vehicles and those with alternative propulsions to remove obstacles for deployment of these vehicles.

Changes to traffic patterns with increasing vehicle automation and CITS systems will require retraining of current licensees and updating of training programs for new licensees. Currently, there is a lack of training schemes based on risk perception and operational skills as well as lack of personalized training schemes for emerging traffic scenarios, vehicle technologies and specific risk to different types of road users. The EC encourages drivers to improve knowledge on using automation features and understand the basics, advantages and limits of related technologies [5].

It is a general observation across road safety sectors that owners of new vehicles with AD and driver assistive functions lack awareness or understanding of new L1-L4 safety systems, often choosing to disable them rather than learn how to use them for increased safety benefit. YouTube abounds with videos of drivers demonstrating various methods to fool automation systems in order to keep them active during inappropriate use case contexts, or deliberately test system limits. Research and news items report on AV crashes caused by operator overconfidence in the automation technology. Barriers to drivers improving competency and appropriate risk avoidance behaviour in using these systems may include:

- Non-useability or lack of appeal of the educational and safety material provided by the manufacturers (manuals).
- Continual changes to technology appearing on the market and non-standardization of functions or interfaces across brands.
- Dissatisfaction with new interface design (e.g. menu screens instead of buttons) and increased attentional and cognitive load to use them.
- Lack of buy-in by drivers who did not select the vehicles themselves (e.g. company cars provided by employers)
- No EU guidelines yet for driver training or testing on L1-L4 systems.
- Current license testing that requires systems be disabled for exams.

2.3 Current examples of training, education and awareness initiatives for road safety

An exhaustive literature review is not provided here, largely because training in general is too broad a topic and literature on training programs for URUs in mixed AV traffic is all but non-existent. Instead, we present current initiatives in training recognized on the EU level that have the greatest relevance and timeliness.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

2.3.1 LEARN! Leveraging Education to Advance Road safety Now!

At the time of drafting the grant proposal we were not aware of this new project initiated in February 2018 by the Flemish traffic engineering foundation Vlaamse Stichting Verkeerskunde (VSV), the European Transport Safety Council (ETSC) and Fundación Mapfre. Indeed, the leader of the project confirmed that there was previously no EU level standard approach to traffic safety and mobility education even though all countries were mandated to supply it.

In the first phase, the project reported on the status of traffic safety and mobility education in Europe. The Key Principles report produced 17 recommendations for all EU countries to implement to ensure high quality traffic safety and mobility education, particularly targeting children and adolescents. Finally, The *LEARN! Manual for developing and evaluating traffic safety and mobility education* has just been released as of June 2021, in tandem with a webinar. It sets out recommendations, criteria and an evidence-based model for developing and implementing sound educational activities in an accessible way (see Figure 2.1) [6]. As such, it provides an important standard that may be referred to and adapted for the development of road safety training and educational goals and strategies.

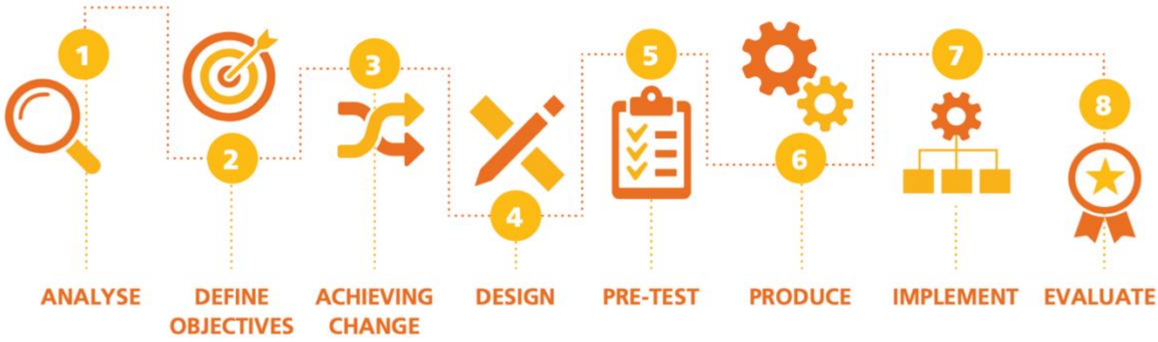

Figure 2.1 The LEARN! model for developing traffic safety and mobility educational programs. Source ETSC [6]

2.3.2 The Initial Rider Training (IRT) model for motorcyclists

The Initial Rider Training Project (2011, Figure *2.2*) was led by FEMA (the Federation of European Motorcyclists’ Associations) with the support of the EC Mobility & Transport, ACEM (European Association of Motorcycle Manufacturers), FIM (Fédération Internationale de Motocyclisme) and Vägverket (the Swedish Road Administration), now Trafikverket, and the International Association for Driver Education (IVV) with the aim of producing EU guidelines for improved pre-licence training to reduce the number of riders killed and injured. The IRT model takes a modular based approach to a progressive licensing system.

The publication lays out the model’s essential elements to be included in initial rider training programs, including a teaching methodology based on specific exercises. Additionally, the project evaluated the potential for e-Coaching programs to provide rider training and a report was produced containing guidelines and requirements for such a program. It is unknown

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under Grant Agreement 861570.

whether implementation or effectiveness has been assessed. The manual is available on a permanent page of the EC site [6].

Theoretical	Machine control	Traffic interface
1 Road regulations	1 Machine familiarity	1 Positioning in traffic
a general rules and regulations	a automatic controls	a slower than traffic
b motorway rules and regulations	b manual controls	b at traffic speed
2 Signs and markings	c advanced braking systems	2 Distance
a general signs and markings	2 First movements	3 Curves and bends
b motorway signs and markings	3 Gears, brakes and direction	a right hand
3 Machine dynamics	a automatic gears	b left hand
4 Hazard awareness	b manual gears	4 Anticipation
a other road users	c separate braking systems	a other road users
b environment and infrastructure	d advanced braking systems	b environment and infrastructure
5 Helmets and appropriate clothing	4 Steering and counter-steering	5 Junctions
6 Social responsibilities	5 Low speed manoeuvring	6 Overtaking
a noise	6 Hazard management	7 Motorways
b first aid and accidents	a swerving	8 Group riding
7 Impairment	b emergency braking	9 Journey planning
8 Attitude and behaviour		
1a, 1b, 2a, 2b, 3, 4a, 4b, 5, 7, 8	4, 5, 6a, 6b	1a, 1b, 2, 3a, 3b, 4a, 4b, 5, 6, 7, 8, 9
e-Coaching. Virtual no-risk exposure to hazards and consequences of attitude and behaviour.		

Figure 2.2 Initial Rider Training model – thematic module outline. Source EU Mobility & Transport [7]

2.3.3 Online resources and examples of KT & TE&A strategies

There are numerous road safety organizations and URU advocacy groups with publicly accessible websites, actively engaged in advancing road safety and providing outreach and resources in the form of education and awareness materials and strategies. Memberships and target audiences range from road safety researchers and professionals, to OEMs, to public, private and research organizations, communities, consumers, educators, and private citizens. Depending on the aims of the organizations, the scope of these sites may span a variety of road users or be dedicated to specific mobility/URU types. The range of organizations includes government transport websites, national and international safety councils, vehicle manufacturers, URU advocacy groups, and NGOs & Charities promoting road safety and accident prevention.

Table 2.1 provides a selection of some leading examples from organizations with a focus on road safety. Their websites offer many excellent examples of Knowledge Translation of evidence for multiple audiences for multiple goals and a range of formats: reports (including policy, vehicle testing, roadmaps, Vision Zero updates) research, manuals, news items, safety tips, awareness and behaviour change campaigns, safety media libraries, resources on toolkits for community activism and more. Regular news, updates and research on automated vehicle systems can be found on the ETSC, Institute for Road Safety Research,

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

Netherlands (SWOV), German Road Safety Council (DVR), Federation of EU Motorcyclists Associations (FEMA) sites but is scarce on sites devoted to non-motor vehicle travel, presumably because the timing of penetration makes this less relevant than currently identified priorities for change.

Table 2.1 Examples of organizations providing resources, education and awareness on road safety

Organization	Activities & Resources
ETSC European Transport Safety Council	EU News and publications on vehicle automation, URU & driver safety. Promotion of active mode use and lower speed limits in urban areas. Road safety projects, campaigns and resources. https://etsc.eu/
LEARN! Project (ETSC)	Framework for Traffic Safety & Mobility education in the EU – Reports, guidelines, manual, resources, webinars. https://www.trafficsafetyeducation.eu/
SWOV Institute for Road Safety Research, NLDS	Research on Infrastructure and Traffic, Road User Behaviour, Human Factors and Vehicle Automation, and Data and Analysis for Policy. Reports, KT, news. Targeted resources for road user groups. https://www.swov.nl/en
DVR German Road Safety Council	Research, development, activism, education, training, active mode promotion.
IFZ Institute for two-wheeled safety	Research and KT on motorcycle safety, training providers, resource library (German language) https://www.ifz.de/
Parachute Canada	Prevention of injury due to accidents Research, KT, resources, Vision Zero program (road safety campaigns & contests) https://www.parachute.ca/
WHO UN Road safety Collaboration	https://www.who.int/groups/united-nations-road-safety-collaboration UN Global Road Safety Week Campaigns, resources, shareable media, campaign & community activism toolkit https://www.unroadsafetyweek.org/en/home
Streetsmarts Queensland Govt, Australia	Resources and Safety promotion for each road user type https://streetsmarts.initiatives.qld.gov.au
Living Streets, UK	Promotion of walkable cities through engagement activities, campaigns, resources, tools, news, environmental auditing, capacity building among citizens, lobbying and policy change. https://www.livingstreets.org.uk

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

Organization	Activities & Resources
ECF European Cyclists' Federation	Lobbying, promotion and policy change for safety and increased use of active modes; KT, research, training, resources. https://ecf.com/
FEMA Federation of European Motorcyclists' Associations	Advocacy and promotion for motorcycling preservation and safety. Research and syntheses on safety technologies, consumer information, regulation.
Preventable – The Community Against Preventable Injuries	Promoting behaviour change to reduce injury due to accidents. Library of video ad campaigns. https://www.preventable.ca

2.4 Predicting safety issues and priorities in future AV-to-URU interactions

In addition to academic studies on all aspects of operator and URU interactions with AVs, studies and reports are being produced by independent research institutes, EC, International Transport Forum (ITF), OEMs (e.g. Volvo Trucks safety Report, 2017 [8]). The SWOV report, *Safe interaction of automated vehicles with vulnerable road users* (2016), provides an overview of current knowledge on interactions between URUs (cyclists & pedestrians) with partial AVs, in order to "identify critical elements in vehicle-pedestrian/cyclist interactions in a future (partly) automated era" [9] (p. 22). Despite the large number of studies surveyed, the report confirms that how pedestrians and cyclists (and PTW riders) may respond to partially and fully automated vehicles is understudied. This recognized gap has implications for feasibility of developing training programs at this stage in AV penetration. This report further highlights the need for the kinds of technological advancements being developed in SAFE-UP, stipulating that they must be able to reliably detect URUs, predict their intentions and actions, and function in adverse weather conditions. Here it is worth summarizing the main open questions, challenges and recommendations from the report.

Open questions include whether the increasing introduction of automated driving systems into the traffic mix will result in even more risk to URUs, and what messages and methods of communications AVs should use. In particular, when interacting with AVs,

- Will increasing mixed traffic bring new risks to URUs?
- How should AVs and URUs communicate intentions?
- How will behaviour and decision making for URUs be the same or different?
- How will behaviour and decision making be affected in the context of hybrid AV and non-AV traffic?
- How can interactions between road users be optimized? Through training? Infrastructure? Regulations?

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

How can AV systems be designed to deal with the complexity of human interactions? Key points to consider are:

- Successful interactions often rely on informal, not formal rules. These may be locally specific.
- Traffic interactions are influenced by the road context and how this interacts with the different needs of each participant.
- Individual factors influence how interactions unfold – e.g. skills, capabilities, knowledge, motivation, personality, state-of-mind etc.
- Interpretations of each participant regarding the traffic situation and awareness of risk must be compatible … differences in interpretation likely lead to conflict. This could apply equally to interactions between URUs and AVs.

Conclusions & recommendations

- Formal, non-ambiguous cues between URUs and AVs will have to be adopted.
- Personal taste and opinion on AVs, may positively or negatively affect URU behaviour in interactions.
- Behavioural adaptation may cause some URUs (or drivers) to reduce safety margins due to increased perception of safety around AVs
- New road rules and legislation may be required.
- Caution in applying statistical data: proposed interventions must be inclusive (there is no 'average' URU) but specific to the context (regional differences in crash risks and factors).

Considering these expected challenges, there appears to be a need for TE&A strategies which keep pace with changes and at least fill transitional gaps in safety as the technology matures. At the same time, interventions proposed must be balanced against ethical concerns, such as infringement of basic personal freedoms, inequality of access to safety benefits due to demographic or economic differences, shifting of liability to URUs. Interventions should also refer to community-to-global level aims to decrease traffic congestion and increase space and safety of active mode use to meet health, safety, sustainability and climate roadmaps.

SAFE-UP aims to advance current knowledge on URU-AV interactions through WP2 activities: enhanced models of URU behaviour (pedestrians, cyclists, motorcyclists) are being developed based on the initial SCS. In Task 2.5 these will be integrated into the AIMSUM traffic simulations to analyse interactions at the micro-level, considering different conflict scenarios and safety systems.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

3. Methods & processes – Developing TE&A for road safety innovation

3.1 Introduction

Creating TE&A programs for URU safety in future mixed automated traffic is a daunting task, given that these contexts are not yet a pervasive reality. Still, SAFE-UP has accepted the challenge to create proactive measures to ensure safety in the emerging traffic context, of which Training, Education and Awareness is an integral part.

From a content perspective, we can start with results from T2.1 on initial Safety-Critical Scenarios. The analysis of crash causation related to the interaction between infrastructure and behaviour can provide new perspectives on existing safety issues, and new conversations with KUs. At the same time, we can begin to think about how the proposed interventions will impact current risks, behaviours and opinions of new AV safety technology. Given the limitations, it seems that creating and testing innovative approaches to developing TE&A strategies for road safety innovation seems an apt parallel to the project's main activities in developing of safety technologies. Development of this approach is guided by two overarching questions:

> *How can research results be translated into effective educational and awareness raising initiatives with measurable impacts?*
>
> *How can we create, within a 3-year research innovation project, programs that do not have a shelf life, and are not limited in application context, but can be adapted and updated according to new traffic realities, different contexts and diverse users?*

Instead of creating a token program with limited scope or shelf life, our strategy for tackling these two problems is to experiment with adapting two existing evidence-based frameworks – Knowledge Translation from the research impact field and Constructive Alignment from higher education theory and practice – to create sample TE&A strategies and resources, and then to test these and report on their potential effectiveness, along with assessing the frameworks and strategies developed for their ongoing potential use in the realm of road safety innovation. Thus, in fulfilling the aims of WP6 we will contribute by developing new approaches to improving the impact of Research and Innovation (R&I) in road safety for the benefit of society. Importantly, this approach involves development of social processes to engage with road users and other stakeholders in knowledge exchange for the co-creation of new knowledge and strategies for road safety. This approach also represents a strategy to fulfil the daunting requirements of the call, that updateable, flexible programs consider *diversity* of road users, different *contexts* and different *road user-groups* (e.g. PTW riders, pedestrians, seniors, children, new licensees, car drivers & passengers).

Further, we add that the development of TE&A materials and programs, proposed strategies for achieving behaviour change or educational goals should be chosen based on research

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

evidence that demonstrates effectiveness of the approaches, applying appropriate behavioural and educational models.

The planned activities must be feasible given the limited timeline of the project and in particular limitations in funds and human resources for WP6. Ideally this work would be carried out by a team of specialists including researchers in education, psychology, behaviour change, plus professionals in web and graphic designers, social media and communications. Timing of outputs among WPs is also critical regarding feasibility and scope of chosen TE&A activities. *Timeliness* of knowledge sharing can greatly influence its uptake or acceptability. If the knowledge or training is of high quality, but there is not yet a real or perceived need, it may not be possible to accurately evaluate its (potential) effectiveness. Considering these issues, our strategy was to begin developing frameworks and KT strategies and material based on the initial SCS identified in T2.1. These can then be tested and evaluated, refined and updated later in the project with data from future SCS analyses.

The overarching logic flow for WP6 strategies is as follows:

1. Develop processes (Knowledge Translation for Road Safety Innovation, the Safety Partner Network) carried out in T6.3, to support all other WP6 tasks;
2. Adapt frameworks (KT Plan + Constructive Alignment for design of educational programs) and apply them to the SAFE-UP results;
3. Create initial outputs as working examples for TE&A approaches to future URU safety;
4. Test and collect feedback on programs and materials developed, with inputs from external stakeholders (SAFE-UP advisory board, AB, expanding SPN and public). Update and refine the items as time and timing of WP2 and WP3 outputs permit.
5. Report on the performance, acceptance and useability of TE&A materials and programs, with lessons learned, suggestions for further development, implementation, and measurements of impact, to be reported in the final T6.3 deliverable.

Figure 3.1 illustrates how the activities in WP6 fit together and integrate with other WPs. The funnel represents the KT processes (see section 3*.2 Translating SAFE-UP results into TE&A objectives*) from T6.3 which began at project kick-off and will continue through to project end, supporting the other WP6 tasks as well as fulfilling specific goals such as the Safety Media Library. Project inputs come from WP2 – definitions of current and Future Safety-Critical Scenarios, and WP3 – including enhanced sensors for URU detection in bad weather, active safety systems for collision avoidance, and CITS for sharing information among different traffic participants to deliver timely warnings to protect URUs. Outputs from these activities relevant to WP6 are represented by the purple circle, 'New knowledge & systems' providing content and safety themes for defining TE&A objectives. In T6.1 we have determined initial 'Target audiences' or KUs. Determining 'Specific needs' relates to different realms: the needs of knowledge users in how *information* is tailored and delivered to them (educational design), the specific *safety needs* and risks associated with mobility mode

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

types and user demographics, and the interests, concerns and paradigms of interest groups and URU advocacy groups that must be considered to determine relevance of results for optimizing buy-in and uptake.

The proposed approach is to adapt 2 existing models to the realm of road safety innovation – Knowledge Translation (KT) as a best practice in planning pathways to research impact, and Constructive Alignment in educational design, from higher education research. Within WP6 these two frameworks are nested, with outcomes from the KT process feeding into and supporting the TE&A activities. KT is the overarching methodology applied in T6.3 and will be described in detail in deliverable *D6.2 Knowledge Translation, outreach and raising awareness*. For now a brief description of relevant aspects will suffice.

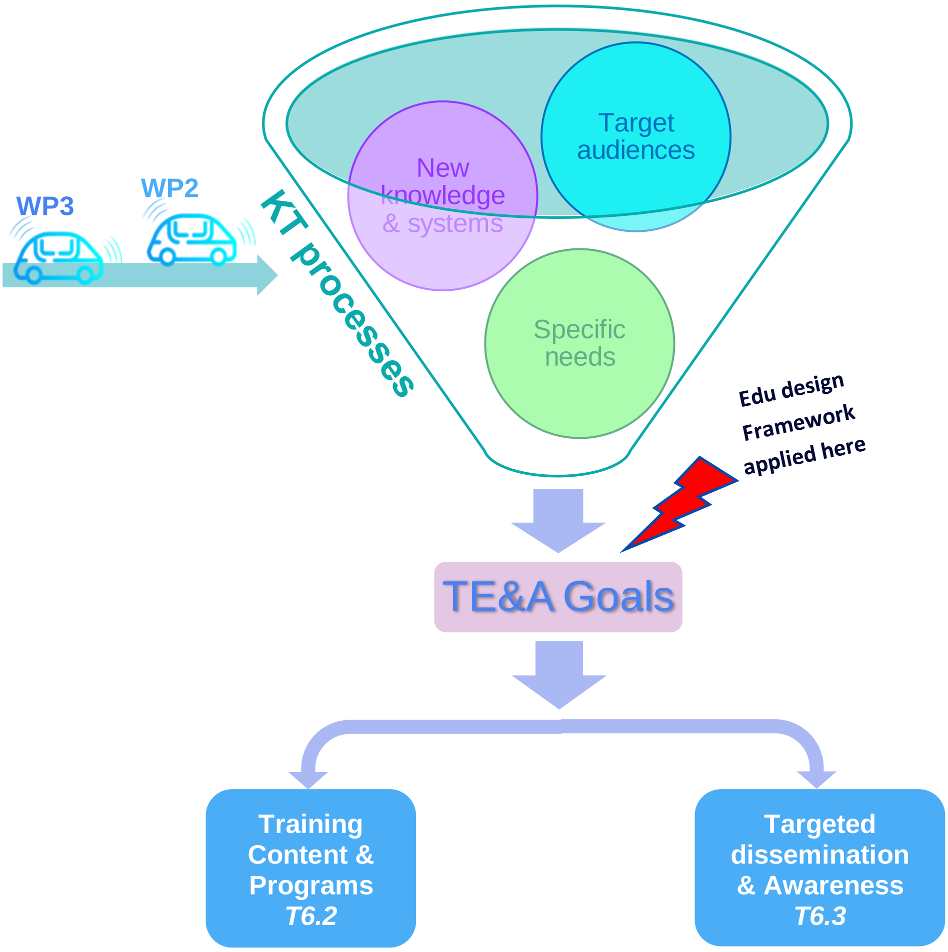

Figure 3.1 Identification of training, education & awareness targets through inputs from T6.3 and WPs 2 and 3

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

3.2 Translating SAFE-UP results into TE&A objectives

The discipline of Knowledge Translation encompasses scholarship and practice aimed to increase research impact through targeted dissemination of results, thus avoiding research waste (i.e. of public funds) and providing a positive benefit by ensuring timely delivery of results to the people who need them in format(s) they can access and use [10]. Other conceptualizations of this practice are Knowledge Mobilization, Knowledge Translation and Exchange, Engaged Scholarship, and Research Impact. KT can occur at many stages of research, and is a precursor to research implementation. The KT goals are determined for each target audience and could be any of the following: to generate awareness, interest or buy-in, to share knowledge, inform decision-making or to stimulate new research questions. KT goals may also be directed towards facilitating behaviour, practice or policy change or be directed towards technology transfer or commercialization [10].

The methodology and timeline for T6.3 activities is guided through the use of an evidence-based tool for planning for research impact, the KT Planning Template© (KTPT) [11]. Figure 3.2 is a simplified version of some of the steps in the KT Plan adapted for SAFE-UP WP6 objectives. Since all WP6 tasks are embedded in the KT plan, it is for this reason T6.3 started at the beginning of the project and will provide ongoing support to all WP6 tasks. Details will be provided in deliverable D6.2.

The process laid out in the KT Planning Template involves targeted dissemination of the research for applications beyond academia to impact multiple levels of society, and possibly beyond predicted aims or uses [12]. Stakeholder engagement is fundamental to this process as they are the next Knowledge Users (KU) on the pathway to impact, with their inputs and feedback being essential to ensuring relevance and useability of KT products [13]. They may also collaborate on the co-creation of new knowledge and practices. It is an iterative process with goals and strategies being updated according to feedback from users and emerging new evidence. Thus by definition the KT practice is aligned with the original Horizon 2020 call requirements for an approach towards providing educational and awareness strategies with the possibility of being updated to incorporate new data and to match the pace of the increased implementation of automated driving functions, and with the flexibility to be tailored to different contexts and (road) user groups.

To maximize the impact of WP6 efforts to promote URU safety through SAFE-UP outputs, and given the budget and human resources limitations for WP6, it is important to consider a range of target audiences for TE&A. That is, although it appeared the call had a priori defined targeting URUs themselves for training as the most effective strategy for promoting safety in future mixed traffic, safety impact may be enhanced by reaching organizations and initiatives already positioned to have a large impact on URU safety for example, through policy change or legislation. This means not just the road users themselves, but also policy makers, OEMs, researchers and public authorities, safety councils, educators and their institutions may be targeted for training, education and awareness objectives on different aspects or interpretations of SAFE-UP results.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

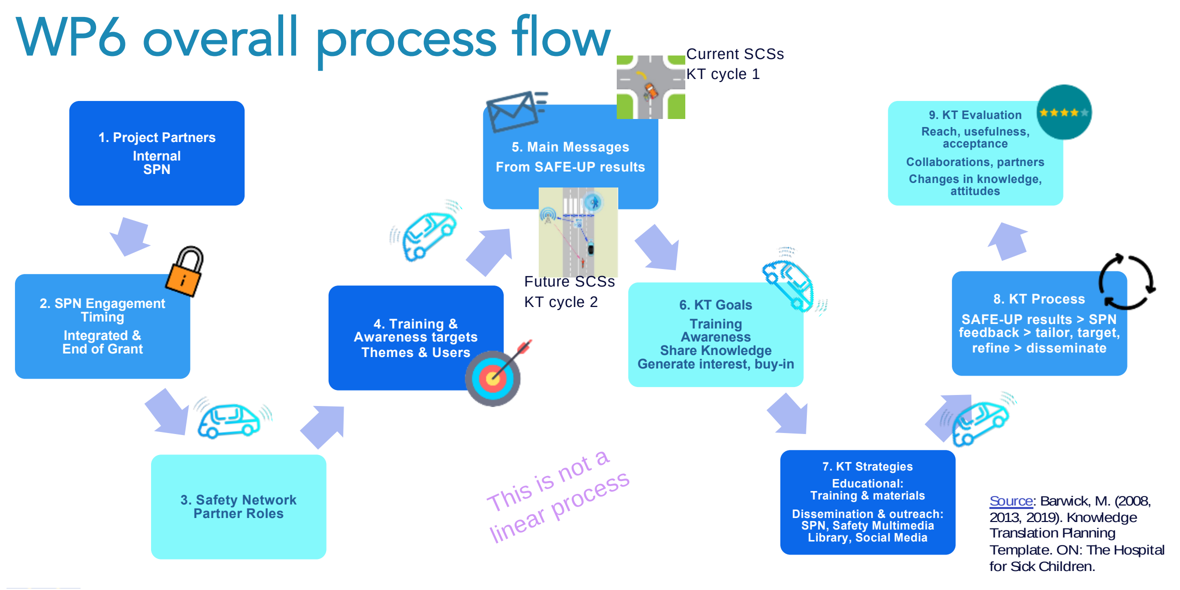

Figure 3.2 Simplified depiction of the steps in the SAFE-UP Knowledge Translation plan from T6.3. T6.1, T6.2 and T6.4 are embedded at different stages and processes of this plan.

How T6.1 is oriented within T6.3 and the process

Steps 1-3: develop collaborative partnerships between SAFE-UP and externals experts and URU advocates for co-creation and dissemination of new knowledge to ensure TE&A goals will be evidence-based, targeted, relevant and used.

Steps 4-6: workshops between internal and external partners to identify target audiences, relevant results from D2.6, on which to define specific TE&A objectives in terms of desired new behavioural, awareness or competency outcomes and the strategies proposed to achieve them. Strategies for each KU by KT goal will determine which objectives will serve as outputs to T6.2 for development of teaching & learning (training) programs, which will be handled through T6.3 for general awareness and targeted dissemination (i.e. through Safety Media Library and possible collaborative initiatives).

Steps 7-9: T6.2 and T6.3 with their specific goals will continue to work in parallel and in mutual support. We foresee that any content and formats developed have the potential for modification in other formats and for other audiences to enhance reach and dissemination.

Note: Steps 5 through 9 should not be seen as unidirectional and closed, but cyclical and iterative with refinements and updates for ongoing goals and audiences, as new information emerges (internal and external) and feedback is received. New TE&A subgoals may be added if time permits.

During the KT process, engaging with internal partners and external stakeholders (Tier 1 Knowledge Users or KUs), we distil the most important and relevant Main Messages (MMs) from the results which should be communicated. Tier 1 KUs, such as URU advocacy groups, or traffic education developers, help define target audiences, or Next Knowledge Users (Tier

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

2 KUs). Then we can set appropriate KT goals based on the MMs and specific needs and risks.

Correctly viewed, 'training', while defined as a WP6 outcome, is not a goal but a strategy. The goal is generally, to improve current and future URU safety through sharing SAFE-UP results to reduce risks to road users. In the logic flow of KT, we begin with the evidence and safety innovations developed in the project. In consultation with expert stakeholders in road safety and URU advocacy, we co-create new knowledge from the research results. This follows a logic flow from evidence → contextualized interpretation → target audiences → learning, skill and behavioural goals → KT strategies. Using this scheme, we more clearly see the positioning of training as a possible strategy. The choice of training over some other intervention must also be aligned with the specific KU and learning goals identified, and according to appropriate evidence-based models of learning and behaviour change.

3.3 Development and role of the Safety Partner Network

Outreach to a first priority set of representative stakeholders was initiated in step 1 of the KT process of Task 6.3 (see Figure 3.2). Organizations were identified as experts and representatives of the interests of pedestrians, bicyclists and motorcyclists. Other important stakeholders were selected for their positioning with respect to driver education and licensing, CITS implementation and city planning networks. Representatives from these organizations accepted invitations to become members of the ad hoc Safety Partner Network (SPN).

These external partners were engaged to collect their expert advice and knowledge on the specific needs and concerns of different road user and knowledge user groups. Their inputs thus support and inform T6.1 in helping to refine TE&A objectives and to tailor information to specific audiences. Furthermore, successive stages of the KT process will leverage their networks for dissemination of future WP6 TE&A outputs, and explore opportunities to co-create TE&A products and initiatives. Details of the KT and engagement processes will be provided in D6.2. Inputs collected thus far to inform the present deliverable were achieved via three engagement activities:

1. One-on-one initial interviews between the researcher and a representative of each external organization engaged as a Safety Network Partner (SNP) of the ad hoc SAFE-UP SPN;
2. A group meeting with SNPs to discuss acceptability or non-acceptability of training versus educational or awareness raising approaches for URUs;
3. In a workshop hosted by WP6, researchers for Task 2.1 shared results on initial SCS from D2.6 with interested members of the SPN with the aim for WP6 to receive feedback from their members and target audiences on relevance and usefulness.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

3.4 Framework for the design of training & educational programs for future road safety

Once our targets and goals for TE&A are defined, we apply a framework based on the theory of Constructive Alignment for designing effective training and educational programs and strategies. At this point we can distinguish between goals for which training and educational strategies are identified as most appropriate for achieving the desired outcomes (T6.2) versus dissemination strategies (T6.3 ongoing).

Instead of trying to create one training program that might suffer from quickly becoming out-of-date in the constantly changing mixed traffic context, we proposed developing a framework that could be applied, tested, refined and updated. It is intended to guide and facilitate the creation of evidence-based training schemes including a methodology to define desired learning and behaviour change outcomes, key performance indicators (KPIs), plus the development of tools to assess learning. The framework, described in section *4.4 Proposed Training & Learning Design framework for developing educational & learning programs for URU safety in future traffic contexts* will be adaptable for application in addressing future scenarios, and for taking into consideration different road contexts. Using the framework, training and educational material and awareness strategies will be developed to educate all road users on AV technology with a focus on ensuring URU safety.

3.5 Data collection & Inputs to T6.1

The main inputs for TE&A activities in SAFE-UP come from WP2 results on the initial and future Safety-Critical Scenarios and WP3 results and Demos 2, 3, 4 on enhanced sensors in adverse weather conditions, active safety systems, and CITS for timely warnings.

3.5.1 Summary of current factors and issues relating to URU interactions with cars and drivers

Table 3.1 below summarizes the data collected in the SWOV 2016 literature review on the key characteristics to be considered regarding interactions between URUs and AVs based on current knowledge.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

Table 3.1 Factors influencing decision making and behaviour of URUs in interaction with cars and drivers. (Source: SWOV Safe interaction of automated vehicles with vulnerable road users, 2016)

Individual differences	Sub-group	Crossing Roads	Reference (Cited in SWOV, 2016)
Age	Older cyclists & pedestrians compared to younger	• Prefer designated crossings, feel less safe where they are absent • More cautious when crossing • Tend to look towards the ground when crossing and not at their surroundings • Acceptable crossing gaps [define?] are larger	• Bernhoft & Carstensen (2007) • Dommes et al. (2015) • Dommes et al. (2015); Zito et al. (2015) • Demiroz, Onelcin & Alver (2015)
Age	Children	• Children that are frightened tend to behave more hesitantly leading to a higher risk of crash	• Shen, McClure & Schwebel, (2015)
Gender	Males compared to females	• More likely to copy crossing behaviour of others • Commit more violations • Make more errors • Are more prone to aggressive behaviour	• Faria et al. (2010) • Antic et al. (2016) • Antic et al. (2016) • Antic et al. (2016)

Vehicle behaviour	Vehicle Dynamic Parameter	Crossing Roads	Ref (Cited in SWOV)
Vehicle speed	Low compare to high	• Pedestrians feel safer and cross more slowly	• Demiroz, Onelcin & Alver (2015)
Vehicle speed	Slow approach + early braking	• Positive effect on pedestrian decision-making	• Schneeman & Gohl (2016)
Vehicle speed	Gap acceptance	• Pedestrians accept a higher gap for higher vehicle approach speeds	• Kadali & Vedagiri (2013)

Safety system	User	(Possible) adaptations **in** Crossing Roads	Ref (Cited in SWOV)
ABS	Drivers	• Inattentive driving resulting from feeling safer • Overestimation of safety under certain conditions	• Aschenbrenner & Biehl (1994)
Road lighting	Drivers	• Compensation (increased speed, reduced attention) interacted with age and gender • Confounder: Drivers during daylight and night may be different sub-groups, not the same drivers…averaging obscured	• Assum et al., 1999

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

Safety system	User	(Possible) adaptations **in** Crossing Roads	Ref (Cited in SWOV)
		different behavioural adaptations by driver groups.	

Safety system	User	(Possible) adaptations in Crossing Roads	Ref (Cited in SWOV)
Future AVs	Cyclists Pedestrians	• Acceptance of smaller gaps • Running red lights • Right of way violations • Less attentive to other traffic participants (e.g. conventional vehicles) • Deliberate testing of AV responses with sudden behaviour	• SWOV (2016)

User expectations	Influences on user expectations for others' intentions and decision making	Ref (Cited in SWOV)
Predictions of others' intended actions	Combination of • Traffic rules in force • Infrastructure design • Behaviour of other road users	• Björklund & Åberg (2005)
Predictions of others' intended actions	• Past experiences in similar traffic situations	• Herslund & Jørgensen (2003)
Mis-match of expectations results in perceptual failure	• Bi-directional cycle path à driver does not expect to see a cyclist approaching intersection from 'wrong' side of the road, results in perceptual failure even if looking in the right direction	• Räsänen & Summala (2000)
Mis-match of expectations results in perceptual failure	• Drivers looked but failed to see other road users …. Expectations are implicated in perceptual failures.	• Herslund & Jørgensen (2003); Akhtar et al. (2010); Klassen, El-Basyouny & Islam (2012)
Expectations direct attentional priorities	• Drivers fail to detect cyclists because they do not expect the presence of cyclists and prioritize their attention towards approaching cars • EXPERIENCED drivers tend to make this mistake more often.	• Herslund & Jørgensen (2003) • Klassen, El-Basyouny & Islam (2012)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

	• Drivers do not detect pedestrian red light runners in time because they are less alert [to this possibility]	
Expectations	• Are likely to be based in part on the context: both traffic composition and culture	• Haworth et al. (2015)
Expectations of pedestrians & cyclists [& PTW riders] in evolving mixed AV traffic	• May not be very reliable ▪ How will they distinguish AV from conventional vehicles? ▪ How will they know what kinds of behaviour to expect from AVs?	• SWOV (2016)

3.5.2 WP2 Future Safety Critical Scenarios

Outputs from WP2 provide the inputs for two key subtasks of T6.1:

1. Identify and understand current and future safety priorities by URU/mobility mode;
2. Provide new knowledge on road user interactions in SCS from which to determine TE&A objectives.

These subtasks provide the bases for deciding on target audiences and TE&A objectives, to inform development of learning and awareness activities and materials to be developed in T6.2 and T6.3. Materials and strategies developed will later be updated with results from T2.5 on future SCS predicted from simulations.

Task 2.1 and 2.5 will provide the key relevant project outputs to be used in WP6.

- Deliverable 2.6 (D2.6) *Use case definitions and initial safety-critical scenarios*
    - Submitted to the EC end of September 2021.
    - Outcomes: definition of initial Safety-Critical Scenarios for (i) passenger car collisions resulting in death or serious injury of occupants; (ii) car-involved crashes resulting in death or serious injuries to pedestrians, bicyclists or PTW riders.)
    - Results are now being integrated into T6.1/T6.3.
    - A workshop on car-to-pedestrian and car-to-cyclist SCS was held at the end of November between researchers and SPN for inputs into this deliverable. A similar workshop on car-to-PTW SCS is planned for December 2021 or January 2022, to inform specific TE&A targets and objectives regarding PTW rider safety.
- D2.8 (M17) & D2.13 (M29) *Analysis of simulation results and identification of future safety-critical traffic interactions*

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

- This task will run from M16 to M34.
- Outcomes: prediction of Future Safety-Critical Scenarios resulting from the disruption to traffic by AVs.
- Results will be integrated into T6.2 and T6.3 as they emerge, through updates to materials and strategies based on T2.1 results.

Developing TE&A materials and strategies based on initial (current) SCS is relevant to the stated goal of addressing the evolving traffic context as AV functions are already a part of the modal mix. The evidence provided by T2.1 on current SCS highlights the persistent safety issues that still need to be addressed as public safety priorities. Since these scenarios will be targeted for developing the SAFE-UP safety innovations (demonstrators 2-4), in developing strategies to address initial SCS at the same time we can be looking ahead to how these may change with the introduction of specific automated safety functions and CITS. Similarly, external experts can be solicited for their input on likely future concerns regarding the purposes and functions of proposed innovations.

3.5.3 WP3 Active safety systems for vehicle-URU interaction

WP6 will follow the progress in these tasks and evaluate emerging results for their potential and feasibility towards new additional KT goals to be realized through T6.2 and T6.3 activities, given appropriate time and resources remaining in the project.

- Task 3.2 Enhanced URU detection under bad weather conditions. Prototype sensors will be demonstrated in Demo 2. The main focus will be on detection of pedestrians and cyclists, and not PTW riders due to the greater technical challenges in sensor design.
- Tasks 3.3 and 3.4 advanced vehicle dynamic intervention functions to avoid critical events will be integrated with sensors into Demo 3.

Results from Demo 4 will be used to define MMs, KT goals and strategies related to the promotion of URU connectivity through wearables.

- Task 3.5: On-time warning provisions to URUs and drivers in critical conditions (Demo 4).

Tasks 3.3-3.5 finish in M28, so timing to integrate outputs into WP6 tasks might be tight and must be considered when evaluating feasibility of potential TE&A goals.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

4. Outcomes & Results – SAFE-UP approach to TE&A for road safety innovation

4.1 Data collection results to inform TE&A objectives

4.1.1 Stakeholder responses to SAFE-UP proposed safety innovations and TE&A aims

The EU recognizes the Safe Systems approach as essential to meeting Vision Zero Goals. Applying this approach requires that proposed interventions involve inputs from multiple stakeholder points of view. Determination of evidence-based guidelines is important to assuring relevance of TE&A goals and strategies, encouraging buy-in, acceptance, uptake and useability. The inputs received from the SPN (see Table 4.1) included how to conceptualize 'URUs', 'road safety/road danger' etc. which reflects current paradigms and concerns as well as debates on best practice in communicating about road crashes.

Table 4.1 Organisations targeted for engagement in T6.1 activities

Organization	User Group, Activities	Relation to SAFE-UP
FEMA - Federation of European Motorcyclists' Associations	Lobbying PTW rider advocacy	Safety Partner Network
IFP - International Federation of Pedestrians	URU representative & advocacy	Safety Partner Network
ECF - European Cyclists Federation	Safety promotion Tech innovation Information provider URU representative & advocacy, lobbying	Safety Partner Network
EFA - European Driving Schools Association	driver training safety initiatives, public outreach	Safety Partner Network
IFZ - Institute for two-wheeled safety	PTW rider advocacy, research	Safety Partner Network
POLIS - Cities network on transport innovation	city transport planning	Advisory Board
ERTICO - ITS Europe	smart transport, ITS	Advisory Board

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

ETSC – LEARN! Project	EU framework for road safety & mobility education in schools	Through Advisory Board contact, ETSC

Inputs were collected from 4 international federations of URU associations representing the concerns, rights and interests of pedestrians (IFP), cyclists (ECF) and motorcyclists (FEMA, IFZ), respectively. Remote interviews and meetings with a representative of each group were carried out online. In addition, two members of the advisory board were engaged: the contact for ERTICO for their expertise on engagement with stakeholders of Intelligent Transport Systems (ITS) from both public and private sectors (ERTICO) and the contact from POLIS for promoting a new paradigm of city planning. Table 4.1 lists the relevant organizations engaged for feedback on URU TE&A based on SAFE-UP outcomes.

Input on unprotected road user needs, concerns and key issues was gathered in interviews and meetings with representatives of URU advocacy groups in initial 1-on-1 meetings. Perspectives and inputs included the organizations' guiding paradigms as well as possible resistance to aspects of SAFE-UP's outcomes. Key points raised included concerns for how proposed AV systems will possibly infringe on personal freedoms, provide advantages for certain segments of road users while creating additional risks or burdens for others, shifting of liability to the victim, hampering the goals of increasing active mode use and decreasing the proportion of passenger cars in pedestrian dense urban zones. The most critical concerns and relevant advice contributed by stakeholders are summarised in Table 4.2 and expanded in the following paragraphs.

Jaywalking is a design flaw, not a human flaw [14]

It matters how we communicate research on vehicle-to-URU crashes. The way we conceptualize 'road safety' affects formulation of the problem statement and the possible solutions explored. Walking and cycling advocates even criticize this term as deflecting from the real sources of 'road danger'. The fact is that historically, roads have been designed to facilitate car travel, not active mode travel, and all the dangers to pedestrians and cyclists stem from this reality. For example speed limits are largely designed for the safety of vehicle occupants, setting appropriate speeds for the manoeuvres required in the infrastructure settings (such as slowing down to enter roundabouts). Recent widespread campaigns (WHO UN Streets for Life #Love30) promote reducing speed limits in urban areas, based on evidence that lower speeds reduce URU injuries severity and likelihood of fatalities from crashes. As a planning and urban (re)engineering imperative this paradigm shift links to SDGs for decarbonization, decreasing urban traffic congestion, improving health through increased air quality and more active populations, and reductions in road fatalities and serious injuries. In the EU, fatalities among pedestrians, cyclists and motorcyclist make up roughly half [15] of all road fatalities.

Walking and cycling advocates point to the history of victim blaming to shift responsibility for car-to-pedestrian crashes away from motorists [16, 17, 18]. In the early 1900s, personal

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

automobiles exploded into unprepared urban spaces with shockingly high casualties. Lobbyists for the automobile industry invented the term 'jaywalking' and wrote 'news coverage' of crashes for newspapers, biasing the accounts to shift blame on pedestrians. [16, 17, 18] Familiarization with this history is important

Table 4.2 Stakeholder concerns, issues, perspectives on TE&A for URU safety in future AV traffic

Themes	Key Points
Identity (representation)	Being a pedestrians is a natural state, so interventions for safety must be universally applicable regardless of differences in, e.g. age, sensory-motor capacity, economic status, etc. Quality, therefore interventions must consider diversity in needs and capacity. Differently, cycling is a learned skill that requires sharing the road space with cars, leading to cyclists having a strong political identity. PTW riders are often misrepresented (e.g. collectively as risk takers) and underrepresented in research & urban mobility planning discussions even while they are recognized as important in future modal mix for variety of purposes (i.e. also for urban mobility, work) especially in Southern EU countries. PTWs are often left out of URU discussion by active mode promoters. [These points integrated from speakers in Motorcycling in a safe system w/s]
Terminology for VRUs	VRU classification system is problematic, e.g. grouping pedestrians, cyclists and PTWs can obscure important differences. 'Vulnerable' should be exchanged for 'unprotected'. Alternatively, 'preferred modes', 'active modes'.
Language of 'road safety'	Language used reflects the operating paradigm which influences problem-solving approach….the focus must remain on cars as the source of danger, not active mode use and unprotected road users as the problem.
The future is *not* now	It is hard to imagine or predict the realities of future traffic contexts and user needs …so how do we begin thinking about training, education & awareness for URU safety in mixed AV traffic? There are many more immediate safety needs and concerns yet to be resolved.
Preferred paradigm for road safety solutions: Look to source of danger, obvious solutions. Disconnect between OEMs and user needs (re: shared urban spaces)	Cars – mass and speed… reduce number of cars and their speed in pedestrian dense urban areas. Reduce number of personal vehicles in pedestrian dense urban areas; emphasize AVs for rideshare and public transport or segregate users. *"we want more car-less drivers, not more driver-less cars"*

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

Themes	Key Points
Training & education for walking, cycling – unintended consequences of messaging	Education or training on using active modes should promote uptake and enjoyment (health & sustainability SDGs); focusing solely on the dangers may discourage use.
Training for two-wheelers	Training on cycling is important for children, both for how to ride and how to be safe in traffic. Many schools have programs teaching the safe enjoyment of cycling. PTW riders need training and testing on hazard awareness and perception – cognitive aspects are not balanced or integrated with technical skill requirements. PTW riders need to be trained to TRUST the technology – safety systems work. Rider training can only address risk to a certain extent – the problem of drivers not noticing PTWs must be addressed with technology, i.e. CITS and warnings.
Training for car drivers Limitations in current driver/rider training and testing criteria. Training for driving instructors to be more effective. (standardize?)	Consensus on the need to train drivers in correct use of AD systems. Driver training in rules, protocols and skills will not necessarily bring the desired behaviour in traffic participation. There is a need for driver training that instils values and competence, not just the minimum to pass exams. Parents model norms and habits, not necessarily desired behaviour. Driving schools need guidelines on integrating training on automated systems including current lower automation levels.

for stimulating critical reflection on how we conceptualize and practice road safety.

There are a number of problems with taking a ‘follow the rules better’ approach targeting URUs. For one, once a rule is created, there will always be exceptions that have not been taken into account: if the rule is to ‘exchange a glance with a driver before crossing’, there will be people who can’t see or situations in which it is not possible (e.g. windshield reflections). Exchange of glances may not guarantee acknowledgement. On a motorcycle, it may be faster or more informative to take cues from vehicle motion or sound, as visual attention demands are dynamic and multiple.

Focus on participation failures by URUs, without reference to how the infrastructure may support ‘wrong’ behaviour, could obscure the real sources of danger and thus misdirect intervention efforts. What appears as sudden, unpredicted behaviour from a pedestrian or cyclist may in fact be the result of mutual sightline obstruction or abrupt transitions between URU infrastructural support and road traffic with no warning for drivers or URUs.

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under Grant Agreement 861570.

Who should receive traffic safety training? Ethics and appropriateness.

Discussion on this topic raised serious concerns regarding universality, infringement on personal freedoms, misallocation of institutional power, access and equitability, and shifting of liability to the victim. Institutions should not prescribe training programs for active mode use, since organizations and authorities should focus on removing road danger through (re)design, speed adjustments, policy and legislative changes. Any adaptations that pedestrians and cyclists could make should be seen as the lowest priority and solely a provisionary measure, thus TE&A raising goals on safety behaviour should be seen as complementary to a larger systems approach, but not be the main focus.

Another concern relates to access vs. exclusion in relation to proposed safety benefits of training (or technology). Any proposed intervention needs to consider the possibility that certain groups are excluded, e.g. the young and elderly, people with cognitive, sensory, physical impairments, socio-economic status, access, etc. We must be careful of unintended effects that privilege/improve safety for some users will disadvantage or increase risk for others.

The question of ethics and applicability of training is easier with PTW riders, considering the required skills and adherence to traffic codes. Cycling does require training, first in learning to operate the vehicle and then to operate it safely while interacting with traffic and infrastructure. In the Netherlands and Germany, primary school children have to take a mandatory cycling test. Required training may not be applicable or ethical for some groups, for example the young or elderly, who should nevertheless have free access to this mode.

The e-bike brings yet more safety questions, especially as they are increasingly used by the elderly, who suffer more single bike crashes with this mode due to the different dynamics. Additionally, drivers find it difficult to estimate the speed of *e*-bikes (similar to PTWs). This issue may be compounded by false expectations for lower speeds when the elderly are seen riding them.

Promotion of unprotected mobility modes

We need to think of vulnerable road users as *valuable* road users. Any TE&A effort to increase safety should especially encourage, rather than discourage, active mode use, since it is through the use of unprotected modes such as walking, cycling, riding PTWs and new micro mobility options that road safety can meet sustainability. To emphasize the importance of this conceptualization, advocates propose the term ‘preferred modes’ when speaking of walking and cycling. Motorcycles are seen as an increasingly essential part of the modal mix, especially in countries where it is a mobility necessity due to economic constraints or traffic congestion. In countries where PTW riding is optional but could reduce traffic congestions, perceived high risk may discourage use of this mode.

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under Grant Agreement 861570.

Key interventions to reduce dangers for URUs are targeting the redesign of vehicles and infrastructure and changes in policy and legislation. TE&A initiatives may provide an effective complement but should never be the main focus.

Educational messages and strategies needed to be carefully crafted to promote awareness of risks and uptake of safety habits, but without producing unintended negative effects of reducing active mode use by increasing perceptions of danger. Increasingly, children do not cycle or do not know how to cycle, in part because parents consider it to be too dangerous. "If you teach to ride a bike, you encourage a valuable mode; if you teach fear of cars, you discourage a valuable mode." On the other hand, the learner's context should be considered in assessing the feasibility of TE&A goals: if the driving norms and infrastructure are too dangerous, efforts to train children will look too dangerous.

Driver Training & AD systems

The EFA representative observed that how car drivers perceive interactions, and the behaviours they expect from other users, is based on their own experience. If drivers do not accept other road users' behaviours easily, it is likely because they do not understand the needs of other mobility users. The best drivers are thus the ones who already have experienced other mobility modes. To be a safe driver, it is therefore important to collect experience from different points of view. These viewpoints are in line with the research summarized in section 3.5.1 from the SWOV report, showing that a mismatch in expectations of drivers can cause perceptual failures.

EFA DRIVING TRAINING MATRIX

	EUROPEAN CAT "B" LICENCE	
	TO BE DONE IN DRIVING SCHOOL *(Depending by Country if testing the topic)*	SUGGESTED TO BE DONE IN DRIVING SCHOOL *(To be tested)*
THEORY	Norms of Behavior	Rules and Road Signs
	Road Safety	Marking
	Hazard Perception	Car Maintenance
	Liability & Responsibility	Hazard Perception Test
	Speed/Alcohol&Drugs/Distraction	Norms of Behavior
	Insurance Behavior	Insurance
	First Aid	Crash is not an accident
	Road Crash Consequences	
PRACTICAL	By Night	Parking and Vehicle Manouvring
	Rural Roads	Urban Roads
	High Speed Roads	Rural Roads
	Bad Weather Conditions	High Speed Roads
	Safe use of ADAS	Safe use of ADAS
	Eco-Driving	
	Urban Area and E-mobility	

Figure 4.1 EFA Driving Training Matrix [19]

The EFA is also concerned about how to integrate training on AV systems into the current driver training and licensing programs, since this has not yet been

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

established at the EU level. The EFA is currently proposing a framework, the Driving Training Matrix (Figure 4.1) [19] to provide updates to driver training curricula that will address the gap in training for drivers on their vehicle's current automation systems. They propose a matrix delineating between *knowledge* and *competence* aspects of the driving task, specifying necessary aspects of competence such as AV systems use, that are currently not included in driver exams but could be trained and evaluated by driving schools. The EFA Matrix was presented at the recent PIARC conference, "Connected and Autonomous Vehicles and Roads: A path towards a safer future", October 2021.

Training versus education and awareness

- **Training** is telling a person what to do, whereas **education** can provide critical thinking skills for making better choices, based on new knowledge acquired. While driver training is necessary, this may not ensure safe behaviour, which will more likely come through education.
- **Awareness raising** is making a person aware of reality and thus could be most useful for informing about new technology with its benefits and limitations.
- **PTW training** is not just about following road rules, it should also aim to increase operational, analytical and hazard perception skills, and the integration of these, in order to reduce the risk of finding oneself in a critical situation. Importantly, riders need training and practice on their bikes' new safety technology, both to understand how to use it and to trust it.
- **Pedestrians** (and potentially cyclists) are 100% of the population.. There cannot be licensing for pedestrians or tests that must be passed in order to be a 'safe pedestrian', Therefore TE&A efforts should be framed as educational and awareness raising goals.

General education or awareness information on safety is acceptable; required training on 'correct behaviour' e.g. for pedestrians from public authorities would be unethical and a misdirection of the power and responsibility of such entities (which should focus on removing danger). It is normal for parents, families and peers to share safety knowledge and teach children how to be safe. Schools are situated between parents and institutions. Safety education through teachers should include citizen training (activism) for how to promote and improve road safety in one's community. A particular concern was whether lack of training could be used to shift liability to a URU injured in a crash.

CITS and wearable devices for URUs

The response to wearable devices for URUs to receive warnings was a decisive 'no' from pedestrian and cycling advocates. The objections covered a range of concerns, including

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

safety, freedoms, capacity, equity and liability issues. One of the main concerns was how this technology may disadvantage road users who cannot or choose not to use such devices.

Although WP3 – Demo 4 is not targeting PTW riders, motorcycle interest groups are strongly in favour of CITS systems to improve communication between PTWs and other vehicles. A strong safety benefit is anticipated when the CITS systems can help to compensate for the common failures of drivers to notice approaching PTWs or misjudge speed and gap. ACEM's program Safe Ride to the Future 2.0 outlines the motorcycle industry's strategy for promoting motorcycle use and implementing advanced safety technology and future connectivity. ACEM, FEMA and IFZ all support the efforts of the Connected Motorcycle Consortium to advance implementation of this technology, which is recognized as essential to reducing the frequency of death and serious injury of motorcyclists in crashes with other vehicles, or alone in curves.

The expert on ITS implementation and speaking on behalf of the Stakeholders public-private partnership on ITS (ERTICO–ITS Europe) whose members include a number of OEMs, CITS providers and national Ministries, highlighted how CAVs will 'see' very differently than humans in cases of automation, using digital landscapes. This could impact the nature of how our (as URUs) interactions with vehicles will change. As the SWOV report highlighted, interactions fail and result in conflicts when traffic participants interpret contexts differently. Education and awareness on these differences will be important to ensure safe interactions between URUs and AVs. Especially interesting is the fact that , as the ITS expert stated, the transition between low and full automation will be of some decades' duration, making it imperative for us to first become educated and aware on how to behave (and how vehicles will behave) in what is called mixed traffic: the situation where automated vehicles and legacy vehicles will co-exist. Mixed traffic will require URUs to behave in a way that is safe for both types of vehicles and to perceive 'safety' with two (parallel) meanings. In addition, connectivity is designed to benefit all, founded on a shared responsibility logic. CITS will not work if we do not all participate.

4.1.2 WP2 Task 2.1 Initial SCS and identification of target safety themes

4.1.2.1 T2.1 aims & summary of results

The new analyses of crash data performed in T2.1 tell us about the situations that account for the most frequent and serious crashes between URUs and car drivers in urban areas. Included in the outcomes are the specific factors that influence how, where and why these crashes occur. Results were provided on car-to-pedestrian, car-to-cyclist and car-to-PTW crashes. Relative frequencies were established by scenario types, categorized by the relative motions between traffic participants just before the collision (e.g. whether the car was travelling straight or turning left or right, whether the URU was crossing from the left or right). These separate scenarios were then correlated with frequencies of injuries and fatalities to estimate relative overall frequencies for different scenario categories and when

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

analysed in combination with possible contributing factors. The defined scenarios are provided in Table 4.3.

4.1.2.2 Car-to-pedestrian and car-to-cyclist Safety-Critical Scenarios

Possible contributing causal factors were examined. These included infrastructure context (e.g. within or outside an intersection), presence of crossing support for pedestrians & cyclists (designated vs. non-designated crossings) and sight obstructions. In addition, frequencies of scenario types were compared for differences in good versus adverse weather conditions. Finally, behavioural factors to do with missing communication between the driver and URU, traffic violations and judgement errors were investigated for possible differences related to the infrastructure context and weather conditions.

An investigation of naturalistic driving data (NDD) supplemented these analyses based on data drawn only from crashes resulting in injuries or fatalities. Recordings from driver's points of view and actions as well as cyclists' actions provide insights into the interactions that result in near misses or crashes.

The details provided by the T2.1 analysis are important to the design of the active safety systems for enhanced URU detection and collision avoidance, and for the development of the CITS on-user warning system delivered through an app. They also provide detailed insights that may be applicable to an update of general public knowledge and understanding of traffic participation risks, which can be contextualized in the current widespread paradigms of the Safe Systems Approach and Shared Responsibility. To provide TE&A to all road users based on these and future SCS results, we try to adopt a similar approach by providing educational materials and activities that do not merely target individual URU types but rather promotes the understanding of modal-specific risk within an overall view of shared participation and understanding of each other's needs and requirements. In addition, instead of attempting an admonitory approach of trying to get road users to conform to rules and protocols ("incorrect" behaviour-punishment approach), we aim to engage on cognitive and metacognitive levels to encourage participants to better understand and evaluate the specific risks and failures leading to crashes and to make better choices based on a value of shared responsibility.

4.1.2.3 Car-to-PTW Safety-Critical Scenarios

Analysis from two different studies using the Motorcycle Accidents In Depth Study (MAIDS and the German In-Depth Accident Study (GIDAS) databases provide new details about the conflict scenarios that account for the most frequent and serious crashes between PTW riders and car drivers in urban areas. Analyses on crashes between cars and small versus large PTWs, separately, revealed some important differences that may be related to differences in use cases. Particularly, small PTWs (<= 50cc engine size) also include scooters and mopeds. Overall, for both groups, the majority of car-involved crashes occur in urban areas, however riders of large PTWs were more at risk for fatal crashes in rural areas in oncoming longitudinal (parallel paths between vehicles) scenarios. Behavioural failure characteristics of the respective crash participants were related to the conflict configurations, infrastructure, sight obstructions, adverse weather conditions and respective

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

directions of travel of the participants. For example, rider failures were the more common main contributing factor in longitudinal crashes, whereas failures by car drivers were more common in crashes when the car tried to cross the path of the PTW.

Car-to-pedestrian	Car-to-bicyclist	Car-to-PTW
PC moves forward 1. Pedestrian crossing from left without sight obstruction† 2. Pedestrian crossing from left with sight obstruction† 3. Pedestrian crossing from right without sight obstruction† 4. Pedestrian crossing from right with sight obstruction† 5. Pedestrian walking in longitudinal direction PC moves backwards 6. PC reverse PC turns 7. PC turning left 8. PC turning right PC in other crashes 9. Other	PC moves forward 1. Bicyclist crossing from right† 2. Bicyclist crossing from left† 3. Bicyclist longitudinal same direction 4. Bicyclist longitudinal opposite direction PC moves backwards 5. Bicyclist in conflict with PC reversing PC is stationary 6. Bicyclist in conflict with stationary PC PC turns 7. Bicyclist in conflict with PC turning left† 8. Bicyclist in conflict with PC turning right† PC in other crashes 9. Bicyclist Other	PC moves forward 1. PTW crossing from right 2. PTW crossing from left 3. PTW longitudinal same direction a. PTW ahead longitudinal same direction b. PTW following longitudinal same direction 4. PTW longitudinal opposite direction PC moves backwards 5. PTW PC reverse PC is stationary 6. PTW in conflict with stationary PC PC turns 7. PTW in conflict with PC turning left 8. PTW in conflict with PC turning right PC in other crashes 9. PTW Other

Table 4.3 Safety-Critical Scenarios defined in T2.1 [1]
PC = passenger car. Scenarios highlighted in blue font were prioritised in T2.1 as those having >10% of the shares for all injury cases and killed or severely injured (KSI) cases. Additionally, the † indicates the SCS further defined as most relevant for advanced intervention systems and infrastructure-based CITS support (Demos 3 & 4).

Authors of the MAIDS study combined an in-depth analysis of crash causal factors in SCS to propose specific training interventions for car drivers and motorcycle riders, and underlined the potential safety benefits of CITS and automated emergency systems to support riders and drivers at junctions. Characteristics of longitudinal crashes suggest the potential for onboard systems to support the rider and mitigate failures that contribute to longitudinal crashes. In looking towards future SCS, the results highlight the need for AVs equipped with effective PTW detection at junctions, and the likely increased risk to riders if detection systems function poorly. Meanwhile, it is a consistent problem that drivers and

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

riders still do not understand human limitations in perception, speed estimation and reaction time.

For car-to-PTW crashes, urban crashes made up 94% of cases for small PTWs and 85% of cases for large PTWs. For small PTWs crossing crashes covered 37% of all injury cases and 56% of KSI cases. Large PTWs crossing crashes covered 34% of all injury cases and 34% of KSI cases. It was notable that in longitudinal oncoming involving large PTWs, 30% of KSI cases were in rural contexts. The defined scenarios are provided in Table 4.3.

4.1.3 WP2 further analyses and Task 2.5 Future Safety-Critical Scenarios (SCS)

As mentioned in section 3.5.2, in order to develop TE&A content on future SCS, WP6 must wait for results to come from other work packages that may not be available until the later stages of the project. In the T2.1 activity, due to timing constraints, a planned further detailed study of driver behaviour in both critical and non-critical situations using NDD analysis will be shifted to T2.2. The analysis will be used to calibrate the simulations in T2.2 to T2.5 for determining the future SCS. While awaiting T2.5 outcomes, results from the T2.2 analysis may be relevant for TE&A objectives and progress will be followed by WP6. Regarding all developments from WP2, feasible updates to targets and activities for WP6 will be planned accordingly. The authors of D2.6 remark, "…such an analysis may also be relevant for the identification of safety-critical scenarios that typically do not lead to crashes today but could potentially have high crash risk in future traffic." Such findings would be very relevant for education and awareness for future safety.

4.1.4 DEMO 4 Delivery of Timely warnings through CITS

The aim of T3.5 is to enhance the safety and visibility of URUs in future interaction scenarios with AVs by implementing CITS services connecting infrastructure, vehicles and smart devices of URUs for sharing position information to provide timely warnings of potential hazards. Importantly, both connected and non-connected URUs will be considered. For the non-connected URUs, sensors mounted on road-side units RSUs (infrastructure) will send warning messages to the vehicle. As there was an explicit statement in the call to promote use uptake of connected safety technology, Demo 4 activities will be followed closely for outcomes that are integrated to ongoing development of TE&A objectives.

4.2 SAFE-UP TE&A target safety themes and audiences

The overall target themes for SAFE-UP TE&A were determined from the project's objectives in light of further research into current gaps and discussions with external partners from the Advisory Board (AB) and the Safety Partner Network (SPN).

The themes outlined below in Table 4.4 reflect some adjustments and refinements of the general aims stated in the original call. These changes were required for more accurate alignment with the objectives and workflow timing of other SAFE-UP WPs, as well as

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

improved understanding of user needs through stakeholder engagement. Early on, WP6 interpreted Demo 4 as an opportunity to develop a training approach for users of the wearable app, however a user interface will not be developed in this activity. Instead, the focus is on a proof of concept with regard to the timing of warnings to URUs and vehicle emergency avoidance functions. In discussions with the Demo 4 partners, we agreed in principle on the potential for using outcomes for TE&A on the limitations and safe operating parameters of such CITS systems. Through work in Task 6.3 on stakeholder engagement (Safety Partner Network) to integrate expert advice and perspectives on URU needs, additional gaps and suggested training needs have been identified: Training for OEMs, public authorities on communication and engagement with URU groups to enhance development and implementation of interventions. General themes identified for TE&A objectives

Table 4.4 General themes identified for TE&A objectives

Safety Theme / Area	**Target Audience(s)**	**Focus**	Comments
Safety-Critical Scenarios	• All road users	• Car2URU analysis • Multiple POVs • Shared responsibility • Learner as multi-modal user	• Current SCS • Future SCS
Driver training on systems use (L2-L4?)	• Current drivers • Future drivers • Association of driving schools • Driving schools • Driving instructors	• Link to SAFE-UP innovations WP3, WP4	• A general approach to this issue is beyond the scope, timeline or available resources of SAFE-UP or WP6
Demos 2 & 3 Enhanced sensors & active safety Demo 4 CITS & app for URU smart devices	• All road users	• TE&A on System capabilities & limitations • Proof of concept – timely warnings can be delivered • How will unconnected URUs be protected?	• Regarding promotion of connectivity…how to generate acceptability?
Inclusion of URU advocates in planning & implementation of road safety innovations	• OEMs • public authorities • decision makers • researchers	• URU groups have expertise to address important gaps in how ‘road safety’ is conceptualized • Understand URU concerns & needs to guide better solutions	• Identified gap, disconnect between needs/desires of cities and road users & planning by OEMs and decision makers.

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under Grant Agreement 861570.

		• communication for buy-in, acceptance • adjusting paradigms to correct for bias	

4.2.1 Target URU subgroups as TE&A safety priorities

Different reports available on the relative frequencies of road crash fatalities and injuries, identifying high-risk contexts and risk factors as well as particular sub-groups of road users at higher risk. The SAFE-UP Task 2.1 deliverable D2.6 provides a summary from WHO and the EU Community Accident Road database (CARE) on overall crash statistics by region, mobility type, and infrastructure contexts as well as an up-to-date analysis (with data from 2018) on selected crash cases from the CARE and GIDAS databases.

Currently, this analysis did not differentiate by age or gender, so some older results are provided here. Although the SWOV report, *Safe interaction of automated vehicles with vulnerable road users* refers to data published by ETSC in Making Walking and Cycling on Europe's Roads Safer [15] covering the period 2011-2013, they identify specific high risk sub-groups among pedestrians and cyclists which have not yet been defined in SAFE-UP:

1. Most fatally injured pedestrians and cyclists are male
    - Males are consistently overrepresented in crash statistics
        - Pedestrian fatalities 36% female; 64% male
        - Cyclist fatalities 22% female; 78% male
2. Fatalities - are highest for older pedestrians and cyclists (dead per million population, dpM)
    - Pedestrians <50 years old: 7.5 dpM; 50-64 years old: 13 dpM, > 65 years old (highest fatalities): 28 dpM
    - Cyclists <50 years old: 2.6 dpM; 50-64 years old: 5.3 dpM; > 65 years old: 10 dpM
3. Children had the lowest frequencies of fatalities as pedestrians or cyclists. This does not necessarily reflect regional statistics – for some countries children have the highest fatalities.

A potentially important limitation of the T2.1 outcomes for TE&A scope relates to the data used to perform the in-depth scenario and behavioural analyses because of the necessary level of detail offered. The GIDAS data were collected in two regions in Germany (Hannover and Dresden), hence the relevance and specificity for target audiences and their specific contexts needs to be considered. In D2.6, the authors outline plans for WP5 (T5.3) to develop methodologies to extrapolate the results to the EU level for estimations of safety benefits of SAFE-UP safety systems. Additionally, these extrapolations may address representation of specific URU sub-groups such as children, elderly, road workers, etc.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

Relevant aspects of these analyses and outcomes will be incorporated into WP6 TE&A outcomes where possible.

Among motorcyclists, new licensees are at particularly high risk due to the high cognitive and motor demands of handling the bike while manoeuvring in traffic and watching for possible hazards. This understanding is reflected in graduated licensing programs. Websites promoting motorcycling enjoyment and safety also target seasonal risks, as seen when riders return to the road after not riding during the winter months. Older motorcyclists returning to riding after abstaining for extended periods are also at higher risk for crashes, likely due to loss of skill from disuse, possibly both motor and cognitive (hazard perception and anticipation). Motorcyclists also experience restricted vision from helmets. Motorcyclists are particularly at risk as a group because the slender shape makes them difficult to see or to estimate their speed of approach. There is current interest in assessing specific risks for pedelec (e-bicycle) users since they look like bicycles but travel at higher speeds, which may be unexpected for other road users, having consequences for their risk perception and decision-making.

4.3 Defining TE&A objectives from SAFE-UP outcomes and SPN engagement

This section presents the first cycle of TE&A objectives translated from T2.1 results on initial (current) SCS, as of September 2021. The identified objectives also take into account inputs collected thus far through engagement with stakeholders and external experts (Safety Partner Network and Advisory Board). In this dual approach it is possible to extract content from SAFE-UP research linked to relevance and need. This process is ongoing and iterative, as WP6 continues to identify and prioritize TE&A objectives based on:

1. Emerging project results from the other SAFE-UP work packages (2nd cycle);
    - Future Safety-Critical Scenarios
    - Demos 2, 3, 4
2. Knowledge User needs (considering multiple audiences, not just road users);
3. Ongoing engagement with SPN and expanded outreach;
4. Feasibility based on resources, time remaining in the project, and timeliness of the information (i.e. can it be useful and applicable now or will uptake and relevance depend on having reached certain milestones in AV penetration?).

Table 4.5 below summarizes TE&A objectives following the KT formula for planning pathways from research results to impact (MM + KU → KT goals → KT strategy). The Main Messages (MMs) here are in a first draft stage, to be refined further as necessary. The KT Goals and strategies columns provide some initial ideas for strategies. These will be

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

developed and defined as well as specific division of tasks between T6.2 and T6.3 (see steps 5-9 of the WP6 Workflow diagram, Figure 3.2).

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

Table 4.5 Translating SAFE-UP results and SPN inputs into Main Messages and TE&A Goals for specific target audiences

	Main message	Evidence	KUs -Target audience(s)	KT / TE&A Goals	KT & TE&A Strategies & Feasibility
ENGAGEMENT PROCESS	• Results on car-to-URU crash frequencies and factors must be translated to be appealing, relevant and accessible to the specific stakeholders & external expert audiences (e.g. Tier 1 KUs). • Presentation of results must be contextualized in concerns of cities and URU advocacy groups in order for results to be appealing and promote the credibility and relevance of the project for these groups (Tier 1 KUs and Tier 2 KUs organizations)	Input from SPN – (all encounters) Input from SPN and WP2 partners (Workshop 1) Too much time spent on gaps, omissions; responding to false criticism of gaps in analysis or faults with the research question.	Researchers Tier 1 KUs SPN Ministries & OEMs	Educate & build capacity among researchers to understand stakeholder information needs, working paradigms to more quickly towards problem solving based on identification of shared values and goals. Inform, generate buy-in, nurture trust, establish credibility & links to concerns and values of KUs to be relevant.	• Simplified infographics, summaries using appropriate language for target audiences as determined through the KT activities • Accessible and simple results summaries • Infographics as executive summaries • Short animations explaining what the project is doing, how it fits into the complete picture as one aspect of the solutions.
KT OF INITIAL SCS (T2.1)	• In anticipation of disruptions to traffic patterns in evolving AV traffic, SAFE-UP is developing safety innovations to protect people outside and inside cars, together with educational and awareness strategies to keep people up-to-date on safety technology developments and how to keep Unprotected Road Users safe.	Project motivations, aims and activities.	Tier 1 KUs (SPN, AB, external partners); general public	Generate awareness, buy-in and acceptance. Make the research available to a broad audience.	• Short explanatory video(s) • Other materials for broad audiences focussing on different content elements from video

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

	Main message	Evidence	KUs -Target audience(s)	KT / TE&A Goals	KT & TE&A Strategies & Feasibility
KT OF INITIAL SCS (T2.1)	• New analyses on crashes between passenger car drivers and pedestrians and cyclists highlight the most frequent scenarios resulting in serious injury or death to pedestrians. • New technologies are being developed to reduce the occurrence of these crashes by compensating for human errors and sensory limitations (such as limited visibility). • In future traffic, AVs will not commit traffic violations that put pedestrians & cyclists at risk. Until then, we can all do our part to keep unprotected road users safe. • New analyses of crash data tell us about the situations that account for the most frequent and serious crashes between car drivers and people cycling or walking in urban areas.	T2.1 results in D2.6: Initial Safety-Critical Scenarios	• Public • Infrastructure designers • Drivers • Cyclists & pedestrians • Mobility planners, policy-makers • Educators, parents • Driving schools	Inform, educate and promote general awareness; Improve or acquire specific skills: • e.g. for safer traffic participation, hazard perception • how to use the material to generate teaching and learning activities (educators) • using the evidence to inform driver's license training and testing policy • using the evidence to inform city planning, infrastructure planning and community activism Promote behaviour, practice change.	• Summaries, syntheses • Training modules using animations, in-depth crash data and/or crash reconstructions • approach: focus on understanding the traffic conflicts and interactions, from a multiple user POV, training all road users on specific risks to each modal user, in shared responsibility, system paradigm

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

	Main message	Evidence	KUs -Target audience(s)	KT / TE&A Goals	KT & TE&A Strategies & Feasibility
KT OF INITIAL SCS (T2.1)	• Naturalistic driving studies that record driver's points of view and actions as well as the pedestrians' and cyclists' actions provide insights into the human behaviour failures that result in near misses or crashes. • New understanding of car-to-URU interaction failures can inform (re)design for safer infrastructure. • New understanding of car-to-URU interaction failures shows how CITS will help everyone avoid crashes and keep people walking and cycling safe.	T2.1 results in D2.6: Initial Safety-Critical Scenarios	Broad and specific audiences	Various - TBD	• Training and active learning modules supported by Animations using multiple user POV • Animations using multiple user POV • Teaching and learning activities based around animations of SCS using multiple user POVs to demonstrate interactions
KT OF INITIAL SCS (T2.1)	• Future automated driving functions will help reduce the number of crashes caused by traffic violations, mistakes and misjudgements. Until then, we all need to understand why crashes happen and how we can prevent them.	First statement: support is equivocal Second statement: based on T2.1 results in D2.6: Initial Safety-Critical Scenarios	Broad & specific audiences	• Inform, share knowledge, • generate buy-in and acceptance; • improve hazard perception skills, behaviour change, road strategies and metacognitive skills for self-monitoring, adapting	• Multiple formats (e.g. interactive learning modules, infographics, tip sheets, summaries animations) providing different levels of detail • Animations using multiple user POV for SCS

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

	Main message	Evidence	KUs -Target audience(s)	KT / TE&A Goals	KT & TE&A Strategies & Feasibility
KT OF INITIAL SCS (T2.1) PTW RIDERS	• Critical car-involved crash scenarios for PTW riders continue to be junctions, with the most common cause being a failure of the driver of the opponent vehicle. Development and dissemination of effective educational and training schemes for PTW riders continues to be a priority, but must be accompanied by infrastructure and CITS based support to reduce danger and supply warnings between vehicle operators. • Enhanced sensors will take longer to implement for effective PTW detection.	T2.1 results in D2.6: Initial Safety-Critical Scenarios; report by Connected Motorcycle Consortium	PTW OEMs PTW associations Road safety councils ACEM FEMA & members CMC IFZ Driving schools Researchers Riders Drivers	• Inform, share knowledge, corroborate, compare • Identify common ground, goals and gaps • Inform, share knowledge; • Improve hazard perception skills, behaviour change, road strategies; • Metacognitive skills for self-monitoring, adapting behaviour to new situations	• Multiple formats (e.g. interactive learning modules, infographics, tip sheets, summaries animations) providing different levels of detail • Teaching & learning activities based around animations of SCS using multiple user POVs to demonstrate interactions
KT OF FUTURE SCS (T2.5)	*For now: this is what we are expecting to find……how the technology will help safeguard URUs from current risk scenarios*	T2.5 results: Future Safety-Critical Scenarios	Public Infrastructure planners, designers, educators	Inform, educate, promote general awareness; Train in specific skills e.g. • hazard perception; • correct use of AV systems (drivers)	• Updates to TEA materials previously developed for T2.1 results • New materials, time/resources permitting.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

	Main message	Evidence	KUs -Target audience(s)	KT / TE&A Goals	KT & TE&A Strategies & Feasibility
KT OF DEMO 4 (WP3)	• SAFE-UP demonstrates how using CITS technology, combining information collected from vehicles, infrastructure and connected URUs via wearables, can provide timely warnings of heavy traffic, risky areas, and correct use of systems (drivers) • Even combined with automated avoidance systems, there are limitations to how quickly vehicles can respond to avoid a collision. It is important for the public to understand what situations these systems can handle, and what would be the risks if the situation exceeds their limitations.	Demo 4 (WP3) timely warning systems	Drivers Cyclists and pedestrians Driving schools	Inform, educate and promote general awareness, user confidence.	• Informative videos about current SCS and how implementation of CITS developed in SAFE-UP will improve safety, what people will need to know • Other, TBD as appropriate and feasible

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

4.4 Proposed Training & Learning Design framework for developing educational & learning programs for URU safety in future traffic contexts

WP 6 has proposed adapting an existing evidence-based framework from higher education research to be implemented as a tool for designing effective & adaptable Training Educational and Awareness programmes. In applying the Constructive Alignment approach to TE&A in road safety innovation, we can facilitate WP6 outcomes using an existing methodology for effective educational course and program designing through alignment of:

1. Main messages (content) drawn from current and future Safety-Critical scenarios (WP2), active and connected safety technologies (WP3)
2. learning objectives (target outcomes as changes in knowledge, use and behaviour)
3. KPIs
4. Learning assessment and program evaluations.

To meet the requirement of creating updateable TE&A programs that match the pace of increasing AV implementation, Bigg's theory of Constructive Alignment (CA) is considered as an existing evidence-based framework to guide design of educational and training programs. Why choose an approach based on higher education research for TEA on road safety innovation? CA combines two areas of scholarship. Central to constructivist theories is the recognition of the importance of learner's activities in creating meaning and new knowledge. Alignment guides design of the three key elements of a program: learning objectives, teaching and learning activities (TLAs), and assessment methods. Current priorities in planning for future safe mobility call for approaches based on the Safe System approach and shared responsibility. Participation in traffic requires the complex interaction of multiple skills, spanning simple motor skills, procedural knowledge, dynamic analysis, decision-making, strategy, motivation, and social interaction. Most educational approaches only address knowledge and remembering [20], while higher cognitive functions such as hazard anticipation and mitigation strategies, or self-reflection on decision making are not effectively addressed. Fundamental to this CA is a systematic approach for ensuring that all relevant levels of knowledge and cognitive functioning are elicited in TLAs. In so doing, there is a better chance of creating TE&A strategies that can produce the desired changes in knowledge, practice and behaviour, along with effective methods for evaluating "performances of understanding" [21].

The following sections describe the essential characteristics of the approach and steps for applying it to WP6 tasks for translating SAFE-UP outcomes of future SCS and safety innovations into TE&A strategies. Supporting references and materials are provided in the References and Appendix chapters, respectively.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

4.4.1 Bigg's theory of Constructive alignment and application to TE&A for road safety innovation

> *Constructive Alignment is an approach to course design which begins with the end in mind (i.e. what should students know and be able to demonstrate at the end of the course). It assumes that when learning objectives, assessment methods, and teaching and learning activities are intentionally aligned, that the outcomes of learning are improved substantially (Blumberg, 2009). The process of constructive alignment emphasizes that students are central to the creation of meaning, and must be provided with opportunities to actively select, and cumulatively construct their own knowledge (Biggs, 1996).*
>
> *– Natasha Kenny, PhD Explorations in Higher Education [22]*

> *"…the careful specification of learning objectives is the most important step in the course design process because it informs all the other design choices."*
>
> *Whetten [20, p. 344]*

For decades now, research on learning and higher education has emphasized the need for a paradigm shift from content to outcomes, and from *teaching centred* to *learning centred* approaches [20] (Figure 4.2). This shift is motivated by the failures in the traditional transmission model of education, in which the focus is on the *expert's knowledge* and the *content* to be delivered.

Figure 4.2 Paradigm shift in educational design models from content to desired outcomes as changes in the learner

Just as current scholarship in education recognizes the need to be learner-centred, in order to facilitate uptake and implementation of research, KT emphasizes focus on the Knowledge User. The KT process involves the use of KU inputs to tailor the content and format of knowledge products to the users' context and requirements for information format and delivery.

The Constructive Alignment approach, instead of beginning with the educational content (*What should we teach?),* asks, *What changes in Knowledge, Capacity, Behaviour or Values*

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

do we want to see? By beginning with the end in mind, content choices and learning objectives are clarified and kept relevant. The aims of the SAFE-UP project already provide the statement of the overall objective: the reduction of URU fatalities and injuries from collisions with cars. The problem statement we address here is how to extract relevant content from the project results and translate these into learning objectives and educational strategies to maximize the positive safety benefits?

The paradigm shift seen in scholarship on learning and education of the individual resonates with a fundamental premise of Knowledge Translation: engagement with Knowledge Users in the co-creation of new knowledge or practice change. In KT of research results for social benefit, the KUs addressed could be individuals, groups or organizations. Both approaches recognize the limitations of one-way delivery of expert knowledge, without regard for how or if the knowledge will be used (or useable). KT scholarship highlights the limitations of this *push* approach for achieving research impact, taking a user-centred *pull* approach to extract KU interpretations on relevance, and needs for tailoring and targeting research translation. Best practice in both education and planning for research impact consider *who will use the information we have to share*. Involvement of the knowledge user or learner helps in defining the most useful and relevant aspects, and then in creating clear goals for desired changes in capacity, practice and behaviour.

Thus, T6.3 applies the KT framework, extracting Main Messages from project results. These MMs become the evidence-based content from which to formulate learning and awareness objectives with input from the target KUs, to better address their needs and contexts.

Next, applying the Constructive Alignment framework, the identified learning objectives are stated as clear Learning Outcomes (LO) describing what the learner should be able to do or understand as a result of the learning.

> *"..students learn best when they have clear learning goals and when comprehension is viewed as a means to the end of personally relevant learning applications…it is through meaningful application that lasting comprehension takes place." (Whetten [20] p. 345)*

Whetten [20] explains the relationship between learning objectives and content: "…learning objectives should focus on what students will be able to apply, analyse, evaluate, or create, with the understanding that remembering and understanding the relevant course content is a critical prerequisite." (p. 345) For example, drivers may remember road rules, such as 'give way to pedestrians at zebra crossings', but may not proactively anticipate or evaluate situations where they may, in their vehicle, present a potential risk to someone else, or include a sense of responsibility for others' safety as part of their decision-making.

With regard to current road risks and safety priorities addressed in training, these are outlined in the EC's GDE Matrix (Figure 4.3), "Goals for Driver Education". All the important safety and procedural themes appear to be included but are stated as *content* topics, not as what the learner should be able to do or how they can be taught to choose less risky

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

behaviours or reflect critically on their own decision-making processes. By restating content as performance outcomes in learner-centred terms, the program designer is forced to think deeply and specifically about what kinds of learning experiences could bring about a specific change in competence or behaviour.

Content of training: Best practice: The fundamental goal of the education, training and licensing process should be to create drivers who are safe, and not just technically competent….. Essential to this is a training process that engages novice drivers personally and emotionally, increasing their awareness of their own limitations and of the dangers inherent to driving. It is important to focus on the fundamental beliefs about driving, including assessment of the trainees own skills and motives for driving, as well as the basic skills needed for driving." [23]

GDE matrix

(Goals for Driver Education)

(Hatakka, Keskinen, Glad, Gregersen, Hernetkoski, 2002)

	Knowledge and skill	Risk increasing aspects	Self assessment
Goals for life and skills for living	Lifestyle, age, group, culture, social position etc, vs driving behaviour	Sensation seeking Risk acceptance Group norms Peer pressure	Introspective competence Own preconditions Impulse control
Goals and context of driving	Modal choice Choice of time Role of motives Route planning	Alcohol, fatigue Low friction Rush hours Young passengers	Own motives influencing choices Self-critical thinking
Driving in traffic	Traffic rules Co-operation Hazard perception Automatization	Disobeying rules Close-following Low friction Vulnerable r.u.	Calibration of driving skills Own driving style
Vehicle control	Car functioning Protection systems Vehicle control Physical laws	No seatbelts Breakdown of vehicle systems Worn-out tyres	Calibration of car-control skills

Figure 4.3 *GDE matrix for Driver Education.* Source: EC Mobility and Transport – Road Safety [23].

Note that in the description of the GDE Matrix [23] (Figure 4.3), the focus is on the *content* of training as the Best Practice measure. What is missing is the translation of these objectives into clear outcome statements about what drivers should be able to do, and following logically from these, what evidence-based learning activities will elicit these desired

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

changes in the learner, and how learning and behaviour change can be appropriately measured.

Bloom's revised Taxonomy of Educational Objectives (Figure 4.4), described in Krathwohl (2002) [24] is a tool for clearly defining Learning Outcome statements from learning objectives. It allows precise classification of educational goals along the two dimensions: type of *Knowledge*, described using nouns, and *Cognitive Process*, specified with active verbs. Krathwohl describes the process of drafting the LO statements as follows:

> *"Objectives that describe intended learning outcomes as the result of instruction [or activities] are usually framed in terms of (a) some subject matter content and (b) a description of what is to be done with or to that content. Thus, statements of objectives typically consist of a noun or noun phrase – the subject matter content – and a verb or verb phrase – the cognitive process(es)." (Krathwohl [24], p. 213)*

Examples of traffic participation skills stated in terms of relevant cognitive process using verbs:

- **Remembering:** Remembers that AV sensors systems predict pedestrian intent from head movements.
- **Applying:** Responds to request to take over control from automated driving functions at the freeway exit.
- **Analysing:** Observes traffic patterns and analyses them to search for potential hazards before taking an action.
- **Evaluating:** Determines when to engage or disengage an L4 ADS function based on current driving context and understanding of system use cases and limitations. Assesses traffic flow to decide when it is safe to cross at an uncontrolled crossing based on known risk factors.
- **Creating:** e.g. students use knowledge gain from training to create their own evidence-based safety messages that are relevant and engaging for them and their peers. Organizations adapt SAFE-UP knowledge outcomes to enhance existing safety campaigns and strategies or create new ones.

The *knowledge dimension* categorizes the subject matter content hierarchically from more concrete to abstract: Factual, Procedural, Conceptual or Metacognitive knowledge. Simply put, metacognition is thinking about thinking. Metacognitive knowledge relates to learner's awareness of their own thinking processes and uses this to adapt how they reason and operate. The *cognitive dimension* identifies the mental processes required, from simple to complex.

The hierarchical structure of the taxonomy can also be used to aid a progressive approach to learning design, with material and LOs of a simpler category considered as prerequisites to mastery of objectives at the next category. For WP6 TE&A aims, the Taxonomy hierarchy can also be applied to determining which LOs would be best achieved through specific exercises and interactive training modules with the opportunity for feedback (T6.2), and which could be achieved simply through sharing of inclusive information packets accessible

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

to broad audiences. The taxonomy will also help WP6 to duplicate content in different formats for different audiences, in providing the level of detail and complexity indicated by the specific KT objective (see Figure 3.1). Appendix 8 contains support materials to aid writing and coding of the LOs.

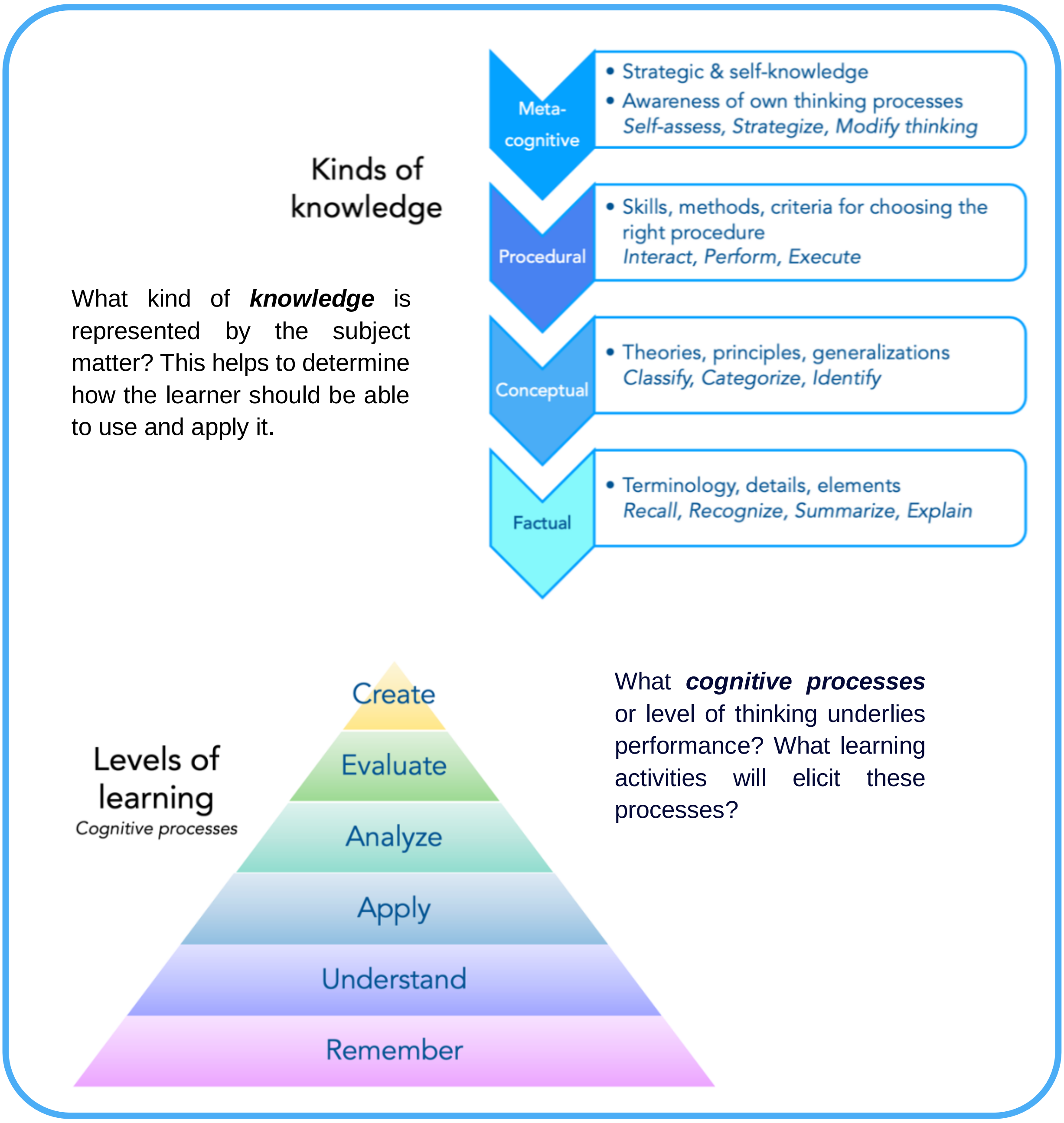

Figure 4.4 Bloom's revised Taxonomy of Education Objectives. Adapted from [24]

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

By applying the revised taxonomy, coding of each desired Learning Outcome informs the design and selection of appropriate teaching and learning Activities (TLA) and assessment methods. The same action verb used in a Learning Outcome can be used in creating TLA and assessments. This is a method for systematically ensuring alignment among the three key course design elements. This process of creating alignment of the three aspects should not be considered linear. By checking forwards and backwards, the different elements can be refined and the LOs further clarified. The program design elements and alignment process are depicted in Figure 4.5., with arrows between each element to illustrate the forward and backward process to ensure alignment. Learning outcomes are stated using active verbs – a few examples are shown in the centre of the figure. The verbs can also used to ensure alignment when creating TLAs and assessment methods to.

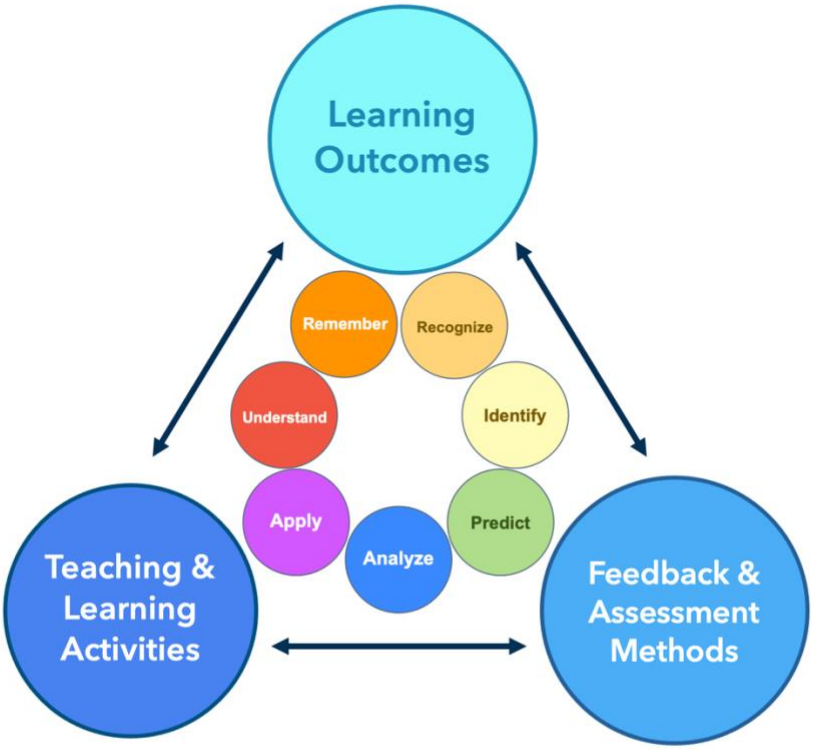

Figure 4.5 The three key components in course design, using the Constructive Alignment approach.

The Revised Taxonomy can be used as a way to cross-check, to make sure that the learning activities address all the knowledge areas and cognitive levels, and that there are no keeps or over-emphasized areas. Bloom's Taxonomy has frequently been used to assess how well educational objectives are distributed across the levels of the cognitive dimension:

> *"Almost always, these analyses have shown a heavy emphasis on objectives requiring only recognition or recall of information, objectives that fall in the Knowledge category. But, it is objectives that involve the understanding and use of knowledge, those that would be classified in the categories from Comprehension to Synthesis, that are usually considered the most important goals of education." (Krathwohl [24, p. 213])*

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

For road safety training, this approach can force us to think about possible ways to *engage learners at higher cognitive and metacognitive levels*, such as developing values of social responsibility and self-reflection on risk-taking or becoming a community activist to implement local change. Such goals will require reference to appropriate behaviour change models and research from implementation science. Table 4.6 is a simple example of an alignment diagnostic test.

Table 4.6 Course/KT strategy alignment diagnostic test.
Adapted from Whetten [20], p 353.

V KT & Learning Strategies	**Course/program objectives Or KT Goals**		
	Understand	Apply	Create
Infographic	X		
Interactive video online training module	X	X	
Guidelines for adapting materials for targeted audiences	X	X	X
Tip sheets	X	X	
Toolkit for community activism		X	X
Training seminar for policy developers	X	X	X

If we want education and awareness raising strategies to perform beyond simple diffusion of information to initiate change in behaviour and current practices, they must be founded on the scholarship on behaviour change. This requirement is recognized in the LEARN! framework and in research implementation (which is the next step in the pathway to research impact after Knowledge Translation). There are many evidence-based behaviour change models available in the research. The selection of which one to use depends on the specifics of the research results, context and behaviour change goals. The Behaviour Change Wheel of Michie et al. (2011) [25] in Figure 4.6 synthesizes 19 different behaviour change frameworks into a classification system and implementation tool for interventions. It is particularly interesting for road safety innovation, as it both reflects the complexity of the problem and provides a framework for thinking about a structured and evidence-based approach. We should note that the implementation of SAFE-UP results for behaviour change is beyond the scope of the project. However, through KT we can begin to lay the groundwork by informing, generating interest and buy-in. In addition we will begin developing educational and training materials using the framework, and then test them to obtain feedback in order to refine and update both the development methodology and the materials. (See section 8 Appendix for related resources on the Behaviour Change Wheel).

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

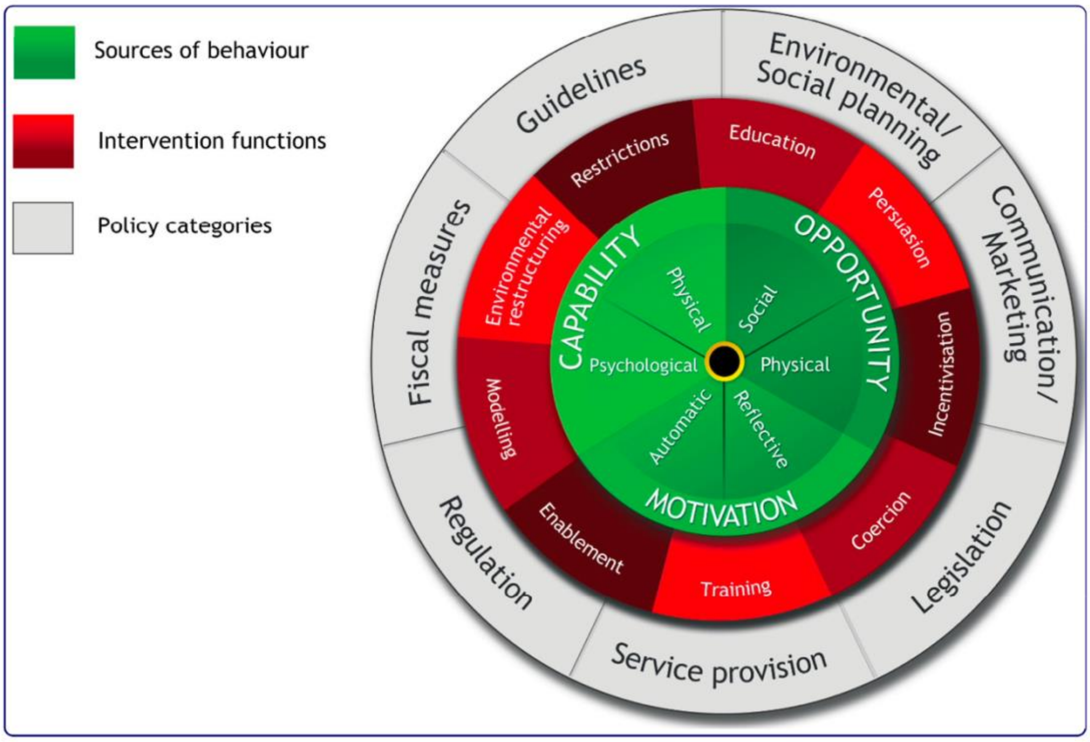

Figure 4.6 The behaviour change wheel: A new method for characterising and designing behaviour change interventions. Source: Michie, et al., 2011. Implementation Science [25].

Designing Learning Assessments

Whetten cites Wiggins [26], explaining the logic of this "backwards design" which proposes that consideration of how learning will be *assessed* is a prerequisite to the learning activities. Krathwohl [24] offers the following questions to guide selection of assessment methods:

- Given the stated LOs, what would be the best ways to assess learning?
- How can we assess higher learning outcomes (e.g. self-reflection, social responsibility, changes in values)?
- How can learning assessment activities be used to enhance and extend learning and engagement with the subject matter? (E.g. the assessment process further integrates the learning, promotes accurate perception of new skills and abilities and stimulates further learning).
- What would be the best evidence for learning from this course?

In considering the above, rather than presenting a learning module and then testing understanding through questions like, "what did you learn from this exercise", the following format could be used:

1. Introduce the purpose of the activity by explicitly connecting it to specific learning objectives.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

Example: After completing the activity unit, students will be able to evaluate potential risk areas in their neighbourhoods based on the SCS. Students will be able to justify proposed behavioural, infrastructural and CITS interventions to reduce risk.

2. Evaluate learning through questions probing ability to apply the knowledge. *Example: What did you learn from this activity about how to effectively evaluate potential risks to URUs as you approach different infrastructure contexts?*

This style of assessment also provides an opportunity to promote more deeply integrated learning, through reflection on how one's thinking has changed as a result. It also has the potential to stimulate ongoing learning through development of self-reflective and metacognitive skills. Thus we could take the learning activity one-step further:

3. What are some ways you could share or use your new knowledge to make changes in your own behaviour or community to reduce the danger for unprotected road users?

Now we are challenging learners to become proactive safety promoters, contextualized within their own peer groups and communities. At the same time, as researchers we can collect valuable feedback about how SAFE-UP results are most relevant to different KUs, and how we can generate more impact by involving KUs through engagement, dissemination and outreach.

4.4.2 Applying the TE&A approach to SAFE-UP outcomes

Figure 4.7 illustrates how the nested frameworks of the KT Plan and educational design can be used to translate and link SAFE-UP results to the desired user-level outcomes that will bring about the proposed safety benefits. The examples used for outcomes from SAFE-UP activities, key messages and desired outcomes are very general for simplicity. In application they would be much more specific as outlined in Table 4.5. A general outcome (KT goal) is determined based on an identified MM and a target KU. Then, going through the steps of design using Constructive Alignment, the specific individual Learning Outcomes needed to achieve the KT goal are itemized, coded by the Level of Learning and Type of Knowledge. Now we are ready to decide what KT strategies or teaching and learning activities would be most effective. Distinguishing between T6.2 and T6.3 subtasks (educational & training programs vs Safety Media Library and outreach dissemination, respectively) will depend on the strategies chosen for each goal. There will be supportive overlap between tasks as we expect to produce different materials in different formats for different audiences, but based on the same piece of evidence (tailoring and maximizing reach). For example if a desired Learning Outcome is to share new knowledge of specific risk scenarios, this can be done through infographics, research summaries or tip sheets shared with broad audiences. If the LO is to apply the new knowledge to do a local analysis on risk priorities, a practical course covering knowledge and skills objectives may be most effective. Both types of approaches and associated materials can also form different aspects in a comprehensive TE&A approach.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

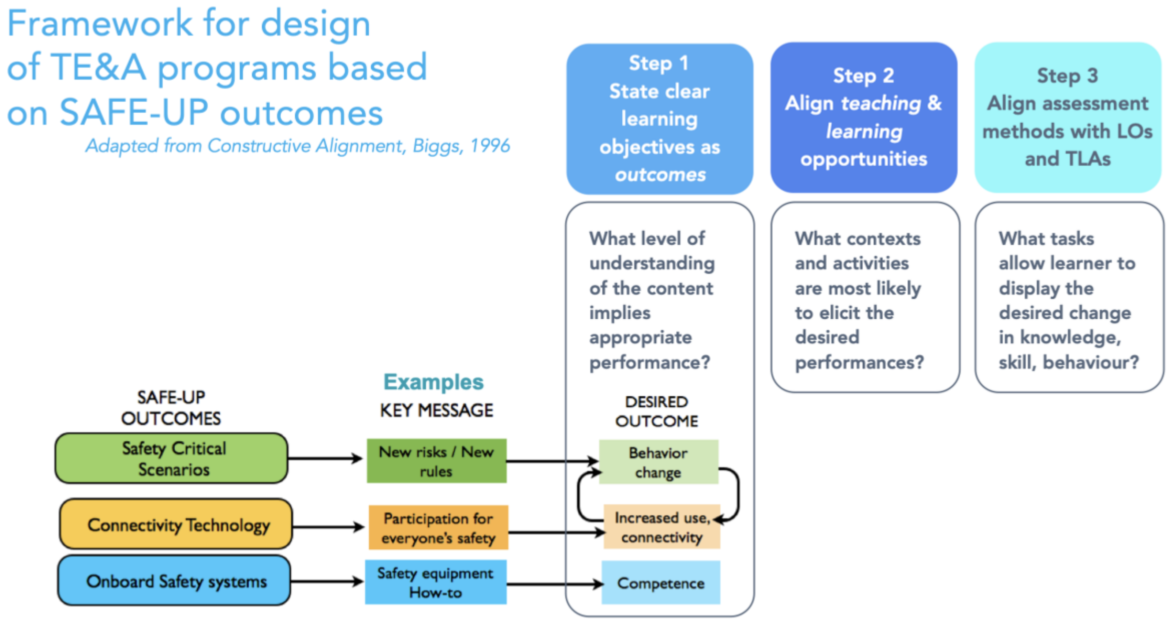

Figure 4.7 Nested KT & Constructive Alignment frameworks for translating SAFE-UP outcomes into TE&A programs

For each Main Message determined from the evidence, each overall learning objective is broken down into clearly stated target Learning Outcomes (LOs). The LOs are written as active verb statements describing specifically what we want learners to be able to do, or how we want their behaviour to change. Then each LO is coded according to the type of knowledge and cognitive process. This coding requires some deep thinking about the learning outcomes. In tandem with deciding on the learning activities and assessment methods, this becomes a backwards and forwards crosschecking process which will stimulate clarification and refinement of the learning objectives.

---

*"Learning objectives…. may outline the material the instructor intends to cover or the disciplinary questions the class will address. By contrast, learning outcomes should focus on **what the student should know and realistically be able to do** by the end of an assignment, activity, class, or course. For this reason, learning outcomes often start with a version of the phrase "By the end of this course, students will..."*

Source: University of Toronto [27]

Note that the Appendix contains more support materials to aid writing of the LOs and coding of the respective knowledge types and associated cognitive processes. Below is a list of points to keep in mind when writing the LOs.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

- State LOs in terms of what the learner should be able to do at the end of the course or learning module. Use verbs that best describe the function.
- Write the overall LOs first, then sub LOs targeting individual specific skills, behaviour, knowledge.
- The LOs can be stated explicitly before the learning activity so the learner understands the goals at the outset.
- The LOs can also be used by the learner as criteria for self-evaluation on learning, and for evaluation of effectiveness of the course after completing the learning activity.

Below is an example of a possible set of specific LOs for an educational module:

By the end of this training session, students will be able to:

- ✓ **Understand & remember** potential safety benefits associated with different automated driving and emergency functions.
- ✓ **Understand & remember** potential risks associated with AV limitations.
- ✓ **Identify** AV & CAV vehicle in the traffic flow.
- ✓ **Predict** the movements of AVs of different levels of automation.
- ✓ **Analyse** the environment for potential hazards to oneself and URUs.
- ✓ **Apply** appropriate actions to avoid conflicts.
- ✓ **Recognize** the benefits of staying connected as a URU.

After determining LOs, possible TE&A strategies (and assessment methods), need to be based on evidence demonstrating effectiveness. Proposed strategies will need to be evaluated for feasibility. Figure 4.8 illustrates the different considerations relating to choosing Target Audience, deriving goals and strategies based on Key Messages, and how these concerns must be evaluated with regard to Feasibility within the scope, timeline and resources of the project. For example, we may find that the most effective learning or behaviour change strategy for a given goal and target audience will not be possible due to constraints in resources, time or expertise. In such a case a “next best” approach could be taken, or opportunities for external collaborations could be explored. The framework can also be used to determine which goals should be targeted for dedicated educational and training schemes and which can be achieved through general educational and awareness raising strategies.

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under Grant Agreement 861570.

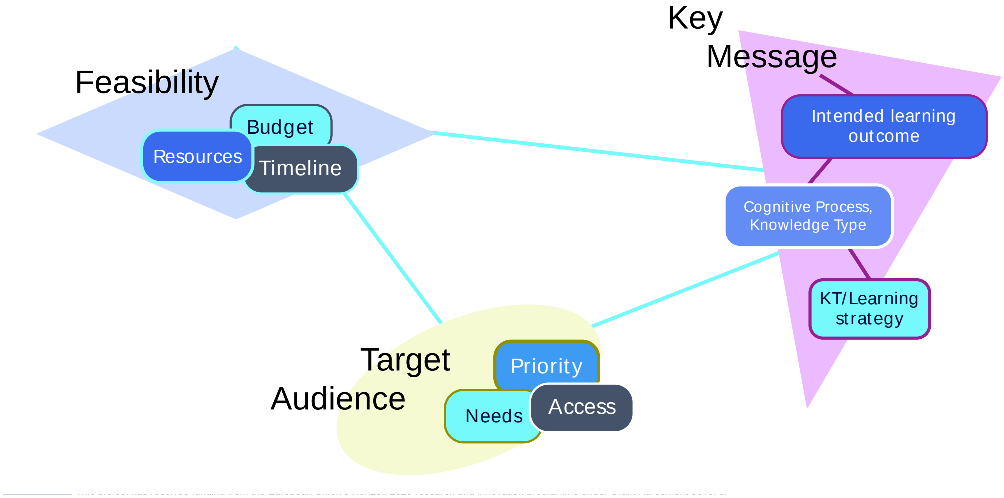

Figure 4.8 The framework can be used to prioritize TE&A goals and determine which will be produced in T6.2 versus T6.3 activities.

4.5 KPIs for TE&A programs

At the time of drafting of the project proposal, an initial list of general KPIs (below) for training and educational programs was outlined, to be refined according to findings on specific Knowledge Users needs and interests, and defined target TE&A activities. The KPIs should also include content, format and delivery, as well as user-centred tailoring (e.g. regional, age, etc.) of educational and knowledge products:

Initial list of general KPIs

1. Training programme effectiveness.
2. Potential impact on targeted users.
3. Training content relevance and accessibility to ensure user uptake.
4. Framework for training programme development is flexible & updatable
   - Allows updating of courses, dissemination topics and educational information.
   - In pace with increasing automation and advancements in road safety technology.
5. Media, formats and messages are inclusive, addresses diversity.
   - adaptable to specific user types, demographic groups.
   - relevant to cultural, regional & infrastructure contexts.

Detailed KPIs and suggested indicators for evaluating TE&A programs and initiatives to be carried out in T6.2 and T6.3 are presented in Table 4.7. These have been defined by integrating identified TE&A objectives with information collected on targets KU needs, and adapting evaluation guidelines and metrics from the Knowledge Translation Planning Template and the Constructive Alignment framework presented above in section 4.4.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

Table 4.7 Detailed KPIs & indicators for TE&A programs & initiatives

	Performance Criteria by category of Knowledge User (KU)		Performance Measures	
Performance characteristics	**WRT target KU(s) as road users**	**WRT target KU(s) as next KUs**	**Proposed Targets end-of-grant†**	**Proposed Targets by 2030**
Content Main Messages Learning objectives KT Goals	• Evidence-based – from: ○ SAFE-UP outcomes ○ Stakeholder inputs ○ Literature & crash statistics analyses ○ Future mobility roadmaps ○ road safety roadmaps ○ Roadmaps for CAV & CITS R&I? • LOs are clearly defined and coded by *knowledge type & cognitive process* • Updateable to integrate new evidence • Timely, i.e. applicable now or near future	• Internal, external experts and URU advocacy groups consulted & involved. • Evidence-based – from: ○ SAFE-UP outcomes ○ Stakeholder inputs ○ Literature & crash statistics analyses ○ Future mobility roadmaps ○ road safety roadmaps ○ Roadmaps for CAV & CITS R&I • Updateable to integrate new evidence • Timely, i.e. applicable now or near future	• Inclusion of relevant, high quality references • Number & type of organizations consulted, their relevance and positioning as influencers, representatives of users • Approval, acceptance of 85% of MMs defined • Collaborations – with who, what was the nature, importance • Each Learning Outcome is evidence-based	• Evidence of continued development and refinement based on SAFE-UP contribution
Content Relevance	• Detail of content matches user context (consider feasibility) • Addresses mobility choices/uses & known safety concerns • Timing (i.e. applicable to levels of AV penetration, current safety priorities)	• Detail of content matches user mandates & activities • Addresses internally identified priorities and gaps • Timing (i.e. applicable to levels of AV penetration, current safety priorities)	• E.g. 60% of URU associations surveyed give ratings of above average usefulness, effectiveness, etc. • Favourable comments & feedback from organizations (separated by type) • Favourable comments & feedback from learners, private individuals • E.g. Scale ratings >50%	• Has provided overall a sound basis for current knowledge • Has stimulated development of new knowledge in some areas • 10 citations for each key document in academic and other literature (e.g. policy reports, driver training programs, traffic safety and mobility educational programs)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

	Performance Criteria by category of Knowledge User (KU)		**Performance Measures**	
Performance characteristics	**WRT target KU(s) as road users**	**WRT target KU(s) as next KUs**	**Proposed Targets end-of-grant†**	**Proposed Targets by 2030**

Content & TE&A goals
 	
Acceptable
	• User-centred
	• Links to user paradigm/values
	• Language, word usage is appropriate
		• Aligned with organizational
		  ○ Values
		  ○ Interests
		• Activities
		• Create standards for 'how to communicate about road safety for URUs in current and future mobility planning'
			• Favourable comments
			• Suggestions for feasible improvements
			• Scale ratings >50%
			• Communication standards document accepted in principle
				• Shows min 25% improvements in previous scores
				• Demonstrated contribution to improving stakeholder engagement practices in the implementation of road safety innovation

TE&A Strategies	• *(Refer also to content criteria)*
	• Evidence-based
	  ○ Road safety education initiatives
	  ○ Learning models
	  ○ Behaviour change models
	• Feasible (KT plan → TE&A objectives updated regularly)
	• Alignment between LOs, TLA, Assessment methods
	• Addresses all relevant knowledge levels and elicits cognitive processes, according to stated LOs
	• TLA are engaging & stimulate active learning
		• *(Refer also to content criteria)*
		• Evidence-based (external partners consulted)
		  ○ Demonstrated interest in SAFE-UP outcomes
		  ○ Demonstrated interest in WP6 aims
		• Agreement with KUs on knowledge required, formats, and timing of exchange
		• KT plan (updated regularly)
			• Within limited WP6 budget or with receipt of in-kind assistance internally, or externally
			• Within project timeline
			• Coordinates realistically with timing from outputs from other WPs
			• Achievable with limited WP6 human resources (time, budget & expertise/capacity)
			• Alignment is confirmed through tools and collaborative peer assessment (researchers & interested partners)
				• Has provided overall a sound basis for current approaches
				• Approaches have been further tested, refined, developed
				• 10 citations for each key document in academic and other literature (e.g. driver training programs, traffic safety and mobility educational programs)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

	Performance Criteria by category of Knowledge User (KU)		Performance Measures	
Performance characteristics	**WRT target KU(s) as road users**	**WRT target KU(s) as next KUs**	**Proposed Targets end-of-grant†**	**Proposed Targets by 2030**
Effectiveness & potential impact	Objectives for learning, skill and behavioural changes are met • Self-evaluation • Performance scores • Knowledge change • Intended use • Attitude change (before vs. after) • E.g. number of driving school associations who have tested & evaluated TE&A materials	Objectives for informing knowledge exchange, skill, practice and behavioural changes are met • Knowledge change • Intended use • Attitude change (before vs. after) • E.g. number of driving school associations who have tested & evaluated TE&A materials Program or service indicators • outcome data • reports on implementation • feedback • process measures	• > 50% of Performance scores rate at > 50% • > 50% of organizations involved give favourable feedback • Overall scoring summaries for uptake, useability, usefulness, accessibility, reach etc.: • Qualitative evals of ‘beneficial & useful’ (of *harmful / neutral / beneficial)* ○ Any items rated harmful to be analysed, removed or remedied • Quantitative measures individually and overall > 50%	• Shows minimum 15% improvements in previous scores • Increased engagement and dissemination • Increased number of collaborations • Increased number of citations • Uptake and development of products (adding to knowledge, TE&A goals) and processes (adding to practice) created in SAFE-UP
Uptake & Implementation	• Shared & promoted through networks & memberships to their members	• Shared internally • Shared & promoted through networks and memberships to their members • Intent to use • How it will be used • Informs policy, practice *Depending on specific usage, needs*	• # of URU associations who have shared each item by user group represented • # of driving school associations who have shared TE&A materials • >50% expressing intent to use	• Report on recommendations for development of future TE&A based on evaluations of TE&A outputs • Proposed plan for tracking and evaluation strategies post end-of-grant • KU is an influencer

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under Grant Agreement 861570.

	Performance Criteria by category of Knowledge User (KU)		**Performance Measures**	
Performance characteristics	**WRT target KU(s) as road users**	**WRT target KU(s) as next KUs**	**Proposed Targets end-of-grant[†]**	**Proposed Targets by 2030**
Useability	• Fills a gap in knowledge needs • Is applicable • Format/presentation	• Fills a gap in knowledge needs • Is applicable to organization's processes and priorities • Level of detail meets needs • Format/presentation meets needs	• # of driving school associations who have tested & evaluated TE&A materials Use indicators (numbers) • *# intend to use* • *# adapting the information* • *# using to inform policy or advocacy, enhance programs, training, education, or research* • *# using to improve practice or performance*	
Usefulness	• Timeliness Use indicators • Read/browsed • Satisfaction • Usefulness of • Gained knowledge • Changed views	• Inform practice, policy, etc. Use indicators • Read/browsed • Satisfaction • Usefulness • Gained knowledge • Changed views • Systems change	Use indicators • Number of times read/browsed • Satisfaction Y/N; scale >50% • Usefulness Y/N • Gained knowledge (what?); performance scores • Changed views (how, what?) • Changes to systems (how, what?)	
Accessibility	• Hosted online where target KUs are seeking similar information • Broad & specific audiences • Universality • Diversity • Engaging, promotes sharing • Duplication of information in multiple formats, levels of detail	• SAFE-UP TE&A materials are shareable, accessible online • Summaries, synthesis papers, etc. provided as requested • Engaging – MMs are linked to concerns, mandates, activities, paradigms	• Not possible to address all categories in this project directly through materials created (see *Feasibility*). Collaborate with partners to tailor & disseminate	• Accessible in all EU languages • Known as a key source for TE&A materials and new research on implementing road safety for URUs

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

	Performance Criteria by category of Knowledge User (KU)		Performance Measures	
Performance characteristics	**WRT target KU(s) as road users**	**WRT target KU(s) as next KUs**	**Proposed Targets end-of-grant†**	**Proposed Targets by 2030**
Tailoring Road user mode, characteristics	• Choice of target groups are evidence-based • Specific risk groups (elderly, children, new drivers, road-workers) • mobility modes; • regions • infrastructure • cultural, behaviour norms, language • Individual differences: ○ e.g. age, gender ○ sensory-motor capacity ○ personality & motivations[?] • Engaging, promotes sharing	• Choice of target groups are active and important in road safety and/or URU advocacy • Information is delivered to who needs it, in formats they can use, in a timely manner • Takes into account their overarching paradigm, aims, interests and activities • Collaborative co-creation of new knowledge aids tailoring of results for their own use and their target audiences	TE&A for road users on URU safety First priorities • messages for broad audiences are general & inclusive (universality) • material translated into 3-4 languages; • specific risk groups will be addressed in an 'education from multiple road user POV approach'; • Training specifically targeting drivers & PTW riders. Next • More specific targets will be addressed based on testing and feasibility analysis, and also depending on outcomes from the future SCS simulation analyses (T2.5)	• Duplication in more languages • Refinement to address more, and more detailed, safety themes • Refined to address more specific targets based on emerging evidence and feedback
Updateable	• Framework allows definition of general evidence-based learning objectives and tailoring to different target learners • TLA design approach encourages feedback & inputs from the user/learner: new knowledge, regional data, self-	• TE&A strategies (KT) allows ○ integration of new knowledge (content, tailoring to KUs) obtained from next KUs (and as SPN is scaled up)	• Feedback, evaluations, new data will be collected and updates integrated into TE&A programs and materials (time allowing) • Report provided on recommendations for updates and improvements, including	• Estimation of continued use of materials? How they will need to be updated and adapted to changing AV penetration levels? • Processes established an streamlined to collect data for ongoing updates,

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

	Performance Criteria by category of Knowledge User (KU)		Performance Measures	
Performance characteristics	**WRT target KU(s) as road users**	**WRT target KU(s) as next KUs**	**Proposed Targets end-of-grant†**	**Proposed Targets by 2030**
	evaluations, program/materials evaluation • Delivery format includes methods to collect data for refining TLAs: ○ Learner performance data and inputs for updating & refining both content and TLA strategies • Integrates emerging results from other WPs into content & objectives	○ timely provision of new results from SAFE-UP to KUs ○ collaborative opportunities for co-creation of new knowledge and TE&A strategies to promote URU safety in current and future traffic	content and process aspects to updated versions and • Recommendations, lessons learned	determination of new TE&A objectives.
Reach & Dissemination	• Scalable distribution • Potential for regional tailoring • See *Accessibility & Tailoring* above	• Shared with relevant organizations & their memberships • Organizations assist in dissemination & recording of reach, use, usefulness measures • KU is an influencer – enhances exposure Champion for a specific initiative *(see feasibility)*	• # and type of dissemination partners • # of platforms on which material is available on and functionality Reach indicators (# distributed, # requests, # downloads/hits, media exposure	Requires an implementation plan (including mass media campaigns) which is beyond the scope or resources of WP6 KT activities in SAFE-UP

Adds to research
 	
generates new data (this links to *Updateable*)
	• Training & learning modules provide new data by including new tools to collect:
	  ○ Performance (learning) measures
	  ○ Before and after measures (scores, attitudes, opinions, usefulness, etc.)			

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

	Performance Criteria by category of Knowledge User (KU)		Performance Measures	
Performance characteristics	**WRT target KU(s) as road users**	**WRT target KU(s) as next KUs**	**Proposed Targets end-of-grant†**	**Proposed Targets by 2030**
	• Strategies to collect evaluations TE&A items are included in design of modules ○ E.g. each online item is linked to a feedback form to collect measures on intent to use, relevance, usefulness, suggestions for improvement, etc.			

Some of this information has been adapted from the KTPT©, SickKids® [9].

†Not all measures listed apply to both Tier2 KUs (i.e. individual learners, TLAs targets) and Tier1 KUs (stakeholder organizations, general dissemination targets). # = number (quantity).

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

5. Approaches to defining TE&A priorities in future SCS

5.1 Initial training priorities in future SCS

In the original Grant Agreement, we foresaw the following possible priorities for TE&A targeting car drivers (which are also applicable to PTW riders):

- *Specifically, drivers will receive information about the following:*
    - *Adjust their actions (related to strategical, tactical and operational skills);*
    - *Organize and allocate their driving tasks, taking into account the presence of AVs in the road environment;*
    - *Enhance existing participation and driving communication skills.*

- *Similarly, URUs will be informed so that they can:*
    - *Adjust their actions (related to strategic, tactical and operational skills);*
    - *Enhance perception and anticipation of risks associated with new traffic patterns, AVs and different vehicle occupant roles;*
    - *Identify risks associated when crossing transition zones, having different levels of digital or infrastructural safety support or automation levels;*
    - *Understand the safety benefits of new connectivity tools that provide warnings and communications between URUs and other road users and increase the use of these systems;*

We will re-evaluate these TE&A aims in reference to results emerging from T2.5 on future SCS and interactions between AVs and URUs. In the meantime the strategy will be to

- Start with LOs based on initial SCS and behavioural factors identified as contributing to crashes
- Consider how these interactions may change with the introduction of safety systems developed in SAFE-UP.

5.2 URU-vehicle-AV conflicts tool for categorizing possible URU-to-car interaction risks

Table 5.1 is a possible tool to categorize car-to-URU interaction types, from inputs from WP2 and WP3 scenario analyses. The aim is to use it to help define, organize and prioritize T&A targets by URU type, scenario and behavioural aspects of both participants. It can also be

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

used as an aid for discussions with WP2 partners to get inputs for WP6 and assure accurate translation of research results into Main Messages.

The tool is structured to conceptualize interactions along two dimensions, one representing the URUs POV of the AV and its possible behaviour; the other representing the AV POV on the URU and their possible behaviour. Each one is given three levels of performance (which are not necessarily hierarchical).

The behavioural analysis results from D2.6 can be integrated into the matrix to inform TE&A priorities. A different template can be created and filled for each URU type and scenario. Details can be added in each cell to predict, *“No conflict”* or *“Possible conflict”,* according to different contributing factors (e.g. infrastructure, weather, URU individual factors). Note that this could change depending on the URU group or sub-group considered.

The example in Table 5.1 uses scenarios of designated crossings and pedestrians crossing from the right or left side in front of the vehicle traveling straight. To analyse the possible combinations, tables are created for each scenario and URU combination, with AV factors on one axis and URU factors on the other. Two examples are provided below (Table 5.2 Pedestrian at designated crossing; Table 5.3 pedestrian at undesignated crossing), which were partially filled out by the WP6 researcher and then refined with feedback from technical partners. Thus the greyed-out areas define non-relevant possibilities or considered beyond the scope of the project. Note that where an interaction is determined as resulting in *no conflict,* it does not mean no education or awareness is needed - no conflict may depend on learning a communication strategy for example.

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under Grant Agreement 861570.

Table 5.1 Matrix to categorize possible conflicts to prioritise TE&A objectives and targets

AV Performance	PEDESTRIAN POV		L4 AV POV	URU behaviour
HIGH Optimal system functioning	AV gives precedence according to infrastructure, rules & signalization • Assumes no other relevant interaction partners No conflict		Pedestrian obeys rules, movements are predictable No conflict	HIGH BUT SITUATIONAL Optimal URU participation
CONDITIONAL Situation complexity may exceed design specifications even if functioning May not ensure URU safety	AV obeys rules, another vehicle* continues through designated crossing • Mixed traffic scenario* Possible conflict		Pedestrian entry into carriageway was sudden or an infraction, or exhibits unexpected changes of mvt speed or direction • Movements are unpredictable Pedestrian attention is misdirected, acts without properly assessing actual traffic scene or consideration of obstructions • Decisions to enter are inappropriate Possible conflict	RISKY URU or other actors show unpredictable or inappropriate behaviour
INSUFFICIENT Or OUTSIDE SYSTEM USE CASES Other interventions & safety strategies are necessary	AV functions fail or situation exceeds design limitations • Sight obstructions • Sensor malfunctions • TTC too short • Weather/light conditions • Operator failure (e.g. misuse, takeover failure) Possible conflict		Pedestrian individual inherent limitations • Vision, hearing • Height (children, also wheelchair....) • Motor capacity e.g. movement speed, nimbleness • Cognitive capacities (children, mentally handicapped, state impairment) Sensory, motor or cognitive failure >> possible wrong decisions (e.g. timing) leading to conflict Implications for CAV & CITS design to address these limitations.	REQUIRES ASSISTANCE OR MUST TAKE EXTRA CAUTION URU Functional limitations sensory-motor influence crossing performance

†Stopping AV could have become the sight obstruction when stopping.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

Table 5.2 Example of filled matrix for Pedestrian at designated crossing

Instructions: *Fill in (discuss) the grid for each square (scenario x VRU group)*

AV \ URU	CORRECT	RISKY *Including deliberate attempts to test AV response*	INHERENT LIMITATIONS or REDUCED CAPACITY
OPTIMAL	No conflict T&A for VRUs on importance of correct? What constitutess correct behavior…what about other users? Future perfect! For now, only freeways. Training for car drivers, PTW riders.	Possible conflicts But not appropriate to near future? Will be relevant to future drivers and standard traffic training for children.	Address as future guidelines? Refer to WP 3 outocmes on detection. Infrastructure & signalization should account for these groups?
CONDITIONAL	**Avs** will not be released into use if performance is conditional	**Avs** will not be released into use if performance is conditional	Avs will not be released into use if performance is conditional
	Misuse by operator could be important: parallel autonomy – AV detects a poss crash, tries to steer away. If driver holds the wheel they might interrupt the maneuver.	**Misuse by operator** could be important (parallel autonomy – AV detects a poss dcrass, tries to steer away. If driver holds the wheel they might interrupt the maneuver.	Likely conflicts VRUs must take extra care & attention to traffic in these scenarios. Communication with Avs? Wearable C-ITS warnings? (Demo 4)
INSUFFICIENT OR FAILURE	High conflict risk T&A relevant for L2, L3 – esp. Where there are not typically many VRUs Car drivers VRUs Will not consider VRUs on Hwy	High conflict risk T&A relevant for L2, L3 – esp. Where there are not typically many VRUs Car drivers VRUs	XXXX

Table 5.3 Example of filled matrix for Pedestrian at non-designated crossing

Instructions: *Fill in (discuss) the grid for each square (scenario x VRU group)*

AV \ URU	CORRECT	RISKY *Including deliberate attempts to test AV response*	INHERENT LIMITATIONS or REDUCED CAPACITY
OPTIMAL	***[What consitutes correct VRU behavior?]***	Possible conflicts But not appropriate to near future? Will be relevant to future drivers and standard traffic training for children.	Address as future guidelines? Refer to WP 3 outocmes on detection.
CONDITIONAL	**Avs** will not be released into use if performance is conditional	**Avs** will not be released into use if performance is conditional	Avs will not be released into use if performance is conditional
	Misuse by operator could be important: parallel autonomy – AV detects a poss crash, tries to steer away. If driver holds the wheel they might interrupt the maneuver.	**Misuse by operator** could be important (parallel autonomy – AV detects a poss dcrass, tries to steer away. If driver holds the wheel they might interrupt the maneuver. **Road workers** – (where do they fall?) Must be considered.	
INSUFFICIENT OR FAILURE	High conflict risk T&A relevant for L2, L3 – esp. Where there are not typically many VRUs Car drivers VRUs Will not consider VRUs on Hwy	High conflict risk T&A relevant for L2, L3 – esp. Where there are not typically many VRUs Car drivers VRUs	XXXX

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

6. Discussion

This deliverable aims to address the perceived need for training, education and awareness strategies to proactively ensure safety of URUs in future hybrid traffic contexts in which conventional vehicles, partial, and full AVs interact with Unprotected (Vulnerable) Road Users.

The process of introducing AVs to the market is likely going to be long and gradual, with fully autonomous vehicles restricted to certain areas, specified routes, or possibly segregated by infrastructure from other mobility modes. It is unlikely we will see private full AVs in urban areas – more likely public transport and ride shares operating at very low speeds will be used in the beginning. Thus it is likely people will be able to habituate themselves gradually in learning how to interact safely around these vehicles.

In the ideal future, AVs would operate and communicate in ways that are completely intuitive for people external to the vehicles, so no education would be required beyond the current basic knowledge taught to maturing children. Diverse stakeholders consider the idea of education for pedestrians in order to be safe around AVs as impossible, impractical and unethical. However, general awareness raising is likely to be needed, at least as a provisional measure, during the transition to CITS implementation and technological maturity of AVs and automated emergency functions.

A main point of consensus among diverse stakeholders and URU advocates is the need for better driver training, to enhance safety behaviour motivated by a sense of shared responsibility, and for skilled use of advanced safety and AD functions. We see important links with the EFA and the LEARN! initiative, as providing key channels through which SAFE-UP can share actionable, evidence-based messages to inform driver training and licensing and policy, and through schools in the preparation of future drivers and road participants.

The LEARN! framework for educational development on traffic safety and mobility shares many common priorities with SAFE-UP and the WP6 objectives described in this deliverable. As a key principle of the LEARN! framework, instilling good traffic participation behaviour early in life will be more successful than trying to change the habits of older drivers. Still, training updates for current licensees must be considered to keep pace with changing traffic patterns, risk scenarios and new required skills and knowledge. As well, young people may be more accepting of CITS technology as a way of life. Importantly, these efforts must be linked to the larger context of planning for future mobility, increased active mode use is seen as a key pillar spanning multiple SDGs, such as improved health, urban sustainability and air quality, and reduced traffic congestion [28]. Another commonly recognized priorities are the use of up-to-date evidence-based content; objectives going beyond simple knowledge acquisition to life-long behaviour change; metacognitive learning to promote self-reflection and sense of shared responsibility for road safety. And finally, delivery of information in positive messages that support active mode use, and that are relevant to the user/learner and their context.

Use of the terms ‘training’, ‘education’ and awareness’ carry different connotations for, and in relation to, different road users. The three concepts overlap, but distinctions can be

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under Grant Agreement 861570.

considered in terms of the *strategies* used to achieve each and the *purposes* behind their implementation. *Awareness raising* is indicated for changes or new evidence that affect everyone, and that can be achieved via a broad range of strategies, including public campaigns and community activism through formats accessible and relevant to a range of audiences. *Education* implies more detailed and broader knowledge tailored to specific learner demographics, with the general aim to provide enough background understanding of a subject area to allow the knowledge user to make their own informed choices. *Training* could be interpreted as organized activities designed to facilitate acquisition of specialized knowledge, protocols, or skills for (safe) application in a specific context and meeting identified performance standards. Successful completion of a training program suggests achievement of a level of competence required to operate in a certain domain. With this interpretation of training, it is easy to justify the state requirements for licensing of drivers and motorcycle riders. Training (for children in schools) may also be applicable to safe operation of a bicycle in traffic. Responsibility for the provision of such training is appropriate at a community level or school level, but would be unethical as a requirement for the use of this mode, especially, for example by the elderly. Since pedestrians are universal and considering basic human rights and freedoms, the idea of training for the right to move about one's neighbourhood on foot (or in a wheelchair, etc.) appears not only unethical but ridiculous. Considering all this, TE&A targets, as well as the language used to frame and present them, must be coherent with what is acceptable.

That considered, many see a future necessity for *education and awareness* for URUs about how to communicate with AVs. Since it is not yet determined exactly in which traffic context these interactions may take place, or what the AVs modes of communication will be, development of training on this topic now would be neither feasible nor timely. Instead we can focus on current SCS and begin to raise awareness on how hypothetical AVs could behave differently. At the same time we can begin to involve people in the discussion for their thoughts and opinions of possible concerns or solutions relevant to their own contexts. Such feedback could be collected in the form of questionnaires and assessments created as integral parts of educational materials and activities, and then be used to inform updates on current educational programs or inspire new ones.

Concerning behaviour change goals at the level of the road user, while behaviour and participation strategy training are always timely for drivers and PTW riders, such goals for URUs are not yet relevant regarding AVs. Looking ahead, we must ensure that any proposed goals for behaviour change are ethical. Messages must be carefully balanced, based on clear evidence about the roles of behaviour in car-to-URU interactions and carefully considering the role of unsupportive infrastructure for URUs and how this may interact negatively with URU needs, rights, priorities and capabilities. Importantly, "Road users should not have to operate in [or adapt to, be blamed for] a system full of flawed designs that increase the probability of error" [29].

Behaviour change objectives should also be informed by the concerns raised by active mode stakeholders regarding acceptance, sustainability and the changing paradigm for planning future urban mobility that emphasizes Safe System Design with URU safety as the keystone. It is important in planning for impact to consider extending the goals for behaviour (and practice) change to included organizations, policy makers, researchers, etc. as target audiences to support evidence-based implementation of road safety innovation. Finally, any

This project has received funding from the European Union's Horizon 2020 research and
innovation programme under Grant Agreement 861570.

strategies chosen for behaviour change goals should likewise be based on evidence from the literature in order to choose the most appropriate and effective models for the objectives and target audience.

The topic of CITS and wearables for URUs is a critical area for ongoing engagement and the search for the most effective approach for awareness and education. It seems imperative to proactively address possible barriers to acceptance in relation to Demo 4. It will be important to demonstrate the useability and safety benefit of connected apps through personal smart devices in order to promote acceptance of these technologies. It is also important to perform more general surveys among different user groups for their reactions to this technology, since opinions may vary widely by demographics such as age, culture and road user categories. SAFE-UP recognizes that the concept of “vulnerability” may increasingly come to include non-connected road users and those of low IT-literacy, in relation to increasingly connectivity amongst all road users in urban transport systems, and at digital divides between urban and rural contexts. This view has implications for targeted TE&A goals. Promotion and awareness should further underline how connected systems will include sensors on RSUs for detection and protection of non-connected users through warnings to vehicles. A key area relevant for URUs is how CITS could provide risk mitigation in relation to transitional zones where infrastructure supporting cyclists and pedestrians terminates abruptly into the traffic flow with no pre-warnings on either side.

CITS is seen in a very positive light by motorcycling researchers and advocates alike. Indeed it is considered essential to mitigating crashes resulting from drivers not noticing or giving precedence to approaching PTWs. Perhaps the positive enthusiasm of motorcycle proponents for this technology could be leveraged in combination with demonstrated safety benefits in order to nurture more widespread acceptance of URU participation in CITS.

To address the problem of how to develop an updateable approach to defining TE&A objectives and strategies to promote URU safety in future hybrid traffic, this deliverable presents an approach that combines and adapts two existing frameworks: Knowledge Translation for Research Impact and Constructive Alignment in Educational Design. The two frameworks are compatible in applying evidence-based processes to achieve changes in knowledge, capacity and behaviour. The two frameworks are complementary in that CA is focused at the level of the individual, whereas KT targets a range of KUs spanning levels from the individual to organizational and systemic.

KT processes are used to engage stakeholders to identify the most relevant and important aspects of research results for them. Additionally, collaboration aids tailoring of information to the knowledge user or learner. The Constructive Alignment approach aims to achieve educational goals through the careful design of programs focussing on desired outcomes and their associated types of knowledge and levels of thinking. In the context of road safety, this is particularly important for desired Learning Outcomes of higher cognitive skills and behaviour change, as well as skills and strategies for life-long learning. By blending these two frameworks, we do not restrict the definitions for either *learner* or *knowledge user*, suggesting instead these frameworks can be applied to addressing URUs and drivers, policy makers, educators, service providers, OEMs and legislators.

The proposed approach can be used in combination with existing training and educational models and guidelines (e.g. driver education syllabi) because it broadly considers the

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under Grant Agreement 861570.

cognitive functions and knowledge types rather than defining a specific content syllabus or pre-specification of teaching, learning, awareness raising or dissemination strategies. This approach also provides enough flexibility that program creators can take the same safety content and tailor it to different audiences and their contexts, using appropriate evidence-based strategies. Together with the scholarship on higher education, the framework complements the KT plan by providing a detailed methodology for program design and examples for developing engaging, relevant and effective teaching and learning activities.

The KT plan, developed and applied originally in agriculture and health research, is easily adapted to enhancing impact of road safety innovation – road safety is in fact considered a public health concern by the WHO. The overarching goal of KT is to optimize the uptake and useability of research knowledge in the real world to change practice and behaviour. This aim can be applied at all levels of the road safety realm, from EU level strategic planning to the people in the street. Additionally, the separate steps making up the KT planning Template as well as the iterative structure incorporating feedback, learning and updating resonate strongly with the process outlined in the LEARN! framework. In creating all TE&A initiatives and products, it will be important to present and inform about the technologies that will used in future automated traffic scenarios, based on demonstrated benefits for safety, and to clearly contextualize each safety system within a larger framework that includes complementary interventions that will provide an equal safety benefit for unconnected users.

Summary of feedback from SPN

- Inputs from advocates for active modes of the SAFE-UP Safety Partner Network revealed concerns about AV & CITS technology. There was repeated emphasis on the problem of inclusivity to ensure that the benefits of safety are accessible for all.
- Importantly, training or other interventions should not compromise basic rights or freedoms or have unintended consequences of reducing active mobility use or increase vehicle use (through increased perceptions of danger). The term ‘unprotected’ is preferred to ‘vulnerable’, since the latter implies a universal state rather that an effect of vehicle and infrastructure design.
- The sources of road danger should be kept in focus: large, fast vehicles and infrastructure designed primarily to support car travel. Safety interventions must not shift liability or undo responsibility for road safety onto URUs.
- In addition, Safety Network Partners were able to provide needs at the ‘micro’ level with respect to SAFE-UP’s initial Safety Critical Scenarios, emphasizing the importance of conceptualizing any interventions from a systems approach, specifically how infrastructure and the physical environment may disadvantage active modes in ways that encourage rule breaking or failures in noticing traffic or estimating gaps.
- These groups affirmed the growing worldwide imperative to reduce traffic volume and allowable speeds in urban areas, and the UNESCO sustainable development goals (SDGs) to promote active mode use for health and sustainability.

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under Grant Agreement 861570.

- The proposition of connected wearables for URUs was met with extreme reservations by walking and cycling advocacy groups, having concerns of personal freedoms and non-universality of use (i.e. children, elderly, handicapped groups not being able to use it). It will be important to present and promote this technology based on demonstrated benefits for safety, and to clearly contextualize it within a larger framework that includes complementary interventions to ensure an equal safety benefit for unconnected users. It is unknown at this point if the resistance expressed by these stakeholders is representative of what a general public response would be. However, this input helps to identify what kinds of URUs (e.g. of low economic status, inability to use connected devices) may be excluded from the intended safety benefits of such measures. The exchanges with the SPN further highlight the need to develop implementation plans addressing social and basic human rights issues.
- The idea of training for URUs must be handled delicately. For advocates of powered two-wheelers (PTWs), they would like to see more riders taking advantage of high-quality post-license training to refresh/improve/enhance both motor and cognitive (strategic participation, hazard anticipation) riding skills.
- Training on new safety systems was emphasized to improve trust in the technology that has been demonstrated to provide an important safety benefit.

Summary of Potential Objectives:

Based on the priorities and concerns identified in this deliverable, the following TE&A targets that should be considered:

- Increase awareness about the role of CITS, generate acceptance and buy-in through demonstration of how it functions to keep all road users safe, especially URUs, including non-connected. Demonstrate additional benefits of an app to deliver warnings to URUs, such as route planning to avoid congestion and higher risk areas or traffic problems, virtual cross-walk requests, connected with public mobility systems, safe warnings that put pedestrians needs before cars.
- Educate PTW riders and car drivers on PTW safety and the (near) future role of CITS to mitigate urban crashes between PTWs and other vehicles.
- Multiple user POV education on interaction failures in Safety-Critical Scenarios. Anticipation, strategies, and how new technologies will help. Also training and education for community activism.
- Promote correct use of onboard safety functions (ABS and the next generation of gizmos, car L2-L4) – for feasibility base prototype TE&A strategies on WP3 outcomes.
- Train vehicle drivers (including PTW riders) on the safe and responsible use of automated safety and driving systems. When users feel confident in the systems

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

capabilities, they use them more, because they feel comfortable using them and trust that they have a safety benefit for themselves and others.

- All road users – Promote adoption of shared responsibility attitudes through education and awareness on how interactions between vehicle drivers and URUs break down and result in crashes, as well as non-supportive infrastructure contexts to be alert to for URU safety.
- Through TE&A activities and materials, stimulate creative and critical thinking about: 1) assessing one's own environment to identify problems, 2) possible strategies and remedies for current risks, 3) predict how safety innovations may change the situation, positively or negatively, 4) what do we need to know? 5) what can we do now?

The following principles have been recognized as important to guiding our ongoing methodology and development for TE&A interventions to ensure they will be relevant, timely and acceptable.

1. **Shared responsibility & the Safe Systems approach**

The concept of Shared Responsibility extends from a Safe Systems approach, which, in a fundamental shift away from a "blame the road user" focus, looks to crash causes across the entire road transport system: infrastructure design, speed limits, vehicle safety features, education, legislation, licensing and enforcement. Shared responsibility thus implies that we all play our part (as individual road users, and as the researchers and innovators, organizations and authorities responsible for providing the road system) in ensuring the safety of ourselves and others.

2. **Engagement with stakeholder groups and research knowledge users throughout the project**

Representatives from relevant stakeholder groups within in the road safety ecosystem, including URU advocates and associations must be engaged throughout the project to inform (and collaborate on) TE&A efforts. This will ensure inclusion of all points of view and expertise on road users which is fundamental to ensure relevance of translated research results for users, as well as to enhance buy-in, acceptance and uptake of project outcomes.

3. **Multi-stage approach to developing TE&A content and objectives**

It is difficult for road users of today to imagine how future automation will impact their experience and behaviour as unprotected traffic participants. In kind, identification of future SCS and results on system development is emerging gradually throughout the project. Thus, it seems that the best strategy for WP6 is an approach to thematic content that includes the situation as it is today – the initial SCS and how this knowledge can be utilized now. This then forms the basis to explore the prospect of the introduction of connected intelligent transport systems (CITS), how it will function to mitigate current risks and how participation by all road users will improve safety for all. Finally, educational strategies developed on these two themes can be updated to include the future predicted risks for URUs in mixed traffic scenarios of conventional, partially and fully automated vehicles.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

4. **Multi-level approach to target audiences**

This takes into account the range of possible target audiences that can be considered for the TE&A goals. WP6 resources are limited and mass public educational campaigns are clearly beyond scope and feasibility. Therefore, to maximize impact, the strategy chosen is to consider all possible target audiences that can use the new knowledge from SAFE-UP in their own activities, programs and initiatives. For this reason, TE&A outputs will be reproduced in multiple formats, tailored and directed to multiple audiences from organizational down to private citizens. In this way we aim to broaden reach and optimize accessibility and shareability.

Determining TE&A priorities and targets will be an iterative, ongoing process as results continue to emerge though to the end of the project (and probably beyond). This deliverable defines the overarching targets and first priorities. TE&A objectives will be updated as part of ongoing T6.3 activities, and training & educational programs developed in T6.2 will be refined, updated and replicated in various forms, tailored to different audiences and purposes.

5. **Educational design models adapted from higher education research**

Leading models in teaching and learning theory emphasize learner-centred approaches to educational design for coherence between learning goals, activities and assessment methods. Goals should go beyond mere understanding and recall of material to include changes in behaviour, competence and critical thinking. Programs should be relevant to personal needs and context, and engage the learner at all levels of thinking, including higher cognitive and metacognitive processes. Higher learning objectives include lasting change and stimulation of life-long learning strategies. Learning should further facilitate individual decision making and choices, self-monitoring, and auto-adaptation of behaviour. These characteristics suggest potential for the model to address the need for educational strategies that match the complexity of skills, behaviours and values required for participating safely in road traffic, and for being able to adapt and learn in a changing environment.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

7. References

[1] Bálint, A., et al. (2021). *D2.6 Use Case Definitions and Initial Safety-Critical Scenarios*.

[2] ERTRAC. (2019). Safe Road Transport Roadmap Towards Vision Zero: Roads without Victims. ERTRAC Working Group: Road Transport Safety & Security. Retrieved from: www.ertrac.org

[3] EC. (2020). *Ethics of Connected and Automated Vehicles: recommendations on road safety, privacy, fairness, explainability and responsibility*. Retrieved from EC Mobility and Transport: https://op.europa.eu/en/publication-detail/-/publication/89624e2c-f98c-11ea-b44f-01aa75ed71a1/language-en

[4] EC. (2017). *The implementation of Directive 2006/126/EC on driving licenses. Final report.* Retrieved from EC Mobility and Transport. https://op.europa.eu/en/publication-detail/-/publication/bbd8141d-e603-11e7-9749-01aa75ed71a1

[5] EC (2018). "On the road to automated mobility: An EU strategy for mobility of the future". Retrieved from EC Mobility and Transport. https://bit.ly/2Lysy0s

[6] Aigner-Breuss, E., et al. (2021) The LEARN! Manual For Developing And Evaluating Traffic Safety And Mobility Education Activities. *The LEARN! Project: Leveraging Education to Advance Road Safety Now!* Retrieved from ETSC: https://www.trafficsafetyeducation.eu/manual/

[7] FEMA, & EC. (2011). *The IRT Model - European Initial Rider Training Programme*. Retrieved from EC Mobility and Transport: https://op.europa.eu/en/publication-detail/-/publication/4d20db53-f825-421c-9a66-fd54cbc157dc/language-en/format-PDF/source-238920639

[8] Kockum, S. et al. (2017) Volvo Trucks Safety Report. Volvo Trucks Accident Research Team. Retrieved from: https://www.volvotrucks.com/en-en/news-stories/magazine-online/2018/sep/safety-report-2017.html

[9] Vissers, L., et al. (2016). *Safe interaction between cyclists, pedestrians and automated vehicles: What do we know and what do we need to know?* SWOV. Retrieved from SWOV: https://www.swov.nl/publicatie/safe-interaction-between-cyclists-pedestrians-and-automated-vehicles

[10] *Introduction to Knowledge Translation.* [eLearning module] Retrieved from https://www.sickkids.ca/en/learning/continuing-professional-development/knowledge-translation-training/#tools

[11] Barwick, M. (2008, 2013, 2019). Knowledge Translation Planning Template©. SickKids® Learning Institute, Toronto Hospital.

[12] *How to Prepare a Knowledge Translation Plan*. [eLearning Module] Retrieved from https://www.sickkids.ca/en/learning/continuing-professional-development/knowledge-translation-training/#tools

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

[13] Heiden, T., & Saia, T. (2020). *Engaging stakeholders for research impact*. Retrieved from Austin, TX: https://ktdrr.org/products/KTDRR-Stakeholder-Engagement-Brief-508.pdf

[14] The Times Editorial Board. (2021). Editorial: "Trying to cross the street shouldn't be a crime". *Los Angeles Times.* Retrieved from: https://www.latimes.com/opinion/story/2021-09-22/decriminalize-jaywalking

[15] ETSC. (2015). *Making Walking and Cycling on Europe's Roads Safer (PIN Flash 29)*. Retrieved from ETSC: https://etsc.eu/making-walking-and-cycling-on-europes-roads-safer-pin-flash-29/

[16] Stromberg, J. (2015). The forgotten history of how automakers invented the crime of "jaywalking". *VOX*. Retrieved from https://www.vox.com/2015/1/15/7551873/jaywalking-history

[17] Loomis, B. "1900-1930: The years of driving dangerously". The Detroit News: https://eu.detroitnews.com/story/news/local/michigan-history/2015/04/26/auto-traffic-history-detroit/26312107/

[18] Norton, P. D. (2011). *Fighting traffic: the dawn of the motor age in the American city*. Mit Press.

[19] https://www.efa-eu.com/ European Driving Schools Association.

[20] Whetten, D. A. (2007). Principles of effective course design: What I wish I had known about learning-centered teaching 30 years ago. *Journal of management education, 31*(3), 339-357.

[21] Biggs, J. (1996). Enhancing teaching through constructive alignment. *Higher education, 32*(3), 347-364.

[22] Kenny, N. "Let's not take the constructive out of constructive alignment". Retrieved from Explorations in Higher Education: https://natashakenny.ca/2012/03/14/lets-not-take-the-constructive-out-of-constructive-alignment/

[23] Developing Learning Outcomes: A guide for faculty. Retrieved from: Centre for teaching support & Innovation University of Toronto https://teaching.utoronto.ca/

[24] Krathwohl, D. R. (2002). A Revision of Bloom's Taxonomy: An Overview. *Theory Into Practice, 41*(4), 212-218.

[25] Michie, S., van Stralen, M. M., & West, R. (2011). The behaviour change wheel: A new method for characterising and designing behaviour change interventions. *Implementation Science, 6*(1), 42. doi:10.1186/1748-5908-6-42

[26] Wiggins, G. (1998). *Educative assessment: Designing assessments to inform and improve student performance*. San Francisco: Jossey-Bass.

[27] Developing Learning Outcomes: A guide for faculty. Retrieved from: Centre for teaching support & Innovation University of Toronto https://teaching.utoronto.ca/

[28] EC. A fundamental transport transformation: Commission presents its plan for green, smart and affordable mobility [Press release]. Retrieved from https://transport.ec.europa.eu/transport-themes/mobility-strategy_en

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

[29] PIARC. Road Safety Manual *A Manual For Practitioners And Decision Makers On Implementing Safe System Infrastructure!* Retrieved from PIARC: https://roadsafety.piarc.org/en/road-safety-management-safe-system-approach/safe-system-responsibility.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

8. Appendix Support materials for Applying the training and educational design Framework

8.1 Reference sheets for applying Bloom's revised Taxonomy to LOs

The following sheets are provided to aid in writing statements of Learning Objective and applying Bloom's revised Taxonomy for coding the LOs them along the dimensions of *knowledge type* and *cognitive processes.*

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

Bloom's Revised Taxonomy: KNOWLEDGE Dimension

FACTUAL	Factual knowledge objectives require a learner to recall in verbatim, paraphrased, or summarized forms, lists, names or organized information. Learners are not required to apply the knowledge that they have acquired but merely to recall, recognize or state it in their own words. • Knowledge of terminology • Knowledge of specific details and elements
CONCEPTUAL	Learners are using conceptual knowledge when they are able to classify things into categories by their physical characteristics – whether visual, auditory, tactile or olfactory. If learners have acquired a concrete concept, they can identify examples of that concept. From a disciplinary perspective, conceptual knowledge allows the learner to recognize the interrelationships among the basic elements within a larger structure that enable them to function together. • Knowledge of classification and categories • Knowledge of principles and generalizations • Knowledge of theories, models, and structures
PROCEDURAL	Tells the learner in what order certain steps should be taken. Indicates how to do something; methods of inquiry, and criteria for using skills, algorithms, techniques and methods. • Knowledge of subject-specific skills and algorithms • Knowledge of subject-specific techniques and methods • Knowledge of criteria for determining when to use appropriate procedures
METACOGNITIVE	A learner is using metacognitive knowledge when they are aware of their own cognition. Metacognitive strategies relate to a learner's awareness, monitoring and regulation of cognitive processes. Comprehension monitoring strategies are sometimes referred to as metacognition or students' knowledge about their own cognitive processes and their ability to control these processes by organizing, monitoring, and modifying them as a function of learning outcomes" (Weinstein & Mayer, 1986). Metacognitive strategies assist the learner in determining whether they are understanding or learning. • Strategic Knowledge • Knowledge about cognitive tasks • Self-knowledge

Sources: Krathwohl, D. R. (2002). A Revision of Bloom's Taxonomy: An Overview. Theory Into Practice, 41(4), 212-218. Smith, P. L. & Ragan, T. J. (1999). Instructional Design, 2nd Edition. New Jersey: Prentice Hall.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

Bloom's Revised Taxonomy: COGNITIVE Dimension *Levels of Thinking*

REMEMBER Retrieving relevant knowledge from long-term memory	Instructional Objectives	Key Terms	
Remembering requires the recall or recognition of specific elements in a subject area in a way similar to how it was learned. In its simplest form, this includes knowledge of the terminology and specific facts associated with an area of subject matter. At a more complex level it means knowing the major sub-areas, methods of inquiry, classifications and ways of thinking characteristic of the subject area, as well as its central theories and principles. Testing for knowledge objectives requires that students offer the answer out of memory (fill-in the blank questions) or choose items from which they select from a set of given alternatives (multiple choice questions).	• Knows common terms • Knows specific terms • Knows methods and procedures • Knows basic concepts • Knows principles • Knows how to carry out algorithms & simple computations (no decision-making)	define describe identify label list match name	recall recognize reproduce state compute outline
UNDERSTAND Determining the meaning of instructional messages, including oral, written and graphic communication	**Instructional Objectives**	**Key Terms**	
Understanding goes one step beyond the simple remembering of material and represents the lowest level of understanding. It requires that the learner differentiate essentials for the message from aspects unimportant to the message. Understanding suggests that the learner comprehends or internalizes and systematizes the knowledge. Understanding may be shown by translating material from one form to another (words to numbers), by interpreting material (explaining or summarizing), or by extrapolating from the literal communication itself to determine implications, inferences, extensions or conclusions. The student is asked to translate, comprehend, or interpret information based on prior learning.	• Chooses relevant information • Understands facts and principles • Interprets verbal material • Interprets charts and graphs and problems • Knowledge or rules, principles and generalizations • Able to follow a line of reasoning	interpret exemplify select classify compare convert explain extend generalize	identify predict infer paraphrase rewrite summarize distinguish give an example

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

APPLY **Carrying out or using a procedure in a given situation**	**Instructional Objectives**	**Key Terms**	
Applying refers to the ability to use or apply learned material in new and concrete situations. This may include the application of such things as rules, methods, concepts, principles, laws and theories. The student is asked to select, transfer and use data ad principles to complete a problem task with a minimum of direction.	• Applies concepts and principles to new situations • Applies laws and theories to practical situations • Solves routine mathematical problems • Constructs charts and graphs • Demonstrates correct usage of a method or a procedure • Able to analyze data	execute implement change compute discover demonstrate manipulate modify operate	predict prepare produce relate show solve use construct
ANALYZE **Breaking material into its constituent parts and detecting how the parts relate to one another and to an overall structure or purpose**	**Instructional Objectives**	**Key Terms**	
Analyzing is the breakdown of a communication into its component ideas or parts so that the relative hierarchy of the ideas is made clear and/or the relations between the ideas are made explicit. Learning outcomes here represent a higher intellectual level than comprehension and application because they require an understanding of both the content and the structural form of the material. The learner must be able to identify the important elements on a communication together. The student is asked to distinguish, classify and relate the assumptions, hypotheses, evidence, conclusions and structure of a statement or a question. Analysis refers to what is called logic, induction and deduction and formal reasoning.	• Classifies words and statements according to a given analytic criteria • Perceives and infers relationships between elements • Discovers similarities/differences • Discerns a pattern, order, or arrangement of materials • Infers particular qualities or characteristics not directly stated in the reading or lecture • Solves non-routine problems	classify analyze distinguish organize structure compare contrast	categorize order differentiate outline separate subdivide breakdown

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

EVALUATE Making judgments based on criteria and standards	Instructional Objectives	Key Terms	
Evaluating is the making of judgments about the value of ideas, working solutions, methods or material. It involves the use of criteria as well as standards for appraising the extent to which particulars are accurate, effective, economical, or satisfying. The judgments may be quantitative or qualitative and the criteria may be either self-determined or provided externally (Bloom, 1956, p. 195). Evaluation requires that the student make judgments about something he or she knows, analyzes, synthesizes and so forth on the basis of criteria which can be made explicit. Evaluation has two steps. The first step is to set up appropriate standards (criteria) and the second is to determine how closely the object or idea meets these standards.	• Judges the logical consistency of written material • Judges the adequacy with which conclusions are supported by data • Judges the value of a work (art, music, writing) by use of internal criteria • Judges the value of a work (art, music, writing) by use of external standards of excellence	critique check appraise compare conclude contrast criticize describe	discriminate explain justify interpret relate summarize support
CREATE Creating something new based on some criterion	**Instructional Objectives**	**Key Terms**	
Creating is putting together elements and parts so as to form a whole. This involves the process of working with pieces, parts, elements, etc., and arranging and combining them in such a way as to constitute a pattern or structure that was not there before. Therefore, students create integrate and combine ideas into a product, plan, or proposal that is new to them. This cognitive process refers to what is called creative or divergent thinking.	• Writes a well-organized theme • Gives a well-organized presentation • Proposes a plan for an experiment • Integrates learning from different areas into a plan for solving a problem • Formulates a new scheme for classifying objects or events, or ideas • Generates missing links • Combines parts to form a whole • Develops course of action • Generates a high-level conclusion • Explains why	combine compile compose create devise design explain why generate modify organize plan	produce rearrange reconstruct relate reorganize revise rewrite elaborate give reasons for support

Sources: Taxonomy of Educational Objectives (Bloom, 1956). Krathwohl, D. R. (2002). A revision of Bloom's taxonomy: An overview. Theory Into Practice, Vol.41, No. 4, pp. 212-217. Redrawn from: *Prepared by Champlain College: PAREA Research Team - Winter 2004*

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

Additional Resources

Bloom's Revised Taxonomy

ASC Bloom's Taxonomy Webinar – Using the revised Taxonomy to develop study skills

Purdue University website: https://mediaspace.itap.purdue.edu/media/ASC+Bloom%27s+Taxonomy+Webinar/1_3npe2kxf/159939541

Resource packet for webinar: https://drive.google.com/file/d/1N2KuDL7IbpAGQ04RRSwV-Lx8p5RAILMJ/view

Using Bloom's Taxonomy for creating engineering assignments
https://owl.purdue.edu/owl/teacher_and_tutor_resources/writing_in_the_engineering_classroom/using_blooms_taxonomy.html

Educational design

Biggs, J. (1999). What the Student Does: teaching for enhanced learning. *Higher Education Research & Development, 18*(1), 57-75. doi:10.1080/0729436990180105

Fink, L. D. (2013). *Creating significant learning experiences: An integrated approach to designing college courses*: John Wiley & Sons.

8.2 Behaviour change models

www.behaviourchangewheel.com

Michie, S., Atkins, L., & West, R. (2014) The behaviour change wheel: a guide to designing interventions. London: Silverback Publishing.

The Norwegian Council for Road Safety's Model for Behaviour Modification
https://www.trafficsafetyeducation.eu/wp-content/uploads/2019/01/The-Norwegian-Council-for-Road-Safetys-Model-for-Behaviour-Modification.pdf

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement 861570.